Journal of Science and Practice of Pharmacy
December 2022; 9 (1): 447-458
Available at http://www.jsppharm.org; https://doi.org/10.47227/jsppharm.v9i1.1
ISSN: 2449-0458 (print); 2449-0466 (electronic)

Original Research Article

Characterization of Avocado (*Persea americana*) Seed Starch - Physicochemical and Powder Properties

Osaretin D Enadeghe[1*], Sylvester O Eraga[2] and Johnbull A Obarisiagbon[1]

[1]Department of Pharmaceutics and Pharmaceutical Technology, College of Pharmacy, Igbinedion University, Okada, Edo State, Nigeria. [2]Department of Pharmaceutics and Pharmaceutical Technology, Faculty of Pharmacy, University of Benin, PMB 1154, Benin City, 300001, Nigeria.

* For correspondence: *E-mail: eodavy@gmail.com, Tel: +2348039326112*

Abstract

Introduction: Starch is a biopolymer commonly used as an excipient in pharmaceutical formulations due to its biocompatibility, inertness, biodegradability, availability and affordability.
Purpose: The study aimed to extract and characterize the starch isolated from avocado (*Persea americana*) seeds and investigate its disintegrant and binder properties in paracetamol tablet formulations.
Methods: Starch was extracted from avocado seed using standard methods and then subjected to some phytochemical, physicochemical and bulk powder properties analyses. High-resolution analyses using differential scanning calorimetry (DSC), Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM) and x-ray diffractometry (XRD) were also carried out on the extracted starch powder.
Results: Starch extraction yield was 19.61% and the starch was light-brown in colour, odourless, tasteless and smooth in texture. The starch showed a melting point range of 102-114°C and moisture content of 22.7%. It also exhibited a hydration capacity of 2.76 g/g and swelling and moisture sorption capacities of 46.43 and 115.34%, respectively. The starch powder was cohesive with poor flow properties but the DSC, FTIR, SEM and XRD results showed a semi-crystalline powder composed of fluffy discrete particles.
Conclusion: The starch isolated from *P. americana* seeds exhibited good swelling, hydration and moisture sorption capacities, making it a good candidate as a tablet disintegrant.

Keywords: Avocado, starch, physicochemical, high-resolution, analyses

Indexing: Index Copernicus, African Index Medicus

Introduction

Pharmaceutical excipients are raw materials incorporated into pharmaceutical formulations. These excipients are approved before use and considered to be generally recognized as "inactive" and safe for human consumption. In addition, they are known to enhance product stability, guarantee precision and accuracy, and constitute a bulk of the final product [1-3].

Pharmaceutical excipients are blended with the drug to form a homogenous dosage form and are intended to mask the bitter taste, bulk up the product, improve flowability and control API release after administration. These properties improve patient compliance, efficacy, bioavailability and consequently reduce toxic events [4-6].

Starch is a polysaccharide derivative of natural origin, known to have numerous agricultural, and industrial applications. These characteristics are attributed to its versatility, biodegradability, safety, and cost-effectiveness. Starch is a source of energy, which is stored in numerous parts of a plant, including the leaves, roots, nuts, bulbs, stems, stalk, and crop seeds, as well as in staple crops, consisting of cassava, potato, wheat, corn and rice. The molecules possess specific technological properties, including the propensity to serve as a gelling and forming

material, and also as a film former, thickener, fat-mimicking material, etc. There have also been applications as stabilizers in the production of snacks, fruit juice and meat products [7].

The most common sources of starch worldwide include maize (82%), wheat (8%), potatoes (5%), and cassava (5%). As of 2000, the starch market around the globe was estimated at 48.5 million tons, which was inclusive of both native and modified forms, with an output worth €15 billion every year [8]. Starch has frequently been employed in the formulation of immediate-release tablets, featuring the release and availability of drugs within a short period, to the area where absorption occurs.

Avocado (*Persea americana* Miller) is a tropical and subtropical tree of the family Lauraceae. Its fruit that is commonly called avocado pear is popular and enjoyed in many nations though the plant is native to Central America. Avocado seeds are considered a high starch by-product, making it a promising alternative source of unconventional starch. Depending on the variety, the starch content in the seed can vary between 7.8 and 29.3% (on a dry basis) [9-11].

