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Characterization Of Extracted Pectin From Cocoa Pod Husk And Cashew Gum As Formulation Aids For Metronidazole Tablet

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Abstract
Background: *Pectin and cashew gum are biodegradable polymers which can be used as pharmaceutical excipients as binding agents in tablet formulations. Cocoa pod husk and cashew gum exudates as waste agricultural materials are being investigated for use in oral solid pharmaceutical formulations.*
Purpose: *The objective of this study is to extract pectin from cocoa pod husk using a standard method and cashew gum powder from cashew tree exudate using a physical method. These are then characterizing to determine their phytochemical and physical and micromeritic properties of formulated metronidazole granules.*
Methods: *Pectin was extracted from cocoa pod husk using acidic method. The cocoa pod husk was washed with distilled water, cut into smaller pieces, air dried, milled and screened. The dehydrated cocoa pod husk was hydrolyzed with acetic acid at pH of 2.5 to form a supernatant and the precipitate was discarded. Ethanol (99%) was added to the filtrate to precipitate pectin, which was oven dried at 50 °C for 2 hours, milled and screened to obtain fine powder. Cashew gum were collected, cleaned, crushed, milled and dispersed in water. It was filtered, decanted and oven dried 50 °C for 1 hour, milled and screened to obtain fine powder. Phytochemical and physical characterization of extracted pectin and cashew gum were determined. Scanning electron microscopy (SEM) and x-ray diffractogram (XRD) analysis of extracted pectin and cashew gum were determined. Metronidazole granules were prepared by wet granulation using varying concentration of the extracted pectin and gum respectively and their micromeritic properties analyzed.*
Results: *Results of organoleptic and physical properties of CPP and CCG are shown in Table 2, and phytochemical and elemental analysis are recorded in Tables 3 and 4. XRD of extracted pectin and cashew gum powder revealed amorphous nature with little or no crystalline regions. The SEM showed an irregular non-uniform surfaced particle with heterogeneous size, characterized by cracks, pores and flakes for cashew gum. Pectin showed irregularly shaped particles when viewed under scanning electron microscopy (SEM). Micromeritic of metronidazole granules showed that cocoa pod pectin (CPP) and cleaned cashew gum (CCG) have similar properties with those of pectin BP (PBP). The granules have free flow properties with average angle of repose (°): (CPP ≤10, CCG ≤ 25.60, PBP ≤ 27.20), compressibility index (%): (CPP ≤ 20.87, CCG ≤ 14.77 PBP ≤ 17.00, while the Hausner's ratio were (CPP ≤ 1.264, CCG ≤1.133, PBP ≤ 1.205) respectively.*
Conclusions: *The extracted pectin from cocoa pod husk and cashew gum powder were found suitable as pharmaceutical excipient binders in metronidazole tablet formulation.*
Keywords: *Anarcadium occidentale gum, Theobroma cacao; Pectin; Binder; Tablet; Wet granulation.*

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I. Introduction

Developing countries are highly reliant on the importation of pharmaceutical raw materials and finished products, hence the search for natural local and effective excipients that are readily available, safe and economical. Some excipients that have enjoyed wide and considerable use in the pharmaceutical and food industries are pectin and cashew gum. This is due to the fact that pectin and cashew gum act as multifunctional excipients in drug formulation and food industries. The use of excipients dates back thousands of years, with origins traceable to ancient civilizations such as Egypt, Mesopotamia, Greece, and China. These early pharmaceutical formulations relied on natural substances, many derived from plants and minerals, to facilitate the administration and improve the stability of medicinal compounds. For example, honey and wax were frequently used as excipients to improve the texture and taste of remedies, while water, oils, and alcohol acted as solvents or carriers (Van der merwe J, 2020).

The concept of excipients evolved significantly during the Renaissance and early modern period, paralleling advances in chemistry and pharmaceutics. The industrial revolution of the 18th and 19th centuries accelerated the synthesis and purification of excipient materials. Thus, the history of excipients reflects an ongoing interplay between traditional practices and modern pharmaceutical science, underscoring their critical role in ensuring the efficacy, stability, and patient compliance of medicinal products (Patel *et al*., 2020)

Cashew gum is a natural exudate polysaccharide from the bark of *Anacardium occidentale* L. (cashew tree). Over the decades, more work has been done on its extraction, purification methods, physicochemical and rheological properties, and expanded uses beyond local/traditional uses especially since the 1990s. Brazilian patents and research have been a strong contributor in recent years to applications of cashew gum in microparticles, nanoparticle systems, controlled-release (Loureiro *et al*., 2021)

Cashew gum and pectin can be used as a binding agent in tableting of drugs. Binding agents impact cohesive qualities to powdered material, and they precipitate cohesiveness to the tablet formulation thereby ensuring that the tablet remains intact after compression as well as improving the free flowing qualities by the formulated granules of desired hardness and size (Sabalingam *et al*., 2022)

Pectin improves tablet hardness while also enabling rapid disintegration, depending on its degree of esterification (Osei *et al*., 2021). Pectin, a natural polysaccharide, has been widely investigated as a binder in tablet formulations due to its excellent adhesive properties, biocompatibility, and biodegradability. As a binder, pectin helps to improve tablet hardness, reduce friability, and maintain structural integrity during handling and storage (Sharma *et al*., 2022). Studies show that the degree of esterification and molecular weight of pectin significantly influence its binding ability. Low-methoxyl pectin generally provide stronger binding properties, while high-methoxyl pectin enhance gel formation (Osei *et al*., 2021).

Recent research has also focused on modified or composite pectin as binders. For instance, cross-linked or chemically modified pectin have shown improved compressibility and binding performance, making them potential alternatives to synthetic binders in tablets (Obarisiagbon A.J *et al.,* 2023). Thus, pectin represents a sustainable and effective natural binder in modern pharmaceutical formulations.

Metronidazole is a synthetic 5-nitroimidazole derivative that was first introduced in 1959 in France for the treatment of Trichomonas vaginalis infections. Its therapeutic spectrum was later expanded to include protozoal infections such as amoebiasis and giardiasis, as well as anaerobic bacterial infections (Sue *et al.,* 2024)

II. Materials And Methods

Materials

Cocoa pod husk and Cashew gum were obtained from local farmers at Okada, Ovia North East Local Government Area of Edo state, Metronidazole powder BP, Corn starch BP, Magnesium stearate BP were gotten from Qualikens chemical industries New Delhi. Acetic acid and 99% Alcohol was gotten from Royal Salt limited, Lagos. Other chemicals and reagents used were of analytical grades and used as supplied by the vendors.

Methods

Collection and identification of material (plants)

Fresh cocoa pod husk and cashew gum were collected, identified and authenticated at the herbarium of the Department of Pharmacognosy of College of Pharmacy, Igbinedion University, Okada, Edo state. Hebarium Numbers **IUO/16/081** and **IUO/10/011** were assigned respectively.

