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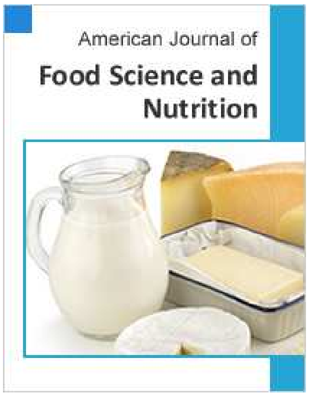


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# Physico-Chemical and Pasting Characteristics of Flour and Starch from Aerial Yam

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## Abstract
In this work, starch extract and the flour of *Dioscorea bulbifera* (aerial yam) were analysed and compared in terms of their physicochemical and functional properties. The results of the proximate analysis showed that, the starch extract had relatively low values for fat (1.59%), protein (0.00%), fat (0.31±0.29%), and ash (0.19±0.83%) as compared to the aerial yam flour, positioning it to exhibit good solubility and swelling properties. This assertion was buttressed by the fact that, the starch extract had significantly higher ($p<0.05$) values for Solubility (24.35±0.40%) and Swelling Power (8.19±0.21%) than the flour. The values obtained for the pasting characteristics of both samples indicated that, the starch extract generally had better Pasting Temperature (78.8°C), Pasting Time (19.25 min), Peak Viscosity (597 BU), Final Viscosity (198 BU), Holding Strength (594 BU), Break down Viscosity (113 BU), and Setback Viscosity (−284 BU) than that of the flour. In terms of colour, the starch extract again had better values for L* (81.20±1.09), a* (−0.59±0.02), and b* (+13.04±0.88). The pasting characteristics of the flour sample was better than that of the starch extract as it had lower amylose (30.00) content but a higher amylopectin (70.00) content. It can therefore be concluded that, the two samples could be used for different products based on the desired characteristics intended to be achieved.

## 1. Introduction

Aerial yam (*Dioscorea bulbifera*) is recorded to be an unpopular yam among the edible yam species which unlike the traditional yam produces aerial bulbis that look like potatoes hence the name aerial/air potatoes. [1] This species of yam is consumed by a small number of communities and is generally underutilized for a number of reasons. These include, it having a relatively bitter after-taste compared to other yam species, is unknown to most people, and much work has not been done on it to suggest uses to which it can be put to. However, there is a lot of potential for aerial yam in terms of its nutritional and functional properties that could be taken advantage of to produce diverse industrial products, not to mention its socio-economic importance. Therefore, investigation into the nutritional, functional and other quality characteristics of the aerial yam is essential, with the ultimate aim being the promotion of its usage, and suggesting plausible products that it could be incorporated into. Functionality of a food is the property of a food ingredient, apart from its nutritional value, that has great impact on its utilization. [2] Industrially, starch is used as a gelling agent, thickener, emulsion stabilizer, and as a water binding agent. Detail work on some food commodities, in terms of their functionality, have been well published [3, 4], but the same cannot be said of aerial yam.

Physicochemical and functional characteristics of starch, such as swelling, solubility index, water binding capacity, amylose and amylopectin, and pasting characteristics, had been used to describe/classify different products such as maize (flint or floury endosperm), rice (waxy/high amylose) and potato (mealy/waxy). In view of the fact that the physicochemical and functional properties of these crops (maize, rice, potato and cassava) have been comprehensively researched and well documented [3, 4], and being utilized industrially, but very little work and documentation are available on aerial yam. The aim of this study was therefore to characterise the starch of aerial yam in order to identify appropriate uses it could be put to, which will invariably stimulate increased production and utilisation as a raw material for starch production.

## 2. Materials and Methods

### 2.1. Source and Preparation of Aerial Yam

The aerial yams were obtained from farmers in the Northern Region of Ghana. The aerial yams were thoroughly washed using potable water and the entire laboratory tests were conducted at the Crops Research Institute (CRI) of the Council for scientific and Industrial Research (CSIR) laboratory at Fumesua in the Ashanti region of Ghana.

