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COMPARISON OF PHYSICO-CHEMICAL AND FUNCTIONAL PROPERTIES OF FLOUR AND STARCH EXTRACT IN DIFFERENT METHODS FROM AFRICA LOCUST BEAN (*PARKIA BIGLOBOSA*) SEEDS

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Abstract

Background: African locust bean tree is an important food tree for both human and livestock such as husks and pods. It plays a very vital role in the rural areas. The aim of this study was to evaluate some physicochemical, mineral characteristics and functional properties of flour and starch extract produced from *Parkia biglobosa* seeds, using different methods.

Material and methods: Three different methods were used for starch extraction in order to get the Starch yield (%), composition analysis for; moisture, protein, fat, ash and fiber contents of flour and starch extracts from *Parkia biglobosa* were determined on dry basis (db), by AACC method, color and PH value measurements was carried out using color flex spectrophotometer, and the official method of AOAC respectively. Pasting properties was determined and X-ray powder starch diffraction was used to examine the crystalline property of flour and starch extract. Gelatinization characteristics and *in vitro* starch digestibility were also determined, test results were processed using one-way analysis of variance (ANOVA).

Results: Flour showed higher ($P < 0.05$), moisture content, fat, carbohydrate, amylopectine, and protein content than starch, while amylose content of this starch was higher ($P < 0.05$). Phosphorus, sodium, magnesium, and potassium minerals content were higher in flour than starch. Pasting properties, gelatinisation, color, pH values, water and oil absorption capacity content of the flour were found to be higher than that of starch. The pasting characteristics showed a decrease of viscosity, final viscosity, set back value, breakdown, and pasting temperature of flour when compared to that of starch.

Conclusion: From our results, we speculate that flour from native *Parkia biglobosa* grown in Guinea under controlled environmental conditions could be considered as an ideal RS material, whereas the extract *Parkia* starch could be an ideal SDS material. Therefore, these may offer an interesting alternative for food developers, depending on their characteristics and functional properties.

Keywords: *Parkia biglobosa*, flour, starches extract, physicochemical and pasting properties

Introduction

African locust bean tree is an important food tree for both human and livestock such as husks and pods. It plays a very vital role in the rural areas. It is also a revenue source within the West African countries; where the seeds are fermented into iru or dawadawa (daddawa), a popular food seasoning known to be richer in protein and vitamin B2; virtually every part of the species is of value as food or fodder (Teklehaimanot, 2004; Tee et al., 2009). In medicine, *P. biglobosa* is used against bronchitis, pneumonia, diarrhea, violent colic, vomiting, sores and ulcers. The root of *P. biglobosa* has been reported to be used in lotions for sore eyes when combined with leaves, they are active against bronchitis, pile, cough, amoebiasis, dental carries and conjunctivitis (Millogo-Kone et al., 2006). All parts of the plant are used to cure different diseases, including malaria and stomach disorders. Moreover, they are also used to treat diseases of farm animals, such as poultry lice, trypanosomes and mouth ulcers of ruminants. It is also used in traditional ceremonies (Teklehaimanot, 2004). It has been reported that the husks and pods are good feed for livestock (Alabi et al., 2005). Although qualitative determination of the chemical and nutritional composition of *P. biglobosa* seeds revealed that it is rich in starch, lipids, protein, carbohydrates, soluble sugars, and ascorbic acid (Ihegwuagu et al., 2009).

Starch is the major storage carbohydrate in plants. It is produced as granules in most plants cells and is referred to as native in this state. The physicochemical properties of starch and its use depend largely on its biological origin and source, and the various sources include cereal, grain, nuts, seeds, leaves, tubers, and root. Because starch finds application in various industries; the research for new sources of starch, like *P. biglobosa* becomes necessary. Starch contributes greatly to the textural properties of various foods and has many industrial applications as a thickener, colloidal, stabilizer, gelling agent, bulking agent, water retention agent and adhesive (Singh et al., 2003). However, the development of value-added products from starch depends on a thorough knowledge of its structure and functional properties.

Furthermore, no study has been conducted to compare the physicochemical properties, mineral profile and functional properties of flour and starch extract in different methods from *Parkia biglobosa* seeds. In this study, the *in vitro* starch digestibility, some physicochemical properties (granular morphology, crystalline structure, color value, water and oil absorption capacities, thermal properties and pasting properties) of flour and starch from *Parkia biglobosa* were investigated. It is expected to provide useful information that can offer further support to the consideration of *Parkia biglobosa* as an alternative source of starch in the food industries.

Material and methods

Africa locust bean (*Parkia biglobosa*), seeds were purchased from Madinah local market (Conakry, Guinea) in March 2012. The sample was shipped down to Wuxi, China through TNT® mailing company (No. GD923580841WW). Porcine (pancreatic α -amylase, amyloglucosidase), were

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purchased from Sigma Aldrich Co., Ltd (Shanghai, China), and glucose oxidase-peroxidase assay kit (cat. No. K-GLUC), was purchase from megazyme international Ltd. (Bray, Ireland). All other reagents used were of analytical grade.

