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A REVIEW ON NATURAL GUMS AND MUCILAGE USED AS SUSPENDING AGENTS IN VARIOUS SUSPENSION

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ABSTRACT

Now a days, a large number of pharmaceutical excipients are obtained from natural sources. Nature has provided us a wide variety of materials to help improve and sustain the health of all living things either directly or indirectly. Gums and mucilage are widely used natural materials for conventional and novel dosage forms. These natural materials have advantages over synthetic ones since they are chemically inert, nontoxic, less expensive, biodegradable and widely available. Gums, Mucilage and their derivatives are a group of polymers extensively used in suspension as suspending agent in various drugs. The present review provides an overview of various aspects of natural suspending agent like general extraction method, physicochemical properties and characterization of gum and mucilage.

KEYWORDS: Gum and Mucilage, Advantages and disadvantages, literature on suspending agent.

INTRODUCTION

Excipients are used as inert vehicle and diluent in formulating a dosage form but in modern pharmaceutical dosage forms they often play different multi-functional roles. Pharmaceutical aid in drug formulations help to modify the drug release, improve stability of dosage form and bioavailability of the active pharmaceutical ingredient, enhance patient acceptability and ensure ease of manufacture. To meet the needs of advanced drug delivery system continuously new improved and modified excipients are developed.[1,2] As natural materials are cost effective, nontoxic, stable, easily available with less regulatory issues, eco-friendly, capable of multiple chemical modifications, degradable and compatible due to their natural origin, so they have been gaining lot of importance in the field of drug delivery.[3] The synthetic excipients are continuously being replaced with natural ones as recent trend toward the use of the vegetable and nontoxic products has increased. Today, a large number of naturally obtained pharmaceutical excipients are available. Like other natural products application of mucilage is increasing in industry so it has become necessary to explore the newer source of plant mucilage for industrial demand.

Some pharmaceutical active ingredients, pharmaceutical liquid dosage such as suspension and other disperse system thermodynamically not stable, thus it required for making in the dosage form. The suspending agent which reduces the rate of sedimentation and it not difficult to re dispersion of sediment particulate matter both by protective colloidal action. It improving the viscosity of the suspending medium. Gums and mucilage are also used as suspending agent and help to suspend insoluble solid substances in liquid formulations. They prevent immediate sedimentation and caking due to their colloidal character and high viscosity. Their high viscous nature makes gum and mucilage as a stabilizer of choice in suspension. The suspending property of mucilage and gums, which have already used in formulating pharmaceutical suspension.

This review gives idea of gum and mucilage have more powerful excipients to be used in different kind of suspension containing active ingredients for its stability. It comments on the gum and mucilage obtained from various plant sources in different concentration and used as suspending agent.

SUSPENDING AGENTS

Suspending agent also known as thickening agents. They are stabilize suspensions. Gum and mucilage are the substances which immediately form colloidal dispersion with water because of its affinity with the dispersion medium and dispersed particles. They are used for decreasing the sedimentation rate of solute in suspension. The sedimentation rate is decrease by increasing the viscosity of liquid vehicle and decreases sedimentation

according to strokes law. They commonly prevent particles settling at the base of a suspension. It could be dispersed by agitation. It is majorly used as thickening agent to help active pharmaceutical ingredients suspended in formulation.

CLASSIFICATION OF SUSPENDING AGENTS

Suspending agents are classified into three types
(i) Inorganic salts, (ii) Synthetic compounds, (iii) Polysaccharides.

1. **Inorganic compounds**
2. **Synthetic compounds**
3. **Polysaccharides:** The official suspending agents were natural polysaccharides but now a days semisynthetic compounds are increasingly used.

Gums and mucilage plants form colloid when combine with water. They includes lipophobic molecules, which can combine with water to form thick gels or solution. Gums and mucilage are noncrystalline substances, transperent, clear and polymers of a monosaccharide or mixed polymers of monosaccharides numerous of them are combined with uronic acids. Gums and mucilage are on hydrolysis yield a mixture of uronic acids and sugar. The nature of the compounds involved the properties of different gums. Highly branched compounds are less viscous and occupy small space than linear polysaccharides of the same molecular weight. The branched monosaccharide components forms gel very easily and more stable because widespread interface along with chains is not possible.[4]

