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Extraction, Physicochemical Characterization, and Comparative Evaluation of Tamarind (Tamarindus indica) and Fenugreek (Trigonella foenum-graecum) Seed Gums as Potential Pharmaceutical Excipients

Sheeba Naaz

Research Scholar, School of Pharmacy, Monad University Hapur (U.P)

Prof. (Dr.) Hemant Bhardwaj

Supervisor, School of Pharmacy, Monad University Hapur (U.P)

Abstract

Natural gums derived from plant seeds continue to attract pharmaceutical interest as renewable, biodegradable, and low-cost alternatives to synthetic polymeric excipients. The present study was designed to isolate mucilaginous gum from the seeds of tamarind (Tamarindus indica L.) and fenugreek (Trigonella foenum-graecum L.) by an aqueous extraction-cum-alcohol precipitation method, and to evaluate the isolated gums for their suitability as pharmaceutical excipients. Percentage yield, organoleptic characters, phytochemical composition, solubility behaviour, micromeritic properties (bulk density, tapped density, Carr's index, Hausner's ratio, angle of repose), swelling index, moisture content, loss on drying, pH, viscosity, melting behaviour, and Fourier-transform infrared (FTIR) spectral profile were determined for both gums using standard pharmacopoeial and literature-reported procedures. Tamarind seed gum was obtained in a higher yield and showed greater viscosity-building and mucoadhesive character, whereas fenugreek seed gum showed a comparatively higher swelling index and moisture-holding capacity, consistent with its galactomannan-rich composition. Both gums were free of alkaloids, tannins, and glycosides, and showed near-neutral pH values that are unlikely to irritate mucosal tissue. FTIR spectra of both gums exhibited characteristic carbohydrate absorption bands, confirming their polysaccharide nature. The micromeritic and functional data obtained indicate that both gums possess flow, binding, and swelling characteristics broadly comparable to established natural excipients such as guar gum, gum acacia, and gum tragacanth, supporting their potential application as binders, disintegrants, suspending agents, and mucoadhesive/release-modifying agents in solid and semi-solid pharmaceutical dosage forms.

Keywords: Tamarind seed gum; Fenugreek seed gum; Galactomannan; Natural polymer; Pharmaceutical excipient; Physicochemical evaluation.

1. Introduction

Excipients are the auxiliary, pharmacologically inactive components that are combined with an active pharmaceutical ingredient to enable manufacture, ensure stability, and control the release or delivery of a dosage form. Historically, excipient technology relied heavily on semi-synthetic and synthetic polymers such as hydroxypropyl methylcellulose, sodium carboxymethyl cellulose, povidone, and croscarmellose sodium. Although these materials are reproducible and well characterized, concerns regarding their cost, non-renewable origin, environmental burden during manufacture, and occasional adverse patient response have renewed interest in excipients of plant origin (Choudhary & Pawar, 2014). Plant-derived gums and mucilages are polysaccharide-

rich exudates or seed reserve materials that are inexpensive, widely available, biodegradable, generally non-toxic, and capable of performing multiple pharmaceutical functions including binding, disintegration, thickening, suspending, emulsifying, gelling, and mucoadhesion within a single dosage form (Prajapati et al., 2013).

Tamarindus indica L. (family Fabaceae) is a large evergreen tree cultivated extensively across the Indian subcontinent and South-East Asia. The kernel powder obtained from its seeds yields a polysaccharide commonly referred to as tamarind seed gum, tamarind kernel powder, or tamarind xyloglucan, composed predominantly of glucose, xylose, and galactose residues. Tamarind seed gum is reported to possess high viscosity-building capacity, mucoadhesive character, and resistance to enzymatic degradation in the upper gastrointestinal tract, properties that have supported its evaluation as a tablet binder, film-forming agent, gelling agent, and matrix-former for sustained and mucoadhesive drug delivery systems (Nayak & Pal, 2017; Malviya et al., 2021).

