Collection, Characterizaton and Conservation of Genetic Resources of Yam Cultivars From Ekiti State, Nigeria

Julius Olaoye Faluyi (jfaluyi@gmail.com)
University of Ife: Obafemi Awolowo University https://orcid.org/0000-0001-7478-7078
Joshua Olumide Matthew
National Horticultural Research Institute
Sekinat Okiki Azeez
Obafemi Awolowo University

Short Report

Keywords: Dioscorea, cultivars, collection, conservation, pounded yam, starch properties

Posted Date: October 11th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-899870/v1

COLLECTION, CHARACTERIZATON AND CONSERVATION OF GENETIC RESOURCES OF YAM CULTIVARS FROM EKITI STATE, NIGERIA

Julius Olaoye Faluyi[1*], Joshua Olumide Matthew[2] and Sekinat Okiki Azeez[1]
[*]Corresponding Author – jfaluyi@gmail.com
[1]Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria.
[2]National Horticultural Research Institute, Ibadan, Nigeria.

ABSTRACT

This study was initiated to restore the genetic resources of yam which had been decimated in a core yam-producing community in Ekiti State, Southwestern Nigeria. Twenty cultivars, consisting of *Dioscorea rotundata, D. cayenensis, D. alata*, and *D. dumetorum* were identified, collected, characterized and multiplied using an On-farm Participatory Method. The yam cultivars were characterized for quality and yield of pounded yam (*iyan*) as well as starch properties. They were later conserved in the Teaching and Research Farm of the Obafemi Awolowo University Ile-Ife.

Morphological characterization separated *Dioscorea alata* (*Ewura*) by its winged vines while *Dioscorea dumetorum* (*Esuru*) was separated by its pubescent spines, trifoliate leaf with acute apex and base and the clustered, irregularly-shaped tuber. All the tubers of the yam cultivars had high storability. Pounded yam quality rated the *Ikumo* and *Ajimokun* cultivars as best while *Odo* was rated average and this was attributed to the swelling properties and amylose content of these cultivars. Yam cultivars with high granules had low swelling capacities. The Brittle Fraction Index of the starch from all the cultivars was lower than 1.0 explaining why the *iyan* they produced had no crust on the surface and kept for long hours after preparation.

From this study, it was concluded that the local yam cultivars collected represent the core of yam genetic resources for utilization in the region. These cultivars are therefore recommended for prioritization in further studies on propagation, conservation and improvement so that a narrow genetic base of cultivars is not encouraged, for example, by promoting cultivars whose vines perform well in tuberization.

Keywords: *Dioscorea,* cultivars, collection, conservation, pounded yam, starch properties

DECLARATIONS

Acknowledgement: The authors wish to Dr. Olubukola G. Abraham for her immense contribution to the carrying out the research and editing of the manuscript.

Funding: This research was funded by the Year 2015-2016 (Merged) Tertiary Education Trust Fund (TETFUND) Research Projects (RP)/IBR Intervention, Batch 7.

Conflict of Interest/Competing Interests: The authors declare no conflict of interest.

Availability of Data: Data is available with the authors and can be assessed from them by mail.

Code Availability: Not applicable

Authors' contribution: JOF supervised and compiled the manuscript, JOM carried out all the research.

Consent for publication: All authors consent to the publication of this manuscript.

INTRODUCTION

The family Dioscoreaceae is the yam family comprising of five genera and 750 species (Murti 2001). Caddick et al. (2000a, b) reported that the family includes four genera: *Dioscorea*, *Trichopus*, *Taca* and *Stenomeris*. The genus *Dioscorea* is the largest of the genera with about 90% of the species in the family. These species are represented in all the geographical regions in which representatives of the family occur (Smith 1937; Onwueme 1978).

The genus *Dioscorea* are principally tuber-bearing plants and they have economic value as food in the tropics. About 600 species are distributed in the subtropical and tropical areas of Africa, America, Asia and Polynesia. About 90 of these species are edible; 10 of them are cultivated for food in West and Central Africa (Coursey 1967; Ayensu 1972; Mignouna et al. 2003; Adegbite et al. 2006; Quain et al. 2011). Nigeria has been reported to be the largest producer of yam in the world while Ghana and Cote d'Ivoire are competing for the second and third positions (Nweke et al. 1991; FAO 2010, 2013).

The most important *Dioscorea* species cultivated for consumption in the West African belt are *D. cayenensis*, *D. rotundata* and *D. alata* (IITA, 2009). The tuber of the yam crop is particularly important as a source of carbohydrates, proteins, minerals and vitamins. Their low glycemic index gives better protection against obesity and diabetes (Bell 1983; Eni 2008). Yam is also important for its cultural uses, pharmaceutical products and as a major source of income generation for the people in yam-growing areas.

The physico-chemical properties of the cultivars of yam have been investigated as a means of understanding the food quality of the major cultivars used for food for generations. Some properties like steaming time and size of starch particles have been reported to affect the functional qualities of yam flour (FAO 1991; Iwuoha and Nwakanma 1998; Iwuoha 1999). Malomo and Jayeola (2010) however suggested that the chemical properties of yam starch depend less on granule dimensions but more on molecular properties and associative forces intrinsic in the cultivars. Iwuoha and Nnanemere (2003) canvassed the need for a comprehensive evaluation of post-extraction and handling of yam flour in the classification of tubers of cultivars of yam.

Yam is a major staple food in Nigeria. The germplasm of yam is a tested combination of cultivars which farmers have used over generations during for which they have built a massive array of protocols in yam care, cultural practices, propagation techniques and preservation through indigenous knowledge.

Yam research in Nigeria has focused on propagation, the state of the seed yam system, conservation of yam germplasm and improvement through selection and breeding. The work on yam propagation has addressed mini setts (Balogun 2004, 2007, 2009), micropropagation through plantlets raised in regular cultures and aeroponics, microtuber production (Balogun 2014; Aighewi et al. 2015), generation of plantlets through regular callus production and somatic embryogenesis, production of encapsulated embryos and propagation from regular botanic seeds. Yam production in Nigeria is restricted to the South-Eastern, South-Western, Middle-Belt and East of River Niger zones where the soil fertility, humidity and rainfall permit its production.

This paper reports a phenomenon of genetic erosion of yam in Ekiti State, Nigeria which is known as a major centre for yam marketing and consumption as staple food when pounded into a paste known as *iyan*. This phenomenon began about 15 years ago when migrants from the Middle Belt region of Nigeria migrated to Ekiti

State to farm (Oluwasusi and Tijani 2013; Agoyi 2013). The indigenous farmers in the State adopted many of their cultivars which were inferior in pounded yam quality and agro-botanical attributes. By the time they pulled back, their yam germplasm had suffered substantial genetic erosion.

This project was located in Omu-Ekiti in the Oye Local Government Area of Ekiti State which is an epicentre of this loss of genetic resources.

The specific objectives of this study were to:

a). conduct an inventory of yam cultivars in use in Ekiti State, identify where the endangered cultivars are still cultivated and collect them for central propagation in Omu-Ekiti;

b). characterize the cultivars through morphological, agro-botanical, pounded yam quality, storability and starch particle studies; and

c). conserve the characterized cultivars as genetic resources for further research and distribution to interested yam farmers for propagation and utilization.

MATERIALS AND METHODS

Germplasm Collection, Characterization and Multiplication of Cultivars of *Dioscorea*

This study employed the On-farm Participatory Research Model in which one farmer grew all the cultivars collected and also contributed his own complement of cultivars. More cultivars were sourced from other farmers in the State as the project progressed. Morphological characterizations were carried out on-field in Omu-Ekiti. These cultivars were moved to the Teaching and Research Farm at the Obafemi Awolowo University, Ile-Ife for the validation of the morphological characters of the cultivars, multiplication and conservation for future use.

Morphological description of the yam cultivars was done according to the IPGRI *Yam Descriptors (*1997) with slight modifications. The yam cultivars were described at the young and mature vegetative stages based on their vine characters (habit, colour, number; presence or absence of wings, spines, pigmentation). The leaves were characterized by shape, length, breadth, presence or absence of hairs, colour and multiple characters of the petiole (spine, hairiness, length, breadth and colour). The tubers were characterized based on their length, circumference, shape, number of tubers per hill, hair density and distribution pattern, number of cusps.

Quality and Yield of Pounded Yam (*iyan*) from the Cultivars Collected.

Yam tubers stored for 6 months and freshly-harvested yam tubers (less than 2 weeks) were used in the preparation of yam paste (*iyan*) using the traditional pestle and mortar system (see Plate 1). Professional pounded yam sellers operating within the Obafemi Awolowo University campus were engaged for this part of the study. Tubers of the yam cultivars collected were peeled and sliced and then made into pounded yam. The parameters recorded are weight of the tubers before and after peeling, yam cooking time, volume of water used in pounding and final weight of the pounded yam paste (*iyan)* for each cultivar. The *iyan* from the yam cultivars were rated good, average and poor by the pounders based on the volume of water required by the cooked tuber during pounding, swelling of the pastes and the paste elasticity and viscosity.

Plate 1: Traditional Preparation of Pounded Yam (*Iyan*)

Two women are involved in pounding. The action recorded is kneading of the paste. The mortar is medium-sized.

