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Isolation and evaluation of some physicochemical properties of *Parkia biglobosa* starch*

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Abstract: This paper describes the isolation and physicochemical characterization of starch obtained from *Parkia biglobosa* (African locust bean). The results show that the properties of starch from this source compare favorably with those of corn starch BP (British Pharmacopoeia), and suggest that it could be useful as a stabilizer in baking powders and as an emulsifier in the food industry.

Keywords: *Parkia biglobosa*; starches; isolation; African locust bean; physicochemical characterization.

INTRODUCTION

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. Native starches from different botanical sources vary widely in structure and composition, but all granules consist of two major molecular components, amylose (20–30 %) and amylopectin (70–80 %). Starch has found immense industrial use in the manufacture of products such as food, textile, paper, adhesives, and pharmaceuticals. The industrial usage is based on the adhesive, thickening, gelling, and film-forming properties as well as its ready availability, low cost, and controlled quality [1,2]. 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.

The African locust bean tree, *Parkia biglobosa*, is a perennial leguminous tree that belongs to the Mimosoideae family. It grows in the savannah region of West Africa up to the southern edge of the Sahel zone 13° N [3]. The tree is not normally cultivated but can be seen in the wild in the savannah region of Nigeria. The seed is commonly called *kaluwa* and the fruit, *dorowa* or *dozim*, around the northern region of Nigeria. *P. biglobosa* tree plays a vital economic role in recycling nutrients from the soil. It is a good source of timber and is useful in making pestles, mortars, bows, hoe handles, etc. *P. biglobosa* tree is usually carefully preserved by inhabitants of the area where it grows because it is also a valuable source of food. The seeds serve as a source of useful ingredients for consumption [3]. It has been reported that the husks and pods are good feed for livestock [2], and the floury pulp can be made into a refreshing drink, rich in vitamin C and sugar [3]. Apart from its excellent caloric and nutrient

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value, its wide adaptability, drought resistance, and multifunctional usage makes it a sustainable source of its by-products.

Research findings have revealed that many native starches, irrespective of their sources, are undesirable for many applications [1] because of their inability to withstand processing conditions such as extreme temperature, diverse pH, acid, alkaline reactions, etc. Because starch finds application in various industries, the search for new sources of starch, like *P. biglobosa*, becomes necessary. 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 [3], no work has been reported in the literature on the isolation and evaluation of the physicochemical properties of the starch obtained from this seed.

The objective of this study, therefore, is to isolate and characterize this starch and provide information on its composition and some selected physicochemical properties that may provide an insight into its usefulness in the food and pharmaceutical industries, using corn starch BP (British Pharmacopoeia) as comparing standard.

MATERIALS AND METHODS

Materials

P. biglobosa seeds were purchased from Karmo market in Abuja, Nigeria, corn starch BP was purchased from Sigma UK, and sodium hypochlorite was purchased from Reckitt. All other reagents used were of analytical grade.

Methods

Starch isolation

A method found in the literature [4] was adopted with slight modification for the isolation of starch. Visible dirt and contaminants were removed from the dark-colored *Parkia* seed (1 kg), which was then steeped in a solution of sodium hypochlorite (70 g) and potassium hydroxide (100 g) in water (2 L) at room temperature (28 °C) for 3 h. The pH of the steep solution was then adjusted to 9, and it was maintained at 100 °C in a thermostatted water bath for 3 h. The solution was drained, and the seeds were immersed in water and left overnight at ambient temperature. The seeds were thoroughly washed, manually dehulled, and the cotyledon was washed repeatedly until the wash pH was neutral. The cotyledon was blended with water for 24 h using a domestic blender. The homogenate was filtered through muslin cloth, and the filtrate was allowed to settle overnight. The supernatant was decanted, and the sediment was centrifuged at 4500 rpm for 10 min. The sedimented starch was re-suspended in water, and the process was repeated six times. The resultant starch was dried at 60 °C in a hot air oven, then ground to powder using a mortar and pestle and stored in cellophane wrapping.