Trigonella foenum-graecum L. (fenugreek), also of family Fabaceae, yields from its seed endosperm a galactomannan-type gum consisting of a linear (1→4)-linked β-D-mannan backbone substituted with D-galactose units at an approximate mannose-to-galactose ratio close to unity. This relatively high degree of galactose substitution confers good aqueous solubility and swelling behaviour on fenugreek gum compared with other galactomannans such as guar and locust bean gum, and has encouraged its evaluation as a suspending, disintegrating, and mucoadhesive agent, in addition to its recognised nutraceutical and antidiabetic properties (Rashid et al., 2018; Dhull et al., 2023; Mishra et al., 2021).

Although tamarind seed gum and fenugreek seed gum have individually been the subject of extraction and characterization studies, comparative reports evaluating both gums side by side, under an identical extraction protocol and an identical battery of pharmacopoeial evaluation tests, remain limited. Such a comparison is of practical value because it allows a formulator to select the excipient whose functional profile — viscosity-building versus swelling capacity, for instance — best matches a specific dosage-form requirement. The objective of the present investigation was therefore (i) to isolate gum from tamarind and fenugreek seeds by a simple, scalable aqueous extraction and alcohol-precipitation method, and (ii) to characterize and compare the two gums using organoleptic, phytochemical, micromeritic, and spectral evaluation techniques, with a view to establishing their suitability as pharmaceutical excipients.

2. Materials and Methods

2.1 Plant Material and Authentication

Mature, healthy pods of tamarind (Tamarindus indica L.) and dried seeds of fenugreek (Trigonella foenum-graecum L.) were procured from the local market. The seeds were cleaned to remove adhering pulp and debris, washed with distilled water, and shade-dried for 48–72 h prior to processing.

2.2 Extraction of Gum

Gum was isolated from both seed sources by an aqueous extraction and alcohol-precipitation method adapted from established literature protocols for seed gum isolation (Kandar et al., 2021; Singh et al., 2011). Cleaned seeds (50 g) were soaked in distilled water (1:10 w/v) for 24 h to soften the seed coat and hydrate the endosperm, after which the swollen mass was ground and boiled gently for 45–60 min with continuous stirring to release the mucilaginous gum into solution. The hot slurry was passed through an eight-fold muslin cloth to remove insoluble husk and fibrous residue, and the filtrate was allowed to cool. The gum was precipitated from the filtrate by the

addition of an equal volume of 95% v/v ethanol, and the precipitate was allowed to settle overnight under refrigeration (4 degrees C). The precipitated gum was separated by filtration, washed successively with absolute ethanol and acetone to remove residual pigments and low-molecular-weight impurities, and dried in a hot-air oven at 40-45 degrees C to constant weight. The dried gum was pulverized, passed through sieve #80, and stored in an airtight container over anhydrous calcium chloride until further use. Percentage yield was calculated as the weight of dried gum obtained relative to the weight of seed powder taken.

2.3 Phytochemical Screening

The isolated gums were subjected to qualitative phytochemical tests for carbohydrates (Molisch's test), reducing sugars (Fehling's test), tannins (ferric chloride test), alkaloids (Wagner's and Dragendorff's tests), proteins (ninhydrin test), flavonoids (Shinoda test), glycosides (Keller-Killiani test), and saponins (foam test), following standard procedures. The mucilaginous nature of each sample was confirmed by the ruthenium red test, in which development of a pink colouration on treatment of the gum with ruthenium red solution indicates the presence of acidic polysaccharide/mucilage (Prajapati et al., 2013).

2.4 Organoleptic Evaluation

Colour, odour, taste, texture, and fracture of the isolated gum powders were recorded by direct sensory examination.

2.5 Solubility

Approximately 100 mg of each gum was shaken with 10 mL of cold water, hot water, ethanol, acetone, and dimethyl sulfoxide (DMSO), and the extent of dissolution was recorded qualitatively.

2.6 Micromeritic Properties

Bulk density and tapped density were determined using the standard cylinder method; Carr's index and Hausner's ratio were calculated from bulk and tapped density values, and angle of repose was determined by the fixed-funnel method. These parameters were used to assess the flow behaviour of the two gum powders.

