

Basil seed mucilage: History, Extraction, Characterization, Pharmaceutical and other Applications

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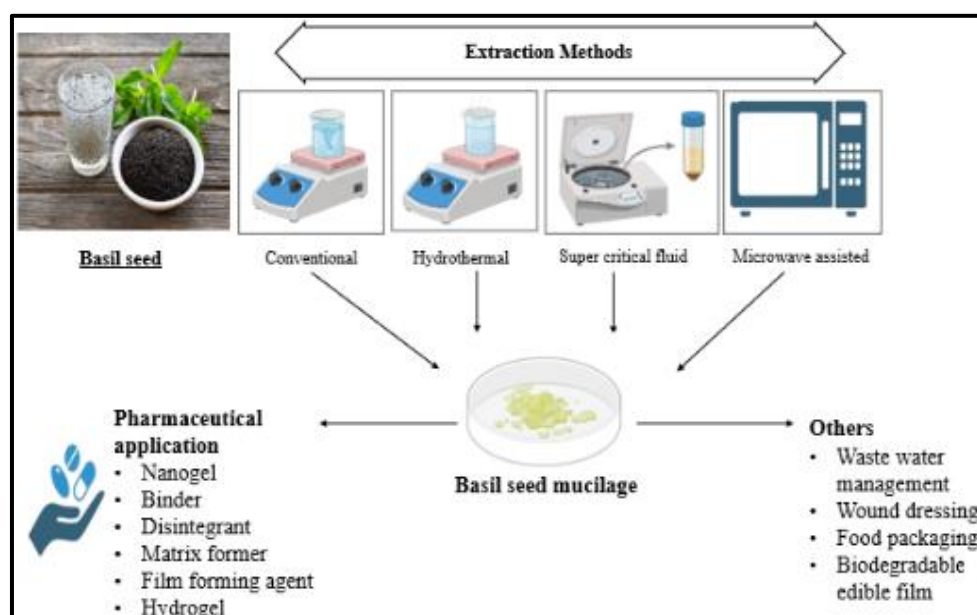
Date of Submission: 10-05-2026

Date of Acceptance: 20-05-2026

Abstract

Basil seed mucilage (BSM), obtained from *Ocimum basilicum*, is a natural, biodegradable, and multifunctional polymer in recent years. Historically used for its traditional medicinal and dietary purposes, BSM has evolved into a viable biomaterial due to its unique physicochemical and functional features. This review contains an extraction of basil seed mucilage by using several methods, such as conventional, hydrothermal, supercritical fluid, and microwave-assisted approaches; these methods have a major impact on yield and quality. Due to the nutritional composition and structural properties of BSM, they contribute to

its superior swelling, gelling, and film-forming abilities. However, its physical features and characterization approaches are able to understand its behavior in different formulations. The crosslinking improves the mechanical strength and stability of the polymer. Due to these qualities, BSM finds out wide application in pharmaceutical industries such as drug delivery systems, binders, and hydrogels, as well as in non-pharmaceutical such as food, cosmetics, wastewater management, and biodegradable materials. Finally, basil seed mucilage provides a diverse and sustainable excipient with substantial potential for future research and industrial applications.



Keyword: Basil seed mucilage (BSM), Extraction, Characterization, Application.

I. Introduction

Ocimum basilicum L., a member of the Lamiaceae family, is widely grown in Jammu and Kashmir, India's Himalayan region. Often referred to as sweet basil, garden basil, or simply basil, this edible herb is popular because of its distinct flavor and scent. They can be used in traditional beverages like falooda and sherbets because of this characteristic. Most often referred to as a sabza seed in India (Nazir and Wani, 2021).

Plant-based mucilage is one of the most common polysaccharides used in many food industries because it can be used in many different ways. Nowadays, people are heavily invested in plant-based biopolymers due to synthetic polymers are now bad for their well-being. Synthetic polymers are very stable in terms of their physical, chemical, and mechanical properties, however that they can be harmful to cells and are not compatible with living things. Among synthetic polymers are: not fitting well with the patient's body, being expensive, and causing both short-term and long-term side effects (Amiri et al., 2021). BSM are the most promising compared to synthetic mucilage, which are found in several parts of the plant. Mucilage is a thick, sticky material produced by practically all plants and some bacteria. Advantages of Basil seed mucilage in the pharmaceutical industry include: They are biodegradable, biocompatible, non-toxic, Provide better tolerance to the patient and have fewer side effects, do not cause allergies in humans, do not irritate the skin or eyes, and have low production costs.

Mucilage can form immediately as a jelly-like structure in the vegetative portions of plants (fruit, leaf, seed, Flower, or stem) as well as in seeds after treatment with water (Dybka-Stepień et al., 2021).

Ocimum seeds are hydrophilic because they contain a fair mix of cellulose and hemicellulose. They can be regarded as a novel, uncommon source of fiber because of their high fiber content and related nutritional properties (Mathews et al., 1993). *Ocimum basilicum* seeds have a swelling index of 34–35. When basil seeds are soaked in water, they become gelatinous. Basil seeds are a special source of natural hydrocolloid with valuable functional properties because they have a high mucilage content. Because of its unusual properties and ease of extraction, some

researchers have recently shown interest in using basil seed gum (BSG) as thickening and gelling agents in the food sector. (Naji-Tabasi & Razavi, 2017).

The seed coat or pericarp of these plants develops a layer of mucilage through the myxodiaspory phenomenon whenever the seeds are moistened. High water absorption capacity, high viscosity, shear thinning behavior, heat resistance, non-Newtonian pseudoplastic behavior, adsorption, emulsifying, and stabilizing capabilities are only a few of its remarkable physical and chemical properties.

1. History and background

Basil seeds are used extensively; they demonstrate a potential advantage. It was noted that pre-1000 seeds used in Ayurveda and Unani medicine were utilized for digestion. Further, in 1971, Iranian scientists first isolated BSM, and they found out the property and tested it as a food emulsifier (Nazir et al., 2017). In the structural study of the xyloglucan backbone, uronic acid was found in 1985. Basil seeds are water-loving and swell up a lot when they touch water. A mucous, meaning gel-like, layer is created surrounding the seed, and they measure water uptake by swelling characteristics. Further 2008 FDA GRAS Status: "Safe to Eat" (Tripathi et al., 2024a). In 2009, mucilage was used as a tablet binder and polymer; pharmaceutical studies looked into this (Bhosale et al., 2009). Mucilage is extracted from a basil seed by a different approach, such as a conventional or hydrothermal one, but it produces a yield much less. A further 2017 RSM method was applied; it gives a yield up to 10-13. Basil seed is a natural polysaccharide mainly containing glucomannan and glucuronic acid that contains an abundance of hydroxyl and carboxyl groups. These functional groups are able to interact with a multivalent cation such as Ca^{2+} , Al^{3+} , or Fe^{3+} . This ionic crosslinking is widely used, and it ultimately improves mechanical strength and drug release behavior. So, a recent report in 2020-23 stated that ionic crosslinking improves mechanical strength, gel strength, and swelling behavior (Rohini et al., 2020). Ionic crosslinking is an effective way to change basil seed mucilage. Recent 2024 basil seed mucilage is utilized in advanced formulations such as a bio adhesive suppository and nanoparticle.