Gum: Gums are considered to be pathological products form any harm to the plant due to not favourable conditions such as lacks, by interruption of cell walls. Gums quikly dissolve in water and mucilage form viscous solution. The gum derived from different parts of plants tragacanth, guar gum and acacia are examples of gums.[5] The gum derived from different parts of plants tragacanth, guar gum and acacia are examples of gums. For example, in seed coats (linseed, psyllium), barks (slippery elm), roots (marshmallow), in the epidermal cells of leaves (Senna) and middle lamella (aloe).[6]

Mucilage: Mucilage are obtained without to the plant. Mucilage are usually normal products of metabolism, formed within the cell (intracellular formation). They are generally standard products of metabolism, polysaccharide hydrocolloids with uronic acids connected with sugar particles. Mucilage is polymers of a monosaccharide or mixed monosaccharides combined with uronic acids. Mucilage consist of arabinose, galactose, rhamnose and galacturonic acid, it is complex polysaccharides. It forms large molecular aggregates in solution. Mucilage existing in plants help for to accumulate water and food as source of energy. It also play a character in seed propagation and stiffening membranes. The term mucilage are those substances which are soluble in water and swell very least in water and they are precipitated which upon addition of alcohol are more or less amorphous or rough mass.[4]

Advantages of gum and mucilage used as suspending agent

1. The gum and mucilage are biodegradable because they are available in the form polymers obtained from living organisms such as plants, animals, microorganisms etc. They are truly renewable source and they have no bad impact on humans or environmental health.
2. They are biocompatible and non-toxic.
3. They are available in low cost because production cost is lower compared with that for synthetic material.
4. The gum and mucilage from different sources are easily collected in different seasons in large quantities due to the simple production processes involved.
5. Local availability (especially in developing countries)- In developing countries, governments promote the production of plant like guar gum and tragacanth because of the wide applications in a variety of industries.
6. Better patient tolerance as well as public acceptance- There is less chance of side and adverse effects with natural materials compared with synthetic one.
7. Edible sources- Most gum and mucilage are obtained from edible sources.

Disadvantages of Gum and Mucilage

1. Microbial contamination- The equilibrium moisture content present in the gums and mucilage is normally 10% or more and, structurally, they are carbohydrates and, during production, they are exposed to the external environment and, so there is a chance of microbial contamination. However, this can be prevented by proper handling and the use of preservatives.
2. Batch to batch variation- Synthetic manufacturing is a controlled procedure with fixed quantities of ingredients, while the production of gums and mucilage is dependent on environmental and seasonal factors.
3. Uncontrolled rate of hydration- Due to differences in the collection of natural materials at different times, as well as differences in region, species, and climate conditions the percentage of chemical constituents present in a given material may vary. There is a need to develop suitable monographs on available gums and mucilage.
4. Reduced viscosity on storage- Normally, when gums and mucilage come into contact with water there is an increase in the viscosity of the formulations. Due to the complex nature of gums and mucilage (monosaccharides to polysaccharides and their derivatives), it has been found that after storage there is reduced in viscosity.[4,7]

CLASSIFICATION OF GUMS AND MUCILAGE

The large quantities of gums and mucilage are present in plants, animals, seaweeds, fungi and other microbial sources. They perform a number of structural and metabolic function. Several classification systems existing for gums and mucilage are as follows: (Table 1)[4, 8 & 9]

Table 1: Classification of gums and mucilage.

Sr. No	Classification	Categories	Example
1	According to the source	Marine Plant Animal Microbial	Agar, carrageenans, alginic acid, laminarin. Gum arabica, gum ghatti, gum karaya, gum tragacanth, khaya and albizia gums; Chitin and chitosan, chondroitin sulfate, hyaluronic acid. Xanthan, dextran, curdian, pullulan, zanflo, emulsan, Baker's yeast glycan, schizophyllan, lentinan, krestin, scleroglucan.
2	Based on Semi-synthetic	Starch derivatives Cellulose derivatives	Hetastarch, starch acetate, starch phosphates Carboxy methyl cellulose (CMC), Hydroxypropyl methylcellulose (HPMC), Methylcellulose (MC), Microcrystalline cellulose (MCC)
3	According to the charge	Non-ionic Anionic Cation	Guar, locust bean, tamarind Arabic, karaya, tragacanth Chitosan
4	According to shape	Linear Branched	Algins, amylose, cellulose Short branches- Xanthan, xylan, amylopectin Branch-on-branch- Amylopectin, gum arabic, tragacanth.
5	Based on monomeric units	Homoglycans Di-heteroglycans Tri-heteroglycans Tetra-heteroglycans Penta-heteroglycans	Amylose, arabinanas, cellulose Algins, carragennans, galactomannans Arabinoxylans, gellan, xanthan Gum arabic, psyllium seed gum Ghatti gum, tragacanth

