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Characterization of *Chrysophyllum albidum* Linn (Family: Sapotaceae) Endosperm Seed Gum for Potential Application as Pharmaceutical Excipient

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ABSTRACT

The study was aimed at characterization of *Chrysophyllum albidum* seed gum (CasG) for potential application as a pharmaceutical excipient.
Microwave-assisted technique was employed for CasG extraction using acetone as an anti-solvent. Physicochemical, pharmacognostic, microbial as well as toxicity profiles of CasG powder was characterized using established methods.
The yield of CasG extract was 15.40 ± 0.05%. Results of physicochemical analysis revealed particle size (110.00 ± 0.18 µm); moisture content (11.73 ± 0.11%); pH (6.0); swelling index (3.19 ± 0.19); water binding capacity (119.0 ± 0.1); viscosity (23.2 ± 0.3 cP); flow rate (2.30 ± 0.12 g/sec); bulk density (0.61 ± 0.01 g/cm^3); tapped density (0.66 ± 0.01 g/cm^3); among others. The phytochemical screening showed presence of reducing sugars and carbohydrates and absence of other tested substances. Microbial evaluation revealed the absence of objectionable organisms such as *Salmonella spp, Shigella spp, Klebsiella spp, Psedomonas spp, Proteus spp, Escherichia coli and Staphylococcus aureus.* The total aerobic microbial, yeasts and mold counts conformed to the microbial limits specified by the United States Pharmacopoeia. LD_{50} value greater than 5000 mg/kg was obtained. There was no observance in the experimental animals of any morbidity, mortality or signs of acute toxicity, treatment related abnormalities on the haematological parameters and organs histopathology at all the administered doses and there were no statistical significance between the control and CasG tested groups for these parameters.
These desirable physicochemical, microbial and toxicological properties suggest that CasG could have good excipient potentials in pharmaceutical formulations.

Keywords: *Chrysophyllum albidum seed gum, Characterizations, Toxicity Profile, Pharmaceutical Excipient.*

Introduction

Pharmaceutical excipients are components of dosage forms which though present in small quantities enable formulations acquire some desirable characteristics that are suitable for administration to patients.[1] Excipients are often times present in greater proportion with regards to the active pharmaceutical ingredient in most formulations thus control a wide variety of functional roles such as physicochemical and biopharmaceutical properties of the active pharmaceutical ingredients in formulation systems.[2,3] They thus play important roles in development of drug formulations[4] which makes it expedient that their selections are pharmaceutically acceptable with regards to non-toxicity, microbial safety and compatibility with active pharmaceutical ingredients.[5]
There is an increasing global interest and use of natural polymers and their derivatives as excipients in formulation systems**.** A polymer is a large molecule (macromolecules) composed of repeating structural units. These subunits are typically connected by covalent chemical bonds. They are characterized by low toxicity, high stability and biodegradability. These properties make them appealing as pharmaceutical excipients.[5, 6]
Gums which are translucent amorphous substances of a monosaccharide or mixed monosaccharides are the commonly used natural polymer excipients. Gums being hydrocolloids contain hydrophilic molecules that can combine with water to form viscous solutions or gels.[7, 8] The structure, type and number of monosaccharides, their configuration, number and location of the linked groups give each gum its peculiar physicochemical characteristics. The degree of polymerization influences the viscosity and hydration rate of gum. Longer molecules tend to produce higher viscosities and take longer to hydrate than shorter ones. A highly branched molecule takes up less space than a straight one with the same molecular weight and therefore provides less viscosity.[8-10] Gums can exist as exudates or extractives from barks and fruits or seeds of plants, respectively.
The search therefore for local pharmaceutical excipients that can be used in formulation of dosage forms informed the study on the potential excipient utility of *Chrysophyllum albidum* seed gum. *Chrysophyllum albidum* Linn (family: Sapotaceae) known as African star apple or Cherry is an indigenous fruit in some Central, East and West African countries like Uganda, Cote d'Ivore, Nigeria, Niger and Cameroon.[11, 12] The fruit is a large berry containing 4-5 flattened seeds,[13] the juice of this fruit is milky while the fleshy pulp (mesocarp) has the ability to form a gum when chewed and therefore relished and consumed as snacks.[14] The fruit has high iron and ascorbic acid contents.[12] The exocarp and mesocarp of this fruit which turns gummy when chewed have recently been evaluated as a binder in dry and wet granulation systems.[15,16] Unlike mesocarp of this fruit, the seeds are not eaten[13] and to the best of our knowledge, seed gum of *Chrysophyllum albidum* has not been characterized for potential applications as excipient in pharmaceutical formulations. In this study, the

