# Physicochemical and Functional Properties of Yellow Yam (*Dioscorea Cayenensis*) Starches and Sensory Quality of Its Custard

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***ABSTRACT***

***Background**: Corn has been the major source of starch used in the production of custard. Therefore there is need to harness other sources of starch for the production of custard.*

***Objective**: This study evaluated some physicochemical and functional properties of starches extracted from two varieties (TDC2790 and TDC2812) of yellow yam (Dioscorea cayenensis) and cornstarch and the sensory attributes of the custard made from the starches.*

***Methods**: Weights of the yam were measured and starch extraction was carried using standard laboratory procedures. Starch yield was calculated, proximate composition, amylose and amylopectin contents, carotenoid, colour and functional properties were determined.*

***Results**: Percentage starch yield from TDC2790 and TDC2812 were 18.97% and 12.50% respectively. Amylose and amylopectin content ranged from 16.10-31.46% and 68.54-83.90%, respectively in the starches, the general low content of amylose in the starches. Carotenoid content ranged from 3.15-6.93µg/g, large variation in total carotenoid content observed among the starches was a reflection of the wide spectrum of the colour of flesh of the yellow yam tubers.*

***Conclusion**: Carotenoid content, functional properties of the starches and sensory attributes of the custard differ significantly ($p<0.05$). The values for turbidity of starch paste increased progressively during storage and this can be attributed to the interaction between leached amylose and amylopectin chains that led to development of function zones, which reflect or scatter a significant amount of light.*

**Keywords:** Custard, Yellow Yam Starches, Carotenoid, Turbidity

## INTRODUCTION

Yam (*Dioscorea spp.*) is a common edible staple food rich in carbohydrate, it is extensively grown in the tropical and subtropical region of the world where it serves as an important source of energy, nutrients and fibre. Yams (*Dioscorea spp.)* are important in household food security and income generation, especially in West and Central Africa where most of the world production occurs[1] Yellow yam (*Dioscorea cayenensis*), obtained its common name from yellow fleshed yam tuber which is as a result of the presence of a yellow pigment (carotenoid). Starch is the main component of yam and thus, provides large proportion of daily caloric intake. The value of the yam as a basic food has been attributed to the high digestibility of its starch, which is present in the form of small granules. Since yam tubers contain about 70–82% starch, the cooking and processing characteristics of yams, the eating and storage quality of yam-containing products, and perhaps the physiological effectiveness of the bioactive ingredients involved will be greatly dependent on the starch properties.

Starch, the food reserve homo-polysaccharide of plants, is a biocompatible, biodegradable, nontoxic polymer, [2] which occurs widely in nature and most commonly used with a host of advantages. It is widely used in food, paper-making, fine chemicals, packing materials, pharmaceuticals, rubber and plastic industries [3]. Generally, root and tuber starches have unique physicochemical properties mostly due to their amylose and amylopectin ratio [4]. The viscosity of starch paste is an important physical characteristic that determines its potential use in various foods. Likewise, pasting properties indicate what physical changes may be expected during the processing of starchy foods. The most important aspect of yam starches is the influence of the properties of starch on the texture and rheology or flow characteristics of food yams [4], and is of importance in relation to processing characteristics.Corn starch is a valuable ingredient to the food industry, being widely used as a thickener, gelling agent, bulking agent and water retention agent [5].Custard is a fine textured food product made from corn starch in which salt, flavoring and coloring agents are added with or without the addition of egg yolk solids, vitamins and minerals. It is primarily consumed as breakfast or weaning food in most developing nations of the tropics especially among children. However, there is need to harness other sources of starch in the making of custard in order to complement the growing human population and increasing demand for high caloric intake in the diet. In recent years, more and more attention has been paid on the activity and extraction process of the active substances contained in yam [6]. Therefore, the objective of this study was to assess physicochemical and functional properties of starches isolated from two varieties of yellow yam spp (*Dioscoreacayenensis)* and also to evaluate the sensory attributes of custard made from it.

## MATERIALS AND METHODS

**Source of Materials:** Two varieties of *D. cayenensis*and a commercial corn starch (Fincap corn flour) were used in all the experiments. The yam varieties (TDC 2812 and TDC 2790) were obtained from the yam breeding programme at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Tubers from representative varieties of *D. cayenensis* were selected by simple randomization procedure from bulk of freshly harvested tubers. All other materials like commercial custard (Unique custard powder), coloring and flavoring were purchased from a local market in Abeokuta and all reagents and equipment used were collected from the Department of Food Science and Technology, FUNAAB.

## METHODS

### Physical attributes of yellow yam

The physical attributes of the tubers were checked to determine the smoothness and presence or absence of dents. The weights were measured using a very precise and sensitive weighing balance and the actual weight was determined by subtracting the value of the peeled from that of the yellow yam before peeling.

### Starch extraction

Starch extraction was done by disruption of yam tissue to expose the starch. Each yam sample for starch extraction was peeled under water to prevent browning reaction and cleaned of adhering soil particles. The tubers were later washed and soaked in 0.1M concentration of Potassium meta- bisulphite for 30min to prevent browning and then grated to produce yam slurry. The resultant slurry was placed in a muslin cloth and lowered into distilled water (DW) inside a bucket. The cloth was held at the mouth and the contents were continuously squeezed to sieve out the starch into the water [7]. The starch was allowed to settle and the supernatant decanted.Further stirring of the starch with distilled water, settling of the starch granules and decantation of the supernatant was done to remove all soluble impurities. This process was repeated till the supernatant was as clear as possible. The wet starch was spread out on trays and allowed to dry at 65°C in a cabinet drier for 24h [8]. The starch was then milled into very fine particle size by a hammer mill, and kept in zip-lock bags in closed plastic containers for analyses.

### Yellow yam starch yield

Starch yield was derived using the calculation below

$$\text{Starch yield (\%)} = \frac{weight\ of\ starch\ (g)}{weight\ of\ edible\ portion} \times 100$$

Determination of Physicochemical Properties

Proximate analysis of yellow yam starch

The moisture, protein, fat, ash and fibre contents of each of the custard formulations was determined in triplicates according to standard procedures [9]. The carbohydrate was determined by difference.

**pH determination**

Two grams of the starches was weighed and mixed with 20ml of distilled water to obtain slurry. The pH was then determined using a calibrated pH meter by inserting the pH probe into the slurry.

