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Evaluation of Physicochemical, Functional and Morphological Characteristics of Starch Extracted from Defatted Conophor Seed (*Tetracarpidium conophorum*)

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Authors' contributions

This work was carried out in collaboration among all authors. Author OYO analyzed and interpreted the physicochemical composition and functional parameters of the starch. The starch pasting properties, Freeze-thaw stability, in-vitro digestibility, Amylose and amylopectin contents were interpreted by Authors IBO, OSI and SAA. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Starch is the main carbohydrate store for numerous crops and each crop has distinct and unique characteristics. This study was aimed at investigating the physicochemical composition, functional properties and morphological characteristics of starch extracted from defatted Conophor seed flour.

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Place and Duration: Food Chemistry Laboratory, Department of Food Science and Technology, and Biochemistry Laboratory of the Federal University of Technology, Akure, from March 2023 to September 2023.
Methodology: Conophor seeds were washed, shelled manually, oven dried, milled into coarse flour and then defatted using solvent extraction method with the use of a soxhlet extractor. The defatted flour was air dried and grounded into fine powder. Starch was extracted by sedimentation at pH 11.0 and then oven dried and grounded into powder. The physicochemical composition, functional properties and morphological characteristics of Conophor starch were studied.
Results: The physicochemical study shows that Conophor starch was abundant in carbohydrate (77.26%) but had a low protein (4.46%), fat (1.99%) and fibre (1.20%) content. Mineral content of the starch were high with calcium (194.17mg/g), copper (0.05mg/g), manganese (0.42mg/g), magnesium (4.26mg/g), iron (0.34mg/g), zinc (1.59mg/g), phosphorus (26.1mg/g), sodium (23.20mg/g) and potassium (37.13mg/g). The functional property of Conophor starch showed a high water absorption capacity (513.33%), oil absorption capacity (347.57%), emulsion capacity (45.48%), emulsion stability (50.00%), swelling index (246.67%), gelation capacity (12.00m/v) and low foaming capacity (12.69%) and foaming stability (3.26%). Conophor starch had a low pasting property with peak viscosity (14.00 RVU), final viscosity (16.00 RVU) and set-back viscosity (4.00 RVU).
Conclusion: The study showed Conophor starch to be a rich source of mineral which makes it suitable for use as a supplement and its functional property makes it capable to be used in some industrial processes. However, the low paste quality of the starch renders it unsuitable for use in food processes that requires high paste formation but may be considered suitable for use in non-food related industries.

Keywords: Starch; extraction; physicochemical; morphological; characteristics.

1. INTRODUCTION

Traditional food is a significant part of African culture and history. Conophor (*Tetracarpidium conophorum*), a member of family Euphorbiaceae is a climber found in the wet parts of Africa especially in Nigeria. The seeds are planted and usually cooked before consumption [1]. Conophor is a legume seed with high amino acid and caloric values [2]. It is rich in protein and a good source of oil that can be incorporated into some poor nutritional food which can be of great benefit to people with very low nutritional status. It has also been stated that Conophor seed has the highest antioxidant activity among plants or legume species [3]. Conophor seed possesses phytochemicals such as phenolic compound, flavonoids and luteolin and also known to be a rich source of minerals. Increase in its consumption has been considered good for human health [4].

Naturally, Starch is an insoluble, non-structural carbohydrate found in plants like Conophor seed in small granules or cells that are produced and stored in tissues of green plants. It is a common carbohydrate in human diet and used as a renewable raw material in industries [5]. Although majorly used in the food industry, gradual advancement in technology has led to its steady relevance in many other sectors such as health and medicine, textile, paper, fine chemicals, petroleum engineering, agriculture, and construction engineering [6].

Starch granules have two polysaccharide polymers which include amylose and amylopectin. Starches extracted from different plants vary in terms of functional properties such as final viscosity of paste or paste stickiness and the end uses. The structure of starch also affects its digestibility in human gut. Starch with reduced digestibility like amylose starches are highly valued because of its health-promoting factors which can be used to prevent against condition such as colorectal cancer and diabetes [7]. Starch can be used as a food additive to control the uniformity, stability and texture of soups and sauces, to resist the gel breakdown during processing and to raise the shelf life of products [8].

The composition and structural differences in starches from diverse sources determines its properties and mode of interactions with other components of foods that gives the final product the desired taste and texture. Therefore, understanding the physico-chemical, functional and morphological structures of starch extracted from defatted Conophor seeds is of great

importance to help determine its potential use in the food industry and to give an insight into the necessity for modification.

2. MATERIALS AND METHODS

2.1 Acquisition of Materials

Conophor seeds were obtained from the Oje farm in Ibadan, Oyo State, Nigeria. The seeds were authenticated at the Department of Crop, Soil and Pest Management, Federal University of Technology, Akure.

2.2 Sample Preparation

2.2.1 Production of defatted conophor flour

The Conophor seeds were washed thoroughly and shelled manually to remove the kernel from the seeds. The removed seeds were washed and sliced (2-3mm) for easy drying. The shredded Conophor seeds were oven dried at 70 ºC for 24 hours and milled into flour according to the method of Barber and Obinna-Echem [9]. The oil of the milled flour was then extracted by solvent extraction method using n-hexane to obtain the defatted flour.

2.2.2 Extraction of starch from defatted conophor flour

Starch was extracted from defatted Conophor flour by method of Muazu et al. [10] with slight modification. Defatted Conophor flour was allowed to soak in distilled water and then sieved. 0.1M sodium hydroxide was added to the mixture to increase pH level to 11.0 in other to separate starch from protein materials and to neutralize the slight acidity. The starch was allowed to settle and Excess sodium hydroxide was removed by washing several times with distilled water in other to bring the pH down to neutral (7.0). The clear supernatant fluid was poured away and sediment starch was collected on a tray and air-dried. Dried starch lump was well grounded, sieved and packaged in an airtight container.

2.2.3 Proximate composition of conophor starch

Proximate composition was evaluated in terms of moisture content, crude protein, fat, ash content, crude fiber and carbohydrate content according to the standard methods [11].

2.2.4 Determination of mineral composition of conophor starch

The mineral composition of the defatted Conophor starch was carried-out by ashing (dry ashing). The atomic absorption spectrophotometer (Buck Scientific, 2004) was used in the determination of the concentration of the minerals. The Standard Association of Official Analytical Chemistry [11] were adopted for estimating calcium, copper, magnesium, manganese, iron, phorsphorus, zinc, potassium and sodium content.

2.3 Determination of the Functional Properties of Conophor Starch

2.3.1 Bulk density

Bulk density was determined according to the method of Asoegwu et al. [12]. Starch sample was placed in a 50ml graduated cylinder and packed by gently tapping the cylinder on the bench top 10 times and the volume of the sample was recorded. The procedure was repeated three times for each sample and the bulk density was computed as g/ml of the sample.