Avocado starch is widely employed in a variety of industrial applications especially in the food industry. Its use in the pharmaceutical industry as an alternative source of starch has received limited research attention. Also, with little or no local reference materials on the characterization of avocado starch, this study aims to carry out a comprehensive characterization of starch extracted from avocado seed in view of its suitability as a pharmaceutical excipient.

Materials

All chemicals used in this study were of analytical grades and used as supplied by local vendors. Avocado fruits were collected from a tree within the Medical Stores Complex, Benin City, Edo State, Nigeria. The seeds were identified by a taxonomist (Dr. A.H. Adewale) of the Department of Plant Biology and Biotechnology, University of Benin, Nigeria. A voucher specimen sample was deposited in the Herbarium Unit of the Department of Plant Biology and Biotechnology, Faculty of Life Sciences, University of Benin, Nigeria (UBH-P408).

Methods

Starch extraction

Starch extraction from Avocado seed was performed based on the method by Loos *et al.* and adopted by Silva *et al.* [12,13]. The avocado seeds already washed and cut into pieces were infused (soaked) in distilled water containing sodium metabisulfite (0.2%) for twenty-four (24) hours, under refrigeration. The soaked pieces were blended in an industrial mixer with 0.2% sodium metabisulfite solution and the resulting mixture was sieved through 200 mesh (0.074 mm). The filtrate was allowed to stand for 4 hours and the supernatant was discarded. The sediment was re-suspended in 0.2% sodium metabisulfite solution, allowed to stand and the supernatant discarded. The starch sediment was washed several times with distilled water and then dried in an oven at 40°C for 12 hours. The resulting starch powder was weighed and the percentage yield of the starch was calculated.

Phytochemical characterizations

The following phytochemical tests were carried out on the extracted starch powders [14].

Test for saponins

About 5.0 mg of the starch powder was introduced into a test tube containing 1.0 ml of distilled water. The test tube was shaken vigorously and allowed to stand for 10 minutes. The presence of a foamy portion of the dispersion was recorded.

Test for flavonoids

About 5.0 mg of the starch powder in a test tube were added 0.5 ml of chloroform, drops of acetic anhydride and drops of sulphuric acid (H_2SO_4). The test tube was placed in a cool water bath and the presence of a brown ring formed at the interphase was noted.

Test for alkaloids

About 1.0 ml of a 10%w/v suspension of the starch was placed in a test tube and 1.0 ml of 1.0% sulphuric acid was slowly added. The test tube was placed in a cool water bath and 1.0 ml of Picric acid (Agar's reagent) was added. A yellowish (amber) precipitate formed was recorded. Similarly, 1.0 ml of a 10%w/v suspension of the starch placed in a test tube were added 1.0 ml of 1.0% H_2SO_4 and 1.0 ml of Mayer's reagent. A creamy precipitate formed was noted.

Test for tannins
A 1.0 ml of a 10%w/v dispersion of the starch in a test tube were added 5.0 ml of distilled water and a few drops of 0.5% ferric chloride. A greenish-black colouration was formed and recorded.

Test for cardiac glycosides
About 1.0 g of the starch sample was boiled with 10 ml of 70% alcohol in a water bath at 100°C for 2 minutes, cooled and filtered using a 12.5 mm sized filter paper. About 10 ml of distilled water and 5 drops of lead acetate were added to the filtrate, shaken and filtered. Three (3) drops of chloroform were added to the filtrate in a test tube to form an immiscible phase with the chloroform below.

The test tube was then placed above a hot water bath for the water to evaporate. This was carefully done because chloroform is highly inflammable. The content of test tube was allowed to cool before the addition of 3.0 ml of glacial acetic acid and 3 drops of 5% ferric chloride. The test tube was kept in an ice bath and 3.0 ml of concentrated sulphuric acid was then added. A reddish-brown ring formed at the interphase which turned blue on standing was recorded.

Physicochemical characterizations

Organoleptic properties
The physical characteristics of odour, taste, colour and texture were examined by five different people, and scores ranging from 5 to 0 were assigned to each attribute, in order to define the extreme conditions of being acceptable or not. The respective individual scores were then compiled and the 3 predominant responses were defined as positive [15].

Chemical test
The extracted starch powder was subjected to iodine test by introducing 1-2 drops of iodine solution (iodine dissolved in aqueous potassium iodide solution) to about 2-3 ml of starch dispersion. This test was conducted to ascertain the presence of polysaccharides.