GENERAL EXTRACTION METHODS OF GUM AND MUCILAGE

The number of method used for isolation of gum and mucilage. Before going extraction the gum/mucilage containing plant part can be collect and authenticate. Then followed by dried in sun or oven at 105^0C, the material can be grind and sieve. The gum/mucilage can be extracted from plant parts by various methods like heating, solvent precipitation, and microwave assisted extraction. The following methods can be used for isolation of gum/ mucilage:

1. Heating method:
2. Solvent precipitation:

A. Precipitation of mucilage in alcohol
B. Precipitation of mucilage in acetone

3. Microwave oven extraction:
4. Extraction by deflating with petroleum ether

A. Deflating by 12 hrs. Shaking with petroleum Ether
B. Deflating by Soxhlet apparatus with petroleum Ether

1. Heating method[10]

Fig. 1: Heating Method for extraction of gum and Mucilage.

2. Solvent precipitation: The solvent precipitation method can be used for precipitation of gum/mucilage. The Alcohol and Acetone use for precipitation. This is the simple, most common and easy method. This method can be used most commonly.[11-13,15]

A. Precipitation of mucilage in alcohol

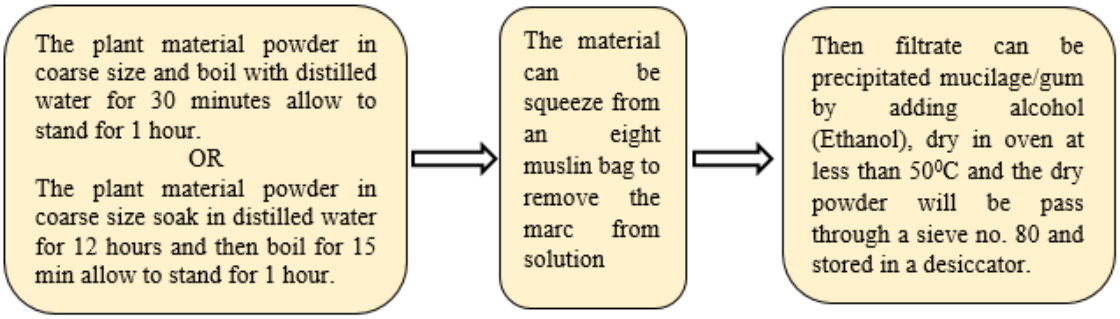

Fig. 2: Extraction of mucilage by alcohol precipitation method.

B. Precipitation of mucilage in acetone

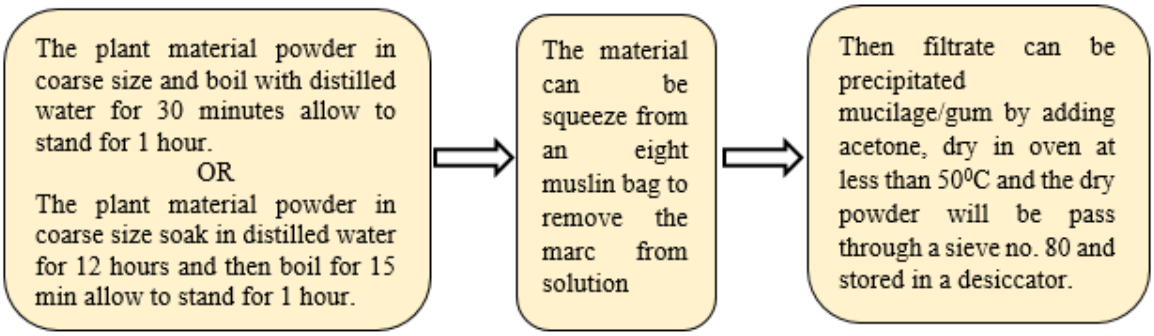

Fig. 3: Extraction of mucilage by acetone precipitation method.