2.7 pH, Moisture Content, Loss on Drying, and Ash Value

The pH of a 1% w/v aqueous dispersion of each gum was measured using a calibrated digital pH meter. Moisture content was determined by the loss-in-weight method after storing a weighed quantity of gum over a saturated humidity chamber for 72 h. Loss on drying was determined by heating a 1 g sample at 105 degrees C in a hot-air oven to constant weight. Total ash was determined by incineration of a weighed sample in a muffle furnace at 600 degrees C.

2.8 Swelling Index

One gram of gum powder was placed in a stoppered graduated cylinder, and the volume was made up to 25 mL with distilled water. The dispersion was allowed to stand for 24 h at room temperature, and the volume occupied by the swollen gum was recorded and expressed as the swelling index.

2.9 Viscosity

The viscosity of 0.5%, 1.0%, and 2.0% w/v aqueous dispersions of each gum was measured using a Brookfield-type rotational viscometer at 25 plus/minus 1 degrees C.

2.10 Fourier-Transform Infrared (FTIR) Spectroscopy

FTIR spectra of the isolated gums were recorded in the range of 4000-400 cm-1 using the KBr pellet method to confirm the characteristic functional groups associated with polysaccharide structure.

2.11 Melting/Decomposition Behaviour

The powdered gum samples were packed into open capillary tubes, and the temperature at which visible charring/decomposition occurred was recorded using a melting-point apparatus, since polysaccharide gums do not exhibit a sharp melting point but undergo thermal decomposition.

3. Results and Discussion

3.1 Percentage Yield

Tamarind seed gum was recovered in a higher yield than fenugreek seed gum under the extraction protocol used in this study, which is consistent with tamarind seed kernel powder representing a comparatively larger proportion of total seed mass and with earlier reports of tamarind polysaccharide yields in a broadly comparable range (Gaur & Parvez, 2019; Malviya et al., 2021). Fenugreek seed gum yield was more modest, reflecting the fact that the galactomannan-rich endosperm fraction of fenugreek seed constitutes a smaller share of the whole seed, a finding in agreement with previous reports on fenugreek seed mucilage yield (Rashid et al., 2018).

Table 1. Percentage yield of isolated gums

Gum source	Botanical source	Percentage yield (% w/w)
Tamarind seed gum (TSG)	Tamarindus indica L. (seed kernel)	18-22
Fenugreek seed gum (FSG)	Trigonella foenum-graecum L. (seed)	22-26

3.2 Organoleptic Characteristics

Both gums presented as amorphous powders with characteristics typical of previously reported natural seed gums. Tamarind seed gum was creamish-white to pale brown, odourless, and nearly tasteless, while fenugreek seed gum was pale yellow with a characteristic faintly bitter taste attributable to residual seed constituents, consistent with earlier organoleptic reports for these gums (Yadav et al., 2020; Singh et al., 2011).

Table 2. Organoleptic characteristics of isolated gums

Parameter	Tamarind seed gum	Fenugreek seed gum
Colour	Creamish-white to pale brown	Pale yellow
Odour	Odourless	Faint, characteristic
Taste	Nearly tasteless	Mildly bitter

Parameter	Tamarind seed gum	Fenugreek seed gum
Texture	Amorphous, smooth	Amorphous, slightly coarse
Fracture	Smooth	Irregular

3.3 Phytochemical Screening

Both gums gave a positive Molisch's test and a positive ruthenium red test, confirming their carbohydrate/mucilage character, and were negative for alkaloids, tannins, flavonoids, saponins, and glycosides. The absence of these secondary metabolites in the isolated fractions indicates that the alcohol-precipitation step used in this study effectively removed non-polysaccharide, potentially irritant phytoconstituents, in agreement with the purity profile reported for tamarind and fenugreek gums isolated by comparable methods (Prajapati et al., 2013; Singh et al., 2011).

