



Investigation on the Quality of Fermented White Yam Flour (Elubo) At Different Drying Temperatures

A.S. Ajala¹ --- T.O. Idowu²

^{1,2}Department of Food Science and Engineering, Ladoko Akintola University of Technology, Ogbomoso, Nigeria

(✉ Corresponding Author)

ABSTRACT

Fermented yam flour called 'elubo' among 'Yorubas' is a product from yam tubers and is one of the most staple foods in West African countries which provide a good source of carbohydrate for people. Knowledge of the anti-nutritional factors and the physicochemical properties of this flour would reduce the detrimental effects on human health and provide information on their end use quality, thereby leading to increased utilization of the flour. In this study, white yam samples were sorted, blanched and dried in the tunnel dryer at a temperature of 50, 60 and 70°C. The samples were then cooled, milled, sieved and packaged. The results for moisture, protein, fat, ash, crude fibre and carbohydrate ranged between (7.32 to 10.74) %, (5.19 to 5.32)%, (3.98 to 4.39)%, (3.02 to 3.78)%, (2.69 to 2.82)%, (73.27 to 75.50)% respectively. The result obtained on swelling power, solubility index, bulk density and water absorption capacity ranged from (4.83-5.21) %, (16.71-16.81)%, (1.01-1.15)g/ml and (143.02-151.50)% respectively. The tannin, saponin and phytate content ranged between (0.37-0.42) %, (2.16-2.80)mg/100g and (52.23 to 58.48)mg/kg respectively. The thermal diffusivity, specific heat capacity, thermal conductivity, energy property also ranged from (2.81-2.95) x10⁷ m²/s, (1.62-1.75) kJ/kgk, (0.17-0.21) W/mK and (1497.91 kJ - 1549.68) kJ respectively. The results showed that drying of 'elubo' at 70°C produced better quality in terms of reduction in moisture content and anti-nutritional factors, high values in functional properties and also high energy values.

Keywords: Fermented yam flour, Anti-Nutritional, Proximate, Functional, Thermal and energy properties.

DOI: 10.20448/803.1.1.1.10

Citation | A.S. Ajala; T.O. Idowu (2016). Investigation on the Quality of Fermented White Yam Flour (ELUBO) At Different Drying Temperatures. Canadian Journal of Agriculture and Crops, 1(1): 1-10.

Copyright: This work is licensed under a [Creative Commons Attribution 3.0 License](https://creativecommons.org/licenses/by/3.0/)

Funding : This study received no specific financial support.

Competing Interests: The authors declare that they have no competing interests.

History : **Received:** 20 May 2016/ **Revised:** 1 June 2016/ **Accepted:** 6 June 2016/ **Published:** 10 June 2016

Publisher: Online Science Publishing

1. INTRODUCTION

Yam is one of the major food crops in Nigeria. The crop is important in household food security, diet diversification, employment and income generation as well as alleviation of poverty [7]. It is ranked as the fourth major root crop in the world after cassava, potatoes and sweet potatoes, with annual production of above 28 million metric tonnes [17]. Nigeria is the world's largest producer of yams, with *D. rotundata* and *D. alata* as the two most cultivated yam species and ranked 2nd after cassava as root crop in the country [7]. The

