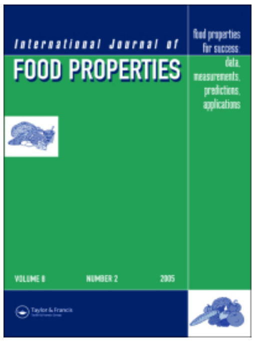

International Journal of Food Properties

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ljfp20

Physicochemical and pasting properties of flour and starch from two new cassava accessions

Raphael Aidoo, Ibok N. Oduro, Jacob K. Agbenorhevi, William O. Ellis & Nana B. Pepra-Ameyaw

INTERNATIONAL JOURNAL OF FOOD PROPERTIES
2022, VOL. 25, NO. 1, 561–569
https://doi.org/10.1080/10942912.2022.2052087

Physicochemical and pasting properties of flour and starch from two new cassava accessions

Raphael Aidoo, Ibok N. Oduro, Jacob K. Agbenorhevi, William O. Ellis, and Nana B. Pepra-Ameyaw

Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

ABSTRACT
Some new cassava accessions have been developed and released because of their high yield, resistance to disease, adaptability to wider ecological environment, and less cost of production. However, their flour and starch properties have not been characterized for potential food applications. In the present study, starch and flour were produced from two new cassava accessions (*Sika Bankye* and *Bankye Hemaa)* and evaluated for their physicochemical and pasting properties. The flour samples recorded higher values for the various functional parameters compared to their starch counterparts. Both flour samples had a similar water absorption capacity (WAC) of ~263% but the associated starch from *Bankye Hemaa* recorded the lowest value of 38.6%. *Bankye Hemaa* flour recorded the highest oil absorption capacity (OAC) (121%) and could be exploited as potential flavor retainer in products. Flour from *Bankye Hemaa* also recorded the highest swelling power (882 ± 29%), which was indicative of their good thickening and stabilizing functionalities. *Sika Bankye* starch had the highest setback viscosity (723 ± 32 RVU), which was indicative of its lower susceptibility to retrogradation and potential use in products that require highly viscous paste and processed at high temperatures.

ARTICLE HISTORY
Received 27 September 2021
Revised 2 February 2022
Accepted 7 March 2022

KEYWORDS
Sika Bankye; *Bankye Hemaa*; Physicochemical properties; Pasting properties

Introduction

Cassava (*Manihot esculenta*) is a persistent root tuber that is cultivated mostly in subtropical areas due to its presumed persistence in such areas. It is mostly grown for its enlarged roots; however, its leaves and stem can be very vital for other benefits (medicinal, food, and propagation). It is ranked as the world's sixth (6th) most important crop and the most important crop in Ghana FAO,[1] contributing about 22% of the national agricultural Gross Domestic Product[2] Some local cassava accessions include *Abasafitaa, Tek Bankye, Sika Bankye, Dabo*, and *Gblemoduade*.[3]

Cassava root, the most consumed part of cassava, is a rich source of carbohydrates, consisting of about 25–30% starch and also has a good flour yield, ranging within 10–30%.[4] The starch composition, which is converted to glucose in the body, makes it a reliable source of energy with an estimated metabolized energy of about 3000–3279 kcal/kg. It also ranks as the third largest source of energy for humans with a contemporary global dependence of about 500 million people.[5–7,8, 9]

The bulky nature and higher perishability of cassava (usually ranging from 2 to 3 days after harvesting due to post-harvest physiological deterioration) are major hitches for cassava cultivation. This demands that processing techniques are employed to reduce bulkiness for easy containment and also increase shelf life to reduce perishability, thereby maximizing its utilization and reducing post-harvest loss.[10] Cassava root is utilized as a staple food for human consumption and industrially

CONTACT Jacob K. Agbenorhevi jkagbenorhevi@yahoo.com Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

processed into flour and starch. They are less bulky and less perishable and are used as major ingredients in various food systems, though their industrial application contributes a very minute proportion to their total utilization.[11]

Cassava flour and starch are high-value cassava products with many industrial applications especially in food systems. Their effective functionalities are facilitated by their amylose (20–30%) and amylopectin (70–80%) contents.[12] Flour is utilized in the commercial production of bread, cakes, cookies, noodles, etc., due to their unique characteristics. There has also been a recent exploitation of the flour for ethanol production (with good yield, taken a proper mechanization is employed), sugar syrups, etc. Starch is commonly used in food systems as thickeners, stabilizers, and sometimes in the production of sugar syrups for use in confectioneries as sweeteners.[13]