3. Microwave oven extraction

The phytoconstistuents extracted fro plant the microwave energy can be used. It is a simple, fast, clean, eco-friendly and efficient method. It saves energy, fuel and electricity. Microwave extraction based on the principle as maceration or percolation, but the speed of breaking up of the plant cells and tissues is much greater. Microwave assisted extraction methods require a shorter time and less solvent, and provide a higher extraction rate and better products at a lower cost.[14]

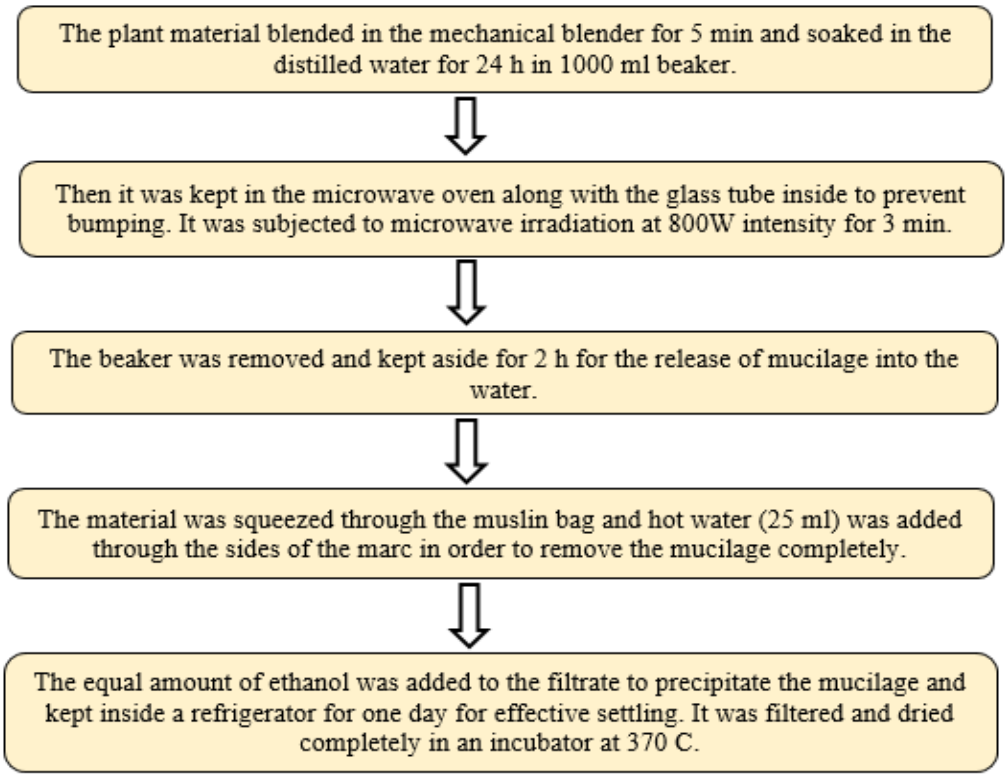

Fig. 4 Gum/mucilage extracted by Microwave oven extraction.

List of gum containing natural plants: The gums present in high quantities in a varieties of plants which are listed below.

Synonym	Biological source	Chemical constituents	Percentage gum W/V	Suspending agent use in various drugs	References
Agar,	Agar is the dried gelatinous substance obtained from *Gelidium amansii* Family- Gelidanceae.	It consists of two polysaccharides as agarose and agaropectin. Agarose is used for gel strength and Agaropectin for the viscosity of agar solutions.	0.5-1%	Paracetamol	[20]
Cashew gum,	It is gummy exudates derived from cashew *Anacardium occidentale L*. belonging to Family	Cashew gum is chemically composed of 61 % galactose, 4 % arabinose, 7 % rhamnose, 8 % glucose, 5 % glucuronic acid and < 2 % other sugar residues 3, 4 while hydrolysis of the gum yields L-arabinose, L-rhamnose, D-galactose and glucuronic acid. The gum has a highly branched galactan framework comprising of chains of (1→3)-linked β-D galactopyranosyl units interspersed with β-(1→ 6) linkages.	10%	Sulphamethoxazole	[21]
Citrullus lanatus	The biological source of watermelon is *Citrullus lanatus* belonging to family Cucrbitaceae.	It mainly contains proteins, vitamin-B, vitamin-C, minerals, fats, amino acid citrulline and beta carotene.	0.5-2%	Paracetamol	[22]
Cola acuminata gum	Cola acuminata gum (CAG) extracted from *Cola acuminata* pods belonging to family	Cola acuminata seeds contain xanthine derivatives such as caffeine, theophylline and theobromine. The pharmacological effects of cola nut seeds include stimulation of central nervous system and gastric acid secretion.	1-3%	Calamine suspension	[23]
Cordia gheraf Gum	fresh immature fruit of *Cordia gheraf*	Suspending agent concentration D-fructose, D-xylose, L-rhamnose and D-galactouronic acid (from fruit mucilage), hydrocarbon and n-hexacosanol (from leaf) have been reported from the plant bark of Cordia gharaf [6] contains alkaloids, glycoalkaloids, coumarins and salts of potassium chloride.	2.5%	Paracetamol suspension	[24]
Grevia gum	Grewia polysaccharide gum is obtained by extraction from the inner stem bark of the edible plant *Grewia mollis, Juss*, (Fam. Tiliaceae).	The polysaccharide gum consists of glucose and rhamnose as the main monosaccharide components and galacturonic acid as the main sugar acid	0.5%	Ibuprofen	[25]
Gum acacia,	Gum Acacia, which is obtained from acacia plant which belongs to the Fabaceae family (subfamily Mimosoidae).	Chemically, the natural gums are acidic complex polysaccharides composed of salts of sugars other than glucose: L-arabinose, Dgalactose, L-rhamnose and D-glucuronic acid combined with certain metallic cations such as	1-4%	metronidazole benzoate	[26]