The starch was then defatted in accordance with a slightly modified literature method [5]. Thus, a suspension of starch in petroleum ether was shaken thoroughly for 24 h, then the supernatant was decanted into a tarred Petri dish and evaporated on a hot plate, and the weight of the residue was recorded. This process was repeated, and the combined residue weights gave the fat content as a percentage of the initial starch weight.

Determination of chemical composition

The ash value, water solubility, acid insolubility, bulk, tapped and true densities, amylose/amylopectin, and protein were determined using standard methods [6–9].

Elemental analysis using atomic absorption spectrophotometer

Three elements, namely, calcium, iron, and phosphorus were determined using an atomic absorption spectrophotometer (AAS) for the metals and UV spectrophotometer for phosphorus.

Determination of some physicochemical properties

pH determination was done by shaking a 20 % w/v dispersion of the samples in water for 5 min, and the pH was determined using a pH meter (Corning, UK).

Methods reported elsewhere were used in the determination of moisture content, solubility, swelling [6], and water absorption capacities [10].

Foam capacity: A slightly modified method [11] was used; essentially, 2 g of each starch sample was separately homogenized in 100 ml of distilled water using a vortex mixer for 5 min. The homogenate was poured into a 250-ml measuring cylinder, and the volume occupied after 30 s was noted. The foam capacity was expressed as the percent increase in volume. The mean of three replicate determinations is presented.

Emulsion capacity: 2 g of each starch was dispersed in 25 ml of distilled water and vortexed for 30 s. 25 ml of vegetable oil was then added gradually and the mixing continued for another 30 s. The suspension was centrifuged at 1600 rpm for 5 min. The volume of oil separated from the sample was read directly from the tube. Emulsion capacity is the amount of oil emulsified and held per gram of sample [10].

Pasting properties/viscosity using Rapid Visco Analyzer

The pasting temperature and viscosity of 12 % w/v of both *Parkia* and corn starches were readily assessed using the Rapid Visco Analyzer model RVA-3D made compatible with a computer. The samples were assessed for peak viscosity, hold or trough, breakdown, final viscosity, set back, peak time, and pasting temperature.

Gelatinization temperature and particle size analysis were carried according to the method found in literature [6].

Differential scanning calorimetry (DSC)

Gelatinization properties of the samples were characterized using a Netzsch DSC 204 F1 Phoenix (Netzsch, Germany). Nitrogen, at the rate of 20 ml/min, was used as purge gas; 2.7 mg of powdered material was sealed in an aluminum pan and heated from 30 °C up to 400 °C at the rate of 10 °C/min, followed by a cooling cycle back to 30 °C at the same rate. The onset of gelatinization temperature (T_0), peak temperature (T_p), gelatinization temperature at end (T_e), and melting enthalpy (ΔH) were recorded.

RESULTS AND DISCUSSION

Table 1 represents the chemical compositions of *Parkia* and corn starches, while Tables 2 and 3 show some physicochemical properties of *Parkia* and corn starches and the pasting properties of *Parkia* and corn starches, respectively.

Table 1 Chemical composition of *Parkia* and corn starches.

S/N	Parameters	*Parkia* starch	Corn starch
1	Fat (%)	28.0 ± 0.0	1.0 ± 0.0
2	Protein (%)	28.4 ± 0.0	3.4 ± 0.0
3	Total ash (%)	3.0 ± 0.0	1.0 ± 0.0
4	Water-soluble ash (%)	0.0 ± 0.0	0.0 ± 0.0
5	Acid-insoluble ash (%)	0.0 ± 0.0	1.0 ± 0.0
6	True density (g/ml)	2.3 ± 0.2	2.7 ± 0.0
7	Amylose:amylopectin ratio (%)	23:8 ± 0.1	8.5:91.5 ± 0.0
8	Phosphorus (mg/100 g)	188.6 ± 0.0	36.0 ± 0.0
9	Calcium (mg/100 g)	45.3 ± 0.0	18.6 ± 0.0
10	Iron (mg/100 g)	65.6 ± 0.0	15.2 ± 0.0

Table 2 Some physicochemical properties of *Parkia* and corn starches.

