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Characterization of Starch from New Cassava Accessions at Different Maturity

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Abstract Cassava (*Manihot esculanta*) is a root crop which serves as an important source of starch on a global scale. The objective of this work was to investigate the characteristics of starch from some new cassava accessions at different maturity. Six new cassava accessions (*Abrabopa*, *Agra*, *Amansen*, *Ampong*, *Bankyehemma* and *Duadekpakpa*) were harvested at four different months (from April – July 2017; i.e., 7-10th month) after planting. The starch was extracted using the conventional method of starch extraction and their yield calculated. The amylose was determined by means of spectrophotometry whereas pasting properties of the starches were analyzed using Rapid Visco Analyzer. Average starch yield ranged from 18-29% with the highest yield recorded in the 10th month for the various varieties studied. There were no significant differences ($p > 0.05$) in the peak viscosity, final viscosity, peak time and pasting temperature but significant differences were recorded for setback, trough and breakdown of the starch samples. The amylose (14-25%) and amylopectin (76-85%) content of the varieties differed significantly ($p < 0.05$). The present work shows that maturity affects the starch yield, composition and pasting properties of the new cassava accessions and this should be considered in deciding the time to harvest each accession for specific food and non-food industrial applications.

Keywords: *Manihot esculanta, starch yield, amylose, amylopectin, pasting properties*

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1. Introduction

Starch forms a major component of cassava (*Manihot esculenta*) and it is an essential raw material for food and non-food industries worldwide [1]. The dry weights of cassava tubers contain 80-90% carbohydrate, out of which 80% is starch and the rest constitute glucose, fructose and maltose [2]. Starch contributes greatly to the texture of many foods and is widely used for applications including not limited to; thickener, colloidal stabilizer, gelling agent, bulking agent and adhesive [3]. It is also famous for its use in several African diets, textiles, plywood, paperboard, pharmaceuticals, petroleum and brewing. This diverse usage of cassava starch is due to its many characteristics, such as high paste viscosity, high paste clarity, and high freeze-thaw stability, which are advantageous for industrial purposes [4].

Depending on the botanical source of starch, by-products demonstrate different functionality as a result of the variance in their granular structure, amylose and amylopectin content and branch chain length distribution, which affects their physical and chemical properties [4].

Cassava starch has been studied and characterized for its different properties such as granule structure, pasting properties and functional properties such as swelling power and solubility [5,6,7].

The starch used in the manufacture of glucose syrup, for example, must be as pure as possible with low protein content (particularly soluble protein). In this respect, cassava starch is preferable to other starches.

In 2000, the Food and Agricultural Organization [8] reported that global demand for cassava starch could increase at an annual rate of 3.1%, with regional growth rates expected to be 2.3% for Africa, 4.2% for Asia and 3.4% for Latin America. This resulted in an increased research into cassava starch production.

A previous study on cassava flour from different fertilizer protocols revealed that the physiochemical properties of the flour were significantly affected by different cassava varieties and fertilizer protocols [9].

Cassava varieties such as '*Abasafitaa*' (clone-TMS(4)1425), '*Afisiafi*' (coded-TMS 30572), Tek bankye (coded Isu-White (Isu-W), '*Glemoduade*' (coded TMS 50395) and '*Doku* duade' are among the locally bred and selected varieties that have been endorsed by the Ghana Ministry of Food and Agriculture (MOFA) and the Crop Research Institute as high starch yielding varieties [10].

It is important to note that; starch yield from cassava is dependent but not limited to variety, maturity, cultivation practices and extraction methods. It has been shown that optimization of starch extraction from cassava using crude pectolytic enzymes from *S. cerevisiae* was dependent on variety as well as the treatment combinations adopted [11].

Current research on cassava is centred on improving the quality of starch and incorporating it into other flour to make composite flour and weaning foods [12,13]. Genetic modifications for starch crops have also in most cases led to the development of starches with improved and targeted functionality in some reports [14].

The characteristic of food and their products which are usually formulated with starch are influenced by the functional properties of starch [15]. Functional properties such as the viscosity of starch are important when used as gum replacers [16]. The ability of starch to form paste or gel also determines the texture and quality of food product [17]. The functional and pasting properties of starch have been reported to influence gelling ability, fat and water binding and thus the textural quality of food products that have their substitute [17].