Different Methods of starch extraction

Preparation flour

The seeds were screened to eliminate the bad ones. One kilogram of cleaned *Parkia biglobosa* seeds were added to 4 L, water and left overnight. The seeds were manually de-hulled, dried in oven at 60°C, then dry milled to a fine power, ground to pass through a 60 mesh sieve and flour was kept into polyethylene bags before being stored in desiccators until further analysis.

Method (1) Starch extract

The method of Adebowale and Lawal (2002), was employed, with modifications, for the starch extract. One kg of *Parkia biglobosa* flour was suspended in 10 L of 0.5% (w/v), NaOH solution. It was stirred for 5hrs at 28°C. After stirring, the suspension was centrifuged at 1600 g for 30min. The supernatant was discarded and the sediment was re-suspended in distilled water and centrifuged, this process was repeated four times. The starch suspension was then neutralized and the sediment starch was dried at 60°C for 12hrs, and then ground into powder using mortar and pestle and to pass through a 60 mesh sieve. It was stored in polythene bag until use.

Method (2) Starch extract

The method of extraction of starch from *Parkia biglobosa* seeds was adopted with little modification (Omojola et al., 2010). Clean seeds (1kg), washed in water, were crushed and soaked for 5hrs, in sodium metabisulphite solution (10 L 1.5% w/v), at room temperature (28°C). Thereafter, the seeds were removed and wet milled into a homogenous fine paste using domestic blender. The paste was dispersed in a large volume of 1.5% sodium metabisulphite, and filtered through muslin cloth. The suspension was allowed to settle and the supernatant was decanted. The sediment starch layer was re-suspended in sodium metabisulphite solution and the process was repeated for four times. At each stage of washing, the suspension was allowed to stand for about 24hrs, for proper sedimentation after which the supernatant was decanted. The mucilage on the starch was scraped continuously until a pure starch was obtained. The resulting starch was dried at 60°C for 12hrs, then ground into powder using mortar and pestle and to pass through a 60 mesh sieve. It was stored in polythene bag until use.

Method (3) Starch extract

Parkia biglobosa seeds were screened to eliminate the bad ones. One kilogram of cleaned *parkia biglobosa* seeds were conditioned to 25% moisture content by the addition of 4 L of distilled water and held for 6hrs, at 28°C with occasional stirring. The conditioned sample was sun dried to final moisture of approximately 10%. The dry seeds dehulled for 5min., using disc attrition mill (No, 1A premier). The dehulled seeds were milled in an attrition mill and ground to pass through a 60 mesh sieve, obtained flour. Then, Starch extract flour was steeped in distilled water (1:5) for 12hrs, at 28°C, washed and ground for 10min., in a crown star mixer electric blender (model:CS-BL100B), at high speed. The slurry obtained was re-suspended in 2 L of distilled water. The suspension obtained was filtered through the filtrate was allowed to sediment. The starch cake was then dried in a conventional oven at 60°C for 12hrs, then ground into powder using mortar and pestle and to pass through a 60 mesh sieve. It was stored in polythene bag until use.

All the three methods of starch extraction were determined as yield starch:

Starch yield (%) = (weight of starch × 100 / (weight of parkia seed ground)).

Composition analysis

Moisture, protein, fat, ash and fiber contents of flour and starch extract in different methods from *Parkia biglobosa* were determined on dry basis (db), by AACC method (AACC, 2000). The starch content of the flour and starch extract in different methods were determined by the by polarimetric method of AACC (2000), and amylose using methodologies described by Mohana et al. (2007). Additionally, amylopectin content (100-amylose percentage), was estimated. Mineral composition was evaluated using the Atomic Absorption Spectrophotometer procedure reported by AOAC (1995).

Color and PH value measurement

Parkia biglobosa seed flour and starch extract were monitored for their color using color flex spectrophotometer (Model no 45/o, CX075, Hunter Lab Reston, VA, USA, 2002), after being standardized using Hunter lab color standards. The parameters recorded were L, a and b co-ordinates of the CIE scale. The pH of *Parkia biglobosa* flour and starch was measured immediately on the homogenate at 28°C by potentiometric technique according to method of the official method of AOAC (1995).

Water and oil absorption capacities

The water absorption capacities (WAC), and oil absorption capacities (OAC), of starch and flour from *Parkia biglobosa* were determined by the procedure of Adebowale and Lawal (2004).

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Pasting properties determination

Pasting characteristics were determined with a rapid visco analyzer (RVA), (New port scientific, RVA TECMASTER, Australia). First, 2.5 g of *Parkia biglobosa* flour and starch extract sample were weighed into a dried empty canister, and then 25 mL of water was dispensed into the canister containing the sample. The solution was thoroughly mixed and the canister was well fitted into the RVA as recommended.

Scanning Electron Microscopy (SEM)

Examination by SEM was carried out. Flour and starch extract Samples were gold coated and scanned by using an Electro scan Quanta 200, environmental scanning microscope (Fei Company, Netherlands).

