Evaluation of Instant Pounded Yam Flour Produced from Yellow Yam (*Dioscorea Cayenensis*)

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ABSTRACT

This study was aimed at determining the chemical, pasting, functional and organoleptic properties of instant pounded yam flour (IPYF) produced from *Dioscorea cayenensis*. Fresh yams obtained from a market in Akure, Ondo State, Nigeria, were peeled, washed, sliced to 2, 4 and 6 mm thicknesses with FUTA Slicer. A half portion was blanched at 90 °C and other at 100 °C for 10, 15 and 20 minutes, drained, dried using hot air oven at 60 °C and the dried chips were milled, sieved and package in white polythene bag. Control samples were prepared using *Dioscorea rotundata*. The samples were analysed for physicochemical, functional, pasting, minerals and organoleptic properties. All data obtained were subjected to statistical analysis. The result of the study showed that IPYF produced from *Dioscorea cayenensis* had significant higher values in all parameters than the once from *Dioscorea rotundata*, except in fat, dispersibility and organoleptic properties. It indicates that, *Dioscorea cayenensis* has good qualities than *Dioscorea rotundata* when processed to IPYF based on physicochemical, functional and pasting properties. IPYF of 4 mm at 100 °C for 10 minutes is recommended from yellow yam.

Keywords: *Instant pounded yam flour, Yellow yam, White yam, Drying, Milling.*

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Highlights of this paper

- This study reports the potentials of using *Dioscorea cayenensis* for Instant pounded yam flour instead *Dioscorea rotundata* that is commonly used.
- *Dioscorea rotundata* was found more suitable in terms of physicochemical, functional and pasting properties.

1. INTRODUCTION

More than six hundred species of yam tuber exist, but few are important as staple food in the tropics. According to Ike and Inoni [1] these include white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea cayenensis*), water yam (*Dioscorea alata*), trifoliate yam (*Dioscorea dumetorum*), aerial yam (*Dioscorea bulbifera*) and Chinese yam (*Dioscorea esculenta*). Yam consists of high energy, protein and iron content, but low Calcium and Zinc. It also provides protein three times more superior than the one of cassava and sweet potato. Apart from food, yams are also sources of nutraceutical compounds like saponins and sapogenins, which are precursors of cortisone used medically in the treatment of arthritis and some allergies [2].

Yellow yam (*Dioscorea cayenensis*) is the major variety of yam produced in Southwest Nigeria mainly by traditional farmers [3-5]. Yam undergoes many challenges such as, high production cost, post-harvest losses and low yields. During its planting and growing seasons, yam is scarce and expensive because, it is a seasonal crop that is mostly available during the harvesting period [6-9]. Storage life of yam is limited to their dormancy period, after which it begins to sprout and quickly lose dietary value. Yams are eaten mostly as boiled, pounded yam and amala [10, 11].

Yam is processed into pounded yam; this is regarded as the Yoruba's dough meal but eaten across tribes in Nigeria and Africa. It is made from cooked yam tubers by peeling fresh yam, boiling and pounding until a sticky elastic dough is formed. But, the perishability nature of yam due to its high moisture content suggests its low shelf life. Hence the need to process it into less perishable product like instant pounded yam flour (IPYF) [12]. IPYF is yam processed into flour by peeling, washing, cutting, blanching or boiling, drying, grinding into flour and then turned in boiling water to form a stiff dough meal. It is assessed for texture, which consists of smoothness, elasticity, consistency, stickiness and hardness [13].

According to Djeri, et al. [14] *Dioscorea cayenensis* has been relegated to the background as a result of traditional bias which fails to recognise its unique qualities: rich in carotene, possess high potential to elasticity when cook, a good property for acceptability of pounded yam and it is very adaptable to temperate region and highly resistant to drought [15, 16]. But it is more susceptible to deterioration than white yam. Therefore, according to Barau, et al. [17] converting it to IPYF after harvest will enable its better utilization and preservation.

2. MATERIALS AND METHODS

2.1. Material Used for the Study

The yam species used for this study was yellow yam (*Dioscorea cayenensis*). The tubers were procured from a yam market in Akure. All chemicals were of analytical grade.

2.2. Experimental Design

The experimental design was carried out using general factorial design having three factors (thickness, parboiling temperature and parboiling time) (3×2×3) factorial which resulted to 18 samples Table 1.

2.3. Method Used for the Study

IPYF were processed using the production procedures as described by Olaoye and Oyewole [18]. It was processed by removing bruised yellow yam tubers, peeled, washed with water to remove debris and dirt, sliced using Federal University of Technology (FUTA) Slicer to 2, 4 and 6 mm thicknesses, parboiled at temperature of 90 and 100 °C for 10, 15 and 20 minutes, drained with sieve and dried using hot air oven at 60 °C. The dried chips were milled, sieved and packaged in polythene bags.

Table-1. Experimental design; varying thickness, temperature and time of parboiling.

Treatment	Material type	Code	Thickness (mm)	Parboilin time (min)	Parboiling temperature (°C)
A1	Yellow yam	Y90-2-10	2	10	90
A2		Y90-2-15	2	15	90
A3		Y90-2-20	2	20	90
A4		Y100-2-10	2	10	100
A5		Y100-2-15	2	15	100
A6		Y100-2-20	2	20	100
B1	Yellow yam	Y90-4-10	4	10	90
B2		Y90-4-15	4	15	90
B3		Y90-4-20	4	20	90
B4		Y100-4-10	4	10	100
B5		Y100-4-15	4	15	100
B6		Y100-4-20	4	20	100
C1	Yellow yam	Y90-6-10	6	10	90
C2		Y90-6-15	6	15	90
C3		Y90-6-20	6	20	90
C4		Y100-6-10	6	10	100
C5		Y100-6-15	6	15	100
C6		Y100-2-20	6	20	100
CON	Commercial product	Control			

Y90-2-10 (pounded yam flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

2.4. Analyses Carried Out

Determination of the Proximate Composition of IPYF: The proximate composition of the samples was determined using the standard procedures described by AOAC [19].

2.5. Determination of the Physicochemical Properties of IPYF

2.5.1. pH Determination

The pH was determined by the method described by Akpapunam and Sefa-Dedeh [20] and Mbaeyi-Nwaoha and Onweluzo [21] where 10 g of the sample was dissolved in 100 ml of distilled water. The mixture was allowed to equilibrate for 3 minutes at room temperature. The pH was then determined by inserting the electrode of the pH meter in the sample then taking the result displayed on the pH meter.

2.5.2. Total Titratableacidity (TTA)

This was determined by the method described by AOAC [19]. The sample was dissolved in distilled water and mixed thoroughly.1 ml of phenolphthalein indicator was introduced nto10 ml of the mixed solution. It was titrated against standard sodium hydroxide solution until pink colour persisted for about10-15 seconds for complete neutralization.

2.5.3. Amylose and Amylopectin Content

The method of Hoover and Ratnayake [22] was used. It is a colorimetric method in which amylose forms starch iodine complex (dark blue colour) due to its high affinity for iodine. About 0.1 g of the flour sample was solubilized with 1 ml of 95% ethanol and 9 ml of 1 N sodium hydroxide (NaOH), and heated in a boiling water bath for 10 min; 1 ml of the extract was made up to 10 ml with distilled water. To 0.5 ml of the diluted extract was added 0.1 ml I N acetic acid and 0.2 ml iodine solution (0.2 g Iodine+2.0 g KI in 100 ml of distilled water) to develop a dark blue colour. The coloured solution was made up to 10 ml with distilled water and allowed to stand for 20 min for complete colour development. The solution was vortexed and its absorbance was read on a spectrophotometer (Milton Roy Spectronic 601) at 620 nm**.** Absorbance of standard corn amylose with known amylose concentration was used to estimate the amylose content in the sample using Equation 1 as given below:

$$\%\ \text{Amylose} = \frac{\%\ \text{Amylose of standard} \times \text{Absorbance of sample}}{\text{Absorbance of standard}} \times 100 \qquad 1$$

% Amylopectin was obtained by subtracting the amylose content from that of starch.

2.5.4. Carotenoids Concentration

Total carotenoids concentration (TCC) was determined by UV/Visible absorption spectrophotometry (uQuant, Biotech Instruments, USA), at absorbance of 450 nm and using the absorption coefficient of ß-carotene in petroleum ether (2592) [23, 24].

2.5.5. Total Soluble Solids

1 g of flour sample was weighed into beaker and dissolved with 10 ml of distilled water. The sample was thoroughly mixed and total soluble solids of the samples were determined by putting a drop on the prism of hand refractometer. The values were expressed as percentage (%) degree brix.

2.6. Temperature – Based Functional Properties of IPYF

2.6.1. Determination of Swelling Power and Solubility Index

Swelling power and solubility index were determined using the method described by Takahashi and Seib [25]. It involved weighing 1 g of the sample into 50 ml centrifuge tube. 50 ml of distilled water was added and mixed gently. The slurry was heated in a water bath at 80°C for 15 min. During heating, the slurry was stirred gently to prevent clumping of the flour. On completion of15 min, the tube containing the paste was centrifuged at 3000 rpm for 10 minutes. The supernatant was decanted immediately after centrifuging. The weight of the sediment was taken and recorded. The moisture content of the sediments gel was therefore determined to get the dry matter content of the gel using Equation 2.

$$\text{Swelling power} = \frac{\text{Weight of wet mass sediment}}{\text{Weight of dry matter in the gel}} \times 100 \qquad 2$$

Solubility index (%) = Weight of dry solid after drying ×100

2.7. Functional Properties of IPYF

2.7.1. Water and Oil Absorption Capacity

Water absorption capacity was determined using the method of Sathe and Salunkhe [26] as modified by Adebowale, et al. [27]. Ten millilitres of distilled water was added to 1.0 g of the sample in a beaker. The suspension was stirred for 5 minutes. The suspension obtained was then centrifuged (with Celtech 80-2B centrifuge) at 3555 rpm for 30 minutes and the supernatant measured in a 10 ml graduated cylinder. Water absorbed was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant. The same procedure was repeated for oil absorption except that oil was used instead of water.