Cassava is considered as one source of starting material for the production of starch in industries as it contains a high amount of starch and has many advantages for starch production due to certain properties such as high level of purity, excellent thickening characteristics, and desirable textural characteristics among others. It is also a cheap source of raw material for the starch industries [18]. As new and improved cultivars are being developed, it has become important to extract starch from these new cultivars for further studies on their physiochemical and functional properties.

The objective of the present work was to characterize starch from some new cassava accessions at different maturity.

2. Materials and Methods

2.1. Materials

New varieties of cassava namely: *Agra*, *Bankyehemma*, *Amansen*, *Duadekpakpa*, *Abrobopa* and *Ampong* were harvested from Kwame Nkrumah University of Science and Technology (KNUST) school farm, Anwomaso in the Ashanti Region of Ghana. After planting, the varieties were harvested on the 7th, 8th, 9th and 10th month for the studies.

2.3. Isolation of Starch

The starch was extracted using the conventional method of starch extraction. The freshly harvested cassava tubers of all the varieties were peeled and washed. The washed cassava was then grated with a metal grater. 100g of the grated cassava was measured using a mass balance (Model: ML204/01, Mettler Toledo, Switzerland) and blended with 100 mL of distilled water with a stainless-steel warring blender for 1 min for each variety. The slurry was sieved using cheesecloth in a mesh into a container (bowl). It was then washed with extra distilled water until the cassava was fibrous. The filtrate was allowed to stand for 5 hr and then decanted. The starch material was then air dried for 2 days at room temperature. The masses of the dried starch were measured and then packed in zipper locked bags. Yield for each variety was calculated from the mass of the dried starch and the mass of the grated cassava (100g) expressed as a percentage.

2.3. Pasting Characteristics

Rapid Visco Analyzer Model 4500 (RVA) was used in the analysis of the pasting properties of the starch samples. Newport Scientific correction formula for moisture content was used to prepare starch suspension of samples. The pasting properties was determined by method described by [19] with some modifications The starch slurry was placed into the RVA and heated from 50°C to 95°C with 2mins holding time. The slurry was cooled at 2mins holding time. The peak viscosity, trough, breakdown, final viscosity, peak time, pasting temperature and setback were analyzed using thermocline for windows software. The analysis was duplicated.

2.4. Determination of Amylose and Amylopectin

Amylose was determined using iodine colorimetric method [20]. The absorbance of the solutions was measured and recorded at 620 nm using a Spectrophotometer (Shimadzu Spectrometer UV-1800). The experiment was duplicated. The concentration of amylose in the samples was determined using the calibration curve. The amylopectin content was calculated by subtracting the percentage of amylose from 100%.

2.5. Statistical and Data Analysis

Data were analyzed statistically by means of two-way analysis of variance using Statistical Package for Social Sciences (SPSS, IBM SPSS Statistics v20). All statistical tests were carried out 5 % significance level.

3. Results and Discussion

3.1. Starch Yield

Improvement of cassava is mainly based on increasing starch content and starch yield in order to ensure maximum utilization of the crop. For this reason, varieties with high starch contents and starch yield are being sought for. Starch yield is known to be affected significantly by maturity i.e. continuous ageing of cassava plant [21]. Starch yield observed from this research work was seen to be lower at the 7th month for all varieties and increased steadily and was greater in the 10th month. The yield ranged from (18.00% - 29.33%) for the various varieties at different stages of maturity (Table 1). This observation was in accordance with other research on cassava starch yield [22] in which starch yield was affected by maturity. Stage of harvest or maturity had a significant difference on starch yield ($p < 0.05$). There was no significant difference between the yields of starch for the various varieties at the same confidence level. These observations are important since starch serves as a relevant parameter for evaluation of the quality of starch-containing foods. Harvesting of the crop is often based on starch yield [23].

