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# Studies on the Production and Evaluation of Starch from Yam (*Dioscorea spp.*) and Cocoyam (*Colocasia esculenta*) Tubers Cultivated in Nigeria

**Hauwa H, LaminuHH, Falmata AS, BINTU BP, Maryam Babakura Chamba G, Babagana M and Modu S***

*Department of Biochemistry and Biological Sciences, Faculty of Science University of Maiduguri, Nigeria*

***Corresponding Author:** Modu S, Department of Biochemistry and Biological Sciences, Faculty of Science University of Maiduguri, Nigeria.

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## Abstract

The starches of yam (Dioscorea spp.), and cocoyam (Colocasia esculenta) were extracted with water and with 0.03M conc. ammonia solution. Their whole flours were also prepared which served as the control and cassava starch was used as the reference standard. All data obtained were subjected to analysis of variance and Duncan multiple ranges was used to compare the means. Their proximate compositions, functional and physicochemical properties, mineral elements, water-soluble vitamins and antinutrients were analyzed using standard laboratory procedures. The extracts/starch obtained showed that the percentage yield of starch was higher in yam (50.05, 50.56 for ammonia and water respectively) and lower in cocoyam (43.80, 34.48 for ammonia and water respectively). The use of ammonia significantly increased ($P < 0.05$) the yield of cocoyam starch from 34.48 % 43.80%. The results of the proximate analysis showed that the moisture content (10.99, 9.85 cocoyam and yam respectively), ash (3.22 and 2.10), crude protein (4.60 and 3.60) and fibre content (7.09 and 11.99) of the flours were significantly higher than in their corresponding starches (with the exception of YSW which showed a higher moisture content of 14.22 above its flour). Lower values of flours than the starches were recorded for carbohydrates (73.48, 85.05, 84.73 and 71.70, 85.33, 80.30 for cocoyam and yam respectively) and energy (314.95, 315.69, 315.49 and 304.29, 350.43, 329.54 for cocoyam and yam respectively). The results of the functional and physicochemical properties showed that the water absorption capacity (with values 2.16 g/ml, 1.04 g/ml, 1.04 g/ml, and 1.36 g/ml, 1.02 g/ml, 0.42 g/ml for yam and cocoyam flours and starches respectively) and bulk density (0.65 g/ml, 0.63 g/ml, 0.76 g/ml, and 0.57 g/ml, 0.54 g/ml, 0.51 g/ml for yam and cocoyam flours and starches respectively) were generally low. The pH of the flours ranged from 8.42 to 8.49 while that of the starches from 7.31 to 5.39. Phytic acid levels were significantly low (from 0.82% to 0.11% for cocoyam and yam respectively) and this signifies a better nutritional value. The differences between the water and ammonia extracted starches in amylose (27.73, 27.78 %T, and 16.32, 15.80 %T yam and cocoyam respectively) and amylopectins (72.36, 72.21 %T and 83.62, 84.31 %T yam and cocoyam respectively) were not significant at $P>0.05$. Swelling power increased with increase in temperature and cocoyam had the highest swelling power of 3.53 g/g at 90°C while yam had lowest value of 2.07 g/g at the same temperature. Also, cocoyam starch water exhibited the highest paste clarity of 60.94 %T and yam starch water exhibited the lowest (49.32 %T). Both yam and cocoyam flours and starches were highly viscous at both share rates used but cocoyam was the most viscous. All the functional and physicochemical values obtained were comparable to the standard. The levels of the trace and heavy metals analyzed were within the safe limits. Vitamins B1, B2 and B6 levels were higher than the recommended daily allowances and Vitamin C level was very low and in most cases not detected.

***Keywords:*** *Predictive models; Equi-energetic servings; Glycemic response; Common processed food products; Macronutrient composition; (non-) diabetic*

## Introduction

Roots and tubers belong to the class of foods that basically provide energy in the human diet in the form of carbohydrates and also provide some minerals and essential vitamins [1]. The terms (roots and tubers) refer to any growing plant that stores edible material in subterranean root, corm or tuber [2]. Historically, very little attention has been paid to root crops by policy-makers and researchers as most of their efforts have been concentrated on cash crops or the more familiar grains. It is considered by many authorities that the increasing dependence in developing countries on imported cereals is unsustainable and the trend should be reversed by stimulating reliance on indigenous crops, in particular roots and tubers. The importance of these crops as a global source of food carbohydrates is well established. Regrettably, research and development on roots and tubers is limited and tends to be focused on pre-harvest production only, especially genetic improvement. What is needed is a well designed, integrated strategy of production, processing, and marketing to stimulate increased consumption and establish in developing countries the full potential of these crops, particularly with reference to their contribution to food self-sufficiency [3].

The tropical tuber crops are important food in the humid tropics because of their high carbohydrate content which is mainly in the form of starch. Industrial applications based on starch for these crops have been also increasingly recognised. Though cassava has been processed to give starch for many years, extraction of starch from the other tubers has not received much attention. Lack of enough information on the properties of these starches has contributed to limited utilization of these starches in industry. Knowledge on properties of the starches from these crops therefore would unravel the opportunities offered by these root crops and help their utilization.

In attempt to increase peoples' preference towards these underutilized food sources, there is a need to transform these commodities into value added products such as flours or starches [4]. In these forms, they can be fortified with other nutrients, thus improve low content of proteins or vitamins in certain tubers and roots. Transformation into starch also increases the storage efficiency as well as the self-storage. Moreover, in the form of starch, the application of these materials can be broadened either in food or non-food industries. In food industry, starch is used for thickening, filling, binding, or taste. Sometimes, starch is converted into sweeteners. On the other hand in non-food applications, starch is used in textile, paper, plywood, adhesive, pharmaceutical, and fuel industries [5].

Hence, this work was initiated with the objective of producing a pure starch from these tubers and evaluating their chemical and functional properties in order to explore the possibility of their uses in industries and for nutritional studies.

## Materials and Methods

### Materials

### Source of Material

The raw yams and cocoyam were purchased from Custom Market Area of Maiduguri, Borno Stateand the cassava starch was purchased from Tafa Balogun market of Lagos State. The tubers were authenticated by a Plant taxonomist from Department of Biological Science, University of Maiduguri.

### Flour Preparations

### Preparation of Whole Yam flour

Two fresh yam tubers of 1 kilogram each without rot or decay was thoroughly washed sliced into 2 mm thick disc, arranged on a tray and sun-dried for 8h. It was then milled into flour using double disc attrition milling machine. The flour was then packaged in an air-tight polythene bag for analysis [6].

### Preparation of Whole Cocoyam flour

The freshly harvested cocoyam corms were washed, sliced into chips of 1.5 mm thickness, sun-dried, milled into flour and packaged for analysis.

**Extraction of Starch**

Starch was extracted using the wet method described by Benesi., *et al*. (2004) [7], using tap water and ammonia solution (0.03 M).