2.7.2. Bulk density

Bulk density was determined using the method of Akpapunam and Markakis [28] and Udensi and Okaka [29]. Ten grams (10 g) of sample was weighed into 50 ml graduated measuring cylinder. The sample was packed gently by tapping the cylinder on the bench top. The volume of the sample was recorded.

2.7.3. Dispersibility

Dispersibility was determined using the method described by Kulkarni, et al. [30]. Ten grams of the flour sample was weighed into 100 ml measuring cylinder, water was added to each volume of 100 ml, the set up stirred vigorously and allowed to stand for three hours. The volume of settled particles was recorded and subtracted from 100 using Equation 3.

$$\text{Percentage dispersibility} = 100 - \text{volume of settled particle} \qquad 3$$

2.7.4. Swelling Index

Swelling index was determined using the method described by Ojinnaka, et al. [31]. One gram of the flour was weighed into 10ml measuring cylinder and the volume it occupied was recorded (V1). Distilled water was added until the 10ml mark was reached. The cylinder containing the sample and distilled water was left to stand for 45 minutes after which the new volume (V2) was recorded. The swelling index was expressed as the ratio of the final over the initial volume.

2.7.5. Gelation Capacity

The gelation capacity was estimated according the method of Coffmann and Garciaj [32] as modified by Adeleke and Odedeji [33]. Flours dispersions of 4-14% (w/v) were prepared with distilled water in test tubes and mixed for 2 min. The mixtures obtained were boiled for 1 hr in a bain-marie and cooled at laboratory temperature. The least gelation concentration of sample flours (that is, the lowest concentration that gives a stable gel when tests tube is inverted) was determined.

2.7.6. Emulsification Capacity

The procedure of Adeleke and Odedeji [33] was used. 1 g of the flour sample was suspended in 50 ml centrifuge tubes and centrifuge at 4100 rpm for 5 minutes. The emulsification capacity was calculated using Equation 4:

$$\text{Emulsification capacity} = \frac{\text{Height of Emulsified layer}}{\text{Height of whole layer}} \times 100 \qquad 4$$

2.8. Determination of Pasting Properties of IPYF

Pasting characteristics were determined with a Rapid Visco Analyser (RVA super 3, Newport Scientific pty. Ltd, Australia). A 3-g sample of flour (at 14% moisture level) was dissolved in 25 ml of water in a sample canister. The sample was thoroughly mixed and fitted into the RVA as recommended [34]. The slurry was heated from 50 to 95°C with a holding time of 2 min followed by cooling to 50 °C with another 2 min holding time. The 12-min profile was used, and the rate of heating and cooling was at a constant rate of 11.25 °C/minute. Corresponding values for peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature from the pasting profile were read from a computer connected to the RVA.

2.9. Determination of Minerals Composition of IPYF

The mineral contents were analysed using [19]. Using dry ashing, the sample was ashed at 550 °C for 3 h. 5 ml of 6N hydrochloric acid (HCl) was mixed with the ash and made up to 50 ml with distilled water. Selected minerals including iron (Fe), calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), lead (Pb), copper (Cu), phosphorus (P) and zinc (Zn) were determined by atomic absorption spectrophotometer.

2.10. Evaluation of Organoleptic Properties of Reconstituted IPYF

IPYF was reconstituted into paste using 50 g of flour and 150 ml of boiled water. This was thoroughly stirred with a wooden spoon for smooth consistency, covered and cooked for about 5 minutes, stirred and wrapped in polyethylene and then kept in a cooler prior to sensory evaluation. A control was prepared from commercial product, using the same preparation method. Organoleptic properties were carried out by twenty semi trained panellists. The panellists evaluated the samples using questionnaires for scoring the sensory attributes of appearance, taste, hardness, consistency, stickiness, taste, colour, elasticity, and overall acceptability on a 9-point hedonic scale, presented to them in an environment with no interference for bias expression, and under bright lighting.

2.11. Statistical Analyses of Data

Statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL). All experiments were performed in triplicate and the mean values were reported. Comparisons between means were performed with Duncan Multiple Range test. Differences between means were evaluated as significant at $p<0.05$.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition of IPYF

The results of proximate analysis of instant pounded yam flour produced from yellow yam (IPYFY) and control are as presented in Table 2. Dietary fibre is mainly needed to keep the digestive system healthy. Fibre content of IPYF produced from yellow yam had highest value of 3.30% while control had 0.84%. They were significantly different at 95% confidence level ($p<0.05$). Olaoye and Oyewole [18] reported fibre highest value of 3.01% for *Dioscorea rotundata*, which shows that, *Dioscorea cayenensis* has higher fibre content when processed into IPYF.

Ash is a reflection of mineral status. Ash content of IPYFY had highest value of 3.07% while control had 2.05%. They were significantly different at 95% confidence level ($p<0.05$). Olaoye and Oyewole [18] reported ash highest value of 1.50% for *Dioscorea rotundata*, which shows that, *Dioscorea cayenensis* has higher ash content when processed into IPYFY.

Protein content of IPYFY had highest value of 5.92% while control had 4.75%. They were significantly different at 95% confidence level ($p<0.05$). Olaoye and Oyewole [18] reported protein highest value of 4.58% for *Dioscorea rotundata*, this shows that, *Dioscorea cayenensis* has higher protein content.

Table-2. Proximate compositions% (dry basis) of IPY.

Samples	Fibre	Ash	Protein	Fats	CHO
Y90-2-10	1.03± 0.00^{fg}	1.99± 0.02^{b}	4.65±0.01^{e}	5.03±0.03^{bc}	87.30±0.08^{bc}
Y90-2-15	1.13±0.00^{def}	1.93±0.00^{b}	2.75±0.01^{i}	4.96±0.00^{bc}	89.23±0.13^{a}
Y90-2-20	0.80± 0.12^{hi}	2.04±0.00^{b}	5.78±0.011^{b}	4.79±0.55^{bc}	86.59±0.70^{c}
Y100-2-10	0.73± 0.00^{i}	2.00±0.00^{b}	3.92±0.01^{h}	5.13±0.03^{bc}	88.22±0.44^{b}
Y100-2-15	0.89± 0.12^{hi}	1.01±0.02^{c}	4.75±0.01^{e}	5.24±0.01^{bc}	88.11±0.02^{b}
Y100-2-20	0.94± 0.00^{gh}	2.00±0.01^{b}	4.85±0.01^{d}	4.75±0.56^{bc}	87.46±0.72^{bc}
Y90-4-10	0.86± 0.12^{hi}	2.01±0.02^{b}	4.63±0.01^{e}	5.01±0.00^{bc}	87.49±0.83^{bc}
Y90-4-15	1.22± 0.06^{de}	1.98±0.02^{b}	5.78±0.02^{b}	5.05±0.00^{bc}	85.97±0.25^{cd}
Y90-4-20	3.30±0.06^{a}	1.99±0.04^{b}	5.63±0.01^{c}	5.09±0.00^{bc}	83.99±0.48^{f}
Y100-4-10	1.25±0.00^{d}	1.69±0.57^{bc}	5.92±0.01^{a}	4.43±0.57^{c}	86.73±0.01^{c}
Y100-4-15	2.69±0.00^{b}	1.98±0.01^{b}	4.61±0.01^{e}	4.70±0.56^{bc}	86.02±0.29^{c}
Y100-4-20	3.24±0.00^{a}	2.02±0.01^{b}	5.58±0.01^{c}	5.08±0.00^{bc}	84.08±0.59^{e}
Y90-6-10	3.28±0.00^{a}	3.07±0.03^{a}	4.16±0.01^{h}	4.83±0.58^{bc}	84.67±0.80^{de}
Y90-6-15	1.25±0.00^{d}	1.66±0.55^{bc}	5.90±0.01^{a}	5.73±0.58^{b}	85.46±1.61^{d}
Y90-6-20	1.29±0.06^{d}	1.63±0.53^{bc}	4.12±0.01^{h}	5.15±0.00^{bc}	87.83±1.20^{bc}
Y100-6-10	0.94±0.00^{gh}	2.01±0.03^{b}	4.46±0.01^{f}	4.42±0.54^{c}	88.18±0.53^{b}
Y100-6-15	1.07±0.06^{efg}	1.66±0.55^{bc}	4.24±0.01^{g}	4.72±0.58^{bc}	88.31±0.80^{b}
Y100-6-20	1.76±0.02^{c}	2.00±0.01^{b}	2.79±0.01^{i}	5.07±0.00^{bc}	88.39±0.13^{b}
Control	0.84±0.00^{i}	2.05±0.02^{b}	4.75±0.01^{e}	7.26±0.00^{a}	85.10±0.40^{d}

*Means that do not share a letter in the same column are significantly different at 95% confidence level ($p<0.05$). CHO (carbohydrate). Y90-2-10 (pounded yam flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

3.2. Physicochemical Properties of IPYF

The results of physicochemical properties of IPYFY and the control were presented in Table 3. Physicochemical properties are important for food processing and quality, because they influence functional properties of flour which in turn affect the textural quality of food products, [35-37].

The pH of IPYFY had highest value of 6.47 while control had 5.37. pH of the IPYFY is significantly higher than the control. This indicates that, control has more acidic strength than IPYFY, this implies that if both are reconstituted, the control can stay longer or consistent.

The total carotenoids concentration of IPYFY had highest value of 0.31(mg / 100g) while control had 0.00 (mg/100g). IPYFY can contribute some amount of vitamin A (retinol) in the diet and reduce vitamin A deficiency (VAD) that is endemic in Sub Saharan Africa [38-40]. Total titratable acidity has direct correlation with pH, the lower the pH the higher the titratable acidity. The total titratable acidity of IPYFY 0.69% is significantly higher than the control 0.58%. Low values of acidity are an indication of little or no fermentation. The total soluble solids of IPYFY is 2.07 while control had 0.53. It indicates that, control has low sugar content compare to IPYFY.