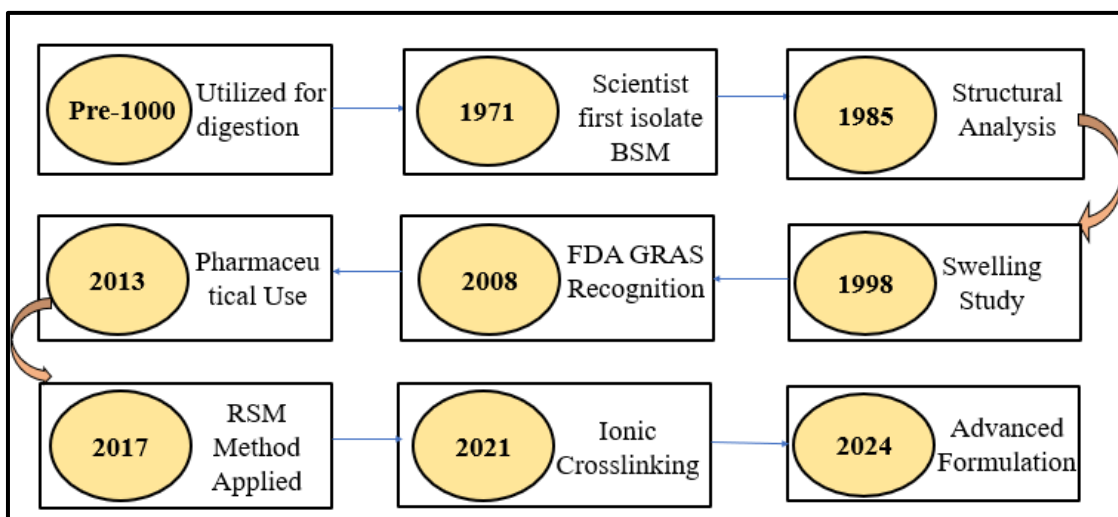


Figure 1- Historical evolution of basil seed mucilage technology in pharmaceutical industries

The USDA (Mathews et al.) outlines the botanical classification of basil. (1993). Basil seeds are derived from *Ocimum basilicum*, a member of the Lamiaceae family. These seeds are black, ovoid to elliptical, and feature a smooth, glossy surface. Immersion in water triggers rapid expansion and the formation of a transparent gelatinous coating, resulting from the mucilage found on their outer surface. Dried basil seed mucilage presents as a

white or off-white powder. *Ocimum basilicum* is taxonomically categorized within Kingdom Plantae, Sub-kingdom Tracheobionta, Super division Spermatophyta, Division Magnoliophyta, Class Magnoliopsida, Sub-class Asteridae, Order Lamiales, Family Lamiaceae, Genus *Ocimum* L., and Species *basilicum*, bearing the binomial name *Ocimum basilicum*.

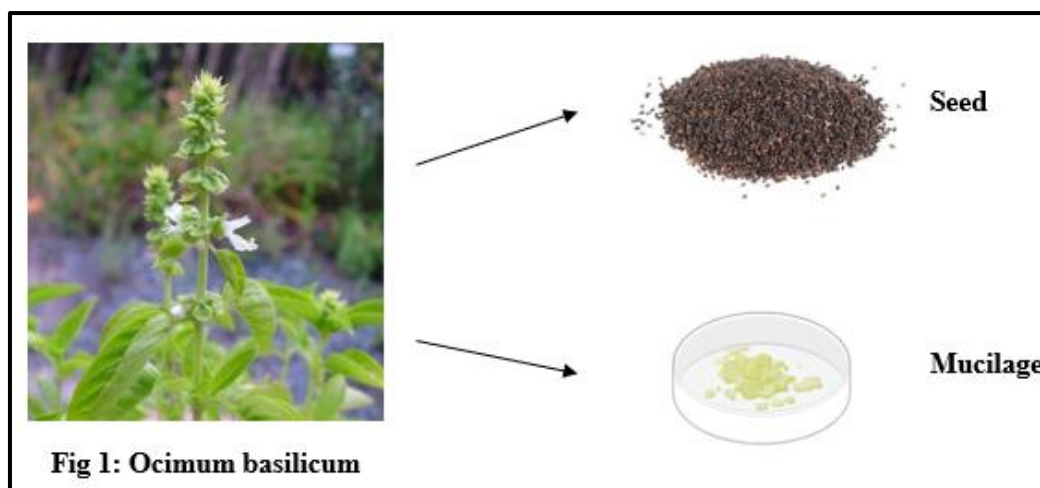


Figure 2- *Ocimum basilicum* plant

2. Extraction and Isolation

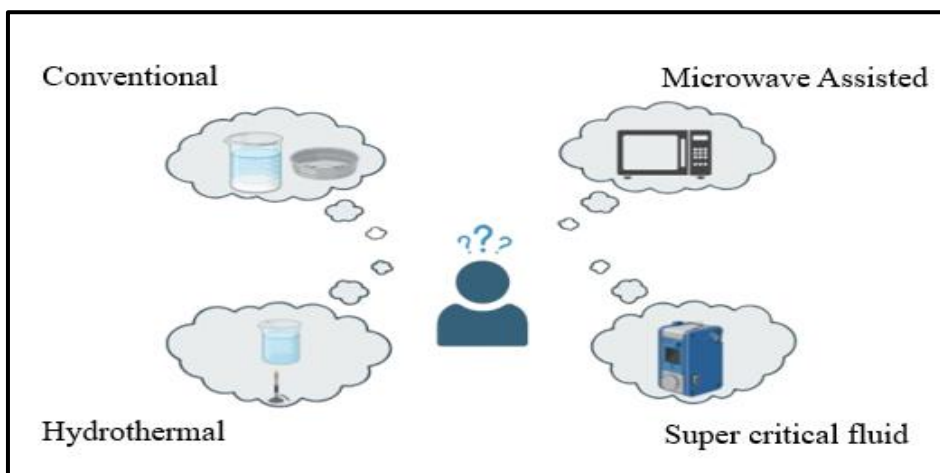


Fig 3: Schematic presentation of BSM extraction

3.1 Conventional extraction

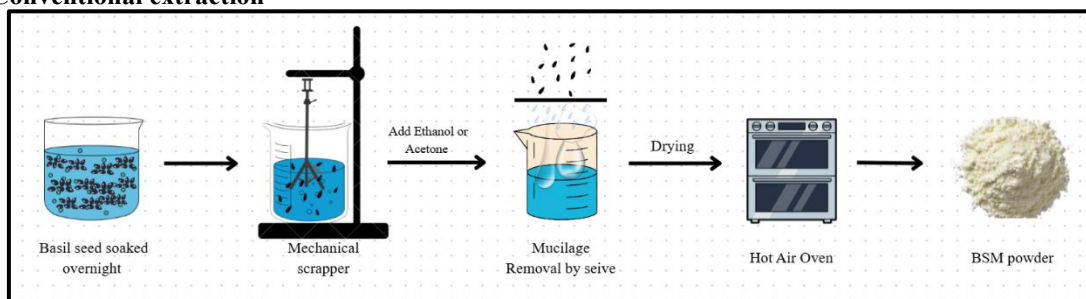


Fig 4: Conventional extraction method

Procedure:

The basil seeds were weighed appropriately and swell in Deionized water overnight (12–24 hours) at room temperature facilitates thorough diffusion of water into seed coats, expanding the mucilage up to 20–100 times its dry volume without heat degradation. Scrape the mucilage layer from the seed surface mechanical scrapper employed at 5000 RPM for 1-hour Pure ethanol or Acetone was added to the removed mucilage Lastly isolated mucilage was passed via a filter No. 40 Eliminate additional

water/ethanol content and then dried in a Hot air oven to obtain dry BSM powder(Nazir et al., 2017). Some of these advantages of these methods are as follow: offers simplicity and reliability using basic equipment including water baths, stirrers, and sieves, Ideal for small scale, Cost-effective with modest equipment needs. And disadvantages are the requirement for pricy quality solvents, high extraction periods and necessitate a longer soaking period, Low selectivity & possible degradation of thermolabile chemicals.