Extraction of pectin from cocoa pod husk and cleaning of cashew gum

The cocoa pod husk was de-sanded and washed thoroughly with distilled water, it was then cut into smaller unit and air dried for about 7 days, the dried cocoa pod husk was milled and screened (Barrios *et al* 2022). A specific ratio of substrate- extract 1:10 w/v was used for each sample. 200 g of dried and milled cocoa pod husk was used with 2000 ml of acidulated water with corresponding acid (acetic acid) to achieve the pH level of 2.5 according to experimental design. The hydrolysis was performed placing the sample in a flask with a mechanical stirrer and a thermometer. A heating mantle was used to reach the system temperature of 90°C and held for 30 minutes. Continuous stirring guaranteed the temperature uniformity within the system and prevented solid materials from depositing at the bottom of the flask. The mixture was indirectly cooled to 30°C to stop hydrolysis process. The mixture was made to settle, and the supernatant (composed of pectin and water) and a wet solid (precipitate) were formed. The mixture was decanted and the supernatant further strained to recover any trace of precipitate. To precipitate pectin, 99 % alcohol corresponding to 2:1(v/v) filtrate-ethanol ratio was added to the filtrate. The mixture was made to settle by standing for 30 minutes and was decanted. The wet solid precipitate corresponds to pectin and the supernatant contained pectin traces, water and ethanol. Same filtrate- ethanol ratio was added to the supernatant to recover the remaining pectin. The pectin was poured into a petri dish and oven dry at 40°C until constant weight was achieved. The pectin was then milled, screened and stored in an air tight container for further analysis.

The cleaning of cashew gum involved several steps to remove impurities and improve quality (Loureiro *et al.,* 2021). Cashew gum was collected from the bark of the Cashew trees and was cleaned, crushed and blended.

It was then suspended in distilled water and the debris was removed from the mixture. The mixture was made to settle while standing for about 40 minutes and was decanted, the solid residue which corresponded to the cashew gum was dried, blended, screened to get the cashew gum powder.

Phytochemical analysis and characterization of extracted pectin and cashew gum powder

Extracted pectin and cashew gum powders were subjected to phytochemical analysis, comprising test for alkaloids, saponins, flavanoids, tannins and others.

Physicochemical properties of extracted pectin and cashew gum powder

Assessment of organoleptic properties of CPP and CCG comprising odour, taste, colour and texture were examined using sensory organs and observations (Pitre *et al*., 2025, Akinmoladun *et al.,* 2023)

Solubility of Extracted pectin and cashew gum: About 1g of extracted pectin and cashew gum were weighed and dispersed in 20 ml distilled water in a test tube at 25°C. The dispersion was intermittently shaken for the period of 24 hours and then filtered using a pre-weighed filter paper. The result of the residue on the filter paper was air dried and weighed.

$$\text{Solubility} = \frac{mass\ of\ solute\ dissolved\ (g)}{volume\ of\ solvent\ (ml)} \text{ ------------------------------------- } 1$$

Melting point: Extracted pectin and cashew gum powder were each packed into a one-ended sealed capillary tube and tapped on hard surface for the powders to form a column at the bottom of the capillary tube. The capillary tube was inserted into the heating block of a Gallenkamp melting point apparatus set at 60^0C, the temperature of the heating block when the sample started to melt was recorded. The temperature was raised till the sample turned black completely and melting temperature was recorded (Kuwata, 2025).

Swelling capacity/index: The method of Okoye *et al.,* (2023) was used to determine the swell index of extracted pectin and cashew gum powder. Two grams of extracted powders were poured into a measuring cylinder and tapped for about 50 times in the 50 ml measuring cylinder and the tapped volumes were noted and recorded. They were then dispersed in distilled water and made to the mark with more water. The dispersions were allowed to stand undisturbed for 24 hours and the volume of the sediments noted. The swelling index was calculated using:

$$\text{Swelling capacity} = \frac{v_2 - v_1}{v_1} \times 100 \ \ldots\ldots\ldots\ldots\ldots.\ldots\ldots\ldots..2$$

Where v_1 = powder tapped volume, v_2 = volume of the sediment.

Hydration capacity: About 1.0 g of the extracted powders were introduced into each four 15 ml centrifuge tubes and 10 ml of water were added to each tube to form a dispersion. The tubes were covered and shaken for about 2.0 minutes and allowed to settle for 10 minutes. The resulting supernatants were decanted and the sediment weighed. The hydration capacity was calculated from the ratio of the sediment and dry extract weights (Okoye *et al*., 2023).

Moisture Content: A crucible containing about 1g of the extract was placed in a hot air oven operated at 10°c for 4h. The crucible content was weighed at the end of the experiment and the difference between the starting and the final weight of the extracts were calculated as moisture content (Akinmoladun *et al.,* 2023).

Moisture sorption capacity: This involved creating a 100 % relative humidity environment at room temperature, using a Pyrex dessicator containing distilled water. The extracts were dried for 4 hours at 120 °C in the oven. Two grams of pre-dried extracts were transferred into a dry petri-dish of known weight and transferred into the humidity chamber. The samples were allowed to equilibrate at room temperature over one week and re-weighed. The moisture sorption characteristics were determined as the difference in weight before and after equilibrium under predetermined relative humidities and expressed in percentage (Okoye *et al*., 2023).

Bulk Density: About 20 g of extracted pectin and cashew gum were weighed separately and carefully poured into 100 ml measuring cylinder. The volume occupied by the powder was noted and record as bulk volume. The processes were carried out in triplicate and the average values obtained were used to calculate the bulk density using equation:

$$\text{Bulk density} = \frac{Mass\ of\ powder}{\text{Bulk}\ value}\ (g/ml) \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots3$$

Tapped Density: Extracted pectin and cashew gum each (20 g) were separately transferred into a 100 ml measuring cylinder and mechanically tapped on a flat surface about 100 times to a constant volume which were recorded as the tapped volume. This procedure was carried out in triplicate and values obtained were used to calculate the tapped density using equation: (Obarisiagbon and Uhumwangho, 2018).

Tapped density = $\frac{mass\ of\ powder}{tapped\ value}$ $(^{g}/_{ml})$ ……………………4

Carr's (compressibility) Index: Carr's (compressibility) index of extracted pectin and cashew gum were evaluated and expressed using (Carr, 1965):

Carr's index = $\frac{Tapped\ density - Bulk\ density}{Tapped\ Density} \times 100$ …………………………5

Hausner's ratio: The ratio of the tapped density to the bulk density of the extracted pectin and cashew gum were calculated. Triple determinations were done and average value obtained (Obarisagbon and Uhumwangho, 2018).

