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Extraction and Characterization of the Gum Exudate of *Anacardium occidentale* for its potential as an Excipient in Drug Delivery Systems

Modupe O. Ologunagba[1], Sanyog Jain[2], Kaushik Thanki[2], Sarasija Suresh[3], Sharon Furtado[4], Chukwuemeka P. Azubuike[1], Silva B. Olanrewaju[1]

[1]*Department of Pharmaceutics & Pharmaceutical Technology, Faculty of Pharmacy, University of Lagos, Idi-Araba, Lagos, Nigeria.*
[2]*Centre of Nanotechnology and Drug Delivery, Department of Pharmaceutics, National Institute of Pharmaceutical Education and Research (NIPER), Mohali, Chandigarh, Punjab, India.*
[3]*Drug Design and Development, Department of Pharmaceutics, M.S.Ramaiah University of Applied Sciences, Bangalore, India.*
[4]*Department of Pharmaceutics, M.S. Ramaiah University of Applied Sciences, Bangalore, India.*

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ABSTRACT

Natural polymers are preferentially used over synthetics as excipients in formulation systems. Characterization of a polymer is essential to determine its suitability as an excipient. This study aimed at extraction and characterization of *Anacardium occidentale* (Anacardiaceae) gum for its potential as an excipient in drug delivery systems. *Anacardium occidentale* gum (AoG) sourced from South West Nigeria was extracted from the dried stem bark exudate gum using a modified established method. Physicochemical, pharmacognostical and solid state parameters were characterized. Extraction yield was high (72%w/w); it had desirable organoleptic properties, moisture content (9.32% ± 0.03), total ash values (2.00% ± 0.00), acidic pH (5.0), low swelling capacity (3.71 ± 0.04) swelling index (2.37 ± 0.073), hydrated to form gel (hydrogel). Phytochemical studies of AoG showed absence of tested bioactive substances; Magnesium ion was the predominant amongst its divalent metallic ions content, it did not contain hazardous lead ion. The FTIR spectrum established its polysaccharide nature as stretches of alkanes, alkynes, alcohols, phenols, phenyl, acetyl, carboxylic acids, carboxylate, ethers, aldehydes and ketones functional groups were observed, hence modifiable. Morphological structure revealed sharp irregular discrete particles with size range of 79.4 µm and 144 µm. Powder diffraction pattern showed the existence of two prominent peaks at 13.50 and 19.2 0 2 Theta, AoG thermal analysis showed that it is thermally stable.
AoG had good and desirable physicochemical properties such as hydrogel formation which could be employed either as a matrix layer former or carrier agent in drug delivery

Introduction

There is an increasing and preferential use of natural polymers over synthetics as excipients such as (bioadhesives, gelling agents, matrix formers, target specifics, carrier agents) in conventional, modified and novel drug formulation systems. [1-5] Natural polymers are polysaccharides composed of a large group of polymers with varying chemical composition, large derivatizable groups and a wide range of molecular weights. They are characterized by inertness, low toxicity, high stability, biocompatibility, biodegradability and economically cheaper to the synthetics. [4, 6]. Gums are high molecular weight polysaccharides which are formed from sugar and uronic units. Gums are hydrophilic in nature and may be classified as natural, semi-synthetic or modified and synthetic. Natural gums can be obtained as exudates or extractives from the bark of stems, branches and roots of various plants. Plant families notable for the production of gums are Anacardiaceae, Combritaceae, Meliaceae, Rosaceae and Rutaceae.[7]The production of gums by plants have been suggested to occur either as products of normal plant metabolism or as a protective mechanism against a pathological condition afflicting the plant; or as a consequence of infection of the plant by microorganisms. Gums form dispersions or hydrocolloids in aqueous medium which suggests that they could be useful in drug delivery. They form gels (hydrogels) on hydration in aqueous medium to produce mesh like network systems which can reduce the diffusional pathlength of liquid which slow capillary flow of fluid in the system. Hydrogels also exhibit environmental-responsive gelation and rheological flow behavior that confer controlled drug release characteristics to a system and can be so tailored to specific therapeutic needs. Hydrogels therefore exhibit characteristics that can be utilized in the formation of matrix systems for fast or delayed drug release or as drug carriers in micro or nanoencapsulation forms.

Anacardium (cashew) tree gum is obtained as exudates from the stem bark of *Anacardium occidentale* L. (family: Anacardiaceae), a tree that grows in many tropical and subtropical countries. It is commonly available in many regions of Nigeria. The gum is a complex polysaccharide with highly branched galactan framework of (1→3)-linked β–D-galactopyranosyl units interspersed with β-(1→ 6) linkages [8-9] and is chemically composed of 61% galactose, 14% arabinose, 7% rhamnose, 8 % glucose, 5 % glucuronic acid and < 2% other sugar residues The presence of glucuronic acid (pKa ~ 3.5) enables cashew gum to behave as a polyanion at pH > 4 21, which enhances its ability of interacting with cations.

