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Extraction and Some Characteristics of Mango Seed Kernel Starch for Industrial Applications

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ABSTRACT

Starch is extensively used for various applications in many industries such as food, pharmaceutical, textile, and many more. Mango starch is a better solution to reduce the reliance on food crops starch for food security. Starch is a polymer of hexa carbon monosaccharide–D–glucose. It is highly abundant in corn seeds, potato tubers, and the roots and stems of other plants. All green plants make and store D-glucose in the form of spherical starch granules: 2–100 µm in diameter. Most commercially available starches are isolated from grains such as maize, rice, and wheat and from tubers such as cassava and potato. A novel starch from mango seed was extracted and characterized using a standard method for potential industrial applications. A high yield of 76.82 % and further characterized through Proximate analysis, with a moisture content of 4.790, ash content of 0.210, the starch protein content of 0.043, and starch lipid 0.380. FTIR, morphological structures, and some physical characteristics such as water binding capacity (WBC), solubility, and other parameters were observed for their suitability in industrial applications.

Keywords: *Mango starch, proximate analysis, morphological structures, solubility, FTIR, and Scanning Electron Microscopy*

INTRODUCTION

Starch is a natural polymer, an inexpensive and abundant resource that is biodegradable and can easily be degraded in water. Often used as filler to replace petroleum-derived synthetic polymers to reduce environmental pollution [1]. Thus, it finds its applications in many industries. Starch is a polymeric carbohydrate composed of anhydroglucose units. This is not a uniform material, and most starches contain two types of glucose polymers: a linear chain molecule termed amylase and a branched polymer of glucose termed amylopectin [2].

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Starch is the reserved carbohydrate stored as glucose in plants to meet energy needs. It is a natural polymer comprising hundreds of thousands of glucose units linked together by glycosidic bonds. It is the most common carbohydrate in human diets and contains large amounts such as yam, cassava, wheat, corn, rice, potatoes, and mushrooms [3]. Starch is a white, granular, organic chemical that all green plants produce. Starch is a soft, white, tasteless powder insoluble in cold water, alcohol, or other solvents. The primary chemical formula of the starch molecule is $(C_6H_{10}O_5)_n$. Starch is a polysaccharide comprising glucose monomers joined in α 1,4 linkages. The simplest form of starch is the linear polymer amylose, while amylopectin is the branched form. Starch in chloroplasts is transitory, accumulates during the light period, and is utilized during the dark. Storage starch accumulates in reserve organs during one phase of the plant's lifecycle and is utilized at another time. Starches from the reserve organs of many plants are important in commerce [4].

Starch made from mango seeds kernel is non-edible. These seeds are generally thrown away, and hence their use results in substantial value addition. Yield from seeds is about 60 %. Starch constitutes the major part of the carbohydrate; the rest comprises mono- and disaccharides, particularly maltose, and saccharose. The typical starch content is 22 %. The starch granules vary in size from 4-40 µm with 19 µm on average. The amylose content is approximately 18 %. Chemically, starch is a polymer of D-glucose units linked in two forms, alpha-1,4 links between the linear molecules and alpha-1,6 links at the branch points. The links of D-glucose units form the macrostructure of starch as a mixture of amylose, a predominantly linear polymer with some slight branches, and amylopectin, a highly branched polymer. The formation of α – links in a starch molecule enable some parts of starch polymers to generable helix structures; this is determined by the orientation of hydroxyl (-OH) groups on the first carbon atom (C_1) and the pyranose ring. Studies on the starch's chemical properties and structure have recognized that it comprises two components, both polysaccharides: amylose (20 – 30 %) and amylopectin. The ratio of these compounds varies, subject to the source of origin [5].

The amylose is a linear polysaccharide composed of D-glucose units linked by α(1 – 4) linkages (Figure 1). These chains are partially ramified with some α(1 – 6) linkages. Depending on the botanical source and the extraction process, amylose molecular weight varies from 10^5 to $10^6 gmol^{-1}$ with a poly disparity ranging from 1.3 to 2. 1 [6]. The amylose chain shows a single or double-helical conformation with a rotation on the α(1 – 4) linkages. Amylose is a linear portion of starch. It is a polymer of glycopyronosyl monomers linked to each other by α (1 – 4) linkages. Amylopectin has the same backbone as amylose but is a branched polymer of α (1 – 6) monomer linkages [7].