Starch Particle Studies

Starch was extracted from peeled, weighed and diced yam tubers soaked in distilled water for 48 hours to soften according to the modified method of Farhat et al. (1999). The soaked diced pieces were blended and the slurry was poured into a container filled with distilled water for 24 hours followed by sieving to obtain the extracted starch. The starch was then dried in a hot air oven, milled and stored. The parameters studied are: morphological and physical properties, swelling capacity, water retention and amylose content, viscosity of the starch particles.

Starch Particle Size, Shape and Density

This was determined by viewing starch powder stained with tincture of iodine under the light microscope (X40 objective). Three hundred starch particles were observed randomly and measured using an ocular micrometre fixed in microscope. Photomicrographs of the starch granules were documented. The size and shape descriptors used in this study are defined below:

$$\text{Equivalent Circle Diameter (ECD)} = 2\sqrt{\frac{A}{\pi}} \quad (1)$$

$$\text{Aspect Ratio (AR)} = \frac{b}{l} \quad (2)$$

$$\text{Elongation Ratio (ER)} = \frac{l}{b} \quad (3)$$

$$\text{Roundness (RD)} = \frac{4\pi A}{p^2} \quad (4)$$

$$\text{Irregularity (IR)} = \frac{p}{l} \quad (5)$$

$$\text{Circularity (CR)} = \frac{4A}{\pi l^2} \quad (6)$$

$$\text{Heywood diameter} = ((0.77 \times l \times b)/\pi)^{1/2} \quad (7)$$

where, b = minimum Feret diameter, l = maximum Feret diameter, A = projected area of the particle and p = perimeter of the particle.

The starch particle density was determined using the liquid pycnometer method according to Alebiowu and Itiola (2002). In this method, acetone was used as the displacement fluid. The bulk density of each starch powder at zero pressure (loose density) was determined by pouring the powder at an angle of 45º through a funnel into a glass measuring cylinder with a diameter of 31 mm and a volume of 10 mL (Paronen, 1983; Itiola, 1991). Determination was done in triplicate. The relative density, D_0, of each starch powder was obtained from the ratio of its loose density to its particle density. The Hausner's ratio (Herman, 1989), determined as the ratio of the initial bulk volume to the tapped volume, was obtained by applying 100 taps to 30 g of each starch sample in a graduated cylinder at a standardized rate of 38 taps per minute according to the British Standard Institution (1979). The packing properties were obtained using a modification of Kawakita equation and the degree of volume reduction due to tapping was calculated from Equation (8).

$$C = \frac{v_0 - v_N}{v_0} \quad (8)$$

where, N = the number of taps and C = volume reduction due to tapping, V_o and V_N are the powder bed volumes at initial and nth tapped states, respectively.

Swelling Capacity and Water Retention Capacity

The method described by Bowen and Vadino (1984) was used. Five grams of each starch was poured into a 100 mL measuring cylinder and the bulk volume measured (V_1). Deionized water (90 mL) was added and the suspensison was well shaken for 5 min. Water was added to make up to 100 mL. The suspension was left for 24 h before the sedimentation volume was read (V_2). The swelling capacity was calculated as V_2/V_1. Determinations were done in triplicate, using the method of Ring (1985). To 5 g of each starch in a 100 mL measuring cylinder was added 90 mL of deionized water and the suspension was well shaken for 5 mins. Water was then added to make 100mL. Fifteen milliliters of the suspension was centrifuged (Optima Centrifuge type, BHG 500, Germany) for 25 mins at 5000 rpm. The supernatant was discarded and the residue weighed (W_1). The residue was then dried at 70 °C to constant weight (W_2) in a hot air oven. The water retention capacity was computed as W_1/W_2. Determination was done in triplicate.

Starch Amylose Content

Amylose content was determined in triplicate for each cultivar starch powder using the method of Juliano (1971) and Hoover and Ratnayake (2002). Approximately 0.1 g (100 mg) of the starch powder of each cultivar was weighed into a 100 mL volumetric flask and 1 ml of 99.7-100 % (v/v) ethanol and 9 ml of 1N NaOH were carefully added and the solutions were mixed well. The sample was heated for 10 mins in a boiling water bath to gelatinize the starch. The sample was then removed from the water bath and allowed to cool to ambient temperature, then filled up to the mark with distilled water and shaken thoroughly. About 5 mL of the mixture was then pipetted into a 100 mL volumetric flask. Acetic acid (1 N, 1 ml) and 2 ml of iodine solution were added, topped to mark with distilled water and shaken thoroughly, while ensuring that the flask was wrapped in aluminium foil to prevent photo-degradation of the iodine–starch complex. Absorbance (A) was then read using a spectrophotometer (6850 Double beam spectrophotometer-jenway) at 620 nm wavelength. A blank was prepared by following the same procedure, except that no starch sample was added in the volumetric flask and used to standardize the spectrophotometer at 620 nm. The amylose content was calculated as:

Amylose content (%) = 3.06 x A x 20, where A is the absorbance reading at 620 nm, 3.06 is the predetermined gradient of standard amylose calibration curve, and 20 is the dilution factor.

Viscosity Studies of the Starch Powders

The viscosity profile of each of the starch materials was obtained using a heating and cooling viscometer, series 3RVA (Rapid Visco Analyser) coupled with Thermocline for Windows software (Newport Scientific Pty. Ltd. Warriewood, NSW Australia). The test proceeded and terminated automatically. Heating of the slurry in the equipment was done under a constant rate of shear and the increase in viscosity of material was measured as torque on the spindle and a curve was traced (Thomas and Atwell, 1999). Various parameters: peak viscosity, peak time, peak temperature, trough viscosity, breakdown, final viscosity, setback from trough and setback from peak were determined from the trace.

RESULTS

Morphological Studies

The twenty cultivars of four *Dioscorea* species studied were dileanated based on the morphology of the vine, leaf and tuber of the cultivars (Plates 2, 3). Table 3 shows the character states of the vines (smooth, spined, pubescent; branched/unbranched), leaf forms (shape, colour, base type) and tuber forms (shape, hairiness and its distribution patterns, occurrence of cusps, colour of flesh). These characters dilienated all the cultivars studied. *Dioscorea alata* (*Ewura*) was separated by its winged vines while *Dioscorea dumetorum* (*Esuru*) was separated by its pubescent spines, trifoliate leaf with acute apex and base and the clustered, irregularly-shaped tuber.

Standardization of Pounded Yam Quality

The mortar and pestle are the major tools for the preparation of *iyan*; both are carved from wood: *Vitellaria paradoxa* C.F. Gaertn. for the mortar and *Blighia sapida* K.D. Koenig used to be prime wood materials for the pestle. The protocol used in this study was decoded from the wealth of experience of the professionals used in this aspect of the study. The entire process of *iyan* production from peeling of yam through boiling to the production of the final paste is open and completely under the control of the professionals.

The first step in the production process of *iyan* is peeling of yam which involves a total removal of the bark and all rotten parts and dead spots on the tuber. This is followed by the boiling process which is strictly monitored by inspecting the tuber pieces.

The major steps involved in achieving a good quality pounded yam is the crushing of the boiled yam (*Tite* and *Wiwo*) which ensures the mashing of the boiled yam before proceeding to pounding it for homogeneity. This is followed by a Check Point which involves the removal of lumps. Further pounding is done to achieve a smooth paste and then water (hot or cold) is added as required followed by gentle pestle work, pounding and kneading to ensure a hot final *iyan* paste. The mortar in Plate 1 shows two ladies doing the pounding; this ensures that the process can be fast, efficient and monitorable to achieve the desired paste quality for the paste.

All the yam cultivars stored well. Yam tubers were traditionally stored in the open, under shade in the olden days and they stored well round-the-year. Tubers will also store well in well-ventilated store rooms. As the tubers started to germinate, the vines were removed to prevent weight loss. *Ikumo* had the least percentage loss for fresh and stored yam tuber and it did not rot. The respondents preferred *Ikumo* and *Ajimokun* cultivars for pounded yam as they required the largest volume of water which is important for achieving high quantity of pounded yam during pounding. The paste from these two cultivars were also smooth and elastic. *Odo* cultivar was rated average because of the water it required during pounding. This could be as a result of its swelling properties and amylose content. High moisture and physicochemical composition which includes amylose content and swelling capacity of the of yam starches had been reported to be an important factor in the production of quality pounded yam.

Starch Analysis of the Yam Cultivars

The shape of the starch granules was mainly oval-oblong; a few are oblong granules (Table 6; Plate 4). The roundness (RD), circularity (CR), and irregularity (IR) values of the starch particles observed in this study are less than 1.0, the value of a perfect circle. The Bulk Densities of the starch particles are around 0.5 while the Porosity, which measures the absorbent characteristics of the starches, is between 0.6 and 0.7 for all the cultivars (Table 6) .