Cashew gum has been recommended as an alternative to standard acacia gum. It has therefore been used as a binder in tablet formulations [7, 9, 10] an agglutinant for capsules and pills, [8] gelling agent in topical gel [12], suspending and emulsifying agent. [13]

Drug delivery is an emerging formulation technology and strategy to challenges posed by physicochemical or pharmacological properties of drug candidates in which natural polymers have found increasing use as excipients [1-5]. The ability of a polymer to provide its intended action

*Corresponding author. E mail: mologunagba@yahoo.com
Tel: +2348033953141

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chiefly lies on its physicochemical, pharmacognostical, rheological and solid state properties, therefore, properties such as solubility, water sorption, swelling capacity, pH, metallic ion content, thermal profile morphology, compatibility profile and viscosity among others should be established for any potential excipient. Furthermore, the inherent diversity of structures of the polymers due to geographical locations, climatic and soil conditions, age and maturity of plant etc. necessitate an extensive understanding of the surface and bulk properties of the polymers that can produce the desired functionalities.[14]

Excipient characterization is thus essential in any formulation study in order to achieve the set goal intended of the formulation.

AoG has recently been evaluated in drug delivery such as free films on paracetamol tablet cores, encapsulation of *Lippia sidoides* essential oil in cashew gum/chitosan polymeric matrix in nanoparticulate form [7, 15] however, there is paucity of data on its attributes /properties that could be employed or projected as potentials of its excipient utility in drug delivery. This is because most of the information obtained from previous studies involved characterization of this polymer with focus on its composite carbohydrate monomers, solid state and some physicochemical properties. It is therefore relevant that more pre-formulation studies on this gum be conducted in order to evaluate its properties as inference of its excipient potentials in drug delivery.

Thus this study aimed at extraction, characterization of *Anacardium occidentale* gum and projection of its properties as potentials of its excipient utility in drug delivery.

Materials and Methods

Collection and Authentication of Gum

The *Anacardium occidentale* (Fam: Anacardiaceae) (Cashew) gum was obtained by incision on the stem bark of the trees grown in Ipe-Ikun an area in Akoko South West Local Government of Ondo State, South West, Nigeria. The gum was collected between September and October 2012 during the day time. This plant (*Anacardium occidentale*) was identified, authenticated by the Curator of Botany Department (Pa Daramola) and assigned voucher number LUH 5453 in the herbarium of the Department of Botany, Faculty of Science, University of Lagos, Nigeria. The crude exudate was dried in an oven at 40ºC for 96 h and the sizes of the particles were reduced using a blender. The powder gum was packaged into a wide mouthed air tight transparent plastic container.

Extraction and Purification Process

The gum was extracted from the exudate by a modified method reported by Okoye *et al*., [12, 16] as follows: The pulverized cashew exudate was screened through a 600 mm sieve. Thereafter, 100 g of the powder was soaked in 500 mL of distilled water at room temperature (30ºC) with intermittent stirring for one week. At the end of the one week, the dispersion was strained through a muslin bag and the resulting mucilage was precipitated by mixing it with thrice its volume of 96% ethanol. The precipitated gum was filtered using a filter cloth (calico linen) to ensure that all debris was removed and air dried. Further purification of the gum was carried out by dissolving it in fresh distilled water to yield 1.0% w/v solution. This solution was filtered using a 100% cotton cloth overlaid with 2-inch-thick surgical cotton wool (Maimed GMBH, Germany) and the resulting filtrate mixed with thrice its volume of 96% ethanol to precipitate the gum. The precipitated gum was harvested and soaked in 200 mL of 96% ethanol for 18 h and finally air dried in order to remove the peroxidase. The dried flakes of this purified gum were finely powdered using a blending machine and the purified finely powdered gum was stored in an air tight open-mouthed screw capped glass bottle.

Physico-chemical Properties Characterizations

Extracted Gum Yield

The dried extracted AoG was weighed and the percentage yield expressed relative to the initial weight of the crude exudate.

Organoleptic Properties

The colour, odour, taste and texture of the powdered extracted gum were assessed.

Moisture Content

The percentage of moisture content of 2 g sample of extracted AoG was analyzed using electronic moisture analyzer (Type MB 35, OHAUS, Switzerland).

Flow properties

The Bulk and Tapped densities, Hausner's ratio, Carr's (Compressibility) Index, Angle of Repose of extracted AoG were determined in accordance with the method detailed by Azubuike *et al*. [17]

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pH of Extract

This was done by preparing a 5.0% w/v aqueous (distilled water) dispersions of extracted AoG in distilled water and the pH measured using a pH meter (Oaklon ;Model 1100). The pH meter was set to neutral (7.4) at a room temperature of 28°C and the electrode was immersed into the separate gum dispersions). Triplicate determinations were carried out and the mean recorded.

Swelling Index

Swelling index is the volume in mL occupied by 1 g of a hydrophilic material including any adhering mucilage after it has swollen in an aqueous liquid for 4 h. The method described by Musa *et al* [18] was utilized, with slight modification. Briefly, one gram of extracted AoG of particle size less than 150 µm was accurately weighed and carefully transferred into a 50 mL measuring cylinder. It was moistened with 1 mL of ethanol 96% and 25 mL of distilled water was added. The cylinder was firmly closed and shaken vigorously every 10 min for 1 hour and then allowed to stand undisturbed for 3 hours. The volume occupied by the polymer gum under test after the entire 4 hours was measured. The mean of triplicate determinations was recorded as the swelling index.