		sodium, potassium, calcium and magnesium.			
Gum ghatti, Indian gum, Gum arabic	It is the gummy exudates obtained from the tree bark of *Anogessius latifolia Wallich*, belonging to Family Combretaceae.	Ghatti gum consists of calcium salt of a complex high molecular weight polysaccharide made up of sugars and uronic acid units. One of the polysaccharide acid, ghattic acid contains mainly arabinose, galactose, mannose, xylose and galacturonic acid. On hydrolysis of ghatti gum, it also affords aldobiouronic acid 6-0-β-Dglucopyranosyl uronic acid and D- galactose which is also found in gum acacia.	5-8%	Phenytoin	[27]
Gum Tragacanth,	It is the air dried gummy exudates, flowing naturally or obtained by incision, from the stems and branches of *Astra-galus gummifer* Labill and certain other species of *Astragalus*, belonging to Family Leguminosae.	Tragacanth consists of a water-soluble fraction known as tragacanthin (8-10%) and a water swellable fraction known as bassorin (60-70%). It contains about 15% of methoxy group which swell in water; this constituent of gum is responsible for its high viscosity.	2-5%	Zinc Oxide	[28]
Albizia gum	The gum obtained from legumes of *Albizia zygia* belonging to Family Leguminosae.	It consists of ß -1– 3 linked D-galactose units with some ß-1-6-linked D galactose units.	1-3%	Indomethacin and Paracetamol	[29]
Karaya gum,	Gum karaya is a dried, gummy exudates obtained from the tree *Sterculia urens* (Roxburgh); *Sterculia tragacantha* (Lindley) or other species of Sterculia, belonging to Family Sterculiaceae.	It consists of heteropolysacchrides of sugars and uronic acid. It doesnot contained methoxyl groups.	5-7%	paracetamol	[30]
Leukanea seed gum,	Leucaena gum obtained from leaves and seeds *Leucaena leucocephata* belonging to Family Fabaceae.	Leucaena leucocephala leaves and seeds contain lipids, crude protein and carbohydrates. The seeds contain tannin and oxalic acid. The leaves and seeds also contain a toxic and non-protein substance known as mimosine. A seed contains 25 percent gum and are highly viscous solutions at low solute concentrations.	0.5-2%	zinc oxide	[31]
Mucuna gum	Mucuna gum obtained from seed endosperm of *Mucuna flagillepes* belonging to Family Papillionaceae.	Mucuna composed of mainly D-galactose along with D-mannose and D-glucose.	0.5%	glibenclamide	[32]
Sodium alginate	Sodium alginates is an acidic linear polysaccharide found in certain species of brown algae such as *Macrocytis pyrifera* belonging to Family Lessoniaceae	Alginate consists of α-l-guluronate (G) and β-d-mannuronate (M), and the residues are arranged in a block structure of a homopolymer (polyguluronate or polymannuronate) or a heteropolymer (a mixed sequence of these residues)	1-5%	Lamotrigine, Rofecoxib, Oxcarbazepine	[33]