X-ray Powder starch Diffraction

X-ray Powder Diffraction, a Shimadzu Lab XRD-6000, was used to examine the crystalline property of flour and starch extract. The scanning region of the two (θ), angles was from 2° to 35° which covers all the significant diffraction peaks of starch crystallites.

Gelatinization characteristics

Measurements were performed using a Differential Scanning Calorimetry (DSC-7, Perkin Elmer Inc., UK), equipped with a thermal analysis data system. Measurements were made on starch/flour: water slurries (1:4) (w/w). After sealing, the pans were equilibrated for 12hrs, and the samples heated in the calorimeter from 20-120°C at 10°C/min. The temperatures of the characteristic transitions, onset (T_0), peak (T_p) and conclusion (T_c) were recorded and the enthalpy (DH) of the transition was expressed as J/g on a dry weight basis.

In vitro starch digestibility

Starch digestibility of both parkia flour and starch was determined using by the Approved method 32-40 (AACC, 2000). Parkia flour and starch were incubated with pancreatin (10mg), and amyloglucosidase (12u), in 4 ml of 0.1M sodium maleate buffer (pH6.0), at 37°C with continuous shaking (200 strokes/min), for 0.5-16hrs, after incubation, ethanol (95%), was added to inactivate the enzyme and the sample was centrifuged at 2000 rpm for 10 min. glucose content of the supernatant was measured by a glucose oxidase- peroxidase assay kit (magazime international Ireland Ltd, Bray Ireland). rapidly digestible starch (RDS) and slowly digestible starch (SDS) were those digested within 0.5 h and at 0.5-16h respectively; resistant starch (RS) was starch not hydrolyzed even after 16hrs.

Statistics

The test results were processed using one-way analysis of variance (ANOVA). Differences at $p < 0.05$ were considered to be significant. SAS software (version 8.1), was used for the analysis.

Results and Discussion

Composition of *Parkia biglobosa* flour and Starch extract in different methods

The composition of flour and starches extract of different methods from *Parkia biglobosa* seeds determines their pasting and other characteristics. Table 1, show the chemical composition of *Parkia biglobosa* flour and starch extract. The starch yields obtained in different methods (1, 2 and 3), were 27.75%, 28.03% and 32.86% respectively. This result was comparable than those reported by (Chanapamokkhot and Thongngam, 2007), sorghum starch were extracted from sorghum grains, their yield values were 27.55 and 30.72% for 439S (KU 439 starch), and 804S (KU 804 starch), respectively. Method (3), starch extraction *Parkia biglobosa* shown that Water gave the highest yield of starch while protein content of the starch obtained was low (0.12%). Therefore, water was used as the extraction solvent in this investigation to minimize use of chemicals. Under exhaustive washings with water, a high yield of starch with high purity was obtained. Although diluted sodium hydroxide was often used as the solvent to remove impurities such as protein, lower yield of starch was obtained because there could be some starch loss through dissolution in an alkali medium. In general, the goals of starch extraction are high yield and high purity.

The values of the chemical composition of the flour were protein content 22.35%, crude fat 11.83%, ash 1.62%, fibre 4.89% and starch content 44.14%. The chemical composition is a simple and convenient way illustrating the purity of the starches extract, whereby higher starch and lower content of other components (protein, fat, ash, fibre), are highly desirable. The protein, fat, ash and fibre contents of *Parkia biglobosa* starches were lower than flour; this result was comparable to bambara groundnut (Sirivongpaisal, 2008). The results indicate that pure starches could be obtained from *Parkia biglobosa*. The total starch content of *Parkia biglobosa* flour used in this study was 44.14%. This result was comparable than those reported by Rehman et al. (2001), for kidney beans (44.4–47.8%), and higher than those of mucuna bean (27.1%; Siddhuraju and Becker (2005). The starches extract in different methods (1, 2 and 3), were 91.39%, 93.84% and 97.24% respectively, these values were comparable to those reported by Chung et al. (2008) AC Nautica (94.5%), Majesty (96.7%), and Red Kanner (100%). The total carbohydrate ranged from 91.04% to 89.61% and apparent amylose contents 36.19% to 33.06% *Parkia* starches were higher than *Parkia* flour (48.08 carbohydrate and 9.32% apparent amylose), due to removal of protein, fibre and fat. These results were in accordance with the earlier reports (Shimelis et al., 2006, Chung et al., 2008). Moreover, higher amylose contents are desired in starches that are to be used for the manufacture of noodles. The amylose content of starch samples along with the other components present has a good bearing on the pasting properties and hence these properties were analyzed.