Swelling Capacity

The method described by Mahmud *et al*. [19] was adopted. Five (5) gram of extracted AoG was placed in a 100 mL measuring cylinder and tapped 200 times after which the volume of gum extract was noted as (Vo). Distilled water was added to the 80 mL mark and left to stand for 24 h after which the new volume obtained was recorded as (V_1). This process was carried out in triplicate and the swelling capacity Φ, was calculated as the ratio of the final volume to initial volume ($\Phi = Vo/V_1$)

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Pharmacognostic Properties (Probate and Phytochemical Screening) Characterizations

Ash Values

The ash values were determined in accordance with the established methods with the use of a furnace (Carbolite AAF1100, Parsons Lane, Hope Valley, S336RB, England). Two (2) grams of AoG was placed into a tarred crucible. The content was ashed at 450ºC for 3 hours until a whitish grey matter was obtained. The sample temperature was then allowed to drop to 100ºC and removed from the furnace, cooled in a desiccator over silica gel and reweighed using an analytical balance (Adventurer-Pro, Ohaus). The weights of the residues (carbon- free ash) were determined and expressed as percentages of the initial materials. The mean value of the three separate determinations for extracted AoG was recorded.

In order to determine the acid insoluble ash for AoG, the ash obtained from the above was boiled with 25 mL of 2 M HCl for 5 min. The insoluble residue was separated by centrifugation at 2000 rpm for 5 min using a centrifuge (Thermo Scientific, Heraeus, Labofuge 200, Germany). The sediment was re-suspended in a hot water and evaporated to dryness in a tarred crucible. The weight of the residue was expressed as a percentage of the initial weight of the material.

Phytonutrients

The screening for the presence of various phytonutrient constituents in AoG extract, i.e. carbohydrates (Molish test, Ruthenium test), reducing sugars (Fehlings test), alkaloids (Dragendorff's test), steroids and terpenoids (Liebermann Burchard test), tannin and phenolic compounds (Ferric chloride test), flavonoids (Shinoda test), amino acids (ninhydrin test), etc., were undertaken by the usual methods prescribed in standard texts. [20,21]

Solid State Characterizations and Compatibility Assessments

Metallic ion (Elemental) content Analysis of Gum Polymers

The metallic ion analysis was undertaken with the Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS, Thermo Fischer Scientific iCAP 7000 Series/ICP) using 5 mg of AoG. Concentrations of Cadmium (Cd), Copper (Cu), Iron (Fe), Magnesium Mg, Calcium (Ca), and Manganese (Mn), in the AoG sample were determined.

Fourier Transform Infra -Red Spectrophotometric (FTIR) analysis
The FTIR analysis of extracted AoG was carried out using the apparatus FTIR-8400S Spectrophotometer (Shimadzu, Japan) and Spectrum 400 (Perkin Elimer Ins. USA).
Two milligrams (2 mg) of extracted AoG and 200 mg KBr were powdered and compressed into a pellet. The resulting pellet was mounted on the sample holder and the system was purged with nitrogen gas. Scanning was conducted in the range (ATR) of 400 cm^{-1} to 4000 cm^{-1} with a resolution of 1 cm^{-1}. Triplicate measurements were made and the spectrum with the clearer peaks was chosen.

Differential Scanning Calorimetry Analysis (DSC)
This analysis was performed in order to investigate the melting and crystallization behavior of the gum polymer powder. Five milligrams (5 mg) of the purified, dried and finely powdered AoG was carefully weighed using the analytical balance (Mettler Toledo AB54, Switzerland). The sample was sealed in aluminium pans. Calibration of the calorimeter was done with indium and the purge gas was nitrogen and measurements were recorded using Differential Scanning Calorimetry (DSC, 2000, TA, Instruments USA,) instrument. The sample of AoG was separately heated at a temperature of 25 to 200ºC using the ramp method at a rate of 10ºC/min under nitrogen flow rate of 20 mL/min, followed by cooling back to 25ºC at the same rate after which the outcome was examined/assessed.

X-Ray Powder Diffraction (XRPD) analysis
X-ray diffraction pattern test was carried out separately on the AoG extract using the Diffractometer- Powder X-Ray Diffractor (D8 Advance Burker, Germany). Powder sample was finely ground and thinly spread in the sample holder of diameter 10 mm. This was then placed on the stage of the instrument and scanned continuously at a step time of10.16 sec, temperature of 25ºC, using an anode material of Cu with K"1 and K"2 equal to 1.54060Aº and 1.54443Aº, respectively at 40 kV and 10 mA. Scanning of AoG extract sample was initiated at 5.0251º22 and ended at 119.9751º22 at step size of 0.05º22.

Scanning Electron Morphological Study of Extracted Gum Polymers
This was conducted using the Scanning Electron Microscope (SEM-S-3400, Hitachi, Ltd, Japan). About 5 mg of the extract uncoated was placed on the sample holder and vacuum was created using the pump set at 5kV. The x250 magnification range was employed to examine the sample.