Locust bean gum Carob bean gum.	Locust bean gum is extracted from the endosperm of the seeds of the carob tree *Ceretonia silique* belong to family	Carbohydrates (40–60%), polyphenoliccompounds, especiallytannins (18–20%), dietary fibers (27–50%), minerals and low amounts of protein (3-4%) and lipids (0.4–0.8%).	3-5%	Lamotrigine	[34]
Tamarind seed polysaccaride,	Tamarind seed polysaccharide which is obtained from the seed kernel of *Tamarindus indica* belonging to Family Leguminosae	Tamarind seed polysaccaride contain glucose, galactose and xylose	5-8%	Nimesulide	[35]
Xanthan gum,	Xanthan is a microbial polysaccharide produced from *Xanthomonas compestris*	The primary structure of xanthan consists of repeating pentasaccharide units consisting of two D-glucopyranosyl units, two D-mannopyranosyl units and one D-glucopyranosyluronic acid.	0.05-0.5%	Ibuprofen	[36]

List of mucilage containing natural plants: The mucilage present in high quantities in a varieties of plants which are listed below.

Synonym	**Biological source**	**Chemical constituents**	**Percentage mucilage W/V**	**Suspending agent use in various drugs**	**References**
Asario mucilage, Chandrasura	The mucilage obtained from seeds *Lepidum sativum* belonging to Family Cruciferae.	Protein, fat, dietary fibre (DF), and potassium respectively. Glutamic acid, leucine, methionine.	12%	Suspending agent in paracetamol suspension.	[37]
Abelmoschus esculentus (okara gum)	The mucilage obtained from *Abelmoschus esculentus* belonging to family Malvaceae	It is a polysaccharide consisting of D-galactose, L-rhamnose and L-galacturonic acid with some fractions of glucose, mannose, arabinose and xylose.	4%	Abelmoschus esculentus mucilage as a suspending agent in paracetamol suspension.	[38]
Cassia tora mucilage, Foetid cassia	The mucilage derived from the seeds of *Cassia tora*, belongs to Caesalpiniaceae	It contain antroquinone, β- sitosterol, Chrysophanol, physcion, rubrofusarin, and emodin.	2.5%	Sulphadimidine	[39]
Cissus rubiginosa	The mucilage obtained from fruits of *Cissus rubiginosa* is a tropical plant belonging to the family Vitaceae.	Flavanoids, sterols, triterpanoids, stilbenes, iridoids and 3, 3, 4, 4’ tetra hydroxybiphenyl.	0.5%	paracetamol oral suspension	[40]
Hibiscus mucilage	It is leaves of *Hibiscus rosasinensis Linn*. Which are belonging to the family Malvaceae.	It contain undecanoic acid, tridecanoic acid, tricosanoic acid, tricosan-1-ol, triacontan-1-ol, tartaric acid, stearic acid, palmitic acid, octanoic acid.	8.3%	Paracetamol	[41]
Fenugreek seeds	The mucilage obtained from seeds of *Trigonella foenum graceum* belong to Family Leguminosae	Steroidal sapogenin, diosgenin, Alkaloids such as trigocoumarin, nicotinic acid, trimethyl coumarin and trigonelline.	1%	Acetaminophen suspension	[42]
Isapgol mucilage, Spogel seeds	It consists of dried seeds of *Plantago ovata Forsk* belonging to Family	Chemically, it contains pentosan and aldobionic acid, Rhamnose, arabinose and galactouronic acids are hydrolyzed	2%	paracetamol	[43,44]

	Plantaginaceae.	products of mucilage. Fixed oils and proteinsare also present in the drug.			
Ocimum seed mucilage	Mucilage obtained from seeds of *Ocimum basilicum L.* belonging to Family Lamiaceae	Mucilage contains xylose, arabinose, rhamnose, and galacturonic acids.	1%	Paracetamol	[45]
Banana peel	The mucilage obtained from banana peels of *Musa paradisiaca* belong to Family Musaceae	Presence of alkaloids, carbohydrate, glycosides, tannins, proteins and amino acids. Bananas are an excellent source of potassium vitamin A, B6, C, and D.	2-4%	Paracetamol	[46]
Chlorophytum borvilianum	The mucilage obtained from tubers of *Chlorophytum borivilianum* belong to Family liliaceae	Saponin glycosides and alkaloids. Tubers also contain carbohydrates, proteins and abundant amount of mucilage. Recently one fructo-oligopolysaccharide has been isolated and evaluated.	1-3%	Zinc oxide suspension	[47]
Dika nut mucilage	Dika nut mucilage obtained from *Irvingia gabonensis* and *Irvingia excelsa* belonging to Family Irvingiaceae	The seed of the plant contains lipids and polymeric constituents. Its products are of varied pharmaceutical uses and include Dika wax and Dika fat.	2 %	magnesium trisilicate suspension	[48]
Cissus rufescence	The gum derived from the stem of *Cissus rufescence* Family Amphelidaceae	It contain steroids, Iridoids, flavonoids, stilbenes and triterpenes.	0.6 - 1.0%	zinc oxide suspension	[49]
Spinach	The mucilage obtained from leaves of *Spinacia oleracea L.* belong to Family Amaranthaceae.	Raw spinach is 91% water, 4% carbohydrates, 3% protein, and contains negligible fat. It is a rich source (20% or more of the Daily Value, DV) of vitamin A, vitamin C, vitamin K, magnesium, manganese, iron andfol ate.	20%	Zinc oxide suspensions	[50]