Amylose or amylopectin ratio has been reported to impart definite characteristics and functionality to starches by determining the basic texture and nature of their products [41]. Amylose content has been observed to have a high effect on the swelling power, viscosity, solubility, pasting and other textural qualities of starchy foods [42]. Amylose and Amylopectin of IPYFY 24.29% and 69.76% are significantly higher than that of control 19.82%. and 59.94%, which indicate that *Dioscorea cayenensis* has more starch.

Table-3. Physicochemical properties of IPYF.

Samples	AMY %	AMP %	TTA %	TCC (mg / 100 g)	PH	TSS °Brix
Y90-2-10	21.42±0.05^{e}	62.20±0.54^{def}	0.57±0.00^{ab}	0.10±0.01^{f}	6.47±0.06^{a}	1.77±0.06^{cde}
Y90-2-15	20.67±0.05^{f}	65.85±0.15^{c}	0.36±0.00^{d}	0.09±0.00^{fg}	6.47±0.06^{a}	1.77±0.06^{cde}
Y90-2-20	22.97±0.07^{b}	59.51±0.74^{ghi}	0.52±0.40^{bc}	0.09±0.00^{fg}	6.37±0.06^{ab}	1.77±0.06^{cde}
Y100-2-10	22.44±0.06^{c}	61.64±0.42^{defg}	0.49±0.42^{bcd}	0.09±0.01^{fg}	6.23±0.06^{bcde}	1.87±0.06^{abcd}
Y100-2-15	13.48±0.05^{k}	68.84±0.04^{ab}	0.47±0.00^{bcd}	0.11±0.00^{e}	6.13±0.06d^{ef}	1.77±0.06^{cde}
Y100-2-20	20.80±0.05^{f}	62.70±0.71^{de}	0.42±1.04^{cd}	0.06±0.00^{i}	6.33±0.06a^{bc}	2.07±0.06^{a}
Y90-4-10	21.17±0.06^{e}	62.85±0.86^{de}	0.54±0.00^{bc}	0.15±0.00^{b}	6.13±0.06^{def}	1.97±0.15^{abc}
Y90-4-15	21.92±0.06^{d}	60.03±0.28^{fghi}	0.60±0.53^{ab}	0.07±0.00^{h}	6.07±0.06^{ef}	2.07±0.06^{a}
Y90-4-20	18.09±0.06^{h}	61.37±0.51^{defg}	0.40±0.62^{cd}	0.13±0.00^{c}	6.47±0.06^{a}	1.73±0.06^{de}
Y100-4-10	15.74±0.07^{i}	67.56±0.08^{b}	0.52±0.42^{bc}	0.31±0.00^{a}	6.13±0.06^{def}	1.73±0.06^{de}
Y100-4-15	24.29±0.06^{a}	58.68±0.34^{i}	0.52±0.40^{bc}	0.05±0.00^{i}	6.03±0.06^{f}	1.73±0.06^{de}
Y100-4-20	21.41±0.06^{e}	58.91±0.63^{hi}	0.40±0.64^{cd}	0.03±0.00^{j}	6.23±0.06^{bcde}	2.03±0.06^{ab}
Y90-6-10	18.14±0.07^{h}	61.64±0.85^{defg}	0.54±0.00^{bc}	0.09±0.00^{g}	6.17±0.06^{cdef}	1.83±0.06^{bcde}
Y90-6-15	21.22±0.06^{e}	61.14±1.71^{efgh}	0.47±0.00^{bcd}	0.09±0.00^{fg}	6.13±0.06^{def}	1.63±0.06^{e}
Y90-6-20	20.63±0.07^{f}	62.99±1.15^{de}	0.54±0.00^{bc}	0.07±0.00^{h}	6.17±0.06^{cdef}	1.83±0.06^{bcde}
Y100-6-10	14.67±0.07^{j}	69.76±0.59^{a}	0.69±0.52^{a}	0.14±0.00^{b}	6.07±0.06^{ef}	1.63±0.06^{e}
Y100-6-15	21.40±0.05^{e}	63.76±0.48^{d}	0.69±0.52^{a}	0.12±0.00^{d}	6.13±0.06^{def}	2.03±0.06^{ab}
Y100-6-20	22.03±0.10^{d}	62.55±0.58^{de}	0.54±0.00^{bc}	0.12±0.00^{d}	6.27±0.06^{bcd}	2.03± 0.06^{ab}
Control	19.82±0.28^{g}	59.94±0.67^{fghi}	0.58±0.94^{ab}	0.00±0.00^{k}	5.37±0.06^{g}	0.53±0.06^{f}

*Means that do not share a letter in the same column are significantly different at 95% confidence level (p<0.05). AMY (amylose), AMP (amylopectin), TSS (total soluble solids), TTA (total tiratable acidity) and TCC (total carotene concentration).Y90-2-10 (pounded yam flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

3.3. Temperature-Based Functional Properties of IPYF

The results of temperature-based physicochemical properties of IPYFY and the control were presented in Table 4. Solubility based on temperature of IPFYY was 13.63% at 30 °C, 13.63% at 60 °C and 15.27% at 90 °C while that of control was 8.21% at 30 °C, 4.60% at 60 °C and 3.29% at 90 °C respectively. Solubility of IPYFY was significantly higher than the control at (p<0.05), even at increasing temperature.

Swelling power is an indication of presence of amylase which influences the quantity of amylose and amylopectin present in the flour. Moorthy and Ramanujam [43] reported that the swelling power of flour granules is an indication of the extent of associative forces within the granule. Swelling power is also related to the water absorption index of the starch-based flour during heating [44]. According Ruales, et al. [45] the higher the swelling power, the higher the associate forces. Swelling power of IPYFY was 87.02% at 30 °C, 91.29% at 60 °C and 90.31% at 90 °C while control has 75.37% at 30 °C, 83.58% at 60 °C and 85.22% at 90 °C respectively. The variation in the swelling power indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water. Moderate and high swelling power enhance the functionality of flours in such food systems like breakfast cereals, baby foods and fufu, [46].

3.4. Functional Properties of IPYFY

The results of functional properties of IPYFY were presented in Table 5. Gelation capacity is the least gelation concentration. The gelation capacity of IPYFY is the highest (1.33) while control had 0.73. Emulsification capacity is the maximum amount of oil that can be emulsified by protein dispersion. The emulsification capacity of IPYFY 36.42% is significantly higher than that of control 12.02%. Oil absorption capacity is the ability of the flour to absorb oil. The oil absorption capacity of IPYFY 2.18 (g/ml) is also significantly higher than that of control 0.77

(g/ml). Fagbemi [47] reported that, good oil absorption capacity of flour samples suggest that they may be useful in food preparations that involves oil mixing like in bakery products, where oil is an important ingredient.

Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food. Water absorption capacity of flour gives an idea of swelling capacity of starch granules during reconstitution [27, 48]. It is desirable in food systems to improve yield, consistency and give body to the food [49, 50]. Water absorption is an important parameter to be considered in the preparation of mash, snack foods, extruded foods, and baked products. Higher absorption is preferred for making mash while lower absorption values are more desirable for making thinner gruels. It is an important functional characteristic in the development of ready-to-eat foods since high water absorption capacity may assure product cohesiveness [51]. This is because higher values increase the unit yield of products. The higher the water absorption capacity, the greater the amount of water required to make dough or batter of the pre-determined consistency, and this is used as a baking guide [52]. The water absorption capacity of IPYFY 2.89 (g/ml) is significantly higher than that of control 2.19 (g/ml).

Bulk density is affected by the particle size and the density of the flour which is very important in determining the packaging requirements, material handling and the application in wet processing in food industry [53, 54]. The bulk density of IPYFY was 0.54 (g/cm^3) while control had 0.46 (g/cm^3). Swelling index is the degree of exposure of the internal structure of the starch present in the flour to the action of water. The swelling index of IPYFY had highest value of 2.83 (g/ml) while control had 1.27 (g/ml).

Dispersibility is the ability of flour to be wet without the formation of lumps, with simultaneous disintegration of agglomerates. It is an index of the ease of reconstitution of flour into a fine consistency paste during stirring [53]. The importance of dispersibility is that, it indicates the reconstitution ability of the sample [42]. The dispersibility of IPYFY 67.00% is significantly lower than that of control 76.00%.

Table-4. Temperature-based physicochemical properties of IPYF.