Although cassava starch and flour have gained a fair utilization stance in various industries, the characterization of their properties is a prerequisite for their application. According to Eriksson,[14] the physicochemical and pasting properties of flour and starch are vital information that enhance their effective and appropriate application in food systems. It has also been reported by Adegunwa *et al.*[15] that the properties of cassava flour and starch differ from cassava varieties, accessions, or cultivar. A previous work showed that maturity affects the starch yield, composition, and pasting properties of the cassava accessions .[3] Some new varieties released are known to have higher yield, dry matter, resistance to African cassava mosaic disease, and are adaptable to wider ecological environments. They also form wider canopies at early stages of development and this competes favorably with weeds, thus reducing labor input and costs for farmers .[16] It is therefore essential to characterize each new accession to enhance their industrial utilization. The objective of the present study, therefore, was to characterize the physicochemical and pasting properties of flour and starch produced from these two new cassava accessions.

Materials and methods

Materials

Two cassava accessions, *Sika Bankye* and *Bankye Hemaa* were obtained from the Department of Agricultural Engineering, KNUST-Kumasi. The two accessions had 12 months maturity period and were harvested in February 2020. All the chemicals used were analytical-grade reagents.

Flour production

Flour production was done as described by Kaur *et al.*[4] About 2 kg of chunks of peeled cassava samples were washed, grated and transferred onto a drying pan and dried in an electric hot air oven dryer at 50–55°C for 24 h to ~15% moisture content. The dried grated tubers were then milled for 5 min using waring blender (Binatone, model no: BLG-555, China) regulated at 30-s interval. The milled sample was sieved with a 0.1 mm sieve and packed in Ziploc bags prior to analysis.

Starch extraction

The extraction of starch was done as described by Kaur *et al.*[4] About 2 kg of fresh tubers were peeled, washed, and grated with a metallic grater. The grated cassava was suspended into 10 L water, filtered through a double fold cheese cloth after stirring with a wooden rod for 5 min, and the filtrate was allowed to stand for 2 h for the starch to settle. The top liquid was then decanted and discarded leaving the sediment. About 5 L of water was then added to the separated sediment, stirred, and filtered again through a double fold cheese cloth. The filtrate was allowed to stand for another 2 h for the starch to settle and then decanted to remove the top liquid. The collected sediment (starch) was dried at 55°C for 1 h in an electric hot air oven dryer, milled for 5 min using a Waring blender (Binatone, model no: BLG-555, China) regulated at 30-s interval. The milled sample was sieved using a 100-μm mesh sieve and packed in Ziploc bags prior to analysis.

Physicochemical and pasting properties

Water absorption capacities (WAC) of flour and starch were determined as previously reported.[17] About 1 g of sample was mixed with 10 mL distilled water in a 15 mL graduated centrifuge tubes and then stirred on a vortex mixer for 5 min. The mixture was allowed to stand for 30 min at room temperature, centrifuged at 3000 rpm for 15 min using Hettich Zentrifugen D7200 centrifuge (Tuttlingen, Germany), and the supernatant was carefully decanted. Water absorption capacity was calculated using the equation below.

$$\mathrm{WAC}\ (\%) = \frac{\text{Weight of absorbed water}}{\text{Weight of flour}} \times 100$$

Oil absorption capacities (OAC) of flour and starch were determined as previously reported by Chandra and Samsher.[17] About 1 g of sample was dissolved in 10 mL of oil in a 15 mL graduated centrifuge tubes and then stirred on a vortex mixer for 5 min. The mixture was allowed to stand for 30 min at room temperature, centrifuged at 3000 rpm for 15 min using Hettich Zentrifugen D7200 centrifuge (Tuttlingen, Germany), and the supernatant was carefully decanted. Oil absorption capacity was calculated using the equation below.

$$\mathrm{OAC}\ (\%) = \frac{\text{Weight of absorbed oil}}{\text{Weight of flour}} \times 100$$

Swelling power and solubility index of the flour and starch were determined as previously reported Dossou *et al.*[18] Approximately 1 g of sample was mixed with 10 ml of distilled water in a 15 mL graduated centrifuge tube and heated at 85°C for 30 min in a water bath (Isotemp 205, Fisher Scientific, 255 Boulevard, Malaysia). The resulting slurries were allowed to cool to room temperature and centrifuged at 3000 rpm for 15 min using Hettich Zentrifugen D7200 centrifuge (Tuttlingen, Germany). Decanted supernatants were evaporated in an electric hot air oven at 105°C for 30 min. The dried supernatants and sediments were weighed. Calculations of swelling power and solubility index were done using the equations below.