Heusner's ratio $\frac{Tapped\ Density}{Bulk\ Density}$ …………………………………………6

Flow Rate: About 20 g of the extracted pectin and cashew gum were separately weighed into glass funnels. The orifice was then open at time 0 second and the time taken for the entire mass powder to pass through the funnel orifice was recorded. This was carried out in triplicates and the mean value recorded. The flow rate was calculated as:

Flow rate = $\frac{Weight\ of\ powder\ (g)}{Time\ (s)}$ ……………….. ……………..7

Angle of repose: Angle of response was determined by allowing about 30 g of extracted pectin and cashew gum each to flow through funnel with orifice placed at a fixed height onto a selected base flat surface to form a cone-like heap on the flat surface. The height of the heap was measured and the angel of response Θ, was calculated:

Angle of repose (θ) $= tan^{-1}\, h\,/\,r$ ……………. ……………………8

High resolution analysis of CPP and CCG

High resolution analysis of extracted pectin (CPP) and cashew gum powder (CCG) were determined under the following: Scanning electron microscopy (SEM) and X-ray diffraction (XRD) and results printed and recorded.

Table 1. Formula for Metronidazole Tablet (400mg/tablet) of different binders

Ingredients Formulation	Batch Cpp I		Batch Cpp Ii		Batch Cpp Iii		Batch Cpp Iv	
	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)
Metronidazole Bp	400	24	400	24	400	24	400	24
Lactose Powder Bp	100	6	100	6	100	6	100	6
Corn Starch Bp	60	3.6	60	3.6	60	3.6	60	3.6
Cpp		5%		7.5%		10%		12.5%
Magnesium Stearatebp1%W/W	5.6	0.34	5.6	0.34	5.6	0.34	5.6	0.34
Compression Weight	560	33.6	560	33.6	560	33.6	560	33.6
Ingredients Formulation Ii	**Batch Ccg I**		**Batch Ccg Ii**		**Batch Ccg Iii**		**Batch Ccg Iv**	
	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)
Metronidazole Bp	400	24	400	24	400	24	400	24
Lactose Powder Bp	100	6	100	6	100	6	100	6
Corn Starch Bp	60	3.6	60	3.6	60	3.6	60	3.6
Ccg		5%		7.5%		10%		12.5%
Magnesium Stearatebp1%W/W	5.6	0.34	5.6	0.34	5.6	0.34	5.6	0.34
Compression Weight	560	33.6	560	33.6	560	33.6	560	33.6
Ingredients Formulation Iii	**Batch Pbp I**		**Batch Pbp Ii**		**Batch Pbpiii**		**Batch Pbpiv**	
	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)	Qty/Tab (Mg)	Qty/60 Tabs(G)
Metronidazole Bp	400	24	400	24	400	24	400	24
Lactose Powder Bp	100	6	100	6	100	6	100	6
Corn Starch Bp	60	3.6	60	3.6	60	3.6	60	3.6
Pectin Bp		5%		7.5%		10%		12.5%

Magnesium Stearatebp1%W/W	5.6	0.34	5.6	0.34	5.6	0.34	5.6	0.34
Compression Weight	560	33.6	560	33.6	560	33.6	560	33.6

CCG = CLEANED CASHEW GUM; CPP = COCOA POD PECTIN; PBP = PECTIN BP

Preparation of metronidazole granules

Granules were prepared by wet granulation method of massing and screening. Three formulations with four batches each were prepared using the extracted pectin, cashew gum powder and one standard binder, pectin BP. The dried materials were sieved, and about 24 g of metronidazole powder, 6 g of lactose powder, 3.6 g of corn starch were respectively weighed and mixed geometrically in a bowl until uniform powder mix was obtained. Binder slurry (5 %w/v) of extracted pectin was prepared and added to the dried mix powder. This was mixed gradually and until a moist and cohesive mass was formed. The wet mass was screened through a 10 mesh sieve (710 μm) sieve size using a spatula. The resulting granules were dried in hot air oven at 50 ^{0}C for 1 hour and then dry screened through 20 mesh sieve size. The granules were allowed to cool and marked as Cocoa pod pectin 1 (CPP1) and stored in an air tight container. The same procedure was used for the remaining three batches of CPP formulations. Similarly, same procedure was followed in the preparation of granules for formulation two and three of cashew gum and pectin BP (standard binder) respectively.

Micromeritic analysis of metronidazole granules

The granules physicochemical properties were analyzed and evaluated, using the same technique and procedures adopted during extracted pectin and cashew gum. The granules flow rate, angles of repose, bulk and tapped densities, Carr's (compressibility) index and Hausner's ratio were evaluated in triplicates and the average values calculated shown in Table 7.

III. Results

Table 2. Organoleptic/physical properties of extracted pectin (CPP) and cleaned cashew gum (CCG)

Properties	Extracted pectin (CPP)	Cashew gum powder (CCG)
Product yield (%)	15.38	25.8
Appearance / colour	Light brown	Light brown with white patches
Texture	Soft &Smooth	Brittle
Taste	Mild mucilaginuous	Mucilaginuous
Odour	Odourless	Odourless
Solubility in water (g/ml)	Slightly soluble	Slightly soluble
Melting point (°C)	174-180	260-291
Swelling capacity (%)	50 ± 0.35	53.6 ± 0.20
Moisture content (%)	13 ± 1.50	12 ± 0.90
Hydration capacity	2.88 ± 0.50	2.13 ± 0.60
Moisture sorption capacity (%_)	36.5 ± 0.41	52 ± 0.30

Table 3. Phytochemical analysis of extracted pectin and cashew gum powder

Phyotochemical constituents	Extracted pectin	Cashew gum
Saponin	+ ve	+ ve
Flavonoids	+ ve	+ ve
Alkaloids	-ve	+ ve
Cardiac glycosides	+ ve	+ ve
Steroids	− ve	− ve
Terpenoids	+ ve	+ ve
Tannins	+ ve	+ ve
Anthraquinones	− ve	− ve

Key:
+ ve = Present; - ve = Absent

Table 4. Elemental analysis results for extracted pectin

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	79.17	56.10
30	Zn	Zinc	2.16	8.34
19	K	Potassium	3.10	7.14
8	O	Oxygen	7.15	6.75
29	Cu	Copper	1.08	4.05
20	Ca	Calcium	1.30	3.08
56	Ba	Barium	0.34	2.75
50	Sn	Tin	0.31	2.18
16	S	Sulfur	0.92	1.74
11	Na	Sodium	1.24	1.69
26	Fe	Iron	0.50	1.66
7	N	Nitrogen	1.11	0.92
15	P	Phosphorus	0.48	0.87
40	Zr	Zirconium	0.14	0.75
38	Sr	Strontium	0.13	0.68
12	Mg	Magnesium	0.45	0.64
13	Al	Aluminium	0.27	0.44
14	Si	Silicon	0.15	0.25
22	Ti	Titanium	0.00	0.00
47	Ag	Silver	0.00	0.00
17	Cl	Chlorine	0.00	0.00