Bulk density (g)= [(Weight of sample (g) / Volume of sample (ml)]

2.3.2 Water absorption capacity (WAC)

Water Absorption Capacity is an index of the amount of water retained within a food matrix under certain conditions. It usually refers to entrapped water but includes bound water and hydrodynamic water and depends upon the condition of determination. It was determined using the procedure of Sathe et al. [13] as modified by Adebowale et al. [14]. Ten (10) ml of distilled water was added to 1.0 g of starch flour sample, the suspension was stirred using magnetic stirrer for 3 minutes. The suspension was transfer into a centrifuge tube and centrifuged at 3,500 rpm for 30 minutes. The supernatant obtained was measured using a 10ml measuring cylinder. The density of water was assumed to be 1g per ml. The water absorbed by the sample was calculated as the difference between the initial water used and the volume of the supernatant obtained after centrifuge. The result was express as a percentage of water absorbed by the blends on %g/g basis.

% WAC = (Weight of water absorbed × Density of water) / (Weight of sample) × 100

2.3.3 Oil absorption capacity (OAC)

Oil Absorption Capacity is an index of the amount of oil retained within a protein matrix under certain condition. It was determined using the method of Sathe and Salunkhe [15] as modified by Adebowale et al. [14]. Ten (10) ml of oil of known specific gravity was added to 1 g of starch flour in a beaker. The suspension was stirred using magnetic stirrer for 3 minutes. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 minutes and the supernatant was measured into a 10 ml graduated cylinder. The density of oil was 0.931 g/ml. The oil absorbed by the flour was calculated as the difference between the initial volume of the oil and the volume of the supernatant.

% OAC = (Volume of oil absorbed × Density of oil) / (Weight of sample) × 100

2.3.4 Swelling index determination

The swelling index of flour samples were determined by the method of Ukpabi Ndimele [16]. Ten (10) g of the Starch flour was weighed and poured into a 100 ml measuring cylinder and the initial volume was taken. Sixty (60) ml of water was then added and allowed to stand for 4h after stirring and then the level of swelling was observed.

Swelling index = (Volume after soaking – Volume before soaking) / (Weight of sample)

2.3.5 Foaming capacity and stability

The method of Coffman and Garcia [17] was used with slight modification in the determination of foaming capacity and stability of the flour samples. 1g of starch flour was dispersed in 50 ml distilled water. The resulting solution was vigorously whipped for ten minutes in a Kenwood blender and then poured into a 100 ml graduated cylinder. Volume was recorded before and after whipping and the % volume increase was calculated according to the following equation. Foaming stability was determined as the volume of foam that remained after 8 hours expressed as a percentage of the initial foam.

% Volume increase = (Volume after – Volume before) / (Volume before) ×100

2.3.6 Emulsion capacity and stability

Emulsion capacity and stability was studied using the method described by Beuchat [18].

Two grams (2g) of starch flour sample was blended in a Kenwood blender (Model A907D, U.K) with 100ml of distilled water for 30 sec at high speed. After complete dispersion, vegetable oil (corn oil) was added continuously in 5ml portions from a burette. Blending continued until the emulsion breakpoint (separation into two layers) was reached. The emulsion capacity was determined at room temperature (30±2ºC) and the emulsion capacity was calculated using the formula shown below:

Emulsion Capacity (%) = [(Height of emulsion layer) / (Height of the content of the tube)] x 100

The stability of the emulsion was evaluated by keeping the emulsion at room temperature (30±2ºC) for 2h, noting the separation of water in the graduated cylinders, the emulsion stability was calculated using the equation;

mulsion Stability (%) = [(Volume of water separated) / (Total Volume of liquid)] x 100

2.4 Gelation Capacity (GC)

The gelation property of the starch flour sample was determined by employing the method of Adebowale et al. [14]. A sample suspension of 2 to 20% (w/v) was prepared in 5 ml distilled water. The test tube containing this suspension was heated for 1 h in boiling water (100°C), followed by rapid cooling in ice. The test tube was then cooled for 24 h at 4 °C. The least gelation concentration (LGC) was determined as the concentration when the sample from inverted test tube did not slip or fall.

2.4.1 Swelling power and Solubility

The swelling power and solubility determination was carried out at temperature 30, 50, 70 and 90ºC respectively, using the method of Waliszewski et al. [19] with slight modification. Four suspensions of starch (1% w/w) were prepared in a centrifuge tube. The suspensions were heated to 30,50,70, and 90ºC, respectively, for 30 min, shaking after every 5min, and left to cool to room temperature, then centrifuged for 15

min at 3000 × g. The supernatant was decanted, and the residual volume was determined. The solid part was dried in an oven for 2 h at 110ºC.

2.4.2 Freeze-thaw stability

The procedure described by Simi and Abraham [20] was used to determine the freeze-thaw stability. Six percent (6%) starch suspension was held at 95ºC for 15 min in a water bath (Digital water Bath-hilmedics H-420), cooled to 50ºC, and kept at this temperature for 15 min. Aliquot of 50mL was sampled into centrifuge tubes and kept at 4ºC for 24h and 48h. Thereafter, samples were centrifuged at 604 g for 10 min and the amount of water separated from the starch gel too was measured. Syneresis (%) was computed using the formula:

$$\text{Syneresis} = \left[\frac{\text{weight of supernatant}}{\text{weight of sample}} \times 100\right]$$

2.4.3 Pasting property

The pasting property of the defatted Conophor starch was assessed using the RVA (Rapid Visco Analyzer).

2.5 The Amylose and Amylopectin of Conophor Starch

Amylose content of tiger nut starches was determined following the method described by Zhu et al. [21]. One hundred milligram of starch was weighed into a 100mL standard bottle and washed with 1 mL of 95% ethanol, followed by 9 mL of 1 N NaOH. The suspension was heated in a boiling water bath for 15 min, with continual shaking. Thereafter the solution was allowed to cool to room temperature and made up to the mark with distilled water. An aliquot (5 mL) of this solution was pipette into a separate 100 mL standard bottle; 1 mL of 1Macetic acid was added followed by 2 mL of iodine solution (0.2 g I + 2 g KI in 100 mL solution), before making up to the mark with distilled water. The resulting solution was mixed thoroughly and allowed to stand for 20 min for color development. The absorbance of the solution was measured at 620 nm using a UV-VIS spectrophotometer (Cecil Instruments, England).