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physicochemical, microbial and toxicological profiles of seed gum of *Chrysophyllum albidum* are reported.

Materials and Methods

Ethanol, hydrochloric acid, acetone, alpha naphthol, sulphuric acid, ferric chloride, Dragendoff's reagent, glacial acetic acid, ethylacetate, methanol, lead acetate, methyl red solution, bromocresol green (0.1%), Fehling's solution, Resorcinol, petroleum ether and chloroform, are all of BDH Laboratory Chemicals Limited, Poole, England and all other reagents were of analytical grades and were used as received from the suppliers.

The ripe fresh fruits of *Chrysophyllum albidum* were obtained from a local market in Sabo area of Ikorodu in Ikorodu West Local Government Area of Lagos State, Nigeria during its fruiting season (March 2016). The plant was authenticated at the Department of Botany, Faculty of Science, University of Lagos, the specimen voucher was LUH: 7453. They were then stored in a cool dry place until used.

Gum Extraction and Purification

The fruits were thoroughly washed with water, the exocarp and mesocarp were peeled off and the seeds were removed and washed. The seeds were sun-dried for a week to allow for ease of cracking. After one week of drying, each dried seed was cracked to remove the endosperm which was sundried for five weeks. The dried endosperm was further subjected to hot air oven (Gallenhamp Oven 300 plus series, England) drying for five days at 40ºC. It was then finely powdered with a traditional hand mill Corona®. The microwave assisted extraction technique[17] was used for extraction with slight modification. The powdered endosperm was soaked in distilled water in an aluminium container for 12 h after which the container was placed in a microwave oven (Akai, Japan) and the soaked endosperm was subjected to microwave irradiation (medium setting) for 10 min. The container was removed from the oven and filtered while hot through a muslin cloth to remove the marc from the solution. The gum was precipitated from the filtrate with acetone. The precipitate was washed with diethyl ether and dried in a hot air (40ºC) oven (Gallenhamp Oven 300 plus series, England). The dried gum powder (CasG) was finely powdered and weighed. The percentage yield was calculated according to the formula below.

$$\text{Percentage Yield} = \frac{\text{Weight of extracted gum}}{\text{Weight of blended peel}} \text{ x } 100$$

Characterization of Chrysophyllum albidum Powder

Physicochemical Parameters

The organoleptic properties, moisture content, swelling capacity, hydration, solubility profiles, pH, bulk and tapped densities, angle of repose and flow rate of *Chrysophyllum albidum* powder were determined using the procedures described in a previous study.[18]

Phytochemical screening

Phytochemical screening of CasG was carried using the modification of methods employed in an earlier study.[19] This included test for flavonoids, tannins, alkaloids and carbohydrates. The authentication of CasG as a gum was undertaken with the Ruthenium red (ammoniated ruthenium oxychloride) evaluation which indicated the red color characteristic of the presence of a gum. [19]

Probate Analysis

This assessed both the qualitative and quantitative values of insoluble matter (total ash and acid insoluble ash) in a biomaterial substance. The percentage content of insoluble matter in CasG was determined according to an official method.[20] Ash content was estimated by the measurement of the residue left after combustion in a furnace at 450°C. The ash obtained from the determination of the ash was boiled with 25 mL of 2 M hydrochloric acid solution for 5 min and the insoluble matter was filtered and washed with hot water and ignited and the subsequent weight was determined. The percent acid insoluble ash was calculated.