Table 5. Elemental analysis results for cashew gum powder

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	63.43	46.27
8	O	Oxygen	21.07	20.47
19	K	Potassium	3.55	8.43
14	Si	Silicon	2.35	4.01
50	Sn	Tin	0.44	3.20
20	Ca	Calcium	1.30	3.15
7	N	Nitrogen	3.11	2.65
13	Al	Aluminium	1.59	2.60
26	Fe	Iron	0.68	2.32
56	Ba	Barium	0.26	2.15
17	Cl	Chlorine	0.78	1.67
11	Na	Sodium	0.99	1.38
38	Sr	Strontium	0.20	1.05
22	Ti	Titanium	0.18	0.52
12	Mg	Magnesium	0.08	0.11
40	Zr	Zirconium	0.00	0.00
47	Ag	Silver	0.00	0.00
30	Zn	Zinc	0.00	0.00
15	P	Phosphorus	0.00	0.00
16	S	Sulfur	0.00	0.00

Table 6. Micromeritic properties of extracted pectin and cashew gum powder

Micromeritics properties	Extracted pectin powder	Cashew gum powder
Angle of repose (^{0})	33.02 ± 0.03	41.98 ± 0.05
Flow rate (g/sec)	2.86 ± 0.13	4.86 ± 0.10
Bulk density (g /ml)	0.34 ± 0.03	0.68 ± 0.01
Tapped density (g/ml)	0.49 ± 0.1	0.84 ± 0.05
Carr's (compressibility) index (%)	30.61 ± 0.06	19.05 ± 0.05
Hausner’s ratio	1.44 ± 0.15	1.24 ± 0.01

Table 7: Micromeritic properties of metronidazole granules

Batches	Binders Conc. (%w/v)	Flow Rate (g/s)	Angle of Repose(°)	Bulk Density(g/ml)	Tapped Density(g/ml)	Carr's index(%)	Hausner's Ratio
CPP -I	5.0	8 ± 0.10	25.20 ± 0.35	0.83 ± 0.015	1.00 ± 0.04	17.60 ± 0.24	1.205 ± 0.003
CPP-II	7.5	5.02 ± 0.01	26.10 ± 0.64	0.91 ± 0.03	1.15 ± 0.01	20.87 ± 0.001	1.264 ± 0.001
CPP-III	10.0	6.81 ± 0.01	23.96 ± 0.59	0.83 ± 0.012	0.94 ± 0.02	11.70 ± 0.002	1.133 ± 0.01
CPP-IV	12.5	8.66 ± 0.02	21.80 ± 0.1	0.86 ± 0.02	1.00 ± 0.1	14.0 ± 0.06	1.163 ± 0.002
PBP-I	5.0	4.81 ± 0.01	27.20 ± 0.27	0.83 ± 0.01	1.00 ± 0.07	17.00 ± 0.2	1.205 ± 0.001
PBP-II	7.5	6.90 ± 0.02	26.10 ± 0.21	0.83 ± 0.01	0.88 ± 0.02	5.68 ± 0.02	1.060 ± 0.001
PBP-III	10.0	6.03 ± 0.03	23.96 ± 0.53	0.75 ± 0.02	0.79 ± 0.02	5.06 ± 0.002	1.053 ± 0.002
PBP-IV	12.5	7.65 ± 0.01	21.80 ± 0.1	0.71 ± 0.021	0.77 ± 0.02	7.78 ± 0.007	1.085 ± 0.002
CCG-I	5.0	6.60 ± 0.03	17.28 ± 0.04	0.83 ± 0.O2	0.94 ± 0.02	11.70 ± 0.004	1.133 ± 0.01
CCG-II	7.5	8.93 ± 0.02	21.08 ± 0.04	0.83 ± 0.02	0.86 ± 0.02	3.49 ± 0.002	1.085 ± 0.002
CCG-III	10.0	6.50 ± 0.03	25.26 ± 0.11	0.75 ± 0.02	0.88 ± 0.02	14.77 ± 0.03	1.133 ± 0.01
CCG-IV	12.0	9.92 ± 0.02	22.95 ± 0.07	0.94 ± 0.02	1.00 ± 0.1	6.00 ± 0.002	1.064 ± 0.002

KEY: CPP = Cocoa pod pectin; PBP = Pectin BP; CPP = Cocoa pod pectin

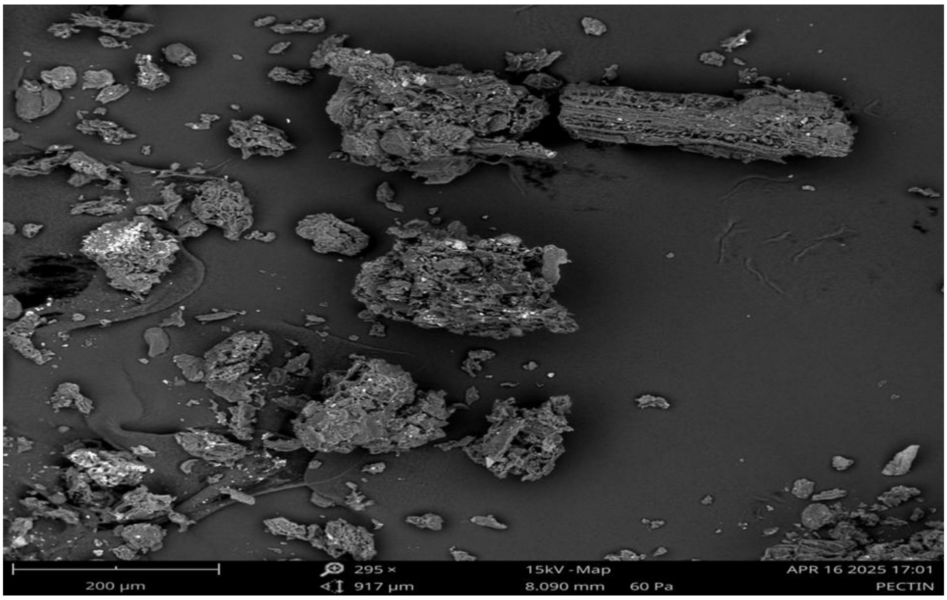


Figure 1(a) Scanning Electron Microscopy (SEM) of extracted cocoa pod pectin 295x