3.2 Hydrothermal Extraction

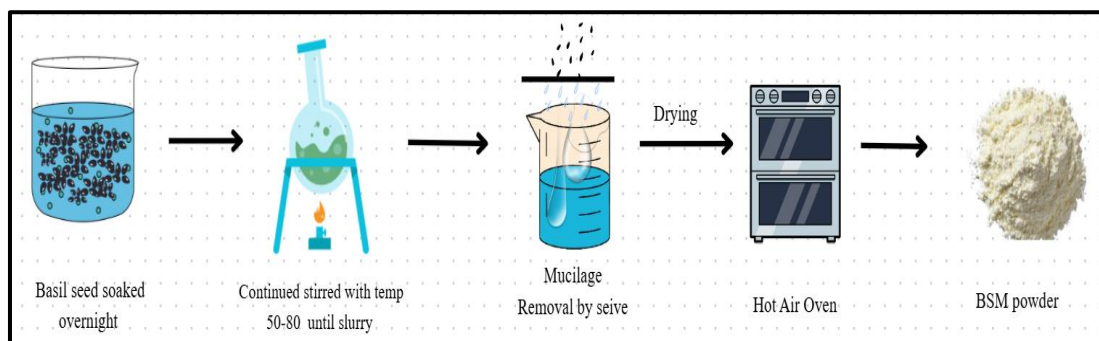


Fig 5: Hydrothermal extraction method

Procedure:

For the extraction of the mucilage, distilled water was added to basil seeds and the mixture was refluxed at a temperature of 50 to 80 degrees Celsius while being continuously magnetically agitated. The extraction process took one to three hours. The mucilage was extracted from the basil seed by running the slurries through a 150 μm . A hot air oven was used to dry the separated mucilage for two hours at 45°C. Mesh sieve and pressing down on the

screen using a rubber spatula. Benefits of these methods are High yield (up to 20% dry weight) with optimal temperature $\sim 57^\circ\text{C}$ and short time, Eco-friendly: uses water, low pressure, no harsh chemicals, Protects mucilage qualities. And disadvantages are such as a Labor-intensive: sifting, drying, residual contamination risk, Temperature sensitive, High temp led to deterioration of mucilage.

3.3 Microwave assisted extraction

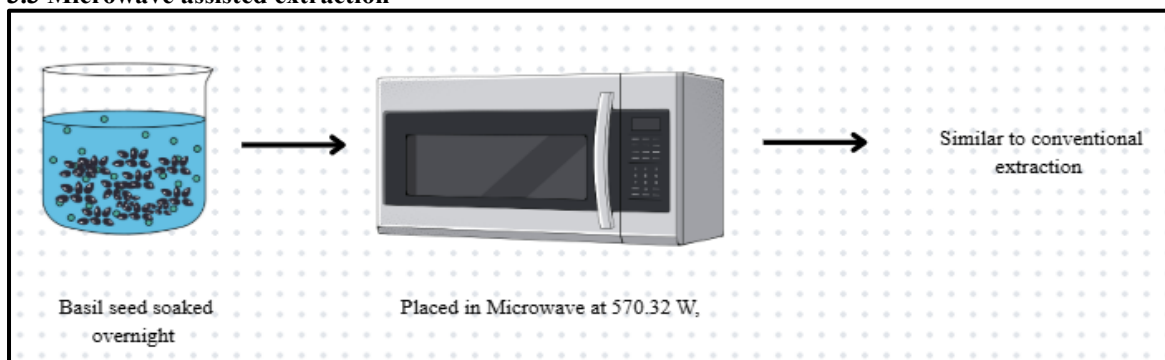


Fig 5: Microwave assisted extraction

Procedure:

The extraction process was carried out in a modified microwave oven that allowed for adjustments to power and time. The seeds were cleaned first, and then soaked in distilled water. They were placed in the microwave oven under different extraction conditions, using response surface methodology, including an extraction time of 4.33 minutes and a power of 570.32 W. The rest of the procedure followed the same steps as the conventional extraction process. The benefits of this method include a higher extraction yield ($17.00 \pm 0.14\%$)

with MAE compared to CE, short extraction time, high yield, selectivity, and better product quality with less solvent use. The functional qualities of the extracted mucilage, such as heat resistance, WAC, FC, and FS, were higher under ideal conditions than with the CE technique. On the other hand, some drawbacks are that it requires precise optimization of power (360–7 The results reveal that when the MT time is increased from 0 to 3 min, the average apparent viscosity of the basil seed gum dispersion drops from 0.173 to 0.100 Pa. s (Shiehnezhad et al., 2023).

3.4 Super critical fluid extraction

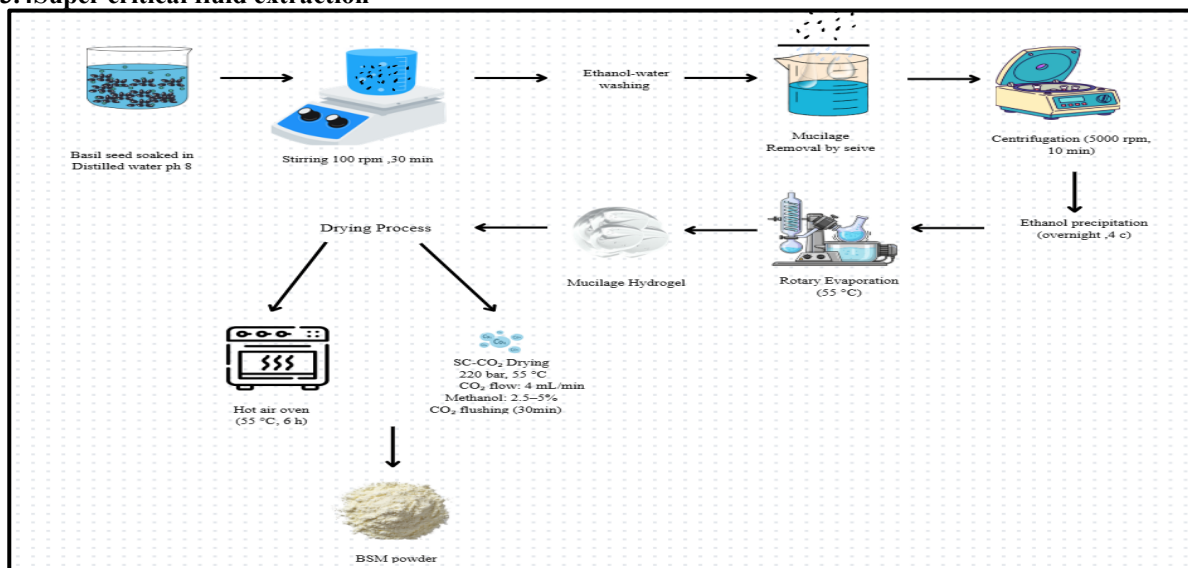


Fig 6: Supercritical fluid extraction

Procedure:

This extraction of basil seed mucilage involves a 3-step involved such as a step A. Extraction and Purification of Basil Seed Mucilage (Method borrowed from Razavi et al.). Desiccation of Basil Seed Mucilage. C. SC-CO₂ Drying Conditions So according to researcher,

Extraction and Purification of Basil Seed Mucilage involved Basil seeds steeped in distilled water (65 °C) at a 50:1 water/seed ratio. Then pH adjusted to 8 by using 0.2 M NaOH with continuously Stirring 100 rpm for ~30 min until complete swelling. Swollen seeds rinsed with ethanol-water combinations (10–90% ethanol). Mucilage mechanically scraped with a revolving rough-plate extractor. Sieving followed by centrifugation (5000 rpm, 10 min) to remove seed residues. Protein and ash removal by adding 100% ethanol (3:1) and keeping overnight at 4 °C. Concentration of crude extract using rotating vacuum evaporator at 55 °C. Led to Formation of a thick viscous hydrogel. Second step involved B. Desiccation of Basil Seed

Mucilage two desiccation methodologies: such as i) Drying in an oven at 55 °C for 6 hours ii) Supercritical carbon dioxide (SC-CO₂) drying for structural conservation. Step C. SC-CO₂ Drying Conditions: 2 mL hydrogel poured into stainless-steel cap, Vessel pressured with pure SC-CO₂. Pressure: 220 bar temperature: 55 °C CO₂ flow rate: 4 mL/min, Co-solvent: methanol Flow rates: 0.1–0.2 mL/min, methanol concentration: 2.5–5%, nonsolvent addition duration: 3 h, pure CO₂ flushing for 30 min to remove leftover methanol, gradual depressurization over ~20 min. Advantages of these methods are preserves polymer structure due to its temperature conditions, preserve porosity and prevent break down of gel, minimize thermal degradation as compared to Hot air oven, end product obtained organic solvent free. On the other hand, disadvantages are high costly due to equipment set up, require technical experts for proper handling, time taking process as compared to a typical drying method(Akbari et al., 2015).