As can be seen in the Table 2, *Parkia biglobosa* flour and starch extract in different methods have phosphorus, sodium, potassium, magnesium, manganese, iron, calcium, and zinc contents in their composition. Concentration of phosphorus, sodium, potassium, and magnesium are

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high in both flour and starches extract in different methods as compared to the content of iron, calcium, manganese and zinc. In spite of the obvious importance, very few researches have been done with regards to the mineral composition in starch *Parkia biglobosa*. On the other hand, it is a general consensus, that mineral composition such as phosphorus changes the functional properties of starch and it is technologically and nutritionally important. Therefore, it will be a goal to determine, and study the relationship between mineral composition and functional properties of *Parkia* flour

Functional Properties of flour and starch *Parkia biglobosa*

Water and oil absorption capacities

Imbibitions of water are an important functional trait in foods such as sausages, custards and dough. Moreover, oil absorption capacity is useful in structure interaction in food especially in flavor retention, improvement of palatability and extension of shelf life particularly in bakery or meat products. The water and oil absorption capacities of starches extract in difference methods and flour from *Parkia biglobosa* seeds are presented in Table 3. The water absorption capacities of *Parkia* flour were higher than that of the starches extract. This result suggests that the flour was more hydrophilic due to a higher protein and carbohydrate content (Table 1). The higher oil absorption capacities of the flour could be due to its higher protein and fat contents, which can entrap more oil. Basically, the mechanism of oil an absorption capacity is mainly due to the physical entrapment of oil by capillary attraction. However, the hydrophobicity of proteins also plays a major role in oil absorption (Voutsinas and Nakai, 1983).

Table1: Chemical composition of flour and starches extract in different methods from *Parkia biglobosa seed*

Samples	Flour	Starch(1)	Starch(2)	Starch(3)
Moisture	11.23±0.05 ^a	8.43±0.08 ^b	7.93±0.11 ^d	8.30±0.07 ^c
Protein	22.35±0.02 ^a	0.85±0.02 ^b	0.53±0.05 ^c	0.12±0.06 ^d
Fat	11.84±0.07 ^a	0.07±0.04 ^c	0.09±0.03 ^b	0.06±0.02 ^c
Ash	1.62±0.04 ^a	0.41±0.07 ^b	0.35±0.02 ^c	0.17±0.05 ^d
Fiber	4.89±0.04 ^a	0.63±0.05 ^c	0.69±0.07 ^b	0.31±0.03 ^d
Carbohydrate	48.08±0.16 ^d	89.61±0.26 ^c	90.41±0.29 ^b	91.04±0.24 ^a
Total starch	44.14±0.32 ^d	91.39±0.45 ^c	93.84±0.56 ^b	97.24±0.43 ^a
Amylose	9.32±0.22 ^d	33.06±0.27 ^c	35.60±0.46 ^b	36.19±0.38 ^a
Amylopectine	90.68±0.23 ^a	66.95±0.28 ^b	64.40±0.47 ^c	63.81±0.39 ^d
Starch yield	ND	27.75±0.56 ^c	28.03±0.49 ^b	32.86±0.37 ^a

Values (Mean ± SD) in the same column with different letters are significantly at (P < 0.05), n=3 ND: Not Determined

Table 2: Mineral composition of flour and starches extract in different methods from *Parkia biglobosa seeds*.

Samples (µg/g)	Flour	Starch(1)	Starch (2)	Starch (3)
Sodium	49.12±0.02 ^a	32.18±0.06 ^b	31.03±0.07 ^d	31.22±0.04 ^c
Potassium	43.39±0.04 ^a	28.15±0.03 ^d	30.23±0.06 ^b	29.13±0.03 ^c
Phosphorus	65.15±0.03 ^a	43.25±0.07 ^b	39.67±0.03 ^d	41.15±0.06 ^c
Calcium	5.79±0.06 ^a	2.95±0.02 ^b	2.83±0.06 ^c	2.63±0.08 ^d
Zinc	2.09±0.04 ^a	1.76±0.04 ^c	1.98±0.01 ^b	1.63±0.07 ^d
Magnesium	25.17±0.05 ^a	13.08±0.02 ^d	14.08±0.06 ^b	13.19±0.04 ^c
Iron	6.28±0.06 ^a	1.91±0.05 ^b	1.38±0.03 ^c	1.21±0.03 ^d
Manganese	9.11±0.01 ^a	3.54±0.02 ^b	2.93±0.05 ^d	3.41±0.08 ^c

Values (Mean ± SD) in the same column with different letters are significantly at (P < 0.05), n=3

Table3: Water and oil absorption capacities of starch extract in different methods and flour from *Parkia biglobosa seeds*

Samples	Water absorbed (ml/g)	Oil absorbed (ml/g)
Flour	2.62±0.23 ^a	1.52±0.45 ^a
Starch (1)	1.39±0.41 ^c	1.03±0.27 ^d
Starch (2)	1.48±0.22 ^b	1.06±0.32 ^c
Starch (3)	1.51±0.34 ^b	1.11±0.29 ^b

Values (Mean ± SD) in the same column with different letters are significantly at (P < 0.05), n=3

Color analysis and pH values of flour and starch extract *Parkia biglobosa*

The color of starch due to the presence of polyphenolic compounds, ascorbic acid and carotene has impact on its quality. Any pigmentation in the starch is carried over to the final product. A low value for chroma, and a high value for lightness are desired for the starch to meet the consumer preference. Color analysis and pH values of flour and starch extract *Parkia biglobosa* (Table 4). Starch extract by different methods had the highest value of whiteness (L = 68.02, 70.13 and 76.06), and lower value of chroma (a = 2.01, 2.10 and 1.63), compared to flour had lowest whiteness value (L = 55.44) and highest value of chroma (a = 7.86). Thus, in this study, color of *Parkia* starches extract can meet consumer preference due to the highest whiteness and lower chroma values. One of the physico-chemical properties of starch important to application is pH value. Starches extract from *Parkia* starch (5.78, 5.93 and 6.22) have approximately the same pH value (Table 4) compared to other various Flours and Starches from Improved Bean Varieties Grown in East Africa (Shimelis et al., 2006).