Sample	Solubility (%)			Swelling power (%)		
Codes	**30 (°C)**	**60 (°C)**	**90 (°C)**	**30 (°C)**	**60 (°C)**	**90 (°C)**
Y90-2-10	8.81 ± 0.00^{fg}	8.87 ± 0.00^{bcd}	10.02 ± 0.29^{abcd}	79.64 ± 0.28^{abc}	80.13 ± 0.29^{d}	78.33 ± 5.97^{abc}
Y90-2-15	7.06 ± 0.29^{i}	8.70 ± 0.57^{cd}	7.22 ± 0.29^{cde}	84.73 ± 0.85^{abc}	85.38 ± 0.57^{abc}	86.04 ± 1.42^{ab}
Y90-2-20	7.22 ± 0.57^{hi}	9.20 ± 1.13^{bcd}	12.15 ± 0.29^{abc}	54.02 ± 1.14^{d}	84.73 ± 1.70^{abc}	77.01 ± 3.98^{bc}
Y100-2-10	8.37 ± 0.00^{fgh}	8.70 ± 1.99^{cd}	6.89 ± 0.00^{de}	82.60 ± 0.57^{abc}	83.74 ± 0.85^{abc}	78.82 ± 0.85^{abc}
Y100-2-15	8.70 ± 0.57^{fg}	12.64 ± 1.14^{a}	5.26 ± 0.57^{e}	84.07 ± 0.57^{abc}	88.51 ± 0.28^{ab}	79.79 ± 6.41^{abc}
Y100-2-20	12.81 ± 0.00^{ab}	11.40 ± 1.59^{ab}	12.48 ± 1.42^{abc}	75.70 ± 1.42^{bc}	84.89 ± 0.28^{abc}	81.45 ± 1.43^{abc}
Y90-4-10	10.35 ± 0.00^{de}	11.82 ± 0.00^{a}	8.05 ± 1.43^{bcde}	80.13 ± 0.57^{abc}	83.25 ± 0.85^{abc}	83.91 ± 0.57^{abc}
Y90-4-15	9.03 ± 0.57^{f}	8.70 ± 0.29^{cd}	9.36 ± 0.00^{bcd}	80.63 ± 0.28^{abc}	84.73 ± 0.85^{abc}	83.75 ± 5.97^{abc}
Y90-4-20	11.49 ± 0.29^{cd}	11.04 ± 0.60^{abc}	12.65 ± 0.28^{ab}	82.10 ± 1.14^{abc}	83.91 ± 1.14^{abc}	80.13 ± 0.28^{abc}
Y100-4-10	8.37 ± 0.00^{fgh}	8.37 ± 0.00^{d}	5.42 ± 1.71^{e}	85.38 ± 0.57^{ab}	85.06 ± 0.57^{abc}	78.97 ± 4.99^{abc}
Y100-4-15	11.66 ± 0.57^{bc}	13.30 ± 0.00^{a}	15.27 ± 0.00^{a}	82.10 ± 1.42^{abc}	77.50 ± 9.95^{d}	71.59 ± 0.28^{c}
Y100-4-20	12.81 ± 0.00^{ab}	13.63 ± 1.42^{a}	13.26 ± 0.82^{ab}	79.15 ± 0.57^{abc}	81.28 ± 0.85^{cd}	80.46 ± 5.40^{abc}
Y90-6-10	7.71 ± 0.57^{ghi}	9.03 ± 0.57^{bcd}	6.07 ± 0.28^{e}	85.55 ± 2.28^{ab}	82.27 ± 0.85^{bc}	83.91 ± 1.14^{abc}
Y90-6-15	12.48 ± 0.28^{abc}	5.42 ± 0.85^{ef}	9.86 ± 4.27^{bcd}	85.38 ± 0.28^{ab}	89.98 ± 1.14^{ab}	80.12 ± 6.98^{abc}
Y90-6-20	9.36 ± 0.00^{ef}	9.03 ± 0.28^{bcd}	13.30 ± 5.12^{ab}	74.38 ± 10.24^{c}	91.29 ± 3.98^{a}	90.31 ± 5.40^{a}
Y100-6-10	8.87 ± 0.85^{fg}	8.70 ± 0.57^{cd}	7.22 ± 0.57^{cde}	83.42 ± 1.14^{abc}	89.00 ± 0.57^{ab}	77.99 ± 6.26^{abc}
Y100-6-15	11.82 ± 0.00^{bc}	7.55 ± 0.57^{de}	9.52 ± 2.28^{bcd}	87.02 ± 1.14^{a}	89.98 ± 1.14^{ab}	80.46 ± 3.70^{abc}
Y100-6-20	13.63 ± 0.28^{a}	12.32 ± 0.00^{a}	10.30 ± 0.39^{abcd}	83.25 ± 0.85^{abc}	83.38 ± 1.17^{abc}	78.99 ± 1.14^{abc}
Control	8.21 ± 0.28^{fghi}	4.60 ± 0.29^{f}	3.29 ± 0.28^{f}	75.37 ± 8.53^{c}	83.58 ± 2.28^{abc}	85.22 ± 1.71^{ab}

*Means that do not share a letter in the same column are significantly different at 95% confidence level ($p<0.05$). Y90-2-10 (pounded yam flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

3.5. Pasting Properties of IPYFY

The results of pasting properties of IPYFY and Control were presented in Table 6. Pasting properties are important quality characteristics in predicting the behaviour of pounded yam paste during and after cooking.

Peak viscosity is the maximum viscosity attained by the paste during the heating cycle, that is, from 50 to 95 °C due to starch granules swelling and leaching out of the soluble components into the solution. It reflects the ability of starch granules to swell freely before their physical breakdown and often correlates with product quality [55]. The peak viscosity of IPYFY 199.92 (RVU) is higher than the control 157.42 (RVU). It is an indication that, IPYFY has high gel strength and elasticity than the control. High peak viscosity contributes to good texture of pounded yam, which basically depends on high viscosity and moderately high gel strength [56].

Trough 1 is considered a measure of the breakdown of hot flour paste. The trough 1of IPYFY is 183.42(RVU) while control had 140.17 (RVU). Breakdown viscosity measures the ability of paste to withstand breakdown during cooling. The breakdown viscosity of IPYFY 24.50 (RVU) is significantly higher than the control 17.25 (RVU). Final viscosity have been reported as the most commonly used parameter to determine the quality of flour-based samples because it indicates flour ability to form a gel or viscous paste after cooking and cooling as well as the resistance of the paste to shear force during stirring [27, 57]. The final viscosity of IPYFY is 324.08(RVU) while control had 253.25(RVU). Setback is the phase of the pasting profile where re-association between flour molecules occurs to a greater or lesser degree. It is the phase of the pasting curve after cooling of the flour to 50 °C. Setback value is the difference between final viscosity and trough. The setback of IPYFY was 140.67(RVU) while that of control was 113.08(RVU). The temperature at which the viscosity of the stirred flour slurry begins to rise is the pasting temperature. It is an indication of the gelatinization time during processing. It is an index characterized by an initial change in viscosity due to the swelling of starch [58]. The pasting temperature of IPYFY 85.60 °C is significantly higher than the control 84.80 °C. Similar pasting temperature values (80.0-87.0 °C) has been reported for different pounded yam flour [56, 59]. The peak time of IPYFY has highest value of 7.00 (min) while control has 6.13 (min).

Table-5. Functional properties of IPYF.

Samples	WAC (g / ml)	OAC (g / ml)	EMU %	GEL	BDT (g / cm³)	DSP %	SWI (g / ml)
Y90-2-10	2.21±0.00^{fgh}	0.96±0.00^{def}	30.50±0.10^{b}	0.87±0.12^{bcde}	0.50±0.00^{bc}	63.00±0.12^{c}	2.46±0.12^{bcd}
Y90-2-15	2.31±0.00^{ef}	0.90±0.11^{def}	22.80±0.10^{e}	0.87±0.12^{bcde}	0.51±0.01^{b}	66.00±0.12^{b}	2.25±0.05^{cd}
Y90-2-20	2.63±0.11^{bc}	0.96±0.00^{def}	21.77±0.03^{e}	0.73±0.12^{de}	0.48±0.00^{cde}	64.00±0.12^{c}	2.45±0.05^{bcd}
Y100-2-10	2.44±0.11^{de}	0.58±0.00^{f}	10.13±0.12^{j}	0.87±0.12^{bcde}	0.46±0.00^{de}	62.00±0.05^{c}	2.46±0.11^{bcd}
Y100-2-15	2.89±0.00^{a}	0.77±0.00^{ef}	10.60±0.11^{j}	1.07±0.12^{abcd}	0.45±0.01^{e}	60.00±0.1^{c}	2.75±0.05^{ab}
Y100-2-20	2.69±0.00^{b}	0.90±0.11^{def}	36.42±0.05^{a}	1.33±0.12^{a}	0.42±0.01^{f}	53.00±0.12 ^{d}	2.83±0.05^{a}
Y90-4-10	2.15±0.05^{fgh}	0.77±0.00^{ef}	30.49±0.06^{b}	0.67±0.12^{e}	0.47±0.01^{de}	60.00±0.06^{c}	2.47±0.11^{bcd}
Y90-4-15	2.18±0.11^{fgh}	1.55±0.53^{bc}	28.62±0.10^{c}	1.33±0.12^{a}	0.51±0.01^{ab}	62.00±0.05^{c}	2.46±0.12^{bcd}
Y90-4-20	2.12±0.00^{gh}	1.92±0.00^{ab}	16.73±0.12^{g}	0.73±0.12^{de}	0.48±0.00^{cd}	64.00±0.12^{c}	2.36±0.11^{cd}
Y100-4-10	2.05±0.06^{h}	1.15±0.00^{cde}	26.16 ±0.11^{cd}	1.07±0.11^{abc}	0.54±0.01^{a}	65.00±0.12^{b}	2.36±0.10^{cd}
Y100-4-15	2.89±0.00^{a}	2.18±0.11^{a}	16.07±0.10^{g}	0.67±0.12^{e}	0.51±0.01^{ab}	62.00±0.12^{c}	2.46±0.10^{bcd}
Y100-4-20	2.18±0.05^{fgh}	1.54±0.00^{bc}	25.07±0.10^{d}	0.67±0.12^{e}	0.51±0.01^{ab}	60.00±0.12^{c}	2.55±0.12^{abc}
Y90-6-10	2.31±0.00^{ef}	1.22±0.11^{cd}	22.74±0.01^{e}	1.13±0.12^{abc}	0.51±0.01^{ab}	67.00±0.12 ^{b}	2.35±0.12^{cd}
Y90-6-15	2.25±0.11^{fg}	1.15±0.00^{cde}	20.89±0.06^{ef}	1.33±0.12^{a}	0.51±0.01^{ab}	67.00±0.12 ^{b}	2.16±0.11^{d}
Y90-6-20	2.12±0.00^{gh}	1.73±0.00^{b}	19.09±0.05^{f}	1.20±0.20^{ab}	0.46±0.01^{de}	64.00±0.11^{c}	2.45±0.12^{bcd}
Y100-6-10	2.69±0.00^{b}	0.83±0.11^{def}	19.09±0.05^{f}	0.80±0.20^{cde}	0.51±0.01^{ab}	66.00±0.11 ^{b}	2.15±0.12^{d}
Y100-6-15	2.50±0.00^{cd}	2.18±0.11^{a}	27.33±0.05^{c}	0.87±0.11^{bcde}	0.51±0.01^{b}	54.00±0.05^{d}	2.26±0.11^{cd}
Y100-6-20	2.89±0.00^{a}	0.64±0.11^{f}	15.02±0.03^{h}	0.73±0.11^{de}	0.46±0.01^{de}	63.00±0.05^{c}	2.34±0.13^{cd}
Control	2.19±0.10^{fgh}	0.77±0.00^{ef}	12.02±0.02^{i}	0.73±0.11^{de}	0.46±0.00^{de}	76.00±0.09 ^{a}	1.27±0.09^{e}