best food among the 'Yorubas' tribe is pounded yam. This food is gotten from yam. To produce it, yam is peeled and boiled. The boiled yam is put inside mortal and pounded to form thick dough. This dough can be eaten with various soups. Yam is also consumed when boiled with salt; it may also be spiced and boiled to make red porridge. Other tribes grate and boiled it with spices to form 'ikokore'. Other form of eating is by frying to form yam chips. Because, it is a tuber that get spoiled easily if not processed, the traditional preservation methods often used is to convert the yams to fermented yam flour known as 'elubo'. In the olden days, 'elubo' was made only from yam tubers that are partly rotten at the time of harvest, or that for some other reasons are unsuitable for storage. But today, it is a staple food that is available round the year, hence good yam tubers are used for its processing. In this modern time, one or two industries are beginning to produce unfermented_instant pounded yam powder. This powder has been precooked; when it is put in hot water and stirred together, it forms a whitish thick dough as conventional pounded yam. However, these industries are so limited that they cannot process more than 0.1% yam produced annually. This implies that most of the yams are processed into fermented yam flour ('elubo'). This 'elubo' when put into hot water and stirred forms a deep brown gelatinized paste called 'amala'. This 'amala' is widely accepted in South-West Nigeria as a staple food which can be consumed with different kind of soups. Production of fermented yam flour involves peeling and dicing the yams. These yams are blanched in hot water and left for 24 - 48 hours for fermentation to take place. The fermented yams are then spread under the sun for 3-4 days to dry. During this drying operation, insect and rodent invade the products to feed on them. At these points, contamination could occur due to dust, insect and rodents. So the products are susceptible to food contamination and poisoning. The popularity of this flour calls for the critical examination of the food vis-à-vis it's functional and energy properties. Study of this important food will provide adequate information for the consumers who depend largely on its nutritional contents. Therefore, the aim of this work is to examine ('elubo') in terms of its proximate, functional, anti-nutritional content and its thermal properties

2. MATERIALS AND METHODS

(a) Materials

Yam (*Dioscorea rotundata*) tubers were purchased at a local market in Ogbomoso, Oyo state, Nigeria. All other reagents used were of analytical grade.

(b) Methods

The yams were washed with water to remove dirt and soil particles. They were peeled, washed and cut into slices of 2mm thickness. The sliced yams were then blanched in hot water at temperatures of 50°C for about 2 hrs, and then steeped for 24 hours. Decantation of the surface water was done after 24 hrs. They were then rinsed and then dried using tunnel dryer at temperature of 50°C 60°C and 70°C. The dried yam chips were then milled into flour using milling machine and packaged into polythene bags for further analysis. The detail of the production is as presented in Figure 1

(c) Chemical analyses of the samples

(i) Proximate determination of 'elubo' flour

Moisture content, ash, crude protein, crude fat, crude fibre and carbohydrate content analyses were carried out using the [11] method.

(ii) Determination of functional property of 'elubo' flour

The functional analyses namely water absorption capacity, bulk density, swelling power and solubility index of the samples were carried out using the [11] method

(iii) Determination of Anti-nutritional factor of 'elubo' flour

Phytate, saponin and tannin were determined using [11] method

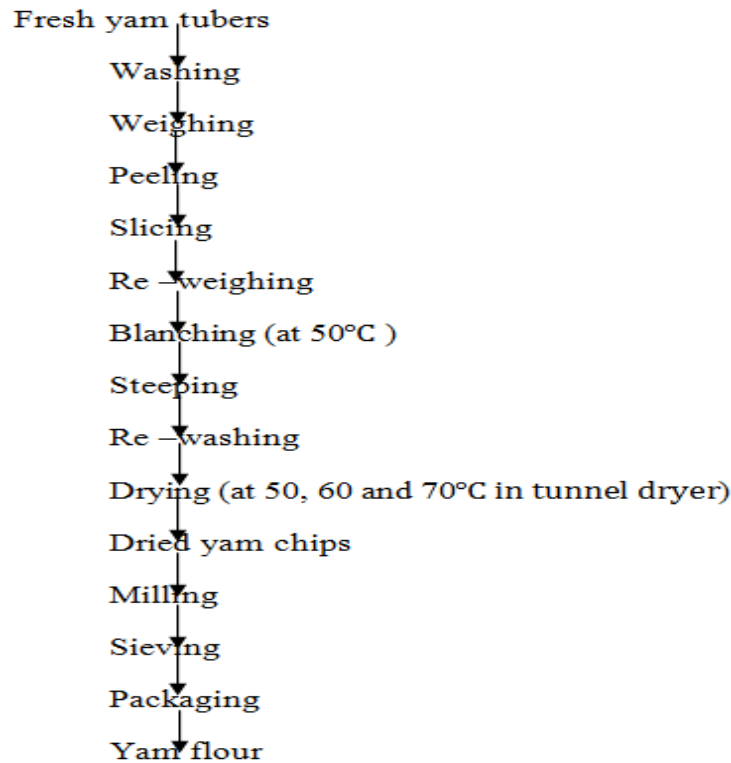


Figure-1. Flowchart of yam flour

Source:[2]-modified

(iv) Determination of Thermal Properties

Thermal diffusivity of the samples was determined using the method below as described by [41] in Equation 1:

$$\varphi = \frac{K}{\rho C_p} \text{ (m}^2\text{/s)} \tag{1}$$

Where φ is thermal diffusivity, K is thermal conductivity, ρ is density and C_p is specific heat capacity.