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Table 4: Color analysis and pH values of flour and starch extract of *Parkia biglobosa*

Samples	Color (L)	Color(a)	Color(b)	pH values
Flour	55.44±0.24 ^d	7.86±0.27 ^a	12.75±0.23 ^a	5.39±0.15 ^d
Starch (1)	68.02±0.12 ^c	2.01±0.31 ^c	10.71±0.28 ^b	5.78±0.18 ^c
Starch(2)	70.13±0.33 ^b	2.10±0.26 ^b	11.83±0.31 ^a	5.93±0.23 ^b
Starch(3)	76.06±0.11 ^a	1.63±0.34 ^d	12.48±0.27 ^a	6.22±0.33 ^a

L= lightness (black/white), a= chroma (green/red), b= hue (blue/yellow). Values (Mean ± SD) in the same column with different letters are significantly at (P < 0.05), n=3.

In vitro starch digestibility

Rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) contents of *Parkia biglobosa* flour and extracted starches are presented in Table 5. RDS, rapidly digested in the small intestine is 1.81% *Parkia* flour. SDS and RS content of *Parkia* flour are 6.84% and 35.49%, respectively. There was no significant difference (P < 0.05), among the *Parkia* flour in RDS and SDS contents. The poor starch digestibility of *Parkia* flour used in the experiment suggested having beneficial effects in the management of diabetes and hyperlipidemia. RDS, SDS, and RS contents of *Parkia* starches extract in different methods ranged between 13.36%, to 11.70%; 62.04% to 60.79% and 21.84% to 18.32% respectively. RDS content of *Parkia* starches extract was substantially lower than corn (24.4%), wheat (40.1%), and rice (32.4%), starches (Zhang and Hamaker, 2006). SDS content, which is considered a desirable form of dietary starches extract, was 62.04% to 60.79%. This value is much higher than those reported by Zhang and Hamaker (2006), for maize (53.0%), waxy maize (47.6%), wheat (50.0%), rice (43.8%), and potato (15.2%), although these were measured using the Englyst method. It is well known that the contents of starch fractions (RDS, SDS and RS), can be affected by various factors such as amylose content, swelling power, granule surface area and starch crystalline structure (Shin et al., 2005). From our results, we speculate that flour from native *Parkia biglobosa* grown in Guinea under controlled environmental conditions could be considered as an ideal RS material, whereas the extract *Parkia* starch could be an ideal SDS material.

Table 5: Starch nutritional fractions of *Parkia biglobosa* flour and starch extracted by *in vitro* starch digestion

Samples	RDS	SDS	RS
Flour	1.81±0.11 ^d	6.84±0.18 ^d	35.49±0.56 ^a
Starch(1)	11.70±0.15 ^c	61.37±0.12 ^b	18.32±0.36 ^d
Starch (2)	12.21±0.21 ^b	60.79±0.16 ^c	20.84±0.41 ^c
Starch (3)	13.36±0.14 ^a	62.04±0.13 ^a	21.84±0.38 ^b

Values (Mean ± SD) in the same column with different letters are significantly at (P < 0.05), n=3. RDS, rapidly digestible starch; SDS, slowly digestible starch; RS, resistant starch.

The morphological characteristics

The morphological characteristics of flour and *Parkia* starch extract in different methods presented elongated granules with a lenticular shape (Figure 1). As shown in Figure 1, Flour (f), showed the presence of starch granules, from small to large and round or oval to irregular or cuboidal, evidence of any fissures or dents, for small and large granules. This is due to the presence of high protein, fat, fiber content. Starch granules of (Figure 1a- c), had small size, spherical shape and plantain starches presented elongated granules with a lenticular shape. The surfaces of all granules appear smooth with no evidence of any fissures or dents. Upon magnification some granules appeared to be either round or oval in shape with "horn(s)" protruding from the surface. This is a unique feature which does not appear in other starches already studied. However, the size and shape of starch granules are determined by the chain length distribution of amylopectin. The morphological characteristics of *Parkia* starch may be important in the hydrolysis of starch by digestive. The variation in size and shape of starch granules may be due to biological origin. The morphology of starch granules depends on the biochemistry of the chloroplast or amyloplast, as well as physiology of the plant (Badenhuizen, 1969). Starch granule size may affect its physicochemical properties, such as gelatinization and pasting, enzyme susceptibility, and crystallinity, amylose content, swelling power and water binding capacity, were significantly correlated with the average granule size of the starches separated from different plants.