*Means that do not share a letter in the same column are significantly different at 95% confidence level ($p<0.05$). BDT (bulk density), SWI (swelling index), GEL (Gelation capacity), DSP (dispersibility), WAC (water absorption capacity), OAC (oil absorption capacity) and EMU (emulsification capacity). Y90-2-10 (pounded yam flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

3.6. Mineral Compositions of IPYFY

The result of mineral compositions of IPYFY and Control were presented in Table 7. The mineral sodium (Na) is important for the control of water balance in the body. It also helps with normal nerve impulse regulation and muscle contraction. Potassium is a mineral that helps the kidneys to function normally and control blood pressure. The high potassium and low sodium contents of the yam samples may make them good potassium-sodium balance in the human body, and so protect against osteoporosis and heart diseases [60]. The recommended daily intake of sodium is between 1110 and 3300 mg while potassium (K) between 1875 and 5625 mg is considered adequate and safe. However, too much of any the two can be harmful to the body. IPYFY has 1.35 (mg /100 g) and 4.48 (mg /100 g) while control has 0.93 (mg /100 g) and 3.08 (mg /100 g) for sodium and potassium respectively.

With this appreciable content of potassium "K" in the samples, both the test samples and the reference could be recommended for people with high blood pressure [61] but may not be suitable for people with renal failure.

Table-6. Pasting properties of IPYF.

Samples	Peak1 (RVU)	Trough 1 (RVU)	Breakdown (RVU)	Final Viscosity (RVU)	Setback (RVU)	Peak time (min)	Pasting temperature (°C)
Control	157.42±2.08^{de}	140.17±4.44^{d}	17.25±2.00^{c}	253.25±2.14^{d}	113.08±2.00^{d}	6.13±0.02^{b}	84.80±0.20^{a}
Y100-2-10	199.92±2.00^{a}	183.42±2.00^{a}	16.50±1.00^{c}	324.08±3.22^{a}	140.67±2.00^{a}	7.00±0.15^{a}	77.50±0.10^{bc}
Y100-2-15	176.75±2.00^{c}	164.17±2.74^{b}	12.58±2.00^{cd}	274.25±1.53^{c}	110.08±1.00^{d}	7.00±0.10^{a}	77.45±0.02^{bc}
Y100-2-20	145.50±2.52^{e}	141.42±2.00^{d}	4.08±2.00^{d}	255.50±3.63^{d}	114.08±3.20^{d}	6.73±0.02^{ab}	75.95±0.02^{c}
Y100-4-10	156.92±3.51^{de}	141.00±3.06^{d}	15.92±3.50^{c}	265.00±2.00^{c}	124.00±1.53^{c}	7.00±0.01^{a}	81.55±0.29^{a}
Y100-4-15	126.08±2.52^{f}	104.17±2.00^{g}	21.92±4.08^{a}	206.75±3.11^{f}	206.75±4.09^{e}	7.00±0.02^{a}	84.85±0.06^{a}
Y100-4-20	148.17±2.52^{e}	136.83±2.22^{d}	11.33± 2.00^{d}	220.83±2.36^{e}	84.00±5.37^{f}	7.00±0.13^{a}	79.90±0.42^{a}
Y100-6-10	165.58±2.00^{d}	143.92±4.12^{cd}	21.67±3.16^{a}	262.67±4.24^{c}	118.75±2.00^{c}	7.00±0.19^{a}	83.90±0.35^{a}
Y100-6-15	110.42±2.00^{g}	95.75±3.00^{h}	14.67±2.29^{c}	170.33±2.00^{g}	74.58±3.66^{g}	7.00±0.10^{a}	83.95±0.10^{a}
Y100-6-20	130.75±2.08^{f}	118.75±2.52^{f}	12.00±3.58^{d}	195.83±1.00^{f}	77.08±2.00^{f}	7.00±0.20^{a}	81.55±0.87^{b}
Y90-2-10	164.25± 4.04^{d}	144.58± 3.51^{cd}	19.67±2.00^{b}	249.33±4.21^{d}	104.75±2.57^{e}	7.00±0.57^{a}	82.35±0.53^{a}
Y90-2-15	141.33±6.24^{ef}	116.83± 5.64^{f}	24.50±4.12^{a}	216.42±3.00^{e}	99.58±2.00^{e}	7.00±0.82^{a}	85.55±0.10^{a}
Y90-2-20	140.33±2.65^{ef}	119.83±3.12^{f}	20.50±2.00^{b}	222.08±4.05^{e}	102.25±3.13^{e}	7.00±0.11^{a}	84.05±0.02^{a}
Y90-4-10	163.75±3.00^{d}	151.17±2.06^{c}	12.58±3.32^{cd}	258.00±2.00^{d}	106.83±2.00^{e}	6.93±0.10^{a}	79.10±0.23^{b}
Y90-4-15	159.42±3.51^{d}	144.67±2.66^{cd}	14.75±2.00^{c}	274.17±2.46^{c}	129.50±4.08^{b}	7.00±0.29^{a}	79.85±0.10^{b}
Y90-4-20	132.17±2.52^{f}	111.42±2.00^{fg}	20.75±6.20^{b}	220.25±2.62^{e}	108.83±2.00^{d}	7.00±0.10^{a}	85.60±0.02^{a}
Y90-6-10	186.67±2.00^{b}	174.00±4.20^{a}	12.67±2.00^{cd}	293.50±6.35^{b}	119.50±3.14^{c}	6.93±0.02^{a}	80.70±0.02^{b}
Y90-6-15	148.33±2.00^{e}	125.50±2.00^{e}	22.83±2.64^{a}	231.83±2.82^{e}	106.33±4.29^{e}	7.00±0.05^{a}	84.05±0.10^{a}
Y90-6-20	180.25±3.00^{c}	161.25±2.00^{b}	19.00±1.00^{b}	292.58±4.12^{b}	131.33±3.05^{b}	7.00±0.66^{a}	81.50±0.52^{b}

*Means that do not share a letter in the same column are significantly different at 95% confidence level ($p<0.05$). Y90-2-10 (pounded yam flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

Yam is considered a good source of magnesium. The recommended daily intake of magnesium "Mg" is set at 300 mg for women and 350 mg for men. The magnesium of IPYFY 0.21(mg /100 g) is the same with that of control. Zinc helps to regulate many of the human body's processes. It is essential for survival and deficiency has serious consequences for health [62]. The amount recommended is 15 mg/day for adults and good sources are sea foods, meat, fish, and whole grains. The zinc of pounded IPYFY (0.04 (mg /100 g) is significantly higher than that of control 0.02 (mg /100 g). The mineral calcium is vital for the development of healthy bones and teeth. It is also needed for muscle contraction and regulation of the heartbeat, and, is involved in the formation of blood clots. A long-term shortage of calcium can lead to osteoporosis, when the bones become brittle and break easily. The calcium content of IPYFY 0.50 (mg /100 g) is significantly higher than that of control 0.31 (mg /100 g).

The iron content of IPYFY was 0.10 (mg /100 g) while control has 0.02 (mg /100 g). Too much copper can be harmful. However, 2 to 3 mg/day intake is considered adequate and safe. Copper content of IPYFY 0.04 (mg /100 g) is significantly higher than that of control (0.00 (mg /100 g). About 800 mg of phosphorus is recommended for adults per day. Peroni, et al. [63] reported higher phosphorus in yam (0.022%) compared to other root and tuber crops. Similarly, Moorthy and Nair [64] reported 0.11 and 0.015% phosphorus in *Dioscorea rotundata* grown in India. IPYFY has 1.05 (mg /100 g) and 0.01 (mg /100 g) of phosphorus and lead while control has 1.01 (mg /100 g) and 0.00 (mg /100 g.

3.7. Organoleptic Properties of Reconstituted IPYFY

The result of organoleptic properties of IPYFY and Control were presented in Table 8. Texture, which in this case consists of smoothness, elasticity, consistency, stickiness and hardness, is one of the main factors for acceptability used by consumers to evaluate the quality of pounded yam [13]. Pounded yam flour has different attributes. Its strecthability, cohesiveness (mouldability), hardness (soft but firm, not very soft or very hard), smoothness and stickiness are the important attributes used in determining its desired quality [65]. There was a significant difference in the colour rating of reconstituted IPYFY 6.70 to control 8.65 at $p<0.05$.This indicates that, the reconstituted control sample has better colour that attract and acceptable to the consumers. Also in taste, stickiness, elasticity, hardness, mouldiness and appearance, reconstituted Control sample was rated significantly higher than reconstituted IPYFY at $p<0.05$.

4. CONCLUSION

Results of the study indicate that, *Dioscorea cayenensis* has good qualities in term of proximate, physicochemical, functional and pasting properties than *Dioscorea rotundata* when processed to instant pounded yam flour. The acceptability of the product from organoleptic point of view, though a subjective test, is less when compared with the control. For better retention of the nutrition quality parameters in instant pounded yam produced from yellow yam, the yams should be blanched at 100 °C with 4mm thickness for blanching duration of 10 minutes and dried at 65 °C drying temperature.

Table-7. Mineral compositions (mg / 100 g) of IPYF.