$$(\%)\text{Swelling Power} = \frac{\text{Weight of paste}}{\text{Weight of sample}} \times 100$$

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

Amylose content was determined using the iodine colorimetric method.[19] For the standard calibration curve, about 40 mg of 66% potato amylose was weighed into a 50 mL centrifuge tube, and then 1 mL of ethanol (95%) and 9 mL of 1 N NaOH were added. The resulting solution was heated at 100°C for 10 min with the aid of a water bath, cooled, and transferred into a 100 mL volumetric flask. Distilled water was added to the solution to the 100 mL mark of the flask, sealed with a plastic cork and thoroughly mixed. Aliquots of the mixture (0.5 mL, 1.0 mL, 1.5 mL, 2.0 mL, and 2.5 mL) were pipetted into 50 mL centrifuge tubes and 0.1 mL, 0.2 mL, 0.3 mL, 0.4 mL, and 0.5 mL of 1 N acetic acid were added, respectively. For iodine color development, 1 mL of 0.2% iodine solution was pipetted into each tube and after the mixtures have been allowed to stand in a dark space for 20 min, absorbance (A) was read at 620 nm against a reagent blank using a Spectrophotometer (Mettler Toledo, UV5, China).

For the flour and starch samples, 100 mg of each sample was weighed into a 100 mL volumetric flask. Approximately 0.5 mL of 1 N acetic acid and 1 mL of 0.2% iodine were added to an aliquot of 2.5 ml of each solution and the content was mixed. Absorbance was also read at 620 nm after the solutions were allowed to stand in the dark for 20 min. Concentrations of amylose in the samples were estimated using the standard curve for potato amylose. Calculation of percentage amylopectin content was done using the equation below.

$$\text{Amylopectin}(\%) = 100 - \text{Amylose content}$$

The pasting properties of the starch and flour samples were determined following the protocol as previously reported[3,20,21] A paste was formed in pre-weighed canister from each sample using sample mass and volume of water calculated using the moisture content of the respective samples. The canister with the formed paste was fixed into the Rapid Visco Analyzer (RVA Model 4500, Perten Instruments, Australia) for analysis. Each suspension was kept at 50°C for 1 min and then heated to 95°C in 7.5 min with a holding time of 5 min followed by cooling to 50°C in 7.5 min with a 1-min holding time. The pasting parameters (Peak viscosity, Trough viscosity, Breakdown viscosity, Final viscosity, Setback viscosity) were read.

Statistical analysis

Data were analyzed statistically by means of a two-way analysis of variance using STATSGRAPHICS to compare the means of all determined parameters. All statistical tests were carried out at 95% confidence level.

Results and discussion

Physicochemical properties of flours and starches obtained from are *Sika Bankye* and *Bankye Hemaa* are presented in Table 1. Water absorption capacity (WAC) is an index of the maximum amount of water a food product absorbs and retains. In general, WAC was higher in flour samples than starches samples. *Bankye Hemaa* had the highest WAC (263.9%), and its starch had the lowest WAC (38.6%). Comparably, flour from *Bankye Hemaa* had similar WAC (263.9%) as that of *Sika Bankye* (263.2%). On the contrary, a higher WAC (40.43%) was recorded for starch from *Sika Bankye* compared to the WAC of 38.57% recorded for starch from *Bankye Hemaa*. A similar trend of results was reported by Sankhon *et al.*[22] where flours from *Parklia biglobosa* seeds had higher WAC than their respective starches of an average of 2.62 ml/g for flours and 1.39 ml/g starch in their study.

The significant difference in WAC for the starches and flours in this study may be attributed to the fact that the flours contain more water-absorbing molecules (including proteins and other carbohydrates) than the starch. The structural composition of the starch molecules may also account for the differences; thus, high-water absorption could be due to the looser structure in the starch polymer, while lower water absorption is due to a more compact starch polymer structure.[23] Other factors including varietal difference, harvesting time, and botanical source or geographical location are also known to affect WAC.[24]

An advantage of high-water absorption is its influence on easy softening, and easy, as well as increased digestibility. However, the disadvantage is that it also increases water activity, which is likely to cause food spoilage.[25,26] This implies that flours from these cassava accessions may have higher digestibility than their respective starches and higher spoilage tendencies.

Table 1. Physicochemical properties of Sika Bankye and Bankye Hemaa flour and starch samples.