**Yam**

Two tubers (2 kg) of fresh yam were washed, peeled, chopped into approximately 1 cm cubes and then pulverized in a high-speed blender (Model KING, Osaka, Japan) for 5 min. The pulp was suspended in ten times its volume of water or ammonia, stirred for 5 minutes and filtered using double fold cotton cloth. The filtrate was allowed to stand for 2h for the starch to settle and the top liquid was decanted and discarded. Water or ammonia was added to the sediment and the mixture was re-stirred again for 5 minutes. Filtration was repeated as before and the starch from the filtrate was allowed to settle. After decanting the top liquid, the sediment (starch) was sun-dried to a constant weight and stored [7].

**Cocoyam**

Fresh tuberous corms of cocoyam (2 kg) were washed, peeled, washed again, chopped and blended with water or ammonia. It was then filtered, allowed to sediment and decanted. The process was repeated three times and the sediment (starch) was sun-dried and stored as described by [7].

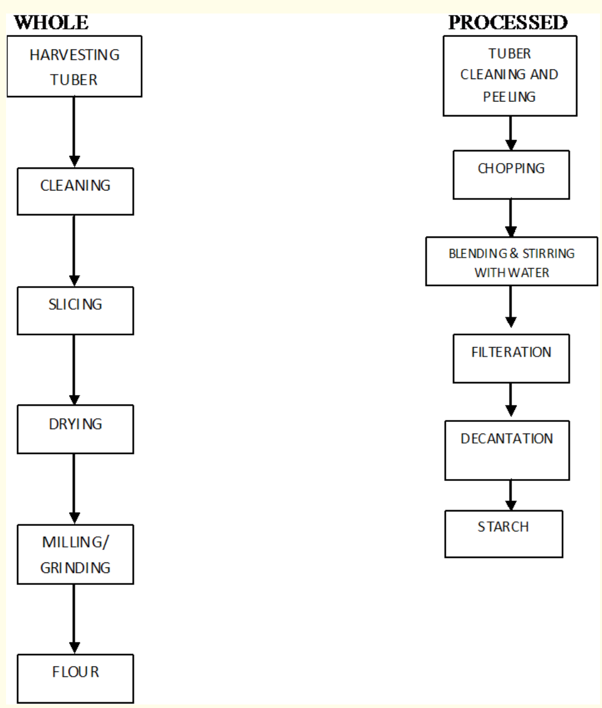


***Figure 1.0:*** *A flow chart for the preparation of whole flour.*

***Figure 2.0:*** *A flow chart for the extraction of starch.*

*Source: (Fakir., et al. 2012).*

## Methods

### Determination of Functional and Rheological Characteristics

#### Water Absorption Capacity (WAC)

Water absorption capacity was determined according to the method of Beuchart's (1977). One gram (1 g) of sample was mixed with 10 ml distilled water. The solution was then allowed to stand at room temperature (25 + 2°C) for 30 mins after which it was centrifuged at 3000 rpm for 30 mins. It was then decanted and the volume of the supernatant was noted in a 10 ml graduated cylinder. WAC (g/ml) was calculated as the difference between the initial volume of water added to sample and the volume of the supernatant.

#### Bulk Density

The Bulk Density (BD) was determined using the method of Okezie and Bello (1988) [8]. 10g of the sample was placed in a 25 ml graduated cylinder and packed by gentle tapping of the cylinder on a bench top ten times from a height of 5-8 cm. The final volume of the test material was recorded and expressed as g/ml.

#### Amylose Content

Starch was dispersed into ethanol and consequently gelatinized with 0.1M solution of sodium hydroxide. An aliquot of the gelatinized starch was treated with 0.1M citric acid before it was treated with an iodine solution. The resulting solutions absorbance was measured spectrophotometry at 620 nm. The same samples were also measured at 570 and 680 nm.

#### Viscosity

Viscosity (AV) was determined by placing 5g of the sample in measuring cylinder of 40 mls of distilled water in a boiling water bath of 75-80°C. The slurry was constantly stirred and until boiling which was continued for 5 min. The slurry was cooled to room temperature 23-25°C and their viscosity was measured with a canon viscometer using spindle no. 3. The actual viscosity readings in centipoises (cp) were calculated with the formula;

Actual viscosity reading (AVR) = M multiply by 10

Where M = Dial reading

#### Swelling Power

The swelling volume of the starch samples were measured according to Santacruz., *et al*. (2003) [9]. 0.5% starch suspensions were prepared in 15 ml Falcon tubes and heated in a water bath at 40, 50, 60, 70, 80 or 90°C for 30 min with constant agitation to avoid sedimentation. This was followed by centrifugation at 3000 x g for 15 min at 20°C. The sedimented fraction was weighed and its mass related to the mass of dry starch was expressed as swelling power (w/w).

#### Paste Clarity

Paste clarity was determined according to Ceballos., *et al*. (2007) [10]. A 1% aqueous solution of starch was boiled at 93oC with repeated shaking for 30 min. The solution was transferred into a cuvette after cooling and transmittance was then measured at 650 nm using a spectrophotometer.

### Determination of Proximate Composition

Proximate analysis was carried out on both the whole flours and the starch extracts of the five roots and tubers mentioned above according to the methods of AOAC. (2011) [11] to determine their proximate composition i.e. their moisture, ash, crude protein, crude fat, crude fibre and carbohydrate content.

#### Determination of Moisture Content (AOAC, 2011) [11]

**Principle:** This method is based on loss on drying at an oven temperature of 105°C. Besides water, the loss will include other matter volatile at 105°C.

Two grams (2g) of the sample was weighed into a petri dish of known weight and dried to a constant weight at 105°C for 5 hours in an oven. The dried sample was cooled, put into a desiccator and weighed. The difference in weight of the sample was equal to the moisture content.

% moisture = loss in weight of drying/initial weight of the sample × 100

**Determination of Ash**

**Principle:** The organic component of food is burnt off in air. The residue is ash which consists of the inorganic components in the form of their oxides. The ash content was determined by combusting the samples in a muffle furnace at 55°C for 12 hours [12].

**Determination of Protein (KJEDAHL METHODS)**

**Principle**

This method will not include nitrogen from nitrites and nitrates but will include nitrogen from proteins, alkaloids, nucleic acids, etc. The organic matter is oxidized by concentrated sulphuric acid in the presence of catalyst and the nitrogen converted to ammonium sulphate. This is then made alkaline, and the liberated ammonia is distilled and estimated. As a very large part of the nitrogen present in foods is derived from proteins, the crude protein is estimated by multiplying the percentage of nitrogen by an appropriate factor.

**Digestion**

About 2 grams (2g) of the sample was weighed into Kjedahl digestion tubes and 20 ml of sulphuric acid was added into the digest. The tube was heated in the digestion chamber for 16-18 hours. NaOH was added and the volume was made up 100 ml by distilled water.