### 2.2. Extraction of Aerial Yam Starch

The wet extraction method was used for the starch extraction. After peeling and grating, 500 g of aerial yam was weighed into a Philip's blender and milled into a pulp. The pulp was collected into a cheese cloth in a colander mounted over a bucket and vigorously washed with water by hand. The fibre was squeezed to drain out the starch milk into the bucket. After the settling of starch granules, the supernatant was decanted and the wet starch open-air-dried for 48 h and blended to a fine powder in a Philip's dry mill and weighed afterwards. The starch obtained was packaged in polyethylene pouches and stored for analysis. Starch yield (%) was calculated using equation 1.

$$\%\text{Yield} = \frac{\text{Dry weight of starch recovered from extraction}}{\text{Dry weight of grated aerial yam}} \text{ x } 100 \quad (1)$$

### 2.3. Aerial Yam Flour *preparation*

The flour was prepared by cutting peeled aerial yam into 2 cm thick slices, oven dried at 60°C for three days, milled, sifted (with a 0.25 µm aperture sieve) and packaged in polyethylene pouches until analysis.

### 2.4. Proximate Analysis

Proximate analysis [moisture, ash, protein, fat, and carbohydrate (By difference)] of samples was conducted according to AOAC. [5, 6]

### 2.5. Functional Properties Determination

#### 2.5.1. Water Solubility Index (WSI), Swelling Power (SP) and Water Binding Capacity (WBC)

Solubility and swelling power determinations were carried out based on a modification of the method by Leach. [7] One gram of aerial yam flour/starch was stirred into 40 ml distilled water contained in a weighed 50 ml graduated centrifuge tube. The suspension was gently stirred to avoid fragmentation of the starch granules. The slurry in the tube was heated at 85°C in a thermostatically regulated water bath for 30 min with constant gentle stirring. The tube was then removed, wiped dry on the outside and cooled to 25°C. It was then centrifuged at 2200 rpm for 15 min. The supernatant was decanted into a pre-weighed moisture dish. The solubility was determined by evaporating the supernatant in a thermostatically controlled drying oven at 105°C for 5 h and the residue weighed. The sedimented paste was weighed and swelling power as well as percent solubility calculated using equations 2 and 3, respectively.

$$\text{Swelling power} = \frac{\text{Weight of sediment}}{\text{Sample weight} - \text{Weight of soluble}} \quad (2)$$

$$\%\text{Solubility} = \frac{\text{Weight of soluble}}{\text{Weight of sample}} \text{ x } 100 \quad (3)$$

The water binding capacity (WBC) of aerial yam starch/flour was determined according to the method described by Medcalf and Gilles. [8] An aqueous suspension of yam starch was prepared by mixing 2.0 grams (dry weight) of flour/starch in 40 ml of distilled water. The suspension was agitated for 1 hour on a Griffin flask shake and centrifuged at 2200 rpm for 10 min. The supernatant was decanted from the wet flour/starch, drained for 10 min and the wet flour/starch was then weighed. The percent water binding capacity was calculated using Equation 4.

$$\%\text{Water binding capacity} = \frac{\text{Weight of bound water}}{\text{Weight of sample}} \text{ x } 100 \quad (4)$$