Parameter	H	S	HS	SS
WAC (%)	263.9 ± 19.3^a	263.3 ± 7.2^a	38.6 ± 8.5^b	40.4 ± 2.3^b
OAC (%)	121.0 ± 13.3^a	119.0 ± 6.3^b	104.5 ± 1.5^b	87.6 ± 8.5^c
Swelling Power (%)	882.2 ± 29.3^a	765.4 ± 39.6^b	852.5 ± 48.2^a	831.1 ± 13.3^a
Solubility (%)	2.4 ± 0.3^a	4.5 ± 0.8^b	0.8 ± 0.6^c	0.8 ± 0.2^c
Amylose (%)	22.9 ± 0.7^a	23.1 ± 0.1^a	20.40 ± 0.3^a	22.0 ± 1.1^a
Amylopectin (%)	77.1 ± 0.7^a	76.9 ± 0.1^a	79.6 ± 0.3^a	78.0 ± 1.1^a

Values are presented as the Means ± SD of duplicate determinations. Means in a row with equal superscripts are not significantly different (p>0.05). WAC: Water Absorption Capacity, OAC: Oil Absorption Capacity, H: Bankye Hemaa Flour, S: Sika Bankye Flour, HS: Bankye Hemaa Starch, SS: Sika Bankye Starch.

Oil absorption capacity (OAC) is a very important parameter for determining the flavor retaining ability of flours and starches. The flour and starch samples had OAC in the range 119.02–121.01% and 87.85–104.54%, respectively. Though the flour samples had higher OAC values than the starch samples, there was, however, no significant difference ($p > 0.05$) between *Sika Bankye* flour (119.02%) and *Bankye Hemaa* starch (104.54%). The OAC of the flour samples in this study is lower compared to the reported 190–220% for some cassava flour accessions, they are, however, higher than the 61.50–72.50% reported for High Quality Cassava Flour (HQCF).[27,28] Results for the starch samples are also higher than the reported 9.20% for some cassava starches.[29]

The variations in the results may be attributed to the difference in the hydrophilic components of the samples.[17] The higher the hydrophilic components (carbohydrate and protein), the lower the OAC, and vice versa. Therefore, the flour samples may be said to be more lipophilic than the starch samples and hence their relatively high OAC. The lower OAC recorded for the starch samples could be attributed to its major components being hydrophilic (chains of glucose).

Food ingredients with high OAC are usually employed as important ingredients in lipid-based product formulation for flavor retention purposes and to enhance other organoleptic properties (mouthfeel, smoothness, etc.). High OAC ingredients also maximize the absorbance of fat soluble vitamins (A, D, E, and K) in most lipid-based fortified food products. This supposes that the flour samples could serve as better alternatives in food formulations that require good flavor retention and fat-soluble vitamin absorption for enhanced product quality.[28]

Swelling power determines the tendency of a substance to be hydrated and stands as one of the ways of measuring food quality.[30] The swelling power of the flour samples ranged from 765.4% to 882.3% with corresponding water solubility of 2.4–4.5% and the starch samples also had swelling power values that ranged from 831.1% to 852.5% with corresponding water solubility of ~0.8%. Generally, flour and starch from *Bankye Hemaa* had higher values for swelling power and lower solubility than *Sika Bankye* flour and starch. Also, while the starch samples were not significantly different ($p > 0.05$) in their respective results for swelling and solubility, it was not so for the flour samples. Oladunmoye *et al.*[31] reported in a study that swelling power and solubility index are negatively proportional. Thus, high swelling power should have a correspondingly low solubility index, which was apparent in the results shown in Table 1.

Although amylose and amylopectin ratios affect swelling and solubility, stronger intermolecular interaction and higher hydrophobicity account greatly for greater swelling power and lower solubility.[24] Flours with low solubility indices against high swelling powers are suitable for making dough with high elasticity.[32] However, flours with high swelling power and a corresponding low solubility could be utilized effectively as functional ingredients for pastry products.[33] Thus, flours and starches from *Bankye Hemaa* and *Sika Bankye* could be used in products, such as bread, pasta, and other viscous foods, because of their relatively high swelling ability and lower solubility.