**Distillation**

Five milliliters (5 mls) of borate was pipetted into a conical flask and 3 drops of bromocresol and methylene indicator were added into the conical flask. Five milliliters of the digested sample was introduced into the distillation flask through the funnel and 15-20 ml of 40% NaOH was added into the distillation flask. All the inlets were closed.

The conical flask containing the borate and mixed indicators was placed at the extended tube (outlet) of the distillation unit and 50-75 ml of the distillate was collected into the conical flask. This was titrated with standard HCl.

**Standardization of HCl**

Five milliliters (5 ml) of ammonium solution was pipetted and distilled with about 15 ml of 40% sodium hydroxide solution. The liberated ammonia was collected in a conical flask containing 5 ml of 2% boric acid and 4 drops of mixed indicator. The ammonia solution was titrated with standard HCl. The amount of HCl required for the titration was the acid factor that was used in the calculations of crude protein content.

The percentage protein was calculated using the formula:

$$\frac{A \times N \times F \times 14.007}{Weight\ of\ sample \times aliquot\ taken} \times 100$$

Where;

A = Volume of the acid used

N = Molarity of acid

F = Factor 6.25

**Determination of Crude Fat (AOAC, 2011) [11]**

**Principle:** Gravimetric estimation of fat from a dry powdered solid after a continuous extraction with light organic solvent e.g. petroleum ether N-hexane.

Fat was determined by the soxhlet extraction method. About 3g of each sample was weighed into fat extraction thimbles and covered with cotton wool to prevent splashing of the sample during extraction. The extraction units (tecator soxhlet 1046) were set up and fat was extracted using petroleum ether.

$$\%\ Extractable\ fat = \frac{W_3 - W_2}{W_1}$$

Where;

$W_1$ = Weight of sample before extraction

$W_2$ = Weight of sample without fat

$W_3$ = Weight of flask with fat

**Determination of Crude Fibre (AOAC, 2011) [11]**

Four hundred and fifty milliliters (450 ml) of glacial acetic acid was measured into a one-liter flask; 500 ml of distilled water was added. Fifty milliliters (50 ml) of concentrated nitric acid and 20g of trichloroacetic (TCA) acid were added and mixed thoroughly.

Two grams (2g) of the sample was weighed and transferred into a 250 ml of quick fit conical flask: 100 ml of the digestion mixture was added and refluxed with occasional shaking for 45 minutes. The mixture was then filtered through ash-less filter paper using suction. This was then washed with 100 ml of boiling distilled water and then with 50 ml of alcohol followed by 50 ml of petroleum ether. The filter paper with the sample was then dried at 100°C to a constant weight. The filter paper was weighed to obtain the weight of residue. The residue was then put in a crucible which has already been weighed and ashed at 600°C for 4 hours. The crucible was then removed and placed in a desiccator to cool after which it was weighed again.

**Calculation:**

b = Weight of paper + residue

a = Weight of paper alone

c = b - a = Weight of residue

c = Weight of dish + ash

d = Weight of dish alone

f = e - d = Weight of ash

c – f = Weight of crude fibre

Weight of sample used = 2g

$$\%\ of\ crude\ fibre = \frac{c - f}{2g} \times 100$$

**Determination of Carbohydrate (nitrogen-free extract)**

The carbohydrate (nitrogen-free extract) content was determined by the difference obtained after the subtraction of total crude protein, fat, ash and crude fibre from the total dry matter.

Percentage of carbohydrate (nitrogen-free extract) = 100 -- (% moisture + % protein + % ash + % fat + % crude fibre).

**Total Energy (AOAC, 2011) [11]**

The total energy value was calculated according to the method of Mahgoub (1999), using the formula: Total energy (Kcal/100 g) = [(% available carbohydrates × 4) + (% protein × 4) + (% fat × 4)]

**PH Determination**

Five grams (5g) of each sample was taken and homogenized in 20 ml of sterile distilled water. The resulting suspension was decanted and its pH was measured using a calibrated pH meter (Henshaw and Ikpoh, 2010).

**Determination of Mineral Elements**

Atomic Absorption Spectrophotometer (AAS) AA 6800 series Shimazo Corp was used for the determination of P, K, Fe, Zn and Mn.

Two grams (2g) of sample was weighed into a crucible and incinerated at 600°C for 2 hours. The ashed sample was transferred into 100 ml volumetric flask and 100 ml of distilled water added into it and readings taken on the AAS. The appropriate lamps and correct wave length for each element was specified in the instruction manual as follows:

P = 213.6 nm, K = 766.5 nm, Zn = 213.9 nm, Mn = Fe = 248.3 nm

**Determination of Phytic acid (Davies and Reid, 1979) [13]**

One gram (1g) of sample was extracted in 40 ml of 0.5M nitric acid for 1 hour. The sample was filtered and 5 ml of 0.08M ferric chloride was added. It was then boiled for 20 min and then filtered. The free iron ($Fe^{3-}$ ) remaining in the solution was then determined calorimetrically by adding 2 ml of 0.005M ammonium thiocyanate and the iron-binding capacities of the extracts were determined by difference. The wavelength used was 680 nm. The results were then expressed in terms of mg Fe bound $g^{-1}$ sample extracted.

**Determination of Water-Soluble Vitamins**

Uv-vis spectrophotometer shimadzu 2500 was used for the determination of vit B1, B2, B6 and C.0.2 grams of each sample was weighed accurately and placed in a test bottle. 5 ml of solvent (methanol) was added and allowed to stand for 1h 30 min so as to extract properly. It was then filtered. 2 ml of the filtrate was placed in a cuvette and then was run in the uv-vis spectrophotometer against the vitamin standard. The appropriate wavelength for each vitamin was as follows; B1 = 269 nm, B2 = 266 nm, B6 = 324 nm and Vit C = 478 nm.

**Statistical Analysis**

All determinations were carried out in triplicate. All data collected were subjected to analysis of variance and Duncan multiple ranges was used to compare the means (GraphPad InStat Version 3.10).

## Results

**Proximate composition**

Table 1 represents the proximate composition of flours and their isolated starches. A significant (P < 0.05) difference was observed in the moisture content between the flours with cocoyam flour having the highest value (10.99%) and yam flour having the lowest (9.85%). Among the ammonia extracted starches, there was also a significant (P < 0.05) difference in the moisture content with yam starch having the highest value (9.79%) and cocoyam starch having the least value (9.59%).The same trend was observed in the water extracted starches with yam having the highest value (14.22%) and cocoyam having the lowest (9.86%).