Solubility
Exactly 100 mg of starch was dispersed in 10 ml of distilled water contained in a test tube at room temperature. The dispersion was shaken intermittently for 24 hours and filtered using a pre-weighed filter paper. The resulting residue on the filter paper was air-dried and weighed. Solubility was calculated as the percentage difference between the initial weight of the starch sample and the final weight of the filter paper residue [16].

Melting point
The starch powders were packed into a capillary tube sealed at one end and tapped on a hard surface for the powders to form a column at the bottom of the capillary tube. The tube was inserted into the heating block of a Gallenkamp melting point apparatus. The temperature of the heating block was raised from room temperature at 0.5 °C per minute until the sample melted and the melting temperature was recorded.

Hydration capacity
About 1.0 g of the starch powder was introduced into each of four 15 ml centrifuge tubes and 10 ml of water was also added to each tube to form a dispersion. The tubes were covered and shaken for about 2.0 minutes, allowed to settle for 10 minutes and centrifuged at 1000 rpm for 10 minutes with a bench centrifuge. The resulting supernatant was decanted and the sediment weighed. The hydration capacity was calculated from the ratio of the sediment and dry starch weights [17].

Swelling index/capacity
A 1.0 g quantity of the starch powder was tapped 100 times in a 50 ml measuring cylinder and the tapped volume obtained was recorded. A dispersion of the powder was formed in the cylinder with a mixture of 1.0 ml of 96% ethanol and 25 ml of distilled water. The dispersion was made up to 50 ml mark with more distilled water, closed firmly and shaken vigorously at 10 minutes' intervals for 1.0 hour. The dispersion was allowed to stand for 3.0 hours and the volume of the sediment was recorded. The swelling capacity was calculated as the difference between the sediment and tapped volumes of the starch powder [17].

Moisture content
A crucible containing about 1.0 g of the starch was placed in a hot air oven operated at 105°C for 4 h. The crucible content was weighed at the end of the experiment and the difference between the starting and final weights of the starch was calculated as the moisture content [16].

Moisture sorption capacity

The Deetae *et al*. method was adopted to determine the starch moisture sorption properties [18]. This involved creating a 100% relative humidity (RH) environment at room temperature, using Pyrex desiccators containing distilled water. The starch powder was pre-dried for 4 hours at 120 °C in an oven. Then, 2.0 g of pre-dried starch was transferred into a dry Petri dish of known weight. This was then transferred into the humidity chamber. The sample was allowed to equilibrate at room temperature, over one week and re-weighed. The moisture sorption capacity was determined as the differences in weight before and after equilibration under the predetermined relative humidity and expressed in percentage.

Bulk and flow properties

Established procedures were used to evaluate the bulk and flow properties of the native avocado seed starch powders [19,20].

Bulk density

Approximately, 30 g of starch powder was transferred into a 250 ml measuring cylinder and the occupied volume was obtained and both values were used to determine the bulk density (g/ml) with Equation 1.

$$\text{Bulk density} = \frac{\text{Weight of powder (g)}}{\text{Bulk volume (cm)}} \quad \ldots. (1)$$

Tapped density

The cylinder containing the bulk starch powder was tapped 100 times on a workbench and the final volume after tapping was noted and used to determine the tapped density using Equation 2.

$$\text{Tapped density} = \frac{\text{Weight of powder (g)}}{\text{Tapped volume (cm)}} \quad \ldots. (2)$$

Carr`s compressibility index

The Carr's index (% compressibility) of the starch powder was evaluated by determining the differences between the bulk and tapped densities and consequently dividing the value obtained by the tapped densities. The result of this ratio was expressed in the form of a percentage using Equation 3.

$$\text{Carr's index} = 100 \times \frac{\text{Tapped density - Bulk density}}{\text{Tapped density}} \quad \ldots. (3)$$

Hausner's ratio

Hausner's ratio was also determined by dividing the tapped density by the bulk density of the starch as in Equation 4. Triple determinations were performed and the mean values were obtained.

$$\text{Hausner's ratio} = \frac{\text{Tapped density}}{\text{Bulk density}} \quad \ldots. (4)$$

Angle of repose

The starch powders were poured into a funnel and placed at a fixed height from a selected base. The powder was then allowed to flow onto the selected base. The angle of repose was then calculated by determining the inverse tangent from the height and radius values of each cone formed using Equation 5.