Ten of the cultivars are greater than 40 µm in starch particle length which corresponds to the Equivalent Circle diameter. The values for circularity and irregularity (IR) confirm the oval-oblong shape of the starch particles. The mean bulk density of the starch particles are around 0.5 while the Porosity is between 0.6 and 0.7. Starch powders with large granules as typified by *Gambari*, *Anika*, *Gaungaun* and *Obabi* had low swelling. The Viscosity values for *Anika*, *Areyingbakumo*, *Gambari*, *Obabi* and *Ogunmole*, were generally high and the Peak

Temperature values were also high followed by the cluster of *Boki*, *Ikumo*, *Ajimokun* and *Okunmodo* among which some higher Peak Temperatures were recorded. The swelling capacities of the starches levelled between 55 and 60; Water Retention Capacity is highest for *Ilesu* followed by *Ikumo*, *Boki*, *Areyingbakumo* and *Ajimokun*. The Amylose Contents flattened out between 45.96 and 36.70 for all the cultivars; none is outstanding for this parameter.

Starch powders of *Gaungaun* and *Lolo Ayin* had the highest and lowest amylose contents, respectively. The large amylose contents of the large starch granules might be responsible for their low swelling properties. *Ajimokun*, *Ilesu* and *Sandpaper* formed paste with large volumes of water. All the yam cultivars had Brittle Fracture Index lower than 1.0 which explains why the *iyan* they produced did not have crust on their surfaces when kept for long hours.

None of the yam flowers had good flowabililty; only *Ilesu* powder had a fair flowability followed by *Lolo Ayin*. At the highest tapping, *Anika* and *Gaungaun* had the lowest flowability ratings. At low tapping, the starch particles with smaller particle sizes were still better packed.

The highest pasting temperatures were observed in *Boki* and *Ilesu* which means that the cultivars required high gelatinization temperatures which translates into longer cooking time. Peak Viscosity values rated *Anika*, *Obabi*, *Ogunmole*, *Gambari*, *Areyingbakumo*, *Odo*, *Ajimokun* and *Ikumo* as outstanding in that order (Table 9). Again, all the cultivars are of good standing with respect to this parameter. The profile for Peak Temperature shows high values for all the cultivars. Breakdown Viscosity is highest for *Anika* followed by *Lolo Ayin*, *Obabi*, *Okunmodo* and *Areyingbakumo*. *Ilesu* had a relatively poor value of 9.46 but the other cultivars recorded intermediate values.

TABLE 1: Vegetative Characteristics of the Vines at Maturity of the Yam Cultivars Studied

Cultivars	Plant Type	Twining Habit	No of Vines	Vine Branching and Form	Inflorescence type and position	Colour	Spine	Spine Position
Ajimokun	Climber	Sinistrorse	1	Opposite secondary		Green	- base, ++ above	Vine
Ame	"	"	1	Opposite secondary		"	- base, + above	"
Anika	"	"	1-3	Strong primary, alternate secondary		Brownish-green	++ base and above	"
Areyingbakumo	"	"	1	Alternate secondary	Solitary; axilary	"	- base, ++ above	"
Boki	"	"	1-5	Opposite secondary	Paniculate, solitary; axilary	Green	+++ base, + above	vine & base
Digbiri	"	"	1	Opposite secondary		Brownish-green	- base, + above	Vine
Esuru	"	"	1	Vine and leaves hairy		Green	- base, ++ above	Petiole & Vine
Ewura	"	"	3	Vine and petioles winged		"	-	-
Gambari	"	"	1-2	Opposite primary	Solitary, paniculate	Brownish-green	+++ base, ++ above	Vine
Gaungaun	"	"	2-6	Opposite secondary		"	-	-
Gbongi	"	"	1	Opposite secondary		"	+++ base, ++ above	"
Igangan	"	"	1 -2	Alternate branching	Paniculate; axilary	Green	++ base and above	"
Ikumo	"	"	1	Opposite primary		Brownish-green	+++ base, ++ above	"
Ilesu	"	"	1-2	Alternate primary, opposite secondary		Green	+++ base and above	"
Lolo Ayin	"	"	2	Alternate branching		"	- base, + above	"
Obabi	"	"	1-2	Alternate primary	paniculate	"	+ base, ++ above	Vine Base
Odo	"	"	1-4	Alternate primary		Brownish-green	+++ base and above	Vine Base, many but short
Ogunmole	"	"	2-6	Alternate secondary		Brownish-green	++ base and above	Vine
Okunmodo	"	"	1-4	Opposite secondary		Green	++ base and above	"
Sandpaper	"	"	1	Scapose primary, opposite secondary		Brownish-green	+++ base and above	"

- =absent; + = sparse; ++ = few; +++ = many

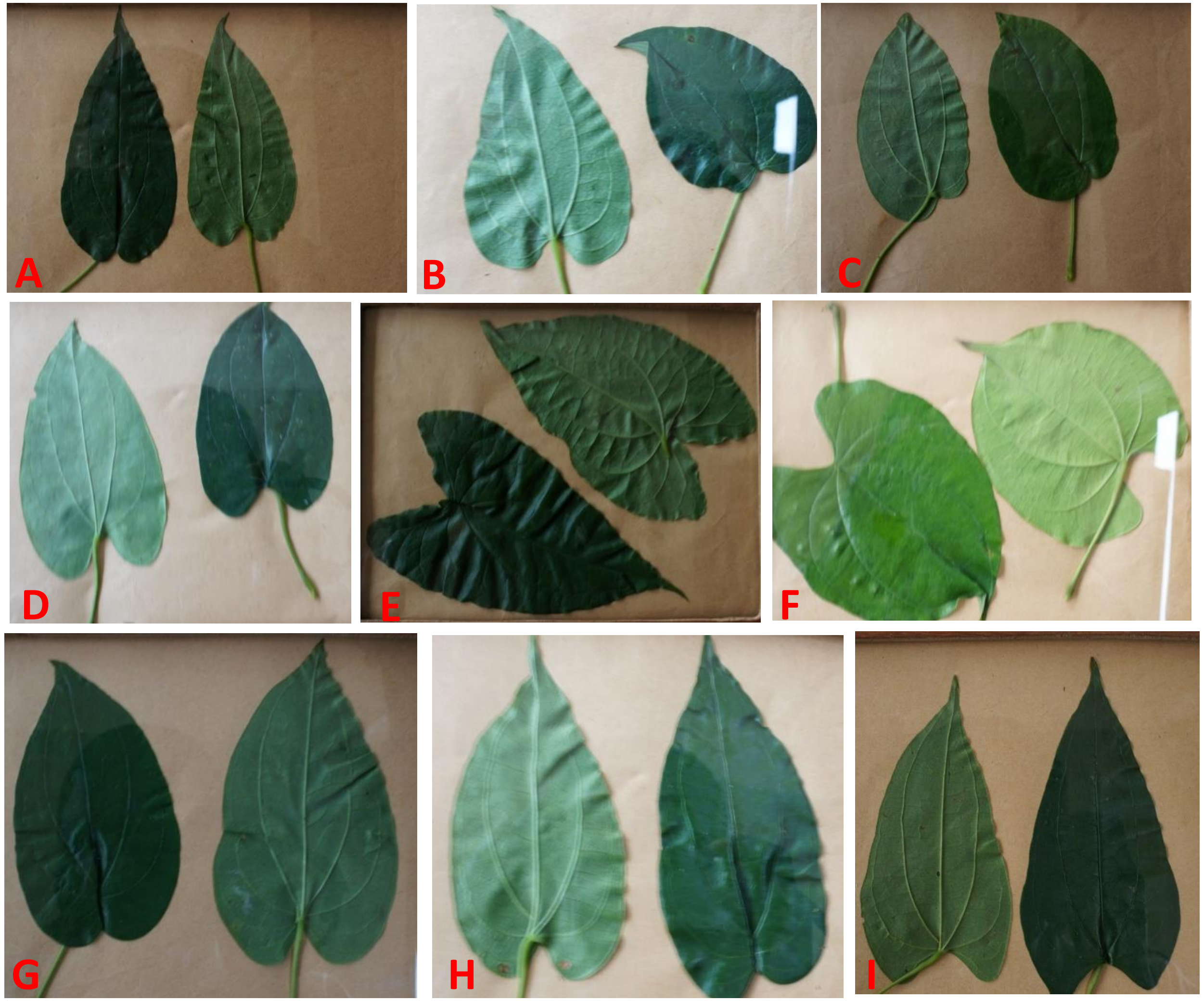

Plate 2: Leaf Form and Shape in the Cultivars of *Dioscorea* Studied

A. Ajimokun (*D. rotundata*)
B. Anika (*D. rotundata*)
C. Areyingbakumo (*D. rotundata*)
D. Gambari (*D. rotundata*)
E. Gaungaun (*D. rotundata*)
F. Igangan (*D. cayenensis*)
G. Ikumo (*D. rotundata*)
H. Boki (*D. rotundata*)
I. Odo (*D. rotundata*)

TABLE 2: Vegetative Characteristics of the Tubers of the Yam Cultivars Studied.