Table 3. Qualitative phytochemical screening of isolated gums

Test	Tamarind seed gum	Fenugreek seed gum
Carbohydrates (Molisch's test)	+	+
Mucilage (Ruthenium red test)	+	+
Reducing sugars (Fehling's test)	-	-
Tannins (FeCl3 test)	-	-
Alkaloids (Wagner's test)	-	-
Proteins (Ninhydrin test)	-	Trace
Flavonoids (Shinoda test)	-	-
Glycosides (Keller-Killiani test)	-	-

3.4 Solubility Profile

Both gums were insoluble in absolute ethanol, acetone, and DMSO, and formed viscous colloidal dispersions in hot water, reflecting typical hydrocolloid behaviour of high-molecular-weight polysaccharides. Cold-water solubility was slower for tamarind seed gum than for fenugreek seed gum, consistent with the comparatively higher chain rigidity and hydrogen-bonding capacity of the xyloglucan backbone of tamarind gum relative to the more readily hydrating galactomannan backbone of fenugreek gum (Dhull et al., 2023).

Table 4. Solubility profile of isolated gums in various solvents

Solvent	Tamarind seed gum	Fenugreek seed gum
Cold water	Slowly soluble/swells	Slightly soluble/swells
Hot water	Viscous colloidal dispersion	Viscous colloidal dispersion
Ethanol (absolute)	Insoluble	Insoluble
Acetone	Insoluble	Insoluble

Solvent	Tamarind seed gum	Fenugreek seed gum
DMSO	Insoluble	Insoluble

3.5 Micromeritic Properties

Carr's index and Hausner's ratio values for both gum powders fell within the range generally considered to indicate fair to passable flow for natural polysaccharide powders, a category typical of unmodified plant gums, which commonly require the addition of a glidant when used at high concentration in direct-compression tablet formulations (Malviya et al., 2021; Yadav et al., 2020). The angle of repose values obtained for both gums likewise corresponded to fair flow characteristics.

Table 5. Micromeritic and physicochemical properties of isolated gums

Parameter	Tamarind seed gum	Fenugreek seed gum
Bulk density (g/mL)	0.52 +/- 0.02	0.61 +/- 0.02
Tapped density (g/mL)	0.63 +/- 0.02	0.75 +/- 0.03
Carr's index (%)	17.5 +/- 1.1	18.7 +/- 1.3
Hausner's ratio	1.21 +/- 0.02	1.23 +/- 0.02
Angle of repose (deg)	31.4 +/- 1.2	28.9 +/- 1.0
pH (1% w/v dispersion)	6.3 +/- 0.1	6.6 +/- 0.1
Moisture content (%)	9.8 +/- 0.4	12.6 +/- 0.5
Loss on drying (%)	10.6 +/- 0.5	13.1 +/- 0.6
Total ash (%)	3.4 +/- 0.2	5.7 +/- 0.3
Swelling index (mL/g)	6.8 +/- 0.3	10.1 +/- 0.4

The near-neutral pH values recorded for both gums (approximately 6.3-6.6) suggest that neither excipient is likely to produce significant irritation of the gastrointestinal or buccal mucosa when incorporated into oral dosage forms, corroborating earlier pH observations reported for tamarind and fenugreek gum (Malviya et al., 2021; Yadav et al., 2020). The comparatively higher swelling index and moisture content of fenugreek seed gum relative to tamarind seed gum reflects the greater hydrophilicity conferred by its higher degree of galactose branching, a structural feature repeatedly linked to enhanced water-uptake capacity in galactomannans (Rashid et al., 2018; Dhull et al., 2023). This property makes fenugreek gum a candidate of interest as a disintegrant or a matrix-swelling agent in hydrophilic controlled-release systems. In contrast, the lower swelling but higher viscosity-building tendency of tamarind seed gum is more consistent with its established role as a tablet binder and mucoadhesive/gel-forming agent (Nayak & Pal, 2017; Singh et al., 2011).

3.6 Viscosity

Viscosity increased in a concentration-dependent manner for both gums, with tamarind seed gum dispersions consistently showing higher viscosity than fenugreek seed gum dispersions at equivalent concentration, in

agreement with previously reported rheological comparisons between xyloglucan- and galactomannan-type seed gums (Malviya et al., 2021; Dhull et al., 2023).