**Amylose content determination**

Amylose content was determined by weighing approximately 0.1 g (100 mg) of the starch samples into a 100 ml volumetric flask and 1 ml of 99.7 to 100 % (v/v) ethanol and 9 ml of 1N-sodium hydroxide (NaOH) was carefully added and the mouth of the flask was covered with foil and the content was mixed well. The sample was heated for 10 min in a boiling water bath to gelatinize the starch (the timing starts when boiling begins). The samples were removed from the water bath and allowed to cool very well. It was then filled up to the mark with distilled water and shaken well. About 5 ml of the mixture was pipetted into another 100 ml volumetric flask. Acetic acid (1 N, 1.0 ml) and 2 ml of iodine solution were added, and top to mark with distilled water. Absorbance (A) was read using spectrophotometer at 620 nm wavelength. The blank containing 1 ml of ethanol, 9 ml of sodium hydroxide, was boiled and top up to the mark with distilled water. 5 ml was pipetted into a 100 ml volumetric flask. Approximately, 1 ml of 1N acetic acid and 2 ml of iodine solution was added and then filled up to the mark, this was used to standardize the spectrophotometer at 620 nm[10,11]. The amylose content was calculated as:

Amylose content (%) = (3.06) x (A) x (20)

= 61.20 x (A)

Where, A = Absorbance value.

Amylopectin (%) = 100 - Amylose content

**Determination of Color parameters**

Color parameters (L*, a*, and b*) were measured using a colorimeter (Chroma Meter CR-400/410) [12]. The equipment was standardized each time with a white and black ceramic plate. Samples were scanned at five different locations to determine lightness (L*), redness (a*) and yellowness (b*) parameters. Reported values were the average of three determinations.

**Determination of Carotenoid content**

Carotenoid content was determined by mixing 6g of the sample with about 5g of hyflosupercel (celite, a filtration aid) and 15ml of 70% methanol (v/v), and filtered through a Buchner funnel with filter paper. The residue was extracted two more times with 15ml acetone-petroleum ether 1:1 (v/v). The extracts were then transferred to 500ml separatory funnel. About 5ml of 10% KOH in methanol (v/v) was added and the mixture allowed standing for 90min. Partition was achieved by adding 15ml of petroleum ether and 20ml of 20% NaCl (w/v), and mixed gently. The hypophasic (lower) layer was discarded, the epiphasic (upper) layer was washed three times with 20ml of distilled water to remove excess acetone, filtered through a small funnel containing 3g anhydrous sodium sulphate to remove residual water. The funnel was plugged with glass stopper to hold sodium sulphate. The filtrate was made up to 100ml with petroleum ether and the absorbance was measured at 450nm, the wavelength of maximum absorption for β-carotene in petroleum ether [13]. The total carotenoids were expressed as β-carotene equivalents (μg/100g) of fresh weight.

Total carotenoids content (μg/g) $= \frac{A \times V(mL) \times 10^4}{A_{1cm}^{1\%} \times P(g)}$

Where A = Absorbance;

V = Total extract volume;

P = sample weight;

$A_{1cm}^{1\%}$ = 2592 (β-carotene Extinction Coefficient in petroleum ether).

**Determination of Functional Properties**

**Swelling power and solubility index**

The swelling power was determined 1.0 g of the dried starch sample was weighed into a pre-weighed graduated centrifuge tube appropriately labeled. Exactly 10ml of distilled water was added to the weighed starch sample, the solution was stirred and transferred into a water bath and heated for 1 h at 90°C with constant stirring. The samples were cooled to room temperature under running water and centrifuged at 3000 rpm for 15 min. The supernatant was carefully decanted into a pre weighed petri-dish and dried at 105°C for 1 h [14]. The centrifuge tube containing the

gel was weighed.
The swelling power and solubility index was calculated as:

$$Swelling\ power\ (g/g) = \frac{Weight\ of\ the\ wet\ mass\ of s\ ediment}{Weight\ of\ sample}$$

$$Solubility\ index\ (\%) = \frac{Weight\ of\ soluble}{Weight\ of\ sample} \times 100$$

**Water Binding Capacity**
Water binding capacity was derived using the modified method cited. About 1g of the samples (starches) was suspended in 10 ml distilled water in a centrifuge tube, stirred for 30 min intermittently and then centrifuged at 3000 rpm for 10 min. The supernatant was decanted and the weight of the gel formed was recorded [15]. The water binding capacity (WBC) was calculated as gel weight per gram dry sample:

$$WBC(\%) = \frac{Gram\ of\ boundwater}{Weight\ of\ sample(g)} \times 100$$

**Water Absorption Capacity (WAC)**
One gram sample was mixed with 10 ml distilled water and stirred occasionally for one hour in previously weighed centrifuge tube. The dispersion was centrifuged at 1500 rpm for 30 min. The supernatant was decanted and the tube was weighed after removal of the adhering drops of water. The weight of water (g) retained in the sample was reported as WAC [16].

**Oil Absorption Capacity (OAC)**
One gram of sample was mixed with 10 ml oil and stirred occasionally for one hour in previously weighed centrifuge tube. The dispersion was centrifuged at 1500 rpm for 30 min. The supernatant was decanted and the tube was weighed after removal of the adhering drops of oil. The weight of oil (g) retained in the sample was reported as the OAC [17].

**Pasting Properties**
Pasting characteristics was determined with a Rapid ViscoAnalyser. A 3g sample (starch) was dissolved in 25 ml of water in a sample canister. The sample was thoroughly mixed and fitted into the RVA as recommended [18]. The slurry was heated from 50 to 95°C with a holding time of 2 min which will be followed by cooling to 50°C with another 2 min holding time. The 12min profile was used and the rate of heating and cooling was at a constant rate of 11.25°C/min. Corresponding values for peak viscosity, trough, breakdown, final viscosity, setback, peak time and pasting temperature from the pasting profile was read from a computer connected to the RVA.

**Dispersibility**
This was determined by measuring 10g of starch, which was suspended in 100ml measuring cylinder and distilled water was added to reach a volume of 100ml. The set-up was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percent dispersibility [19].

**Bulk density**
The bulk density (BD) was determined by placing 10gof sample in a graduated cylinder (50 ml) and packed by gently tapping the cylinder on the bench top (10 times) to form a reasonable height. The volume of sample was recorded. BD was expressed as grams material per milliliter [20].

**Least Gelation Concentration**
Least gelation concentration of the sample was measured with slight modification. Appropriate sample suspensions of 2, 4, 6, 8 and 10% was prepared in 10 ml of distilled water. The test tubes containing these suspensions were heated for one hour in a boiling water bath followed by rapid cooling under running cold tap water. The test tubes were further cooled for 2 hours at 4°C. The least gelation concentration was determined as that concentration which did not fall down or slip when the test tube was inverted [21].