The specific heat capacities of the samples were obtained from the method of [13] and is as shown in Equation 2

$$C_p = 4.180X_w + 1.711X_p + 1.929X_f + 1.547X_c + 0.908X_a \tag{2}$$

Where C_p is the specific heat capacity in KJ/Kg K and X are the respective mass fractions of water, protein, fat, carbohydrate and ash present in each yam flour sample and obtained from proximate compositions.

Thermal conductivity may be defined as the rate of heat flow through unit thickness of materials per unit area normal to the direction heat flow and per unit time for the unit temperature. The thermal conductivities of the samples were determined using the expression developed by [42] and is as expressed in Equation 3 thus:

$$K = 0.25X_c + 0.155X_p + 0.16X_f + 0.135X_a + 0.58X_w \quad 3 \quad \text{Where}$$

K= is thermal conductivity of sample in $W/M^{\circ}C$

X_c = Carbohydrate, X_p = Protein, X_f = Crude fat, X_a = Ash content, X_w = Moisture content

The energy value of the food sample was calculated using model given by [41] as presented in Equation 4:

$$\text{Energy value (KJ)} = (\% \text{ carbohydrate} \times 17 + \% \text{ protein} \times 17 + \% \text{ fat} \times 37) \quad 4$$

The value was then converted to kilojoules per 100g.

(d) Statistical Analysis

The statistical analysis of each sample was performed using the statistical package for social scientists (SPSS 20.0 versions). The data generated from these investigations were analyzed using analysis of variance (ANOVA) and Duncan multiple range tests was used to separate the means.

3. RESULTS AND DISCUSSION

(a) Proximate Composition of 'Elubo' Flour

The result obtained from the proximate analysis carried out on the 'elubo' flour is as shown in Table 1. The moisture content of each samples ranged from 7.32 to 10.74% and were significantly different from each other at $p < 0.05$. This falls within the maximum level of 14% recommended for flour and flakes, [6] and thus a good index for storage. Sample A has the least moisture content of 7.32% which makes it better than sample B and C for storage, while the moisture content of the sample C was high indicating that the sample were more prone to microbial attack in the course of storage. The lower moisture content of all the samples however indicated that they can be stored favorably for a long period. The value of moisture content for 'elubo' reported in this study was in close range with the value reported by [2].

The protein content results ranged from 5.19 to 5.39% and indicated that there was no significant difference among the sample as shown in Table 1. These values are both significantly higher than 1.53% (1.53g/100g) given as the average protein content of *Dioscorea spp* [43]. This is because during fermentation, some complex carbohydrate molecules have been broken down to form protein. The protein content level in this work were greater than the values reported of 'elubo' by [3] but in close range with the values reported by [1] and [32] but less than the value of 7.73 % reported by [25].

The fat compositions ranged from 3.98 to 4.39% and were not significantly different from each other as shown in Table 1. The values of fat content were higher than the value reported by [3] with value of 2.00% and [33] with 1.5%. Fat serve as energy store in the body. It can be broken down in the body to release glycerol and free fatty acids. The glycerol can be converted to glucose by the liver and used as a source of energy. It has been reported that 1 g of fat provides 37 kcal of energy [18].

The crude fibre composition ranged from 2.69 to 2.82% and was not significantly different from each other. The values compared well with other research findings such as [5]; [25] and [43]. Dietary fibre reduces the risks of cardiovascular diseases. Report have shown that increase in fibre consumption might have contributed to the reduction in the incidence of certain diseases such as diabetes, coronary heart disease, colon cancer and various digestive disorder [23].