2.6 In-Vitro Starch Digestibility

The *in vitro* starch digestibility was estimated by the method described by Singh et al. [22]. Fifty milligram of the sample was dissolved in 1.0 ml of 0.2 M phosphate buffer (pH 6.9). Twenty milligram of pancreatic α amylase and amyloglucosidase were dispersed in 50 ml of the same buffer and 0.5 ml of both the sample and the enzymes were added to the sample suspension and incubated at 37ºC for 2 h. About 2 ml of 3-5 dinitrosalicyclic acid (10% acqeous solution) was added and the combination was heated for 5 min in a water bath. Upon cooling, the solution was made up to 25 ml with distilled water and filtered before measurement of absorbance at 540 nm. A blank was run simultaneously by adding 3-5 dinitrosalicyclic acid first to the same suspension before the addition of the enzyme solution and incubated at 37ºC for 2 h. Maltose was used for the standard curve determination and the *in vitro* starch digestibility values were expressed as mg/ g (concentration) of the starch present in the sample.

2.7 Colour Attributes of Conophor Starch

Colour was determined using a colour meter PCE-CSM 2 (Deutschland GmbH) connected to a CQCS3 software (PCE Instruments UK Ltd, United Kingdom). Whiteness Index (WI) was calculated as follows**:**

$$WI = [(100 - L^{*})^{2} + a^{*2} + b^{*2})^{1/2}]$$

Where,

WI = Whiteness index,
L = Lightness
a = Green to red
b = Blue to yellow

2.8 Scanning Electron Microscopy (SEM) of Conophor Starch

The granular morphology of Conophor starch was characterized by using SEM (JEOL JSM-6390, Tokyo, Japan). The starch was first coated with platinum before imaging at a voltage of 3.0 kV and X1200 magnification.

2.9 Statistical Analysis

Statistical analysis was done using IBM SPSS Statistics software version 21. Analysis of variance (ANOVA) was used to compare the mean values of the flour blend at $p<0.05$.

3. RESULTS and DISCUSSION

Table 1 shows the proximate compositions of Conophor starch. Moisture content obtained from

Conophor starch was 12.10%. The result obtained is higher than that of Wayah and Safiya [23] who examined the nutritional component of tiger-nut starch. Moisture plays an important role in product storage stability. The result obtained in milled food products with moisture less than 13% are considered to be stable from moisture deterioration [24].

Table 1. Proximate composition of Conophor Starch

Variables	% Amount
Moisture (%)	12.10±0.19
Protein (%)	4.46±0.07
Fat (%)	1.99±0.01
Fibre (%)	1.20±0.18
Ash (%)	2.99±0.05
Carbohydrate (%)	77.26±0.50

Values are expressed as mean ± standard deviation of triplicate readings.
Means with different letters in the same column are significantly different in the same column at the p≤0.05 level.

The value of protein content of Conophor starch was found to be 4.46%. Proteins as reported by Okoli et al. [25] are made up of amino acids. The value obtained is higher than the protein obtained from cassava starch as reported by Ogunbode et al. [26].

The amount of crude fat in Conophor starch is 1.99%. The amount of fat content in food determines its shelf-life. An increase in the amount of fat composition in food could speed up food spoilage by promoting rancidity which could result to the production of off-flavours and odours. Also, diet high in fat predisposes consumers to different illnesses like obesity, heart diseases [27]. Therefore, Conophor starch is free from oil related spoilage.

The value of Ash content obtained from Conophor Starch in the study as shown in Table 1 is 2.99%. The percentage of ash content from this study is lower than that of cassava starch reported by Ogunbode et al. [26]. The amount of ash present in a food material could be used as a measure of the percentage mineral constituent of the food since ash is the inorganic residue remaining after water and organic matter have been removed by heating in the presence of an oxidizing agent [28].

Crude fibre value (1.20%) in Conophor starch was higher than (0.5.00%) reported by Zubair et al. [29]. Crude fibre content is an intrinsic component of diet, it increases stool bulk and decreases the time waste materials spend in the gut.

The carbohydrate content of Conophor starch obtained was 77.26%. The carbohydrate content obtained was higher compared to the sample reported by Zubair et al. [29].

Table 2 shows mineral compositions of Conophor starch. It was observed that Conophor starch has Calcium (194.17mg/g), Magnesium (4.26mg/g), Copper (0.05mg/g), Manganese (0.42 mg/g), Iron (0.34 mg/g), Zinc (1.54 mg/g), Phosphorus (26.10 mg/g), Sodium (23.2 mg/g) and Potassium (37.13 mg/g). Studies have reported that Zinc, Magnesium and Calcium play a vital role in glucose metabolism. They serve as co-factors for enzymes involved in glucose metabolism which can increase the insulin action by activation of insulin receptor [30,31]. Mineral elements are very important in metabolic processes in maintenance of osmotic pressure, regulating muscle contractions, transmitting of impulses, acid-base balance, absorption of glucose, bone formation, etc. [32]. Potassium plays vital role in amino acid and protein synthesis [33]. The molar ratio of Na/K in the Conophor starch is within the recommended value of (< 1.0); hence, it may be recommended for people with high blood pressure. The Ca/P molar ratio of Conophor starch is 7.44; this implies that the Ca/P molar ratio of Conophor starch is within FAO recommendation (>1.0). Therefore, Conophor starch can serve as calcium booster to prevent osteoporosis in an adult and ricket in children. Food is considered ‘good’ if Ca/P ratio is above one and poor if the ratio is less than 0.5, while Ca/P ratio above two helps to increase the absorption of calcium in the small intestine [34].

Table 3 shows the functional properties of Conophor starch. The bulk density of Conophor starch is 0.42 g/ml. The result obtained from this study is low compared to the report by Zubair et al. [29]. It has been reported that food with low bulk density can be used as food complement [35]. It enhances easy digestibility in children with immature digestive system [36]. The water absorption capacity of Conophor starch obtained was 513.33%. Water absorption capacity in food indicates the amount of water content it can absorb and retain. It also enhances food digestibility [37]. Excessive amount of water can cause food to deteriorate which could result in

spoilage [38]. The value of oil absorption capacity obtained for Conophor starch as shown in Table 3 is 347.00% which is higher than that of banana and plantain starch reported by Olatunde et al. [39]. It has been reported that high oil absorption capacity promotes flavour and mouth feel when used in food preparation [40]. The value of foaming capacity from this study is 12.69%. The foaming capacity of Conophor starch was well compared with 14.363% obtained from open sun-dried cassava starch and higher than 11.417% obtained from solar drying of cassava starch respectively [41]. The foam capacity of all starch can be rated as low since they do not contain considerably high amount of protein as foaming capacity is influenced by the surface activity of proteins [41]. Foaming stability of Conophor starch 3.26% is lower than 60.193% obtained for oven dried cassava starch reported by Robert [41]. Emulsion capacity (EC) is related to the amount of oil, non-polar amino acid residue present on the surface of protein, water and other components in the food. Conophor starch has emulsion capacity content of 45.48% which is lower compared to other foods; this may be because starches are polysaccharides that mostly act as stabilizer in emulsions by enhancing the viscosity of the aqueous phase [42]. The value of emulsion stability obtained from Conophor starch is 50.00%. Emulsion stability is the measure of the steadiness of emulsion formed by protein. The nature of proteins with the composition of charged, non-charged polar and non-polar amino acids make them potential emulsifiers and surfactants that possesses both hydrophilic and hydrophobic properties and are able to interact with both water and oil components in food systems [43]. The percentage swelling index of Conophor starch is 246.67%. The swelling index shows the degree of exposure of the internal structure of starch granules to action of water. It is a measure of the hydration capacity [44]. The gelation capacity obtained for Conophor starch was 12.00%. Gelation capacity is the formation of gel from a food system that has biopolymers [45,46] such as starch, protein etc. Gelation properties are dependent on the nature of the protein and other non-protein component in a food sample [47].