Amylose and amylopectin contents are the major constituents of flour and starch, and thus, they invariably influence their structural and textural characteristics. A range of 22–23% amylose content was recorded for the flour samples, and a range of 20–22% was recorded for the starch samples. The amylopectin content also ranged from 76% to 77% for the flour samples and 78–79% for the starch samples. In both cases, there was no significant difference. The results for amylose content conform to the ~20% reported by Onitilo *et al.*,[31] the 17–22% reported by Maxiya-Dixon *et al.*,[20] and the 19–23% reported by Baah *et al.*[32] for some cassava accessions. However, the results are comparatively lower than that of some rice varieties (≥25%) and maize (~74%).[19]

Amylose and amylopectin have been reported to play integral roles in determining the functionality of flour or starch. In some cases, lower amylose can affect high swelling power and water absorption capacity. Also, flours and starches with high amylose content usually yield products, which are very hard and less sticky.[19] This implies an indelible correlation between the amylose and amylopectin content and the results obtained for the other physicochemical properties of *Bankye Hemaa* and *Sika Bankye* flour and starch. However, factors such as starch granule size, the extent of starch damage, varietal difference, lipid interruption, temperature, and so on, can greatly influence this trend.[34] With reference to a report by Thumrongchote *et al.*[35] which classified amylose into high amylose (≥24%), intermediate amylose (20–24%), and low amylose (12–20%), both flour and starch samples conform to the intermediate amylose classification and therefore can yield products with intermediate hardness and stickiness.[19] Furthermore, Trinidad *et al.*[36] recommended the consumption of a product with intermediate amylose content as it minimizes susceptibility to type 2 diabetes and other sugar-related ailments. Thus, the flour and the starch samples from *Bankye Hemaa* and *Sika Bankye* could be utilized in that regard.

The pasting properties of the flour and starch samples are as presented in Table 2. Pasting property is one vital functional property, which measures the ability of flour or starch to form a paste. It is a parameter that cannot be sidelined in the measurement of the quality of flour and starch since it dictates the textural integrity of products.[23] Peak viscosity is a measure of the highest viscosity a starch granule can attain before collapsing.[37] Peak viscosity of the flour and starch samples ranged from 3094.50 to 3134.5 RVU and 3678.5 to 3960.5 RVU, respectively, with observably high values for the starch samples. *Bankye Hemaa* starch had the highest value (3960.5 RVU), the lowest pasting time (6.70 min) and the lowest pasting temperature (69.45°C), while *Sika Bankye* flour with the lowest peak viscosity (3094.5 RVU) had the highest peak time (7.47 min) and a pasting temperature (71.23°C) which had no significant difference ($p > 0.05$) with the highest value (71.58°C for Sika Bankye starch). These results are conformable to a report by Oyeyinka *et al.*[38] which implied an inverse proportionality between peak viscosity and pasting time and also peak viscosity and pasting temperature, hence higher peak viscosities have lower pasting times and temperatures. Reportedly, higher peak viscosity ingredients have been associated with, but not limited to, weak molecular interactions between starch granules, which stimulate their susceptibility to disintegration, and this also informs the significant difference in the peak viscosity results in this study.[23,24,39] Other factors include varietal differences, processing methods and conditions, blending, and starch-hydrocolloid interactions.[40]

The breakdown viscosity shows the resilience of the paste to shear stress and the stability of the paste during thermal treatment.[24] Lower breakdown viscosity dictates the tenacity of the paste to thermal and shear interruptions, which is very vital in determining the stability of pastes.[23] The breakdown viscosity of the flour and starch samples ranged 1860.5–1919.5 RVU and 2457.00–2591.0 RVU, respectively. The results imply that the flour samples with the lowest breakdown viscosities may comparatively withstand high heat treatments and shear stress, and therefore would be more appropriate for incorporation into products that require high-temperature treatment.

High setback viscosity indicates lower susceptibility to retrogradation during cooling (the reordering of the starch granules upon cooling).[24] *Bankye Hemaa* starch had the highest setback value (723.0 RVU) and hence could be utilized as an ingredient in products that require cold temperature storage (glues, wood fillings, etc.) and also for making pasta and some highly viscous local delicacies like fufu.[24,37,39] However, the flour samples with comparatively lower setback values (391.0 RVU and 418.0 RVU for *Sika Bankye* and *Bankye Hemaa*, respectively) could also be utilized in making low viscous foods like complementary baby foods.

Table 2. Pasting properties of *Sika Bankye* and *Bankye Hemaa* flour and starch samples.