The result of the ash content range between 3.02 to 3.78% and sample A and B were not significantly different but sample C was significantly different at $p < 0.05$. This result showed the ash contents value of the samples were higher when compared to 0.6-1.7% reported for cultivated yam species in Nigeria by [35] and 0.94% reported by [25]. They are also higher than 1.84% reported for *Dioscorea rotundata* by [26]. Although the values are lower than those for *Dioscorea alata*, *Dioscorea esculenta* and *rotundanta* as reported by [16]. The reason could be due to difference in varieties of yam used for the 'elubo'. However, the result indicates that the samples could be good sources of nutritionally essential minerals and trace elements.

All the samples have high carbohydrate content values ranging from 73.27 to 75.50%. This is because yams are rich in carbohydrate as other tubers. Samples A and C were significantly difference from each other while sample B was not significantly different. Carbohydrate supplies energy to cells such as brain, muscles and blood. It contribute to fat metabolism and spare proteins as an energy source and act as mild natural laxative for human beings and generally add to the bulk of the diet [22]; [19].

Table-1. Result of proximate composition of Yam flour (%)

Sample	Moisture	Protein	Fat	Fibre	Ash	Carbohydrate
A	7.32 ^a ± 0.01	5.32 ^a ± 0.09	4.29 ^a ± 0.23	2.80 ^a ± 0.31	3.78 ^b ± 0.06	75.50 ^b ± 0.50
B	8.96 ^b ± 0.24	5.39 ^a ± 0.02	4.39 ^a ± 0.02	2.69 ^a ± 0.02	3.60 ^b ± 0.13	73.99 ^{ab} ± 0.35
C	10.74 ^c ± 0.41	5.19 ^a ± 0.22	3.98 ^a ± 0.11	2.82 ^a ± 0.52	3.02 ^a ± 0.05	73.27 ^a ± 0.64

Mean value of different superscript along the same column are significantly different from each other at ($p < 0.05$).

Sample A = Dried at 70°C, Sample B = Dried at 60°C, Sample C = Dried at 50°C

(b) Functional Properties

The values of the swelling capacity of the fermented yam flour are as shown in Table 2. The swelling power ranged from 4.83 to 5.21 (%). There was no significance difference at ($p < 0.05$) between samples A and B but sample C had significant difference when subjected to analysis of variance. These results for swelling power were in agreement with the earlier finding of [24]. From the table, swelling power increased with increase in temperature of drying from 50 to 70 °C. The reason could be that as temperature of drying affected the moisture content of the sample with inverse relationship, this in turn affected the swelling capacity of the samples. It may also be that swelling power increased with temperature which may be attributed to swell in granule over a range of temperature. 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 yam starches. The swelling power is an indication of presence of amylase which influences the quantity of amylose and amylopectin present in the yam flour [27], [30]. Therefore, the higher the swelling power, the higher the associate forces as reported by [40] in [27]. The variation in the swelling power indicates the degree of exposure of the internal structure of the starch present

in the flour to the action of water. The values of solubility index ranged from 16.71 to 16.81% as shown in Table 2. There was no significant difference between all the samples. The values are in close range with the values of yam flour reported by [27] with values of 16.19 %. Sample C gave the least value for solubility index and this may be attributed to its low swelling power. Swelling power has been associated with flour functional properties. High amylose content has been linked to low swelling power due to greater reinforcement of the internal network by amylose molecules as reported by [39].

The results obtained for bulk density ranged from 1.01 to 1.15g/ml as shown in Table 2. There was significant difference between the samples A and C. The values of bulk density in this report are greater than the results obtained by [33] with value of 0.65g/ml. The differences in bulk densities obtained may be as a result of corresponding moisture content available in their particle sizes. The bulk and packed density is generally affected by the moisture content in flour [6]. [37] reported that bulk density is influenced by the structure of the starch polymers and loose structure of the starch polymers could result in low bulk density.

The results obtained for water absorption capacity ranged from 143.02 - 151.50 % as shown in Table 2. There was no significant difference between samples B and C but sample A was significantly different at $p < 0.05$. The values were less than the value reported by [27] with value of 267.76%. Water absorption capacity depicts the amount of water that an insoluble starch is able to hold in relation to its weight. Therefore, the water absorption index measures the extent of water retention in yam flour and this affects the ability of the yam flour to form paste.