Cultivars	Tuber Length (cm)	Tuber circumference (cm)	Tuber Number per Heap	Hair Density and Position*	Tuber Shape	Number of cusps*
Ajimokun	32.77 ± 2.425^{abcde}	41.33 ± 5.236^{c}	2	Few at the proximal region	Laterally-compressed, oblong	2
Ame	40.30 ± 2.300^{cde}	33.80 ± 0.9708^{abc}	2	Many at the proximal region	Oblong	-
Anika	35.15 ± 0.9060^{bcde}	35.32 ± 0.5214^{abc}	2-3	Few at the proximal region	Cylindrical	5-7
Areyingbakumo	33.97 ± 5.164^{bcde}	35.03 ± 4.797^{abc}	1	Few through out	Irregular-oblong	2-5
Boki	31.40 ± 1.701^{abcd}	37.39 ± 4.398^{bc}	1	-	cylindrical	6-8
Digbiri	30.37 ± 2.924^{a}	20.29 ± 0.4591^{c}	1	Few through out	Oval	2
Ewura	35.67 ± 2.906^{bcde}	19.18 ± 0.5021^{bc}	1 rarely 2	Many through out	Oval	2-3
Esuru	Irregular	Irregular	Aggregated tubers	Few at the proximal region to the mid-region	Irregular	2-4
Gambari	38.73 ± 3.952^{cde}	36.19 ± 1.674^{bc}	1	Many throughout with thorns	Cylindrical	-
Gaungaun	29.85 ± 1.744^{abc}	33.26 ± 1.053^{abc}	3-4	Many through out	Oval	-
Gbongi	41.15 ± 1.150^{de}	33.35 ± 0.9791^{abc}	2	Few from the mid- region that reduces to the distal region	Cylindrical-oblong	-
Igangan	35.00 ± 2.754^{bcde}	12.46 ± 0.2784^{a}	2	Few through out	Oblong	2
Ikumo	27.72 ± 2.638^{ab}	35.69 ± 2.905^{bc}	1, rarely 2	Many through out	Oval, Oval-oblong	-
Ilesu	36.87 ± 1.785^{bcde}	28.64 ± 2.619^{ab}	2	Few from mid-region to the distal region	Cylindrical	-
Lolo Ayin	23.57 ± 5.206^{a}	32.06 ± 2.912^{abc}	1	Few through out	Cylindrical	3
Obabi	41.73 ± 1.906^{de}	32.89 ± 4.742^{abc}	2	Few at the proximal region	Irregular Oblong	-
Odo	40.40 ± 1.102^{cde}	33.47 ± 3.334^{abc}	1	-	Oblong, Oval	3
Ogunmole	36.27 ± 3.034^{bcde}	35.11 ± 5.925^{abc}	1	Few throughout	Elongated, Oblong	7
Okunmodo	32.50 ± 8.218^{abcde}	42.07 ± 5.874^{c}	2	Few at the proximal region	Laterally-compressed	2-6
Sandpaper	42.5 ± 1.102^{e}	37.58 ± 1.918^{bc}	1 and always big	Many throughout, mostly at the proximal region	Oblong	2-3

*- = absent **Means with the same letter along columns are not significantly different at $P \leq 0.05$.

Plate 3: Tuber Form in the *Dioscorea* Cultivars Studied.

A. Odo (*D. rotundata*)
B. Anika (*D. rotundata*)
C. Gaungaun (*D. rotundata*)
D. Ogunmole (*D. rotundata*)
E. Gambari (*D. rotundata*)
F. Ajimokun (*D. rotundata*)
G. Areyingbakumo (*D. rotundata*)
H. Ikumo (*D. rotundata*)
I. Okunmodo (*D. rotundata*)
J. Boki (*D. rotundata*)
K. Obabi (*D. rotundata*)

TABLE 3: Summary of the Delineating Morphological and Anatomical Characters of the Yam Cultivars Studied

		MORPHOLOGY	
Cultivars	**Vine**	**Leaf**	**Tuber**
Ajimokun	smooth, single vine	green, cordate	laterally-compressed, few hairs at proximal region, 2 cusps.
Ame	smooth, single vine	dark green cordate	oblong, many hairs reducing towards the distal region, no cusps.
Anika	Multiple vine	green, cordate	cylindrical, few hairs at the proximal region, 5 - 7 cusps
Areyingbakumo	Single vine	green, orbicular	irregular, few hairs throughout the tubers, 2 - 5 cusps.
Boki	Multiple vines, spinous	dark green cordate, sagittate base	cylindrical, smooth, dark, many cusps.
Digbiri	Single vine, smooth	dark green cordate	oval, , few hairs throughout the tuber, 2 cusps.
Esuru	pubescent	trifoliate, pubescent, acute apex and base	A cluster of irregular-shaped tubers > 12.
Ewura	Multiple vines , winged	green cordate, winged petiole	many hairs throughout the tuber, dark thin peel, 2-3 cusps.
Gambari	Multiple vines, spinous	dark green, cordate	cylindrical, many hairs with thorns throughout the tuber, no cusps.
Gaungaun	smooth, multiple vines	dark green cordate, sagittate base	oval, many hairs throughout the tuber, 3-4 per heap, no cusps.
Gbongi	spinous, single vine	green, cordate	cylindrical-oblong, few hairs from the mid-region downward, no cusps.
Igangan	spinous, multiple vines	light green, orbicular	oblong, few hairs throughout the tuber, yellow flesh, no cusps.
Ikumo	spinous, single vine	green, cordate	oval, many hairs throughout the tuber, no cusps.
Ilesu	spinous, multiple vines	green, cordate	cylindrical, few hairs from mid-region downward, no cusps.
Lolo Ayin	smooth, multiple vines	green, cordate	cylindrical, few hairs throughout the tuber, 3 cusps.
Obabi	spinous, multiple vines	green, cordate	Irregular-oblong, few hairs at the proximal region, no cusps.
Odo	spinous, multiple vines	green, cordate, sagittate base	cylindrical, smooth, light-coloured, 3 cusps.
Ogunmole	spinous, multiple vines	green, cordate	oblong, few hairs throughout the tuber, 7 cusps.
Okunmodo	spinous, single vine	green, cordate	laterally-compressed, few hairs at proximal region, 2-6 cusps.
Sandpaper	spinous, scapose	dark green, long cordate, sagittate base	oblong, many hairs mostly at the proximal region, always 1 big tuber, no cusps.

TABLE 4: List of Terminologies in *Iyan* Processing technique and their English Equivalents

Yoruba	English	Definition
Koko	Lumps	Discrete fragments/particles of yam in the dough.
Riro	Firmness and elasticity of dough	Paste is like puree; tends to regain shape after deformation. This term defines the five textural attributes of pounded yam (springiness, cohesiveness, hardness, smoothness and stickiness) which the traditional professionals have mastered and used for quality assurance.
Wiwo	Crushing	The first stage of pounding to reduce the tuber into smaller fragments.
Tite	Pounding	Initial pounding to convert the smaller fragments of yam into coarse paste.
Gigun	Pounding	More vigorous pounding to achieve a smooth paste.
Rin	Kneading	Dexterous sideways working of pestle to convert the paste into a smooth, uniform mass.
Iyan	Pounded Yam	Fine paste, the final product.

Table 5: Pounded Yam Characteristics of the Yam Cultivars Studied

Cultivar	Tuber Weight before Peel (kg)		Tuber Weight after Peel (kg)		%Loss		Cooking Time (min)		Water Required (cl)		Pounded Yam Weight (kg)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Ajimokun	9.724±0.0899^{l}	5.90±0.2309^{de}	7.22±0.079^{m}	3.71±0.009^{d}	25.79	37.06	42.06±0.028^{h}	29.02±0.012^{b}	175.12±0.071^{i}	150.02±0.0088^{d}	8.30±0.036^{l}	4.01±0.008^{d}
Ame	5.65±0.0202^{d}	NA	3.87±0.049^{d}	NA	31.38	NA	32.12±0.062^{c}	NA	87.61±0.074^{f}	NA	5.12±0.064^{f}	NA
Anika	8.12±0.0583^{i}	8.41±0.0088^{f}	6.32±0.026^{j}	4.51±0.008^{e}	22.16	46.36	47.14±0.074^{j}	45.01±0.006^{d}	70.19±0.077^{e}	200.04±0.0306^{e}	6.89±0.025^{i}	5.51±0.005^{g}
Areyingbakumo	7.53±0.0258^{g}	NA	4.89±0.025^{h}	NA	35.15	NA	48.04±0.019^{k}	NA	87.726±0.077^{f}	NA	5.09±0.015^{f}	NA
Boki	6.90±0.03092^{f}	NA	4.63±0.035^{g}	NA	33.00	NA	32.11±0.075^{c}	NA	20.15±0.083^{a}	NA	4.74±0.061^{d}	NA
Gambari	7.73±0.0733^{h}	NA	5.71±0.070^{i}	NA	26.06	NA	38.12±0.065^{f}	NA	87.61±0.073^{f}	NA	6.33±0.025^{h}	NA
Gaungaun	4.49±0.0141^{b}	5.81±0.008^{d}	3.31±0.007^{c}	4.81±0.0088^{f}	26.28	17.20	19.08±0.039^{a}	50.01±0.009^{e}	52.74±0.075^{d}	125.01±0.0088^{c}	4.08±0.035^{c}	4.61±0.0088^{e}
Gbongi	6.15±0.0204^{e}	NA	4.46±0.015^{f}	NA	27.42	NA	45.06±0.038^{i}	NA	52.74±0.085^{d}		5.13±0.022^{f}	NA
Ikumo	8.07±0.0102^{i}	5.81±0.0088^{e}	6.88±0.024^{l}	5.31±0.0088^{g}	14.72	13.37	54.14±0.0743^{l}	29.01±0.0088^{b}	140.13±0.0619^{h}	150.01±0.0088^{d}	6.81±0.0080^{i}	5.01±0.0088^{f}
Ilesu	3.604±0.0093^{a}	2.81±0.0088^{b}	2.95±0.021^{b}	1.51±0.0088^{b}	18.20	46.209	30.04±0.0186^{b}	35.01±0.0088^{c}	52.53±0.0204^{c}	25.01±0.0088^{a}	3.73±0.0217^{b}	1.45±0.00088^{b}
Lolo Ayin	4.91±0.0086^{c}	1.61±0.0088^{a}	4.07±0.037^{e}	0.81±0.0088^{a}	17.18	49.59	42.07±0.0387^{h}	22.01±0.0088^{a}	105.10±0.0404^{g}	25.01±0.0088^{a}	5.23±0.02168^{g}	1.01±0.009^{a}
Obabi	7.714±0.0093^{h}	NA	5.71±0.0086^{i}	NA	25.95	NA	33.07±0.0391^{d}	NA	70.13±0.05428^{e}	NA	6.28±0.01077^{h}	NA
Odo	6.86±0.0196^{f}	NA	4.90±0.012^{h}	NA	28.52	NA	48.07±0.0387^{k}	NA	35.08±0.0441^{b}	NA	4.84±0.0217^{e}	NA
Ogunmole	9.49±0.02^{j}	NA	6.63±0.018^{k}	NA	30.21	NA	35.12±0.0652^{e}	NA	70.14±0.0743^{e}	NA	7.41±0.0071^{k}	NA
Okunmodo	3.58±0.01^{a}	5.11±0.0088^{c}	2.81±0.009^{a}	3.41±0.0088^{c}	21.35	33.25	45.07±0.0387^{i}	54.01±0.0088^{f}	52.51±0.0093^{c}	75.01±0.0088^{b}	3.41±0.0071^{a}	3.11±0.009^{c}
Sandpaper	9.61±0.01^{k}	10.82±0.0120^{g}	7.21±0.009^{m}	6.51±0.0088^{h}	24.97	39.78	39.05±0.024^{g}	50.01±0.0088^{e}	35.11±0.0471^{b}	125.02±0.0120^{c}	7.314±0.0093^{j}	5.51±0.0088^{g}