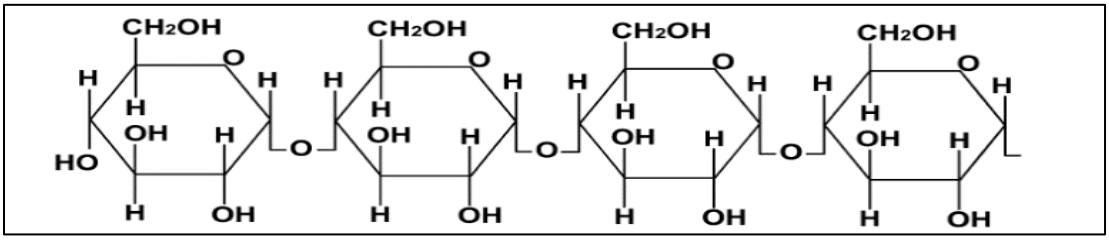

Figure 1: Amylose structure comprised a linear polysaccharide composed of D-glucose units linked by α-1,4[1]-linkages

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Amylopectin is the main starch component and has the same monomeric unit as that of amylose by showing 95% α(1 – 4) linkages and 5% α(1 – 6) linkages (Figure 2). The molecular weights of amylose and amylopectin have been estimated to be about 10^5 and $10^8 gmol^{-1}$, respectively. Both amylose and amylopectin consist of glucopyranose molecules, yet the structural differences between these two polymers determine their different properties.

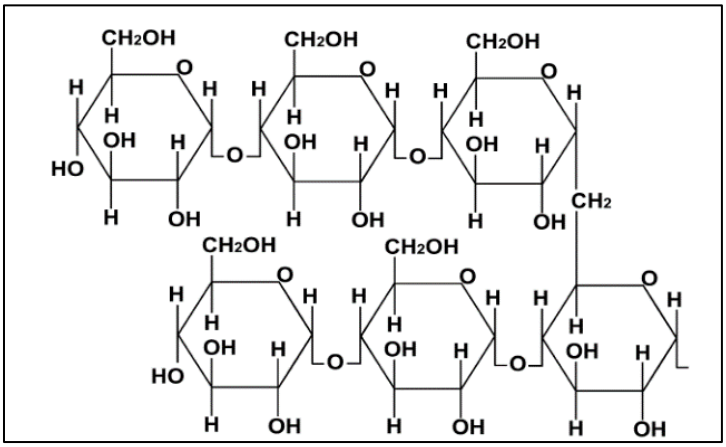

Figure 2: Amylopectin structure comprised of α-1,6[1]-linkage

Natural starches are recently getting consideration as polymers, easily available, non-toxic, readily modified, biodegradable, and biocompatible. The food industry has widely used starch as an adhesive, binding, gelling, and thickening agent. One such source for starch production is mango (Mangifera Indica) seed kernel. India is the largest mango producer, with 44.14 % of the world's total production. Mango flesh is usually consumed or processed in an industry, thus disposing of a large amount of seed as solid waste. Approximately 40–60 % of waste is generated during mango processing, out of which peel and kernel constitute 12–15 % and 15–20 %, respectively. On a dry basis, the Mango kernel contains 65 % starch [8]. Therefore, it has been expanding research for new materials with high performance and at an affordable cost that can be defined by renewability, recyclability, sustainability, biodegradability, and biocompatibility [9].

EXPERIMENTAL

Sample Collection

About 150 pieces of mango fruits were gotten from a local market (Na'ibawa Yan lemur) located along Zaria Road in Kano, Nigeria. Mango belongs to the genus Mangifera of the family Anacardiaceae. The mango is a tropical fruit. The specie of fruit used was identified in the Herbarium of Ahmadu Bello University, Zaria, with a voucher number of 10517.

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Sample Extraction

The kernel of the mango seeds samples will be cut into small pieces and steeped in 0.16 % aqueous solution of sodium hydrogen sulfite for 24 hours for preservation. The solution was decanted, and the samples were grounded in a laboratory blender. The ground slurry was screened through muslin cloth, where it was left, and washed thoroughly with distilled water. After 1 hour, the supernatant was then decanted from the filtrate and allowed the starch layer to settle and re-suspended again in distilled water, followed by centrifuging at 2800 rpm for about 5 min. The upper non-white layer of the residue was scraped off, and the white layer was re-suspended in distilled water and centrifuged. This was repeated four more times, and finally, the starch was collected and dried at 50ºC for 6 hours in an oven [10].