Statistical Analysis
Data obtained were expressed as mean ± standard error of the mean. Statistical analysis was done using one-way analysis of variance followed by Turkey-Kramer multiple comparison test using GraphPad Instat-3 software. Significance of difference was taken at values < 0.05.

Results and Discussion

The extraction, purification and characterization of AoG was successfully undertaken and its extract yield was 72% w/w. Comparatively higher yield of the extract was obtained from the AoG used for this study which was sourced from South-West, Nigeria to the yields of (52.35%.) and (48.0%) reported in two studies [9,12] whose crude extracts were sourced from northern Nigeria. The high percentage yield of extract obtained was close to the reported value of (78.5%) from another study undertaken in Ghana. [7] It could be that the environmental conditions (soil and climatic) in the Southwest of Nigeria was more favourable for gum production and could be contributory to the high yield. The organoleptic properties were pharmaceutically acceptable which should portend its usefulness as an excipient. The moisture content obtained (9.32 ± 0.03%) fell within the USP and BP [22-23] permissible limit for biomaterials, the maximum limit is 15% w/w. This is because water is known to catalyze many degradative processes such as hydrolysis and microbial spoilage; higher moisture content increases the probability of polymer degradation [9, 24] . The low moisture content in AoG purified extract infers its safety as an excipient because the stability will not be compromised by hydrolysis and microbial growth.
The pH of AoG purified extract is in the acidic (pH 5.0) range indicating its pharmaceutical importance. This is because basic excipients promote oxidation of susceptible drugs when used for their formulations [9, 25]. Therefore, acidic and neutral hydrocolloids are more widely used for pharmaceutical formulations. [9, 19] AoG purified extract may therefore possess better drug/excipient compatibility as the pH is closer to neutrality. It is hydrophilic and hydrates in water to form gel of low viscosity and has both low swelling capacity and swelling index. Gums are polysaccharides with numerous sugar molecules and, therefore partially dissolve in water but are insoluble in organic solvents, thus the slight solubility of AoG purified extract in water is characteristic to Anardiacaeae gum producers.
AoG purified extract, though hydrophilic exhibited low hydration profile; this is because AoG is a highly branched polymer, therefore it hydrated slowly to form gel of low viscosity on dispersion in aqueous medium. The low values of swelling capacity and swelling index obtained for AoG purified extract infered its novel excipient potential as a delayed release matrix layer former/system in controlled release formulations as well as a carrier agent in micro and nano-encapsulation systems. This is because swelling capacity of a gum demonstrates its hydrophilic nature and also its ability to swell into gel in an aqueous medium to release an embedded drug. High swelling capacity implies faster hydration and release time and conversely, low swelling capacity results in retarded drug release.
The result of the micromeritics and proximate characterization of AoG is presented in Table 2. It had good micromeritics properties as indicated in the values of the compressibility index and hausner's ratio as well as good powder flow properties; its angle of repose value was 33.82º.
The good micromeritics properties of AoG purified extract indicates its excipient usefulness in solid oral dosage formulations as good powder flow will ensure uniformity of tablet weights, capsule filling as well as compression of formulation ingredients.
It was positive for reducing sugars and carbohydrates but did not contain other phytonutrients (secondary metabolites) such as alkaloids, steroids and terpenoids, tannins and phenolic compounds, flavonoids, amino acids. The absence of phytonutrients in AoG purified extract implied its inert nature which is an expected and important characteristic of an excipient. The presence of reducing sugars and carbohydrate established its polysaccharide nature of biodegradability, biocompatibility, non-toxicity and safety for use as an excipient. The low total ash value also implied its low level of contamination with both plant and siliceous earth materials. The low total ash and water insoluble ash values obtained indicated that AoG had low contamination with plant and siliceous earth materials. This is a good attribute for an excipient material.
The elemental composition of AoG purified extract as shown in Table 3 contained parts per quadrillion (ppq 10^{15}) divalent metal ions on the following rank order: $Mg^{2+} > Ca^{2+} > Fe^{2+} > Mn^{2+}$ and trace amounts of Cd^{2+} and Cu^{2+} which were within the permissive limits and the absence of lead. The values obtained for cadmium, copper and manganese were found to be within the USP specified limit for elemental ion content in a biomaterial. This gum (AoG) purified extract contained moderate levels of iron and calcium and fairly high levels of magnesium. The presence of very high levels of certain metals such as lead (Pb^{2+}) and copper (Cu^{2+}) are poisonous. The quantity of copper in the extracted gum was less than the acceptable limit of 1.3 mg/L prescribed by WHO guidelines. Lead is a highly hazardous metal and it was absent in AoG purified extract. The low concentrations of copper, cadmium ion in AoG purified extract suggest that AoG would be a safe pharmaceutical excipient. [26]
Magnesium ion was the predominant in this study which is not in agreement with some earlier studies[7, 9,27-28] who indicated calcium ion as the predominant ion. This difference could be as a result of factors like soil types, climatic conditions, age of plant, source of plant, post- harvest handling, method of extraction and purification.
The polyvalent metal ions are known to enhance the viscosity of the gums by inducing the polysaccharide chains in the gums to interact inter or intra molecularly. [29] This attribute can be utilized for AoG in a drug delivery technology such inotropic gelation. The FT-IR spectroscopic spectrum of AoG presented in Figure 1 and Table 4 indicated intense bands of absorption of functional groups which were in agreement with literature values and previous workers findings on *Anacardium occidentale* gum. [9, 11]