PHYSICOCHEMICAL CHARACTERIZATION OF THE MUCILAGE

Preliminary confirmatory tests for dried gums and mucilage: The gum/mucilage confirm by the preliminary test such as molisch's, ruthenium red, iodine and enzyme tests are as follows: (Table 2)[16]

Table 2: Preliminary confirmatory tests for dried gums and mucilage.

Sr.no:	Test	Observation	Inference
1	**Molisch's test:** 100 mg dried mucilage powder + Molisch's reagent + Conc. H_2SO_4 on the side of a test tube	Violet green color observed at the junction of the two layers	Carbohydrate present
2	**Ruthenium test:** Take a small quantity of dried mucilage powder, mount it on a slide with ruthenium red solution, and observe under microscope.	Pink color develops	Mucilage present
3	**Iodine test:** 100mg dried mucilage powder + 1 ml 0.2 N iodine solution.	No color observed in solution	Polysaccharides present (starch absent)
4	**Enzyme test:** Dissolve 100 mg dried mucilage powder in 20 ml-distilled water; add 0.5 ml of benzidine in alcohol (90%). Shake and allow to stand for few minutes	No blue color produced	Enzyme absent (distinction between dried mucilage and acacia)

Physical characterization

The purified mucilage can be evaluated for physical characteristics viz., appearance, odour, taste, percentage yield, loss on drying, moisture content, total ash, acid insoluble ash, melting point and charring temperature according to the procedures as described in Indian pharmacopoeia. All these values were tested in triplicate.[17,18]

Loss on drying and moisture content

Weigh accurate quantity of the gum/mucilage under examination. Place in a tarred dish, evaporate initially at as low a temperature latter to at 105°C and dry to constant weight. Owing to the hygroscopic nature of certain residues, it may be necessary to use dishes provided with well-fitting covers and to cool in a desiccator.

Loss on drying and moisture content were calculated by the following formulae:

$$\%\ \text{Loss on drying} = \frac{weight\ loss\ after\ drying}{total\ weight\ brfore\ drying}\ x\ 100 \ldots\ldots\ldots (1)$$

$$\%\ Moisture\ content = \frac{weight\ loss}{dry\ weight}\ x\ 100 \ldots\ldots\ldots (2)$$

Ash value determination

Total ash content: 1 g of gum/mucilage was accurately weigh and evenly distributed in the crucible, dried at 150 °C for 1 h and then ignited at 450 °C for 15 min in an incinerator. Total ash was calculated by the following formula:

$$Total\ ash = \frac{W_1 - W_2}{W_3} x\ 100 \ldots\ldots\ldots (3)$$

Where, W_1 = Weight of crucible after ignition,
W_2= Blank weight of crucible,
W_3= Weight of mucilage

Acid insoluble ash: The ash obtained above was boiled in 25 ml of 2M HCl for 5 min. The insoluble ash was collected on ashless filter paper and washed with hot water. The insoluble ash was transferred into a silica crucible, ignited and weighed. The procedure was repeated to get a constant weight. The percentage acid insoluble ash calculated by using above formula.

pH value determination: The pH of 1% w/v solution of gum/mucilage in distilled water was determined using digital pH meter.

Chemical characterization of gum/mucilage: The extracted gum/mucilage can be subjected for various identification tests for the presence of carbohydrate, tannins, alkaloids, amino acids, glycosides, etc.[17,18]

Solubility study of gum and mucilage: The gum/mucilage solubility study can be check in different solvents in accordance with the specifications of Indian Pharmacopoeia.