Table 4 shows the pasting properties of Conophor starch. Pasting property of a food material is the changes that take place in food when heat is applied in the presence of water. The texture, digestibility and end use of the food product may be affected [48]. Peak viscosity of Conophor starch flour was 14.0 RVU, the value is lower than 270.5 RVU [49] reported for native tigernut starch. Peak viscosity is the maximum viscosity attainable soon after or during cooking. It is an indication of water binding capacity of the starch [50]. Peak viscosity indicates the strength of the paste formed from gelatinization during food processing. High peak viscosity corresponds to high thickening power of starch [51]. The result for peak viscosity of Conophor starch in this study suggests low thickening capacity. The setback value for Conophor starch from Table 4 is 4.00 RVU. This value is significantly lower than 85.3 RVU [49] reported for tigernut native starch. The higher the setback value, the lower the rate of synresis and weeping [50]. The low setback value obtained for Conophor starch in this study indicates a high retro-gradation value. Pasting temperature is said to be the temperature at which viscosity begins to rise [50,51]. The pasting temperature for Conophor starch obtained for this study was zero (0) which implies that the starch of Conophor was not viscous. Low pasting temperature ensures swelling, gelatinization and gel formation during processing [52,53]. Breakdown viscosity of Conophor starch obtained from this study was 2.00 RVU. Breakdown viscosity is a reflection of the stability of peak viscosity during processing [54]. Starch with lower breakdown viscosity has higher tendency to withstand heating and shearing during cooking. Peak time is referred to as the measure of the cooking time [14]. It is the time required for starch to attain the highest viscosity. The peak time obtained for Conophor starch was 5.67 min. The final viscosity of Conophor starch obtained was 16 RVU. Final viscosity is an indication of the ability of starch to form a viscous paste. Modification using acetylation and oxidation increased final viscosity of native water yam starch [55]. A high final viscosity of starch indicates that the paste is more resistant to mechanical shear and may easily form a more rigid gel [56] but, the reverse is the case for the value obtained for Conophor starch in this study. High final viscosity is required in food products such as; soups, sauces and dressings. The trough viscosity which indicates the ability of pastes to withstand breakdown during cooling was low (12.00 RVU) in this study. This observation implies that Conophor starch flour will easily break down during cooling.

Fig. 1 depicts the amylose and amylopectin content of Conophor starch flour. Amylose is an

important part of starch composition which is about 30% in content while amylopectin consists of the remaining 70% [57,58]. The amylose and amylopectin content of Conophor starch flour were (20.50%) and (79.50%) respectively. Amylose content determines the degree of starch digestibility in food. The amylose content plays a critical role in the digestion of starches as starches having low amylose and amylopectin content are more digestible than those with high amylose and amylopectin content. From this study, it was observed that the amylose content of Conophor starch was consistent with the amylose content of native starches (15-30%) noted by Bertoft [59], 10.1- 20.2% for sweet potatoes [60] and 17.9- 23.6% reported for cassava [61]. The amylose content observed in this study was lower than that of cocoyam and yam (26.7%) [62]. Foods with high amylose content are digested more slowly than those with low amylose content, which are less likely to increase blood glucose as in the case of Conophor starch. A moderately high starch digestibility (63.68%) was observed in this study and this could be as a result of its low fiber, and high amylose and amylopectin contents. This result is comparable to that obtained for miracle berry seed starch flour [63]. Report has shown that the amount and nature of crude fiber in foods could influence starch digestibility. High amount of crude fiber in food may reduce the level at which starch is digested by trapping starch granules within viscous protein-fiber-starch network [64].

The phenomenon of freeze-thaw stability refers to the ability of starch to withstand some physical changes that occur during freezing and thawing [65]. It particularly affects products that require low temperature storage. Figure 2 shows the freeze-thaw stability of Conophor nut starch gel at 4^0C for 24h and 48h. From the result, it was observed that syneresis increased with an increase in freezing days which range from 32.63% – 38.06%. The increase in the amount of water exuded from Conophor starch gel during the process of freezing and thawing from 0 – 48h may be related to its low setback value (4.00 RVU). The higher the setback value, the lower the rate of syneresis and weeping [66]. From the result obtained, Conophor starch gel has a tendency to retrograde faster since syneresis

Table 2. Mineral composition of Conophor starch

Mineral	Amount (mg/g)
Calcium	194.17±0.29
Copper	0.05±0.01
Manganese	0.42±0.02
Magnesium	4.26±0.01
Iron	0.34±0.02
Zinc	1.59±0.01
Phosphorus	26.10±0.01
Sodium	23.20±0.26
Potassium	37.13±0.32
Na/K	0.62±0.00
Ca/P	7.44±0.00

Values are expressed as mean ± standard deviation of triplicate readings
Means with different letters in the same column are significantly different in the same column at the p≤0.05 level

Table 3. Functional properties of Conophor nut starch

Component	Amount (%)
Bulky density	0.42±0.02
Water absorption capacity	513.33±11.54
Oil Absorption capacity	347±10.75
Foaming capacity	12.69±0.01
Foaming Stability	3.26±0.08
emulsion capacity	45.48±0.03
emulsion stability	50.00±0.00
swelling index	246.67±11.55
Gelation capacity	12.00±0.00

Values are expressed as mean ± standard deviation of triplicate readings.
Means with different letters in the same column are significantly different in the same column at the p≤0.05 level

Table 4. Pasting properties of Conophor Starch

Pasting Properties	(RVU)
Peak Viscosity	14.00
Trough Viscosity	12.00
Breakdown Viscosity	2.00
Final Viscosity	16.00
Set-back Viscosity	4.00
Peak Time (Min)	5.67
Pasting Temperature (ºC)	err