#### 2.5.2. Determination of Pasting Characteristics

The pasting characteristic of the flour/starch sample was determined using Brabender Viscograph instrument (Viscograph-E, Brabender Instrument Inc. Duisburg, Germany). The moisture content of the flour/starch sample was determined with an electronic moisture analyser (Sartorius MA 45). The moisture content value obtained was input into the software of the Brabender Viscograph, which automatically indicates the weight of flour/starch sample to use and the amount of distilled water to be added to make the slurry. To 40 g of flour/starch (10% moisture level) was added 420 ml of distilled water in a sample canister. The sample was thoroughly mixed and the slurry set into the stainless steel canister of the instrument, and heated at a rate of 1.5°C/min by means of a thermo-regulator at a speed of 75 rpm. The start temperature was 50°C and when the suspension attained 95°C, the temperature was held constant for 15 min (first holding period) as stirring continued. The paste was then cooled down to 50°C at a rate of 1.5°C/min and held for another 15 min (second holding period). The process lasted for 1 hour 30 min and the following parameters were read from the print out of the Brabender Viscograph: Corresponding values for pasting temperature, pasting time, peak viscosity (Brabender Units-BU), Peak temperature, Peak time, Viscosity at 95°C (BU), Viscosity after 15 min at 95°C (BU), Viscosity at 50°C (BU), Viscosity after 15 min at 50°C (BU), Paste stability at 50°C (BU), Paste stability at 95°C (BU), Setback viscosity (BU) and Breakdown viscosity (BU). Paste stability at 95°C and paste stability at 50°C were calculated as the difference between viscosity at 95°C and viscosity after 15 min at 95°C, and the difference between viscosity at 50°C and viscosity after 15 min at 50°C, respectively.

#### 2.5.3. Determination of Amylose Content

The method as described by Williams *et al.* [9] and Juliano [10] was used in determining the amylose content of the aerial yam flour and its starch extract. About 0.1 g of sample (either aerial yam flour or its starch extract) was dissolved using 1 ml of 95% ethanol and 9 ml of 1 N NaOH, and heated in a boiling water bath for 10 min. A 1 ml aliquot of the resultant solution was made up to 10 ml using distilled water. To 0.5 ml of the diluted extract was added 0.1 ml I N acetic acid followed by 0.2 ml iodine solution (0.2 g $I_2$+2.0 g KI in 100 ml of distilled water) to develop the characteristic dark blue colour. The coloured solution was made up to 10 ml with distilled water and allowed to stand for 20 min for total colour development. The ensuing solution was vortexed and a spectrophotometer was used to read its absorbance at 620 nm. The absorbance of a standard corn amylose with known amylose concentration was used to estimate the amylose content.

### 2.6. Colour Measurement

The colour of the flour/starch was measured using a Minolta portable chroma-metre. The hunter lab colour coordinates system L* a* and b* values were recorded and the Light index was calculated as (100/0). The white tile used for calibrating the Hunter L*, a*, b* colour scale had L* = + 97.51, a* = + 0.29 and b* = 1.90 as standards.

### 2.7. Statistical Analysis

Data was analysed using stat graphics (Centurion version). Analysis of variance (ANOVA) was used to test for significant differences among the means. Duncan multiple range tests were used to determine where the significant differences existed among the various samples.

## 3. Results and Discussions

### 3.1. Chemical Composition of Flour and Starch Extract

Table 1 shows the chemical composition of aerial yam flour and starch. The chemical composition of the starch and flour from aerial yam determines its pasting and other characteristics. In this study, the starch yield obtained was 12.39%. The value obtained for starch yield agrees with earlier report [11] for muchumudu yam starch (12.61%). However, the current study value for starch fell below that reported for other aerial yam varieties. There have been reported values [12] between 98.20 – 98.81% and 97.01 – 97.52% for the yellow and mauve fleshed aerial yam, respectively. Differences in yield could be attributed to the level of maturity, variety, and environmental factors, as the content of yam starch changes as growth progresses. [13, 12] There is the likelihood of yield increase over a period of time as moisture is lost to the environment and there is aggregation of starch granules. [14] The fat content obtained for the starch extract in this study (1.59%) was higher than the 0.07% earlier reported for aerial yam yellow cultivar. [12] The ash content of the aerial yam flour was higher than that of the starch extract. The acceptable ash content of starch should be equal to or less than 0.2%. [15] The ash content of the starch extract was lower than (Table 1) the 0.2%, and therefore the starch extract can be termed to be of good quality. The zero protein value recorded for the starch extract agrees with that reported for aerial yam starch. [12] The relatively low fat content and zero value obtained for protein in the starch extract are good, as the presence of these two components negatively affects the swelling property of starches. The lower the values of these two components, the better the swelling and pasting properties of the starch extract. [16, 17] Again, the relatively low values of the ash and fibre content of the starch extract, positions it to exhibit good swelling and pasting properties. [18]

The differences in the proximate composition of earlier works as compared to the current study could be attributed to the growing conditions and stage of maturity of the aerial yam used. A high starch content and low content of protein, ash, fat and fibre for a starch extract is an indication of its high quality. The moisture content of the starch extract was relatively low compared to the flour.