*NA = Not Available;

**Means with the same letter along columns are not significantly different at $P \leq 0.05$.

TABLE 6: Morphological and Physical Properties of the Starch Granules of the Yam Cultivars

Cultivar	L (µm)	B (µm)	Particle Shape	Particle Colour	Equivalent Circle Diameter (ECD) (µm)	Heywood Diameter (d_e) (µm)
Ajimokun	37.58±0.8612^{a}	22.88±0.5843^{a}	Oval-oblong	Light	23.29±0.5263^{a}	28.88±0.6528^{a}
Anika	49.68±1.1969^{d}	30.30±0.7987^{de}	"	Tan 1	30.82±0.7175^{f}	38.23±0.8900^{e}
Areyingbakumo	40.85±0.8089^{b}	28.83±0.6839^{cd}	"	Wheat	27.31±0.5680^{de}	33.87±0.7046^{d}
Boki	41.15±0.8083^{b}	27.13±0.6126^{bc}	"	Wheat 1	26.52±0.5675^{de}	32.90±0.7040^{d}
Gambari	51.00±1.1553^{d}	35.30±0.7197^{f}	"	Linen	33.79±0.6956^{g}	41.91±0.8628^{f}
Gaungaun	49.275±1.1244^{d}	28.85±0.6652^{cd}	"	Ivory 1	29.95±0.6449^{f}	37.15±0.8000^{e}
Ikumo	43.85±0.7533^{c}	31.58±0.6182^{e}	"	Moccasin	24.20±0.4213^{e}	36.76±0.6400^{e}
Ilesu	36.025±0.7802^{a}	26.38±0.6410^{b}	"	Ivory 1	24.49±0.5182^{ab}	30.37±0.6428^{ab}
Lolo Ayin	36.98±0.8229^{a}	26.13±0.6055^{b}	"	Ivory	24.70±0.5159^{abc}	30.63±0.6399^{abc}
Obabi	50.08±0.8957^{d}	34.35±0.7200^{f}	"	Navajo white 1	32.96±0.5633^{f}	40.88±0.6988^{f}
Odo	49.08±0.8987^{d}	31.38±0.5370^{e}	"	Lemongoldenrod3	31.21±0.4867^{f}	38.71±0.6037^{e}
Ogunmole	36.65±0.6157^{a}	28.70±0.5300^{cd}	"	Ivory	25.83±0.4259^{bcd}	32.03±0.5283^{bcd}
Okunmodo	40.38±0.6866^{b}	27.05±0.5275^{bc}	"	Lemon chiffon	26.27±0.4265^{cde}	32.59±0.5290^{cd}
Sandpaper	42.08±0.9475^{bc}	28.53±0.5936^{cd}	"	Ivory	27.54±0.5484^{g}	34.16±0.6802^{d}

**Means with the same letter along columns are not significantly different at $P \leq 0.05$.

TABLE 6 (cont.): Morphological and Physical Properties of the Starch Granules of the Yam Cultivars

Cultivar	Aspect Ratio (AR)	Elongation Ratio (N)	Roundness (RD)	Irregularity (IR)	Circularity
Ajimokun	0.62 ± 0.0124^{ab}	1.70 ± 0.0417^{a}	0.35 ± 0.0211^{ab}	3.64 ± 0.0930^{b}	0.39 ± 0.0079^{bc}
Anika	0.62 ± 0.0126^{ab}	1.67 ± 0.0344^{a}	0.21 ± 0.0195^{a}	4.82 ± 0.1272^{ef}	0.40 ± 0.0080^{bc}
Areyingbakumo	0.71 ± 0.0110^{efg}	1.46 ± 0.0276^{a}	0.25 ± 0.0157^{a}	4.59 ± 0.1089^{de}	0.45 ± 0.0070^{fgh}
Boki	0.66 ± 0.0099^{cd}	2.96 ± 1.4395^{b}	0.47 ± 0.2230^{b}	4.32 ± 0.0975^{cd}	0.42 ± 0.0063^{de}
Gambari	0.70 ± 0.0098^{ef}	1.45 ± 0.0207^{a}	0.16 ± 0.0094^{a}	5.62 ± 0.1146^{g}	0.45 ± 0.0063^{fg}
Gaungaun	0.60 ± 0.0108^{a}	1.77 ± 0.0632^{a}	0.23 ± 0.0243^{a}	4.59 ± 0.1059^{de}	0.38 ± 0.0069^{b}
Ikumo	0.72 ± 0.0090^{fg}	1.41 ± 0.0202^{a}	0.30 ± 0.0167^{ab}	3.35 ± 0.0656^{a}	0.31 ± 0.0038^{a}
Ilesu	0.74 ± 0.0134^{g}	1.41 ± 0.0319^{a}	0.31 ± 0.0201^{ab}	4.20 ± 0.1021^{c}	0.47 ± 0.0085^{h}
Lolo ayin	0.72 ± 0.0130^{fg}	1.45 ± 0.0323^{a}	0.30 ± 0.0158^{ab}	4.16 ± 0.0964^{c}	0.46 ± 0.0083^{gh}
Obabi	0.69 ± 0.0145^{def}	1.49 ± 0.0278^{a}	0.17 ± 0.0127^{a}	5.47 ± 0.1147^{g}	0.44 ± 0.0092^{efg}
Odo	0.65 ± 0.0109^{bc}	1.58 ± 0.0281^{a}	0.18 ± 0.0074^{a}	5.00 ± 0.0855^{cd}	0.41 ± 0.0069^{cd}
Ogunmole	0.79 ± 0.0115^{h}	1.30 ± 0.0195^{a}	0.26 ± 0.0109^{a}	4.57 ± 0.0844^{de}	0.50 ± 0.0073^{i}
Okunmodo	0.68 ± 0.0117^{cde}	1.53 ± 0.0306^{a}	0.25 ± 0.0105^{a}	4.31 ± 0.0840^{cd}	0.43 ± 0.0075^{def}
Sandpaper	0.69 ± 0.0124^{def}	1.50 ± 0.0297^{a}	0.24 ± 0.0105^{a}	4.54 ± 0.0945^{de}	0.44 ± 0.0079^{efg}