Parameter	H	S	HS	SS
Peak Viscosity (RVU)	3134.5 ± 0.7[a]	3095 ± 2[a]	3960 ± 45[b]	3679 ± 97[c]
Trough Viscosity (RVU)	1215 ± 20[a]	1234 ± 16[a]	1369 ± 7[b]	1177 ± 33[a]
Breakdown Viscosity (RVU)	1920 ± 21[a]	1861 ± 18[a]	2591 ± 52[b]	2457 ± 0[c]
Final Viscosity (RVU)	1633 ± 62[a]	1625 ± 6[a]	2092 ± 40[b]	1750 ± 86[a]
Setback Viscosity (RVU)	418 ± 42[ab]	391 ± 21[a]	723 ± 33[c]	573 ± 52[bc]
Pasting time (min)	7.2 ± 0.1[a]	7.5 ± 0.1[a]	6.7 ± 0.0[b]	6.9 ± 0.0[b]
Pasting Temperature (°C)	70.7 ± 0.0[a]	71.2 ± 0.2[ab]	69.5 ± 0.3[c]	71.6 ± 0.3[b]

Values are presented as the means ± SD of duplicate determinations. Means in a row with the same superscript are not significantly different ($p>0.05$). H: Bankye Hemaa Flour, S:Sika Bankye Flour, HS: Bankye Hemaa Starch, SS: Sika Bankye Starch

Final viscosity of the flour and starch samples also ranged 1625–1633 RVU and 1749–2092 RVU, respectively. Final viscosity describes the viscosity of the paste after the entire cooking and cooling process or the viscosity in actual use.[38] With *Sika Bankye* having the highest final viscosity (2092.0 RVU), it could ensure a consistent stability of products when used as a food ingredient for thickening and stabilizing roles.

It is noteworthy that the findings from this study are variable as compared to the properties of flour and starch of the existing cassava varieties/accessions previously reported.[3] However, the new cassava accessions released were on the premise of their high yield, environmental adaptability, and less cost of production. Therefore, from a production and sustainability point of view, these new accessions present an appreciable opportunity to contribute to food security when their flours or starches are utilized for respective potential food and industrial applications.

Conclusion

The flours and starches of *Sika Bankye* and *Bankye Hemaa* had intermediate amylose content. The flour samples had relatively high swelling power, water absorption capacity, and oil absorption capacity, which may be exploited as thickeners or stabilizers, humectants, and flavor retainers in products. The pasting characteristics exhibited by *Sika Bankye* starch suggest its potential use as an ingredient in products that can bear on their characteristic consistency for long.

Acknowledgments

The authors are grateful to Prof. Emmanuel Bobobee (Department of Agricultural Engineering, KNUST) for the kind donation of the new cassava accessions used in the study.

Disclosure statement

The authors declare there is no conflict of interest.

ORCID

Jacob K. Agbenorhevi http://orcid.org/0000-0002-8516-7656

References

[1] FAO. 1977. Cassava Processing. *(Online)* FAO Plant Production and Protection. http://www.fao.org/3/x5032e/x5032e06.htm#cassava%20starch%20and%20its%20ses (Accessed 19/11/2019)

[2] Diao, X. Economic Importance of Agriculture for Sustainable Development and Poverty Reduction: Findings from a Case Study of Ghana. *Working Party Agric. Policy Markets*. 2010, *2*(11), 1–75.

[3] Williams, G.; Ansah, K. O.; Agbenorhevi, J. K.; Oduro, I. N.; Bobobee, E. Characterization of Starch from New Cassava Accessions at Different Maturity. *J. Food Security*. 2019, *7*(5), 170–174.

[4] Kaur, K. E.; Ahluwalia, P.; Singh, H. Cassava: Extraction of Starch and Utilization of Flour in Bakery Products. *Int.J. Food Ferment. Technol.* 2016, *6*(2), 351.

[5] Buitrago, J. A.; Ospina, B.; Gil, J. L., and Aparicio, H. Cassava Root and Leaf Meals as the Main Ingredients in Poultry Feeding: Some Experiences in Columbia. In Proceedings of the 7th Regional Cassava Workshop, Bangkok, Thailand. 2002, 1(1), 523–541.

[6] Egena, S. S. A. 2006. Effect of Different Hydrocyanic Acid Consumption on Nutrient Digestibility in Broilers Fed Cassava Flour Meal. In: Proceedings of 11th Annual Conference of Animal Science of Nigeria (ASAN), pp. 18–21.

[7] Falade, K. O.; Akingbala, J. O. Utilization of Cassava for Food. *Food Rev. Int.* 2011, *27*(1), 51–83.

[8] Olugbemi, T. S.; Mutayoba, S. K.; Lekule, F. P. Effect of Moringa (*Moringa Oleifera*) Inclusion in Cassava Based Diets Fed to Broiler Chickens. *Int. J. Poultry Sci.* 2010, *9*(4), 363–367.