$$\text{Angle of repose } (\theta) = \tan^{-1}\frac{\text{Height of cone (cm)}}{\text{The radius of the cone (cm)}} \quad \ldots (5)$$

Flow rate

This was determined by introducing 10 g of starch powder into a glass funnel. The orifice was then opened at time (0s), and the time (s) required for the entire mass to exit the funnel was measured. Flow rate of the starch powder was calculated with Equation 6.

$$\text{Flow rate} = \frac{\text{Weight of sample (g)}}{\text{Time of flow (s)}} \quad \ldots. (6)$$

Particle density

Liquid paraffin was carefully poured into a glass pycnometer (specific gravity bottle) of 25 ml capacity until full and then weighed (a). It was emptied and rinsed of any residual paraffin with acetone before being dried. A 1.0 g quantity of the starch powder (b) was introduced into the bottle, filled with liquid paraffin and weighed (c). The different weights recorded were used to calculate the particle (true) density of the starch using Equation 7.

$$\rho = b / [(a+b) - c] \, S \ldots (7)$$

Where ρ = particle density of the starch, a = weight of the bottle + liquid paraffin, b = weight of the starch, c = weight of the bottle + liquid paraffin + starch and S = specific gravity of liquid paraffin.

High-resolution analyses

Differential scanning calorimetry (DSC)

Differential Scanning Calorimetry was carried out using the Netzsch DSC 204F1 Phoenix apparatus (Netzsch-Geratebau GmbH, Selb, Germany). Five to ten milligrams of the starch sample were weighed into aluminum pans and sealed. The seal was pierced and calibration of

the calorimeter was done with indium and the purge gas was nitrogen. Heating of the sample was carried out at the rate of 10°C per minute from 30 to 350°C under nitrogen at a flow rate of 70 ml/minute.

Fourier transform infrared (FTIR) Spectroscopy

The FTIR analysis of the starch sample was carried out using Fourier Transform Infrared Spectrophotometer (Spectrum BX, Perkin Elmer, Beaconsfield Bucks, England). The potassium bromide (KBr) pellet method was used. Five milligrams of the starch sample were blended with KBr to 200 mg. The powder was compressed using a Sigma KBr press into a tablet shape. The tablet was placed in the sample compartment and scanned at a range of 4000 - 500 cm^{-1}.

Scanning electron microscopy (SEM)

SEM was conducted on the starch powder sample using a scanning electron microscope (EVO/MAIO, Carl Zeiss Germany). Two milligrams of the starch powder sample were placed on the sample holder and a vacuum was created using the vacuum pump. The electron gun was then aligned to finely focus the electron beam on the sample and different magnifications (×3000, ×4000 and ×5000) were employed to examine the sample. The operating voltage was limited to 5kV to minimize the charging effect on the resolution of the images.

X-ray diffractometry (XRD)

XRD analysis was carried out using the Schimadzu 6000 Model X-Ray Diffractometer (Schimadzu Corp., Japan). The powder was spread over a flat disc and leveled to form a plane surface. The disc with the powder was placed in the sample holder and the scan was performed over 2° to 60° 2-theta at a scanning speed of 60°/minute. The patterns were recorded using NaI scintillator at 40 kV and 25 mA for 60 minutes.

Statistical analysis

Statistical analysis of data was performed using GraphPad Instat (v. 3.06). Experiments were carried out in triplicates and results were reported as mean and standard deviations. Differences between means were determined using one One-way Analysis of Variance (ANOVA), where $p < 0.05$ was considered significant.

Results and Discussion

Starch yield

The result from the percentage yield calculation of the starch extraction process was 19.65%. Although this value is just about a quarter weight of the starting seed materials, it may be considered a high value because the starting was a waste product. Furthermore, this value is comparable and within the range of values obtained by other workers. Alemu *et al* obtained a value as low as 18.3 ± 0.02%, while Martins and his co-workers of a 19.0% yield as against Maryam *et al* with a yield as high as 23.15% [11,21,22].

Phytochemical properties

Results from the phytochemical evaluation of the extracted avocado starch are outlined in Table 1. The starch powders showed presence of phytochemicals such as saponins, flavonoids, alkaloids, tannins and glycosides. Previous studies carried out on the starch by other researchers have revealed the presence of these same phytochemicals in ample amounts [23-25].