There was also a significant (P < 0.05) difference in the ash content (yam flour having the highest value of 2.10 and cocoyam starch having the lowest value of 0.31), protein (cocoyam flour having the highest value of 4.60 and yam starch having the lowest value of 1.52), fibre (yam flour having the highest value of 11.99% and yam starch having the lowest value of 1.95%), carbohydrate (yam starch having the highest value of 85.33% and yam flour having the lowest value of 71.70%) and energy (yam starch having the highest value of 350.43 and cocoyam flour having the lowest value of 314.95) between the flours and their respective ammonia and water extracted starches. However, no significant (P > 0.05) difference was observed in the fat content between the flours and their extracted starches.

| | % Moisture | % Ash | % Crude Protein | % Fat | % Fibre | % Carbohydrate | Kcal/100g Energy |
|---|---|---|---|---|---|---|---|
| YF | 9.85 ± 0.02[a] | 2.10 ± 0.01[a] | 3.60 ± 0.07[a] | 0.43 ± 0.03[a] | 11.99 ± 0.02[a] | 71.70 ± 0.20[a] | 304.29 ± 0.17[a] |
| YSA | 9.79 ± 0.06[ac] | 0.53 ± 0.02[bd] | 1.67 ± 0.04[bd] | 0.54 ± 0.02[ab] | 1.95 ± 0.05[bd] | 85.33 ± 0.03[bd] | 350.43 ± 0.03[bd] |
| YSW | 14.22 ± 0.02[bd] | 0.36 ± 0.01[ce] | 1.52 ± 0.04[ce] | 0.51 ± 0.03[ab] | 3.22 ± 0.26[ce] | 80.30 ± 0.01[ce] | 329.54 ± 0.02[ce] |
| CF | 10.99 ± 0.04[a] | 3.22 ± 0.02[a] | 4.60 ± 0.04[a] | 0.60 ± 0.01[a] | 7.09 ± 0.09[a] | 73.48 ± 0.02[a] | 314.95 ± 0.04[a] |
| CSA | 9.59 ± 0.29[bd] | 0.63 ± 0.01[bd] | 2.65 ± 0.03[bd] | 0.34 ± 0.02[ab] | 2.00 ± 0.04[bd] | 85.05 ± 0.13[bd] | 315.69 ± 0.03[bd] |
| CSW | 9.86 ± 0.05[ce] | 0.31 ± 0.02[ce] | 2.39 ± 0.05[ce] | 0.36 ± 0.01[ab] | 2.01 ± 0.01[ce] | 84.73 ± 0.23[ce] | 315.49 ± 0.28[cd] |
| Values are recorded as means ± S.D. of three determinations, n=3 | | | | | | | |
| Values in the same column with different superscript are significantly different (p < 0.05) | | | | | | | |

*KEY: YF= Yam flour* *YSA= Yam starch ammonia* *YSW= Yam starch water*
*CF= Cocoyam flour* *CSA= Cocoyam starch ammonia* *CSW= Cocoyam starch water*

***Table 1:*** *proximate composition of flours and starches.*

**Mineral Elements Composition**

Table 2 represents the mineral element composition of flours and their isolated starches. A significant (P < 0.05) decrease was observed in the levels of potassium (YF having the highest value of 30.00 mg/l and YSA having the lowest value of 9.47 mg/l), iron (YF highest 5.01 mg/l and YSA lowest 0.95 mg/l), manganese (YF highest 2.98 mg/l and YSW lowest 0.18 mg/l), zinc (YF highest 2.11 mg/l and YSW lowest 1.66 mg/l) and phosphorus (YSA highest 1.42 mg/l and YSW lowest 0.53 mg/l) of the yam flour and its respective water and ammonia extracted starches.

The levels of potassium (59.57 mg/l to 24.93 mg/l), iron (40.51 mg/l to 3.67 mg/l), zinc (19.12 mg/l to 2.78 mg/l) and phosphorus (1.05 mg/l to 0.67 mg/l) decreased significantly (P < 0.05) between the cocoyam flour and its respective starches, while the level of manganese increased significantly (P < 0.05) between the flour and the ammonia extracted starch (1.58 mg/l to 4.01 mg/l) and the water extracted starch significantly decreased (1.58 mg/l to 1.49 mg/l).

**Water-soluble vitamins**

Table 3 represents the water-soluble vitamin levels of the flours and their respective isolated starches. The levels of vitamin B1, B2 and B6 decreased significantly (P < 0.05) between the flours (with values ranging from 31.98 to 23.43 mg/l B1, 20.90 to 18.30 mg/l B2 and 16.35 to 9.92 mg/l B6) and their respective starches (with values ranging from 13.04 to 4.57 mg/l B1, 4.49 to 1.15 mg/l B2 and 6.89 to 3.82 mg/l B6). Vitamin C was only detected in the flours and in yam starch ammonia (0.08, 0.03 and 0.05 mg/l).

**Water absorption capacity, Bulk density, pH and Phytic acid**

Table 4 represents the water absorption capacity, bulk density and pH of the flours and their isolated starches.

| | K | Fe | Mn | Zn | P |
|---|---|---|---|---|---|
| YF | 30.00 ± 0.25[a] | 5.01 ± 0.03[a] | 2.98 ± 0.08[a] | 2.11 ± 0.02[a] | 0.92 ± 0.02[a] |
| YSA | 9.47 ± 0.03[bd] | 0.95 ± 0.02[bd] | 0.51 ± 0.02[b] | 1.91 ± 0.01[bd] | 1.42 ± 0.02[bd] |
| YSW | 23.92 ± 0.09[ce] | 1.66 ± 0.01[ce] | 0.18 ± 0.01[c] | 1.66 ± 0.01[ce] | 0.53 ± 0.02[ce] |
| CF | 59.57 ± 0.72[a] | 40.51 ± 0.04[a] | 1.58 ± 0.03[a] | 19.12 ± 0.10[a] | 1.05 ± 0.02[a] |
| CSA | 24.93 ± 0.12[bd] | 3.67 ± 0.03[bd] | 4.01 ± 0.02[bd] | 2.78 ± 0.01[bd] | 0.67 ± 0.02[bd] |
| CSW | 26.00 ± 0.01[ce] | 5.12 ± 0.02[ce] | 1.49 ± 0.01[ce] | 2.99 ± 0.02[ce] | 0.77 ± 0.02[ce] |
| Values are recorded as means ± S.D. of three determinations, n=3 | | | | | |
| Values in the same column with different superscript are significantly different (p < 0.05) | | | | | |

*KEY: YF= Yam flour CF= Cocoyam flour*

*YSA= Yam starch ammonia CSA= Cocoyam starch ammonia*

*YSW= Yam starch water CSW= Cocoyam starch water*

***Table 2:** Mineral elements composition of flours and starches (mg/l).*

| | Vit B1 | Vit B2 | Vit B6 | Vit C |
|---|---|---|---|---|
| YF | 31.98 ± 0.44[a] | 20.90 ± 0.05[a] | 16.35 ± 0.05[a] | 0.08 ± 0.01 |
| YSA | 5.11 ± 0.02[bd] | 1.15 ± 0.04[bd] | 3.82 ± 0.03[bd] | 0.05 ± 0.02 |
| YSW | 6.32 ± 0.02[ce] | 3.35 ± 0.04[ce] | 6.43 ± 0.13[ce] | ND |
| CF | 23.43 ± 0.08[a] | 18.30 ± 0.05[a] | 9.92 ± 0.02[a] | 0.031 ± 0.003 |
| CSA | 13.04 ± 0.29[bd] | 4.49 ± 0.04[bd] | 5.44 ± 0.05[bd] | ND |
| CSW | 4.57 ± 0.03[ce] | 2.32 ± 0.03[ce] | 6.89 ± 0.04[ce] | ND |
| Values are recorded as means ± S.D. of three determinations, n=3 | | | | |
| Values in the same column with different superscript are significantly different (p < 0.05) | | | | |

*Y: YF= Yam flour CF= Cocoyam flour*

*YSA= Yam starch ammonia CSA= Cocoyam starch ammonia*

*YSW= Yam starch water CSW= Cocoyam starch water*

***Table 3:** Water-Soluble Vitamins Of Flours And Starches (Mg/L).*

A significant decrease ($P < 0.05$) in the water absorption capacity was observed between all the flours and their respective starches. In bulk density, no significant decrease ($p > 0.05$) was shown between the flours and the starches.