**Gelatinization Temperature**
One gram of the sample was weighed into 100 ml beaker. Hundred milliliters of distilled water was added (1% aqueous solution) and placed on heater. After gelatinization the temperature was measured using thermometer.

**Turbidity**
One percent aqueous suspension of the starch sample was heated in a water bath at 90 °C for 1 h with constant stirring. The suspension was cooled for 1hr at 30°C. The samples were stored for five days at 4°C in a refrigerator and turbidity

was determined every 24 h by measuring the absorbance at 640nm against a water blank with Spectrophotometer. The absorbance measured was interpreted as turbidity [22].

**Preparation of Custard**

Colour additive (egg yellow, 0.13 g), 0.13g flavor additive (vanilla) and little salt was added to 50g starch and thoroughly mixed in a mixer for 10 min [23].Thereafter, the custard powder produced was individually packaged in sealed polyethylene bags and kept at room temperature until the time of usage.

**Sensory Evaluation**

The custard from 100% corn starch and yellow yam starch were prepared into different samples of gruel with boiling water. During preparation, 20g of each of the samples was suspended with 100ml of distilled water in a small plastic bowl. Thereafter, 80ml of boiling water was added to each of the suspended sample to produce hot gruel. The samples of gruel produced was scored by a panel of forty-five untrained panellists drawn from the University for attributes of taste, color, flavor, consistency, mouth-feel and general acceptability using a 9-point Hedonic scale where 1 = dislike extremely and 9 = like extremely [24]

**Statistical Analysis**

The means and standard deviations of all the analyses were calculated. The results were subjected to analysis of variance to detect significant ($p<0.05$) differences among the sample values. The Duncan Multiple-Range Test was used in separating significant mean.

**RESULTS AND DISCUSSIONS**

**Physical attributes of the yellow yam tubers**

The yam tubers were relatively smooth and no presence of dent was seen in all the tubers used, the body of the *D. cayenensis* tubers is cylindrical, extending from the isthmus and widening down at the basal region to the distal nodal region and the head of the variety TDC2790 is small while that of TDC2812 is big. The actual weight of the varieties TDC2790 and TDC2812 were 5.8kg and 4.2kg respectively.

**Starch yield**

The percentage starch yield obtained from the two varieties of yellow yam TDC2790 and TDC2812 are 18.97% and 12.50%, respectively.

**Physicochemical properties of the starches**

The physicochemical properties of the starches of yellow yam (*D. cayenensis*) varieties and cornstarch are shown in Table 1. Amylose-amylopectin ratio is one of the parameters reported to contribute to good textural attributes of root and tuber crops [24]. The amylose content of the starches ranged from 16.10-31.46%, cornstarch had the lowest value and the yellow yam variety TDC 2812 had the highest value. The general low content of amylose in the starches indicated that when these starches are incorporated into food products, swelling of starch will be enhanced [25]. Starch granules with low amylose content are less rigid and swell freely when heated while those with higher amylose content, on the other hand, being better reinforced and thus more rigid, possibly swells less freely. Starch paste behavior in aqueous system depend on the physical and chemical characteristics of the starch granules, such as mean granule size, granule size distribution, amylose/amylopectin ratio and mineral content [26].Viscosity, shear resistance, gelatinization, textures, solubility, tackiness, gel stability, cold swelling and retrogradation are all functions of the starch amylose/amylopectin ratio. Shimelis and Rakshit[27] also stated that as the amylose content increased, the swelling tends to be restricted and the hot paste viscosity stabilizes. Moreover, high amylose contents are desired in starches that are to be used for the manufacture of extrudates [28] The amylopectin confers tighter structure that should normally present less cohesive effect in D. *cayenensis*. There was a significant difference between the amylopectin content ($p<0.05$) of the starches which ranged from 68.54-83.90%. The pH of the starches showed a significant ($p<0.05$) difference and ranged from 5.47-6.71, cornstarch had the least and yellow yam variety TDC 2812 had the highest value. pH which is the measure of the degree of the alkalinity or acidity is an essential measurement of the eating quality since it contributes to taste. High pH starches have been found to have increased solubility; this is due to increased hydrophilic characters of the starch at these pH values [29]. On the other hand, pH values of between 5 and 7 are said to generally stimulate retrogradation. This is because salts of monovalent anions and cations, which have been found to retard retrogradation, are generally absent.

**Table 1: Physicochemical properties of the yellow yam starches and corn starch**

| Sample | %Amylose | %Amylopectin | pH | Carotenoid(μg/g) |
|---|---|---|---|---|
| **TDC 2790** | 21.46±0.07[b] | 78.54±0.07[b] | 6.35±0.03[b] | 4.71±0.19[b] |
| **TDC 2812** | 31.46±0.12[c] | 68.54±0.12[a] | 6.71±0.02[c] | 6.93±0.05[c] |
| **CORNS** | 16.10±0.06[a] | 83.90±0.06[c] | 5.47±0.03[a] | 3.15±0.05[a] |

Values are means of triplicate samples. Mean in the same column with different superscript are significantly different from each other at $p<0.05$.

There are significant differences ($p<0.05$) observedfor carotenoid content and values ranged between 3.15 and 6.93μg/g. Cornstarch had the lowest value of 3.15μg/g followed by the yellow yam variety TDC 2790 with a value of 4.71μg/g while the variety TDC 2812 had the highest value of 6.93μg/g. The yellow coloured tubers of yam generally do contain useful amounts of carotene or pro-vitamin A. Carotenoids contribute significantly to the body's total potential vitamin A intake Carotenoids are easily oxidized because of the large number of conjugated double bonds in the compounds. Large variation in total carotenoid content observed among the starches was a reflection of the wide spectrum of the colour of flesh of the yellow yam tubers. These results agree with earlier conclusion that carotenoids, especially β-carotene are largely responsible for the yellow or orange-fleshed colour in *Dioscoreacayenensis*. The RDA for vitamin A is 800 – 1000 μg retinol equivalent (RE)/day for adults, whereas children and infants require 500μg RE/day (RDA, 2008). Low et al [30] suggested that cultivars having more than 100 μg retinol equivalent (RE) per 100 g fresh roots were good sources of vitamin A. TDC2812 had the highest carotenoid content among the starches and can be said to be good sources of this micronutrient.