Samples	Na	K	Mg	Zn	Ca	Fe	Cu	P	Pb
Control	0.93±0.06^{e}	3.08±0.03^{b}	0.21±0.01^{a}	0.02±0.05^{b}	0.31±0.02^{c}	0.02±0.04^{e}	0.00±0.11^{c}	1.01±0.02^{a}	0.00±0.07^{b}
Y100-2-10	1.18±0.12^{c}	3.19±0.05^{b}	0.21±0.03^{a}	0.02±0.02^{b}	0.39±0.01^{ab}	0.08±0.02^{ab}	0.01±0.02^{b}	0.96± 0.05^{ab}	0.01±0.02^{a}
Y100-2-15	1.08±0.02^{d}	2.40±0.02^{cd}	0.21±0.01^{a}	0.02±0.03^{b}	0.44±0.03^{ab}	0.07±0.06^{b}	0.01±0.05^{b}	0.83± 0.08^{b}	0.01±0.05^{a}
Y100-2-20	1.29±0.02^{b}	2.19±0.02^{cd}	0.21±0.02^{a}	0.02±0.05^{b}	0.43±0.05^{ab}	0.06±0.12^{b}	0.01±0.03^{b}	0.89±0.32^{b}	0.00±0.39^{b}
Y100-4-10	1.17±0.15^{c}	3.07±0.10^{b}	0.21±0.06^{a}	0.02±0.01^{b}	0.40±0.10^{ab}	0.04±0.25^{c}	0.01±0.02^{b}	0.82±0.06^{b}	N^{D}
Y100-4-15	1.14±0.10^{c}	3.19±0.12^{b}	0.21±0.02^{a}	0.02±0.04^{b}	0.41±0.23^{ab}	0.05±0.43^{bc}	0.01±0.04^{b}	0.85±0.03^{b}	0.01±0.03^{a}
Y100-4-20	1.35±0.02^{a}	3.17±0.56^{b}	0.21±0.04^{a}	0.04±0.05^{a}	0.37±0.11^{b}	0.06±0.03^{b}	0.04±0.62^{a}	1.05±0.02^{a}	0.00±0.02^{b}
Y100-6-10	1.15±0.02^{c}	4.48±0.02^{a}	0.21±0.10^{a}	0.02±0.03^{b}	0.38±0.02^{b}	0.05±0.02^{bc}	0.01±0.10^{b}	0.98±0.10^{ab}	N^{D}
Y100-6-15	1.13±0.08^{c}	4.22±0.04^{a}	0.21±0.02^{a}	0.02±0.10^{b}	0.37±0.04^{b}	0.04±0.08^{c}	0.01±0.27^{b}	1.07±0.05^{a}	0.01±0.02^{a}
Y100-6-20	1.14±0.12^{c}	3.47±0.02^{b}	0.21±0.08^{a}	0.01±0.02^{bc}	0.37±0.03^{b}	0.04±0.01^{c}	0.01±0.10^{b}	N^{D}	N^{D}
Y90-2-10	0.85±0.10^{e}	4.36±0.07^{a}	0.21±0.03^{a}	0.02±0.05^{b}	0.31±0.26^{bc}	0.04±0.12^{cd}	0.01±0.35^{b}	1.01±0.03^{a}	0.01±0.46^{a}
Y90-2-15	1.08±0.05^{d}	3.24±0.28^{b}	0.21±0.10^{a}	0.02±0.06^{b}	0.35±0.02^{bc}	0.10±0.02^{a}	0.01±0.08^{b}	0.96±0.02^{ab}	N^{D}
Y90-2-20	1.20±0.10^{bc}	2.56±0.10^{c}	0.21±0.02^{a}	0.02±0.04^{b}	0.38±0.05^{b}	0.03±0.10^{d}	0.01±0.03^{b}	0.91±0.14^{ab}	0.00±0.28^{b}
Y90-4-10	1.11±0.23^{c}	2.89±0.06^{c}	0.21±0.06^{a}	0.02±0.06^{b}	0.37±0.02^{b}	0.04± 0.35^{c}	0.01±0.29^{b}	0.97±0.10^{ab}	0.01± 0.10^{a}
Y90-4-15	1.21±0.02^{bc}	3.20±0.23^{b}	0.21±0.01^{a}	0.02±0.05^{b}	0.39±0.03^{b}	0.05±0.02^{bc}	0.01±0.02^{b}	1.04±0.35^{a}	0.00±0.02^{b}
Y90-4-20	1.04±0.04^{d}	3.40±0.02^{b}	0.21±0.05^{a}	0.01±0.03^{bc}	0.50±0.06^{a}	0.04±0.17^{cd}	0.01±0.13^{b}	0.92±0.43^{ab}	N^{D}
Y90-6-10	1.07±0.03^{d}	4.26±0.01^{a}	0.21±0.02^{a}	0.01±0.02^{bc}	0.34±0.04^{bc}	0.04±0.01^{cd}	0.01±0.10^{b}	1.00±0.02^{a}	0.01±0.04^{a}
Y90-6-15	1.12±0.07^{c}	4.21±0.48^{a}	0.21±0.10^{a}	0.01±0.05^{bc}	0.37±0.08^{ab}	0.09±0.28^{ab}	0.01±0.02^{b}	0.97±0.09^{ab}	0.00±0.02^{b}
Y90-6-20	1.24±0.02^{b}	3.21±0.03^{b}	0.21±0.32^{a}	0.02±0.06^{b}	0.37±0.10^{ab}	0.06±0.02^{b}	0.01±0.09^{b}	0.80±0.10^{b}	0.00±0.05^{b}

**Means that do not share a letter in the same column are significantly different at 95% confidence level ($p<0.05$). N^{D} denote Not detectedY90-2-10 (pounded yam* flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

Table-8. Organoleptic properties of reconstituted pounded yam produced from yellow yam flour.

Samples	Colour	Taste	Stickiness	Elasticity	Hardness	Mouldiness	Appearance	Acceptability
Y90-2-10	4.70±1.63^{cdefg}	5.40±1.43^{bc}	5.65±1.46^{b}	5.55±1.28^{bc}	5.95±1.54^{ab}	5.65±1.23^{bc}	5.30±1.53^{bcde}	5.90±1.07^{bc}
Y90-2-15	5.25±1.16^{bcde}	5.30±1.46^{bc}	5.20±1.70^{bc}	4.15±1.76^{bcde}	4.65±2.08^{b}	5.20±1.54^{bcd}	4.90±1.25^{cdefg}	5.50±1.10^{bcd}
Y90-2-20	5.65±1.42^{bcd}	5.40±1.23^{bc}	5.45±1.54^{bc}	5.65±1.27^{b}	5.75±1.45^{ab}	5.95±1.43^{b}	5.40±1.57^{bcd}	6.20±0.95^{b}
Y100-2-10	3.90±1.29^{efgh}	3.75±1.48^{c}	3.80±1.80^{c}	3.25±1.62^{e}	4.15±2.16^{b}	4.85±1.76^{bcd}	3.65±1.35^{efg}	3.75±1.37^{e}
Y100-2-15	5.10±1.55^{bcde}	4.20±1.64^{bc}	4.90±1.83^{bc}	4.45±1.67^{bcde}	5.15±1.57^{ab}	5.05±1.57^{bcd}	5.60±1.35^{bcd}	5.30±1.13^{bcde}
Y100-2-20	4.35±1.31^{defgh}	4.35±1.39^{bc}	4.70±1.66^{bc}	4.55±1.47^{bcde}	4.90±1.71^{b}	4.75±1.29^{bcd}	4.35±1.23^{cdefg}	4.95±1.32^{bcde}
Y90-4-10	3.30±2.13^{fgh}	3.80±1.91^{c}	4.35±1.95^{bc}	3.90±1.59^{cde}	4.25±2.55^{b}	4.15±2.08^{cd}	3.55±2.24^{fg}	4.35±2.08^{cde}
Y90-4-15	6.40±1.90^{bc}	5.70±1.75^{b}	5.35±1.93^{bc}	4.55±2.01^{bcde}	5.20±1.99^{ab}	5.20±1.91^{bcd}	5.95±1.64^{bc}	5.90±1.33^{bc}
Y90-4-20	2.70±1.59^{h}	4.50±1.67^{bc}	4.20±1.40^{bc}	3.85±1.42^{cde}	4.90±1.89^{b}	4.40±1.73^{bcd}	3.30±1.59^{g}	4.35±1.60^{cde}
Y100-4-10	3.10±1.33^{gh}	4.95±1.57^{bc}	4.85±1.46^{bc}	4.65±1.63^{bcde}	5.55±1.32^{ab}	4.50±1.19^{bcd}	3.60±1.14^{fg}	4.95±1.36^{bcde}
Y100-4-15	4.50±1.70^{defg}	4.25±1.41^{bc}	4.70±1.56^{bc}	4.55±1.28^{bcde}	5.30±1.72^{ab}	4.95±1.47^{bcd}	3.70±1.26^{efg}	5.20±1.64^{bcde}
Y100-4-20	4.15±1.79^{defgh}	4.05±1.82^{bc}	3.95±1.64^{bc}	3.50±1.73^{de}	4.00±2.18^{b}	4.40±1.82^{bcd}	4.15±1.73^{defg}	4.10±1.48^{de}
Y90-6-10	3.55±1.47^{efgh}	4.70±1.53^{bc}	4.30±1.53^{bc}	3.45±1.67^{e}	4.20±2.31^{b}	3.75±1.48^{d}	3.35±1.87^{g}	4.10±1.55^{de}
Y90-6-15	3.70±1.34^{efgh}	4.80±1.67^{bc}	4.95±1.54^{bc}	4.65±1.53^{bcde}	4.40±1.67^{b}	5.15±1.50^{bcd}	4.55±1.64^{cdefg}	5.05±1.32^{bcde}
Y90-6-20	5.00±1.97^{bcdef}	4.80±2.04^{bc}	4.80±1.94^{bc}	4.55±1.85^{bcde}	5.05±1.93^{ab}	4.70±1.72^{bcd}	4.85±1.98^{cdefg}	5.10±1.77^{bcde}
Y100-6-10	4.25±1.65^{defgh}	4.95±1.85^{bc}	4.65±1.53^{bc}	4.00±1.41^{bcde}	4.60±2.09^{b}	4.90±1.33^{bcd}	5.20±1.28^{bcdef}	5.30±1.22^{bcde}
Y100-6-15	6.70±1.49^{b}	5.85±1.90^{ab}	5.35±1.46^{bc}	5.20±1.54^{bcd}	5.45±1.57^{ab}	5.85±1.66^{bc}	6.65±1.14^{ab}	6.30±1.56^{b}
Y100-6-20	3.80±1.51^{efgh}	4.45±1.91^{bc}	4.95±2.24^{bc}	4.50±1.76^{bcde}	4.05±2.21^{b}	4.65±1.69^{bcd}	3.55±1.47^{fg}	5.35±1.69^{bcd}
Control	8.65±0.67^{a}	7.55±1.54^{a}	7.50±1.00^{a}	7.60±1.00^{a}	7.05±1.93^{a}	8.00±0.97^{a}	8.20±1.20^{a}	8.40±0.82^{a}