In the phytic acid content of the flours and the extracted starches, no significant decrease ($P > 0.05$) was observed between yam flour and its respective starches (from 0.11 to 0.11 and 0.10%), while for cocoyam, a significant decrease ($P < 0.05$) was observed (from 0.82 to 0.11 and 0.12%).

| | WAC (g/ml) | Bulk Density (g/ml) | Phytic acid (%) | pH |
|---|---|---|---|---|
| YF | $2.16 \pm 0.14^{a}$ | $0.65 \pm 0.03^{a}$ | $0.11 \pm 0.01^{a}$ | 8.42 + 0.02 |
| YSA | $1.04 \pm 0.04^{bd}$ | $0.63 \pm 0.04^{ac}$ | $0.11 \pm 0.01^{ab}$ | 7.31 + 0.02 |
| YSW | $1.04 \pm 0.06^{cd}$ | $0.76 \pm 0.01^{bd}$ | $0.10 \pm 0.01^{ab}$ | 5.39 + 0.01 |
| CF | $1.36 \pm 0.11^{a}$ | $0.57 \pm 0.02^{a}$ | $0.82 \pm 0.03^{a}$ | 8.49 + 0.01 |
| CSA | $1.02 \pm 0.08^{bd}$ | $0.54 \pm 0.03^{ab}$ | $0.11 \pm 0.01^{bd}$ | 6.48 + 0.02 |
| CSW | $0.42 \pm 0.03^{ce}$ | $0.51 \pm 0.02^{ab}$ | $0.12 \pm 0.01^{cd}$ | 5.91+ 0.01 |
| Values are recorded as means ± S.D. of three determinations, n = 3 | | | | |
| Values in the same column with different superscript are significantly different (p < 0.05) | | | | |

*KEY:* *YF= Yam flour* *CF= Cocoyam flour*

*YSA= Yam starch ammonia* *CSA= Cocoyam starch ammonia*

*YSW= Yam starch water* *CSW= Cocoyam starch water*

***Table 4:*** *Wac, Bulk Density, Ph, Phytic Acid.*

**Rheological Parameters of Starches**

Table 5 represents the percentage yield, amylose content, amylopectin and paste clarity of the extracted starches.

A significant increase (P < 0.05) was observed in the percentage yield of both yam (50.56 to 52.05%) and cocoyam (34.48 to 43.80%). The use of ammonia significantly increased the percentage yields.

For amylose, no significant decrease (P > 0.05) was shown between yam starch ammonia and yam starch water (27.78 and 27.73 %T), but significant decrease (P < 0.05) was shown between the two and the standard (values lower than the standard 33.48 %T). The same trend was shown for cocoyam (15.80 and 16.32 %T).

For amylopectin, a significant decrease (P < 0.05) was observed between the starches of yam, cocoyam and the standard (values higher than the standard 66.34 %T; 72.21 and 84.31 %T respectively). Among the water extracted starches, cocoyam starch had the highest amylopectin value (83.62 %T) and yam starch had the lowest (72.36 %T). The same trend was observed in the case of ammonia extracted starches.

A significant increase (P < 0.05) in paste clarity was observed between both the starches of yam (49.32 and 48.15), cocoyam (54.71 and 60.94) and the standard (70.78).

**Swelling Power**

Table 6 represents the swelling power of the starches at temperatures 60, 70, 80 and 90°C. A significant increase (P < 0.05) was observed in all the water and the ammonia extracted starches and the standard as the temperature increases from 60 to 90°C. The highest peak (3.53 g/g) was observed at 90°C and the lowest (0.57 g/g) at 60°C.

| | AM (%T) | AP (%) | Yield (%) | PC (%T) |
|---|---|---|---|---|
| YSA | 27.78 ± 0.08[a] | 72.21 ± 0.28[a] | 52.05 ± 0.10[a] | 49.32 ± 0.02[a] |
| YSW | 27.73 ± 0.10[a] | 72.36 ± 0.16[a] | 50.56 ± 0.08[b] | 48.15 ± 0.05[a] |
| STD | 33.48 ± 0.08[bc] | 66.34 ± 0.36[bc] | 57.45 ± 0.04[cd] | 70.78 ± 0.03[cd] |
| CSA | 15.80 ± 0.08[a] | 84.31 ± 0.21[a] | 43.80 ± 0.05[a] | 54.71 ± 0.01[a] |
| CSW | 16.32 ± 0.08[a] | 83.62 ± 0.10[a] | 34.48 ± 0.03[b] | 60.94 ± 0.01[b] |
| STD | 33.48 ± 0.08[bc] | 66.34 ± 0.36[bc] | 57.45 ± 0.04[cd] | 70.78 ± 0.03[cd] |
| Values are recorded as means ± S.D. of three determinations, n = 3 | | | | |
| Values in the same column with different superscript are significantly different (p < 0.05) | | | | |

*KEY: YSA=Yam Starch Ammonia CSA= Cocoyam starch ammonia*
*YSW= Yam starch water CSW= Cocoyam starch water*
*STD= Standard*

***Table 5:*** *Rheological Parameters of Starches.*

| | SP60 | SP70 | SP80 | SP90 |
|---|---|---|---|---|
| YSA | 0.58 ± 0.03[a] | 1.38 ± 0.03[a] | 2.02 ± 0.03[a] | 2.72 ± 0.02[a] |
| YSW | 0.57 ± 0.02[a] | 1.08 ± 0.02[b] | 1.57 ± 0.03[b] | 2.07 ± 0.02[b] |
| STD | 2.23 ± 0.03[cd] | 6.58 ± 0.03[cd] | 8.47 ± 0.03[cd] | 10.21 ± 0.01[cd] |
| CSA | 0.72 ± 0.02[a] | 2.04 ± 0.02[a] | 2.67 ± 0.01[a] | 3.53 ± 0.03[a] |
| CSW | 0.37 ± 0.02[b] | 1.20 ± 0.01[b] | 2.01 ± 0.01[b] | 3.32 ± 0.03[b] |
| STD | 2.23 ± 0.03[cd] | 6.58 ± 0.03[cd] | 8.47 ± 0.03[cd] | 10.21 ± 0.01[cd] |
| Values are recorded as means ± S.D. of three determinations, n = 3 | | | | |
| Values in the same column with different superscript are significantly different (p < 0.05) | | | | |

