

RESEARCH ARTICLE

Investigating Bael Fruit Gum Powder as Natural Polymer for Pharmaceutical Drug Delivery

Dipak P Mali^{1*}, Dhanashri R Patil², Ravina D Sutar³, Dinanath T Gaikwad³

¹Department of Pharmaceutical Quality Assurance, Krishna Institute of Pharmacy, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, Maharashtra, India.

²Department of Pharmaceutical Quality Assurance, Bharati Vidyapeeth College of Pharmacy, Kolhapur, Maharashtra, India.

³Department of Pharmaceutics, Bharati Vidyapeeth College of Pharmacy, Kolhapur, Maharashtra, India.

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ABSTRACT

Nowadays, the use of natural products is crucial in pharmaceuticals. Currently, natural products made with natural polymer offer various biomedical applications. The objective of the present research was to characterize the bael fruit gum (*Aegle marmelos L.*) as a natural polymer and investigate its potential in pharmaceutical drug delivery. Extraction of bael fruit gum was carried out by simple maceration technique. Further, the extract was subjected to different phytochemical analysis. The characterization part was studied with sophisticated techniques such as fourier-transform infrared (FTIR) and X-ray diffraction (XRD). Additionally, swelling and viscosity behavior were estimated as per the reported methods. Phytochemical analysis confirms the existence of major secondary metabolites like tannins, flavonoids, saponins, alkaloids, and triterpenoids. FTIR results showed identical peaks of phytochemicals, which confirmed the presence of identical functional groups. XRD study indicates that extract nature is amorphous. The swelling behavior and viscosity study resulted in the rheological performance at an optimum and desired level. In conclusion, this research indicates the potential of bael fruit gum as a natural polymer for pharmaceutical applications, contributing to the discovery of new natural products and promoting their industrial use.

Keywords: Bael fruit gum, Phytoconstituents, Swelling, Viscosity.

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INTRODUCTION

Limitations of synthetic polymers and safe application of natural polymers make sense and focus to research on natural polymers as well as their applications in several health domains. Natural polymers are sourced from Animalia and Plantae and include proteins, polyesters and polysaccharides. These polymers have been employed in a variety of human applications, like imaging, prostheses, medication delivery, and pharmaceutical excipients. A few of these polymers are naturally occurring in our food. It is well known that these polymers are identified by the biological setting and directed toward metabolic breakdown.¹ Due to the similarities between components of extracellular matrix (ECM) and natural polymers, these polymers may also prevent the stimulus of persistent immunological responses and toxicity, which are frequently found with synthetic polymers.^{2,3}

A polymer is a large molecule (macromolecule) made up of repeated structural monomers. Usually, these monomers are joined by covalent chemical bonds. Despite the availability

of both synthetic and natural polymers, natural polymers are widely and preferably used for medicinal reasons due to their affordability, accessibility, and lack of toxicity. With a few exclusions, natural polymers are also potentially biodegradable, chemically modifiable and biocompatible. Plant-derived substances can present a number of difficulties during the synthetic process since they must be created in small quantities and with complicated structural combinations that may vary depending on the location of the plants and other factors, like the season.⁴

O-glycosidic linkages link various monosaccharides to form polysaccharides. Their physical characteristics, including gelling potential, viscosity, solubility, and/or surface and interfacial qualities, depending on differences in the proportion of monosaccharides, chain morphologies, type and patterns of linkage and molecular weight. Polysaccharides are found in abundance throughout nature and the reason their origin in renewable resources, including microorganisms, animals and plants. Additionally, because polysaccharides carry out a

*Author for Correspondence: dipakpmali19@gmail.com

variety of physiological tasks, they offer a varied number of probable applications within regenerative medicine and tissue engineering fields.¹

Aegle marmelos L. (Genus: *Aegle*; family: Ructaceae) is known in India as Bael, which is found in the dry regions of South Asian countries. Indians have employed the herb *A. marmelos* (L.). The Indian traditional medical system (ayurveda) and diverse indigenous folk medicine utilize the plant's parts, including the leaves, bark, roots, fruits, and seeds, extensively to cure a variety of illnesses.⁵ This fruit is full of bioactive substances that are good for health, like vitamins, flavonoids, organic acids, polyphenols, and carotenes. Additionally, it has considerable amounts of vital minerals, namely copper, sodium, calcium, manganese, phosphorus, potassium, and iron. Various phytochemicals like auranol, aegeline, psoralen, lupeol, marmelide, marmelosin, etc. of bael fruit exhibit a variety of biological actions, including astringent, antibacterial, antemetic, antihelminthic, antispasmodic, and antiulcer.⁶