S/N	Parameters	*Parkia* starch	Corn starch
1	pH	5.6 ± 0.0	6.4 ± 0.0
2	Bulk density (g/ml)	0.5 ± 0.9	0.5 ± 1.6
3	Tapped density (g/ml)	0.7 ± 0.0	0.9 ± 0.5
4	Moisture content (%)	6.0 ± 0.0	11.0 ± 0.0
5	Gelatinization temperature (°C)	95.0 ± 0.0	72.0 ± 0.0
6	Foam capacity (%)	3.3 ± 0.0	1.0 ± 0.0
7	Emulsion capacity (%)	41.9 ± 0.9	48.0 ± 0.5
8	Water absorption capacity (%)	116.0 ± 0.0	92.8 ± 0.1
9	Reitch particle size distribution (μm)	24.0 ± 0.0	15.0 ± 0.0
10	Peak viscosity (RVU)	–2.7 ± 0.0	259.3 ± 0.00

Table 3 Pasting properties of *Parkia* and corn starches.

S/N	Peak viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min)	Pasting temp. (°C)
Parkia	–2.7	–3.4	0.7	–3.0	0.4	1.1	95.0
Corn	259.3	192.7	66.6	269.5	76.7	5.4	85.0

Discussion

The starch obtained was slightly off white in color, and the yield was about 11 % w/w. The pH of 5.6 obtained for *Parkia* starch is within the pH range of 3–9 obtained for most starches in use in the pharmaceutical, cosmetics, and food industries. The water-soluble and acid-insoluble ash contents of *Parkia* starch compare favorably with those of corn starch BP (Table 1). The total ash content of parkia was found to be higher than that of corn starch. This is probably due to their biological origin and the methods of extraction [6]. Density results also show that *Parkia* starch compares favorably with starch BP. The ratio of amylose to amylopectin for *Parkia* starch was found to be 23:77 compared to 8.5: 91.5 for corn starch (Table 2). This result is consistent with an earlier report [12], that starches from leguminous sources have high amylose content. A high water absorption capacity was obtained for *Parkia* starch, and this tends to corroborate the high amylose content. It has been reported [13] that the degree of water absorption of a starch is directly related to its amylose content. Starches with high amylose content were likely to have higher water absorption capacity, and this has been found to improve the capacity of starch granules to expand in volume without collapsing [14].

Swelling and solubility

The swelling and solubility profiles of *Parkia* and corn starches are shown in Figs. 1 and 2, respectively. There was a temperature-dependent increase in both swelling and solubility of the starches. Both starches show steady increase in swelling and solubility between 60–85 °C, and a sharp drop in the solubility of *Parkia* starch as the temperature increased further. Generally, *Parkia* starch exhibits a lower swelling capacity and a higher solubility profile than corn starch. This observation is consistent with earlier reports [12,14]. These authors attributed this phenomenon to a high degree of intermolecular association in their investigative starch. Other scholars [6,14] have also attributed low swelling and solubility to high amylose and fat contents. The relatively high fat content of *Parkia* starch (Table 1), therefore, may also contribute to the low swelling and solubility noticed.