Vibrations of stretches and bends identified for AoG were specific for the C-H; O-H; C-C; C-O and C=O bonds of the different functional groups. Thus, C-H bends of alkenes functional group occurred at 416.60 cm^{-1} - 995.20 cm^{-1} and C-O stretches of carboxylic acids, alcohol, esters, ether functional groups occurred at 1016.42 cm^{-1} - 1400 cm^{-1}; whilst C=C stretches of phenol, phenyl, alcohol and alkene functional groups occurred at 2214.3 cm^{-1} - 2956.67 cm^{-1},; stretches for the bonds of the alkyne functional groups occurred at 2100 cm^{-1} - 2200 cm^{-1} and O-H stretches of alcohol, phenol functional groups occurred at 3317.34 cm^{-1} - 3917.16 cm^{-1} whilst O-H (bonded) of the carboxylic acid, alcohol

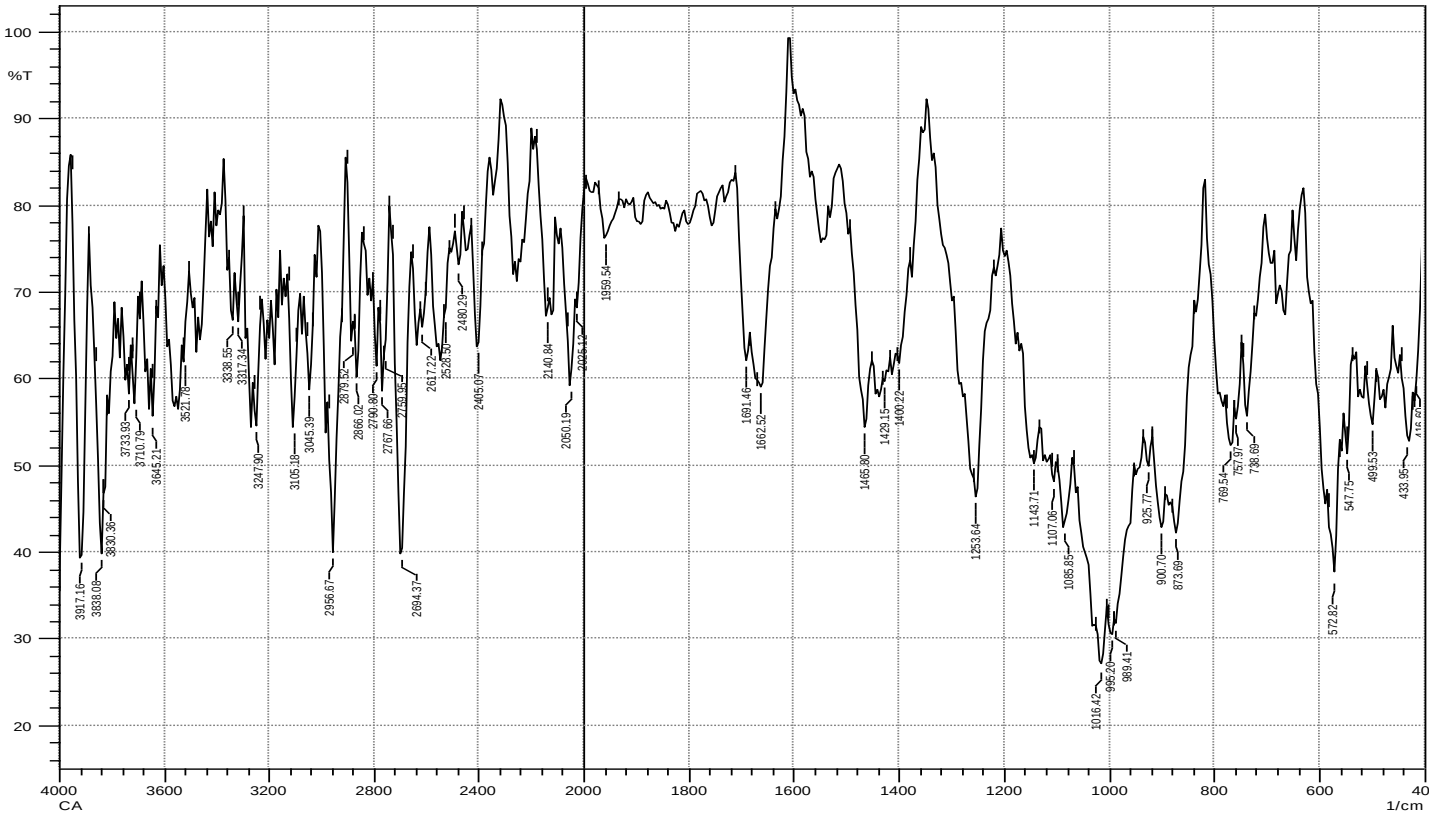

Figure 1: FTIR Spectrum of extracted *Anacardium occidentale* gum

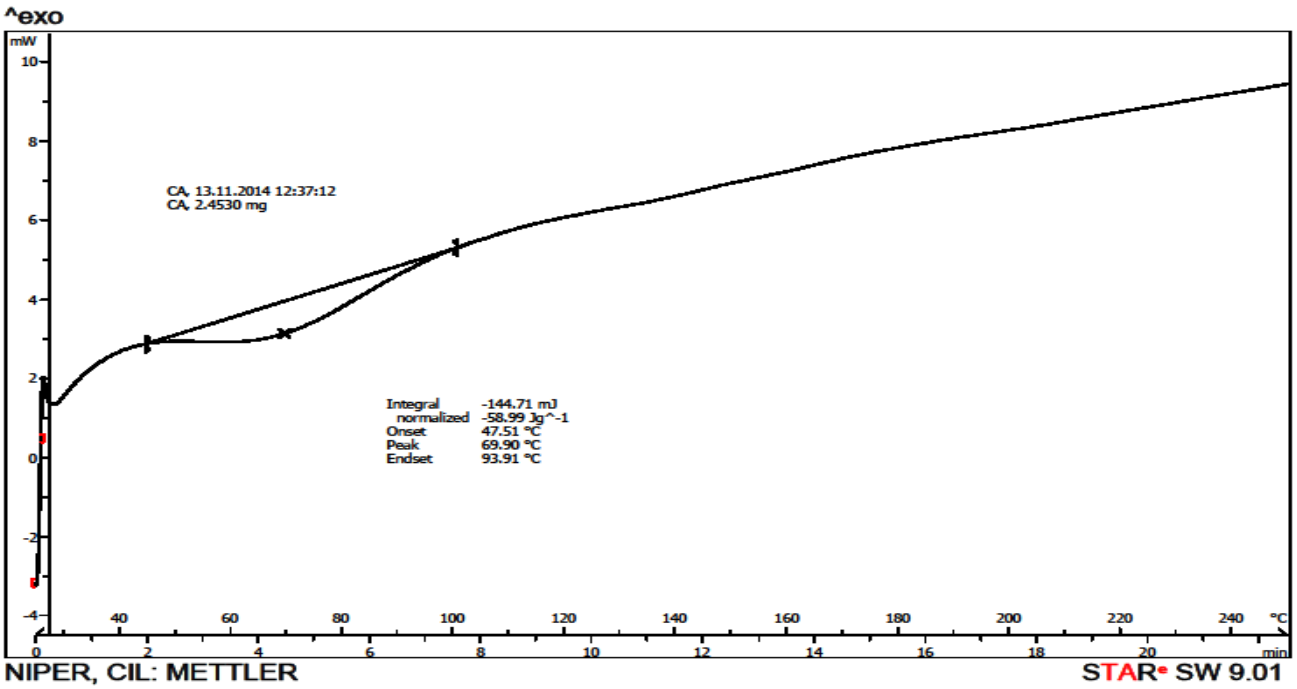

Figure 2: Differential Scanning Calorimetry (DSC) Thermogram of extracted *Anacardium occidentale* gum recorded in a dynamic nitrogen atmosphere (50 mL min-1), and at a heating rate of 2 °C min^{-1}.