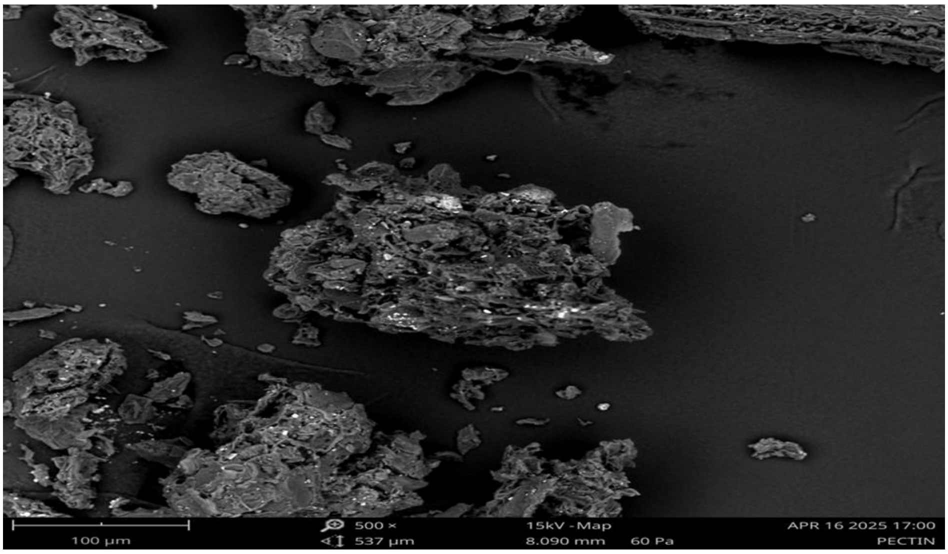
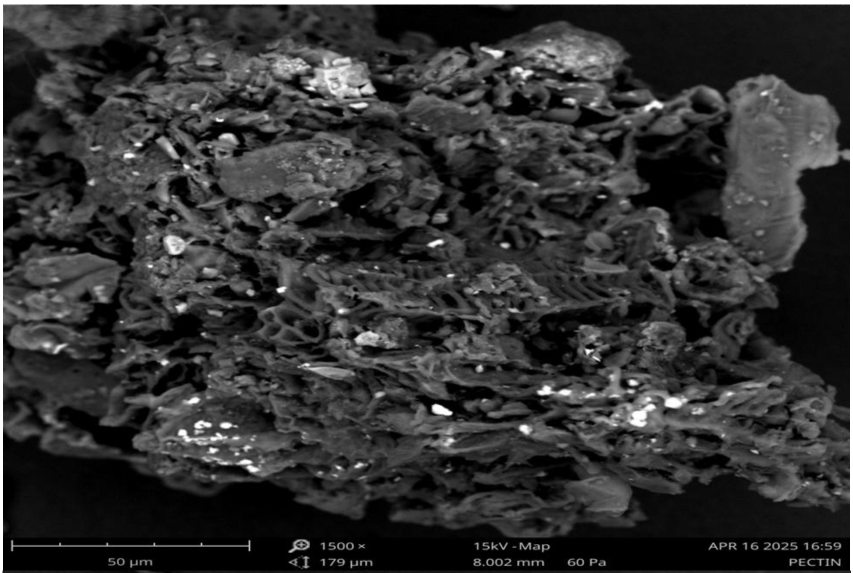


Figure 1(b) Scanning Electron Microscopy (SEM) of extracted cocoa pod pectin 500x



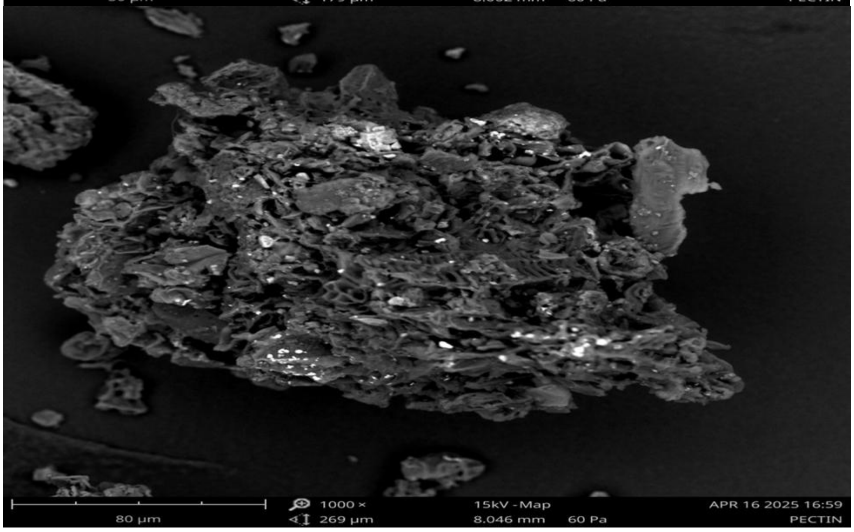


Figure 1(c) Scanning Electron Microscopy (SEM) of extracted cocoa pod pectin 1000x

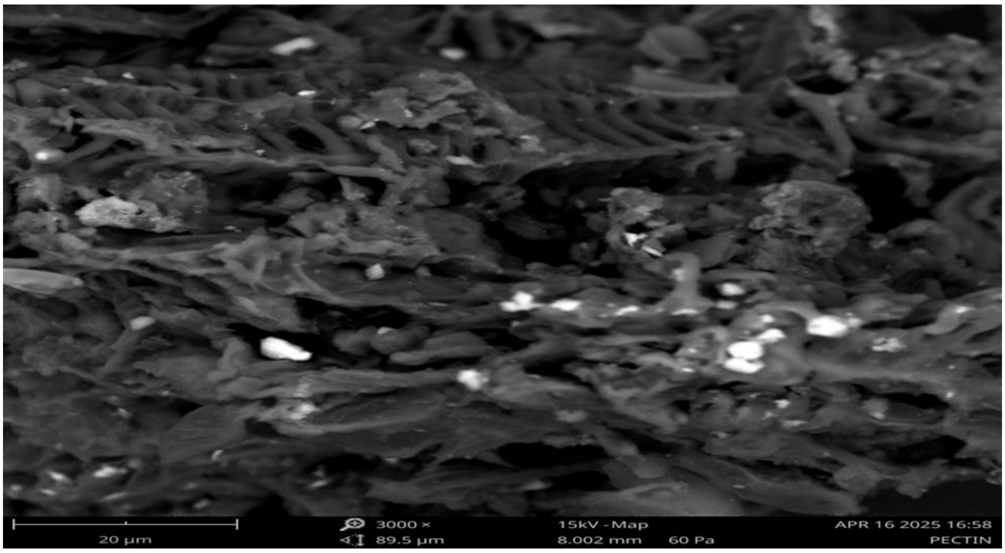


Figure 1(d) Scanning Electron Microscopy (SEM) of extracted cocoa pod pectin 3000x