Bael fruit was reported to have seed oil (12.5%), riboflavin (0.005%), and tannin (0.985%).^{7,8} According to quantitative analysis, the bael fruit reported a high amount of fiber, and carbs. Bael fruit is a wonderful source of vitamins, proteins and minerals.⁹

The present study focuses in detail insight into the phytochemical analysis and characterization of bael fruit gum (BFG) powder (*A. marmelos* L.) to validate its medicinal potential for practice as a natural polymer in pharmaceutical drug delivery systems.

MATERIAL AND METHODS

BFG was collected from the local market. The acetone solvent was used for the extraction of BFG. The percent practical yield was decided by using the equation i.e.

$$\text{Percentage yield (\%)} = \frac{\text{Practical yield}}{\text{Theoretical yield}} \times 100$$

Physicochemical characterization of BFG was done.

Powder of bael fruit gum was collected from extraction and used to identify phytochemicals that are present in fruit extract. The phytochemical screening procedure as shown in Table 1.¹⁰⁻¹²

FTIR Spectroscopy

An IR spectrophotometer (Bruker) was used to record the fourier-transform infrared (FTIR) spectra of BFG. The dry powder that had been lyophilized was combined with potassium bromide (K-Br) and formed into pellets. The FTIR spectra were obtained at the wavelength range between 4000 and 400 cm^{-1} . Interpretation gives a clear idea about the functional groups that are present in bael fruit gum powder.¹³

Powder X-ray Diffraction

X-ray diffraction (XRD) was done to identify the nature of the bael fruit gum powder. A Siemens D5000 X-ray diffractometer (Make: Philips, Model: PW 3710) was used to examine the XRD patterns of the BFG Powder. A powder sample was

Table 1: Procedure for phytochemical screening

Constituents	Test	Procedure	Observation
Alkaloids	Wagner's reagent	Potassium iodide (2 gm) and iodine (1.27 gm) were liquified in distilled water. Two drops of this prepared solution were added to the sample filtrate.	Reddish brown precipitate
Cardiac glycoside	Legal test	Dissolve extract in pyridine then add NaOH and sodium nitroprusside are added alternatively.	Red colour
Tannins	Lead acetate test	1-mL of filtrate + 2-4 drops of lead acetate solution.	White precipitate
Triterp enoids	Salko waski reagent	Extract mixed with chloroform concentrated H_2SO_4 .	The chloroform layer emits red light, whereas the acid layer emits green light
Saponins	Foam test	1ml extract was diluted to 20 mL with distilled water and was shaken for 15 minutes in the graduate cylinder	Foam lasts for more than 15 seconds
Flavo noids	Shinoda test	Few fragments of Mg ribbon & conc. HCl is added to extract.	Pink color
Carboh ydrates	Molish test	Take 2 mL of extract, then add 2-3 drops of molish reagent	Violet ring observed

enclosed in rectangular aluminum cells where $\text{CuK}\alpha$ radiation was set as 1.54056 at 40 mA and 45 kV.¹⁴

Swelling Behaviour

The 10 mg of BFG powder was poured into distilled water, 0.1 N HCl, or phosphate buffer of different pH like 1.2, 6.8, or 7.4 and kept for 23 to 24 hours. To calculate the swelling index (SI), the following formula was used:

$$\text{Swelling Index} = \frac{W_f - W_i}{W_i}$$

Where, W_f is the weight of swollen material and W_i is the initial weight of the dry material.¹³

Viscosity

The 5.0% w/v dispersion of bael fruit gum powder was prepared and the viscosity was measured at shear rates between 10 and 100 rpm and at 23°C on Viscometer (LVDV-E). Spindle 2 was employed, and three minutes were given for the data to stabilize before the viscosity was recorded.¹⁴

Extraction of Bael Fruit Gum

Gum precipitation method was used for the extraction of BFG. Moderately ripe fruits of bael were collected from the *A. marmelos* tree. The translucent, viscous, amber-colored fluid was collected and labeled as BFG. A thick slurry was created when this gum was added to 2% v/v g-acetic acid

solution in a beaker, then it was heated in a water bath for 45 minutes with constant stirring and was stored overnight. To eliminate particles, the slurry was passed through muslin fabric. Then it was mixed with acetone (1:1) to precipitate the gum. The mixture was oven-dried at 50°C. Then the precipitate was ground into fine powder having a light brown color. The obtained gum was further refined by re-suspending and re-precipitating in water and with acetone, respectively. To create pure BFG powder, the gum was finally dialyzed and freeze-dried.¹⁵

RESULT AND DISCUSSION

BFG powder was whitish brown in color which had characteristics of odour and bitterness in taste. The extract powder was shown in Figure 1.