The aerial yam flour had relatively high moisture, fat, ash, protein and fibre content than the starch extract. This is to be expected as the starch extract is devoid of other nutritional components.

***Table 1.*** *Percent chemical composition of aerial yam flour and starch extract.*

| Samples | Moisture | Protein | Fat | Ash | Fibre | Starch yield | starch |
|---|---|---|---|---|---|---|---|
| Flour | 71.57±0.13 | 7.12±0.22 | 1.59±0.06 | 2.82±0.45 | 1.92±0.31 | – | 14.25±0.12 |
| Starch extract | 15.62±0.89 | 0.00 | 0.31±0.29 | 0.19±0.83 | 0.85±0.19 | 12.39 | 82.12±0.11 |

### 3.2. Functional Properties of Aerial Yam Flour and Starch Extract

The results obtained for water binding, solubility, and swelling power of flour and starch extract of the aerial yam are shown in Table 2.

There was no significant difference ($p>0.05$) in the water binding capacity (WBC) between the starch extract and the flour sample, although that of the flour was slightly higher than that of the starch extract. The presence of other components, particularly protein, can bind water and that may explain why the flour sample had a relatively higher WBC than the starch extract. The values obtained for the samples in this work were higher than that obtained by Addy *et al*. [11] for *D. rotundata* varieties. A higher WBC is relevant in ensuring that food products possess good texture as well as having the ability to stabilise starches, which invariably reduces retrogradation and syneresis during storage, retorting and freezing. [19, 20]

The solubility of starch in the extract was significantly higher ($p<0.05$) than that in the aerial yam flour sample. This could be attributed to the presence of relatively high amount of fat present in the flour sample as starch binds with lipid materials, making it bulky and increasing its hydrophobicity, and consequently reducing solubility in water. [21, 22, 23] The values obtained in this work are higher than that obtained for *D. rotundata* varieties [11], and compares favourably with sweet potato varieties. [24] *D. bulbifera* starch can therefore be used in formulating weaning foods for infants, among other uses.

The swelling power indicates the hydration capacity of the insoluble starch fraction in water and expressed in grams of water absorbed per gram of insoluble fraction. From Table 2, the swelling power of the starch extract was higher than that of the flour ($p<0.05$). This was to be expected as the concentration of starch granules was higher in the extract than that of the whole flour. The swelling power of starch is negatively affected by the presence of fat and protein in the sample. [16, 22, 25] This may account for the observation made since the protein and fat contents of the aerial yam flour were higher than that of the starch extract. The swelling power values obtained for the aerial yam starch extract and flour, in this work, were lower compared to that obtained for D. *rotundata* varieties [11], but were higher than that for sweet potato varieties. [24]

From Table 2, there was a positive correlation between solubility and swelling power of the samples. This was contrary to results obtained by Kusumayanti *et al.* [24]

***Table 2.*** *Functional properties of aerial yam flour and starch extract.*

| Sample | Water binding capacity | Solubility | Swelling Power |
|---|---|---|---|
| Flour | $312.42\pm7.54^{a}$ | $22.47\pm0.21^{a}$ | $7.19\pm0.31^{a}$ |
| Starch extract | $311.27 \pm 6.50^{a}$ | $24.35 \pm 0.40^{b}$ | $8.19 \pm 0.21^{b}$ |

