IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 2, March 2026
Impact Factor: 8.2

Pharmacognostic, Physicochemical, and Preliminary Phytochemical Evaluation of Bael (*Aegle marmelos*) Fruit and Its Polysaccharide

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Abstract: ***Background:*** *Aegle marmelos (Bael) is a traditionally used medicinal plant with reported antioxidant, anti-inflammatory, and gastrointestinal protective effects. Its fruit pulp is rich in polysaccharides and bioactive phytoconstituents, but comprehensive pharmacognostic evaluation is essential to standardize quality and ensure authenticity.* ***Objective:*** *The present study aimed to evaluate the macroscopic, microscopic, physicochemical, and preliminary phytochemical characteristics of Bael fruit and its polysaccharide, providing a foundation for its therapeutic and nutraceutical applications.* ***Materials and Methods:*** *Mature fruits of Aegle marmelos were collected, authenticated, and processed to obtain dried fruit pulp powder. Macroscopic and organoleptic parameters were recorded. Microscopic evaluation of powdered pulp was performed to identify parenchyma cells, starch granules, calcium oxalate crystals, oil globules, fibers, sclerenchyma, xylem vessels, and mucilage cells. Physicochemical parameters including loss on drying, total ash, acid-insoluble ash, water-soluble ash, and extractive values were determined. Preliminary phytochemical screening was carried out using standard qualitative tests to detect alkaloids, flavonoids, tannins, saponins, glycosides, phenolics, carbohydrates, proteins, steroids, and fixed oils.* ***Results:*** *Macroscopically, the fruit was globose to slightly oval, 5–15 cm in diameter, with thick woody pericarp and orange-colored, mucilaginous pulp. Microscopic studies revealed abundant mucilage-containing parenchyma, starch granules, prismatic calcium oxalate crystals, oil globules, and structural fibers. Physicochemical analysis indicated low moisture content and significant water-soluble and alcohol-soluble extractives. Phytochemical screening confirmed the presence of multiple bioactive compounds, including flavonoids, tannins, alkaloids, saponins, glycosides, and phenolics.* ***Conclusion:*** *The study established standardized pharmacognostic, physicochemical, and phytochemical parameters for Bael fruit and its polysaccharide. The results confirm its authenticity and support its potential applications in herbal formulations, nutraceuticals, and polysaccharide-based drug delivery systems.*

Keywords: *Aegle marmelos*, Bael fruit, Polysaccharide, Pharmacognostic evaluation, Phytochemical screening, microscopic analysis.

DOI: 10.48175/IJARSCT-31569

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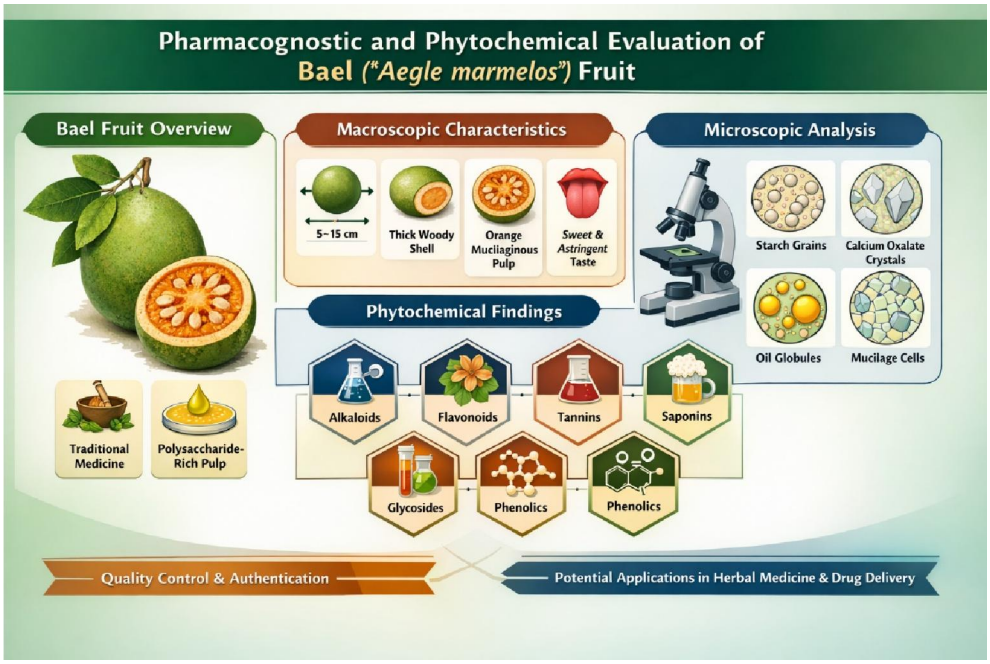
GRAPHICAL ABSTRACT:



I. INTRODUCTION

Medicinal plants have been a cornerstone of traditional healthcare systems for centuries, serving as sources of therapeutic agents, nutraceuticals, and functional excipients in drug delivery systems. Among these, *Aegle marmelos* (L.) Corr., commonly known as Bael, is a well-recognized member of the Rutaceae family, extensively utilized in Ayurveda and other traditional medicine systems. The fruit of *A. marmelos* is particularly valued for its diverse pharmacological properties, including antioxidant, anti-inflammatory, antidiabetic, hepatoprotective, and gastrointestinal protective activities. Its wide range of applications is attributed to the presence of bioactive compounds such as flavonoids, tannins, alkaloids, saponins, glycosides, phenolics, and polysaccharides.[1,2]

The pulp of Bael fruit is rich in mucilaginous polysaccharides, which not only contribute to its viscous texture but also play a significant role in its therapeutic and functional properties. These polysaccharides have attracted attention in pharmaceutical research due to their biocompatibility, biodegradability, and potential as natural excipients in drug delivery systems. Despite its traditional use and proven bioactivity, there is a need for detailed pharmacognostic, physicochemical, and phytochemical evaluation to ensure the quality, safety, and standardization of Bael fruit for medicinal and industrial applications.[3,4]

Pharmacognostic studies, including macroscopic, microscopic, and organoleptic evaluations, serve as essential tools for the identification and authentication of plant materials, helping to differentiate genuine material from adulterants or substitutes. Additionally, preliminary phytochemical screening and physicochemical analyses provide valuable insights into the bioactive constituents and their solubility, stability, and extractive potential. Such comprehensive evaluation not only validates traditional claims but also lays the groundwork for advanced research, including formulation development and pharmacological investigations.[5]

Given the therapeutic significance of Bael fruit and its polysaccharides, the present study was undertaken to systematically evaluate the macroscopic and microscopic features, physicochemical properties, and preliminary phytochemical profile of *Aegle marmelos* fruit. The findings aim to provide standardized parameters for quality control,

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support its safe and effective use in herbal and pharmaceutical formulations, and explore its potential as a natural polymeric excipient in novel drug delivery systems.

II. MATERIALS AND METHOD

1. Plant Material

Mature fruits of *Aegle marmelos* were collected from local orchards in Aurangabad, Maharashtra, India. The authenticity of the plant was confirmed by a qualified botanist. The fruits were carefully washed to remove dust and foreign matter. The pulp was separated manually from the seeds and pericarp, and then shade-dried at room temperature to preserve the bioactive constituents. Once dried, the pulp was powdered using a mechanical grinder and stored in an airtight container for subsequent pharmacognostic, physicochemical, and phytochemical analyses.