Table-2. Functional Properties of 'Elubo' Flour

Sample	Swelling capacity (%)	Solubility (%)	Bulk density (g/ml)	Water absorption capacity (%)
A	5.21 ^b ± 0.04	16.81 ^a ± 0.04	1.01 ^a ± 0.004	151.50 ^b ± 2.30
B	5.17 ^b ± 0.01	16.76 ^a ± 0.03	1.10 ^{ab} ± 0.02	146.60 ^a ± 0.01
C	4.83 ^a ± 0.05	16.71 ^a ± 0.08	1.15 ^b ± 0.05	143.02 ^a ± 0.01

Mean value of different superscript along the same column are significantly different from each other at ($p < 0.05$).

Sample A = Dried at 70°C, Sample B = Dried at 60°C, Sample C = Dried at 50°C

(c) Anti-nutritional Properties of the 'ELUBO' FLOUR

The results obtained for tannin ranged from 0.37 to 0.42% and is as shown in Table 3. There was no significant difference between all the samples. The values of tannin reported in this work compared were in close range with the results gotten in [4] of yams with values range from 0.463 to 0.603%. The level of tannin in the flour decreased as the drying temperature increased from 50-70°C. The same observation was reported for sorghum flour by [20]. Tannin affects the nutritive value of food products by forming complex with protein (both substrate and enzyme) thereby inhibiting digestion and absorption as reported by [36]. They also bind iron, making it unavailable [8]. Reduction to safe level of the anti-nutritional factors is essential to improve the nutritional quality of yam and effective utilization of its full potentials as human food.

Table 3 shows the results of saponin in the 'elubo' flour obtained which ranged from 2.16 to 2.80mg/100g which was higher than the results gotten in [4]. Sample A was significantly different from sample C but sample B was not significantly different from A and C. The levels of the saponin reported was within the range values of cultivated white

yams reported by [15] with values of 1.03 to 2.71 mg/199 g. In 'amala', preparation, heat and most processing applications significantly reduce or totally eliminate most of these anti-nutrients [34].

Table 3 shows the values of phytate present in the 'elubo' samples. The values ranged from 52.23 to 58.48mg/kg. There was no significant difference between samples A and B but sample C was significantly different. [28] have shown that cassava, cocoyam and yam contain 624mg, 855mg and 637mg of phytate per 100g respectively. These values were higher than the values reported in this work because fermentation and processing had reduced the phytate level of yam flour by 91.8% thus reducing its adverse effect. As temperature increased from 50 to 70 °C, the value of phytate content reduced drastically. Higher temperature does deactivate the activity of phytate as reported by [14]. Phytate content has been known to lower the bio-availability of minerals.

Table-3. Anti-nutritional analysis of Yam Flour

Sample	Tannin (%)	Saponin (mg/100g)	Phytate (mg/kg)
A	0.37 ^a ± 0.04	2.16 ^a ± 0.05	52.23 ^a ± 1.14
B	0.41 ^a ± 0.02	2.62 ^{ab} ± 0.08	52.59 ^a ± 0.05
C	0.42 ^a ± 0.004	2.80 ^b ± 0.33	58.48 ^b ± 2.18

Mean value of different superscript along the same column are significantly different from each other at (p<0.05).

Sample A = Dried at 70°C, Sample B = Dried at 60°C, Sample C = Dried at 50°C

(d) Thermal and Energy Properties of 'Elubo' Flour

Table 4 shows the inherent thermal diffusivity of the samples. There was no significant difference between the thermal diffusivity of the samples which ranges from 2.81 to 2.95 x10⁷ m²/s). The values compared well with thermal diffusivity values which were published for some other foods as reported earlier, [41]; [38]; [31].