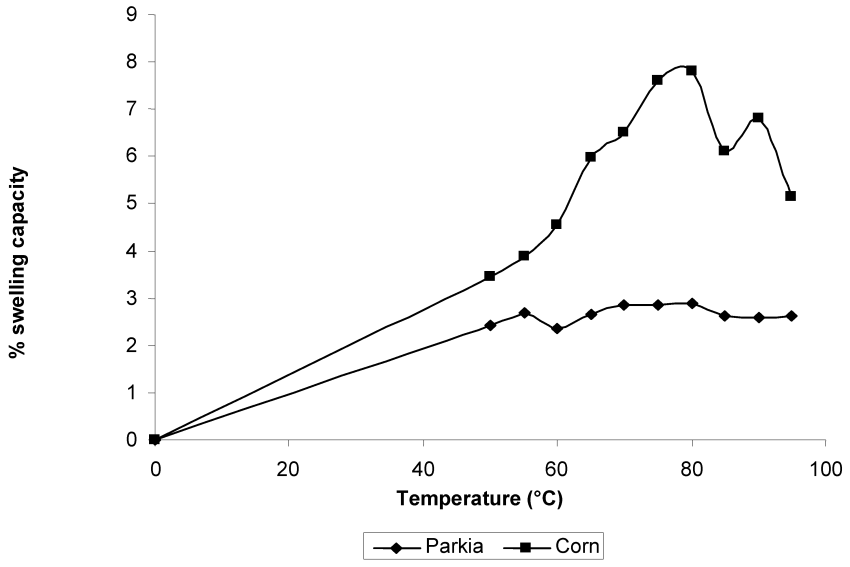

Fig. 1 Percent swelling pattern of *Parkia* and corn starches.

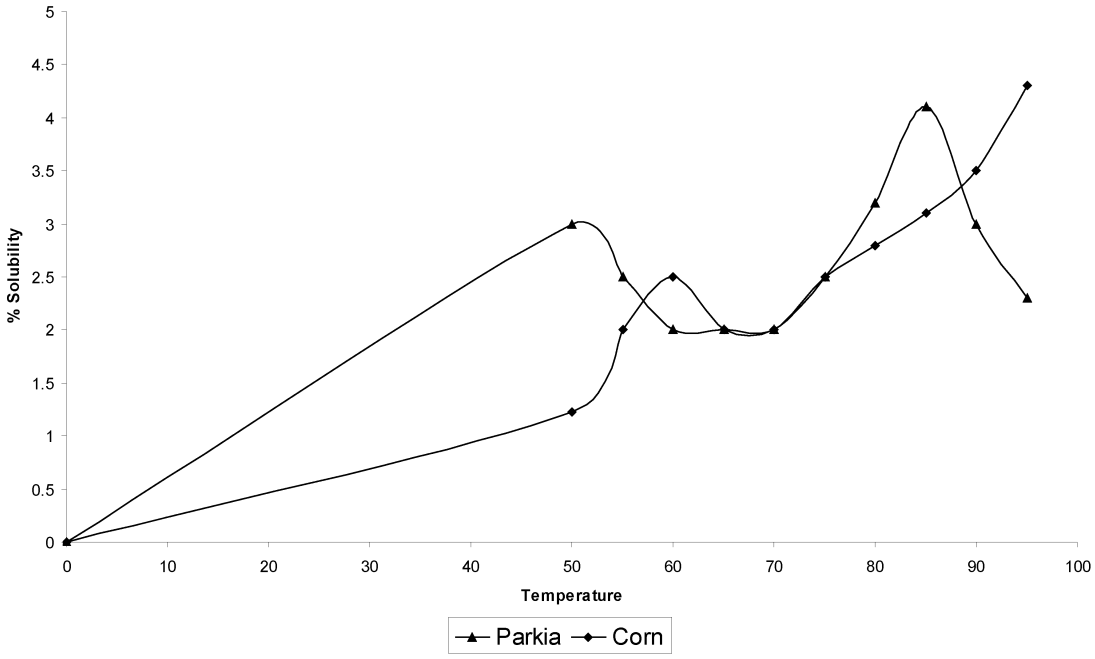

Fig. 2 Percent solubility pattern of *Parkia* and corn starches.

Morphology

Figure 3 shows the photomicrographs of *Parkia* and corn starches. *Parkia* starch shows a mixture of large-, rhombic-, and some small-sized granules, which are bigger than the more uniform, round-shaped corn starch granules. This observation is not unexpected as the biological/botanical origin of starch has been reported to affect its physicochemical properties such as shape, size, and morphology. It has been