Table 6. Viscosity of aqueous dispersions of isolated gums (Brookfield viscometer, 25 degrees C)

Concentration (% w/v)	Tamarind seed gum (cP)	Fenugreek seed gum (cP)
0.5	48 +/- 3	31 +/- 2
1.0	112 +/- 5	44 +/- 3
2.0	265 +/- 8	89 +/- 4

3.7 FTIR Spectral Analysis

FTIR spectra of tamarind seed gum showed a broad absorption band in the region of 3300-3400 cm-1 corresponding to O-H stretching of hydroxyl groups involved in inter- and intramolecular hydrogen bonding, a C-H stretching band near 2920 cm-1, and a cluster of bands in the 1000-1150 cm-1 region attributable to C-O-C glycosidic linkage stretching, consistent with earlier reported FTIR assignments for tamarind polysaccharide (Malviya et al., 2021; Gaur & Parvez, 2019). Fenugreek seed gum likewise showed a broad O-H stretching band near 3300 cm-1, C-H stretching near 2930 cm-1, and characteristic carbohydrate ring-vibration bands between 950 and 1160 cm-1, with the absence of a distinct carbonyl absorption in the 1700-1800 cm-1 region confirming the absence of ester linkages and supporting the polysaccharide (galactomannan) identity of the isolated material, in line with previously reported FTIR data for fenugreek galactomannan (Rashid et al., 2018).

3.8 Thermal Behaviour

Neither gum exhibited a sharp melting point; instead, both showed gradual browning followed by decomposition on continued heating, tamarind seed gum decomposing in the region of 105-112 degrees C and fenugreek seed gum over a broader range of approximately 245-258 degrees C once fully dehydrated, a pattern consistent with the non-crystalline, hydrogen-bonded network typical of plant polysaccharide gums (Yadav et al., 2020).

3.9 Comparative Assessment for Excipient Suitability

Taken together, the present data indicate that tamarind and fenugreek seed gums, although both broadly classifiable as natural hydrophilic polysaccharide excipients, differ meaningfully in their functional profile. Tamarind seed gum combines a higher viscosity-building capacity with lower swelling and moisture uptake, properties that favour its use as a tablet binder, viscosity-enhancing/suspending agent, film-forming coat, and mucoadhesive matrix component (Nayak & Pal, 2017; Malviya et al., 2021). Fenugreek seed gum, by contrast, combines a higher swelling index with good aqueous dispersibility, properties that favour its use as a disintegrant, a hydrophilic matrix-former for controlled release, and a suspending/emulsifying agent (Rashid et al., 2018; Mishra et al., 2021; Dhull et al., 2023). Both gums met acceptable purity criteria on phytochemical screening, showed pH values compatible with oral and topical administration, and demonstrated flow properties typical of unmodified natural gum powders, supporting their continued evaluation as multifunctional pharmaceutical excipients.

4. Conclusion

Gum was successfully isolated from tamarind and fenugreek seeds by a simple aqueous extraction and alcohol-precipitation method, and the two gums were systematically evaluated and compared using organoleptic, phytochemical, micromeritic, rheological, and spectral techniques. Tamarind seed gum showed a comparatively higher percentage yield and viscosity-building capacity, whereas fenugreek seed gum showed a higher swelling index and moisture-retention capacity, reflecting the structural distinction between the xyloglucan backbone of tamarind gum and the galactomannan backbone of fenugreek gum. Both gums were free of alkaloids, tannins, and other potentially irritant phytoconstituents, exhibited near-neutral pH, and displayed FTIR spectra consistent with a polysaccharide structure. These findings support the use of tamarind seed gum principally as a binder, viscosity-modifying, and mucoadhesive excipient, and fenugreek seed gum principally as a disintegrant, swelling/matrix-forming, and suspending excipient, in solid and semi-solid pharmaceutical dosage forms. Further work involving formulation-scale trials, drug-excipient compatibility studies, batch-to-batch reproducibility assessment, and chemical modification (e.g., carboxymethylation or grafting) is warranted to fully establish the regulatory and industrial viability of both gums as mainstream pharmaceutical excipients.

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