### 3.3. Pasting Characteristics of Aerial Yam Flour and Starch Extract

The pasting characteristics of starch and aerial yam flour are presented in Table 3. The pasting temperature and pasting time were higher in the flour sample as compared to the starch extract. This observation agrees with earlier findings [11] to the effect that, as pasting temperature increases for *D. Rotundata* samples, there was a corresponding increase in the pasting time. The presence of other components, such as proteins, lipids, etc., interferes with the pasting characteristics of food media. [26] Again, the pasting temperature suggests the likely gelatinization time during processing [27] and gives an indication of the least temperature needed for cooking, energy cost and the stability of other components. [28] Pasting temperature as reported by Swinkel [22] is the temperature at which viscosity begins to rise whiles pasting time provides an indication of the minimum time required to cook a given food sample. It was observed in this study that the aerial yam starch had the lowest pasting time (19.25 min) and temperature (78.8°C) making it suitable for the production of foods that require shorter processing time. The values for both the pasting time and pasting temperature for aerial yam starch in this study were higher than reported for Asobayere, muchumudu, pona and Labreko yam starches. [11] The variations in values may be attributed to specie differences.

Peak viscosity that indicates the water binding capacity of starch [29, 30, 31], is the ability of the flour/ starch to form a paste. It also indicates the strength of the paste formed from gelatinisation during food processing. [32] Aerial yam starch had a comparatively higher peak value than the aerial yam flour, and the value of 597 BU observed for the starch in this study was significantly higher than reported for water yam varieties [31] and followed the same trend as observed for achi starch and flour. The high peak viscosity observed for the starch indicates its suitability for food products that needs high gel strength and elasticity. [33] The low breakdown (0.00 BU) viscosity of the flour is indicative of the stability of the flour hot paste and relative low setback (- 11.00), demonstrating low tendency of the flour to retrograde. This implies that, the flour would be useful in the food processing industry as high retrogradation easily leads to staling of bread, quick precipitation and loss of viscosity in sauces. [33] The higher setback viscosity of the starch makes it suitable for the production of non-wheat noodles. The high breakdown value of the starch is indicative of its low paste stability, this normally follows a high final viscosity, a parameter used to indicate stability of a paste. The starch extract exhibited higher values for final viscosity and holding strength compared with the flour. This observation was corroborated by findings of Ikegwu *et al*. [33] They observed higher final viscosity and holding strength values for achi starch compared with achi flour.

Generally, With the exception of the pasting temperature and time, the aerial yam starch extract exhibited high values in all the parameters measured than its flour component.

***Table 3.*** *Pasting characteristics of aerial yam flour and starch extract.*

| Sample | Pasting Temperature (°C) | Pasting Time (min) | Peak Viscosity (BU) | Final Viscosity (BU) | Holding Strength (BU) | Break down Viscosity (BU) | Setback Viscosity (BU) |
|---|---|---|---|---|---|---|---|
| Flour | 85.50 | 24.30 | 57.00 | 46.00 | 57.00 | 0.00 | -11.00 |
| Starch extract | 78.8 | 19.25 | 597 | 198 | 594 | 113 | -284 |

### 3.4. Colour Characteristics of Aerial Yam Flour and Starch Extract

The colour brightness coordinate L* measures the degree of whiteness, ranging between black (0) and white (100). The chromaticity coordinate a* measures red when positive and green when negative, while b* measures yellow when positive and blue when negative. The values of a* and b* range between −60 and +60. Starch, which is colourless, can be coloured as a result of the presence of polyphenols, carotene, and other compounds. [33] Consumer acceptability is affected by the presence of colour in starch, which is an indication of low quality. [34] From Table 1, the colour brightness (L*) of the starch extract was significantly higher ($p<0.05$) than that of the flour. The relatively high brightness value of the starch extract and low value of the chromaticity coordinate (a*) is desirable. This is because, starch with a high colour brightness value and a low a* value are desired by consumers. [33, 35] The b* value for the flour sample was higher than that of the starch extract, indicating that the flour sample had a relatively higher yellow colour as compared to the starch extract. The starch extract was therefore better in terms of the b* value than the flour, and could thus be incorporated into products without affecting their colour.