Crystallinity of starch granule

The X-ray diffraction pattern of flour and *Parkia* starch extract in different methods are shown in (Figure 2). The crystallinity is produced by the ordering of the amylopectin chains. The clustered branches of amylopectin occur as packed double helices. The crystalline structure exhibited distinct X-ray diffraction pattern that can be classified into three categories: A, B and C type crystal (Hizukuri, 1996). The XRD results of *Parkia* starch showed a typical A-type pattern, with strong reflections at 2θ about 17°, 20°, 27.5° and 35°. However, the *Parkia* starches showed a higher reflections peak in 17°, it was maybe amylopectin crystallinity. This result is consistent since it is widely accepted that the amylopectin is the predominant crystalline component in granules, with the short branched chains forming local organizations compatible with cluster model. Much remains to be learnt about how amylose and amylopectin are tightly packed in the starch granules. The X-ray diffraction pattern may depend on the starch origin as well as the environmental growth conditions.

As shown in Figure 2, *Parkia* flour sample had clear A-type diffraction patterns with main reflections at 2θ=17.2°, 23.2°, 32°, 35° and 38°. The crystallinity characteristics of *Parkia* flour was different to *Parkia* starch, however, the intensity of the reflections of *Parkia* flour was lower. These result indicated that other components might affect the crystallinity, the relative crystallinity of *Parkia* flour maybe related to protein and fat in the *Parkia* flour granules, despite the relative crystallinity of *Parkia* flour was dependent on the crystallinity of *Parkia* starch. *Parkia* flour granules contained proteins and fat which influence the granule structure and crystallinity of grains.

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Pasting properties

Rapid Visco-Analyzer (RVA), was used to determine the pasting properties of the starches extracted in different methods and flour from *Parkia biglobosa*. The pasting curves were recorded and the RVA the plots are presented in Figure 3. *Parkia* starches extract showed the highest peak viscosity, final viscosity, setback value, breakdown, and pasting temperature ranged from 512cP to 447cP, 530cP to 479 cP, 236cP to 218 cP, 210cP to 186 cP, and 95°C to 92°C, respectively. However, the *Parkia* flour showed the lowest of 345 cP, 346cP, 160 cP, 159cP and 77.57°C, respectively. These differences in results were due to the amylose content, and molecules interact to forming a matrix that increases viscosity. The result of *Parkia* flour is different with *Parkia* starches extract. These differences suggested that the protein and fat of *Parkia* flour influenced the pasting properties. This may be caused by the reaction of amylose and lipid, or protein and starch gel. Some researchers who have reported that proteins and fat influenced the pasting properties of rice starch and the forming of amylose–lipid complex (Marco and Rosell, 2008; Dautant et al., 2007; Kaur and Singh, 2000), which significantly affect the final viscosity, setback value, and pasting temperature of rice flours. The factors which influence this property may include the size and shape of the starch granules, ionic charge on the starch, kind and degree of crystallinity with in the granules, presence or absence of fat and protein, and perhaps, molecular size and degree of branching of the starch fractions (Schoch and Maywald, 1968). Furthermore, the viscogram profiles depends on many factors such as, botanic source (type of starch), granule size, concentration, amylose /amylopectin ratio, other endogenous materials (particularly fat and phosphors), added ingredients (salts, sugar, pH modifier etc.) and physical history after pasting (time, temperature and shear stress/shear rate).