Table 1. Percentage Yield, Amylose and Amylopectin of Six Cassava Accessions at Different Maturity

Maturity/Cassava Accession	Yield (%)	Amylose (%)	Amylopectin (%)
Month 7			
Bankyehemma	19.33 ± 0.58^{a}	14.53 ± 0.12^{a}	85.47 ± 0.12^{c}
Ampong	19.00 ± 0.00^{a}	20.51 ± 0.87^{bc}	79.49 ± 0.87^{a}
Agra	19.67 ± 0.58^{ab}	23.16 ± 0.03^{c}	76.84 ± 0.03^{a}
Duadekpakpa	19.33 ± 0.58a	21.23 ± 1.58a	78.77 ± 1.58a
Amansen	19.00 ± 0.00a	15.95 ± 1.46a	84.05 ± 1.46a
Abrabopa	18.00 ± 1.00ab	23.89 ± 1.65a	76.10 ± 1.65a
Month 8			
Bankyehemma	22.00 ± 1.73^{bc}	22.20 ± 0.16^{bc}	77.80 ± 0.16^{ab}
Ampong	23.33 ± 1.16^{cd}	22.24 ± 2.55^{bc}	77.76 ± 2.55^{ab}
Agra	21.67 ± 1.53^{bc}	19.80 ± 0.73^{bc}	80.20 ± 0.73^{ab}
Duadekpakpa	20.00 ± 1.73^{a}	25.14 ± 2.20^{a}	74.86 ± 2.20^{a}
Amansen	23.33 ±2.08^{abc}	19.83 ± 0.15^{a}	80.17 ± 0.15^{a}
Abrabopa	18.33 ± 1.00^{abc}	17.85 ± 3.15^{a}	82.15 ± 3.15^{a}
Month 9			
Bankyehemma	25.00 ± 1.00^{d}	20.84 ± 0.71^{bc}	79.16 ± 0.71^{ab}
Ampong	24.67 ± 0.58^{cd}	19.16 ± 0.52^{abc}	80.84 ± 0.52^{abc}
Agra	23.33 ± 0.58^{cd}	21.08 ± 0.10^{bc}	78.92 ± 0.10^{ab}
Duadekpakpa	24.67 ± 1.15^{bcd}	17.95 ± 1.09^{a}	82.05 ± 1.09^{a}
Amansen	25.67 ± 1.53^{cd}	16.40 ± 2.19^{a}	83.60 ± 2.19^{a}
Abrabopa	25.00 ± 0.00^{cd}	17.68 ± 0.04^{a}	82.32 ± 0.04^{a}
Month 10			
Bankyehemma	25.67 ± 0.58^{d}	19.43 ± 0.94^{bc}	80.57 ± 0.94^{ab}
Ampong	25.00 ± 0.00^{cd}	19.62 ± 0.45^{bc}	80.38 ± 0.45^{ab}
Agra	23.67 ± 0.58^{cd}	17.52 ± 0.38^{ab}	82.48 ± 0.38^{bc}
Duadekpakpa	25.00 ± 1.00^{cd}	20.08 ± 0.40^{a}	79.92 ± 0.40^{a}
Amansen	26.66 ± 2.31^{d}	19.62 ± 0.38^{a}	80.38 ± 0.38^{a}
Abrabopa	29.33 ± 2.08^{cd}	20.12 ± 2.76^{a}	79.88 ± 2.76^{a}

Values are Mean ±SD. Mean values in the column under the same month with different superscript letter are significantly different ($p < 0.05$).