The results obtained for specific heat ranged from 1.62 to 1.75 KJ/kg K as shown in Table 4. There was no significant difference among the samples at p< 0.05. The values obtained in this report were higher than that of [21] who obtained 1.205 KJ/KgK using scanning calorimeter, for bone dry native cassava. However in processing foodstuffs, higher values of specific heat usually lead to more energy transfer and improved heat transfer conditions.

The values of thermal conductivity are as presented in Table 4. The samples did not exhibit significant difference. The values ranged from 0.18 to 0.19 W/mK. Increase in thermal conductivity may be due to an increase in moisture content of the samples. From Table 2, it can be deduced that thermal conductivity increased with an increase in density and, therefore, more mass of the sample was contained per unit volume. The greater the density of a sample, the lower the volume of air in the particle interstices. Since air is a poor conductor of heat, the less the quantity present, the better the conduction. In addition, the greater the density, the greater the contact between particles, hence, higher thermal conductivity. Thermo-physical properties are significantly dependent on changes in moisture content and temperature as reported by [12]. Thermal conductivity is important to predict or control heat flux and processing time. Published results on thermal properties have shown that it is also influenced by a number of factors which include porosity, moisture content, composition of the agricultural material and fiber orientation [29].

The energy values of the fermented 'elubo' flour are as presented in Table 4. The calculated energy values ranged from 1497.91 kJ to 1549.68 kJ. Sample A and B were not significantly different while sample B

and C were not significant difference but sample A and C were significantly different. The values of energy reported in this work are greater than the values of 731.75 kJ reported for *Dioscorea rotundata* by [9]. The high energy value is attributed to the high carbohydrate content. Carbohydrate supplies energy to cells such as brain, muscles and blood. It contributes to fat metabolism and spare proteins as an energy source and act as mild natural laxative for human beings and generally add to the bulk of the diet [22], [19].

Table-4. Thermal and Energy properties of Yam flour

Sample	Thermal diffusivity($\times 10^7 \text{m}^2/\text{s}$)	Specific heat capacity(KJ/kgk)	Thermal conductivity(W/mK)	Energy (KJ)
A	2.95 ^a ±0.03	1.62 ^a ±0.06	0.17 ^a ±0.01	1549.68 ^b ±1.39
B	2.81 ^a ±0.01	1.66 ^a ±0.03	0.19 ^a ±0.00	1526.33 ^{ab} ±10.40
C	2.88 ^a ±0.05	1.75 ^a ±0.14	0.21 ^a ±0.01	1497.91 ^a ±18.85

Mean value of different superscript along the same column are significantly different from each other at (p<0.05).

Sample A = Dried at 70°C, Sample B = Dried at 60°C, Sample C = Dried at 50°C

4. CONCLUSION

From the results obtained in this study, it can be concluded that drying at a temperature of 70°C produced better sample of fermented white yam flour (*D. rotundata*) in terms of reduction of the anti-nutritional factors, high proximate and functional properties and also high energy values.

REFERENCES

- [1] Adegunwa M.O., Alamu, E.O. and Omitogun L.A. (2011). Effect of processing on the nutritional contents of yam and cocoyam tubers. *Journal of Applied Biosciences*, 46: 3086– 3092.
- [2] Adejumo B. A., Okundare, R. O., Afolayan, O. I. and Balogun, S. A. (2013). Quality attributes of yam flour (elubo) as affected by blanching water temperature and soaking time. *The International Journal of Engineering and Science*, 2(1): 216-221.
- [3] Adewale, O. O., Bukunola, O.B. and lfeoluwa, Olotu A. (2014). Changes in nutritional composition, functional, and sensory properties of yam flour as a result of presoaking. *Food and Nutrition. Food Science & Nutrition*, 2(6): 676– 681.
- [4] Afiukwa, C.A., Ogah, O., Ugwu, Okechukwu, P.C., Oguguo, J.O., Ali, F.U. and Ossai E.C. (2013). Nutritional and antinutritional characterization of two wild yam species from Abakaliki, Southeast Nigeria. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 4(2): 840-847.
- [5] Agoreyo B.O, Akpiroroh O.A, Orukpe O.A, Osaweren R., and C.N Owabor (2011) *Asian Journal of biochemistry*, 6: 458-464.
- [6] Ajala, A. S., Babarinde, G. O. and Olatunde, S. J. (2012). Effect of temperatures, air velocity and flow rate on quality attributes of dried cassava chips. *Asian Journal of Agriculture and Rural Development*, 2(4): 527 – 535.
- [7] Akinoso, R. and Olatoye, K. K. (2013). Energy utilization and conservation in instant-pounded yam flour production. *International Food Research Journal*, 20(2): 575-579.
- [8] Aletor VA, Adeogun OA (1995). Nutrient and anti-nutrient components of some tropical leafy vegetables. *Food Chem*, 53: 375-379.