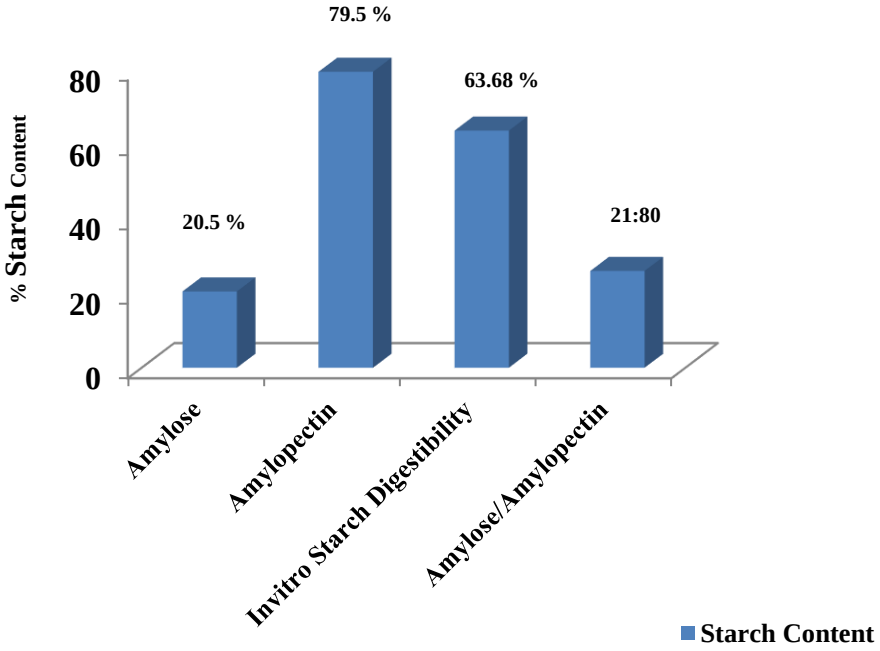

Fig. 1. Conophor Starch Content

relates to the tendency of starch to retrograde. Higher syneresis value was reported for yellow (65%) and black (68%) maize [67]. The result obtained in this study was closer but higher than the 22.3% reported by Akonor [68] for starch syneresis of fedearroz rice variety. Report shows that samples produced with native corn starch suggests their susceptibility to syneresis while those produced from modified starches may improve the visco-elastic properties, freeze-thaw and heat stability of products [69].

Fig. 3 shows the swelling power and solubility of Conophor starch. The swelling power of Conophor starch ranged between 3.15 – 4.72%. Swelling power increased with an increase in temperature from 30ºC to 90ºC. From this study, it was observed that Conophor starch had a low swelling power compared to that of cassava flour 9.233 – 12.513% [70]. The low swelling power of Conophor starch could be attributed to the strength and character of the micellar network within the starch granules which is the major contributing factor to the swelling behavior of starch. A highly associated starch with extensively strong-bonded micellar network structure is readily resistant to swelling [70]. This implies that the increase in temperature decreased the strength and character of the micellar network of the starch. The higher the amylose content, the lower the swelling power. The swelling power of starch depends on the ability of amylose to solubilize in water thereby allowing water to be absorbed by starch granules [71]. The value obtained for swelling power suggests that an increase in temperature weakened the starch granules by allowing interaction between the amylose (water soluble fraction) molecules sited in bulk amorphous regions and the branched segment of

amylopectin (water insoluble fraction) in the crystalline regions. The swelling power of flour samples relate mostly to their protein and starch contents. Higher protein content in flour may cause the starch granules to be embedded within a stiff protein matrix which minimizes the access of starch to water and restrain the swelling [72]. The solubility of Conophor starch ranged from 1.98 – 3.17%. A slight increase in solubility was observed as temperature raised from 30ºC to 70ºC (1.98-1.99%) and at 90ºC, solubility increased to 3.17% a margin of 1.18%. These values are very much lower than the 7.57% and 10.46% reported for cassava starch [73]. The low solubility obtained in this study could be attributed to the amylose content, since the solubilized amylose molecules leach from the swelled starch granules of flour [74].

Fig. 4 shows the colour properties of Conophor starch. Values are 79.73 for Lightness (L*), 8.11 for Red-green (a*), 20.45 for Yellow-blue (b*), 22.00 for Chroma (c*) and 68.37 for Hue (h*). The increased value of lightness shows the whitish colour of the starch.

The scanning electron micrograph of Conophor starch is shown in Fig. 5. Starch granules occurred in a single rough irregular cluster having sharp tips. Residual protein and drying condition have been reported as possible causes of clusters of starch granules [75]. An oval smooth surface granule with varying sizes was reported by Awoluet al. [49] for native tigernut starch. An oval and round shaped granule was reported for native jack bean starch [76].