**Proximate composition of the starches**

The proximate composition of the yellow yam starches and cornstarch are shown in Table 2. The moisture content varied significantly at $p<0.05$ and ranged from 9.58-12.55%, cornstarch had the lowest value of 9.58 while yellow yam variety TDC 2790 had the highest value of 12.55. Good quality starch should have moisture content in the range of 10-13.5% to ensure better shelf life [31], the moisture content of the yellow yam starches falls within this range while that of the cornstarch falls below which may be probably due to a longer drying period of the starch. Hence, drying periods can be monitored and regulated to ensure that moisture content of these starches fall within the acceptable range. The protein content of the starches was significantly($p<0.05$) different from each other ranging from 1.01 to 1.46%, yellow yam variety TDC 2790 had the lowest (1.01%) and yellow yam variety TDC 2812 had the highest (1.46%). In general the process used in this study showed that the protein content for all the starches tested was higher than those that have been reported in literature i.e.: 0.10-0.5% for yam starch [32]. Low protein contents in starch is an indication of a high level of purity because a low protein content is an indication of absence of endosperm protein which could affect the purity and crystallinity of the starch and as a result could adversely affect the physicochemical properties of the starches according toTester and Morrison [25].

**Table 2: Proximate composition of starches from Yellow yam varieties and cornstarch**

| Samples | %Moisture | %Protein | %Ash | %Fat | %Fibre | Total CHO |
|---|---|---|---|---|---|---|
| **TDC 2790** | 12.55±0.06[c] | 1.01±0.25[a] | 0.01±0.00[a] | 4.14±0.42[a] | 0.00 | 82.26±0.58[a] |
| **TDC 2812** | 12.14±0.06[b] | 1.46±0.13[b] | 0.02±0.00[a] | 3.92±0.26[a] | 0.00 | 82.46±0.15[a] |
| **CORNST** | 9.58±0.08[a] | 1.17±0.24[ab] | 0.11±0.01[b] | 3.75±0.26[a] | 0.00 | 85.38±0.43[b] |

Values are means of triplicate samples. Mean in the same column with different superscript are significantly different from each other at $p<0.05$.

The ash content ranged from 0.01 to 0.11. Crop difference may account for the differences in ash contents. Ash content of less than or equal to 0.20% is an indication of good quality starch and it was seen that the values recorded fall within this range. The fat content of the starches showed no significant difference ($p<0.05$) and the values ranged from 3.75-4.14%, cornstarch had the lowest value while yellow yam variety TDC2790 had the highest. There was no trace of fibre in the starches and this may be due to the removal of the outer layers and this also indicates a good digestibility of the starches. The total carbohydrate of the starches ranged from 82.26-85.38% which showed a significant difference between the yellow yam starches and the cornstarch ($p<0.05$). This result may be due to the high moisture and fat content in the yellow yam starches.

**Color Parameters of the starches**

The mean values of colour parameters are presented in Table 3. Significant difference ($p<0.05$) was observed in the color of the samples. Color is an important factor or attribute considered as far as appearance and consumer acceptability of a product is concerned. The value for lightness ranged from 82.44-93.78%, TDC2812 starch had the lowest value and yellow yam variety TDC2790 had the highest value, although there was no significant difference between the starch of TDC2812 and cornstarch. The value for the redness ranged from -1.23 to 1.69, cornstarch had the lowest value of -1.23 and the yellow yam variety TDC2812 had the highest value of 1.69, significant difference ($p<0.05$) was observed between the redness of all the starches. The value for the yellowness ranged from 4.30 - 10.46, starch of the yellow yam variety TDC2790 had the lowest value of 4.30 and variety TDC2812 had the highest value of 10.46, significant difference ($p<0.05$) was also observed within the values.

**Functional properties of the starches**

The results of the functional properties of the starches are presented in Table 4. Swelling power and solubility index provide evidence of the magnitude of interaction between starch chains within the amorphous and crystalline domains and also evidence of association bonding within the granules of the starches [33], a high swelling index indicates low associative forces between the granules of the starch. The swelling power of the starches showed a significant ($p<0.05$) difference between the yellow yam starches and cornstarch. TDC2812 starch recorded the highest value of 7.15g/g followed by variety TDC2790 with a value of 7.13g/g and the lowest being cornstarch with a value of 5.82g/g. These results indicated that starch of yellow yam TDC2812 may have the lowest associative force and cornstarch may have the highest associative force. High solubility indices in starches could be attributed to the easy breakdown of the linear fraction (amylose) which is released or leached out during the swelling process. The solubility indices of the starches differ significantly ($p<0.05$) which showed that TDC2790 had the highest value of 3.25% followed by TDC2812 with value of 2.48% and cornstarch had the lowest value of 1.73%. Water absorption capacity (WAC) is a very important property of all flours and starches used in food preparations, it is a useful indication of whether flours or starches can be incorporated into aqueous food formulations especially those involving dough handling where an increase in unit yield is desirable. It also indicates the gelling capacity of the starch and also very important in the texture of food systems. The WAC of TDC2790 and cornstarch differ significantly at $p<0.05$ from that of TDC2812. Starch of yellow yam TDC2812 had the highest value of 0.83ml/g followed by TDC2790 with a value of 0.61ml/g while cornstarch had the between the starches of the two yellow yam varieties but a significant difference at $p<0.05$ was recorded between

**Table 3: Color Parameters of starch from Yellow yam varieties and cornstarch**

| Samples | Lightness(L*) | Redness (a*) | Yellowness (b*) |
|---|---|---|---|
| **TDC 2790** | $93.78\pm0.00^{b}$ | $0.26\pm0.00^{b}$ | $4.30\pm0.01^{a}$ |
| **TDC 2812** | $82.44\pm0.01^{a}$ | $1.69\pm0.00^{c}$ | $10.46\pm0.01^{c}$ |
| **CORNSTARCH** | $82.68\pm4.61^{a}$ | $-1.23\pm0.12^{a}$ | $5.18\pm0.74^{b}$ |

Values are means of triplicate samples. Mean in the same column with different superscript are significantly different from each other at $p<0.05$.