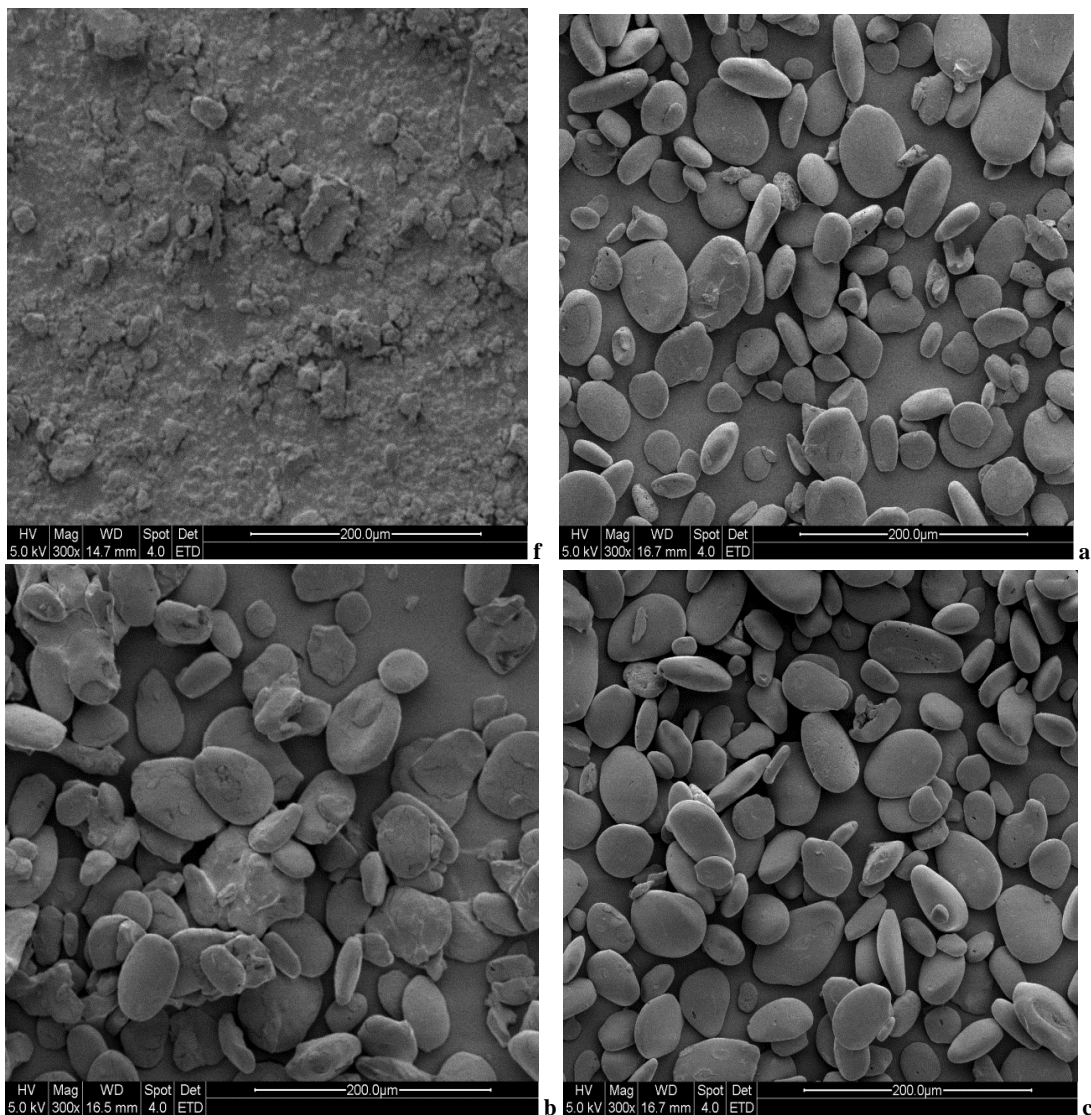


Figure 1: (f, a-c): Scanning electron micrographs of *Parkia* flour (f) and different methods starch extract (a): S1 0.5% NaOH, (b): S2 1.5% Na₂S₂O₅, (c): (S3 1:5w/v flour/water ratio).

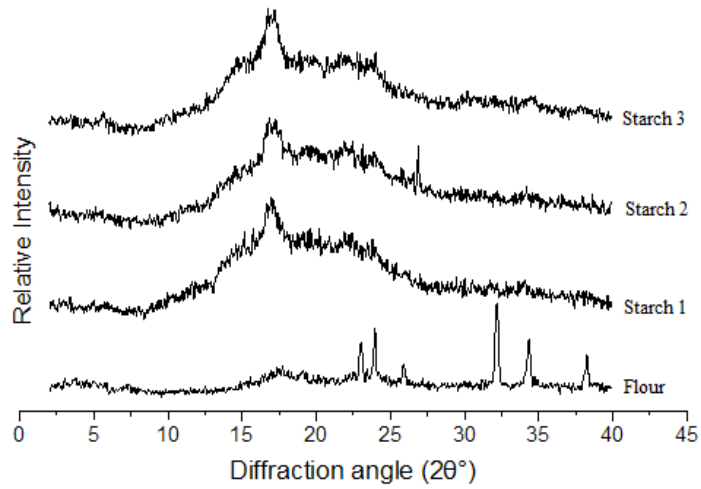


Figure 2: X-ray diffractograms of Parkia flour (F) and different methods starches extract (S1 0.5% NaOH), (S2 1.5%Na₂S₂O₅), (S3 1:5w/v flour/water ratio) in *Parkia biglobosa* seeds.