Rheological Characterizations

The viscosities of the dispersions of CasG at 2, 5, 10, 15 and 20% w/v concentrations were determined at shear rates of 0.5, 1, 1.5, 2, 2.5 and 3 rpm using a Brookfield viscometer (spindle number 2) at 25°C and shear rate of 1 rpm.

Microbial load determination

Microbial load determination was carried out on CasG powder using the. procedures employed by Ologunagba *et al*[21] as indicated in established methods (USP, 2015)[22] for microbial limit test.

This was carried out using different selective media (Biotec products)- Sabouraud Dextrose Agar (specific for fungal organisms-yeast and mould organisms); Tryptone Soya Agar (specific for aerobic count); Mannitol Salt Agar (specific for Staphylococcal count); Pseudomonas *Cetrimide* Agar (specific for Pseudomonas) ; Eosine Methylene Blue Agar (specific for *E.coli*); Thiosulphate Citrate Bile Salt Sucrose Agar (specific for *Vibrio cholerae*); Nutrient Agar (specific for *Proteus swirming*); *Salmonella Shigella* Agar (specific for salmonella/shigella) and Mac Conkey Agar (specific for enteric bacteria-Coliform and Bile Tolerant gram negative organisms) .

The microbial load determinations included: Total combined yeast and mold count; Total aerobic count; Total staphylococcal count; *Pseudomonas* count; *E. coli* count; *Vibro cholerae*; *Proteus swarming*; *Salmonella/Shigella* counts; Coliform counts; Bile Tolerant gram -ve organisms.

The dispersion of CasG in sterile 3% Tween 80 was vortexed with a Vortex Vibrator (JP Selecta s.a. Spain; Serial No: 0514265, Model code: 7001721) and diluted to give two different dilutions (1:10 and1:100). Petri dishes were labeled appropriately with the dilutions and the media to be populated. All petri dishes that were labeled 1/10 (1:10) dilutions had 19 mL of the respective media aseptically poured into them and were correspondingly inoculated with 1 mL of the 1 in 10 dilution (stock solution of the cashew gum polymer dispersion). This procedure was undertaken inside a sterile cupboard (ESCO class II Biohazard Safety Cabinet, Singapore). This procedure was repeated for the petri dishes of the different media labeled 1/100 (1 in 100) dilution. At the end of this procedure, each microbial specific media had two petri plates of 1 mL of a 1 in 10 and 1 in 100 dilutions of the gum polymer dispersion and filled with 19 mL of the appropriate agar type. They were thoroughly mixed and allowed to set. For each culture medium, three determinations and one control were prepared. Sampling and inoculation was separately undertaken with these two dilutions.

Sabouraud Dextrose Agar (SDA) plates were incubated up-right at room temperature to avoid the spores being dispersed. All other plates were incubated and their controls were incubated at 37 ± 2ºC (Remi Industries Ltd, Mumbai-India; Model 400053; Serial No: I11C-2368 and Astell Hearson, England, Model: JBF042, Nov 86, Serial No: OV10045) for the required specific incubation period (72 hours/one week).

Petri dishes maintained for bacterial studies were observed daily for 72 hours for growth and further identification of the organisms. Sabouraud Dextrose Agar plates were observed daily for one week to allow for full development of fungi for identification. This determination was repeated after a storage period of 6 and 12 months.

Toxicological Evaluation

Study Protocols

Male mice weighing between 18-36 g were used for the study. They were housed in a standard environmental condition and fed with rodent standard diets and water *ad libitum*. Animal care and handling conformed to OECD guidelines.[23] The Lethal Dose (LD_{50}) of CasG and its acute toxicity profile were determined.

Lethal Dose (LD_{50}) and Acute Toxicity Determinations

The limit test dose of 5000 mg/kg and acute toxicity evaluations on mice (18-36 g) were in accordance with the officially stipulated protocols and guidelines by Organization for Economic Cooperation Development (OECD) [23,24] were undertaken. The animals were observed individually for acute toxicity signs and behavioural changes 1 h post-dosing, and at least once daily for 14 days. Haematological parameters (red blood cell, white blood cell) of CasG treated and control mice were evaluated.