**Table 4: Functional properties of starch from Yellow yam varieties and cornstarch**

| Samples | SP (g/g) | WAC (ml/g) | OAC (ml/g) | BD (g/ml) | %SI | %WBC | GT(°C) | %DISP |
|---|---|---|---|---|---|---|---|---|
| **TDC 2790** | 7.13±0.39$^{b}$ | 0.61±0.05$^{a}$ | 0.51±0.02$^{a}$ | 0.85±0.02$^{b}$ | 3.25±0.87$^{b}$ | 164.73±0.84$^{b}$ | 79.33±1.15$^{b}$ | 81.00±1.73$^{a}$ |
| **TDC 2812** | 7.15±0.33$^{b}$ | 0.83±0.14$^{b}$ | 0.56±0.03$^{a}$ | 0.83±0.00$^{b}$ | 2.48±0.52$^{ab}$ | 174.78±1.92$^{c}$ | 78.67±1.15$^{b}$ | 79.33±0.58$^{a}$ |
| **CORNS** | 5.82±0.39$^{a}$ | 0.56±0.03$^{a}$ | 0.76±0.03$^{b}$ | 0.65±0.00$^{a}$ | 1.73±0.23$^{a}$ | 150.40±0.70$^{a}$ | 71.33±1.15$^{a}$ | 85.33±1.15$^{b}$ |

Values are means of triplicate samples. Mean in the same column with different superscript are significantly different from each other at p<0.05SP-Swelling power, WAC-Water absorption capacity, OAC-Oil absorption Capacity, BD-Bulk density, SI-Solubility index, WBC-Water binding capacity, GT- Gelatinization temperature, DISP- Dispersibility

them and cornstarch. TDC2790 had the lowest value of 0.51ml/g followed by variety TDC2812 with a value of 0.56ml/g while cornstarch had the highest value of 0.76ml/g and this could probably be due to elimination of fibre and reduction of protein during the isolation of the starches [23]. The bulk density of the starches ranged from 0.65g/ml to 0.85g/ml, there was a significant difference (p<0.05) between the yellow yam varieties and cornstarch, variety TDC2790 had the highest value of 0.85 followed by variety TDC2812 which had a value of 0.83 and cornstarch had a lower value of 0.65 compared to the others. However, low bulk density is a desirable character when powdered foodstuffs are to be packed in a limited space and in addition materials with high bulk density also find use where they can be incorporated into light snack foods [34]. The water binding capacity (WBC) of the starches was significantly (p<0.05) different. The values are 164.73%, 174.78% and 150.40% for variety TDC2790, TDC2812 and cornstarch respectively. The high value of water binding capacity of variety TDC2812 could be attributed to the loose association of starch polymer, amylose and amylopectin in the native granules [35].WBC is important in texture and quality of some foods since they stabilize starches against effects such as syneresis, which sometimes occur during retorting and freezing [31]. These results indicated that the starch of yellow yam variety TDC2812 had the highest water binding capacity and thus, may be better for use in products that require high unit yield. The gelatinization temperature of the starches ranged from 71.33°C to 79.33°C. The result showed a significant difference at p<0.05 between the yellow yam starches and cornstarch although, there was no significant difference between the two yellow yam starches. The gelatinization temperature obtained was considerably higher than for wheat starch (55.6 to 63.0°C). Dispersibility is a measure of reconstitution of flour, flour blends or starch in water, the higher the dispersibility the better the flour reconstitute in water [19]. There was no significant difference between the values for the yellow yam starches but a significant difference at p<0.05 was recorded between the yellow yam starches and cornstarch. The values for the dispersibility are 81.00%, 79.33% and 85.33% for yellow yam variety TDC 2790, TDC2812 and cornstarch respectively.

The turbidity values of the starch paste increased progressively during storage as shown in Figure 1. There was no significant difference between the turbidity of the starches in day1 but as the days increased observable significant differences existed between the cornstarch and the yellow yam starches although no significant differences existed between the two varieties of the yellow yam. The increase in turbidity during storage can be attributed to the interaction between leached amylose and amylopectin chains that led to development of function zones, which reflect or scatter a significant amount of light [22]. Turbidity development in starch pastes during storage have been reported to be affected by factors such as granule swelling, granule remnants, leached amylose and amylopectin, amylose and amylopectin chain lengths, intra- or intermolecular bonding, lipid and cross-linking substitution [36].

The least gelation concentration of the starches is shown in Figure 2. The least gelation concentration is the concentration at which the starch will form a strong gel that will not slip. At 2% concentration, variety TDC2790 and TDC2812 formed no gel while cornstarch formed a weaker gel. At 4% concentration, variety TDC2790 and TDC2812 formed a weaker gel compared to cornstarch which formed a weak gel. At 6% concentration, variety TDC2790 and TDC2812 formed a weak gel compared to cornstarch which formed a strong gel. At 8% concentration, variety TDC2790 and TDC2812 formed a strong gel compared to cornstarch which formed a stronger gel. At 10%

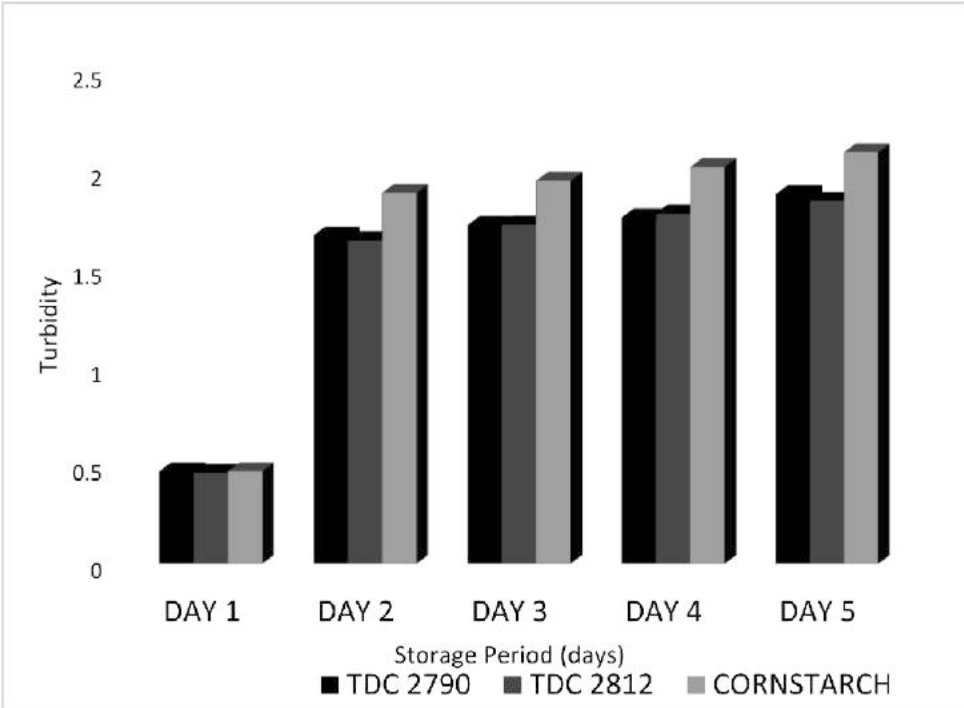
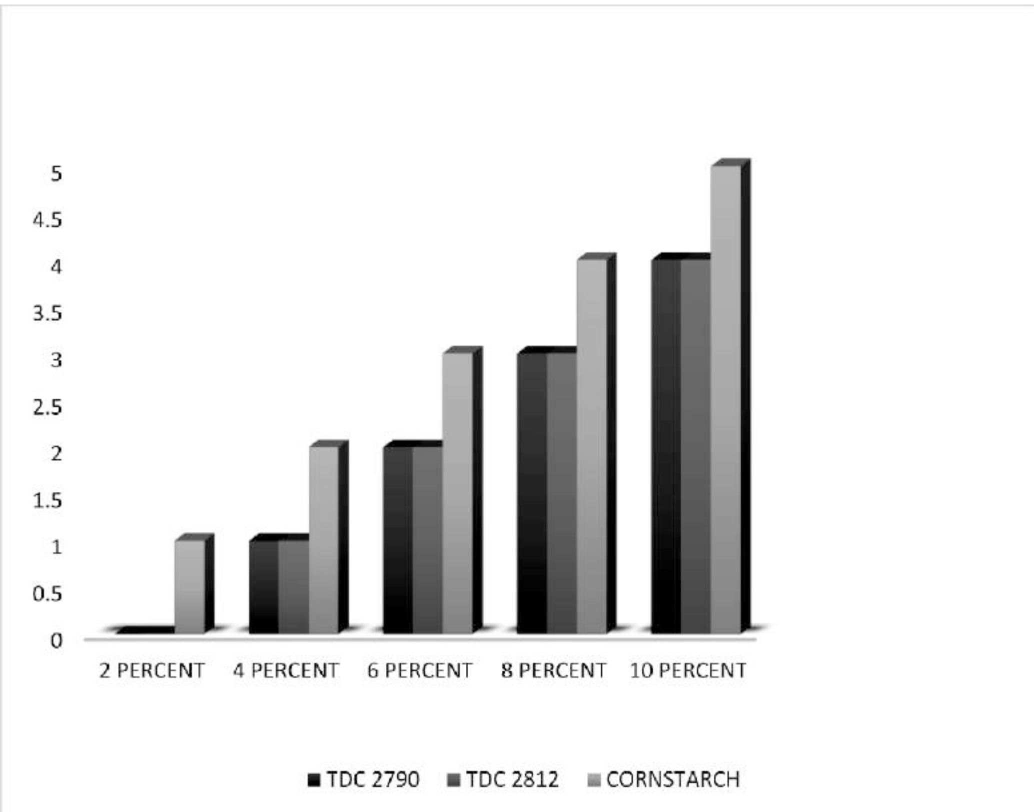