[9] Onitilo, M. O. E.; Sanni, L. O.; Daniel, I.; Maziya-Dixon, B.; Dixon, A. Physicochemical and Functional Properties of Native Starches from Cassava Varieties in Southwest Nigeria. *J. Food Agric. Environ.* 2007, *5*(4), 108–114.

[10] Kusumayanti, H.; Handayani, N. A.; Santosa, H. Swelling Power and Water Solubility of Cassava and Sweet Potatoes Flour. *Proc.Environ. Sci.* 2015, *23*, 164–167.
[11] Naziri, D.; Quaye, W.; Siwoku, B.; Wanlapatit, S.; Viet Phu, T.; Bennet, B. The Diversity of Postharvest Losses in Cassava Value Chains in Selected Developing Countries. *J. Agric. Rural Develop. Tropics Subtropics*. 2014, *115*(2), 111–123.
[12] Taghvaei, S.; Motiee, F.; Shakeri, E.; Abbasian, A. Archive of SID Effect of Amylose / Amylopectin Ratio on Physico-mechanical Properties of Rubber Compounds Filled by Starch Archive of SID. *J. Appl. Chem. Res.* 2010, *4* (14), 53–60.
[13] Li, S.; Cui, Y.; Zhou, Y.; Luo, Z.; Liu, J.; Zhao, M. The Industrial Applications of Cassava: Current Status, Opportunities and Prospects. *J. Sci. Food Agric.* 2017, *97*(8), 2282–2290.
[14] Eriksson, E. Flour from Three Local Varieties of Cassava (Manihot Esculenta Crantz): Physico- Chemical Properties, Bread Making Quality and Sensory Evaluation Evaluation. *Swedish Univ. Agric. Sci.* 2013, *371*, 1–41.
[15] Adegunwa, M. O.; Sanni, L. O.; Maziya-Dixon, B. Effects of Fermentation Length and Varieties on the Pasting Properties of Sour Cassava Starch. *Afr. J. Biotechnol.* 2011, *10*(42), 8428–8433.
[16] WAAPP. 2022. Cassava. http://waapp.org.gh/released-technologies/cassava
[17] Chandra, S.; Samsher, E. S. E. Assessment of Functional Properties of Different Flours. *Afr. J. Agric. Res.* 2013, *8* (38), 4849–4852.
[18] Dossou, V. M.; Agbenorhevi, J. K.; Alemawor, F.; Oduro, I. Physicochemical and Functional Properties of Full Fat and Defatted Ackee (*Blighia Sapida*) Aril Flours. *Am. J. Food Sci. Technol.* 2014, *2*(6), 187–191.
[19] Gandebe, M.; Ngakou, A.; Ndojouenkeu, R. (2017) Changes in Some Nutritional and Mineral Components of Nerica Rice Varieties as Affected by Field Application with Mycorrhiza and Chemical Fertilizer in Northern Cameroon. pp. 823–839.
[20] Maziya-Dixon, B.; Adebowale, A. A.; Onabanjo, O. O.; Dixon, A. G. O. Effect of Variety and Drying Methods on Physico-chemical Properties of High Quality Cassava Flour from Yellow Cassava Roots. *Int. Inst. Trop. Agric.* 2005, *7*(1), 635–641.
[21] Ofori, J.; Tortoe, C.; Agbenorhevi, J. K. Physicochemical and Functional Properties of Dried Okra (*Abelmoschus Esculentus L.)* Seed Flour. *Food Sci. Nutr.* 2020, *8*, 4291–4296.
[22] Sankhon, A.; Amadou, I. E.; Yao, W. R.; Wang, H.; Qian, H.; Sangare, M. Comparison of Physicochemical and Functional Properties of Flour and Starch Extract in Different Methods from Africa Locust Bean (Parkia Biglobosa) Seeds. *Afr. J. Traditional Complementary Altern. Med.* 2014, *11*(2), 264–272.
[23] Adebowale, A. A.; Sanni, L. O.; Onitilo, M. O. Chemical Composition and Pasting Properties of Tapioca Grits from Different Cassava Varieties and Roasting Methods. *Afr. J. Food Sci.* 2008, *2*(1), 77–82.
[24] Falade, K. O.; Okafor, C. A. Physical, Functional, and Pasting Properties of Flours from Corms of Two Cocoyam (Colocasia Esculenta and Xanthosoma Sagittifolium) Cultivars. *J. Food Sci. Technol.* 2015, *52*(6), 3440–3448.
[25] Ijarotimi, O. S.; Keshinro, O. O. Comparison between the Amino Acid, Fatty Acid, Mineral and Nutritional Quality of Raw, Germinated and Fermented African Locust Bean (*Parkia Biglobosa*) Flour. *Acta Scientiarum Polonorum Technologia Alimentaria*. 2012, *11*(2), 151–165.
[26] Ocheme, O.; Oloyede, O.; Mahmud, A. H. Production and Evaluation of Bread Using Blends of Wheat Flour and Fermented Plantain Flour. *Niger. Food J.* 2010, *28*, 284–293.
[27] Adebowale, A. A.; Sanni, S. A.; Koleoso, Y. S. Chemical and Functional Qualities of High Quality Cassava Flour from Different SMEs in Nigeria. *Afr. J. Root Tuber Crops*. 2011, *9*(1), 11–16.
[28] Eleazu, O. C.; Eleazu, K. C.; Kolawole, S. Use of Indigenous Technology for the Production of High Quality Cassava Flour with Similar Food Qualities as Wheat Flour. *Acta Scientiarum Polonorum Technologia Alimentaria*. 2014, *13*(3), 249–256.
[29] Eke-Ejiofor, J.; Owuno, F. The Functional Properties of Starches, Physico-Chemical and Sensory Properties of Salad Cream from Cassava and Potatoes. *Int. J. Nutr. Food Sci.* 2014, *3*(6), 567.
[30] Adams, Z. S.; Wireko-Manu, F. D.; Agbenorhevi, J.; Oduro, I. Improved Yam-Baobab-Tamarind Flour Blends: Its Potential Use in Extrusion Cooking. *Sci Afr.* 2019, *6*, 1–15.
[31] Oladunmoye, O. O. E.; Aworh, O. C.; Maziya-Dixon, B. E.; Ochuko, L. E.; Gloria, N. Chemical and Functional Properties of Cassava Starch, Durum Wheat Semolina Flour, and Their Blends. *Food Sci. Nutr.* 2014, *2*(2), 132–138.
[32] Baah, F. D.; Oduro, I.; Ellis, W. O. Evaluation of the Suitability of Cassava and Sweet Potato Flours for Pasta Production. *J. Sci. Technol.* 2005, *25*(1), 16–24.
[33] Mensah, A. A. 2013. Comparative Evaluation of Physicochemical and Functional Properties of Cassava Flour from Different Fertilizer Protocols. Published Thesis (MPhil.), Kwame Nkrumah University of Science and Technology, Ghana. 75–80.
[34] Nuwamanya, E.; Baguma, Y.; Emmambux, N.; Rubaihayo, P. Crystalline and Pasting Properties of Cassava Starch are Influenced by Its Molecular Properties. *Afr. J. Food Sci.* 2011, *4*(1), 8–15.
[35] Thumrongchote, D.; Suzuki, T.; Laohasongkram, K.; Chaiwanichsiri, S. Properties of Non-Glutinous Thai Rice Flour: Effect of Rice Variety. *Res. J. Pharm. Biol. Chem. Sci.* 2012, *3*, 150–164.