*Means that do not share a letter in the same column are significantly different at 95% confidence level ($p<0.05$). Y90-2-10 (pounded yam flour of 2 mm at 90°C for 10 minutes), Y90-2-15 (pounded yam flour of 2 mm at 90°C for 15 minutes), Y90-2-20 (pounded yam flour of 2 mm at 90°C for 20 minutes), Y100-2-10 (pounded yam flour of 2 mm at 100°C for 10 minutes), Y100-2-15 (pounded yam flour of 2 mm at 100°C for 15 minutes), Y100-2-20 (pounded yam flour of 2 mm at 100°C for 20 minutes), Y90-4-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-4-15(pounded yam flour of 4 mm at 90°C for 15 minutes), Y90-4-20 (pounded yam flour of 4 mm at 90°C for 20 minutes), Y100-4-10 (pounded yam flour of 4 mm at 100°C for 10 minutes), Y100-4-15 (pounded yam flour of 4 mm at 100°C for 15 minutes), Y100-4-20 (pounded yam flour of 4 mm at 100°C for 20 minutes), Y90-6-10 (pounded yam flour of 4 mm at 90°C for 10 minutes), Y90-6-15 (pounded yam flour of 6 mm at 90°C for 15 minutes), Y90-6-20 (pounded yam flour of 6 mm at 90°C for 20 minutes), Y100-6-10 (pounded yam flour of 6 mm at 100°C for 10 minutes), Y100-6-15 (pounded yam flour of 6 mm at 100°C for 15 minutes), Y100-6-20 (pounded yam flour of 6 mm at 100°C for 20 minutes) and control (commercial product).

REFERENCES

[1] P. C. Ike and O. E. Inoni, "Determinants of yam production and economic efficiency among small-holder farmers tn Southeastern Nigeria," *Journal of Central European Agriculture*, vol. 7, pp. 337- 342, 2006.

[2] V. Ezeocha and P. Ojimelukwe, "The impact of cooking on the proximate composition and anti-nutritional factors of water yam (Dioscorea alata)," *Journal of Stored Products and Postharvest Research*, vol. 3, pp. 172-176, 2012.

[3] T. Onyeka, D. Petro, G. Ano, S. Etienne, and S. Rubens, "Resistance in water yam (Dioscorea alata) cultivars in the French West Indies to anthracnose disease based on tissue culture-derived whole-plant assay," *Plant Pathology*, vol. 55, pp. 671-678, 2006. Available at: https://doi.org/10.1111/j.1365-3059.2006.01436.x.

[4] P. Odjugo, "The effect of tillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscorea cayenensis) in Midwestern Nigeria," *African Journal of Biotechnology*, vol. 7, pp. 4500-4507, 2008.

[5] A. Emmanuel, "Yam production in Orire local government area of Oyo State, Nigeria," *Farmer's Perceived Constraints World Young Researchers*, vol. 1, pp. 16- 19, 2011.

[6] O. Awoniyi and B. Omonona, "Production efficiency in yam-based enterprises in Ekiti State, Nigeria," *Journal International of Central European Agriculture*, vol. 7, pp. 627-636, 2007.

[7] O. Izekor and M. Olumese, "Determinants of yam production and profitability in Edo State, Nigeria," *African Journal of General Agriculture*, vol. 6, pp. 205-210, 2010.

[8] E. Ayanwuyi, A. Akinboye, and J. Oyetoro, "Yam production in offrire local government area of Oyo State, Nigeria: Farmer's perceived constraints," *World Journal of Young Researchers*, vol. 1, pp. 16-19, 2011.

[9] Y. Musa, J. Onu, I. Vosanka, and I. Anonguku, "Production efficiency of yam in Zing Local Government Area of Taraba State, Nigeria," *Journal of Horticulture and Forestry*, vol. 3, pp. 311-317, 2011. Available at: https://doi.org/10.5251/abjna.2012.3.8.311.317.

[10] A. Ojokoh and R. Gabriel, "A comparative study on the storage of yam chips (gbodo) and yam flour (elubo)," *African Journal of Biotechnology*, vol. 9, pp. 3175-3177, 2010.

[11] O. O. Adewale, B. O. Babatunde, and I. Olotu, "Changes in nutritional composition, functional, and sensory properties of yam flour as a result of presoaking," *Food Science & Nutrition*, vol. 2, pp. 676-681, 2014. Available at: https://doi.org/10.1002/fsn3.150.

[12] O. Karim, R. Kayode, S. Oyeyinka, and A. T. Oyeyinka, "Proximate, mineral and sensory qualities of "Amala" prepared from Yam flour fortified with Moringa leaf powder," *Food Science and Quality Management*, vol. 12, pp. 10-22, 2013.

[13] C. N. Egesi, R. Asiedu, J. K. Egunjobi, and M. Bokanga, "Genetic diversity of organoleptic properties in water yam (Dioscorea alata L)," *Journal of the Science of Food and Agriculture*, vol. 83, pp. 858-865, 2003. Available at: https://doi.org/10.1002/jsfa.1343.

[14] B. Djeri, P. Tchobo, Y. Adjrah, D. Karou, Y. Ameyapoh, M. Soumanou, and C. Souza, "Nutritional potential of yam chips (Dioscorea cayenensis and Dioscorea rotundata Poir) obtained using two methods of production in Togo," *African Journal of Food Science*, vol. 9, pp. 278-284, 2015. Available at: https://doi.org/10.5897/ajfs2014.1207.

[15] C. Mestres, S. Dorthe, N. Akissoé, and J. D. Hounhouigan, "Prediction of sensorial properties (color and taste) of amala, a paste from yam chips flour of West Africa, through flour biochemical properties," *Plant Foods for Human Nutrition*, vol. 59, pp. 93-99, 2004. Available at: https://doi.org/10.1007/s11130-004-0028-z.

[16] N. Akissoe, C. Mestres, J. Hounhouigan, and M. Nago, "Prediction of the sensory texture of a yam thick paste (amala) using instrumental and physicochemical parameters," *Journal of Texture Studies*, vol. 37, pp. 393-412, 2006. Available at: https://doi.org/10.1111/j.1745-4603.2006.00059.x.

[17] A. Barau, J. Reuben, and E. Aboki, "Comparative analysis of yam production in Northern and Southern Zones of Taraba State, Nigeria," *Journal Agriculture Resources*, vol. 1, pp. 7-23, 2013.

[18] J. O. Olaoye and S. N. Oyewole, "Optimization of some "poundo" yam production parameters," *Agricultural Engineering International: CIGR Journal*, vol. 14, pp. 58-67, 2012.

[19] AOAC, *Official methods of analysis*, 12th ed. Washington DC: Association of Official and Analytical Chemists, 2005.

[20] M. Akpapunam and S. Sefa-Dedeh, "Traditional lactic acid fermentation, malt addition, and quality development in maize-cowpea weaning blends," *Food and Nutrition Bulletin*, vol. 16, pp. 1-9, 1995. Available at: https://doi.org/10.1177/156482659501600113.

[21] I. Mbaeyi-Nwaoha and J. Onweluzo, "Functional properties of sorghum (S. bicolor L.)-pigeonpea (Cajanus cajan) flour blends and storage stability of a flaked breakfast formulated from blends," *Pakistan Journal of Nutrition*, vol. 12, pp. 382-397, 2013. Available at: https://doi.org/10.3923/pjn.2013.382.397.

[22] R. Hoover and W. Ratnayake, "Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada," *Food Chemistry*, vol. 78, pp. 489-498, 2002. Available at: https://doi.org/10.1016/s0308-8146(02)00163-2.

[23] D. B. Rodriguez-Amaya and M. Kimura, *HarvestPlus handbook for carotenoid analysis Technical Monograph Series No. 2*, pp. 2-51, 2004.

[24] T. Sanchez, H. Ceballos, D. Dufour, D. Ortiz, N. Morante, F. Calle, T. ZumFelde, M. Dominguez, and F. Davriux, "Prediction of carotenoids, cyanide and dry matter contents in fresh cassava root using NIRS and Hunter colour technique," *Food Chemistry*, vol. 151, pp. 444-451, 2013.

[25] S. Takahashi and P. Seib, "Paste and gel properties of prime corn and wheat starches with and without native lipids," *Cereal Chem*, vol. 65, pp. 474-483, 1988.

[26] S. K. Sathe and D. K. Salunkhe, "Functional properties of the great bean Northern (Phaseolus vulgaris L.) Proteins: Emulsion, foaming, viscosity, and gelation properties," *Journal of Food Science*, vol. 46, pp. 71-75, 1981.

[27] Y. Adebowale, I. Adeyemi, and A. Oshodi, "Functional and physicochemical properties of flours of six Mucuna species," *African Journal of Biotechnology*, vol. 4, pp. 1461 - 1468, 2005.