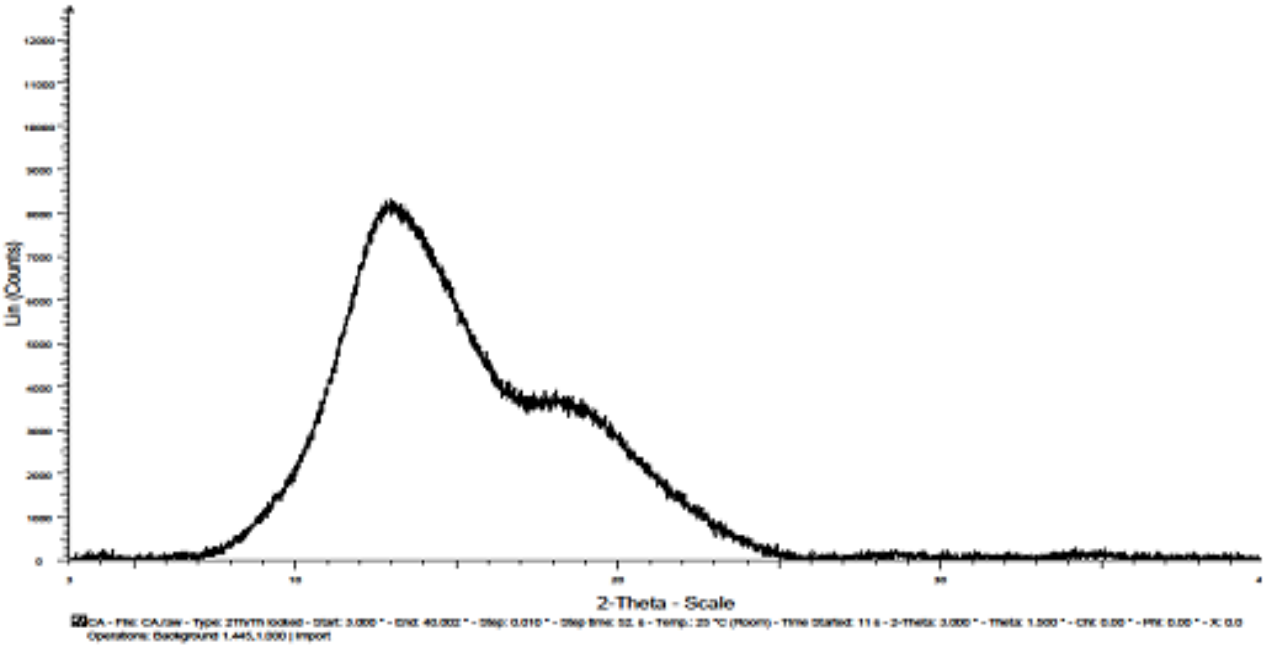

Figure 3: X-Ray Diffractogram (XPRD) graph of extracted *Anacardium occidentale* gum

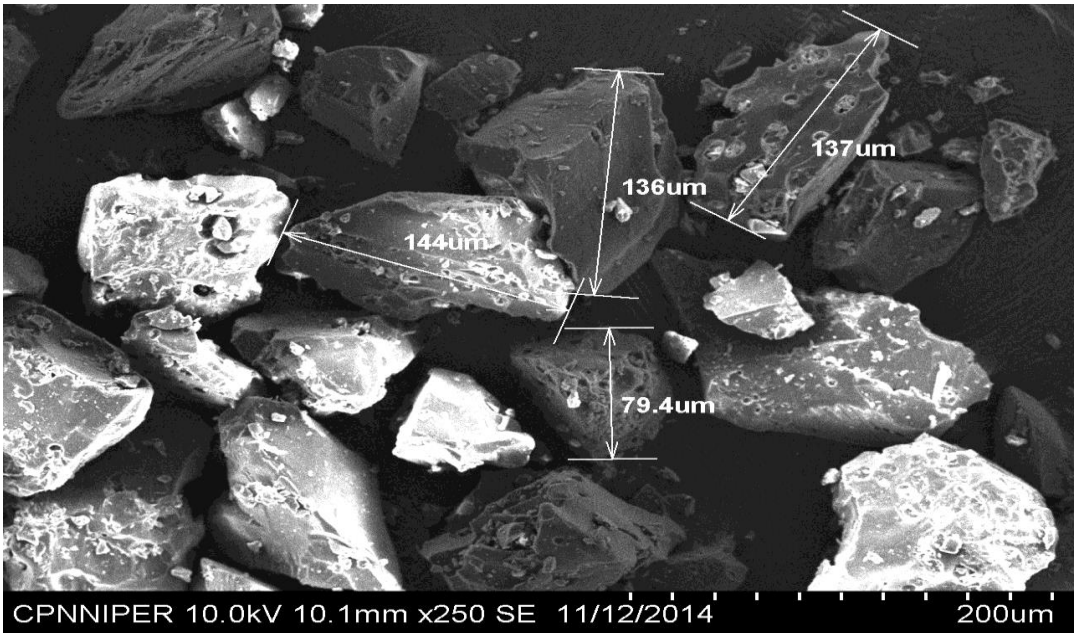

Figure 4: Scanning Electron Micrograph of extracted *Anacardium occidentale* gum @ x250 magnification

and phenol functional groups occurred at 3200 cm^{-1} - 3500 $cm^{-1}$and C-H stretches of alkane, alkene and aldehyde functional groups occurred at 2815 cm^{-1} - 3106 cm^{-1} whilst C=O stretches of ester, carboxylic acid, aldehyde and ketone functional groups occurred ^{at} 1700 cm^{-1} - 1800 cm^{-1}.The region between1500 cm^{-1} - 1800 cm^{-1} is typically used to detect the presence of carboxylic group, whilst, peaks at 1740 cm^{-1} - 1228 cm^{-1} are typical of acetyl groups [30]. Natural gums usually contain fractions of sugar acid units which would usually impart a weakly anionic character to the gum macromolecule. This explains why the absorption bands of carboxylate groups of the galactouronic acid residues of AoG were observed and identified at 1016 cm^{-1} and 1400 cm^{-1}. The absorption finger print regions for carbohydrates are observed at 800 cm^{-1} and 1200 cm^{-1}, for AoG purified extract, the finger print region identified laid within 710 cm^{-1} - 1040 cm^{-1}. This is in agreement with the official specification as well as the previous workers. [11, 22,].

The presence of these different functional groups indicates that the parent structure of AoG is modifiable and can act as a drug carrier for many active pharmaceutical ingredients. Result indicates that AoG is a polysaccharide, thus it is biodegradable which indicates its potential usefulness as an excipient.