Table 1: Phytochemical constituents of the test starch

Properties	Avocado starch
Saponin	Present
Flavonoids	Present
Alkaloids	Present
Tannins	Present
Glycosides	Present

Organoleptic properties

The results from the organoleptic evaluation of the extracted avocado starch are presented in Table 2. The native avocado starch was light brown in colour after extraction. It also exhibited a smooth texture to touch and was also tasteless and odourless. The light brown colouration of the native starch powder may be attributed to the level of bleaching carried out during the extraction process.

Table 2: Organoleptic properties of the test starch

Properties	Avocado starch
Appearance	Light brown
Taste	Tasteless
Odour	Odourless
Texture	Smooth

Physicochemical properties

Some physicochemical characteristics of the extracted native avocado starch are presented in Table 3. The powder showed presence of polysaccharides (starch) with the change in the colour of the starch dispersion to blue-black colouration following the addition of iodine solution.

Table 3: Physicochemical properties of the test starch

Properties	Avocado starch
Chemical (iodine) test	Presence of starch
Solubility (Ambient temperature)	Slightly soluble
Melting point (°C)	102-114
Moisture content (%)	22.7 ± 2.40
Hydration capacity (g/g)	2.76 ± 1.20
Swelling capacity (%)	46.43 ± 1.50
Water sorption capacity (100% RH) (%)	115.34 ± 1.55

RH = Relative Humidity

The starch powders showed slight solubility in water at ambient (room) temperature. Starch solubility is a phenomenon involving the solubilization of the amylose component in starch molecules during gelatinization, which increases at higher pasting temperatures [26]. This characteristic differs from starch to starch, probably due to differences in the intrinsic structure, chain length and distribution.

The extracted starch powders exhibited a melting temperature range of 102-114°C. Studies have shown that the starch granule is composed of crystalline side chains (amylopectin) interspaced with amorphous segments (amylose), hence the semi-crystalline nature of starch [27,28]. The range in temperature may be attributed to the amorphous portions of the starch molecule.

Moisture content of the extracted starch powder was as high as 22.7 ± 2.40%. Moisture content of starch powder is a determinant of the microbiological stability of the starch when stored in a humid environment. Although the British Pharmacopoeia recommends a 5.0-7.0% moisture content for powders, similar studies have obtained values as high as 15-20% [29-32].

These relatively high values may be attributed to the final drying of the starch extraction process as longer drying times have resulted in powders with low moisture content [31,32]. Starch moisture content has also been reported to affect some physicochemical properties of dosage forms prepared with the starch. The tensile strength and disintegrant ability of tablets have been reported to be affected by the moisture content of the starch used in its preparation [29-32].

The hydration and swelling capacities of the extracted avocado starch were found to be 2.76 ± 1.20 and 46.43 ± 1.50%, respectively. Hydration capacity measures the ability of the starch to hydrate as a gel under certain conditions while the swelling capacity measures the ability of the starch powder to swell on contact with fluids. The results obtained in the study would suggest difficulties for the avocado starch in taking up water in its gel form while the swelling capacity results suggest a starch powder with a swelling ability that is almost half (50%) its volume.

These parameters of the starch have been linked to the starch's particle size distribution. Smaller starch particles have been shown to have a higher potential for rehydration, while the inverse is reported for starch molecules with larger granule sizes [33]. The result obtained in this study is congruent with the outcome of a study by Tang *et al*. where a correlation was established between granule size and granule swelling capacity [34].

The moisture sorption capacity of the extracted starch was 115.34 ± 1.55%. Moisture sorption is a parameter indicating the stability of starch samples under varied environmental conditions. The experiment was designed to simulate a moist environmental conditions and the results showed a significant moisture sorbed by the starch. This result is indicative of a hydrophilic starch powders prone to spoilage under humid storage conditions. Also, the combination of this capacity with the swelling capacity of the starch, the powders may function as a good tablet disintegrant employing the mechanism of swelling [35-38].

Powder flow and bulk properties

Table 4 shows the bulk and flow properties of extracted native avocado starch. Results of the bulk and the tapped densities of powdered starch material showed a significant reduction in volume. These parameters depend largely on the particle shape and size distribution and these reflect the inter-particulate interaction within the powders. These values would indicate powder densification resulting from a wide or large particle size distribution with the smaller

particles filling the voids created between the larger particles [39].