Statistical Analysis

Statistical analysis was performed by one-way analysis of variance (ANOVA) with Tukey test to evaluate significant differences between groups. Significant differences between control and experimental groups were assessed with student's t-test. Values of $p < 0.05$ were considered significant. All statistical analyses were carried out using the SPSS for Window XP Software Program (Version13.0).

Results and Discussion

The yield of 15.40 ± 0.05% CasG from the seed of *C. albidum* was obtained. The yield was low, which indicated the limitation of the extraction method employed, hence it would be necessary to develop a more efficient extraction method. Extraction yields from crude plant material sources do vary (high or low), this effect could be as a result of environmental conditions (soil type, climatic, plant age), gum source (seed or bark) and extraction methods/techniques.[25, 26]

The results of the physicochemical and pharmacognostic studies are presented in Table 1 and Figure 1. The CasG gum was odourless and possessed bland taste, which suggested CasG as a potential excipient for the pharmaceutical industry since it would not affect the taste and smell of the final product.

The CasG gum had fine powder particle size (110 ± 0.18 µm) and the moisture content (11.73 ± 0.11%) was within the maximum permissible British Pharmacopoeia limits.[20] The pH of 6.0 inferred its excipient usefulness to both acidic and basic active pharmaceutical ingredients.

Bulk and tapped densities, Hausner's ratio and Carr's compressibility index as well as angle of repose of a material are measures of compressibility and flow properties of powder materials employed as pharmaceutical excipients. Bulk and tapped densities of a powder give an insight into its flow properties, packaging and arrangement of particles and hence the compactability of granulation and the knowledge bulk and tapped densities as well as Hausner's ratio and Carr's compressibility index gives insight on the compressibility and flow properties of powder.[27]

The bulk and tapped density values showed there was a reduction in volume of the gum powder due to packing under applied pressure from tapping. The Hausner's ratio, Carr's index and the angle of repose values obtained showed that the gum powder had good flow and compressibility properties.[27]

Moreover, the low bulk and tapped densities of CasG would imply loose packing arrangement of its particles and this might explain its high swelling and water binding capacity. This is because water rises by capillary action through pores between particles in a powder. This wicking movement of water through pores in a gum powder activates swelling of its outer layer to form a hydrogel, hence the diffusion of the active ingredient from the formulation.[28] This suggests both binding and disintegrant potentials of CasG.

Ash values reflect the level of adulteration or handling of a biomaterial, therefore proximate analysis is a measure of the total amount of extraneous substances present within biomaterials. The insoluble matter (total ash) content of the extracted CasG was (0.5 ± 0.07%). This value fell within the stated United States Pharmacopeial (USP) permissible maximum limit of 0.5% w/w.[29] This implied its low level of contamination.

CasG has only reducing sugars and carbohydrates as its phytochemical constituent. The presence of carbohydrates and reducing sugars suggested the presence of polysaccharides, and the absence of other tested substances that CasG was not contaminated with those substances. It was also established as a gum with the positive outcome on Ruthenium test.

The moisture content of any material is an index of its water activity and is used as a measure of stability and susceptibility to microbial contamination. The British Pharmacopeia (BP) specified limit of moisture content for conventionally dried botanicals/biomaterials is 15% or less.[20] The moisture content of 11.73% for CasG was found to be within the acceptable range, this therefore implies that CasG would be less prone to microbial contamination and spoilage.

The pH of 6.0 inferred its excipient usefulness to both acidic and basic active pharmaceutical ingredients.

The swelling capacity of the gum demonstrates its hydrophilic nature and also its ability to swell into gel in aqueous media to release the embedded drug. It therefore gives an idea of the viscous nature and binding character of CasG as well as its disintegrant property. The hydration capacity, on the other hand, was suggestive of the water penetrative and retention ability of CasG. Hydration properties could also be linked to the chain length or degree of polymerization of the gum as longer molecules tend to take longer to hydrate than shorter ones. Hence, the hydration and swelling capacity values obtained for CasG suggest this polymer shorter chains or highly branched molecules and ultimately less viscous gum. CasG exhibited poor solubility in both hot and cold water (Table 1). The low solubility of CasG may be due to the presence of insoluble metallic compounds in the gum. Most salts of calcium and magnesium (Group 2 elements) are usually insoluble in water, and therefore the solubility profile exhibited by CasG may be due to these salts.