The percentage extractive yield of BFG was observed to be 21.24% by using acetone solvent.

Phytochemical Screening

Phytochemical screening of BFG powder shows the existence of various constituents, namely, reducing sugar, carbohydrates, tannins, gums, volatile oil, alkaloids, flavonoids, steroids,

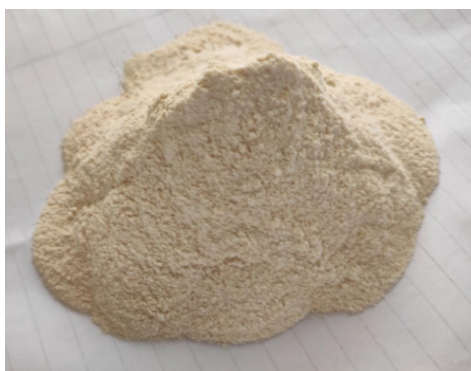


Figure 1: Extract of BFG powder

Table 2: Result of phytochemical test for an extract of bael fruit gum

Constituents	Test	Observation	Inference
Alkaloids	Wagner's reagent	Precipitate of reddish brown color	Alkaloids exist
Cardiac glycoside	Legal test	Pink or red color	Cardiac glycoside present
Tannins	Lead acetate test	Precipitate of white color	Tannin present
Triterpenoids	Salkowski reagent	The chloroform layer emits red light whereas the acid layer emits green light	Triterpenoids present
Saponins	Foam test	Foam lasts for more than 15 sec	Saponins present
Flavonoids	Shinoda test	Pink color	Flavonoids present
Carbohydrates	Molish test	Violet ring observed	Carbohydrates present

protein, and phenolic compounds. Results of this screening are shown in Table 2 and Figure 2.¹⁰

The most crucial elements of BFG were polyphenols and flavonoids, including carotenoids, polysaccharides, alkaloids and coumarins that had the capacity to boost its antioxidant activity. A variety of alkaloids were present in the bael fruit gum, including marmeline, O-isopentenylhalfordinol, fragrine (C₁₃H₁₁O₃N), O-methylhalfordinine, marmin, aegeline, dictamine, aegeline, N-2-[4-(3,3-dimethylallyl oxy)phenyl] ethyl cinnamide, 3- marmesin, N-4 aegeline and marmelosin are the main alkaloids found in the bael fruit gum. Bael fruit gum contains up to 9% phenolic compounds and tannins.¹⁶

FTIR Spectroscopy

FTIR of bael fruit gum was shown in Figure 3 which has functional groups peak appears at 3405 corresponds to OH stretching, peaks observed at 2923.43 indicated that the C-H stretching of alkane and 1639.20 corresponds to C-C stretching of alkane, at 1418.51 contains carboxylate anion (COO) 1229.18 shows C-N stretching, 1077.43 shows C-O-C stretching of ether, 889.24 shows = CH group of alkene. These peaks are identical to alkaloids and flavanoids.

Powder X-ray Diffraction

XRD pattern of BFG is shown in Figure 4. The blended features peaks of bael fruit extract powder in XRD analysis demonstrate the gum's amorphous nature. Peaks at roughly 20° and 2 theta may be seen in the sample.

Swelling Behaviour

The swelling properties of BFG were examined in water, 0.1 N HCl and in varying pH values of 1.2, 6.8, and 7.4 of the