3. Structure & Chemical composition

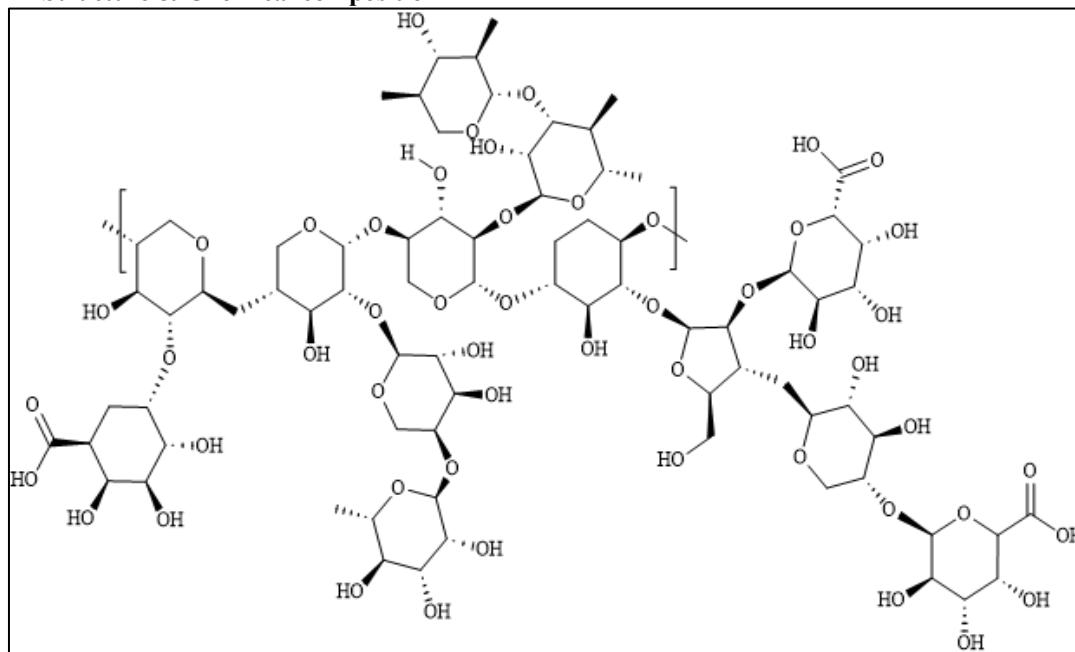


Fig 7: Structure of basil seed mucilage

Table 2: Nutritional Composition

Component	Percentage	References
Total Carbohydrates	43.9 to 63.8 g	(Calderón Bravo et al., 2021).
Protein	9.7% and 33.0%	(Nazir et al., 2017)
Soluble Dietary Fiber	26.19–98.50%	(Hu & Yu, 2013).
Insoluble Fiber	9.63 g	(Bradford et al., 2020)
Lipids (Fats)	14.76g	(Calderón Bravo et al., 2021).
Total Ash	7.4 % of total ash, 1% of acid insoluble ash, & 0.38 % of water-soluble ash	(Tripathi et al., 2024a).
Mineral Content	63.78 mg	(Nguyen-Le et al., 2021).

Based on the research, the mucilage of basil seeds contains high molecular weight polysaccharides (2320 kDa). Monosaccharides units of xylose, arabinose, rhamnose, and galacturonic acid with traces of glucose and galactose. The mucilage of basil seeds contains 43% glucomannans, 24.29% Xylan, and 2.31% glucan. Their hydrophilic fraction is attributed to Xylan, whereas the hydrophobic fraction is represented by glucomannan connected to highly branched arabinogalactan.

Two major fractions have been identified from the polysaccharides extracted from basil seed using cold water extraction and alcohol precipitation: An acid-

stable core glucomannan with a glucose to mannose ratio of 10:2, and (1-4)-linked Xylan alongside acidic side chains at C-2 and C-3 (uronic acid 3–13%) of the xylosyl residues in the acid-soluble portion. In addition, a little amount of glucan (2.31%) has been observed as a degraded cellulose substance with DP = 80(Saedi et al., 2015).

5. Physicochemical properties

5.1 Solubility

Researchers looked into how well basil mucilage dissolved in different solvents. Distilled water exhibited solubility, whereas other solvents such as

Acetone, chloroform & acetone rendered it insoluble and practically insoluble in an ethanol (Tripathi et al., 2024a).

5.2 Swelling index

BSM displayed a swelling capacity of 31.51 ± 0.43 ml/g in a maximum of 6 h at a concentration of 0.25% w/v (* $P < 0.05$), demonstrating its superior skin moisturizing capability. It displayed varying swelling behavior at 24 and 48h in phosphate buffer (pH 6.8) and water. This strong swelling tendency

may be principally attributed to intra- and intermolecular hydrogen interactions with water molecules, as shown with Hibiscus rosa-sinensis mucilage (MAJEE & BERA, 2025). The swelling capacity of basil seed mucilage increases at neutral pH. due to deprotonation of carboxyl group and electrostatic interaction between them because Basil seed mucilage is pH-dependant. While during at acidic pH. and crosslinking the swelling capacity dramatically lowers.

Condition	Swelling capacity	Ionization state	Mechanism	Swelling outcome
Distilled water	20 – 35 mL/	-COO-(Unscreened)	Osmotic swelling	Very high
Neutral (6.8)	15 – 30 mL/g	-COO ⁻ (charged)	Electrostatic repulsion	High
Acidic pH. (1.2)	8 – 18 mL/g	-COOH (neutral)	Hydrogen bonding	Low-moderate
Crosslinked	5 – 15 mL/g	Bound -COO ⁻	Network restriction	Low

Table 3: Effect on swelling index at a different condition

5.3 Viscosity

Dispersion of basil seed gum has high viscosity and exhibits shear-thinning behavior. Basil seed gum dispersion was evaluated using a viscometer (Brookfield, DV2T, RV, USA) at 20. Additionally, the apparent viscosity of the Basil seed gum dispersion fell from 0.173 Pa. s to 0.100 Pa. s.

5.4 Rheology

As per (Salehi et al., 2024) rheological properties of Basil seed gum solutions were determined by applying nonlinear regression method based on minimizing sum of squared error (SSE) and root mean square error (RMSE) values in MATLAB software (version R2012a) successfully modeled using Power law (PL), Bingham, Herschel-Bulkley (HB), and Casson models, and the Power law (PL) model was the best showed an excellent performance with the highest R-value (higher than 0.862) and the lowest SSE values (lower than 10.550) and RMSE values (lower than 0.938) for all gum dispersion.

5.5 Carbohydrate test

In the subsequent phytochemical study, the presence of carbs was confirmed using particular reagents, Molisch test & Fehling's test is performed and confirmed the presence the carbohydrate due to presence of violet ring at the junction & due to production of red precipitate (Tripathi et al., 2024a).