Table 1: Physiochemical and Pharmacognostic Properties of CasG Powder.

Powder Properties	Result
Organoleptic properties (Colour, Taste, Odour)	Light brown, Bland, Odourless
Particle size (µm)	110.00 ± 0.18
Moisture (%)	11.73± 0.11
pH	6.0
Swelling Index (%)	3.19 ± 0.19
Water binding Capacity	119.0 ± 0.1
Viscosity Cp	23.5 ± 0.3
Flow rate (min^{-1})	2.30 ± 0.12
Bulk Density (g/cm^3)	0.61± 0.01
Tapped Density (g/cm^3)	0.66 ± 0.11
Area of Repose (A^o)	30.0 ± 0.1
Compressibility Index	7.6
Hausner's ratio	1.08
Total ash (%)	0.5 0 ± 0.07
Phytonutrients: Reducing sugars; Carbohydrates	Positive
Phytonutrients: (Alkaloids, Flavonoids, Terpenoids, Saponins, Steroids, Anthraquinones, Cardiac Glycosides, Phenolics, Tannins, Amino acids)	Absent

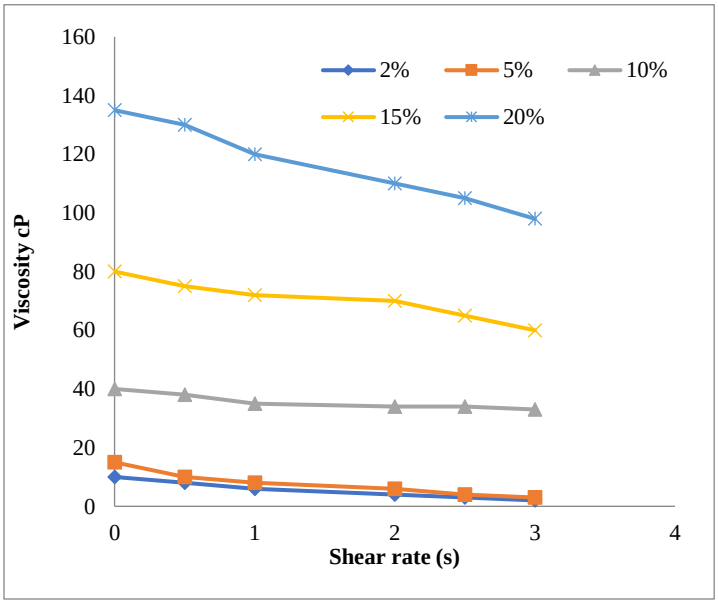


Figure 1: Flow curves of different concentrations of purified CasG at 25°C.

CasG had a low viscosity (23.2 ± 0.30 cP); the influence of concentration on the viscosity of CasG mucilage is shown in Figure 1. There was non-linear increase in viscosity of the CasG dispersion with increase in concentration at the same shear rate. For different concentrations, the viscosity of the gum dispersion decreased with an increase in shear rate, exhibiting a shear thinning behavior, typical of a pseudoplastic rheogram. At high shear rates, the decrease in viscosity could be attributed to a decrease in the number of chain entanglement[30]**.** At low concentrations (2 and 5% w/v), the curves were almost linear exhibiting Newtonian flow.

This behaviour of CasG was consistent with the behavior of most gums. The viscosities of most fluids decrease as temperature increases. This is as a result of a decrease in density due to the volume increase that accompanies temperature rise. Therefore, a decrease in viscosity of 20% w/v CasG mucilage with temperature shown in Figure 1 was consistent with the trend.