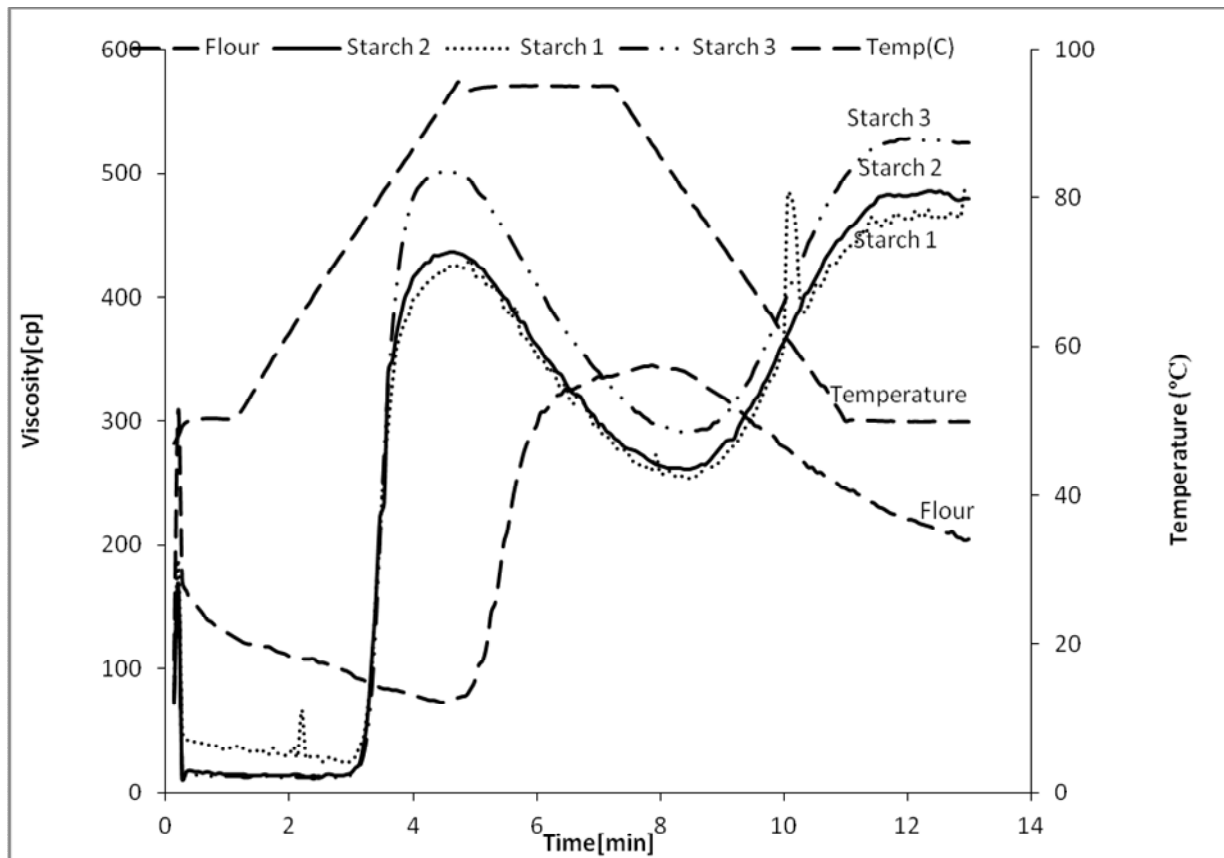


Figure 3: Pasting curves of Parkia flour (F) and different methods starch extract (S1 0.5% NaOH), (S2 1.5%Na₂S₂O₅), (S3 1:5w/v flour/water ratio)

Gelatinisation characteristics

Transition temperatures (T_o, T_p and T_c) and melting enthalpy (DH) of Parkia flour and starches extract in different methods are presented in Table 6. Gelatinisation temperature of starches obtained from *Parkia biglobosa* ranged from 66.13°C to 63.15°C at the onset (T_o), 79.97°C to 71.61°C

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at the midpoint (T_p) and 72.15°C to 69.23°C at the end of gelatinisation (T_c). Then the enthalpy of gelatinisation (DH) was ranged from 14.12 (J/g) to 13.76 (J/g). The gelatinisation temperature of the flour was higher, while the enthalpy of gelatinisation was lower than that of the starches extract. The results were due to the interaction of starches with other flour component such as protein, fat or fiber. Gelatinisation describes the irreversible disruption of molecular order within a starch granule when heated in excess water. Starch gelatinisation temperature and gelatinisation enthalpy are influenced by starch compositions, molecular structure of amylopectin and granule architecture (Tester, 1997). The gelatinization temperature seems to be influenced by the molecular architecture of the crystalline region rather than the amylose content (proportion of crystalline region) of starch (Bao and Bergman, 2004). In addition, the isolation procedures may have an impact on the value.

Table 6: Gelatinization parameters of starches extract and flour from *Parkia biglobosa* seeds

Samples	To °C	T _p °C	T _c °C	DH (J/g)
Flour	76.56±0.14 ^a	93.38±0.42 ^a	89.47±0.24 ^a	4.15±0.33 ^d
Starch (1)	63.15±0.23 ^d	72.97±0.27 ^c	70.13±0.23 ^c	14.12±0.37 ^a
Starch (2)	66.13±0.31 ^b	79.97±0.32 ^b	72.15±0.37 ^b	13.83±0.28 ^b
Starch (3)	65.42±0.45 ^c	71.61±0.36 ^d	69.23±0.29 ^d	13.76±0.36 ^c

Values (Mean ± SD) in the same column with different letters are significantly at ($P < 0.05$), $n=3$.

Conclusion

The decrease in paste viscosities of flour compared to starches extract by different methods in this study are attributed to the interaction of starch with the protein, fat, etc. and plays an important role in governing the pasting properties of starch. Overall, the physico-chemical, minerals and functional properties obtained indicate that *Parkia* starch has useful technological properties for many applications. It can be used in the food processing industry and non-food applications of starch such as in paper and textile industries. The functionality and pasting curve data show that the *Parkia* starch can be used as a functional ingredient in food systems. From the results, it can be concluded that flour and starches extract *Parkia biglobosa* could become interesting alternatives for food developers, depending on their characteristics and functional properties

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