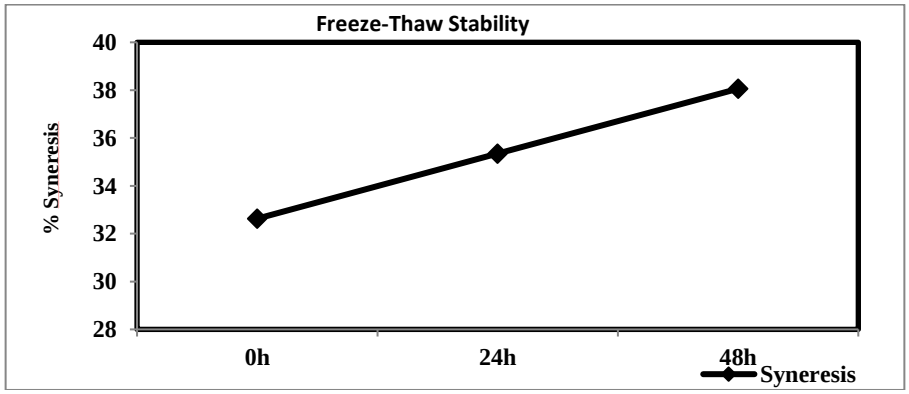

Fig. 2. Freeze-thaw stability of Conophor Starch

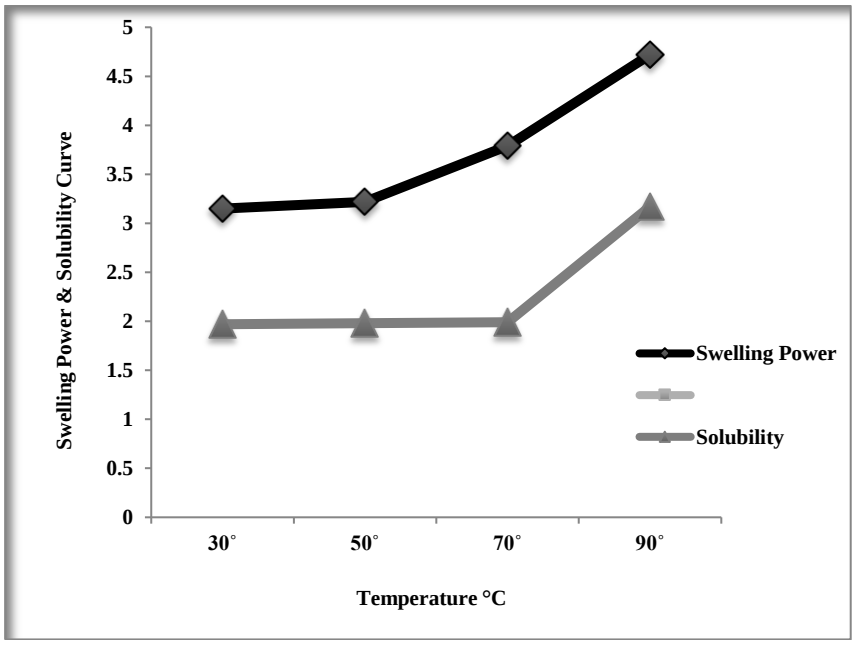

Fig. 3. Swelling power & solubility curve of Conophor Starch

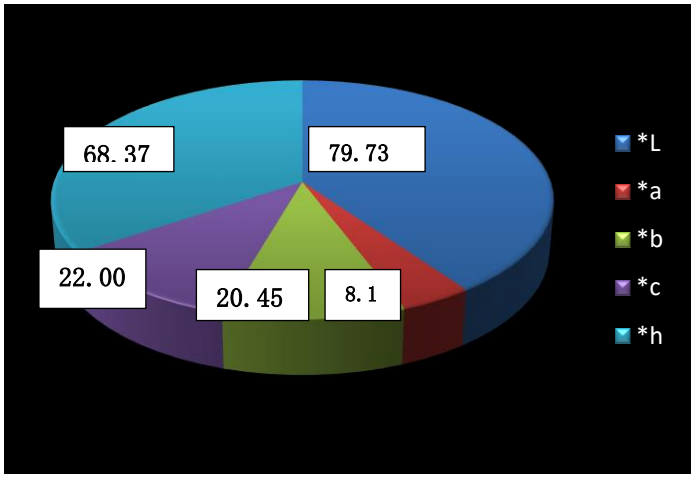

Fig. 4. Colour properties of Conophor Starch

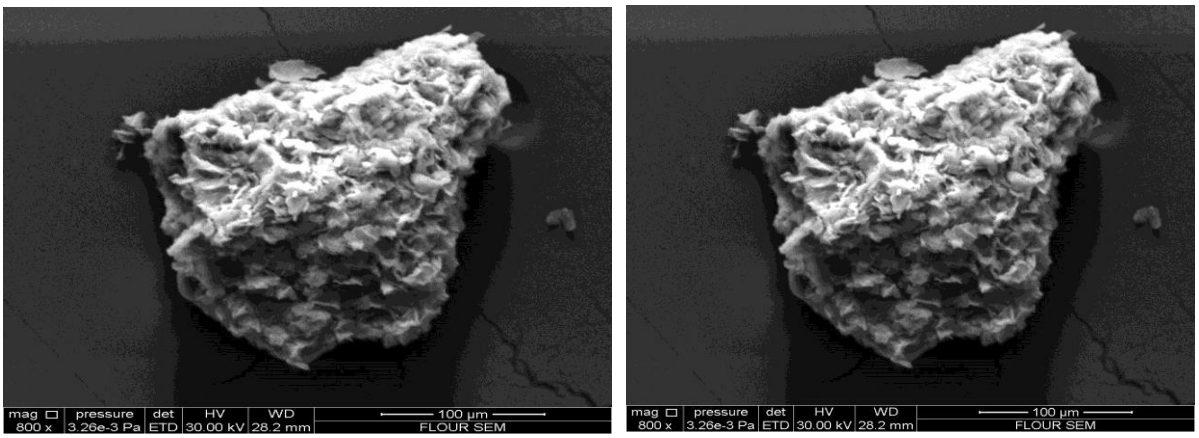

Fig. 5. Scanning electron micrograph of Conophor Starch

4. CONCLUSION

The study showed Conophor starch to be a rich source of mineral which makes it suitable for use as a supplement and its functional property makes it capable to be used as an emulsifier in some industrial processes. However, when comparing the paste property of tiger-nut starch reported by Awolu et al. [49], the low paste quality of Conophor starch renders it unsuitable for use in food processes that requires high paste formation as they affect the texture, digestibility and end use of starch based food commodities. It may be considered suitable for use in non- food related industries. The high amylose and amylopectin content of the starch makes it less likely to increase blood glucose and can therefore be incorporated in functional diet formulations for the treatment of diet related diseases such as diabetes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Enujiugha VN, Ayodele OO. Evaluation of nutrients and antinutrients in lesser known under-utilized oil seeds. Int. J. Food Sci. Technol. 2003;38:525-528.