Flow properties of gum/mucilage: The dried mucilage was tested for the flow properties viz., angle of repose, bulk density, tapped density, compressibility index and Hausner's ratio.[19]

Angle of repose of gum/mucilage: Weigh accuratly 10 g of dried gum/mucilage poured into an open-ended glass cylinder with its bottom resting on a horizontal surface at it's base. On raising the cylinder vertically, the powder flowed out and formed a conical heap as a result of gravitational force balancing the inter-particulate forces. The side of the heap formed an angle with the horizontal base known as the angle of repose. The height of the cone measure with the aid of a pair of dividers and a ruler.

The angle of repose (θ) was calculated using the equation:

$$\theta = tan^{-1}\frac{h}{r} \ldots\ldots\ldots (4)$$

Where, h=height of conical powder heap, r=radius of the circular base.

Bulk density: The bulk density of the powder bed is simply the weight of the powder divided by the whole volume of the bed. The mucilage powder, 25 gm of gum/mucilage poured inside a measuring cylinder through a funnel at atmospheric pressure. The bulk volume (V1) was recorded and the density determined in triplicate.

The bulk density (BD) was determined using the following equation:

$$Bulk\ density = \pi r^2 h \frac{mass\ of\ powder}{bulk\ volume\ of\ powder} \ldots\ldots\ldots (5)$$

Where, r = radius of the cylinder (cm), h = height of the powder column in the cylinder.

Tapped density: Accurately weigh 25 g of gum/mucilage powder sample was transper into a 100 ml graduated cylinder. Tapped the cylinder containing the powder by raising the cylinder and allow it to drop under its own weight using mechanically tapped density tester that provides a fixed drop of (14±2) mm at a nominal rate of 300 drops per min. The cylinder was tapped for 500 times initially and measured the tapped volume (V1) to the nearest graduated units. Repeated the tapping for additional 250 times and measured the tapped volume (V2) to the nearest graduated units. Ratios between the two volumes were calculated in g/ml by the following formula:

$$Tapped\ density = \frac{mass\ of\ powder}{Tapped\ volume\ (V_2)} \ldots\ldots\ldots (6)$$

Hausner's ratio: Hausner's ratio is a number that is correlated to the flowability of a powder and calculated as:

$$Hausner's\ ratio = \frac{Tapped\ density}{Bulk\ density} \dots\dots\dots (7)$$

Carr's index: Compressibility of the powder was determined by Carr's Compressibility index. It is a simple test to evaluate the bulk density and tapped density of a powder and the rate at which it packed down. The formula for Car's index is as follows:

$$carr's\ index\ (\%) = \frac{Tapped\ density - Bulk\ density}{Tapped\ density} X100 \dots\dots\dots (8)$$

Swelling index and swelling capacity gum/mucilage: Accurately weighed 1 g of the purified mucilage transfer into a 50 ml stoppered measuring cylinder. The initial volume of the powder in the measuring cylinder was noted. The volume made up to 50 ml mark with distilled water. The cylinder was stoppered, shaken gently and set aside for 24 h. The volume occupied by the mucilage was noted after 24 h (V2). The ratio of the difference of the initial and final volume (V2−V1) to the initial volume (V1) is the swelling capacity.

$$Swelling\ cpacity = \frac{V_2 - V_1}{V_1} \dots\dots\dots (9)$$

Swelling index (SI) is expressed as a percentage and calculated according to the following equation:

$$Swelling\ cpacity = \frac{V_2 - V_1}{V_1} X\ 100 \dots\dots\dots (10)$$

Apparent viscosity of gum/mucilage: The a pparent viscosity of 1%, 2%, 5% and 10% w/v solution of the mucilage powder in water was determined using a Brookfield viscometer; spindle-64 at 50 rpm.

Spectral Study of gum/mucilage by FTIR: The Fourier transform infra-red analysis was conducted for the structure characterization. FTIR spectra of the gum/mucilage. Air dried powder were taken in a KBr pellet press under mechanical pressure. Approximately 5mg of samples were mixed with 50mg of spectroscopic grade KBr, samples were scanned in the IR range from 500 to 4000 cm^{-1} and analyzed for the presence of different functional groups.

Thermal Studies by DSC: DSC will show the occurrence of exothermal and endothermal changes in the gum/mucilage sample with an increase in temperature. DSC measures the heat loss or gain, resulting from physical or chemical changes within a sample as a function of temperature. It is extensively use to study phase transition of polymers because of its sensitivity and accuracy. Weighed amount of sample were placed in hermitically sealed aluminium pans and were heated at a speed of 20°C/min over a temperature range of 50°C to 450°C in a differential scanning calorimetry (Perkinelmer DSC-7) Nitrogen gas purging was maintained at 20 ml/min.

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