Table 2. Pasting Properties of Six Cassava Accessions at Different Maturity

Cassava Accession	Peak Viscosity (cP)	Trough (cP)	Breakdown (cP)	Final viscosity (cP)	Setback (cP)	Peak time (min)	Pasting temp (℃)
Month 7							
Bankyehemma	4290.5 ± 36.1^{a}	2419.0 ± 127.3^{b}	1817.5 ± 91.2^{ab}	3182.0 ± 128.7^{a}	763.0 ± 1.4^{ab}	4.07 ± 0.2^{a}	73.18 ± 0.7^{a}
Ampong	3904.5 ± 252.4^{a}	2199.0 ± 17.0^{ab}	1705.5 ± 235.5^{a}	2730.0 ± 84.9^{a}	531.0 ± 67.9^{a}	4.30 ± 0.2^{a}	78.33 ± 0.0^{a}
Agra	4245.5 ± 398.1^{a}	2006.0 ± 15.6^{ab}	2239.5 ± 413.7^{ab}	2736.0 ± 398.8^{a}	730 ± 414.4^{ab}	4.00 ± 0.2^{a}	76.80 ± 0.0^{a}
Duadekpakpa	4139.0 ± 265.9^{a}	2227.5 ± 137.9^{ab}	1911.5 ± 128.0^{abc}	3048.5 ± 159.1^{a}	821 ± 21.2^{ab}	4.17 ± 0.14^{a}	77.20 ± 0.57^{a}
Amansen	4080.0 ±181.0^{a}	2304 ± 69.3^{ab}	1773 ± 107.5^{ab}	2885 ± 9.9^{a}	666 ± 60.8^{a}	4.19 ± 0.12^{a}	77.30 ± 1.48^{a}
Abrabopa	3853.5 ± 16.3^{a}	2119.5 ± 118.1^{ab}	1734 ± 101.8^{a}	2816 ±19.8^{a}	696.5 ±74.2^{a}	4.27 ± 0.00^{a}	76.53 ± 0.46^{a}
Month 8							
Bankyehemma	4541.0 ± 244.7^{a}	2098.5 ± 31.8^{ab}	2442.5 ± 276.5^{ab}	2993 ± 94.1^{a}	894.5 ± 3.5^{ab}	4.17 ± 0.1^{a}	72.7 ± 0.1^{a}
Ampong	4783.5 ± 453.3^{a}	2392 ± 137.2^{b}	2391.5 ± 316.1^{ab}	3284.5 ± 334.5^{a}	892.5 ± 197.3^{ab}	4.14 ± 0.2^{a}	76.13 ± 0.3^{a}
Agra	4638.0 ± 241.8^{a}	2276 ± 21.2^{b}	2362 ± 220.6^{ab}	2959.5 ± 94.1^{a}	683.5 ± 72.8^{ab}	4.04 ± 0.1^{a}	76.13 ± 0.1^{a}
Duadekpakpa	4540.5 ±610.2^{a}	2351 ± 274.4^{ab}	2189.5 ± 335.9^{abc}	3229 ± 342.2^{a}	878 ± 67.88^{ab}	4.30 ± 014^{a}	74.45± 0.07^{a}
Amansen	4725.5 ± 201.5^{a}	2301 ± 77.8^{ab}	2424.5 ± 123.7^{c}	3263 ± 14.1^{a}	962 ± 63.6^{ab}	4.07 ± 0.19^{a}	76.00 ± 0.14^{a}
Abrabopa	4859 ± 55.2^{a}	2432 ± 72.1^{b}	2427 ± 17.0^{c}	3158 ± 176.8^{a}	726 ± 248.9^{a}	3.90 ± 0.04^{a}	74.48 ± 0.03^{a}
Month 9							
Bankyehemma	4806.5 ± 451.8^{a}	1947.0 ± 17.0^{ab}	2663.0± 62.2^{b}	3197.0 ± 213.6^{a}	1053.5 ± 68.6^{ab}	3.8 ± 0.2^{a}	71.98 ± 0.0^{a}
Ampong	4145.0 ± 70.7^{a}	1997.0 ± 73.5^{ab}	2148.0± 144.3^{ab}	2548.0 ± 36.8^{a}	551.0 ±110.3^{a}	4.34 ± 0.2^{a}	75.58 ± 0.5^{a}
Agra	4131.0 ± 77.8^{a}	2143.5 ± 145.0^{ab}	2184.0 ± 94.8^{ab}	2370.5 ± 248.2^{a}	423.5 ± 231.2^{a}	3.7 ± 0.1^{a}	74.8 ± 0.6^{a}
Duadekpakpa	4654.5 ± 30.4 ^{a}	2265 ± 33.94^{ab}	2389.5 ± 3.5^{bc}	3140 ± 148.5^{a}	875 ± 182.43^{ab}	4.165± 0.23^{a}	74.8 0± 0.57^{a}
Amansen	3994 ± 274.4^{a}	1910.5 ±0.7 ^{ab}	2083.5 ± 273.7^{abc}	2492.5 ± 88.4^{a}	582 ±87.7^{a}	4.37 ± 0.05^{a}	74.86 ± 0.60^{a}
Abrabopa	4357 ± 393.2^{a}	903.5 ± 149.9^{a}	2550 ± 243.2^{c}	2743.5 ± 224.2^{a}	936.5 ± 74.2^{ab}	3.9 ± 0.42^{a}	74.48 ± 0.12^{a}
Month 10							
Bankyehemma	4670.5 ± 451.8^{a}	2244 ± 309.7^{ab}	2426.5 ± 142.1^{ab}	3472 ± 475.2^{a}	1228 ± 165.5^{b}	3.63 ± 0.4^{a}	62.78 ± 14.0^{a}
Ampong	4148.5 ± 318.9^{a}	2095.5 ± 96.9^{ab}	2053.0 ± 415.8^{ab}	3029.5 ± 173.2^{a}	934.0 ± 76.4^{ab}	4.00 ± 0.7^{a}	73.55 ± 0.1^{a}
Agra	4078.5 ± 231.2^{a}	1728.5 ± 224.2^{a}	2350.0 ± 7.1^{ab}	2548.0 ± 267.3^{a}	819.5 ± 43.1^{ab}	3.83 ± 0.4^{a}	74.9 ± 0.6^{a}
Duadekpakpa	4206.5 ± 323.1^{a}	2115 ± 282.8^{ab}	2091.5 ± 40.3^{abc}	3099.5 ± 212.8^{a}	984.5 ±70.0^{ab}	4.34 ± 0.47^{a}	74.90 ± 0.57^{a}
Amansen	4274± 219.2^{a}	1941 ± 66.5^{ab}	2333 ±152.7^{abc}	3142.5 ±47.4^{a}	1201.5 ± 19.1^{b}	4.44 ± 0.05^{a}	74.55 ± 0.07^{a}
Abrabopa	4347.5 ± 323.1^{a}	1911 ± 165.5^{ab}	2436.5± 157.7^{c}	2849.5 ± 219.9^{a}	938.5 ± 54.4^{ab}	3.94 ± 0.47^{a}	62.73 ± 17.78^{a}