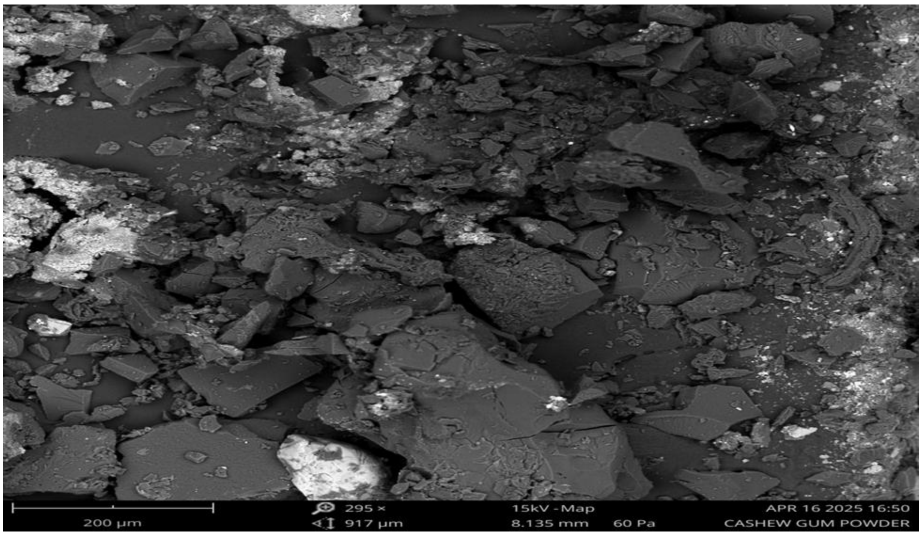


Figure 2 (a) Scanning Electron Microscope (SEM) OF cashew gum powder 295x

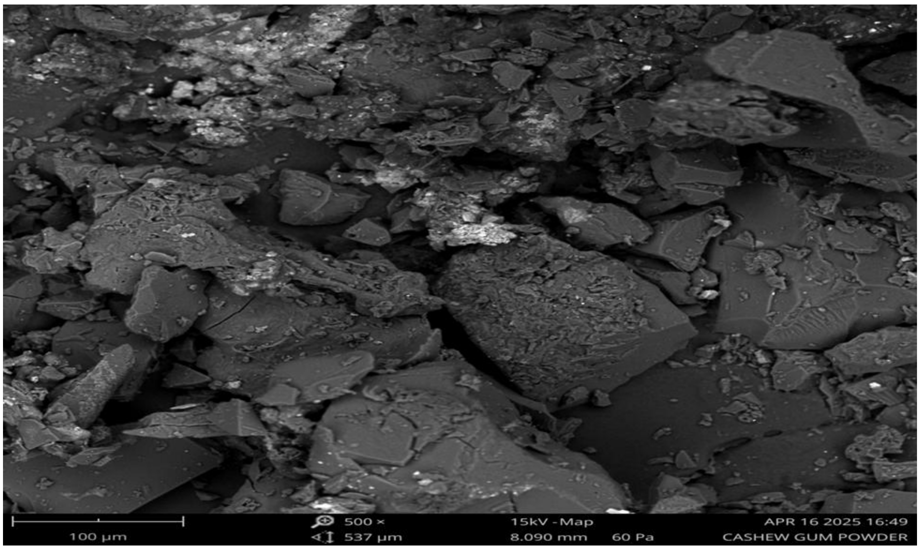


Figure 2(b) Scanning Electron Microscopy (SEM) of cashew gum powder 500x

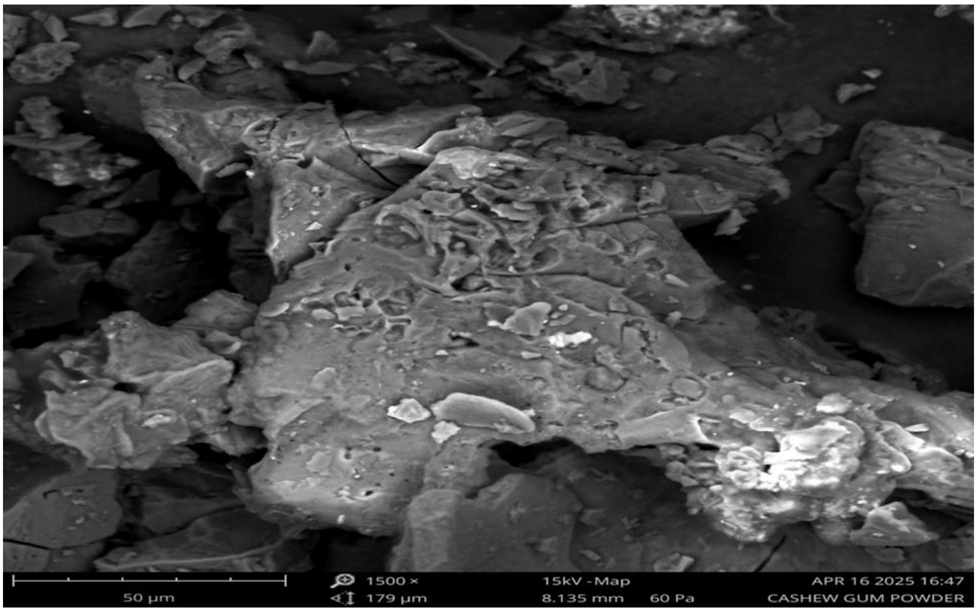


Figure 2(c) Scanning Electron Microscopy (SEM) of cashew gum powder 1500x

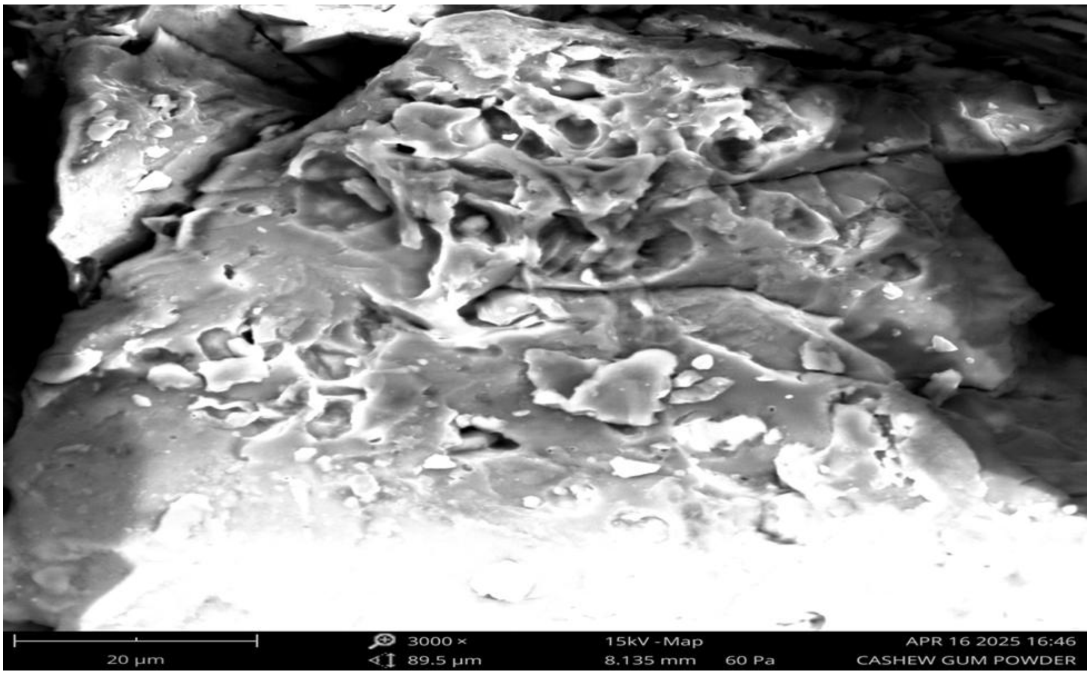