Table 4: Powder properties of the test starch

Properties	Avocado starch
Bulk density (g/ml)	0.47± 0.21
Tapped density (g/ml)	0.71± 0.12
Carr's index (%)	33.80 ± 1.26
Hausner's ratio	1.51 ± 0.10
Angle of repose (°)	25.30 ± 1.25
Flow rate (g/sec)	0.133 ± 0.91
Particle/true density (g/ml)	0.029 ± 0.55

Results computed the Carr's compressibility index (CI) which defines the ability of a material to deform under pressure was 33.80 ± 1.26%. Limits set for this measurement indicate that materials with values ≤ 10 % possess excellent flow, those between 11 and 15 % have good flow, values between 16 and 20 % are representative of fair flow and values > 25 % indicate poor flow. Hausner's ratio (HR) on the other hand as also determined by the bulk and tapped densities, is a measurement of the cohesiveness of a powdered material which describes its degree of densification. Materials with values ≤ 1.25 are said to possess good flowability.

These results when combined with the angle of repose (25.30 ± 1.25°) and flow rate (0.133 ± 0.91 g/sec) of the starch powder indicates a cohesive powder with poor flowability. This conclusion is in line with several previous studies that showed that native starches are generally poor in flowability [19,20,40-42]. The particle density of the extracted starch was 0.029 ± 0.55 g/ml. This small value obtained further confirmed the bulk properties of the starch powder. With the small amounts of voids in the powder remaining from the smaller particle filling up the available voids, it would not be surprising that the particle's true density was small.

High-resolution analysis

Differential scanning calorimetry (DSC)

The results obtained from the thermal analysis of the starch are shown in Figure 1. The thermogram of starch exhibited a single sharp trough at about 118 °C, with smaller troughs at about 85 °C and 180 °C. The major single sharp trough at about 118 °C is representative of the melting point of the starch which is in line with the melting point obtained earlier with the melting point apparatus. While the sharpness of the trough is a representation of the crystallinity of the starch powder, the width of the trough indicates the amorphousity of the powder also confirming the semi-crystalline nature of the starch powders. The two minor troughs at about 85 °C and 180 °C are indicative of the loss of water from the starch sample at 85 °C and the melting point of the degradative product of the starch at 180 °C.

Fourier transform infrared (FTIR)

Results from the FTIR analysis of the starch is shown in Figure 2. Their spectrum of the native avocado starch demonstrated a broad trough in the –OH region (3230 – 3550 cm^{-1}) of the spectrum, which indicates a high saturation with hydroxyl moiety or the O-H stretching of hydrogen bonded hydroxyl groups. This may be ascribed to the presence of intra- and intermolecular hydrogen bonds in the starch granules. Following the broad trough was the −CH2 stretching region at 2947 cm^{-1} and the O-H bending at 1690 cm^{-1}. The anti-symmetric stretching of the C-O-C appeared at 1152 cm^{-1} while the C-O vibrational stretching was at 1080 cm^{-1}. The O-C stretching of the glucose ring appeared at 1010 cm^{-1}. These bands are consistent with bands obtained in previous works regarding infrared scanning of starch powders [41,43-45].

Scanning electron microscopy (SEM)

The results from the scanning electron microscopy used to determine the form and surface characteristics of the extracted native avocado seed starch are seen in Figure 3.3-3.5 at various magnifications (×3000, ×4000 and ×5000). Polygonal, irregular, and granular-shaped nano-sized particles were observed with native starch sample. The starch comprised fluffy granules that were also intact. Polygonal and irregularly shaped starch granule particles have been identified in native starches of various fruits and seeds of plants and our observation is congruent with these earlier reports [46-50].