[28] M. A. Akpapunam and P. Markakis, "Physicochemical and nutritional aspects of cowpea flour," *Journal of Food Science*, vol. 46, pp. 1143-1151, 1981. Available at: https://doi.org/10.1111/j.1365-2621.1981.tb15402.x.

[29] E. Udensi and J. Okaka, "Predicting the effect of blanching, drying temperature and particle size profile on the dispersibility of cowpea flour," *Nigerian Food Journal*, vol. 18, pp. 25-29, 2000.

[30] K. D. Kulkarni, D. N. Kulkarni, and U. M. Ingle, "Sorghum malt-based weaning food formulations: Preparation, functional properties, and nutritive value," *Food and Nutrition Bulletin*, vol. 13, pp. 1-7, 1991. Available at: https://doi.org/10.1177/156482659101300401.

[31] C. Ojinnaka, A. Vuong, J. Helduser, P. Nash, M. G. Ory, D. A. McClellan, and J. N. Bolin, "Determinants of variations in self-reported barriers to colonoscopy among uninsured patients in a primary care setting," *Journal of Community Health*, vol. 40, pp. 260-270, 2015. Available at: https://doi.org/10.1007/s10900-014-9925-8.

[32] C. Coffmann and V. Garciaj, "Functional properties and amino acid content of a protein isolate from mung bean flour," *International Journal of Food Science & Technology*, vol. 12, pp. 473-484, 1977. Available at: https://doi.org/10.1111/j.1365-2621.1977.tb00132.x.

[33] R. Adeleke and J. Odedeji, "Functional properties of wheat and sweet potato flour blends," *Pakistan Journal of Nutrition*, vol. 9, pp. 535-538, 2010. Available at: https://doi.org/10.3923/pjn.2010.535.538.

[34] N. Scientific, "Applications manual for the rapid viscotm analyzer using thermocline for windows," *Newport Scientific Pty Ltd*, vol. 1, pp. 2-26, 1998.

[35] C. Gérard, C. Barron, P. Colonna, and V. Planchot, "Amylose determination in genetically modified starches," *Carbohydrate Polymers*, vol. 44, pp. 19-27, 2001. Available at: https://doi.org/10.1016/s0144-8617(00)00194-6.

[36] S. N. Moorthy, "Physicochemical and functional properties of tropical tuber starches: A review," *Starch-Stärke*, vol. 54, pp. 559-592, 2002. Available at: https://doi.org/10.1002/1521-379x(200212)54:12<559::aid-star2222559>3.0.co;2-f.

[37] S. You and M. Izydorczyk, "Molecular characteristics of barley starches with variable amylose content," *Carbohydrate Polymers*, vol. 49, pp. 33-42, 2002. Available at: https://doi.org/10.1016/s0144-8617(01)00300-9.

[38] WHO (World Health Organization), *Quantifying selected major risks to health. In: Reducing Risks Promoting Healthy Life*. Geneva Switzerland: WHO, 2000.

[39] P. Nestel, H. E. Bouis, J. Meenakshi, and W. Pfeiffer, "Biofortification of staple food crops," *The Journal of Nutrition*, vol. 136, pp. 1064-1067, 2006. Available at: https://doi.org/10.1093/jn/136.4.1064.

[40] J. W. Low, M. Arimond, N. Osman, B. Cunguara, F. Zano, and D. Tschirley, "A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique," *The Journal of Nutrition*, vol. 137, pp. 1320-1327, 2007.

[41] H. Scott, *Understanding starch functionality: relating structure and function. In: Food product design*, January ed. North Brook, IL: Scott, H. Weeks Publishing Co, 1996.

[42] B. O. Otegbayo, F. O. Samuel, and T. Alalade, "Functional properties of soy-enriched tapioca," *African Journal Biotechnology*, vol. 12, pp. 3583-3589, 2013.

[43] S. N. Moorthy and T. Ramanujam, "Variation in properties of starch in cassava varieties in relation to age of the crop," *Starch Starke*, vol. 38, pp. 58-61, 1986. Available at: https://doi.org/10.1002/star.19860380206.

[44] P. J. Loos, L. Hood, and H. Graham, "Isolation and characterization of starch from breadfruit [Artocarpus communis]," *Cereal Chemistry*, vol. 58, pp. 282-286, 1981.

[45] J. Ruales, S. Valencia, and B. Nair, "Effect of processing on the physico-chemical characteristics of quinoa flour (Chenopodium quinoa, Willd)," *Starch-Stärke*, vol. 45, pp. 13-19, 1993. Available at: https://doi.org/10.1002/star.19930450105.

[46] E. C. Okoli, "Effect of gammar irradiation on biochemical, malting and keeping quality of sorghum grain," Ph.D. Thesis, Obafemi Awolowo University, Ile-Ife, 1998.

[47] T. N. Fagbemi, "Effect of blanching and ripening on functional properties of plantain (Musa aab) flour," *Plant Foods for Human Nutrition*, vol. 54, pp. 261-269, 1999.

[48] F. Y. Oladipo and L. M. Nwokocha, "Effect of Sida acuta and Corchorus olitorius mucilages on the physicochemical properties of maize and sorghum starches," *Asian Journal of Applied Science*, vol. 4, pp. 514-525, 2011. Available at: https://doi.org/10.3923/ajaps.2011.514.525.

[49] O. F. Osundahunsi, T. N. Fagbemi, E. Kesselman, and E. Shimoni, "Comparison of the physicochemical properties and pasting characteristics of flour and starch from red and white sweet potato cultivars," *Journal of Agricultural and Food Chemistry*, vol. 51, pp. 2232-2236, 2003. Available at: https://doi.org/10.1021/jf0260139.

[50] O. Malomo, O. Ogunmoyela, O. Adekoyeni, O. Jimoh, S. Oluwajoba, and M. Sobanwa, "Rheological and functional properties of soy-poundo yam flour," *International Journal of Food Science and Nutrition Engineering*, vol. 2, pp. 101-107, 2012.

[51] K. D. Kulkani, G. Noel, and D. N. Kulkani, "Sorghum mail-based weaning food formulations preparation, functional properties and nutritive value," *Food and Nutrition Bulletin*, vol. 17, pp. 1-8, 1996.

[52] Y. Pomeranz, *Wheat chemistry and technology*. New York: American Association of Cereal Chemists Inc, 1971.

[53] A. Adebowale, S. Sanni, and F. Oladapo, "Chemical, functional and sensory properties of instant yam-breadfruit flour," *Nigerian Food Journal*, vol. 26, pp. 2-12, 2008.

[54] K. O. Ajanaku, C. O. Ajanaku, A. Edobor-Osoh, and O. C. Nwinyi, "Nutritive value of Sorghum Ogi fortified with groundnut seed (Arachis hypogaea L.)," *American Journal of Food Technology*, vol. 7, pp. 82-88, 2012. Available at: https://doi.org/10.3923/ajft.2012.82.88.

[55] M. Singh, D. P. Tiwari, A. Kumar, and R. Kumar, "Effect of feeding transgenic cottonseed vis-à-vis non-transgenic cottonseed on haematobiochemical constituents in lactating Murrah buffaloes," *Asian-Australasian Journal of Animal Sciences*, vol. 16, pp. 1732-1737, 2003. Available at: https://doi.org/10.5713/ajas.2003.1732.

[56] B. O. Otegbayo, J. O. Aina, R. Asiedu, and M. Bokanga, "Pasting characteristics of fresh yam (Dioscorea spp.) as indicator of food textural quality in a major yam food product – Pounded yam," *Food Chemistry*, vol. 99, pp. 663-669, 2006. Available at: https://doi.org/10.1016/j.foodchem.2005.08.041.

[57] B. Maziya-Dixon, A. G. Dixon, and A. R. A. Adebowale, "Targeting different end uses of cassava: Genotypic variations for cyanogenic potentials and pasting properties," *International Journal of Food Science & Technology*, vol. 42, pp. 969-976, 2007. Available at: https://doi.org/10.1111/j.1365-2621.2006.01319.x.

[58] E. O. Afoakwa and S. Sefa-Dedeh, "Viscoelastic properties and changes in pasting characteristics of trifoliate yam (Dioscorea dumetorum) starch after harvest," *Food Chemistry*, vol. 77, pp. 203-208, 2002. Available at: https://doi.org/10.1016/s0308-8146(01)00338-7.

[59] D. Sahorè, N. Amani, and G. Nemlin, "The properties of starches from some Ivory Coast wild yam (Dioscorea) species," *Tropical Science*, vol. 45, pp. 122-125, 2005. Available at: https://doi.org/10.1002/ts.12.

[60] S. Walsh, *Plant based nutrition and health*: Vegan Society Ltd, 2003.

[61] A. U. Osagie, *The yam in storage*. Nigeria: Postharvest Research Unit, University of Benin, 1992.

[62] K. H. Brown and S. E. Wuehler, *Zinc and human health: Results of recent trials and implication for programme interventions and research*. Ottawa, Canada: Micronutrient Initiative, 2000.

[63] F. Peroni, T. Rocha, and C. Franco, "Some structural and physicochemical characteristics of tuber and root starches," *Food Science and Technology International*, vol. 12, pp. 505-513, 2006. Available at: https://doi.org/10.1177/1082013206073045.

[64] S. Moorthy and S. Nair, "Studies on Dioscorea rotundata starch properties," *Starch-Stärke*, vol. 41, pp. 81-83, 1989. Available at: https://doi.org/10.1002/star.19890410302.

[65] B. Otegbayo, J. Aina, L. Abbey, E. Sakyi-Dawson, M. Bokanga, and R. Asiedu, "Texture profile analysis applied to pounded yam," *Journal of Texture Studies*, vol. 38, pp. 355-372, 2007. Available at: https://doi.org/10.1111/j.1745-4603.2007.00101.x.