Proximate Analysis

The moisture, ash, protein, lipid contents, water binding capacity, starch, swelling power, and mango seed kernel starch solubility were determined. The method for moisture content determination was adopted by [11] and [12]. The ash content was determined according to the method described by [13]. Thus, the measurement of the residue left after the combustion of 2g of starch in a silica dish at 450ºC and the percentage of ash was calculated relative to the amount of sample combusted. The protein determination used the AOAC (1995) method using the Kjedal apparatus [14]. The lipid content was determined by extracting the lipid with petroleum ether, using a soxhlet setup.

Water Binding Capacity Determination

Water binding capacity (WBC) was determined according to the method described [15] with a few modifications. About 1g of starch was suspended in 20 cm^3 of distilled water, and the suspension was agitated for 1 hour on a shaker, after which it was centrifuged for 10 min at 2200 rpm. The supernatant was decanted, and the starch deposit was drained for 10mins and then weighed. Water binding capacity was calculated using equation 1 [16].

$$\text{WBC (\%)} = (\text{Weight of drained starch} - \text{Weight of the container}) \times 100 \qquad \text{Equation 1}$$

Starch Turbidity

This was determined as described by [17]. A 1 % aqueous suspension of the starch sample was heated in a water bath at about 90ºC for an hour with constant stirring. The suspension was cooled to 30ºC for an hour. The sample was then stored for four days in a refrigerator, and the turbidity was determined with a spectrophotometer at 640 nm absorbance against a blank (water).

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Swelling Power and Solubility

The swelling power and the solubility were determined using the method [18]. An amount of 0.4g of the starch sample in a centrifuge tube was treated with 40 cm^3 of deionized water. The slurry was heated at various temperature intervals of 0, 20, 40, 60, 80, and 100°C in the water bath for 30 minutes. After cooling to room temperature, the solution was centrifuged at 3000 rpm for 15 minutes. The supernatant was carefully recovered, and the swollen starch sediment was weighed. An aliquot of the supernatant was then evaporated overnight in an oven, and swelling power and solubility were calculated from the below Equation 2 and Equation 3.

$$\text{Swelling power (g/g)} = \frac{Weight of Sediments\ (g)}{Weight of dry starch\ (g)} \qquad \text{Equation 2}$$

$$\text{Solubility (\%)} = \frac{Weight of Supernatant\ (g)}{Weight of dry Starch} x\ 100 \qquad \text{Equation 3}$$

RESULTS AND DISCUSSION

FTIR Spectra of the Mango Seed Kernel Starch

The FTIR – Spectra for starch was acquired using FTIR – 8400S (SHIMADZU, Japan) at a frequency range of 4000 – 400 cm^{-1} (Figure 3). The spectra obtained were analyzed for the presence/absence of critical functional groups by comparison with a standard FTIR correlation table. In the spectra of the starch, there is strong broadband due to the hydroxyl group stretching at 3000 – 3600 cm^{-1} [19], a strong absorption band which appears at 1157 – 1643 cm^{-1} is probably due to the C-O-C band in the starch. Another peak at the range of 1000 – 1260 cm^{-1} in these spectra is due to C–O (alkoxy) band in the starch component.