Values are Mean ±SD. Mean values in column under the same month with different superscript letter are significantly different ($p < 0.05$).

3.2. Amylose and Amylopectin Content

Amylose content is an important parameter in almost all starch properties. Low amylose contents lead to an increase in the relative crystallinity of the starch which is an effect of reduced amorphous regions in the starch granule [24]. The amylose and amylopectin of the cassava starch from the various varieties are shown in Table 1. The amylose concentrations for the different varieties ranged from (14.53% ± 0.12 - 25.14% ± 2.20) whiles the amylopectin concentrations were observed to be (74.86% ± 2.20 - 85.47% ± 0.12).

The amylose content of the varieties at different maturities did not follow any particular trend. Variety had no significant effect on the amylose and amylopectin concentrations of the cassava ($p > 0.05$). However, there was a significant difference on both amylose and amylopectin at different maturities ($p < 0.05$).

This observation was in line with a study by some researchers [23,25]. Cassava starch selection of a specific content of amylose is based on its purpose i.e. industrial or as food. Varieties with low amylose content can be used in the production of waxy-starch [26] which is used mainly in the production of adhesives and as binder whereas amylose extender mutants can be produced from those with high amylose content [27].

Amylose content of starch also affects properties such as swelling power and starch solubility of solutions made from starch, in which tend to rely on the leaching of amylose from the crystalline structure of amylopectin into the solution [28].

3.3. Pasting Properties

The viscosity of starch is an important factor for starch characterization. The variance observed in viscosity helps in cultivar selection for food and other industrial purposes. Table 2 shows the results for pasting properties of the six cassava accessions at different maturities studied. It can be observed that the peak viscosity values ranged from 3853.5 ± 16.3 cP to 4806.5 ± 451.8 cP the for six varieties namely *Bankyehemma*, *Agra*, *Ampong*, *Amansen*, *Abrabopa and Duadekpakpa*. Trough, on the other hand, ranged between 903.5 ± 149.9cP and 2419.0 ± 127.3cP. Breakdown values observed were within 1705.5 ± 235.5cP-2663.0 ± 62.2 cP whereas final viscosity ranged between 2370.5 ± 248.2 - 3472 ± 475.2 cP (Table 2).