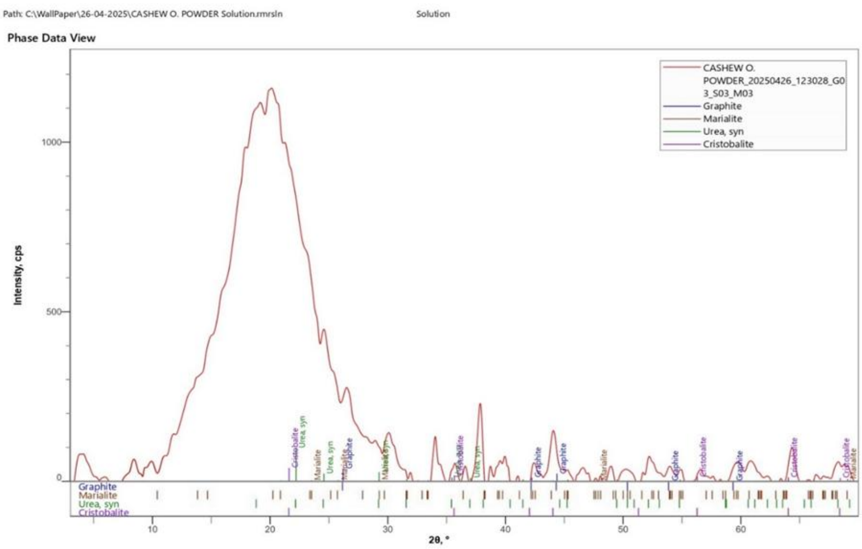
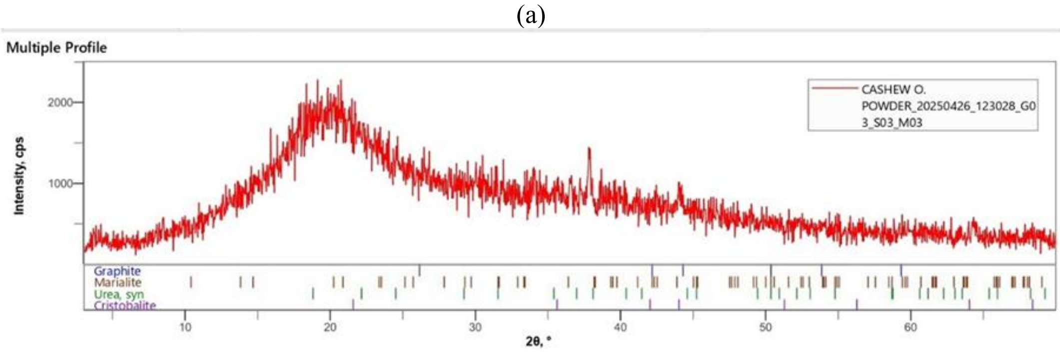


Figure 2(d) Scanning Electron Microscopy (SEM) of cashew gum powder 3000x

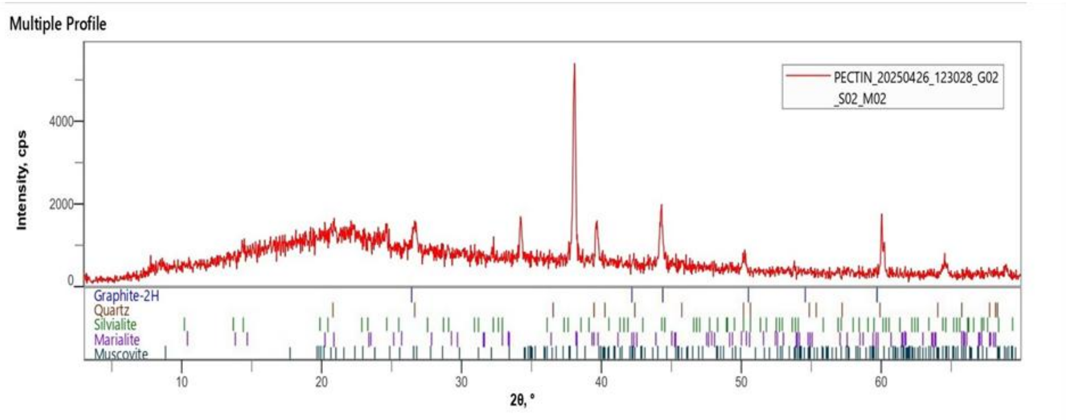


(a)

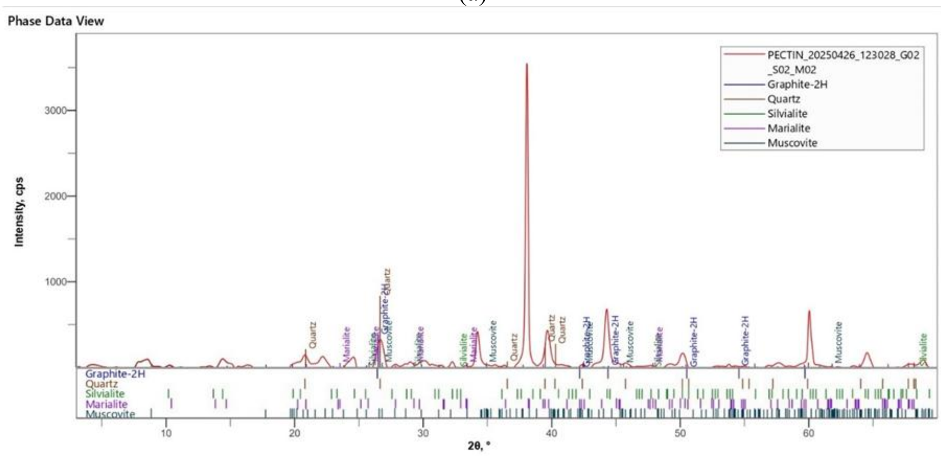


(b)

Figure 3 (a)(b). x-ray Diffractogram of cashew gum powder (CCG)



(a)



(b)

Figure 4 (a)(b). x-ray Diffractogram of cocoa pod pectin (CPP)