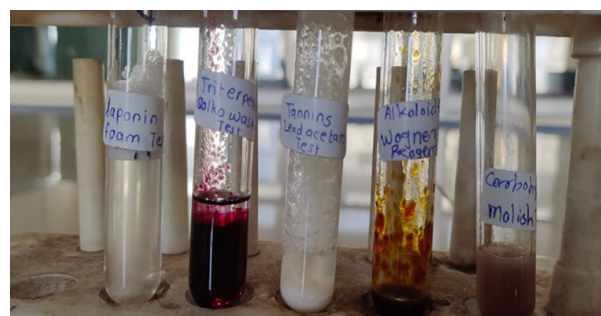


Figure 2: Phytochemical screening of bael fruit gum powder

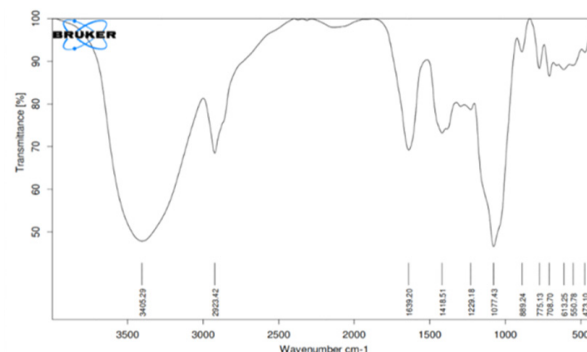


Figure 3: FTIR spectra of bael fruit gum powder

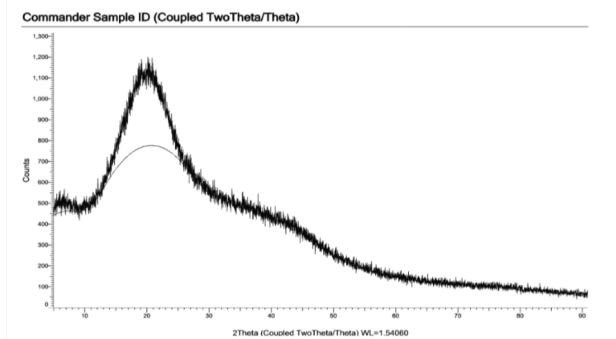


Figure 4: XRD of bael fruit gum powder

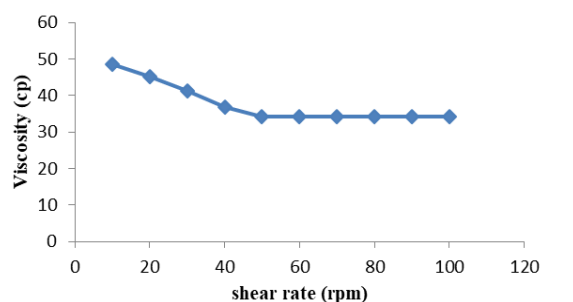


Figure 5: Viscosity (cp) of BFG vs. shear rate (rpm)

Table 3: Swelling behavior data

S. No.	Solvent	Swelling index
1	Water	4.17 ± 0.016
2	pH 7.4	4.07 ± 0.012
3	pH 6.8	3.82 ± 0.02
4	pH 1.2	3.09 ± 0.008
5	0.1N HCl	1.08 ± 0.012

phosphate buffer solutions and were as indicated in Table 3. The following sequence of events was seen when BFG swelled in various media: pH levels of water, 7.4, 6.8, 1.2, and 0.1 N HCl. It was undeniably established that acidic pH reduces swelling. Alkaline swelling was observed to be very high. The high SI of BFG indicated the existence of a high galactose unit content.

Viscosity

The viscosity versus shear rate profile of the bael fruit gum solution is shown in Figure 5. With the increasing shear rate, there were noticeable decreases in the viscosity of the BFG solution. It was clearly observed that as the rate of shear rises from 10 to 50 rpm, the viscosity drops quickly from 48.45 to 34.20 cp. When this rate was altered and kept in the range of 50 to 100 rpm, the BFG solution's viscosity did not further decrease/changed.

CONCLUSION

The study confirms that bael fruit gum extract powder contains a diverse range of phytochemicals, including cardiac

glycosides, alkaloids, flavonoids, triterpenoids, carbohydrates, tannins, and saponins, making it a promising candidate for pharmaceutical applications. FTIR analysis provided insights into the functional groups present in these phytoconstituents, while PXRD results indicated that the extract powder is amorphous, a desirable property for drug delivery systems due to its potential for enhanced solubility and bioavailability.

Swelling behavior analysis showed that an increase in pH leads to increased swelling, suggesting that bael fruit gum could be effectively used in controlled drug-release formulations that respond to pH variations in the gastrointestinal tract. Additionally, the viscosity of bael fruit gum powder decreases with increasing shear stress, indicating good flow properties essential for pharmaceutical processing and formulation.

These results offer an understanding of the physicochemical properties of bael fruit gum powder, demonstrating its potential as a natural polymer in pharmaceutical drug delivery. The study offers fundamental information that could guide further research and development, promoting the use of bael fruit gum in creating innovative, effective, and natural drug delivery systems.

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