**Means with the same letter along columns are not significantly different at $P \leq 0.05$.

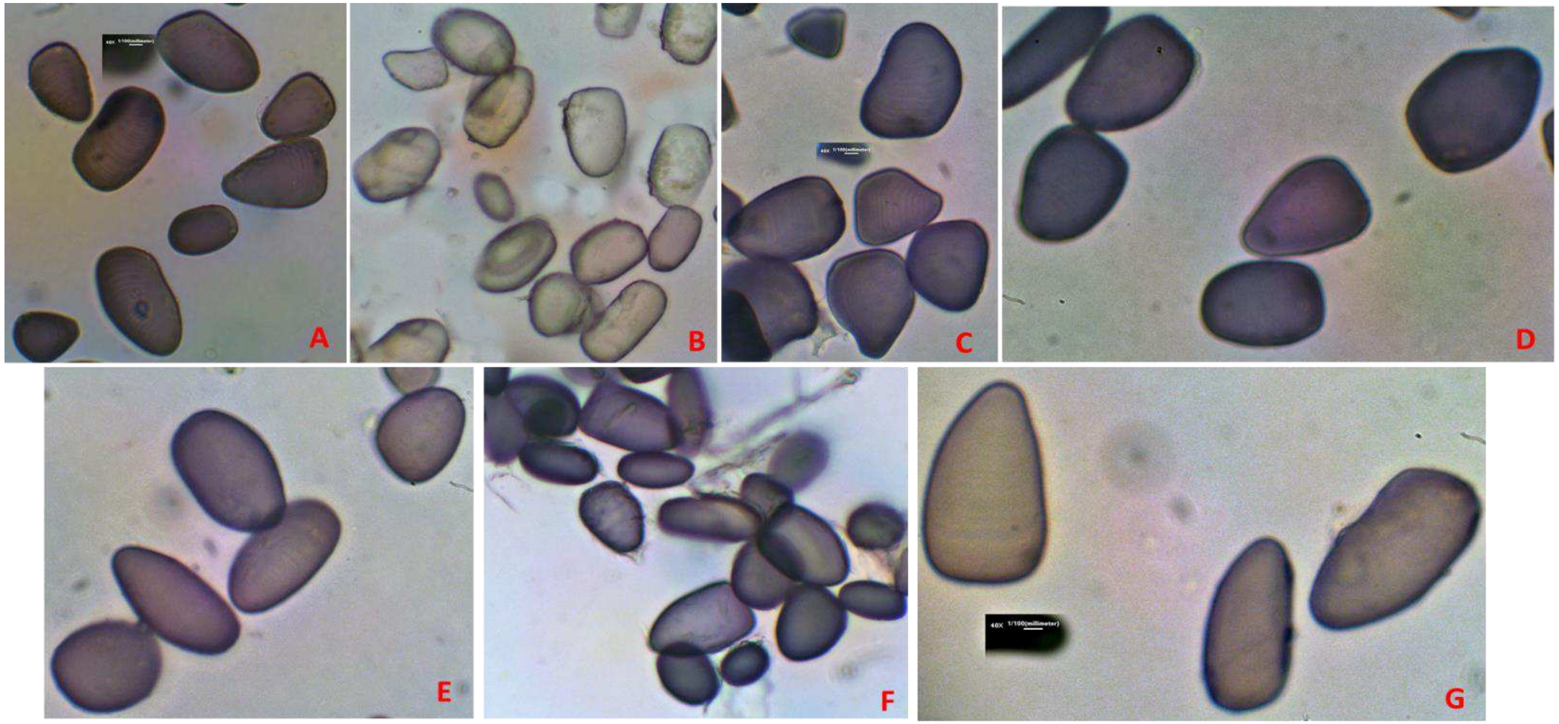

Plate 4: Starch Granules of the *Dioscorea* Cultivars Studied

A. Ajimokun (*D. rotundata*)
B. Anika (*D. rotundata*)
C. Sandpaper (*D. rotundata*)
D. Ikumo (*D. rotundata*)
E. Boki (*D. rotundata*)
F. Gambari (*D. rotundata*)
G. Gaungaun (*D. rotundata*)

TABLE 7: Density of the Starch Powder of the Yam Cultivars

Cultivar	Bulk Density	Tapped Density Number of Taps					Particle Density	Packing fraction	Porosity
		20	40	60	80	100			
Ajimokun	0.49	0.67	0.76	0.77	0.78	0.80	1.67	0.29	0.71
Anika	0.58	0.75	0.78	0.80	0.81	0.83	1.52	0.38	0.62
Areyingakumo	0.48	0.66	0.72	0.77	0.79	0.81	1.54	0.31	0.69
Boki	0.52	0.69	0.75	0.79	0.83	0.83	1.87	0.28	0.72
Gambari	0.58	0.74	0.81	0.85	0.86	0.87	1.37	0.42	0.58
Gaungaun	0.56	0.73	0.75	0.78	0.80	0.81	1.40	0.40	0.60
Ikumo	0.51	0.70	0.75	0.78	0.81	0.82	1.67	0.30	0.70
Ilesu	0.52	0.65	0.71	0.76	0.80	0.83	1.82	0.28	0.72
Lolo ayin	0.53	0.67	0.77	0.83	0.85	0.87	1.69	0.31	0.69
Obabi	0.48	0.67	0.74	0.75	0.77	0.78	1.82	0.27	0.73
Odo	0.52	0.71	0.74	0.77	0.78	0.80	2.09	0.25	0.75
Ogunmole	0.49	0.68	0.74	0.78	0.80	0.80	1.75	0.28	0.72
Okunmodo	0.48	0.67	0.73	0.76	0.78	0.79	1.66	0.29	0.71
Sandpaper	0.57	0.73	0.81	0.86	0.87	0.89	1.90	0.30	0.70

Table 8: Swelling Capacity, Water Retention and Amylose Content of the Starch Powder of the Yam Cultivars

Cultivar	Swelling Capacity	Water Retention Capacity	Amylose Content
Ajimokun	61.54 ± 0.0100^{e}	62.81 ± 4.5560^{ab}	36.76 ± 0.0535^{c}
Anika	52.27 ± 1.0164^{b}	45.23 ± 1.8206^{a}	45.02 ± 0.2160^{i}
Areyingbakumo	55.53 ± 0.4419^{d}	63.46 ± 1.0485^{ab}	32.42 ± 0.0203^{b}
Boki	54.55 ± 0.0100^{cd}	63.68 ± 0.5098^{ab}	44.71 ± 0.0736^{h}
Gambari	45.91 ± 0.6538^{a}	59.98 ± 3.6975^{ab}	45.96 ± 0.1833^{j}
Gaungaun	55.53 ± 0.4419^{d}	50.38 ± 5.1956^{a}	46.47 ± 0.0538^{k}
Ikumo	60.77 ± 0.3440^{e}	71.01 ± 1.0896^{ab}	42.15 ± 0.0541^{f}
Ilesu	60.77 ± 0.3440^{e}	81.10 ± 6.5911^{b}	44.41 ± 0.0736^{g}
Lolo Ayin	55.53 ± 0.4419^{d}	64.22 ± 9.2921^{ab}	26.89 ± 0.0813^{a}
Obabi	53.46 ± 0.4840^{bc}	41.06 ± 15.1514^{a}	42.13 ± 0.041^{f}
Odo	56.44 ± 0.8470^{d}	56.14 ± 2.9690^{ab}	37.13 ± 0.0410^{d}
Ogunmole	59.94 ± 0.7167^{e}	49.98 ± 21.1042^{a}	36.70 ± 0.729^{c}
Okunmodo	59.94 ± 0.7167^{e}	48.90 ± 13.0717^{a}	38.92 ± 0.1227^{e}
Sandpaper	56.44 ± 0.8470^{d}	57.05 ± 10.5319^{ab}	36.776 ± 0.0203^{c}

**Means with the same letter along columns are not significantly different at $P \leq 0.05$.

TABLE 9: Rapid Viscometer Analysis of the Starch Powders of the Yam Cultivars

CULTIVAR	Peak Viscosity (RVU)	Trough Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Setback Viscosity (RVU)	Peak Time (min)	Peak Temperature (ºC)
Ajimokun	592.83±19.00^{ef}	463.21±13.29^{cde}	129.63±5.71^{bcd}	884.96±17.04^{e}	421.75±3.75^{cd}	5.00±.0.01^{bc}	79.08±0.03^{cd}
Anika	779.58±1.000^{i}	306.25±15.00^{ab}	473.33±16.00^{g}	547.00±37.58^{a}	240.75±52.58^{a}	4.40±.0.01^{a}	76.28±0.43^{a}
Areyingbakumo	607.33±10.08^{fg}	373.21±17.79^{bc}	234.13±7.71^{e}	792.75±6.75^{cde}	419.54±11.042^{cd}	4.90±0.03^{b}	79.48±0.38^{d}
Boki	387.42±3.83^{a}	323.46±3.79^{ab}	63.96±0.04^{ab}	678.25±1.75^{b}	354.79±2.04167^{abc}	5.60±0.01^{d}	81.50±0.01^{e}
Gambari	666.46±10.54^{gh}	549.63±15.54^{e}	116.83±5.00^{bcd}	1060.75±1.92^{e}	511.125±13.63^{e}	5.10±0.0.10^{bc}	77.43±0.03^{b}
Gaungaun	405.83±6.25^{a}	225.125±10.875^{a}	180.71±17.13^{de}	733.33±12.92^{bc}	508.21±23.79^{e}	5.10±0.24^{bc}	78.70±0.40^{cd}
Ikumo	548.25±14.17^{cdef}	454.83±42.17^{cde}	93.42±28.00^{bc}	876.92±11.92^{e}	422.0833±30.25^{cd}	5.13±0.01^{bc}	80.75±0.01^{e}
Ilesu	502.83±0.08^{bcd}	493.38±0.38^{de}	9.46±0.29^{a}	765.42±5.33^{cd}	272.04±4.96^{ab}	6.03±0.03^{e}	81.53±0.03^{e}
Lolo Ayn	474.71±27.30^{b}	239.83±2.75^{a}	234.88±24.54^{e}	660.96±83.79^{b}	421.13±81.04^{cd}	5.13±0.01^{bc}	78.70±0.40^{cd}
Obabi	717.88±39.46^{h}	363.71±79.30^{bc}	354.17±39.83^{f}	648.25±31.33^{b}	284.54±47.96^{ab}	4.90±0.03^{b}	77.48±0.03^{b}
Odo	564.29±0.96^{def}	469.80±5.46^{cde}	94.50±4.50^{bc}	845.50±15.17^{de}	375.71±9.71^{bc}	5.07±0.27^{bc}	79.10±0.05^{d}
Ogunmole	708.75±0.08^{h}	547.88±6.96^{e}	160.88±6.88^{cd}	867.54±0.71^{e}	319.67±7.67^{abc}	5.20±0.01^{bc}	78.25±0.05^{c}
Okunmodo	499.25±25.50^{bc}	268.54±29.21^{ab}	230.71±3.71^{e}	794.25±7.08^{cde}	525.71±22.13^{e}	5.20±0.07^{bc}	78.68±0.48^{cd}
Sandpaper	530.00±39.33^{bcde}	382.83±94.33^{bc}	147.17±55.00^{cd}	831.54±10.29^{de}	448.71±84.04^{cd}	5.27±0.13^{c}	80.73±0.03^{e}