**Figure 1: Effect of storage period on the turbidity of the starches**




0 = no gel;1 = weaker gel;2 = weak gel; 3 = strong gel;4 = stronger gel; 5 = strongest gel

**Figure 2: Least gelation concentration of the starches (g starch/100ml of water)**

concentration, variety TDC2790 and TDC2812 formed a stronger gel compared to cornstarch which formed the strongest gel. The results obtained showed that at 8% concentration, starch of the yellow yam varieties formed a gel which did not slip and that of cornstarch was at 6% concentration.

**Pasting properties of the starches**

The mean values of pasting properties of the starches are presented in Table 5. Peak viscosity is a measure of the ability of starch to form a paste, it is also the ability of starch to swell freely before their physical breakdown. It has been reported to be closely associated with the degree of starch damage. According to Sanni*et al*[37], high starch damage results in high peak viscosity. Peak viscosities of the starches varied significantly ($p<0.05$). Yellow yam variety TDC2812 starch had the highest peak viscosity of 452.75RVU while cornstarch had the lowest of 241.71RVU. The high peak viscosity observed in variety TDC2812 implied that it may be suitable for products requiring high gel strength, thick paste and elasticity in pounded yam. High peak viscosity is an indication of high starch content, the difference in peak viscosities may be due to differences in starch contents. The results obtained in this study for the yellow yam varieties is higher compared to that obtained for *Dioscoreaalata*[38]. The trough viscosity value ranged from 182.21 to 315.71RVU, variety TDC2812 had the highest value and cornstarch had the lowest value. No significant difference was observed between the two varieties of the yellow yam but a significant difference existed between them and that of the cornstarch. Breakdown viscosity is an estimation of paste resistance to disintegration in response to heat and shear, lower breakdown viscosity showed greater resistance which would be expected of starches with lower peak viscosities. However, this is not always observed as breakdown viscosity depends on the amount of materials released into the paste. The rate of starch breakdown depends on the nature of the material, the temperature and the degree of mixing and shear applied to the mixture. Higher breakdown viscosity showed lower ability of the sample to withstand heating and shear stress during cooking [29]. Significant differences existed in breakdown viscosities of the starches. Cornstarch and yellow yam variety TDC2812 have the lowest (59.5RVU) and highest (137.05RVU) breakdown viscosities respectively. From this study, starch of yellow yam variety TDC2812 had the highest ability to withstand heating and shear stress during cooking. Final viscosity is used to define the particular quality of starch and indicate the stability of the cooked paste when in actual use; it also indicates the ability to form a various paste or gel after cooling and less stability of starch paste is commonly accompanied with high value of breakdown [35]. No significant difference was observed between the starches of the two yellow yam varieties but a significant difference existed between them and cornstarch. The values ranged from 287RVU to 517.17RVU and variety TDC2790 had the highest value and cornstarch the lowest value. Setback is mainly attributed to some degree of re-ordering of leached amylose, which is often termed short-term retrogradation. It has been reported that a high setback value is associated with a cohesive paste while a low value is an indication of a non-cohesive paste. No significant difference was observed in the yam starches but a significant difference existed between them and that of cornstarch at $p<0.05$. Setback values ranged from 104.79RVU for cornstarch to 208.04RVU for variety TDC2790. The higher the setback value, the lower the retrogradation during cooling and the lower the stailing rate of the products made from the starch [39]

**Table 5: Pasting properties of starches from Yellow yam varieties and cornstarch**

| SAMPLE | Peak (RVU) | Trough (RVU) | Breakdown (RVU) | Final (RVU) | Setback (RVU) | Peaktime (Min) | Pastingtemp (°C) |
|---|---|---|---|---|---|---|---|
| TDC 2790 | $417.29\pm4.65^b$ | $309.13\pm1.35^b$ | $108.17\pm3.30^b$ | $517.17\pm9.90^b$ | $208.04\pm11.26^b$ | $5.2\pm0.10^b$ | $78.63\pm0.60^b$ |
| TDC 2812 | $452.75\pm4.00^c$ | $315.71\pm9.49^b$ | $137.05\pm5.48^c$ | $501.50\pm12.49^b$ | $185.80\pm3.01^b$ | $4.8\pm0.10^a$ | $78.25\pm0.00^b$ |
| CORNS | $241.71\pm7.01^a$ | $182.21\pm3.71^a$ | $59.50\pm3.30^a$ | $287.00\pm0.59^a$ | $104.79\pm4.30^a$ | $5.27\pm0.00^b$ | $76.68\pm0.11^a$ |

Values are means of duplicate samples. Mean in the same column with different superscript are significantly different from each other at $p<0.05$.