The ability of starch to form a viscous paste is determined by the final viscosity [19]. The final viscosities observed in all accessions were low compared to the peak viscosities of the same varieties. This indicates that there is the low tendency of the cassava starch to retrograde [29]. Setback viscosity ranged from 531.0 ± 67.9 cP to 1053.5 ± 68.6 cP while peak time ranged between 3.63 ± 0.4cP - 4.37 ± 0.05cP and the range of pasting temperature was within 62.73 ± 17.78cP - 78.33 ± 0.0cP (Table 2).

Cassava starch has a low pasting temperature of 68°C averagely and that it easily forms a paste as compared to other starches like potato which has an average of 72°C [29] and an average of 69.5°C for rice [30]. This low stability of cassava starch is as a result of heating of granules which makes them lose their molecular structure easily [31]. The pasting temperature of starch from the six different varieties ranged from (62.73 ± 17.78cP - 78.33 ± 0.0 cP). This was contrary to an observation by [29] which reported that the average pasting temperature of cassava starch is 68°C. The high pasting temperature of starch indicates that it has a higher resistance towards swelling. There were no significant differences observed ($p > 0.05$) for peak viscosity, trough, breakdown, final viscosity and setback but peak time and pasting temperature had significant differences ($p < 0.05$). Differences amongst varieties in the final viscosity, on the other hand, could be a result of variances in amylose concentrations. Maturity had no significant effect on the peak time and pasting temperature.

The low peak time of starch from *Bankyehemma* at the 10^{th} month and its low pasting temperature at the same month indicate its low resistance to swelling and easy formation of paste which makes it more suitable for both food and non-food industrial processes because of a decrease in energy costs during production. High breakdown viscosity indicates the low tendency of the starch to withstand heating and shear stress during cooling. The low breakdown of *Ampong* at the 10^{th} month indicates its high stability.

4. Conclusion

The stage of harvest (maturity) had a significant effect on the starch yield of all the cassava accessions studied while variety had no significant effect. The amylose and amylopectin content of the starches also varied significantly. The pasting properties of starch from the various accessions also show that it is necessary to consider suitable maturity time to harvest each accession for specific industrial applications.

Conflict of Interest

None.

References

[1] Mweta, E. D, Physiochemical, functional and structural properties of native Malawian cocoyam and sweet potato Starches. PhD. Thesis submitted to University of Free State Bloemfontein South Africa, (2009).

[2] Tewe, O. O. and Lutaladio, N, Cassava for livestock feed sub-Sahara Africa. Rome, Italy: FAO (2004).

[3] Goel, P.K., Singhal, R.S. and Kulkarni, P.R, Studies on interactions of cornstarch with casein and casein hydrolysates. *Food Chemistry*, 64(3), (1999) pp.383-389.

[4] Sriroth, K., Piyachomwan, K., Sangseethong, K. and Oates, C, Modification of cassava starch. *Żywność Nauka Technologia Jakość. Suplement*, *4*(09), 2002.

[5] Charles A, Chang Y, Ko W, Sriroth K, Huang, T, Some Physical and Chemical Properties of Starch Isolates of Cassava Genotypes. *Starch-Stärke* 56, (2004) 413-418.

[6] Gomes, A., Mendes da Silva, C., Ricardo, N, Effects of annealing on the physicochemical properties of fermented cassava starch (polvilho azedo). *Carbohydrate Polymers* 60, (2005) 1-6.

[7] Zaidul I, Norulaini N, Omar A, Yamauchi H, Noda T, RVA analysis of mixtures of wheat flour and potato, sweet potato, yam, and cassava starches. *Carbohydrate Polymers* 69, (2007) 784-791.

[8] FAO, Agriculture and Consumer Protection, A Global Cassava Market Study, 2000. Retrieved from http://www.fao.org/docrep/007/y5287e/y5287e07.html.

[9] Mensah, A.A, Comparative evaluation of physicochemical and functional properties of cassava flour from different fertilizer protocols. Doctoral dissertation, Kwame Nkrumah University of Science and Technology. (KNUST), Kumasi, Ghana, 2013.

[10] RTIP Fact sheet, No.1, Rev. June 2002.