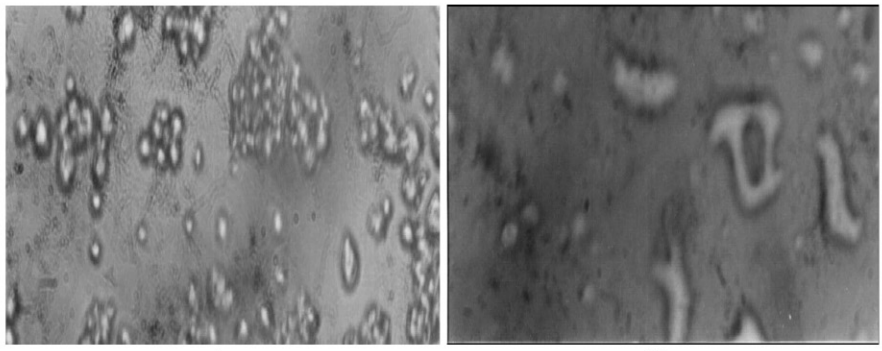

Fig. 3 Photomicrograph of corn (A) and *Parkia* (B) starches.

reported [15,16] that small- and medium-sized starches have possible utilization as fat substituents, stabilizers in baking powder, stiffening agent in laundry and in the manufacture of biodegradable plastics films. *Parkia* starch could, therefore, find application in these industries.

Water absorption capacity

The result of the water absorption capacity shows that *Parkia* starch exhibits higher capacity than corn starch. This is in agreement with previous studies [13], that starches with higher amylose content generally have higher water absorption capacity. *Parkia* starch therefore may be found useful in the baking industry since starches with high water absorption capacity have been reported useful in the baking industry [16].

Gelatinization

The gelatinization temperature of parkia starch was found to be higher than that of corn starch (Table 2). This is probably due to the high fat, amylose, and/or associative forces in *Parkia* starch. Earlier reports [6,14] showed that fat inhibit swelling probably by forming insoluble complexes with amylose, leading to high gelatinization temperatures. High degree and type of molecular association in starch have also been found to influence gelatinization temperatures [14].

Pasting properties

Viscoamylography reveals that *Parkia* starch exhibits a very low peak viscosity (–2.67 rapid viscosity units, RVU) compared to corn starch with a peak viscosity value of 259.33 RVU. The final viscosities of *Parkia* and corn starches are –3.00 and 269.50 RVU, respectively. The high cation content of Parkia starch (Table 1) is most probably responsible for the low viscosity observed. The presence of cations in materials has been reported to decrease viscosities of their solutions [17–19].

Foam and emulsion capacities

The foam capacity of *Parkia* starch (Table 2) is 3-fold higher than that of corn starch, implying that *Parkia* starch could be a better emulsifier than corn starch BP [10].

Differential scanning calorimetry

DSC, because of its sensitivity and accuracy, has been used to study the phase transitions of the gelatinization process [20]. The parameters derived from the thermograms for *Parkia* and corn starches; onset, peak, and endset temperatures ($T_{0,}$ T_{p}, and T_{e}, respectively) are listed in Table 4. The value of these parameters for *Parkia* starch are lower than those of corn starch BP. This suggests that *Parkia* starch is less resistant to heat than corn starch BP. Although parkia starch has higher gelatinization temperature than corn starch BP, its ΔH value (54.6 °C) is unexpectedly lower (61.8 °C). However, our result seems to agree with an earlier study [20], that a starch with high gelatinization temperature may

also have low ΔH value. The DSC thermograms of the starches (picture not shown) indicate a clear difference in the crystallinity of the starches. Corn starch shows both amorphous and crystalline properties, while *Parkia* starch is only amorphous in nature, as indicated by the absence of a melting peak. The area under the transition curve for *Parkia* is lower than that of corn starch, implying that more energy is required to convert corn starch. This corroborates our earlier observation that *Parkia* starch is less stable to heat than corn starch.

Table 4 Thermal properties of *Parkia* and corn starches.

Parameter	*Parkia* peak	Corn peak
Onset temperature (°C)	73.7	101.3
Peak temperature (°C)	74.4	117.9
Endset temperature (°C)	75.3	120.2
Enthalpy of Gelatinization (mJ/mg)	54.6	61.8
$\Delta T(T_e - T_0)$	0.9	18.9
Area (J/g)	–499	–107.1

CONCLUSION

This study reveals that *P. biglobosa* is a good source of starch. The physicochemical properties of the starch obtained from this plant compare favorably with those of corn starch BP. It is, therefore, a potential industrial starch especially for the food and pharmaceutical industries.

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