- [9] Alinnor I.J. and Akalez, C.O. (2010). Proximate and mineral compositions of *Dioscorea rotundata*, (White Yam) and *Colocasia esculenta* (White Cocoyam). Pakistan Journal of Nutrition, 9(10): 998-1001.
- [11] AOAC (2000). "Official methods of analysis of the Association of Official Analytical Chemists". 16th edition (William ed.) Virginia. pp: 834 - 841.
- [12] Barbosa-Canovas GV, Juliano and Peleg M (2006). "Engineering Properties of Food in Food Engineering", In: Barbosa-Canovas,G.V. (Eds), Encyclopedia of Life Support System (EOLSS),UNESCO/Eolss Publishers, Oxford UK, p 830. Available at: www.eolss.net.
- [13] Choi, Y., and Okos, M.R. (1986). Effects of temperature and composition on the thermal properties of foods. In Food Engineering and Process Applications 1:93-101. London: Elsevier Applied Science Publishers.
- [14] Duodu K, Minnaar A, Taylor J. (1999). Effect of cooking and irradiation on the labile vitamins and anti-nutrient content of a traditional African sorghum porridge and spinach relish. Food Chem., 66: 21–27. doi:10.1016/s0308-8146(98)00070-3.
- [15] Ezeocha V. C. and Ojmelukwe P. C. (2013). The impact of cooking on the proximate composition and anti-nutritional factors of water yam (*Dioscorea alata*). Journal of Stored Products and Postharvest Research, 3(13): 172 – 176.
- [16] FAO. (2012). Online statistical database. Rome, Italy Food and Agriculture Organization of the United Nations (www.fao.org).
- [17] Federal Office of Statistics, Nigeria trade summary. Federal office of statistics, (FOS), 2011. Lagos, Nigeria.
- [18] Gaman, P.M. and Sherrington, K.B. (1990). An introduction to food science. nutrition and microbiology, Pergamon Publishers, Oxford. England. pp: 86-87.
- [19] Gaman, P.M. and K.B. Sherrington, (1996). The Science of Food, 4th Edn., Reel Educational and Professional Publishers Ltd., Oxford. pp: 125-136.
- [20] Gangcheng, W., Stuart K. J., Janet, F. B., Sarita, J. B., Vijaya, S., Azra, S., Zhongxiang, F. (2016). Effects of genotype and growth temperature on the contents of tannin, phytate and in vitro iron availability of sorghum grains. Plos One, 11(2): 1-12.
- [21] Gevaudan A, Chuzel G, Didier S, Andrieu J (1989). Physical properties of cassava mash. J. Food Sci. Technol, 24 (6): 637-645.
- [22] Gordon, M.N., 2000. Contemporary nutrition; Issues and Insights. Mc-Graw Hill companies New York. 4th Edn., pp: 102-256. Augustin, J., G.K. Johnson, C. Teitzel, R.H. True, J.M.
- [23] James M. L. and Mark D. H. (2010). Effects of Dietary Fiber and Its Components on Metabolic Health. Nutrients, 2: 1266-1289.
- [24] Jimoh K. O., Olurin T. O. and Aina. J. O. (2009). Effect of drying methods on the rheological characteristics and colour of yam flours. African Journal of Biotechnology, 8(10): 2325-2328.
- [25] Jonathan, G., Ibrinke, A. and Yetunde, O. (2011). Nutritional compositions, fungi and aflatoxins detection in stored 'gbodo' (fermented *Dioscorea rotundata*) and 'elubo ogede' (fermented *Musa parasidiaca*) from South Western Nigeria. African Journal of Food Science, 5(2): 105 – 110.
- [26] Lawal O.O, Agiang M.A and Eteng M.U. (2012). Proximate and anti-nutrient composition of white Guinea yam (*Dioscorea rotundata*) diets consumed in Ibarapa, South West region of Nigeria. Journal of Natural Product and Plant Resources; 2(2): 256-260.