*KEY: YSA= Yam starch ammonia CSA= Cocoyam starch ammonia*
*YSW= Yam starch water CSW= Cocoyam starch water*
*STD= Standard*

***Table 6:*** *swelling power (g/g) of starches.*

**Hot paste viscosity**

Table 7 represents the viscosity of the flours and their isolated starches. At share rate 30, there was a significant decrease (P < 0.05) between yam flour (1011.02), yam starch ammonia (1003.23), yam starch water (1009.37) and standard (1005.40), and between cocoyam flour (1190.04), cocoyam starch ammonia (1116.67), cocoyam starch water (1002.03) and the standard (1005.40).

At share rate 60, also a significant decrease (P < 0.05) was observed between the flours, starches and the standard. Cocoyam had the highest viscosity at both share rates. In general, highest viscosities were observed at share rate 30.

| Share Rate(rpm) | | |
|---|---|---|
| | 30 | 60 |
| YF | 1011.02 ± 0.07[a] | 502.37 ± 0.15[a] |
| YSA | 1003.23 ± 0.25[be] | 501.23 ± 0.26[be] |
| YSW | 1009.37 ± 0.15[cfh] | 503.37 ± 0.15[cfh] |
| STD | 1005.40 ± 0.10[dgi] | 500.80 ± 0.10[dgi] |
| CF | 1190.04 ± 0.24[a] | 592.63 ± 0.15[a] |
| CSA | 1116.67 ± 0.06[be] | 551.23 ± 0.15[be] |
| CSW | 1002.03 ± 0.10[cfh] | 500.57 ± 0.06[cfh] |
| STD | 1005.40 ± 0.10[dgi] | 500.80 ± 0.10[dgh] |
| Values are recorded as means ± S.D. of three determinations, n=3 | | |
| Values in the same column with different superscript are significantly different ($p < 0.05$) | | |

*KEY: YSA= Yam starch ammonia CSA= Cocoyam starch ammonia*
*YSW= Yam starch water CSW= Cocoyam starch water*
*STD= Standard*

***Table 7:*** *Hot paste viscosity (cp) of flours and starches Viscosity (bu).*

## Discussion

### Percentage Yield

The percentage yield of starch ranged between 52.05–34.48% per 2000g each of fresh tubers. The increase in yield observed (from 50.56% to 52.05% yam and 34.48% to 43.80% cocoyam) on using ammonia solution is in line with the reports of Moorthy. (1990) [5]. This is because yam and cocoyam contain high amount of mucilage and presence of mucilaginous material is a major hurdle in starch extraction. Settling takes very long time, which can result in microbial contamination and hence a reduction in starch quality. Therefore, the noticeable helps in preventing possible microbial damage leading to deterioration in quality especially during settling. The pH of the extraction medium was 9.0-10.0, and the normal mould, yeast and bacteria are generally unable to grow under these conditions [5].

In earlier experiments, various chemicals have been tried to improve the extractability of starch, especially from the tubers of *Colocasia* and *Dioscorea* spp. [5]. These include 10% ethyl alcohol, 1% calcium hydroxide solution, 1% cetyl trimethylammonium bromide solution and 1% acetic acid. Among these, only calcium hydroxide solution was found to improve the settling of *Colocasia* starch, but the starch obtained assumed a brownish colour, which could not be removed even by repeated washings. Hence a mixture of alcohol and calcium hydroxide solution was tried, but was found to be ineffective. Cetyl trimethylammonium bromide was not only ineffective, but also led to changes in starch properties. Use of water at 500C did not lead to any improvement in yield of Colocasia starch. However, dilute ammonia solution was found to improve the settling of starch from *Colocasia* and *Dioscorea* sp. Preliminary experiments also showed that the desirable concentration of the ammonia solution is 0.03M [5].

### Proximate Analysis

Results for the proximate analysis showed that the %ash, %crude protein and %fibre of the starches were lower than their corresponding flours and this could be as a result of the extraction process. The moisture content of both the flours and the starches were also generally low and this can be attributed to the low temperature used during the drying. The low moisture contents of both the flours and the starches makes them easy to store at room temperature and less prone to fungal and microbial infections (because food spoilage micro-organism thrive where moisture content is very high), making them a more shelf stable products. These findings agree with those of Aprianita., *et al*. (2009) [4].

The percentage carbohydrate and energy were higher in both the flours and their corresponding starches and this is in line with what has been reported by Enwere. (1998) [14] in the literature that of all the solid nutrients in roots and tubers, carbohydrate is predominant and this make them excellent sources of energy.

**Functional Properties**

**Water Absorption capacity**

The water absorption capacity ranged between 2.16–0.42 g/ml. The value (1.36 g/ml) obtained in this study for cocoyam flour is in line with similar reports of Amandikwa. (2012) [15] that reported a water absorption capacity of sun-dried cocoyam flour as 1.50g/ml.

The low values could be as a result of the low temperature used for the drying which might have led to low moisture content thereby causing the flour and the starch samples to absorb more water [16]. As reported by Hayata., *et al*. 2006 [16], that drying increases the absorption capacity of flour. According to Circle and Smith (1972) [17], water absorption capacity is a useful indication of whether flours can be incorporated into aqueous food formulations especially those involving dough handling. Niba., *et al*. (2001) [18] also stated that water absorption capacity is important in bulking and consistency of products as well as baking applications.

**Bulk Density**

The low bulk density exhibited by both the flours and the starch samples could be as a result of the low moisture they contain as reported by Amandikwa. (2012) [15]. According to Hayata., *et al*. (2006) [16], drying decreases the bulk density of flour and at the same time bulk density gives an indication of the relative volume of packaging material required. Generally, higher bulk density is desirable for greater ease of dispersibility and reduction of paste thickness [19]. Low bulk density of flour are good physical attributes when determining transportation and storability since the products could be easily transported and distributed to required locations [20]. Low bulk density is advantageous for the infants as both calorie and nutrient density is enhanced per feed of the child [21]. High bulk density is a good physical attribute when determining mixing quality of particulate matter [22].

**PH**

The pH of the flours ranged from 8.42-8.49 and that of the starches from 7.31-5.39. PH is an important property in starch industrial applications, being generally used to indicate the acidic or alkaline properties of liquid media [23].

**Phytic Acid**

The phytic acid content of both the flours and the starches were generally low. No significant increase ($P > 0.05$) was seen between the ammonia and the water extracted starches. Aprianita., *et al*. (2010) [4] also reported low levels of phytic acid in yam, sweet potato and cocoyam flours and starches. Low levels of phytic acid could be as a result the fermentation during extraction and these signify a better nutritional value [24].