***Table 4.*** *Colour analysis of flour and starch extract of aerial yam.*

| Parameters | L* | a* | b* |
|---|---|---|---|
| Flour | $77.66\pm1.25^{b}$ | $-0.45\pm0.01^{a}$ | $+19.14\pm0.91^{a}$ |
| Starch extract | $81.20\pm1.09^{a}$ | $-0.59\pm0.02^{a}$ | $+13.04\pm0.88^{b}$ |

Mean values with different superscripts ($^{a,\ b}$) are statistically different.

### 3.5. Amylose and Amylopectin Content of Aerial Yam Flour and Starch Extract

Amylose and amylopectin form the major constituents of starches and their amounts vary based on the type of plant species and variant. [36, 37, 38] From Table 5, the amylose content of the starch extract was significantly higher ($p<0.05$) than that of the aerial yam flour and conversely the amylopectin content of the starch extract was significantly lower ($p<0.05$) than that of the aerial yam flour. The amylose and amylopectin content, obtained in this current work, for the aerial yam flour are similar to that earlier reported [11] for *Dioscorea rotundata* (Pona), but other varieties in the same work such as 'Asobayere', 'Labreko', and 'Muchumudu' had amylose and amylopectin composition different from the aerial yam flour. The amylose/amylopectin ratio obtained in this work for aerial yam flour was lower than that reported for two varieties of *Dioscorea bulbifera*. [12] The amylose and amylopectin content of a food material greatly influences its pasting and viscosity attributes. [39, 40, 41] Higher pasting consistency and viscosity are achieved when the amylopectin component of a food commodity is higher than that of its amylose component. [42, 43] Since amylose tends to retrograde when foods are frozen and thawed [44], high amylopectin content foods will be useful in the preparation of foods for a freeze thaw process. Therefore, high pasting and viscosity properties could be achieved when aerial yam flour is used in food preparation, as per the value of the amylose/amylopectin ratio shown in Table 5.

***Table 5.*** *Amylose and amylopectin content of flour and starch extract of aerial yam.*

| Sample | Amylose (%) | Amylopectin (%) | Amylose/Amylopectin ratio |
|---|---|---|---|
| Flour | $30.00^{b}$ | $70.00^{a}$ | 0.43 |
| Starch extract | $37.50^{a}$ | $62.50^{b}$ | 0.60 |

## 4. Conclusion

The aerial yam flour was found to be high in moisture, fat, ash, protein and fibre, however, it exhibited low values in all the pasting parameters measured with the exception of pasting time and temperature. No significant differences existed between the flour and starch in relation to the water binding capacity. Again, the starch extract had better colour properties. The aerial yam starch will therefore be useful in the production of non- wheat noodles, while the aerial yam flour could be valuable in the food processing industry because of its propensity to exhibit low retrogradation characteristics making it useful in preventing staling of bread and quick precipitation and loss of viscosity in sauces.

## References

[1] Igyor, M. A., Ikyo, S. M., and Gernah, D. I.; The food potential of potato yam (*Dioscorea Bulbifera*). *Nigerian Food Journal* (2004); 22: 209-215.

[2] Mahajan, A. and Dua, S.; Salts and pH induced changes in functional properties of amaranth (*Amaranthus tricolor* L.) seed meal. *Cereal Chemistry* (2002). 79 (6): 834-837.

[3] Singh, N., Kaur, L and Singh, J.; Relationship between various physicochemical, thermal and rheological properties of starches separated from different potato cultivars. *Journal of the Science of Food and Agriculture* (2004); 84:714-720.

[4] Madsen, M. H. and Christensen, D. H.; Changes in viscosity properties of potato starch during growth. *Starch* (1996); 48: 245-249.

[5] AOAC; Association of Official Analytical Chemists Official Methods of Analysis 15th Ed, Gaithersburg. AOAC Press, USA, (1990).

[6] AOAC; Official Methods of the Association of Official Chemists. Official Analytical Int., Arlington, VA, (2000).

[7] Leach, H. W., McCoven, L. D. and Scoch, T. J.; Structure of the Starch granule Swelling and solubility patterns of various starches. *Cereal Chemistry* (1959); 36: 534-544.

[8] Medcalf, D. G and Gilles, K. A.; Wheat Starches 1. Comparison of Physico-chemical properties. *Cereal Chemistry* (1965); 42: 538-568.