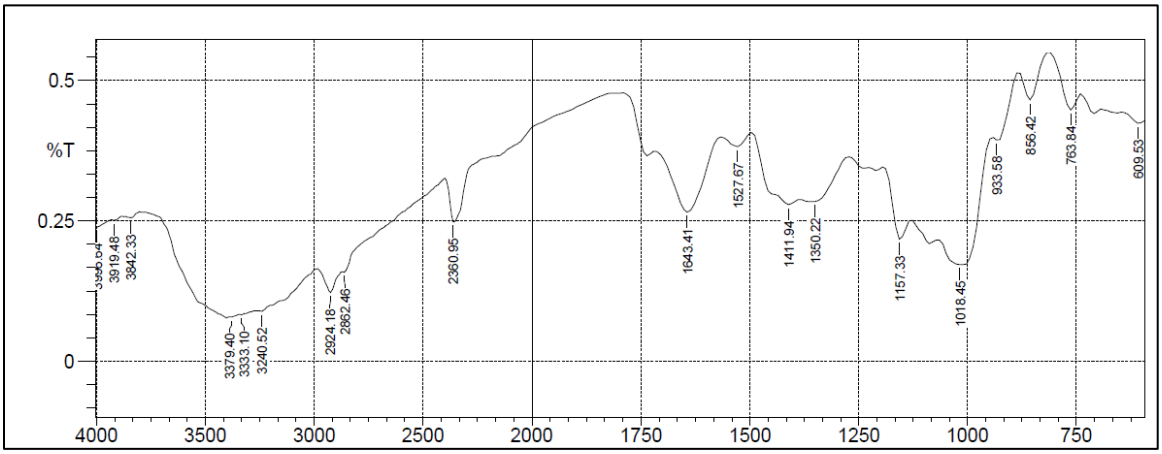

Figure 3: The FTIR spectra of the mango seed kernel starch

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Proximate Analysis of the Mango Starch Extracted

The moisture, ash, protein, and lipid content of the mango starch extract are presented in Table 1. All values are averages of triplicate determinations expressed on a dry weight basis. Another physicochemical parameter, such as turbidity, is shown in Table 2.

Table 1: Proximate analysis of the mango seed kernel starch extracted

Parameter	Percentage composition (%)
Moisture content	4.790
Ash content	0.210
Protein content	0.043
Lipid content	0.38

Table 2: Turbidity of the mango starch extract

Turbidity/NTU	Time/hr
1.61	0
2.53	24
2.51	48
2.42	72
2.31	96
2.33	120
2.40	144

Swelling Power and Solubility

The mango starch extract's swelling power and solubility are presented in Table 3 and Figure 4. The highest swelling power (6.9395) was observed at 60°C. In contrast, the highest solubility percentage (0.4415) was observed when the slurry of the mango starch extract was dried at 70°C.

Table 3: Swelling power and solubility of the mango starch extract

S/N	Temperature (°C)	Swelling Power	Solubility (%)
1	0	3.7760	0.1590
2	10	3.2755	0.1840
3	20	3.7695	0.1793
4	30	3.0395	0.1304

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5	40	3.4065	0.1432
6	50	4.0190	0.1983
7	60	6.9395	0.0383
8	70	5.3995	0.4415
9	80	4.7095	0.3562
10	90	1.0662	0.2963
11	100	6.0205	0.2935