**means with the same letter along columns are not significantly different at $P \leq 0.05$.

DISCUSSION

The yam cultivars were clearly designated on the bases of the morphological characters of the vines (smooth, branched/multiple; spined or smooth), leaf shape; tuber shape, presence or absence of cusps, presence or absence of hairiness and its distribution patterns as detailed out in Table 3. Farmers had no difficulties whatsoever in identifying their yam cultivars but these identities were not that clear with marketers of yam who rely essentially on hairiness of tubers, particularly its occurrence, density and distribution patterns, for the identification of the cultivars.

The vines of yam have very useful agrobotanical characters as the aerial part of the yam crop. The ability to climb stakes and trees enable the vines to display the leaves of the above-ground biomass for the interception of sunlight. All the cultivars studied are climbers but *Boki*, *Gaungaun* and *Areyingbakumo* can make do with spreading their branches on heaps or stubs of trees or low-hanging branches of neighbouring dead trees. Multiple vines are a major advantage for the yam crop; first because it can result in the production of multiple tubers and second, because it can ensure the survival of at least one vine when drought causes vines to die back. Multiple vines occur when the first bud produced by the corm of the yam seed does not exert apical dominance on successive ones.

Yam is propagated through yam sets which are obtained by cutting matured tubers into sizeable units. The second crop is obtained after harvesting the first tuber without damaging the corm and existing roots. This enables the corm to produce another tuber which is often used as yam sets. All the yam cultivars studied have this character but the main tuber of *Gambari* does not produce good yam sets; only the secondary tuber does. This is the main reason, apart from the fact that it does not store well, that the mass adoption of this cultivar created problems for farmers in Ekiti State. Cultivar *Gambari* is however rated highly among consumers because of its suitability for the production of i*yan*. The poor storability is ameliorated by careful digging during harvesting to ensure that the tubers are not injured; they are not even washed for the same reason!

Standardization of Pounded yam (*Iyan*) Quality of the Cultivars Studied

Pounded yam is an important food in Africa and a prominent traditional food consumed throughout Nigeria with *D. rotundata* being the major species widely used (Otagbayo et al. 2007; Adeola et al. 2012). In Ekiti State where this study was domiciled, pounded yam is almost a mandatory meal for all supers. The expertise to make good *iyan* is an acquired habit in women from their formative years. Professional caterers do not lack expertise to hire because there are many experts that the *iyan* tradition has engendered in the population.

The highest cooking time was recorded for *Ikumo* and *Okunmodo* for fresh and stored yam tubers, respectively, which contradicts the result of the Rapid Viscometer Analysis (RVA) peak time and temperature. This could be as a result of the lower temperature intensity used in cooking these yam cultivars when there is less urgency for a meal. The RVA result revealed that most of the cultivars that required high cooking time also had significantly-high peak temperatures for their starch pasting. The respondents identified optimal cooking as a major factor for quality pounded yam while over-cooking reduced paste quality. The result obtained for pasting time of the starch from the Rapid Viscometer Analysis (RVA) is in conformity with the report of Otegbayo et al. (2006).

The quality of a good pounded yam is the function of the textural quality of the yam used which adept caterers have mastered. The specific elements of this quality are attributes like springiness, cohesiveness, hardness, smoothness and stickiness (Bogunjoko 1992; Mensah 1995; Otegbayo et al. 2006; Nindjin et al. 2007). These pasting attributes are ensured by standard cooking practices.

The yam cultivars used in this study demonstrated good textural qualities as evidenced by their high peak viscosity, breakdown viscosity, final viscosity and setback viscosity. Pasting temperatures were also low for fresh yam as reported by Otegbayo et al. (2006). Starch gelatinization resulted in the syrupy nature of the water left after cooking which is always used in the pounding process thereby recycling the gelatinised starch particles.

The pounding process was supervised by physically assessing the paste for the diagnostic attributes with the sense of touch. The term *riro* has been decoded in Table 3 to define the states of textural attribute of pounded yam which the traditional professionals have mastered and used at various check points in the pounding process for quality assurance. The final *iyan* is rolled into a ball of smooth paste that does not stick to the mortar.

Of the twenty cultivars identified and characterised in this study, three (*Dioscorea dumetorum*, *Dioscorea alata* and *Dioscorea cayenensis*) were not used for the preparation of *iyan* because they are not so-used in most of Southwestern Nigeria. As a matter of fact, it is taboo to use *D. dumetorum* for *iyan* in most of this region. It is also important to place the fact that *iyan* is the most hygienic food prepared from yam, as a result of the precision required in its processing from peeling through cooking to pounding, on record. The other preparation from yam is the yam flour, traditionally known as *elubo*, and it is used to prepare *amala* which is another important food in many parts of Southwestern Nigeria. The traditional processes of making yam powder are open to a lot of contamination ranging from use of spoilt yam, incorporation of particulates, animal remains, etc. from unhygienic drying environments (shoulder of roads, open spaces around habitations) and during the marketing process.

Starch Analysis of the Yam Cultivars

High irregularity (IR) has been attributed to the presence of a large amount of amylose which can inhibit the swelling of pounded yam (Gallant and Bouchet 1986; Zeleznak and Hesney 1997; Otegbayo et al. 2011). None of the yam powders had good flowability but *Ilesu*, followed by *Lolo Ayin* recorded fair values of this parameter. Flowability is complex because it depends on many properties (Adeoye and Alebiowu, 2014) among which are size and shape of starch particles. In this regard, the particle size, flowability, swelling and amylose contents of *Gambari* and *Gaungaun* starch powders were high. This contradicts the findings of Alebiowu and Itiola (2002), Otegbayo et al. (2011) and Zhu (2015) which reported a direct relationship between the parameters. The highest and lowest water retention was recorded for *Ilesu* and *Anika* powders. Generally, *D. rotundata* cultivars have closely-associated starch polymers which compare with polymers of other native starches (Falade and Ayetigbo, 2014). Rasper and Coursey (1967) showed that the influence of amylopectin can affect the pasting and gel properties of starches with similar amylose contents. Amylopectin is mainly responsible for water uptake; peak viscosity and associated parameters are generally negatively correlated with amylose content. Final Viscosity can be an important parameter in predicting the textural quality of pounded yam. In this regard, *Gambari* is outstanding.

The major objectives of this study have been achieved. Twenty cultivars of *Dioscorea rotundata* including some from *D. cayenensis*, *D. alata* and *D. dumetorum* have been collected, characterised and will be conserved through regular propagation for further studies and utilization. The morphological and physical properties of the starch granules of the yam cultivars studied and their chemical compositions are in agreement with the studies of Otegbayo et al. (2006). Higher Final Viscosity, Breakdown Viscosity and Setback Viscosity were recorded for all the cultivars. This trend explains the stability of their pastes (Oduro et al. 2000). The pasting temperatures are in the range of 76.28ºC and 81.53ºC which, with the other physical properties, explains the high quality of the paste of the yam cultivars in pounded yam.

The next phase of research on this base collection will be focused on the areas of propagation, conservation and improvement (raising of plantlets from nodal cuttings which will be nurtured through tuberization) as proposed by Balogun et al. (2004; 2007), the use of biotechnology (regular tissue culture techniques such as callus production and differentiation to produce plantlets) and also through somatic embryogenesis, selection of cultivars that produce botanic seeds and generation of hybrids through regular breeding processes.

Previous reports on propagation highlighted the effects of explant, species and genotype on tuberization (Balogun, 2004; 2009). This has limited the adoption of these techniques to cultivars/genotypes that are amenable. The immediate danger in promoting plants that are amenable to specific propagation methods for adoption is the narrowing of the genetic base of materials available for cultivation. The adoption of the core cultivars used by local farmers should not be controlled by the ease of tuberization for a few cultivars/ genotypes. This can be ensured by encouraging peasant farmers to keep their prime cultivars rather than inducing them to adopt the new products of research exclusively. The way forward for yam conservation is to prioritize all the core cultivars for further studies using all the methods available to advance each cultivar for easier propagation, conservation and improvement.