5.6 Mucilage test

Confirmed by using two tests: water & employing ruthenium red Confirmed owing to swelling of extracted basil powder & presence due to presence of red color.

5.7 Ph-determination

pH. determination by utilizing digital pH meter which was determined to be 6.45. This value implies a slightly acidic environment, which is suitable for bio adhesion.

6. Characterization techniques

6.1 Fourier Transform- infrared Spectroscopy (FT-IR)

The FT-IR spectra of the basil seed mucilage absorbance band at 3009 cm^{-1} corresponds to OH stretching, suggesting the presence of hydroxyl groups, which are prevalent in polysaccharides and necessary for water interactions and solubility. Bands at 2924 and 1646 cm^{-1} were attributed to CH_2 stretching, part of the backbone structure of organic molecules and carbohydrates. The band at 1626 cm^{-1} and 1535.34 cm^{-1} , is attributed to asymmetric and symmetric stretching of carboxylate groups, found in uronic acids; these are components of mucilage. Band at 1456 cm^{-1} Detect the presence of protein within the mucilage. The band at 970.19 cm^{-1} corresponds to C-O-C stretching, supporting glycosidic linkage in a BSM, while the band at 1026 cm^{-1} indicates the presence of arabinose in the mucilage(Ghumman et al., 2022a).

6.2 Differential Scanning Calorimetry (DSC)

Thermal measurements involved the study of glass transition temperature (T_g) by differential scanning calorimetry (DSC). The glass transition temperature (T_g) of basil seed mucilage (also called basil seed gum, BSG) typically ranges from 122.5°C to 148.3°C , depending on the extraction method. The glass transition of basil seed mucilage has an onset temperature of 146°C , which is recognized as high. However, the T_g had a narrow range of around $146\text{--}148^\circ\text{C}$ (Nazir & Wani, 2021). The heat capacity of 9.4 J/g demonstrated poor stability above T_g , lower heat capacity also suggested poor molecular structure and amorphous nature.

6.3 X-Ray Diffraction Study (XRD)

During an XRD of BSM around 22.90° , a large peak was found; it indicates the presence of an amorphous structure with minimum crystalline nature, while the absence of a strong peak indicates amorphous nature.

6.4 Scanning Electron Microscopy (SEM)

SEM demonstrates that basil seed mucilage has a very unusual structure of components in the form of discrete, long 'tubules' spread relatively densely at the seed surface with rough, uneven, porous surface morphology and fibrous or network-like structure(Kreitschitz & Gorb, 2018).

6.5 Nuclear Magnetic Resonance (NMR)

The ^{13}C NMR spectra displayed four anomeric resonances in the region of $100\text{--}105\text{ ppm}$, specifically at 100.44 , 102.79 , 104.23 , and 104.69 ppm . The first strong resonance was attributed to C-

1 of -glucuronic acid (-GlcA). The remaining anomeric resonances were assigned to α -rhamnopyranose (α -Rhap, weak), α -Xylo pyranose (α -Xylp), and α -arabino pyranose (α -Arap)(Yili et al., 2014).

7 Biopharmaceutical properties

7.1 Bio-degradability

BSG has hydrophilicity, biodegradability, and varied functions for coatings and films. BSG, being natural, is safe, non-allergenic, and offers possible health advantages. Films and coatings made from BSG efficiently enhance the shelf life of food. Modifying BSG (such as esterification) can improve the characteristics of the coating (Sahraeian et al., 2025).

7.2 Biocompatibility

Basil seed mucilage (BSM), a natural polysaccharide obtained from *Ocimum basilicum*, has showed biocompatibility in different biomedical and pharmaceutical studies. Due to its natural origin and polysaccharide- composition, they exhibit minimum cytotoxicity and shows good compatibility with biological tissues. According to reports some experimental studies involved BSM-based hydrogels, films, and composite scaffolds have reported satisfactory cell adhesion, proliferation, and viability, confirming its cytocompatibility nature(Ghumman et al., 2022a). While, hemocompatibility evaluations indicate low hemolytic activity, supporting its safe interaction with blood components. Also, an in vivo and topical application studies detect the absence of skin irritation or inflammatory response, indicating its suitability for wound dressing and drug delivery systems. All the above report suggest that basil seed mucilage is a biocompatible and safe biopolymer have significant potential for pharmaceutical and biomedical applications.

7.3 Non-Toxic Nature

While according to cytotoxic study the BSM has no detrimental effect in a cell line tests and toxicological evaluation demonstrate that there is no acute toxicological effect in animal studies generally supports its safety and their diverse dietary application(Nguyen-Le et al., 2021).

7.4 Mucoadhesive Nature

According to Tripathi studied that BSM employed in development of microsphere and suppository due its mucoadhesive nature proven by ex vivo investigation disclose that the microsphere

containing polymer they confirmed demonstrate considerable bio adhesive force on rectum (Tripathi et al., 2024b). Multilayered mucoadhesive oral films were produced based on basil seed mucilage as a novel plant polysaccharide.

8 Modification and crosslinking

8.1 Need for modification

Basil seed mucilage (BSM) is water-loving, biodegradable, and biocompatible. It also has a high swelling index and low mechanical strength, which means that if it is used in a sustained release formulation, it can burst and release the drug. To

improve the mechanical stability and controlled drug release behavior, it needs to be crosslinked. According to studies a different crosslinkers used such as calcium ions, organic di-carboxylic acids, glutaraldehyde, acrylic monomers, and polyelectrolyte-forming agents (e.g., sodium alginate) have been used to improve mechanical strength, control swelling index, mucoadhesive properties, lead to achieve sustained drug-release. By applying this crosslinking method led to the formation of polyelectrolyte complexes. They give in a tabular manner like below.

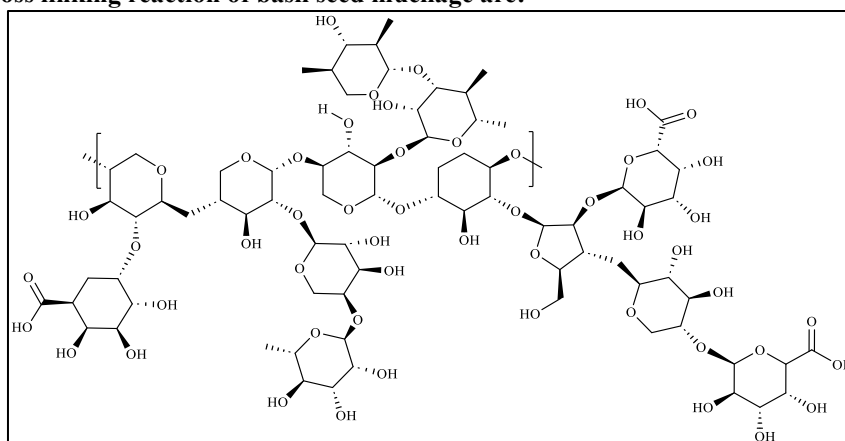
Table no. 4: Crosslinking of basil seed mucilage with different crosslinking agent.