- [27] Malomo, O, Ogunmoyela, O. A. B., Adekoyeni O. O., Jimoh O., Oluwajoba S.O. and Sobanwa (2012). Rheological and functional properties of soy-poundo yam flour. *International Journal of Food Science and Nutrition Engineering*, 2(6): 101-107.
- [28] Marfo, E.K., Sampson, B.K., Idowu, J.S. and Oke, O.L. (1990). Effect of local food processing on phytate levels in cassava, cocoyam, yam, sorghum, rice, cowpea and soybeans. *J. Agric. Food Chem.* 1580-1583.
- [29] Mohsenin N.N. (1980). *Thermal Properties of Foods and Agricultural Materials*. New York: Gordon Breach Science Publishers, p 408.
- [30] Moorthy, S.N. and T. Ramanujam, (1986). Variation in properties of starch in cassava Varieties in relation to age of the crop. *Starch tarke*, 38: 58-61.
- [31] Nwanekezi, E.C. and Ukagu, J.C. (1999). Determination of Engineering properties of some Nigerian Fruits and Vegetables. *Nig. Food J.*, 17: 55-60.
- [32] Ojokoh, A. O. and Gabriel, R. A. O. (2010). A comparative study on the storage of yam chips (gbodo) and yam flour (elubo). *African Journal of Biotechnology*, 9(21): 3175-3177.
- [33] Oladeji B, Akanbi C.T. (2013). Physico-chemical and sensory evaluation of “pound mix” from yam, cocoyam, breadfruit and plantain blends. *Nutr. Food Sci*, 41(6): 430-436.
- [34] Osagie A.U. (1998). Anti-nutritional factors. In: *Nat. Qual. Plant Foods*. pp: 221-244.
- [35] Osagie A.U. (1992) The yam tuber in storage. Post Harvest Research Unit, University of Benin, Nigeria; pp: 107-173.
- [36] Osuntogun, B.A., Adewusi, S.R.A., Adewusi, A., Ogundiwin, J.O. and Nwasike, C.C. (1989). Effect of cultivar, steeping, and malting on tannin, total polyphenol, and cyanide content of Nigerian sorghum. *Cereal Chem.*, 66: 87-89.
- [37] Plaami, S.P (1997). Content of dietary Fiber in Foods and its physiological effects, *Food Rev. publishers' limited*. pp: 97-117.
- [38] Rapusas, R.S., Driscoll, R.H. (1995). Thermo-physical properties of fresh and dried white onion slices. *J. Food Engineering*, 24: 149-164.
- [39] Riley, C.K., Wheatley, A.O., Hassan, I., Ahmad, M.H., Morison, E. and Asemota, H.N. (2004). In vitro digestibility of raw starches extracted from five yam (*Dioscorea spp*) species grown in Jamaica. *Starch/Starke*, 56: 9-7.
- [40] Ruales, J., Valencia, S. and Nair, B. (1993). Effect of processing on the physiochemical characteristics of guinea flour. *Chenopodium guinea Wild Starch*, 46(1): 13-19.
- [41] Singh, R.P. and Heldman, D.R. (2009). *Introduction to Food Engineering*. 4th ed. Great Britain: Academic Press. P 260.
- [42] Sweat, V.E. (1986). Thermal properties of foods. In: Rao MA, Rizvi SSH, editors. *Engineering Properties of Foods*. New York: Marcel Dekker Inc. p 50
- [43] United States Department of Agriculture (USDA) (2014). National Nutrient Database available online at www.nutrition-and-you.com.

Online Science Publishing is not responsible or answerable for any loss, damage or liability, etc. caused in relation to/arising out of the use of the content. Any queries should be directed to the corresponding author of the article.