REFERENCES

Adegbite AA, Saka JO, Agbaje GO, Owolade OF, Olaifa GO, Lawal A and Ojo ST (2006). Survey of plant parasitic nematodes associated with yams in Edo, Ekiti and Oyo States of Nigeria. Afr J Agric Res 1: 125–130. https://doi.org/10.2478/v10045-008-0051-4.

Adeola AA, Otegbayo BO and Ogunnoiki S (2012). Preliminary Studies on the Development and Evaluation of Instant Pounded Yam from *Dioscorea alata*. J. Appl. Sci. Environ. Manage. 16(3): 287 – 290.

Adeoye O and Alebiowu G (2014). Flow, packing and compaction properties of novel coprocessed multifunctional directly compressible excipients prepared from tapioca starch and mannitol. Pharm. Dev. Tech., 19(8): 901–910. https://doi.org/10.3109/10837450.2013.840843

Agoyi TO (2013). Language, Invasion and Insecurity: The History of Àbèsàbèsì. Am. J. Soc. Iss. Hum. 3(2): 68.

Aighewi BA, Asiedu R, Maroya N and Balogun M (2015). Improved propagation methods to raise the productivity of yam (*Dioscorea rotundata* Poir.). Fd. Sec., 7(4). https://doi.org/10.1007/s12571-015-0481-6

Alebiowu G and Itiola OA (2002). Compressional characteristics of native and pregelatinized forms of sorghum, plantain, and corn starches and the mechanical properties of their tablets. Drug Dev. Ind. Pharm. 28(6): 663-72.

Ayensu ES (1972). Anatomy of the Monocotyledons. Clarendon Press, Oxford, pp. 182.

Balogun MO (2009). Microtubers in yam germplasm conservation and propagation: The status, the prospects and the constraints. Biotech. and Mol. Bio. Rev., 4(1): 1–10.

Balogun MO, N. M. and R. A. (2014). Status and prospects for improving yam seed systems using temporary immersion bioreactors. Afr. J. Biotech. 13(15): 1614–1622. https://doi.org/10.5897/ajbx2013.13522

Balogun MO, Ng NQ, Fawole I and Kikumo H (2007). Variations in microtuberization among local, improved and exotic yam accessions in Nigeria. Proceedings of 20th Annual Conference, Biotech. Soc. Nig. Pp. 44-57.

Balogun MO, Ng NQ, Shiwachi SYC, Ng NQ and Fawole I (2004). Comparative effects of explant sources and genotypes on microtuberization in yams (Dioscorea spp.). Trop. Sci., 44: 196–200.

Bell A (1983). Mineral content of yam tubers: Raw, Boiled and as Flour. In: Tropical Root Crops. Production and uses in Africa. Proceedings of a second Triennial Symposium of the International Society for Tropical Root Crops. Africa Branch, Douala, Cameroon, 14 -19th August 1983. pp 157 – 160.

Bogunjoko JST (1992). Research and development into commercial yam processing in Nigeria:Cadbury's poundo yam. In Product Development for Root and Tuber Crops, Proceedings of the Workshop on Processing Marketing and Utilization of Root and Tuber Crops in Africa, October 26–November 2, 1991, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, Vol 3 (G. Scott, P.I. Ferguson and J.E. Herrera, eds.) pp. 471–473, CIP, Lima, Peru.

Coursey DG (1967). Yams: an account of nature, origins, cultivation and utilization of useful members of Dioscoreaceae. Longmans, Greens and co Ltd., UK, pp230.

Eni AO (2008). Epidemiology, Diagnostics and Molecular Studies of Yam Viruses in Ghana, Togo and Benin. Ph.D. Thesis. University of Witwatersrand. Johannesburg, South Africa. 200 p.

Falade KO and Ayetigbo OE (2014). Effects of annealing, acid hydrolysis and citric acid modifications on physical and functional properties of starches from four yam (*Dioscorea* spp.) cultivars. Food Hydrocolloids 3: 1-11. http://dx.doi.org/10.1016/j.foodhyd.2014.07.008

FAO (1991). Yam (Dioscorea spp.) processing. In: Post-harvest and processing technologies of African staple foods: a technical compendium. FAO Agric. Services Bulletin 89. Food and Agricultural Organization (FAO), Rome, pp. 225–235

FAO (2010). FAOSTAT Database. Food and Agriculture Organization, Roma, Italy. Available online at URL: www.fao.org

FAO (2013). FAOSTAT Database. Food and Agriculture Organization, Roma, Italy. Available online at URL: http://faostat.fao.org

Farhat, I.A., Oguntona, T. and Neale, R.J. (1999). Characterization of starches from West African Yams. J. Sci. Food Agr. 79: 2105 – 2112.

Gallant DJ and Bouchet B (1986). Ultrastructure of maize starch granules: A review. Food Microstructure 5:141.

IITA (2009). Yam. International Institute of Tropical Agriculture, Ibadan, Nigeria. Available at [www.iita.org/yam]. Accessed 2012.

IPGRI (1993). Diversity for development: the strategy of the International Plant Genetic Resources Institute. Retrieved from https://www.bioversityinternational.org/fileadmin/user_upload/online_library/publications/pdfs/IPGRI_annualReport_1993.pdf

Iwuoha CI (1999). Effects of Processing on the Physico-chemical Properties of Instant yam Flour from *Dioscorea rotundata* Poir., PhD Dissertation, Federal University of Technology, Owerri, Nigeria.

Iwuoha CI and Nnanemere CJ (2003) Swelling index of yam flour as affected by tuber variety, processing method and analytical temperature. Afr J Root Tuber Crops 15(2):15–17

Iwuoha CI and Nwakanma MI (1998). Density and viscosity of cold flour pastes of cassava (Manihot esculenta Grantz), sweet potato (Ipomoea batatas L. Lam) and white yam (*Dioscorea rotundata* Poir.) tubers as affected by concentration and particle size. Carbohydr. Polym., 37(1), 97–101.

Malomo O and Jayeola AA (2010). Micromorphological and Chemical Characterization of Starches in *Dioscorea rotundata* L. (White Yam), Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 38(1): 14–20.

Mensah EO 1995. Processing Factors that Affect the Textural and Rheo- logical Properties of Yam (*Dioscorea rotundata* Poir) flour. PhD Thesis No. 9511917, pp. 76–79, Cornell University, Ithaca, NY.

Mignouna HD, Abang MM and Fagbemi SA (2003). A comparative assessment of molecular marker assays (AFLP, RAPD and SSR) for white yam (*Dioscorea rotundata*) germplasm characterisation. Ann. Appl. Biol. 1 42: 269-276.

Murti SK (2001). Flora of Cold Deserts of Western Himalaya. Vol. 1. (Monocotyledons).

Nindjin C, Otokoré D, Hauser S, Tschannen A, Farah Z and Girardin O (2007). Determination of relevant sensory properties of pounded yams (*Dioscorea spp*.) using a locally based descriptive analysis methodology. Food Quality and Preference, 18(2), 450–459. https://doi.org/10.1016/j.foodqual.2006.05.005

Nweke FI, Ugwu BO, Asadu CLA and Ay P (1991). Production costs in the yam-based cropping systems of southwestern Nigeria. Research Monograph No. 6, IITA, Ibadan, Nigeria. Resource and Crop Management Division. p.29.

Oduro I, Ellis WO, Aryeetey SK, Ahenkora K and Otoo JA (2000). Pasting characteristics of starch from new varieties of sweet potato. Tropical Science, 40: 25-28.

Oluwasusi JO and Tijani SA (2013). Farmers Adaptation Strategies to The Effect of Climate Variation on Yam Production: A Case Study in Ekiti State, Nigeria. Agrosearch, Vol.13(2):20-31.

Onwueme IC (1978). The Tropical Tuber Crops. John Wiley and Sons. pp. 3-102.

Otegbayo B, Aina J, Abbey L, Sakyi-Dawson E, Bokanga M and Asiedu R (2007). Texture profile analysis applied to pounded yam. J. Texture Studies 38: 355–372.

Otegbayo B, Aina J, Asiedu R and 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(2006): 663–669.

Otegbayo B, Bokanga M and Asiedu R (2011). Physicochemical properties of yam starch: Effect on textural quality of yam food product (pounded yam). J. Fd. Agric. and Env., 9(1): 145–150.

Quain MD, Egnin M, Bey B, Thompson R and Bonsi C (2011). Trans-genic potential of *Dioscorea rotundata*, using Agrobacterium-mediated genetic transformation. Asp. Appl. Biol. 110: 71–79.

Rašper V and Coursey DG (1967). Properties of starches of some West African yams. J. Sci. Fd. Agric. 18.

Smith BW (1937). Notes on the Cytology and Distribution of the Dioscoreaceae. Bulletin of the Torrey Botanical Club. Torrey Botanical Society. 64(4): 189-197.

Zeleznak KJ and Hoseney RC (1997). The glass transition in starch. Cereal Chemistry 64: 121-124.

Zhu F (2015). Isolation, Composition, Structure, Properties, Modifications, and Uses of Yam Starch. Comprehensive Rev. Fd. Sci. Fd. Saf. 14: doi:10.1111/1541-4337.12134.