**Rheological Properties**

**Amylose and Amylopectin**

Amylose (AM) and amylopectin (AP) are the two major components of starch granules. They are the main determinants of swelling power, solubility, pasting and gelatinization of the starches. The functionality of the two main components of starch differs significantly. AM has a high tendency to retrograde and produce tough gels and strong films [25]. In contrast, AP, when dispersed in water, is more stable and produces soft gels and weak films [26].

Results obtained for the total amylose content showed significant variations in the amylose content of all the starches compared to the standard. The difference however between the water and the ammonia extracted starches was not pronounced. This corresponds to the findings of Nuwamanya., *et al*. (2011) [27].

High amylose starches like cassava, sweet potato and irish potato have an increased tendency of water absorption, although, the stability of resulting starch water mixtures is low and the visco-elastic properties are lower coupled to their high tendency to retrograde (Nuwamanya., *et al*. (2011) [27]. This limits the application of such starches in bread making and other food application due to poor dough development and extensibility. High amylose starches also tend to have high water absorption indices leading to drier dough. Firmness also increases as amylose content becomes higher; hence, increasing resistance of starch to take up water [27].

Amylopectin has been widely reported to be responsible for swelling power [28]. The direct proportionality relationship between AP and SP was observed in this study. For instance, cocoyam with the highest percentage amylopectin did have the highest swelling power at any of the investigated temperatures.

**Swelling Power**

The results obtained indicated that swelling power is temperature dependent. The swelling power of all the starches increased as the temperature increased from 60°C to 90°C. Higher swelling indicates a lowering of associative forces between the starch granules and hence considerable disruptions of associative forces seem to take place on extraction with ammonia solution in all the starches. Similar findings were reported by Davies., *et al*. (2008) [23] and Awokoya., *et al*. (2001).

It is also reasonable that as the temperature of the medium increases, starch molecules become more thermodynamically activated, and the resulting increase in granular mobility enhances penetration of water which facilitates improved swelling capacities. Swelling power of starch depends on the capacity of starch molecules to hold water through hydrogen bonding. After gelatinization, these hydrogen bonds between starch molecules are broken and are replaced by hydrogen bonds with water [23].

**Paste Clarity**

Starch gel clarity is a much desirable functionality of starches for its utilization in food industries since it directly influences brightness and opacity in foods that contain them as thickeners. From the results obtained, the paste clarity was high for cocoyam (60.94 %T) and low for yam (48.15 %T). Amylose content is known to influence the clarity of starch pastes as lower amylose starches are easily dispersed, increasing transmittance and clarity. Moreover, yam and cocoyam starches which showed comparatively lower amylose contents (27.78, 27.73; 15.80, 16.32) had higher paste clarities (49.32, 48.15; 54.71, 60.94). We can however, say that yam and cocoyam starches are in conformity with the above observation. These results suggest that paste clarity was influenced by so many factors not only amylose to amylopectin ratio [23].

**Hot Paste Viscosity**

The viscosity (cp) of both the flours and their isolated starches were higher at rpm (share rate) 30 and lower at rpm 60. Viscosity can be considered as a measure of the strength of starch granules, since a higher viscosity indicates that starch granules are intact, while the starch which has undergone chemical and microbial damage loses viscosity. Hence ammonia treatment not only has no chemical effect on starch but also volume [29]. This result showed that cocoyam tuber is more viscous than yam.

**Mineral Element**

Mineral content is a measure of the amount of specific inorganic components present within a food material. The concentrations of minerals in tubers in general are influenced by several factors that include environmental, processing methods and genetic factors [30]. With respect to environmental factors the mineral content could be attributed to the availability of these minerals in the soil. It is estimated that humans require at least 22 mineral elements for a healthy life. Studies have shown that over 60% of world's population are iron (Fe)-deficient and over 30% are zinc (Zn) deficient [30]. Deficiencies of calcium (Ca), magnesium (Mg) and copper (Cu) are also common in both developed and developing countries. These deficiencies can be attributed to the consumption of product from land with low mineral availability, and more refined foods [30].

The flours and the starches contained various amount of mineral elements. Phosphorus, which has been reported to be covalently linked to the starch ranged from 1.34-0.53 mg/100g (with irish potato starch ammonia having the highest value while yam starch water having the lowest) and that of the flours ranged from 1.13-0.92 mg/100g (sweet potato flour highest and yam flour lowest). Phosphorus in starch exists mainly in two forms: phosphate monoesters and phospholipids. Root and tuber starches contain phosphorus in the form of mono phosphate esters covalently bonded to starch while phospholipids are predominant in cereal starches.

The levels of K, Fe, Mn and Zn of the flours were generally higher than in their corresponding water and ammonia extracted starches. These could be attributed to the processing techniques employed during sample preparations; nonetheless the levels of the trace heavy metals were generally within safe limits [30].

**Hot Paste Viscosity**

The water-soluble vitamins are a structurally diverse group of compounds with different absorbance maxima. Therefore, different detection wavelengths were chosen for their detection. The wavelengths used were; 269.00, 266.00, 324.00 and 478.50 nm for B1, B2, B6 and Vitamin C respectively. The levels of vitamins in the flours were higher than in their corresponding starches. All the values obtained were above the recommended daily allowances except for vitamin C which in most cases was not detected. This is in line with what has been reported in the literature that vitamin C is predominantly found in fruits and vegetables. Over consumption of these water-soluble vitamins is generally not a problem especially if the nutrients are obtained through food (Bellows and Moore 2014).

## Summary and Conclusion

As this study has shown, there are great potential applications of tuber starch and flour in the food industry. Each of these components having different physiochemical or beneficial health properties, which may be further examined for either the development of entirely new food products or for the replacement in current food products from the more traditional sources of starch and flour. The examination of the various physicochemical properties found here in this study demonstrates the potential of these products in food processing. Such results may allow for informed choices or diversity of choice when sourcing new ingredients or ingredients with properties to enhance product production and development.

Based on the results of the proximate composition and the functional properties, the low moisture content, bulk density and water absorption are good physical attributes when determining storability and transportation of products in industries. Also, Based on the results of the physicochemical properties of the main extracts (starches), it can be seen that these tuber products have a good potential to be used in the food industry. The high viscosity of cocoyam, yam and sweet potato starches and flours would make them very useful in food applications where high thickening power is desired. The low viscosity of irish potato flour and starch is desirable in the food industry for applications that require lower viscosity and the high paste clarity would make it useful for products where this is required as a thickening agent. In addition to the useful individual properties of these tubers, the high amounts of energy makes these tubers and roots to be used as valuable alternative carbohydrate sources. Added to this, the absence of gluten in these tubers would be advantageous for producing foods for people suffering from celiac disease and may also aid in its prevention. Therefore these tubers may be seen as having very broad applications within the food industry.