Polymer	Crosslinking-Agent	Type of Crosslinking	Mechanism	References
1. Basil seed gum	Calcium ion (Ca ²⁺)	Ionic	Basil seed gum includes an abundance of -COOH groups; thus, calcium ions react with the carboxyl group of uronic acid, leading to the development of the egg box model.	(Razavi et al., 2009)
2. Basil seed mucilage + Tartaric, malic, and succinic acids.	di-carboxylic acid	Chemical	Fourier-transform infrared (FTIR) spectra and detected a 1730 cm ⁻¹ C=O stretching peak, which verified ester linkage between the mucilage and crosslinkers.	(Thessrimua et al., 2019),
3. Basil seed mucilage + Sodium alginate	Sodium tripolyphosphate (TPP)	Ionic crosslinking / PEC	TPP Posses multivalent phosphate ion they build a bridge with carboxylate groups of both polymers, lead to polyelectrolyte production rather than a covalent connection.	Yari et al., 2020a)
4. Basil seed mucilage + Polyvinyl alcohol (PVA)	Glutaraldehyde	Chemical	The hydroxyl groups of OBM and PVA reacted with the aldehyde groups of GA to form acetal cross-links.	(Hosseini & Nabid, 2020)

<p>5. Vinylated Basil seed gum +Methacrylic acid (MA)</p>	<p>Ethylene glycol Di methacrylate (EGDMA)</p>	<p>Free radical addition polymerization</p>	<p>New bonds arise when free radicals attack the C=C double bonds of vinylated basil gum and methacrylic acid, shattering the π bond and forming new σ bonds. The developing chains continue to acquire monomers, and EGDMA joins two chains by generating covalent culminating in a 3D polymer network.</p>	<p>(Sanaei & Mehrshad et al., 2021)</p>
<p>6. Basil seed mucilage + Zinc oxide nanoparticle (ZnO)</p>	<p>Borax (10-20 wt.%)</p>	<p>Diol borate</p>	<p>Borax dissociates to release borate ions, which bind with hydroxyl ($-OH$) groups of the mucilage to produce borate ester linkages, generating the first crosslinks between polymer chains. At the same time, ZnO nanoparticles produce Zn^{2+} ions that bind with $-OH$ and $-COO^-$ groups of the mucilage, further reinforcing the network.</p>	<p>(Tantiwatcharothai & Prachayawarakorn, 2020)</p>
<p>7. Basil seed gum + glutathione (GSH).</p>	<p>Calcium chloride solution</p>	<p>Ionic</p>	<p>The ion gelling process was utilized to generate basil seed gum nanoparticles (BSG NPs). So, calcium ions react with the carboxyl group of uronic acid, which leads to the creation of the egg box model.</p>	<p>(Naji-Tabasi et al., 2017)</p>
<p>8. BSM+ Sodium alginate</p>	<p>Calcium chloride</p>	<p>Ionic</p>	<p>Calcium chloride produces Ca^{2+} ions, which bind to the $-COO^-$ groups of basil seed mucilage and sodium alginate,</p>	<p>(Tripathi et al., 2024b)</p>

			establishing ionic bridges between polymer chains and creating a crosslinked 3D gel network.	
9. BSM + thiolate alginate + dopamineHA	No	Thiol - disulphide	SM, thiolated alginate, and dopamine-HA produce a hydrogel through thiol-disulfide crosslinking, where thiol (-SH) groups on thiolated alginate are oxidized to generate disulfide linkages (-S-S-). These covalent bonds join diverse polymer chains together, forming a stable three-dimensional network.	(Masoomah Sadat Hosseini et al.,2022)

8.2 Cross linking reaction of basil seed mucilage are:



Basil seed mucilage
 ↓ Ionic crosslinking

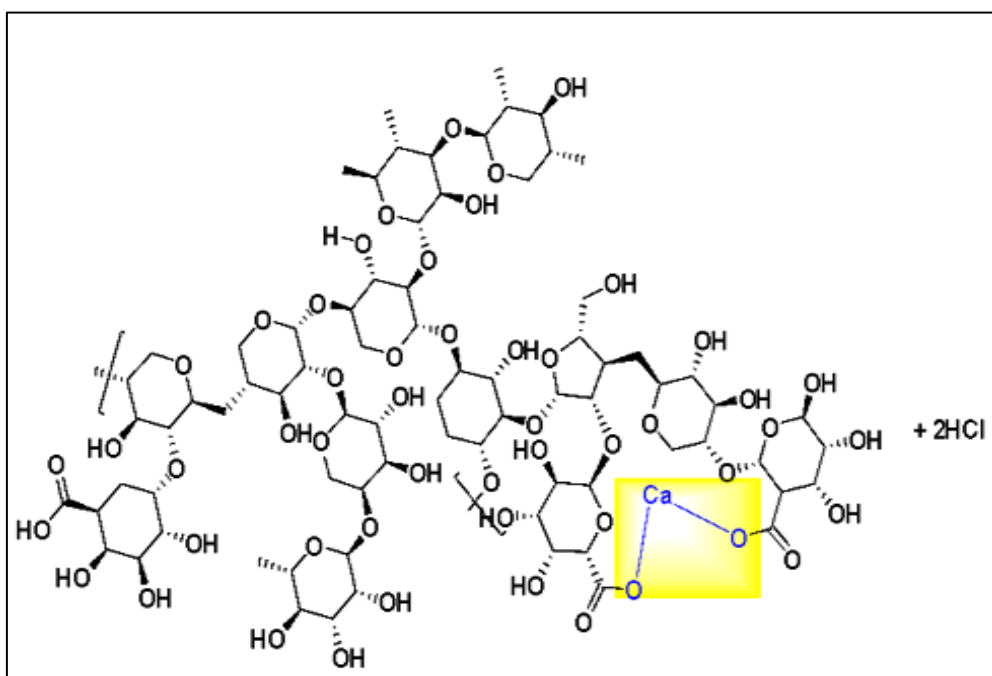


Fig 8: Basil seed mucilage-calcium chloride complex

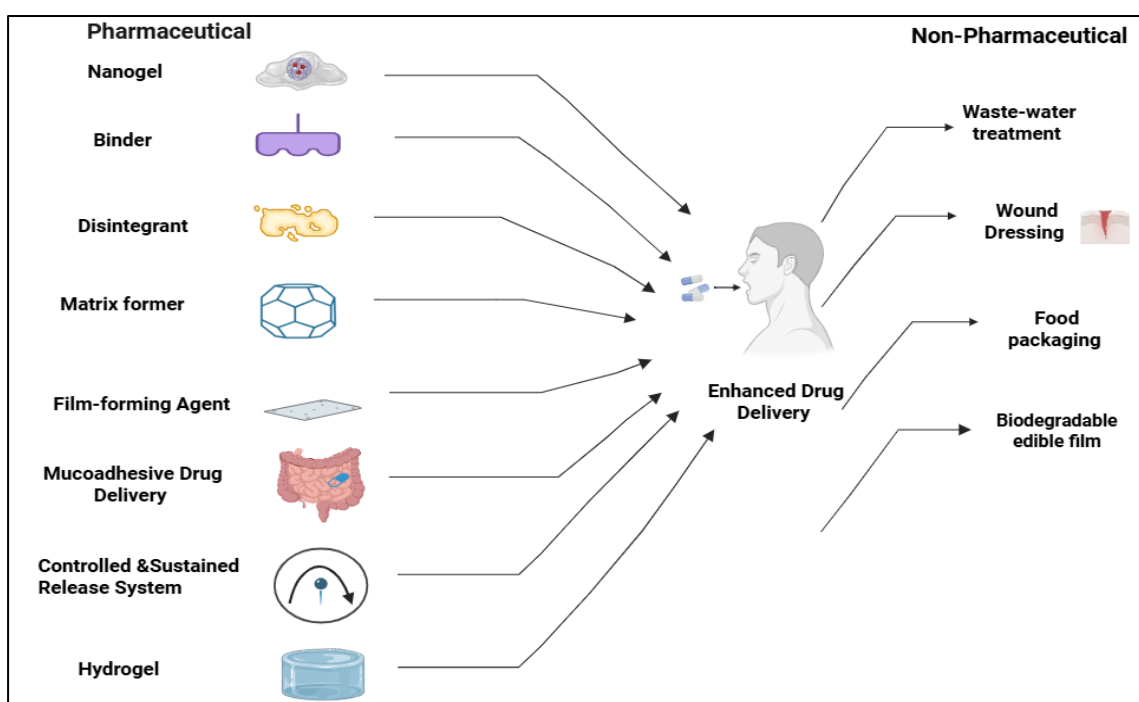


Fig 9: Pharmaceutical and non-pharmaceutical application of basil seed mucilage

9 Application

9.1 Pharmaceutical

Table 5

Mucilage	Application	References
Basil seed mucilage	As a Hydrogel	(Ghumman et al., 2022b; Hosseini & Nabid, 2020)
Basil seed mucilage	As a Binder	(Tripathi et al., 2024b)
Basil seed mucilage	As a Superdisintegrating	(Nayakal et al., n.d.; Sukhavasi & Sai, 2012)
Basil seed mucilage	As a film-forming agent	(Khazaei et al., 2014a)
Basil seed mucilage	Mucoadhesive drug delivery	(Sadat Hosseini et al., 2022)
Basil seed mucilage	Controlled & Sustained released system	(Yari et al., 2020b)
Basil seed mucilage	As a nanogel	(Mortazavi Moghadam et al., 2023)
Basil seed mucilage	As a matrix former	(Saeedi et al., 2015)