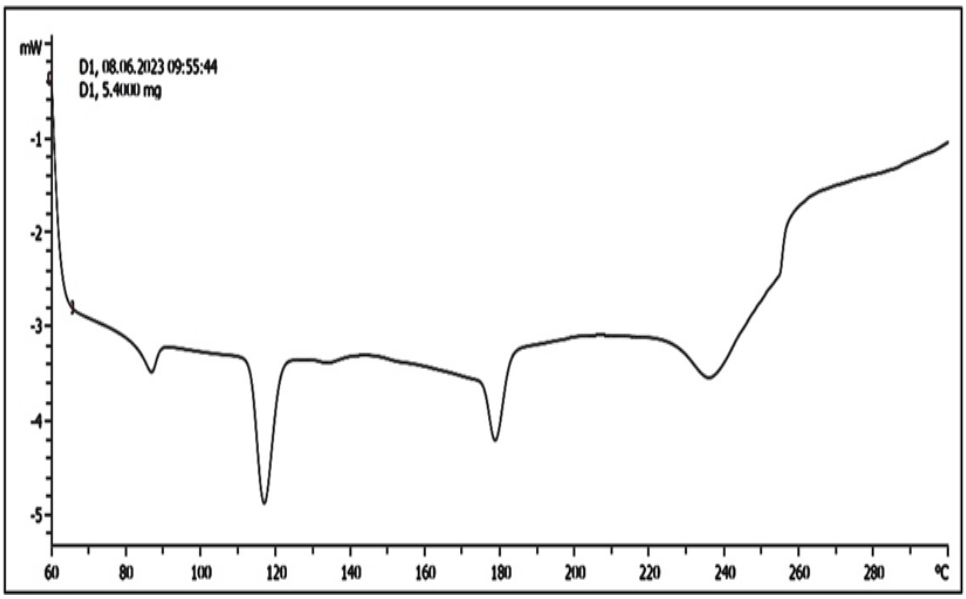

Figure 1: DSC thermogram of native avocado starch

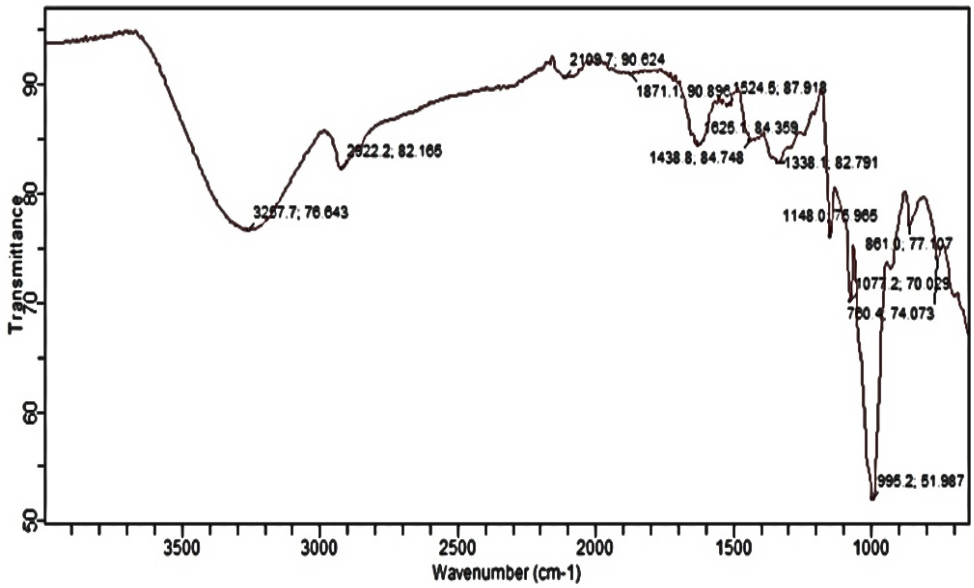

Figure 2: FTIR spectrum of native avocado starch

X-ray diffraction (XRD)

The x-ray diffractogram of the native avocado seed starch powder is shown in Figure 4. The diffraction pattern of the starch powder exhibited the following peaks; the first prominent peak was at 2Θ = 17.17°, d = 5.16264 and of intensity 52.20 counts per second (cts), followed by 2Θ = 34.07°, d = 2.63164 and of intensity 30.61 counts per second (cts), 2Θ = 37.91°, d = 2.37338 and of intensity 85.58 counts per second (cts) and 2Θ = 44.08°, d = 2.05460 and of intensity 31.66 counts per second (cts).

Their Full Width Half Maximum (FWHM) values which are indications of the crystallinity of the powder sample showed that the large value of the first peak, suggests that the material maybe amorphous while the small values of the other three peaks, points towards a crystalline material. Hence, this confirms the semicrystalline nature of the starch sample. Also, these results are in line with previous studies on the crystallinity of starch [51,52].