[9] Williams, V. R., Wu, W., Tsai H. Y., Bates, H. G.; Varietal differences in amylose content of rice starch. *Journal of Agricultural and Food Chemistry* (1958); 6: 47-48.

[10] Juliano, B. O.; A simplified assay for milled rice amylose. *Cereal Science Today* (1971). 16: 334-340.

[11] Addy, R. N. A., Wireko-Manu, F. D., Oduro, I.; Physicochemical and Pasting Properties of Starch Extracted from Four Yam Varieties. *Journal of Food and Nutrition Sciences* (2014); 2(6): 262-269. doi: 10.11648/j.jfns.20140206.14.

[12] Archange, L. M., Soumaila, D., Siaka, B., Tia, G. J., Kouame, L. P.; Physicochemical properties and digestibility of starch from bulbils of two cultivars of *Dioscorea bulbifera* during the growth. *International Journal of Agronomy and Agricultural Research* (2012); 2(12): 34 – 42.

[13] Amani, N. G., Aka, K. G., N'dri, Y. D., Degbeu, K. C. and Sako, A.; Evolution of functional properties of precocious yam starch (*Dioscorea cayenensis-rotundata*) during tuberization. *International Journal of Biological and Chemical Sciences* (2008); 2(3): 324–330.

[14] Ketiku, A. O., and Oyenuga, V. A.; Changes in the Carbohydrate Constituents of Yam Tuber (*Dioscorea rotundata*, Poir) During Growth. *Journal of the Science of Food and Agriculture* (1973); 24(4): 367–373. doi: 10.1002/jsfa.2740240403.

[15] Onwueme, I. C. The tropical tuber crop. John Wiley and Sons, Chinchester (UK), (1982), pp. 189-191.

[16] Schoch, T. J. and Maywald, E. C.; Preparation and Properties of Various Legume Starches. *Cereal Chemistry* (1968); 45: 564–573.

[17] Blazek, J., and Copeland, L.; Pasting and swelling properties of wheat flour and starch in relation to amylose content. *Carbohydrate polymers* (2008); 71(3): 380-387.

[18] Zhou, M., Robards, K., Glennie-Holmes, M. and Helliwell, S.; Structure and pasting properties of oat starch. *Cereal Chemistry* (1998); 75(3): 273-281.

[19] Baker, R. C., Wonghan, P. and Robbins, K. R.; Fundamentals of new food products developments. Science, Volume 16. Elsevier Science Amsterdam, (1994).

[20] Ellis, W. O., Oduro, I., Barimah, J. and Otoo, J. A.; Quality of starch from six Japanese sweet potato varieties in Ghana. *African Journal of Root and Tuber Crops* (2003); 5(2): 38-41.

[21] Hoover, R. and Hadziyev, M.; Characterization of potato starch and its monoglyceride complexes. *Stärke* (1981); 33(9): 290-300.

[22] Swinkel, T. J. M.; Composition and properties of commercial native starches. *Stärke* (1985); 37(1): 1-5.

[23] Kumoro, A. C., Retnowati, D., and Budiyati, C.; Water Solubility, Swelling and Gelatinization Properties of Raw and Ginger Oil Modified Gadung (*Dioscorea hispida* Dennst) Flour. *Research Journal of Applied Sciences, Engineering and Technology* (2012); 4(1): 2854-2860.

[24] Kusumayanti, H., Handayani, N. A. and Santosa, H.; Swelling power and water solubility of cassava and sweet potatoes flour. *Procedia Environmental Sciences* (2015); 23: 164–167.

[25] Bjorck, J., Eliasson, A. C. and Drews, A.; Some nutritional properties of starch and dietary fibber in barby different levels of amylose. *Cereal Chemistry* (1990); 67(4): 327-333.

[26] Kaushal, P., Kumar, V. and Sharma, H. K.; Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*) flour, pigeon pea (*Cajanus cajan*) flour and their blends. *LWT-Food Science and Technology* (2012); 48(1): 59-68.