9.2 Other than pharmaceutical

Basil seed mucilage	Waste water treatment	(Shamsnejati et al., 2015)
Basil seed mucilage	Wound dressing	(Tantiwatcharothai & Prachayawarakorn, 2020)
Basil seed mucilage	Source of essential oil and aroma compounds	(Simon et al., n.d.)
Basil seed mucilage	Food packaging	(Rohini et al., 2020)
Basil seed mucilage	Biodegradable edible film	(Khazaei et al., 2014b)

9.1.1. Hydrogel

A hydrogel is a two-phase material made of porous and permeable particles and at least 10% water or another interstitial fluid. We successfully made highly porous BSG-co-poly (AA) hydrogels using a method based on free radical copolymerization to keep the effects of captopril going. Finally, the study's findings prompted us to suggest that BSG-co-poly (AA)-based hydrogels provide a possible alternative to current dosage forms by permitting sustained and controlled drug administration over lengthy durations (Ghumman et al., 2022b).

Hydrogel films were made based on basil seed mucilage and employing varied ratios of PVA, GA as cross-linker and Gly as a plasticizer. Tetracycline hydrochloride was put in final optimized hydrogels, and the in vitro release was examined. The results revealed that the rate of TH release accelerated with rising pH from 6.5 to 8.5, due to swelling of the hydrogels at higher pH values produced by the ionization of hydroxyl groups of OBM and PVA chains (Hosseini & Nabid, 2020).

As a Binder

Recently, mucilage produced from basil seeds has attracted interest as a promising biopolymer for drug delivery systems. In our study, the authors investigated whether basil seed mucilage could serve as a bio-adhesive carrier for naproxen sodium. Combining basil seed mucilage with sodium alginate is targeted at boosting medication solubility and improving rectal administration (Tripathi et al., 2024b).

9.1.2. As a Disintegrant

Fast-dissolving tablets are the innovative type of tablets that break down/disperse in saliva. The main aim of this study was to create fast-dissolving clopidogrel bisulfate tablets by using basil seed mucilage as a natural super-disintegrating agent. Clopidogrel is a thienopyridine with antiplatelet action. It permanently alters the platelet receptor for adenosine diphosphate. To make clopidogrel bisulfate tablets that dissolve quickly, the direct compression method was used. This involved using holy basil seed mucilage at concentrations of 6, 12, and 18 mg, which acted as a natural super disintegrant (Nayakal et al., n.d.).

In the present study the super disintegrant property of *Ocimum basilicum* gum has been studied. Its extensive swelling, porosity, and wicking action were shown to contribute to its super-disintegrant action. *Ocimum basilicum* gum was used as a super-disintegrant in the formulation of amlodipine besylate fast-dissolving tablets using the direct compression method (Sukhavasi & Sai, 2012).

As a Film-Forming Agent

Natural polymers have recently gotten a lot of attention because of environmental issues and the need for fossil resources to be economically independent. By serving as barriers to regulate the movement of moisture, oxygen, fats, and flavours, they can help food last longer on the shelf.

This study investigated the utilizing of basil seed gum (BSG) as a new film-forming material under the influence of addition of glycerol (GLY) as plasticizer. Edible films based on BSG and three different concentrations of GLY were created, and their water vapor permeability (WVP), as well as physical, thermal and mechanical properties were investigated. The addition of glycerol considerably increased water vapor permeability and solubility of the film ($p < 0.05$). This investigation demonstrated that the BSG had a good potential to be employed in making edible films for diverse food applications (Khazaei et al., 2014a).

9.1.3. Mucoadhesive Drug Delivery

Oral mucosal medication administration, especially the oral thin films (OTF) dosage forms, has received great interest recently due to their flexibility and convenience of usage. According to Masoomah Sadat present study creates an experimental design for the creation of new bi and tri-layer mucoadhesive sublingual films based on basil (*Ocimum basilicum* L.) seed mucilage (OBM) as novel plant-polysaccharide for Oro mucosal administration of nystatin (Nys). The films formulation consists of a drug reservoir-mucoadhesive layer cross-linked via CaCl_2 , with protective mucoadhesive layers based on thiolated alginate (TA) and poly dopamine (PDA). OBM serves as a novel mucoadhesive polysaccharide (Sadat Hosseini et al., 2022).

9.1.4. Controlled and sustained released system

The purpose of this work is to employ plant mucilage in conjunction of SA beads to improve the qualities of SA beads. SA beads containing metformin medication (MET) were modified using basil seed mucilage (BSM) to produce controlled

release was explored. The presence of BSM in the SA structure results in increased stability, less swelling, and hence reduced release (Yari et al., 2020b).

Pellets are playing a dominant role in multi-particulate dose forms, and the utilization of multi-unit pellets is on the rise presently.

The current study was aimed at the formulations and assessment of matrix pellets primed by consuming basil seed mucilage (BSM) as a sustained-release polymer. sustained-release pellets of lornoxicam via the extrusion-spheronization process. These pellets were created utilizing basil seed mucilage as a release retardant polymer, microcrystalline cellulose as palletization assistance, and lornoxicam as a perfect cure. Hence, the study concludes that basil seed mucilage is the best fit for sustained drug release, and the study has to be extended in the future.

9.1.5. As a Nano-gel

Nanogel-based materials have high drug loading capacity, biocompatibility, and biodegradability, which are the main points to build a drug delivery system efficiently. In this study, the impact of adding lemon peel extract-loaded nanogel formed of gelatin and guar gum in casein/basil seed gum film was studied. The outcomes of this study demonstrated that adding the nanogels loaded with lemon peel extract in casein-basil seed gum (CB) film led to improving the features of CB film, including the mechanical properties, thermal stability, hydrophobicity, and water vapour permeability (Mortazavi Moghadam et al., 2023).

9.1.6. As a Matrix former

Hydrophilic matrices have been employed extensively to provide controlled release oral drug delivery. Polysaccharide mucilage derived from the seeds of *Ocimum basilicum* L. (family Lamiaceae) was studied for use in matrix compositions containing propranolol hydrochloride. Basil mucilage was isolated and various pills were manufactured. The effect of mucilage on medication release rate was investigated in comparison with tablets containing two kinds of hydroxypropyl methylcellulose (HPMC K4M and HPMC K100M) as standard polymer. Formulations incorporating *O. basilicum* mucilage were found to display acceptable release pattern (Saeedi et al., 2015).