Table 2: Microbial Load of Extracted CasG Powder

Type of Microbial Group	Microbial Load (Count) of Extracted CasG	USP Values
Total Aerobic Microbial	2800	Not more than 10^5
Total combined Yeast and Mold	270	Not more than 10^3
Bile Tolerant gram – ve	1000	Not more than 10^3
Salmonella spp	Absent	Absent
Shigella spp	Absent	Absent
Echericha coli	Absent	Absent
Klebsiella spp	Absent	Absent
Psedomonas spp	Absent	Absent
Proteus spp	Absent	Absent
Staphylococcus aereus	Absent	Absent

Table 3: Haematological Parameters of mice treated with CasG dispersion (24 hours post treatment)

Haematological Parameters	CasG Dispersion Doses (mg/kg)					Control Group
	200	400	600	800	1000	
RBC	5.70 ± 0.04	5.40 ± 0.05	4.40 ± 0.38	4.40 ± 1.46	4.35 ± 0.22	5.10 ± 0.40
MCV	56.80 ± 2.05	56.30 ± 0.25	56.40 ± 0.35	56.60 ± 1.00	62.30 ± 0.30	60.10 ± 1.61
HCT	33.00 ± 1.20	32.20 ± 0.36	25.40 ± 1.11	24.50 ± 1.10	26.10 ± 0.69	29.90 ± 1.78
PLT	618.0 ± 11.0	621.0 ± 6.0	623.0 ± 13.3	630.0 ± 13.5	629.0 ± 14.0	616.0 ± 8.6
WBC	2.63 ± 0.42	2.73 ± 0.44	2.53 ± 0.45	2.60 ± 0.50	2.26 ± 0.15	2.2 ± 0.44
HGB	10.40 ± 0.10	9.50 ± 0.15	9.70 ± 0.40	9.46 ± 3.20	9.70 ± 0.17	9.83 ± 0.15
MCHC	32.20 ± 0.91	29.30 ± 0.90	32.70 ± 0.93	32.80 ± 0.84	29.60 ± 0.15	28.90 ± 0.44
LYM	84.10 ± 5.70	89.50 ± 0.46	85.20 ± 0.90	77.00 ± 9.50	78.40 ± 0.21	77.70 ± 1.10

Values are Mean ± SEM, n = 5. RBC: Red Blood Cell; MCV: Mean Corpuscular Volume; HCT: Haematocrit; PLT: Platelet; WBC: White Blood Cell; HGB: Haemoglobin; MCHC: Mean Corpuscular Haematocrit Concentration; LYM: Lymphocyte.

Table 4: Haematological Parameters of mice treated with CasG dispersion (15 days post-treatment)

Haematological Parameters	CasG Dispersion Doses (mg/kg)					Control Group
	200	400	600	800	1000	
RBC	5.60 ± 0.06	5.20 ± 0.05	3.90 ± 0.60	3.90 ± 1.70	4.20 ± 0.10	5.00 ± 0.46
MCV	56.60 ± 1.90	58.10 ± 0.10	56.50 ± 2.30	55.00 ± 3.20	61.50 ± 0.20	59.73 ± 1.69
HCT	31.4 ± 0.80	30.7 ± 0.06	26.7 ± 1.20	25.8 ± 12.01	25.4 ± 0.30	30.03 ± 1.59
PLT	619.00 ± 6.20	614.00 ± 11.00	624.00 ± 12.90	637.00 ± 20.00	640.00 ± 10.00	634.00 ± 11.80
WBC	1.80 ± 0.34	2.00 ± 0.43	2.20 ± 1.14	2.50 ± 0.50	1.90 ± 0.10	1.73 ± 0.40
HGB	9.4 ± 0.10	8.5 ± 0.40	8.1 ± 0.10	8.8 ± 3.10	8.5 ± 0.20	8.5 ± 0.42
MCHC	29.70 ± 0.40	28.50 ± 0.50	30.00 ± 0.60	30.50 ± 0.30	28.6 ± 0.15	28.4 ± 0.49
LYM	83.4 ± 4.50	86.4 ± 0.50	84.0 ± 0.60	86.4 ± 9.50	89.6 ± 0.30	81 ± 4.09

Values are Mean ± SEM, n = 5. RBC: Red Blood Cell; MCV: Mean Corpuscular Volume; HCT: Haematocrit; PLT: Platelet; WBC: White Blood Cell; HGB: Haemoglobin; MCHC: Mean Corpuscular Haematocrit Concentration; LYM: Lymphocyte.