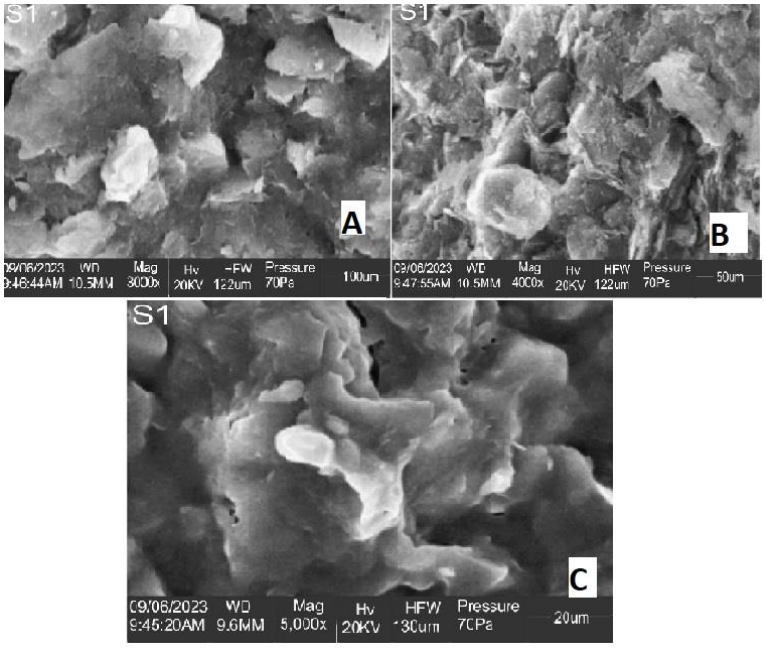

Figure 3: Scanning electron micrographs of native avocado starch (Magnification: A(×3000) B(×4000), C(×5000)

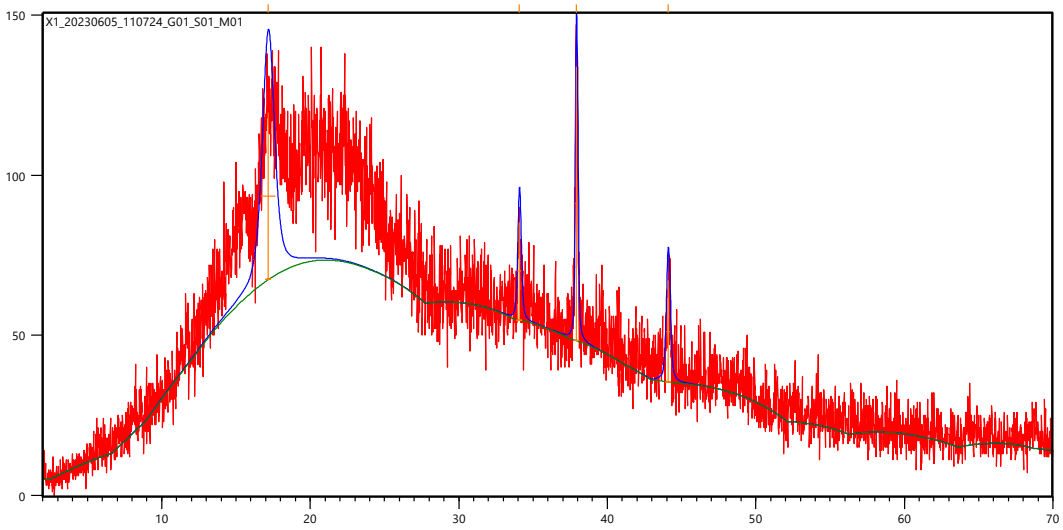

Figure 4: X-ray diffractogram of native avocado starch powder

Conclusion

Native starch was successfully extracted from Avocado seeds with a percentage yield of 19.61%. The starch powder showed presence saponins, flavonoids, alkaloids, tannins and glycosides. The starch powder was cohesive with fair flowability. DSC and XRD analyses presented a semi-crystalline powder material while FTIR and SEM analyses revealed a powder product with comparable functional groups with standard starch samples and polygonal, irregularly shaped nano-sized fluffy powder particles.

The starch powder also exhibited a high moisture content with hydration, swelling and water sorption capacities of 2.76 ± 1.20, 46.43 ± 1.50% and 115.34%, respectively. These physicochemical parameters suggest a powder material that may be a good candidate as a tablet disintegrant.

Conflict of Interest

No conflict of interest is associated with this work.

Contribution of Authors

We declare that this work was done by the author(s) named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors. SOE and

JAO supervised the work and contributed in data analysis. SOE and ODE collected the data and prepared the manuscript. JOA conceived and designed the study. All the authors read and approved the final draft submitted.

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