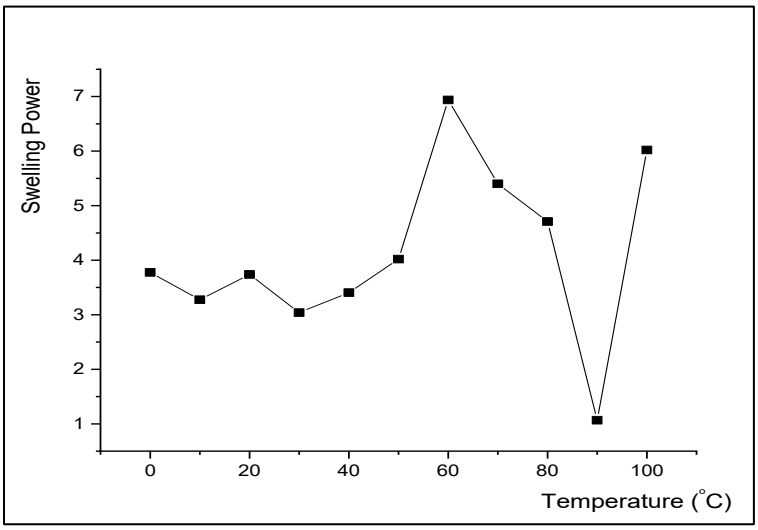

Figure 4: The swelling power of the mango starch extract

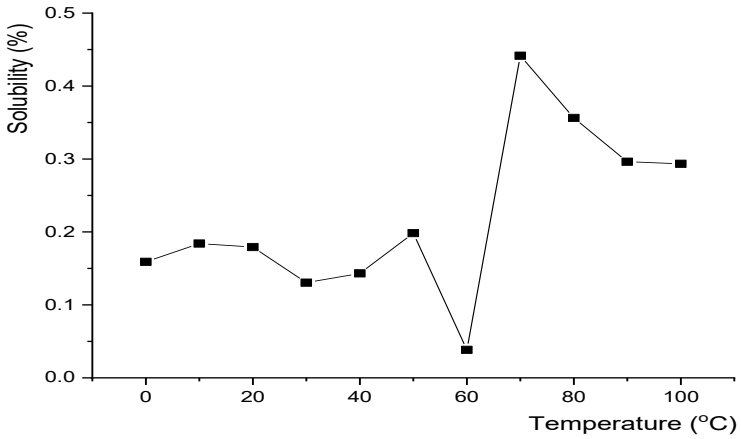

Figure 5: The solubility of the mango starch extract

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Scanning Electron Microscopy (SEM)

Scanning electron microscopy was used to evaluate the miscibility, roughness, and compatibility of the starch, Polyvinyl acetate, and polymer blends through morphological analysis (Figure 6). The machine used was PRO X: Scanning Electron Microscope, Phenonm World, Model no; 800 – 07334, Serial no. MVE01570775. The starch samples' micrographs revealed starch granules at 1600x magnification of 50µm, from small to large and oval to irregular or cuboidal shapes with smooth surfaces. The average diameter of the starch granules ranges from 50 µm to 100 µm. This indicates that the starch had little impact on the granule shape and size [20]. Therefore, surface analysis of the extracted starch performed at different magnifications showed that mango seed kernel starch granules have an oval shape with pores on the surface. The pores also depend on the starch origin, which may be more or less deep; sometimes, they form channels in the interior of the granules [21].

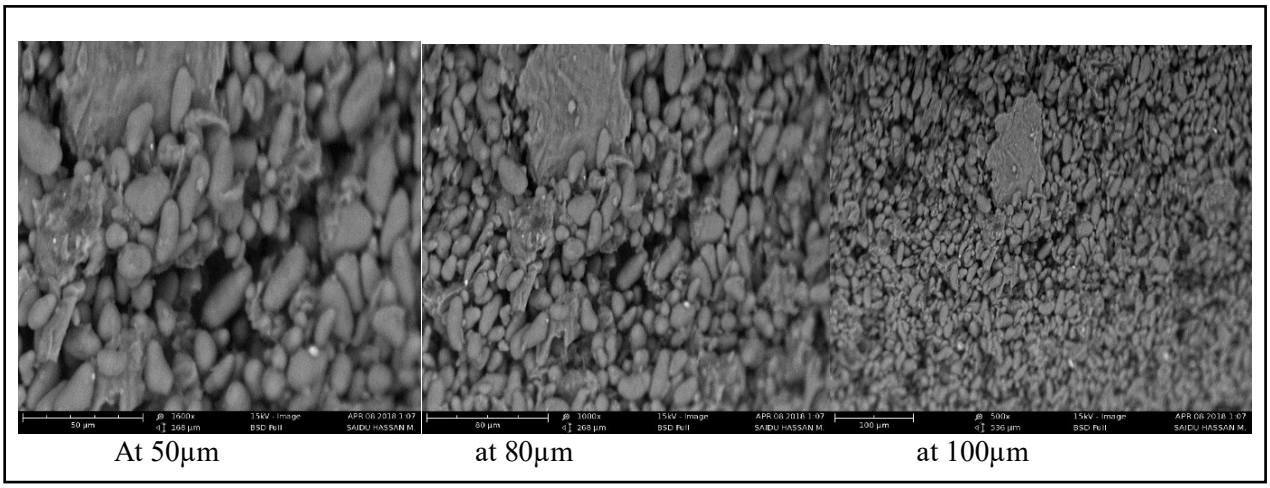

Figure 6: The SEM morphology of the mango seed kernel starch

CONCLUSION

The studies observed it has shown that mango seed starch has excellent potential for future utilization, based on the morphological studies, as shown in the scanning electron microscopy, water binding capacity, the proximate analysis, and even the swelling power and solubility ascertain the starch prospects for many industrial applications.

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Ahmadu Bello University Zaria, for Identifying the species used. The authors also acknowledge the Department of Chemistry, Kano University of Science and Technology Wudil, for Institutional support and assistance.

AUTHOR'S CONTRIBUTION

Saidu Hassan Musa carried out the research and wrote the article. Professor Balarabe Sarki Sagagi conceptualized the central research idea and provided the theoretical framework and writing skills.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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