2. Ekumankama IO, Okeke EC. The consumption and utilization patterns of an indigenous food crop conophor nut (Plukenetia conophora) in Abia and Enugu States. J. Nutr. Sci. 2009;30(1):55-61.
3. Sirilakshmi B. Dietetics.6thed, New Delhi: New Age International Publisher; 2011.
4. Pradhan C, Peter N, Dileep N. Nuts as dietary source of fatty acids and micro nutrients in human health. In: Rao V, Rao L, Ahiduzzaman M, Aminul AKMA, editors. Nuts and Nut Products in Human Health and Nutrition. IntechOpen; London, UK; 2021.
5. Adebowale KO, Lawal OSJ (2003). Starch, *Food Sci. Agric*. 83, 1541-1545.
6. Shuren J. Production and use of modified starch and starch derivativesin China. In: Howeler RH, Tan SL, editors. Cassava's Potential in Asia in the 21st Century: Present Situation and Future Research and Development Needs. In: Proceedings of 6th Regional Workshop; 21–25 2000; Ho Chi Minh City, Vietnam; 2000:553-563.
7. Raigond P, Ezekiel R, Raigond B. Resistant starch in food: a review. J. Sci. Food Agric. 2014;95:1968–1978. DOI:10.1002/jsfa.6966.
8. Santana AL, Meireles MAA. New starches are the trend for industry applications: A review. Food and Public Health. 2014;4(5): 229-241.
9. DOI: 10.5923/j.fph.20140405.04
10. Barber LI, Obinna-Echem PC. Nutrient composition, physical and sensory properties of wheat-African Walnut Cookies. Sky J. Food Sci. 20165(4):024-030.
11. Muazu J, Zakama SG, Dzarmah UJ. Extraction and Characterization of Starch from the Shoot of Borassus aethiopum as a Prospective Pharmaceutical Raw Material. World J. Pharm. Sci. 2014;2 (8):704-710
12. AOAC. Association of official analytical chemist. official methods of analysis of the analytical chemist international, 18th ed. Gathersburg, MD USA; 2012.
13. Asoegwu SN, Ohanyere SO, Kanu OP, Iwueke CN Physical properties of African oil bean seed (*Pentonclethra nacrophylla*). Agric. Eng. Int. J. 2006;44(1):1- 6.
14. Sathe SK, Desphande SS, Salunhkhe DK. Emulsification properties of lupin seed (*Lupinu mutabilis*) protein and protein concentrate. J. Food Sci. 1982;47:191-497.
15. Adebowale KO, Olu-Owolabi BI, Olawumi EK, Lawal OS. Functional properties of native, physically and chemically modified breadfruit (*Artocarpus artillis*) starch. Industrial Crops Production. 2005;21:343-351.
16. Sathe SK, Salunkhe D. Functional properties of the great northern bean (Phaseolus vulgaris L.) protein: emulsion, foaming, viscosity, and gelation properties. J. Food Sci. 1981;46:71–74.
17. Ukpabi UJ, Ndimele C. Evaluation of gari production in Imo State Nigeria. Niger. Food J. 1990;8(1):105-110.
18. Coffman CW, Garcia VV. Functional properties and amino acid content of a protein isolate from mung bean flour. J. Food Technol. 1977;12:473–484.
19. Beuchat LR. Functional and electrophoretic activities of peanut flour. J Agric Food Chem. 1977;25:252.
20. Waliszewski KN, Aparicio MA, Bello LA, Monroy JA. Changes of banana starch by chemical and physical modification. Carbohydr. Polym. 2003;52:237–242.
21. Simi K, Abraham T. Physicochemical rheological and thermal properties of njavara rice (*oryza sativa)* starch. J. Agric. Food Chem. 2008;56:12105–12113.
22. Zhu F, Yang X, Cai Y, Bertoft E Corke H. Physicochemical properties of sweet potato Starch. Starch - Starke, 2011;63: 249–259.
23. Singh U, Klierdeker MS Jambunathan R. Studies on desi and Kabu li chickpeas (*Cicerarieinum*L) cultivars. The level of protein inhibitors. Level of oligosaccharides and *in vitro* digestibility. J. Food Sci. 47:510-412.
24. Wayah S, Safiya S (2015). Assessment of the Nutritional and Antinutritional Components of Tiger nut Residues. Int. J. Sci. Res, 1982:438.
25. Potter N, Hotchkiss J. Food Science.5th Ed. CBS Publishers and Distributors Danyangaji, New Delhi, India; 2006.
26. Okoli BJ, Abdullahi K, Myina O, Iwu G. Caffeine Content of the Nigerian Cola. J. Emerg. Trends Eng. Appl. Sci. 2012;3:830-833.
27. Ogunbode AA, Akinosun AA, Olajide TM. Nutrients and Anti–Nutrient Content of Sundried Cassava Starch Extract Pulp. J. Appl. Sci. Environ. Manag. 2019;23(6): 1133-1135.
28. Omoba OS, Omogbemile A Physcicochemical properties of sorghum

biscuit enriched with Defatted Soy Flour. Br. J. Appl. Sci. Technol. 2013;3(4):1246-1256.
29. Sanni SA, Adebowale ARA, Olayiwola IO, Maziya-Dixon B. Chemical composition and pasting properties of iron fortified maize flour. J. Food Agric. Environ. 2008;6:172-175.
30. Zubair AB, Maxwell YMO, Femi FA, Azeez SO, Jiya MJ, Isah LR, Owheruo JO. Proximate, Mineral and Functional Properties of Maize Starch Complemented with Defatted Sesame Seed Flour. Anchor Uni. J. Sci. Technol. 2020;1(1):61 – 67.
31. Masood N, Baloch GH, Ghori RA, Memon IA, Memon MA Memon MS. Serum Zinc and Magnesium in Type-2 Diabetic Patients. J. Col. Phys. Surg. Pakis. 2009;19:483-486.
32. Ramaswamy R, Gopal N, Joseph S, Murugaiyan SB, Joseph M, Jose D, Kuzhandaivelu V, Velayutharaj A. Status of Micro and Macro Nutrients in Patients with Type 2 Diabetes Mellitus Suggesting the Importance of Cation Ratios. J. Diabetes Mellit. 2016;6:191-196.
33. Peters H, Mgbang JE, Essien NA, Ikpeme CE. Nutritional evaluation of breadfruit and beniseed Composite Flours. Am. J. Food Sci., 2016;3:243-254.
34. Oshodi AJL, Ogungenle HN, Oladimeji NO. Chemical composition, nutritionally valuable minerals and functional properties of benniseed, pearl millet and quinoa flours. Int. J. Food Sci. *Nutr.* 1999;50:35-36.
35. Nieman DC, Butterworth DE, Nieman CN. Nutrition. WmC. Brown, Dbugye, USA, 1992;237-312.
36. Akpata MI, Akubor PI. Chemical Composition and Selected Functional Properties of Sweet Orange (Citrus sinensis) Seed Flour. Plant Food Hum. Nutr. 1999;283-289.
37. Gopaldas T, John C. Evaluation of a controlled 6 months feeding trail on intake by infant and toddlers fed high energy low bulk gruel versus high energy-high bulk density gruel in addition to their habitual home diet. J. trop. Pediatr. 1992;38:278-283.
38. Ijarotimi OS Keshinor OO. Formulation and nutritional quality of infant formula produced from popcorn, bambara groundnut and African locust beans flour. J. microbiol, Biochem, Food Sci., 2012;16: 1358-1388.
39. Ocheme OB, Oloyede OO, Mikalu EG. Effect of lime soaking and cook ing (nixtamilization) on the proximate, functional and some anti-nutritional properties of millet flour. Assumpt. Uni. J. Technol. 2010;14(2):131-138.
40. Olatunde G, Arogundade L, Orija O. Chemical, functional and pasting properties of banana and plantain starches modified by pre-gelatinization, oxidation and acetylation. Cogent Food Agric., 2017;3:10.1080/23311932.2017.1283079.
41. Balogun IO, Olatidoye OP. Functional properties of dehulled and undehulled velvet beans flour (Mucuna utilis). J. Biol. Sci. Biocon. 2010;2:1–10.
42. Robert A. Proximate, Starch, sugar compositions and functional properties of cassava flour. *J. Food Secur.*, 2019;7 (2):40-46.
43. Lael-Calderon F, Thivilliers F, Schmitt V. Structured emulsions, Curr. Opin. Colloid Interface Sci. 2007;12:206-21.
44. Ulloa JA, Rosas-Ulloa P, Ulloa-Rangel BE. Physicochemicaland functional properties of a protein isolate produced from safflower (*Carthamus tinctorius* L.) meal by ultrafiltration. J. Sci. Food Agric.2011; 91:572–577.
45. Arinola SO, Ogunbusola EM, Adebayo SF. Effect of drying methods on the chemical, pasting and functional properties of unripe plantain (*Musa paradisiaca*) flour. Br. J. Appl. Sci. Technol. 2016;14(3):1-7.
46. Oliveira VH. Cashew crop. Rev. Bras. Frutic. 2008;30(1).
47. Ahmad M, Wani S, Masoodi F, Gani A. Incorporation of carrot pomace powder in wheat flour: Effect on Flour, Dough and Cookie Characteristics. J. Food Sci. Technol. 2016;53:3715- 3724.
48. Omowaye-Taiwo OA, Fagbemi TN, Ogunbusola EM, Badejo AA. Effect of germination and fermentation on the proximate compositionand functional properties of full-fat and defatted *Cucumeropsis mannii* seed flours. J. Food Sci. Technol. 2015;52(8), 5257–5263.
49. Ocheme OB, Adedeji OE, Chinma CE, Yakubu CM, Ajibo UH. Proximate Composition, Functional and Pasting Properties of Wheat and Groundnut Protein Concentration Flour Blends. Food Sci. Nutr. 2018;(6):1173-1178.
50. Awolu OO, Ojewumi ME, Isa J, Ojo DO, Olofin H, Jegede SO. Comparative analyses of functional, pasting and