Low setback values are useful for products like weaning foods, which require low viscosity and paste. Temperature is one of the pasting properties which provide an indication of the minimum temperature required for sample cooking, energy costs involved and other components stability. The higher pasting temperature which ranged from 76.68 to 78.63°C for the starches and peak time which ranged from 4.8 to 5.27min indicated higher gelatinization temperature and longer cooking time. This high pasting temperature for the starches indicated their higher resistance towards swelling therefore starches with low pasting temperature and time could have more products development potentials [38].

**Sensory properties of custards made from the starches and a commercial custard.**

The result of the sensory evaluation of the custard made from the starches compared with commercial custard is presented in Table 6. Significant difference ($p<0.05$) was observed among the values obtained. With respect to color, custard from cornstarch had the 16 highest value and the one from yellow yam variety TDC2812 had the least, it was observed that the colour of custard from yellow yam variety TDC2790 was closer to that of the cornstarch. The values obtained for flavor showed no significant difference among the custards of the two yellow yam varieties and cornstarch but a significant difference at $p<0.05$ existed comparing them to the commercial custard. The taste of the commercial custard was observed to be significantly different at $p<0.05$ from that of the two yellow yam varieties but still relatively close to that of the cornstarch. The consistency showed no significant difference between yellow yam TDC2790 and cornstarch but there was a significant difference at $p<0.05$ between the other samples. There was no significant difference in the mouth-feel of the custard from the two yellow yam varieties but comparing it with the commercial custard, a significant difference at $p<0.05$ was observed since the commercial custard had the highest acceptability value. With respect to the general acceptability, there was no significant difference between the custards made from the two varieties of yellow yam but comparing them with that of the commercial custard a significant difference at $p<0.05$ was observed.

## CONCLUSIONS

From the study, the total carbohydrate content of the yellow yam starches are high with no significant difference observed and this supports the fact that carbohydrate made up the bulk of the starches. Usually low amylose content is desired in the manufacture of extrudates therefore, it can be concluded that the yellow yam starches can be of high usage in this production. The low value of swelling power obtained in this study was characterized in the category of high restricted-swelling starch and this characteristic is desirable for the manufacture of custard and other value-added products. There were significant ($p<0.05$) differences between the functional properties of the yellow yam starches and the cornstarch. From the sensory quality evaluation, there was no significant difference between the flavour of the custard of the two yellow yam varieties and the cornstarch, also no significant difference was observed in the consistency of the custard from variety TDC2790 and cornstarch, for the general acceptability of the custard samples, no significant difference was observed between variety TDC2790 and TDC2812. From this study, it can be concluded that the yellow yam custards can compete well with cornstarch custards in the market.

**Table 6: Sensory Properties of Custards made from starches of Yellow yam varieties, cornstarch and a commercial custard**

| SAMPLES | COLOUR | FLAVOUR | TASTE | CONSISTENCY | MOUTHFEEL | GENERALACC |
|---|---|---|---|---|---|---|
| **TDC 2790** | $6.96\pm1.30^{b}$ | $6.53\pm1.56^{a}$ | $6.33\pm1.75^{a}$ | $5.98\pm1.60^{ab}$ | $6.22\pm1.55^{a}$ | $6.38\pm2.09^{a}$ |
| **TDC 2812** | $5.58\pm1.89^{a}$ | $6.16\pm1.40^{a}$ | $6.20\pm1.83^{a}$ | $6.09\pm1.81^{a}$ | $6.18\pm1.76^{a}$ | $6.36\pm1.63^{a}$ |
| **CORNST** | $8.02\pm1.12^{c}$ | $6.67\pm1.51^{a}$ | $6.56\pm1.69^{ab}$ | $6.53\pm1.50^{ab}$ | $6.64\pm1.38^{ab}$ | $7.29\pm1.47^{b}$ |
| **COM.CU** | $7.73\pm0.94^{c}$ | $7.38\pm1.23^{b}$ | $6.96\pm1.00^{b}$ | $7.04\pm1.13^{b}$ | $7.04\pm1.64^{b}$ | $7.20\pm1.82^{b}$ |

Values are means of 45 untrained panelist. Mean in the same column with different superscript are significantly different from each other at $p<0.05$.

**REFERENCES**

1). Zuo, Y. F., and Tang, D. C. (2003). Science of Chinese materiamedica. Shanghai University of Traditional Chinese Medicine Press, Shanghai, China.

2). Weslen, K. B and Weslen, B. (2002). Synthesis of Amphiphilic Amylase and Starch Derivatives. Carbohydrate Polymers, 47: 303-311.

3). Huaiguo, T., Qing, Q., Youping, W., Guohua, L., Liqun, Z. and Jun, M. (2006). Reinforcement of polymer by starch, Macromolecular Materials and Engineering, 291: 629-639.

4). Yen, A., Tzu-Yin, C., George, C. C. (2009). Effect of water content and mucilage on physico-chemical characteristics of Yam (*DiscoreaalataPurpurea*) starch. *J. Food Eng*. 95:106-114.

5).Singh, N., Singh, J., Kaur, L., Sodhi, N. S., Gill, B. S. (2003). Morphological thermal and rheological properties of starches from different botanical sources. Food Chemistry. 81: 219–231.

6). Zhao, G. H., Li, Z. X. and Chen, Z.D. (2003). Structural analysis and antitumor activity of RDPS-I polysaccharide from Chinese yam. *ActaPharmaceuticaSinica*, 38, 37-41.

7). Walter, W. M., Truong, V. D., Wiesenborn, D. P., Carvajal, P. (2001). Rheological and Physicochemical properties of starches from Moist and Dry-type Sweet potatoes. *J. Agric. Food Chem.* 48:2937-2942.

8). Akinwande, B. A., Adeyemi, I. A., Akande, E. O., Ogundipe, O. D. (2004). Effect of substituting flour with yam starch and yam flour on pasting property of composite flour and sensory quality of noodle. NIFST *Proceeding of the 28th Annual Conference*, Ibadan. pp. 257-258.

9). AOAC, (2004). Official Methods of Analysis. Association of Official Analytical Chemists International, Washington D.C., USA.

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

11). Hoover, R., Ratnayake, W. S. (2002). Starch characteristics of black bean, chick pea, lentil, navy bean and pinto bean cultivars grown in Canada. *Food Chem.* 78:489- 498.