[27] Odedeji, J. O. and Adeleke, R. O.; Pasting characteristics of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition* (2010); 9(6): 555-557.

[28] Ikegwu, O. J., Nwobasi, V. N., Odoh, M. O. and Oledinma, N. U.; Evaluation of the pasting and some functional properties of starch isolated from some improved cassava varieties in Nigeria. *African Journal of Biotechnology* (2009). 8 (10): 2310-2315.

[29] Moorthy, S. N.; Physicochemical and functional properties of tropical tuber starches. *Stärke* (2002); 54:559-592.

[30] Mahasukhonthachat K, Sopade P. A and Gidley M. J.; Kinetics of starch digestion in sorghum as affected by particle size. *Journal of Food Engineering* (2010); 96: 18-28.

[31] Oke, M. O., Awonorin, S. O. and Workneh, T. S.; Effect of varieties on physicochemical and pasting characteristics of water yam flours and starches. *African Journal of Biotechnology* (2013); 12(11): 1250-1256.

[32] Eke-Ejiofor, J.; Physico-chemical and pasting properties of starches from cassava, sweet potato and three leaf yam and their application in salad cream production. *International Journal of Biotechnology and Food Science* (2015); 3(2) 23-30.

[33] Ikegwu, O. J., Okechukwu, P. E., and Ekumankana, E. O.; Physico-chemical and pasting characteristics of flour and starch from achi *Brachystegia eurycoma* seed. *Journal of Food Technology* (2010); 8(2): 58-66.

[34] Galvez, F. C. F and Resureccion, A. V. A.; The effects of decortications and methods of extraction on the physical and chemical properties of starch from mung bean [*Vigna radiate* (L). *Wilczec*]. *Journal of Food processing and Preservation* (1993); 17: 93-107.

[35] Liang, Z., Wu, B., Fan, P., Yang, C., Duan, W., Zheng, X., Liu, C. and Li, S.; Anthocyanin composition and content in grape berry skin in Vitis germplasm. *Food Chemistry* (2008). 111: 837–844.

[36] Sandhu, K. S., Singh, N. and Kaur, M.; Characteristics of the different corn types and their grain fractions: physicochemical, thermal, morphological, and rheological properties of starches. *Journal of Food Engineering* (2004); 64(1): 119-127.

[37] Slattery, C. J., Kavakli, I. H. and Okita, T. W.; Engineering starch for increased quantity and quality. *Trends in plant science* (2000); 5(7): 291-298.

[38] Smith, A. M., Denyer, K. and Martin, C.; The synthesis of the starch granule. *Annual Review of Plant Biology* (1997); 48(1): 67-87.

[39] Jane, J., Xu, A., Radosavljevic, Seib, P. A.; Location of amylose in normal starch granules. 1. Susceptibility of amylose and amylopectin to cross-linking reagents. *Cereal Chemistry* (1992); 69(4): 405–409.

[40] Mua, J. P. and Jackson, D. S.; Relationships between functional attributes and molecular structures of amylose and amylopectin fractions from corn starch. *Journal of Agricultural and Food Chemistry* (1997); 45(10): 3848-3854.

[41] Singh, J., Kaur, L. and McCarthy, O. J.; Factors influencing the physico-chemical, morphological, thermal and rheological properties of some chemically modified starches for food applications—A review. *Food Hydrocolloids* (2007); 21(1): 1-22.

[42] Zhou, Z., Robards, K., Helliwell, S. and Blanchard, C.; Composition and functional properties of rice. *International Journal of Food Science and Technology* (2002); 37(8): 849-868.

[43] Miao, M., Zhang, T. and Jiang, B.; Characterisations of kabuli and desi chickpea starches cultivated in China. *Food Chemistry* (2009); 113(4): 1025-1032.

[44] Gaman, P. M, and Sherrington, K. B.; The Science of Food. $4^{TH}$ Edn. Reed Educational and Professional Publishing Limited, Linacre House, Jordan Hill, Oxford OX2 8DP, (1996).