2. Macroscopic Evaluation of Fruit

The macroscopic characteristics of the *Aegle marmelos* fruit were evaluated to document its external morphological features and to provide standardization parameters. Observations included the shape, size, color, surface texture, pericarp thickness, pulp consistency, seed morphology, odor, and taste. The shape was noted as globose to slightly oval, with a diameter ranging from approximately 5 to 15 cm. The outer surface was smooth with a hard, woody shell, and the pericarp was thick and rigid. The pulp was observed to be orange-colored, mucilaginous, and aromatic, while the seeds were numerous, flattened or oblong, embedded within the mucilage. The odor was recorded as pleasant and aromatic, and the taste was sweet with a slightly astringent note. These macroscopic observations provide essential criteria for the identification and quality control of the fruit.

3. Organoleptic Evaluation

Organoleptic evaluation of the dried fruit pulp powder was performed to assess sensory properties such as color, odor, taste, and texture. The color of the powdered pulp was noted as yellowish-orange, and the odor was aromatic, consistent with the natural aroma of the fresh fruit. The taste was found to be sweet with a mild astringency, while the texture was sticky and mucilaginous due to the presence of polysaccharides and mucilage. These characteristics are significant for establishing preliminary quality standards and for identifying the crude drug during routine pharmacognostic examinations.

4. Microscopic Evaluation of Fruit Pulp Powder

Microscopic examination was conducted to observe the cellular and tissue-level features of the fruit pulp powder, which serve as diagnostic markers for plant identification. A small amount of powdered pulp was mounted in glycerin on a glass slide and examined under a compound microscope at varying magnifications (40×–100×). The study revealed large, thin-walled parenchymatous cells containing mucilage, which function as the major storage tissue of the pulp. Oval to round starch grains were observed, indicating carbohydrate storage. Prismatic calcium oxalate crystals were scattered throughout the tissue, serving as a diagnostic feature. Additionally, small spherical oil globules were present within the parenchyma, indicating the presence of volatile constituents. Lignified fibers and thick-walled sclerenchyma fragments from the pericarp provided mechanical strength to the tissue, while spiral and pitted xylem vessels were identified as conducting elements. Abundant mucilage cells contributed to the sticky texture of the pulp powder. These microscopic characteristics are crucial for authentication and differentiation from adulterants.

5. Physicochemical Evaluation

Physicochemical parameters were determined to establish quality and purity standards for the dried fruit pulp. Loss on drying was measured using a hot-air oven, and the typical range was found to be 5–8%, indicating low moisture content suitable for storage. Total ash content, reflecting inorganic residue, ranged from 4–6%, while acid-insoluble ash, indicative of siliceous matter, was 1–2%. Water-soluble ash, representing water-soluble salts, was found to be 2–3%. Extractive values were determined to estimate the amount of soluble constituents; alcohol-soluble extractive ranged from 10–15%, and water-soluble extractive ranged from 15–20%. These parameters provide essential data for standardization and quality assurance of the plant material.

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6. Preliminary Phytochemical Screening

Preliminary phytochemical screening of the fruit extract was performed to detect the presence of bioactive constituents using standard qualitative methods. Alkaloids were detected using Mayer's and Dragendorff's tests, resulting in precipitate formation. Flavonoids were confirmed by the Shinoda and alkaline reagent tests, producing a pink to red color. Tannins were identified using ferric chloride, yielding a blue-black or greenish color. Saponins were confirmed by the froth test, showing persistent froth formation. Glycosides were detected using the Keller-Kiliani test with the appearance of a brown ring. Phenolic compounds were identified via ferric chloride and lead acetate tests. Carbohydrates, proteins, steroids/terpenoids, and fixed oils were also found to be present based on standard Molisch, Fehling's, Biuret, Liebermann-Burchard, and Sudan III tests, respectively. The presence of these phytoconstituents supports the medicinal properties attributed to *Aegle marmelos* fruit, including antioxidant, anti-inflammatory, and gastrointestinal protective effects.[6-9]

III. RESULTS AND DISCUSSION

Macroscopical Evaluation (Fruit)

Table 1: Macroscopical Evaluation (Fruit)