9.1.7. As emulsifying agent in surfactant - free emulsion

The findings of the investigation suggested that the basil seed mucilage exhibits required physicochemical qualities such as water holding capacity, oil holding capacity, swelling index, and rheological property for being studied as a suspending agent and emulsion stabilizer. Investigations on adult and pediatric paracetamol suspensions and surfactant-free emulsions reveal that mucilage from sweet basil seed at an optimum concentration is a potential additive for stabilization of liquid dosage forms and thus may be regarded as a functional biomaterial for pharmaceutical use (Avlani et al., 2019).

9.2. Other applications

9.2.1. Waste-water treatment

In this investigation, the mucilage of *O. basilicum* was employed for decolorization of Congo red (CR). Congo red is a benzidine-based anionic diazo dye and the first synthetic dye capable of coloring cotton directly. *Ocimum basilicum* L. (basil) has been investigated as an active natural coagulant for the removal of dye from a model textile effluent containing Congo red. The mucilage of *O. basilicum* was also found to be highly effective in treating genuine textile wastewater as a solitary coagulant and in conjunction with alum (Shamsnejati et al., 2015).

9.2.2. Wound dressing

The main parameters of an optimal wound dressing are high fluid absorption and retention. Another crucial requirement of a wound dressing is antimicrobial activity. The porous hydrogel sponge applied in wound dressing is effective because it could absorb and retain large amounts of ZnO nanoparticles (ZnO-NP), which have excellent antibacterial activity. The purpose of this research was to develop a new natural antibacterial hydrogel sponge from basil seed (*Ocimum basilicum* L.) mucilage by freeze-drying. ZnO-NP was added to increase the antibacterial activity of the BSM hydrogel sponge (Tantiwatcharothai & Prachayawarakorn, 2019).

9.2.3. As a Source of essential oil and aroma compounds

Basil plants evaluated in this study featured a wide variety of oil components providing a diversity of accessible scents and flavors. Many had a

combination of linalool and methyl chavicol and/or 1,8-cineole, representing the characteristic sweet basil scent. Others had distinct aromas. The major scent compound was eugenol (62%) in 'East Indian' and 'Tree' basil; camphor (61%) in 'Camphor' basil; thymol in 'Green' basil; b-caryophyllene in 'Holy' and 'Sacred' basil; and methyl chavicol in 'New Guinea', and 'Thai Richters' basil. Several purple cultivars ('Holy Sacred Red', 'Opal', and 'Osmin Purple') were rich in Linalool (ca. 77%), as was the green cultivar 'Sweet Fine' (86%). Citral was the major component in all the lemon-scented basil. However, few of these cultivars could compete as industrial sources of these compounds. Surprisingly, 'Camphor' basil, a very strong cultivar, was discovered to have reasonably high oil yield (>5% dry weight) (Simon et al., n.d.).

9.2.4. Food packaging

Ocimum basilicum mucilage-based nanocomposite films were developed. Use of nanocomposites is a well-established strategy for increasing the mechanical and barrier properties of bio-nanocomposite film for food packaging applications. The seed mucilage of *Ocimum basilicum* was applied for the fabrication of bio-nanocomposite films with montmorillonite (MMT) as nanofiller. The films were made by the solvent-casting process (Rohini et al., 2020).

9.2.5. Biodegradable edible film

(Khazaei et al., 2014b) have tested edible films based on BSG and three different concentrations of glycerol (25%, 35%, and 50% w/w BSG) for plasticizing films. BSG creates a transparent film with good mechanical qualities and excellent barrier properties. They concluded that the finest features of BSG films achieved by utilizing glycerol at 25%. Glycerol has a crucial role in making homogeneous flexible BSG films and also impacts physical and mechanical (tensile strength and elongation at break) features of basil seed gum films. Addition of glycerol significantly enhances water vapor permeability and solubility ($p < 0.05$). Increase in glycerol concentration likewise increases the extensibility, but decreases tensile strength. The electron scanning micrograph depicts plasticized films as smooth and homogeneous surface morphology, without pores or cracks compared with those films without glycerol.

10. PATENT

Table no.6:

Patent no./ family	Title	Main application	References
WO2023018855A2/US20240341316A1	Probiotic mucilage-based edible films for the preservation of fruits and vegetables.	Edible coatings and films designed for fruits and vegetables serve to extend shelf life, regulate moisture and gas exchange, and deliver active probiotics as a functional food application.	(US20240341316A1, n.d.)
W02023161749A1/US20250176577A1	Plant-only dairy replacement system for foods	Basil seed mucilage is highlighted as a plant-derived hydrocolloid that enhances creaminess, emulsion stability, and mouthfeel in plant-based cream or milk formulations without relying on animal additives.	(US20250176577A1, n.d.)
W02018106700A1/US20180153106A1	Method for producing food-safe sprouted seed products.	Process for generating microbiologically safer sprouted seeds/powders by controlled fermentation on the mucilage layer, boosting the safety of sprouted seed ingredients.	(US20180153106A1, n.d.)
W02016074099A1/US20160066572A1/US10292402B2	Method of sanitizing edible seeds, particularly mucilage producing seeds.	Industrial sanitization of edible seeds that produce mucilage but release little of it, thereby improving handling and safety for applications in foods and nutraceuticals.	(Mathieu, 2019)

11. Challenge and Limitation

While mucilage's and gums are obtained from nature, their availability varies depending on the parameters of the climate and season. Extraction and purification are essential activities after processing. The growth and productivity of mucilage's and gums may also be impacted by morphological traits (such as seed coat), physical damage to seeds, and inappropriate removal of mucilage's and gums, posing a substantial impediment to costs related and the potential for a mass level of output. The equilibrium moisture level of mucilage's and gums is about 10 percent and the likelihood of microbiological pathogens at any phase of its production is probable. The storage conditions are another significant operation; studies have verified changes in mucilage and gum quality with storing (Amiri et al., 2021).

Basil seed mucilage itself possesses a high swelling index and high viscosity it led to issue during a formulation development. According to research studies Polymer concentration greatly influenced the

size, swelling, and entrapment of naproxen sodium microspheres. The microspheres' size increased with the integration of basil mucilage into the alginate polymer solution due to the increased viscosity of the combined polymer solution, which extended the droplet size (Tripathi et al., 2024b).

12. Future perspective

Basil seed mucilage is natural biodegradable polymer due its property in future they had a wide novel application such as a use in nanoparticle, nanofiber, microsphere. To provide a control and sustained released it cross linked with many natural or synthetic polymer

It also has uses in tissue engineering and biomedicine, such as biocompatible scaffolds for wound treatment, tissue regeneration, and 3D bioprinting matrices. Basil seed mucilage is a bio adhesive polymer that has been used a lot in nasal formulations, buccal drug delivery, and gastroprotective tablets.

13. Conclusion:

Basil seed mucilage obtained from *Ocimum basilicum* is a promising natural biopolymer with tremendous potential across pharmaceutical, nutraceutical, and food industries. This paper highlights its historical past and expanding scientific interest due to its biocompatibility, biodegradability, and non-toxic nature. Various extraction techniques, ranging from classic hydrothermal procedures to sophisticated approaches such as supercritical fluid extraction, play a key role in determining the yield, purity, and functional qualities of the mucilage.

The nutritional profile of basil seed mucilage, rich in polysaccharides, dietary fibers, and vital minerals, further boosts its potential as a functional ingredient. The structure is a complex nature of polymeric network shows an advantage such as such as high swelling capacity, viscosity, and gel-forming ability. These properties are highly used for several pharmaceutical applications, such as a binder, disintegrant, controlled-release agent, and hydrogel-forming material. And the increasing Recent patents and research achievements show increasing interest industrial, notably in creating innovative medicine delivery technologies and functional food formulations.

Future views should focus on better modification approaches (such as chemical functionalization and nanocomposite production), improved extraction efficiency, and research of its potential in targeted and smart drug delivery systems. Overall, this basil seed mucilage is considered as a sustainable and adaptable biomaterial with great possibilities for innovation and commercialization.

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