[11] Agyapong J. K., Extraction of cassava starch with the aid of pectrolytic enzymes from Saccharomyces cerevisiae (ATCC): Effect of cassava varietal difference on the process, Dissertation submitted to Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, 2013.

[12] Annor-Frimpong, I. E., Annan-Prah, A. and Wiredu, R, Cassava as non-conventional filler in communited meat products. *Meat Science* 44(3), (1996). 193-202.

[13] Bokanga, M, Cassava in Africa: the root of development in the twenty-first century. *Tropical Agriculture* 75(1-2), (1998) 89-92.

[14] Jobling, S, Improving starch for food and industrial applications. *Current opinion in plant biology*, *7*(2), (2004) pp.210-218.

[15] Ryu, G. H., Neumann, P. E. and Walker, C. E, Pasting of wheat flour extrudates containing conventional baking ingredients. *Journal of Food Science* 58 (3), (1993) 567-573

[16] Hong, G. P. and Nip, W. K, Functional properties of precooked taro flour in sorbets. *Food Chemistry* 36, (1990) 261-270.

[17] Lii, C., Shao, Y. and Tseng, K, Gelation mechanism and rheological properties of rice starch. *Cereal Chemistry* 78(4), (1995) 393-399.

[18] Ceballos H, Sanchez T, Morante N, Fregene M, Dufour D, Smith A, Denyer K, Perez J, Calle F, Mestres C, Discovery of an Amylose-free Starch Mutant in Cassava. (*Manihot esculenta* Crantz *J. Agric. Food Chem.* 55(18), (2006) 7469 -7476

[19] Agiriga A.N. and Iwe M.O, Influence of Time of Harvest and Variety on the Pasting Properties of Starch from Three Cassava Varieties-A Response Surface Analysis, *British Journal of Applied Science & Technology* 13(5), (2015) 1-14.

[20] B.O. Juliano, *Cereal Sci. Today* 1971, 16, 334 .

[21] 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. *Electronic J. Environmental, Agric. and Food Chem.* 8(8), (2009) 647-665

[22] Sriroth K, Santisopasri V, Petchalanuwat C, Kurotjanawong K, Piyachomkwani K, Oates C, Cassava starch granule structure-function properties; Influence of time and conditions of harvest on four cultivars of cassava starch. *Carbohydrate. Polymers.* 38, (1999) 161-170.

[23] Huang CJ, Lin MC, Wang CR., Changes in morphological, thermal and pasting properties of yam (Dioscorea alata) starch during growth. Carbohydrate Polymers 64, (2006) 524-531.

[24] Tukomane T, Leerapongnun P, Shobsngob S, Varavinit S, Preparation and Characterization of Annealed- Enzymatically Hydrolyzed Tapioca Starch and the Utilization in Tableting. *Starch-Stärke* 59, (2007) 33-45.

[25] Liu Q, Weber E, Currie V, Yada R, Physicochemical properties of starches during potato growth. *Carbohydrate Polymers* 51, (2003) 213-221

[26] Ceballos, I., Ruiz, M., Fernández, C., Peña, R. and Rodríguez, A, The in Vitro Mass-Produced Model Mycorrhizal Fungus, Rhizophagus irregularis, Significantly Increases Yields of the Globally Important Food Security Crop Cassava, 2013.

[27] Vandeputte, G.and Delcour, J, From sucrose to starch granule to starch physical behaviour: a focus on rice starch. *Carbohydrate Polymers* 58, (2004)245-266.

[28] Moore, G. R. P.; Canto, L. R.; Amante, E. G. And Soldi, V, Cassava and corn starch in maltodextrin production. *Química Nova*, São Paulo, 28 (4), (2005) 596-600.

[29] Moorthy, S, Tuber crop starches. Tech Bulletin No. 18 CTCRI, Trivandrum, 2002.

[30] Cameron, K., Wang, Y., Moldenhauer, A, Comparison of Starch Physicochemical Properties from Medium –Grain Rice cultivars Grown in California and Arkansas. *Starch-Stärke* 59, (2007) 600-608.

[31] Novelo-Cen L, Betancur-Ancona D, Chemical and Functional properties of Phaseolus lunatus and Manihot esculata starch Blends, *Starch-Stärke* 57, (2005) 431-441.