IV. Discussion

Table 2 showed the percentage yield of extracted pectin was 15.38% and the relatively low yield may be due experimental conditions such as reaction temperature, concentration of acid by hydrolysis and muslin cloth (pores size) used and cashew gum powder was 25.8%. Phytochemical evaluation of the extracted pectin and cashew gum are showed. The extracted pectin and cashew gum both showed presence of phytochemicals such as flavonoids, tannins, saponnins, glycosides Cand terpenoids. Previous studies carried out by other researchers have revealed the presence of these same phytochemicals in cashew gum (Akinmoladun *et al*., 2023) and pectin (Belwal *et al*., 2022). Oganoleptic properties showed extracted pectin was light to brown in colour with a smooth and soft texture to touch, has a mucilaginous taste and odourless; cashew gum powder exhibited a light brown to off-white in colour, brittle to touch with a mucilaginous taste and odourless. Extracted pectin exhibited a melting of 174 ºC to 180 ºC and cashew gum powder 260 ºC to 291 ºC, which agrees with similar work by Mathavan *et al*., 2024, which indicated that cashew gum powder undergo thermal decomposition at temperature between 220-350 ºC. The extracted pectin was light to brown in colour after extraction with a smooth and soft texture to touch, it has a muicilaginuous taste and odourless, the cashew gum powder exhibited a light brown to off-white in colour after cleaning, brittle to touch with a mucilaginous taste and odourless and exhibited a melting point of 174°C to 180°C. Cashew gum powder had a melting point of 260°C to 291°C, which is similar to work done by Mathavan *et al,*(2024) that showed cashew gum powder undergo thermal decomposition at temperature between 220 - 350°C.

Tables 4 and 5 showed the atomic and weight concentrations of extracted pectin and cashew gum respectively. The results obtained were similar to previous studies by Carvalho *et al*., 2022. The micromeritic properties comprising bulk and tapped densities, flow rate, angle of repose, Carr's index and Hausner's ratio of extracted pectin and cashew gum powder are showed in Table 6. Cashew gum exhibited a fair to passable flow with angle of repose, Hausner's ratio, Carr's index of 41.98° ± 0.05, 1.24 ± 0.01, 19.05% ± 0.05 respectively.

Results obtained from the scanning electron microscopy (SEM) of pectin and cashew gum to determine the form and surface characteristics are shown in Figure(s) 1 and 2. At various magnifications (295x 500x, 1000x, 1500x, 3000x) cashew gum showed irregular non uniform surfaced particles with heterogeneous size characterized by cracks, pores and flakes, reflecting the amorphous nature of polysaccharide, it is largely amorphous in structure with a small crystalline domains and our observation is congruent with these earlier report (Amara *et al*., 2022; Loureiro *et al.,* 2021). At various magnifications (500x, 1000x, 1500x, 3000x), extracted pectin showed an amorphous, non-crystalline powder with irregularly shaped particles when viewed under scanning electron microscopy (SEM), our observations were congruent with those earlier reports (Adebowale *et al*., 2022; Sharma *et al*; 2022). X-ray diffractograms of extracted pectin and cashew gum powders are shown in Figures 3 (a)(b) and 4 (a)(b) .The diffraction pattern of extracted pectin exhibited the following peaks; the first prominent peak was at 2Θ = 26.63°, d = 3.344 and intensity 30 count per seconds (cts), followed by 2Θ = 38.031, d = 2.620 and intensity of 18 count per seconds (cts), followed by 2Θ = 38.031, d = 2.3642 and intensity of 26 count per seconds (cts), followed by 2Θ = 39, d = 2.2751 and intensity 0f 19 count per second (cts) followed by 2Θ = 44.25, d = 2.0450 and intensity of 21 count per second (cts) and 2Θ = 60.006, d = 1.5405 and intensity of 14 count per second (cts). Their full width half maximum (FWHM) values which is an indication of the crystallinity of the powder samples showed that the first peak which is the larger suggest that the material is amorphous while the second peak value which is smaller showed that there is little or no significant crystalline domain. The structural property is advantageous for pharmaceutical and food applications, as the amorphous state improves solubility, swelling and functional performance of pectin. Also these results are in line with previous studies on the amorphous nature of pectin (Pinkaew *et al.,* 2024). Studies confirm that pectin from cocoa pod husk is mostly amorphous with little or no crystalline region depending on the method of extraction. X- ray diffractogram of cashew powder exhibited just one peak at 2Θ = 19.87, d = 4.4636 and intensity of 5 counts per seconds (cts). The full width half maximum (FWHM) value which is an indication of the crystallinity of the powder sample showed that the peak which is large suggest that the materials is largely amorphous. These results are in line with previous studies on the amorphous and non-crystallinity nature of cashew gum (Melo *et al*., 2021, Senyo *et al,* 2023). Results of the pre-compression evaluations of the formulated batches of metronidazole granules are shown in Table 7.

Batches of CPP and CCG comparatively have similar properties with the batches of PBP standard binder. Results indicated that all batches of cocoa pod pectin (CPP), cleaned cashew gum (CCG) and the standard binder PBP granules, have free flow properties with angle of repose (CPP ≤ 26.10°, PBP ≤ 27.20°, CCG ≤ 25.60°). The granules exhibited variable flow rate that were significantly different from one another CPP ≤ (8.66 ± 0.02) g/s, PBP ≤ (7.65 ± 0.01) g/s, CCG ≤ (9.92 ± 0.02) g/s. Values obtained from Carr's indices ranged from (3.49 - 20.87 %) while those of Hausner's ratio were from 1.053 -1.264 and this revealed that all granules have excellent to fair flow characteristics across the batches. Compressibility index (%) which is a measure of compaction of the granules upon tapping were CPP ≤ 20.87, PBP ≤ 17.00, CCG ≤ 14.77; while the Hausner's ratio were CPP ≤ 1.264, PBB ≤ 1.205, CCG ≤1.133 respectively. The relative high bulk and tapped densities observed in all the batches of CPP, CCG and PBP comparatively would mean that CPP had a less or low porosity as CCG and the PBP which is the standard powdered material and therefore would be less compressible. Porosity may hinder densification of bed when external stress is applied (Ding *et al*., 2020, Okeke *et al*., 2021)

V. Conclusion

Pre- compression evaluations of the formulated of the metronidazole granules, showed that all batches of PBP have similar properties with the batches of CCG and CPP. Therefore, cocoa pod pectin and cleaned cashew gum are good sources of binders with competitive functional properties as those of commercial pectin and gums. The conversion of cocoa pod husk and cashew gum exudates into industrial pharmaceutical raw material such as pectin and cashew gum powder will thus contribute to the reduction of agro-industrial waste pollution in the environment as well as adding value to the crop, economic empowerment to the farmers, and individual entrepreneur and increase the national economic base. The study has developed a potential pharmaceutical grade pectin and cashew gum powders for tablet formulation as natural binders from plant waste materials.

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