[36] Trinidad, T. P.; Mallillin, A. C.; Encabo, R. R.; Sagum, R. S.; Felix, A. D.; Juliano, B. O. The Effect of Apparent Amylose Content and Dietary Fibre on the Glycemic Response of Different Varieties of Cooked Milled and Brown Rice. *Int. J. Food Sci. Nutr.* 2013, *64*(1), 89–93.
[37] Awolu, O. O.; Olofinlae, S. J. Physico-chemical, Functional and Pasting Properties of Native and Chemically Modified Water Yam (Dioscorea Alata) Starch and Production of Water Yam Starch-based Yoghurt. *Starch/Staerke*. 2016, *68*(7–8), 719–726.
[38] Oyeyinka, S. A.; Adeloye, A. A.; Olaomo, O. O.; Kayitesi, E. Effect of Fermentation Time on Physicochemical Properties of Starch Extracted from Cassava Root. *Food Biosci.* 2020, *33*(1), 1–8.
[39] Aryee, F. N. A. E.; Oduro, I.; Ellis, W. O.; Afuakwa, J. J. The Physicochemical Properties of X Our Samples from the Roots of 31 Varieties of Cassava. *Food Control*. 2006, *17*(11), 916–922.
[40] Bawa, N. M.; Agbenorhevi, J. K.; Kpodo, F. M.; Sampson, G. O. Pasting Properties of Starch-Okra Pectin Mixed System. *CyTA-J. Food*. 2020, *18*(1), 742–746.