The result of Differential Scannning Calorimetry(DSC) thermogram of AoG purified extract is presented in Figure 2. The thermogram of AoG as depicted in Figure 2 is the enthalpy of relaxation of this polymer between 20°C and 250°C [9, 32]**.** The thermogram shows a broad endothermic

Table 1: Physico-chemical and Pharmacognostic properties of extracted *Anacardium occidentale* gum

Parameter	Result
Yield (%)	72.0
Colour	Greyish white
Odour	Mildly pungent
Taste	Mildly bland
Texture	Finely coarse
Moisture content %	9.32±0.03
pH (2%w/v)	5.0

Hydration profile	Gel formation of low viscosity
Swelling capacity	3.71±0.04
Swelling Index	2.37±0.073
Phytonutrients (Secondary metabolites)	Absent
Reducing sugars & Carbohydrates	Present

Table 2: Micromeritics and Proximate Properties of extracted AoG

Parameter	Result
Bulk Density(g/cm^3)	0.64
Tapped Density(g/cm^3)	0.85
Compressbility Index	24.36
Hausner's Ratio	1.32
Angle of Repose (A°)	33.82º
Total Ash (%w/w)	2.00±0.00
Water Insoluble Ash (%w/w)	0.017±0.003
Carbon-Free Ash (%w/w)	97.30±0.4

Table 3: Metallic ion content of extracted AoG

Serial number	Elemental ion Type	Concentration (ppq)*
1	Cadmium	0.04
2	Copper	9.0
3	Iron	243
4	Magnesium	843
5	Manganese	46
6	Lead	Not detected
7	Calcium	457

* ppq (part per quadrillion) = One part in 10^{15}

transition between 20ºC and 100ºC with an onset transition at 47.51ºC, peaking to 69.9ºC (desolvation temperature) and an ending melting point peak at 93.91ºC, followed by a diffuse exothermic transition which peaked at 250ºC. The enthalpy change in the thermogram of AoG in the first transition was -58.99 mJ and the second transition it was -144.71mJ. The diffuse exothermic peaks confirmed AoG amorphous nature and characteristic polysaccharide degradation. [33] The observed enthalpy change of -144.71 mJ showed that -144.71 mJ of heat was lost as 1 g of the polymer degraded. AoG had crystallization (heat loss exothermic transition),[34] as heating continued beyond crystallization, a temperature was reached when the crystals moved out of the orderly arrangement in a process called melting. Thus, the three stages of decomposition of AoG were observed at 47.51°C, 69.9°C and 93.91°C which corresponded to desolvation, melting and complete decomposition or degradation, [35]. This finding differed from an earlier study [11] that reported absence of glass transition or crystallization for cashew gum. This could be due to the geographical source, climatic and soil variation. The thermal profile showed that AoG purified extract was a thermally stable amorphous polysaccharide that degraded on melting. This implied that AoG is biodegradable, which is a required for an excipient.

The result of the powder X-ray Diffraction of *Anacardium occidentale* is presented in Figure 3. The X-ray Diffractometer (XPRD) evaluation showed characteristic halo peak patterns (Figure 3) for AoG purified extract. The halo peaks occurred at below 25^0 2 Theta which indicated its amorphous nature and the existence of two prominent peaks at 13.5^0 and 19.2^0 2 Theta were observed. This outcome could be because organic molecules are large and their crystals have large unit cells, their interplanar spacings would, therefore be large. The large spacings gave rise to diffraction peaks at small values of ◦2 Theta. Okoye *et al* [11] also indicated a halo peak diffraction pattern in her study of cashew gum. Halo peaks are indicative of powders that are amorphous in nature [37-39]. Many natural gums have also been reported to exhibit similar halo peaks diffraction patterns which therefore indicate and confirm their amorphous nature. [11, 40-43] The two halo peaks identified in the spectrum of AoG purified extract (Cashew gum) indicate the possible existence of two polymorphic forms.

The Scanning Electron Microscopy (SEM) revealed the morphological structures of AoG purified extract in Figure 4. The SEM micrograph of the gum extract is indicative of an amorphous material. This observation further confirmed the earlier findings from this study and assertion on the amorphous nature of this gum polymer undertaken with the XPRD analysis.

In this study, the particles were mostly seen as aggregates of irregular shapes and dimensions which were fibrous in nature. The observed particle size for AoG ranged from 79.4 µm to144 µm. These irregular particles may contribute to mechanical resistance to flow and increase in the low shear viscosity. This attribute could be useful in drug delivery.

Table 4: Characteristic FTIR Peaks heights (ranged) and Stretches of extracted AoG with corresponding assigned Functional Groups

Ranged Peak Heights @ cm^{-1}	Types of Stretches and Bends	Assigned Functional Groups
416.6-995.20	C-H	Alkenes
1016.42-1400.00	C-O	Carboxylic acid, alcohol, ester, ether
1700-1800	C=O	Carboxylic acid, ester, aldehyde , ketone
2214.3-2956.67	C=C	Alcohol, Phenol, Phenyl
2100-2200	C=C	Alkynes
2815-3106	C-H	Alkane, alkene and aldehydes
3200-3500	O-H (bonded)	Carboxylic acid, Alcohol and Phenol
3317.34-3917.16	O-H	Alcohol, Phenol, Polysaccharides

Conclusion

The characterization of extracted AoG has revealed and established its desirable physicochemical, pharmacognostical and solid state properties which suggests its excipient usefulness. Furthermore, the ability to form hydrogel on dispersion in aqueous environment portends its excipient usefulness in drug delivery.

Conflict of interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article are original and that any liability for claims relating to the content of this article will be borne by them.

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