The results also points out that ammonia extraction will be useful for obtaining starch from different tuber crops, without affecting the properties but at the same time offering good yields. In the case of cocoyam starch, which is most difficult to extract, the treatment had definite advantages in increasing yield and also quality of starch.

**Suggestions and Recommendations**

Native starches have limited usage, mainly in the food industry, because they lack certain desired functional properties. The native starch granules hydrate easily when heated in water, they swell and gelatinize; the viscosity increases to a peak value, followed by a rapid decrease, yielding weak-boiled, stringy, and cohesive pastes of poor stability and poor tolerance to acidity, with low resistance to shear pressure, as commonly employed in modern food processing. So, there is need to carry out modifications on these starches so as to produce more satisfactory products for specific food applications. The different ways of modifying native starch consist of altering one or more of the following properties: paste temperature, solids/viscosity ratio, and starch paste resistance to reduction of viscosity by acids, heat and or mechanical agitation (shear), retrogradation tendencies, ionic and hydrophilic nature [31,32,33].

## Bibliography

1. Ogunlakin GO., *et al*. "Effect of drying methods on proximate composition and physico-chemical properties of cocoyam flour". *American Journal of Food Technology* 7 (2012): 245-250.
2. Ugwu FM. "The potentials of roots and tubers as weaning foods". *Pakistan Journal of Nutrition* 8.10 (2009): 1701-1705.
3. FAO. Report on the informal group meeting on the sixth world food survey. Food production yearbook held at FAO Headquarters (1990).
4. Aprianita A., *et al*. "Physicochemical properties of flours and starches from selected commercial tubersavailable in Australia". *International Food Research Journal* 16 (2009): 507-520.
5. Moorthy SN. "Extraction of starches from tuber crops using ammonia". *Carbohydrate Polymers* 16.4 (1990): 391-398.
6. Fakir MSA., et al. "Starch and flour extraction and nutrient composition of tuber in seven cassava accessories". *Journal of the Bangladesh Agricultural University* 10.2 (2012): 217-222.
7. Benesi IRM., *et al*. "Stability of native starch quality parameters, starch extraction and root dry matter of cassava genotypes in different environments". *Journal of the Science of Food and Agriculture* 84.11 (2004): 1381-1388.
8. Okezie BO and Bello M. "Physiochemical and functional properties of winged bean flour and isolates compared with soya isolates". *Journal of Food Science* 53.2 (1988): 450-454.
9. Santacruz S., *et al*. "Three underutilized sources of starch from the Andean region in Ecuador, Part II. Rheological characterization". *Carbohydrate Polymers* 51.1 (2003): 85-92
10. Ceballos H., *et al*. "Discovery of an amylose-free starch mutant in Cassava (manihot esculenta crantz)". *Journal of Agriculture and Food chemistry* 55.18 (2007): 7469-7476.
11. AOAC. Association of Official and Analytical Chemist, Official Methods of Analysis (2011).
12. AOAC. Association of Official and Analytical Chemist, Official Methods of Analysis (2000).
13. Davies NT and Reid SE. "Studies on the phytate: zinc molar contents in diets as a determinant of zinc availability to young rats". *British Journal of Nutrition* 41.3 (1979): 591-603.
14. Enwere NJ. Foods of Plant Origin. Afro-orbisPublications Limited (1998): 194-199.
15. Amandikwa C. "Proximate and Functional properties of open air, solar and oven dried cocoyam flour". *International Journal of Agriculture and Rural Development* 15.2 (2012): 988-994.
16. Hayata M., *et al*. "Effect of drying on functional propertiesof Tarhana". *International Journal of Food Science and Technology* 29: (2006): 457-462.
17. Circle SJ and Smith AK. "Functional properties of commercial edible soybean Protein production". In: Symposium: Seed and proteins (Inglett, G. E. ed). Avi Zub.Co.Inc. Westport. (1972).
18. Niba LL., *et al*. "Physio-chemical. properties and starch granular characteristics of flour from various Manihot esculenta (cassava) genotypes". *Journal of Food Science* 67.5 (2001): 1701-1705.

19. Udensi A and Eke O. Proximate composition and functional properties of flour produced from Mucuna cochinensis and Mucuna utles. In Proceedings of the 1st Annual Conference of the College of Agriculture and Veterinary Medicine Abia State University (2000): 170-174.
20. Agunbiade SO and Sanni MO. The effect of ambient temperature of cassava tubers onStarch quality. Pp 180-194. In: Root Crops. The small processor and development ofLocal Food Industries for market economy. Proceedings of the Eight Triennials Symposium of the International Society forTropical Root Crops. African Branch (ISTRC-AB) 12-14 Nov. IITA, Ibadan Nigeria. (2003): 1993.
21. Onimawo AI and Egbekun KM. "Comprehensive Food Science and Nutrition". (1998).
22. Lewis NJ. "Physical properties of processing systems". Hartnolls Ltd Bodman (1990).
23. Davies EM., *et al*. "Some properties of starches from Cocoyam (colocacia esculenta) and Cassava (manihot esculenta crants) grown in Malawi". *African Journal of Food Science* 2 (2008): 102-111.
24. Bintu BP. Evaluation of the Nutritional Composition of Maize (Zeamays) fermented meal fortified with Cowpea (Vigna unguialata), Bambara nut (Voandzeia subterranean) and Groundnut (Arachis hypogea) (2012): 52.
25. Ashogbon AO and Akintayo ET. "Recent trend in the physical and chemical modification of starches from different botanical sources". *A review* 66 (2014): 41-57.
26. Perez S and Bertoft E. "The molecular structure of starch components and their contribution to the architecture of starch granules". *A comprehensive review: Starch/Starke* 62.8 (2010): 389-420.
27. Nuwamanya E., *et al*. "A comparative study of the physicochemical properties of starches from root tuber and cereal crops". *African Journal of Biotechnology* 10.56 (2011): 12018-12030.
28. Ashogbon AO. "Chemical and functional properties of Cocoyam starch and Wheat starch blends". *International Journal of Biotechnology and Food Science* 2.5 (2014): 94-101.
29. Moorthy SN. "Physicochemical and functional properties of tropical tuber starches". 54 (2002): 559-592.
30. Sanful RE., *et al*. "Effect of Pre-treatment and Drying on the Nutritional and Mineral Composition of D. bulbifera flour". *Journal of Biological and Food Science Research* 4.4 (2013): 37-44.
31. Adebowale YA., *et al*. "Functional and Physicochemical properties flours of mucin species". *African Journal of Biotechnology* 4 (2005): 416-468.
32. Kjeldahl J. "Determination of protein nitrogen in food products". *Encyclopedia of Food Science* (1883): 439-441.
33. Sathe SK and Salunkhe DK. "Functional properties of the great northern bean. Proteins, emulsion foaming, viscosity and gelation properties". *Journal of Food Science* 46.1 (1981): 71-81.

**Volume 3 Issue 2 January 2016**