12).Krokida, M.K., Oreopoulou, V., Maroulis, Z.B. and Marinos-Kouris, D. (2001b). Colour Changes during Deep-Fat Frying. *Journal of Food Engineering*, 48: 219-225.

13). Chan, H. T. Jr. and Cavaletto C. G. (1982). Aseptically packaged papaya and guava puree: Changes in chemical and sensory quality during processing and storage. *J. Food Sci:,* 47:1164-1174.

14). Hirsch, J. B. and Kokini, J. L. (2002). Understanding the mechanism of cross-linking agents ($POCl_3$, STMP, and EPI) through swelling behavior and pasting properties of cross linked waxy maize starches *Cereal Chemistry*: 79(1): 102-107.

15). Soni, P. L., Sharma, H. W., Dobhal, S. S., Bisen, H. L., Savastva, H., Gharra, M. W. (1985). The Starch of Discoreaballophyll and Amorphophaliuscompanulalus Starch/starke 37:6-9.

16). Lin, C. S. and Zayas, J. F. (1987). Functional of corn germ proteins in a model system: Fat binding capacity and water retention. *J. Food Sci*., 52: 1308.

17). Lin, M. J. Y., Itumbert, E. S. and Soulski, F. W. (1974). Certain functional properties of sun flower meal products. *Food Sci*., 39: 368- 370.

18). Newport Scientific (1998). Applications Manual for the Rapid ViscoTM Analyzer Using Thermocline for Windows. Newport Scientific Pty Ltd., Warriewood, Australia, pp. 2-26.

19). Kulkarni, K. O., Kulkarni, D. N. and Ingle, U. M (1991). Sorghum malt based weaning food formulation preparation, functional properties and Nutritive Value. *Food and Nutrition Bulletin.* 13, (14): 322-327.

20). Waring, C. and Kinsella J. E. (1976). Functional properties of novel proteins Alfalfa leaf protein. *J. Food Sci.,* 41: 286-292.

21). Coffman, W. and Garcia, V. V. (1977). Functional properties and amino acid content of protein isolate from mung bean flour. *J. Food techno*. 12: 473-478.

22). Perera, C. and Hoover, R. (1999). Influence of hydroxypropylation on retrogadation properties of native, defatted and heat-moisture treated potato starches. *Food Chemistry,* 64, 361 – 375.

23). Abdalla, A. A., Umsalam, M. A., Abdelhalim, R.A., El Tinay, A.H. and Khalid, A.I. (2009). Physicochemical characterization of traditionally extracted pearl millet starch (Jir); *Journal of Applied Sciences Research*, 5(11): 2016-2027.

24). Otegbayo, B. O., Achidi, A. U., Asiedu, R., and Bokanga, M. (2001). Food quality attributes of *Ponayams*. *Proceedings of the Eighth Triennial Symposium of the International Society for Tropical Root Crops,* Ibadan, Nigeria.

25). Tester, R. F. and Morrison, W. R. (1990). Swelling and gelatinization of cereal starches. I. Effect of amylopectin, amylose and lipids. *Cereal*

*Chemistry,* 67:551-559.
26). Madsen, M. H., Christensen, D. H. (1996). Changes in viscosity properties of potato starch during growth. Starch, 48: 245–249.
27).Shimelis, A. E., Rakshit, S. K. (2005). Proximate composition and physico-chemical properties of improved haricot bean (Phaseolus vulgaris L.) varieties grown in Ethiopia. *J. Food Sci. Technology* (LWT), 38:331-338.
28). Chevanan, N., Rosentrater, K. A., Muthukumarappan, K. (2008). Effects of processing conditions on feed ingredients containing DDGS in single screw extrusion. *Food Bioprocess Technol*. pp 1-10.
29). Adebowale, K., Owolabi, B., Olayinka, O. and Lawal, O. (2005). Effect of heat-moisture treatment and annealing on physicochemical properties of red sorghum starch. *Afr. J. Biotechnol*. 4: 928-933.
30). Low, J., Kinyae, P., Gichuki, S., Oyunga, M. A., Hagenimana, V., Kabira, J. (1997). Combating vitamin A deficiency through the use of Sweet potato. Results from Phase 1 of an action research project in South Nyanza, Kenya. International Potato Center, Lima, Peru.
31). Ellis, W. O., Oduro, I., Barimah, J. and Otoo, J. A. (2003). Quality of starch from six Japanese sweet potato varieties in Ghana. *African Journal of Root and Tuber Crops,* 5(2): 38-41.
32). Freitas, R. A., Paula, R. C., Feitosa, J. P. A., Rocha, S. and Sierakowski, M. R. (2004). Amylose contents, rheological properties and gelatinisation kinetics of yam (*Dioscoreaalata*) and cassava (*Manihotutilisima*) starches. *Carbohydrate Polymers* 55: 3-8.
33).Ikegwu, O. J., Nwobasi, V. N., Odoh, M. O. and Oledinma, N. U. (2009). Evaluation of the pasting and some functional properties of starch isolated from some improved cassava varieties in Nigeria. *African Journal of Biotechnology,* 8 (10): 2310-2315.
34).Yagoub, A. A., (2003). A biophysical study on rosella (*Hibiscus sabdariffa* L.) seed total proteins of the traditionally fermented furundu. Ph.D. Thesis, University of Khartoum, Sudan.
35). Shimelis, E., Meaza, M. and Rakshit, S., (2006). Physicochemical properties, pasting behaviour and functional characteristics of flours and starches from improved bean (Phaseolus vulgaris L.) varieties grown in East Africa. Agricultural Engineering International. CIGR e-journals, FP 05015. Vol. III.
36). Jacobson, M. R., Obanni, M. and BeMiller, J. N. (1997). Retrogadation of starches from different botanical sources. *Cereal Chemistry* 74: 571 – 578.
37).Sanni, L. O., Ikuomola, D. P. and Sanni, S. A. (2001). Effect of length of fermentation and varieties on the qualities of sweet potato gari. *Proceedings of the Eighth Triennial Symposium of the International Society for Tropical Root Crops,* Ibadan, Nigeria. 12- 16 November, 2001. pp. 208-211.
38). Oke, M. O., Awonorin, S. O. and Workneh, T. S., (2013). Effect of varieties on physicochemical and pasting characteristics of water yam flours and starches. *African Journal of Biotechnology* Vol. 12(11), pp. 1250-1256.
39). Adeyemi, A. A. and Idowu, M. A. (1990). The Evaluation of pre-gelatinize maize flour in the development of Maissa a baked product. *Nigerian Food Journal*. 8: 63-73.