morphological characteristics of native and modified tigernut starches with their Blends. Cogent Food and Agric. 2017;3:1306934.
51. Adebowale AA, Sanni LO, Fadahunsi EL. Functional and pasting properties of cassava-sweet potato starch blends. Afr. J. Root Tuber Crops. 2011;9:6–10.
52. Swinkels JJM. Composition and properties of commercial natural starch. Starch – Stärke, 1985;37(1):1–5.
53. Maziya-Dixon B, Dixon AGO, Adebowale AA. Targeting different end uses of cassava: Genotypic variations for cyanogenic potentials and pasting properties. Int. J. Food Sci. Technol. 2007;42:969–976.
54. Eke-Ejiofor J. Physico-Chemical and pasting properties qf starches from cassava, Sweet Potato and Three Leaf Yam and their Application in Salad Cream Production. Int. J. Biotech. Food Sci. 2015;3:23–30.
55. Moorthy SN. Actylation of cassava starch using perchloric acid catalyst. Starch / Starke. 1985;37:301-308.
56. Awolu OO, Olofinlae SJ. 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 – Stärke. 2016;68:719–726.
57. Zhang Y, Gu Z, Hong Y, Li Z, Cheng L. Pasting and rheologic properties of potato starch and maize starch mixtures. Starch – Stärke. 2011;63:11–16.
58. Behail KM, Howe JC. Effect of long-term consumption of amylose vs amylopectin starch on metabolic variables in human subjects. Am. J. Clin. Nutr. 1995;61(2): 334-40.
59. Afolabi OA, Osamudiamen PM, Osundahunsi OF. Chemical properties, In vitro Starch Digestibility and the Estimated glycemic index of water yam, cocoyam, sweet potato and cassava. Appl. Trop. Agric. 2016;21(3)19-26.
60. Bertoft E. Understanding starch structure: recent progress. Agronomy. 2017;7;56-67.
61. (Tortoe C, Akonor PT, Koch K, Menzel C, Adofo K. Physicochemical and Functional Properties of Flour from Twelve Varieties of Ghanaian Sweet Potatoes. Int. Food Res. J. Vol. 2017;24 ;6:2549-2556.
62. Defloor I, Dehing I, Delcour JA. Physico-chemical properties of cassava starch. Starch –St¨arke. 1998;50(2-3):58–64.
63. Amani GNG, Tetchi FA, Colonna P. Molecular and physicochemical characterisation of starches from yam, cocoyam, cassava, sweet potato and ginger produced in the Ivory Coast, J. Sci. Food Agric. 2007;1906–1916.
64. Olatunde TS, Ijarotimi OS, Bolade MK. Composition, antioxidant, angiotensin converting enzyme and carbohydrate hydrolyzing enzyme inhibitory properties of miracle berry Seed (*Synsepalum Duleicificum Daniell*) Flour. Adv. Food Sci. 2021;(43):36-53.
65. Chinma CE, Igbabul BD, Omotayo OO. Quality characteristics of cookies prepared from unripe plaintain and defatted sesame flour blends. Am. J. Food Technol. 2012;7(7):398-408.
66. Karim AA, Norziah MH, Seow CC. Methods for the study of starch retrogradation, Food Chem. 2000;71(1):9–36.
67. Dixon KE, Keefe FJ, Scipio CD, Perri LM, Abernethy AP. Psychological Interventions for Arthritis Pain Management in Adults: A Meta-Analysis. Health Psychol. 2007;26 (3):241-250.
68. Rodriguez-Torres D, Murillo-Arango W, Vaquiro-Herrera HA, Solanilla-Duque JF. Thermal and Physicochemical Properties of Starches from Three Colonbian Rice Varieties. Agron. Colom. 2017;35(1):116-124.
69. Akonor PT, Tortoe C, Oduro-Yeboah C, Saka EA, Ewool J. Physicochemical, Microstructural and Rheological Characterization of Tiger nut (*Cyperus esculentus*) Starch. Int. J. Food Sci. 2019; 1-7.
70. Arocas A, Sanz T, Fiszman SM. Influence of corn starch type in the rheological properties of a white sauce after heating and freezing. J. Food Hydrocol. 2009;23: 901-907.
71. Agbemafle R. Proximate, starch, sugar compositions and functional properties of cassava flour. J. Food Secur. 2019;7(2): 40-46.
72. Nuwamanya E, Baguma Y, Wembabazi E, Rubaihayo P. A comparative study of the physicochemical properties of starches from root, tuber and cereal crops. Afr. J. Biotech. 2011;10 (56):12018-12030.

73. Aprianita A, Purwandari U, Vasiljevic T. Physico-chemical properties of flours and starches from selected commercial tubers available in Australia. Int. Food Res. J. 2009;16,507-520.
74. Baafi E, Safo-Kantanka O. Agronomic evaluation of some local elite and released cassava varieties in the forest and traditional ecozones of Ghana. Asian J. Agric. Res. 2008;2(1), 32-36.
75. Dengate HW. Swelling, Pasting and Gelling of Wheat Starch In: Pomeranz, Y(Ed). Adv. Cereal Sci. Technol. America Association of Cereal Chemist (AACC) St. Paul, MN. 1984;49- 71.
76. Ashogbon AO, Akintayo ET. Morphological, functional and pasting properties of starches separated from rice cultivars grown in Nigeria. Int. Food Res. J. 2012;19(2):665-671.
77. Lawal O, Adebowale KO. An assessment of changes in thermal and physic-chemical parameters of jack bean (*Canavalia ensiformis*) starch following hydrothermal modifications. Eur. Food Res. Technol. 2005;221(5):631-638.

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