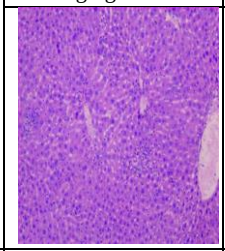
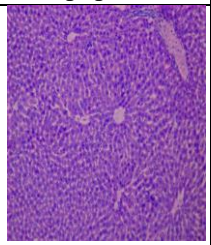
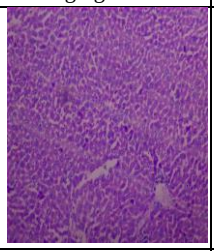
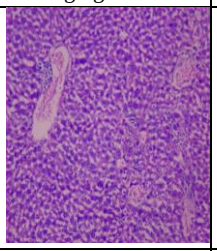
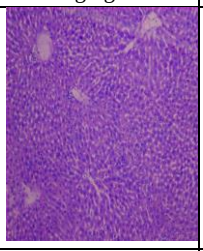
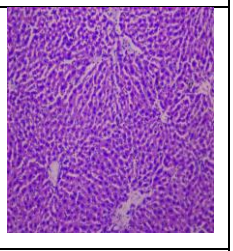
Organ Type	**Photomicrograph of mice tissue on different CasG extract concentrations**					
	200 mg/kg	400 mg/kg	600 mg/kg	800 mg/kg	1000 mg/kg	Control
Liver Tissue						
Histopathological Findings	No observed abnormalities	No observed abnormalities	No observed abnormalities	No observed abnormalities	No observed abnormalities	No observed abnormalities

Figure 2: Photomicrographs of Liver Tissue of mice treated with different concentrations of CasG Extract.

Microbial Evaluation

CasG had acceptable microbial load (Table 2) and safe toxicity profile (Table 3). The total aerobic microbial counts and total combined yeast and mold count did not exceed limits specified by the United States Pharmacopoeia.[29] Objectionable organisms such as *Salmonella spp.*, *Shigella spp.*, *Fscherichia coli*, *Klebsiella spp.*, and *Pseudomonas aeroginosa* were absent in CasG. The acceptable microbial profile obtained for CasG as a fresh extract was also observed when it was re-evaluated on this parameter after 6 and 12 months of storage. This implies stability of this biomaterial which could be due to its low and acceptable moisture content that would not encourage microbial contamination and spoilage**.**

Toxicity Evaluation

The haematopoietic system is one of the most sensitive targets of toxic compounds and is an important index of physiological and pathological status in man and animals.[31] The limit test is primarily used in situations when information indicates that the test material is likely to be non-toxic or of low toxicity.[23] This finding, therefore, suggest that the extract at the limit dose tested was essentially non-toxic. In the acute oral toxicity study undertaken, it was found that the animals were safe up to a maximum dose of 5000 mg/kg body weight as outlined by the Organization for Economic Cooperation and Development (OECD) guidelines which falls under class five values. There were no changes in normal behaviour pattern and no signs and symptoms of toxicity, morbidity and mortality were observed (Figure 2).

Furthermore, it was observed that after 15 days of post treatment, there were no treatment-related changes in haematological parameters between control and treated groups, indicating that CasG was not toxic to circulating red and white blood cells, nor interfered with their production and that of platelets and other blood parameters. Histopathological examinations revealed no histopathologic abnormalities in the tissues of the liver examined in all the groups.

Conclusion

Chrysophyllum albidum endosperm seed gum obtained by microwave-assisted extraction technique had good and desirable physicochemical, pharmacognostic as well as safe microbiological and toxicological profiles. These desirable properties suggest the good excipient potential of CasG in pharmaceutical formulations. The application of CasG as excipient in pharmaceutical dosage forms would be the subject of further study.

Conflict of interest

The authors declare no conflict of interest.

Authors' declaration

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

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