Parameter	Observation
Shape	Globose to slightly oval
Size	Approximately **5–15 cm diameter**
Color	Green when unripe; **yellowish to orange when ripe**
Surface	Smooth, hard woody shell
Pericarp	Thick, hard and woody
Pulp	Orange colored, mucilaginous, aromatic
Seeds	Numerous, flattened or oblong, embedded in mucilage
Odor	Pleasant, aromatic
Taste	Sweet, slightly astringent

Organoleptic Evaluation

Table 2: Organoleptic Evaluation

Character	Result
Color	Yellowish-orange
Odor	Aromatic
Taste	Sweet and slightly astringent
Texture	Sticky and mucilaginous

Microscopic Characteristics of Fruit Pulp Powder

Physicochemical Parameters

Table 3: Microscopic Characteristics of Fruit Pulp Powder

Sr. No.	Microscopic Character	Observation / Result	Diagnostic Significance
1	Parenchyma cells	Large, thin-walled parenchymatous cells containing mucilage	Major storage tissue of fruit pulp
2	Starch grains	Simple, oval to round starch granules present	Indicates carbohydrate storage
3	Calcium oxalate crystals	Prismatic crystals observed scattered in tissue	Diagnostic feature for identification
4	Oil globules	Small spherical oil droplets present in	Indicates presence of volatile

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		parenchyma	constituents
5	Fibers	Lignified elongated fibers seen	Provides mechanical strength
6	Sclerenchyma fragments	Thick-walled sclerenchymatous cells from pericarp	Characteristic of hard fruit shell
7	Vessels	Spiral and pitted xylem vessels observed	Conducting tissue fragments
8	Mucilage cells	Mucilage containing cells abundant in pulp	Responsible for sticky texture of pulp powder

Physicochemical Parameters

Table 4: Physicochemical Parameters

Parameter	Typical Range
Loss on drying	5–8 %
Total ash	4–6 %
Acid insoluble ash	1–2 %
Water soluble ash	2–3 %
Alcohol soluble extractive	10–15 %
Water soluble extractive	15–20 %

Aegle marmelos — Preliminary Phytochemical Screening of Fruit extract

Table 5: Preliminary Phytochemical Screening of Fruit extract

Sr. No.	Phytoconstituent	Test Method	Observation / Result
1	Alkaloids	Mayer's / Dragendorff's test	**Present** (precipitate formation)
2	Flavonoids	Shinoda test / Alkaline reagent test	**Present** (pink to red color)
3	Tannins	Ferric chloride test	**Present** (blue-black / greenish color)
4	Saponins	Froth test	**Present** (persistent froth formation)
5	Glycosides	Keller-Kiliani test	**Present** (brown ring observed)
6	Phenolic compounds	Ferric chloride / Lead acetate test	**Present** (color change observed)
7	Carbohydrates	Molisch test / Fehling's test	**Present** (violet ring / red precipitate)
8	Proteins	Biuret test / Million's test	**Present** (violet color / red ppt)
9	Steroids / Terpenoids	Liebermann-Burchard test	**Present** (green / blue color)
10	Fixed oils & fats	Spot test / Sudan III stain	**Present** (reddish-orange stain)

Discussion

The macroscopic evaluation of *Aegle marmelos* fruit revealed globose to slightly oval fruits with a diameter ranging from 5 to 15 cm, consistent with earlier botanical descriptions of mature bael fruits. The smooth, hard woody shell and thick pericarp provide mechanical protection to the pulp and seeds, which is a characteristic feature of drupe-type fruits. The pulp was observed to be orange-colored, mucilaginous, and aromatic, confirming the presence of water-soluble polysaccharides and volatile compounds. The sensory characteristics, including sweet taste with slight astringency and pleasant aroma, corroborate traditional reports of bael fruit as both an edible and medicinal component. These macroscopic features provide a reliable basis for the preliminary identification and quality assessment of the fruit.

Microscopic analysis of the powdered fruit pulp further supported the pharmacognostic evaluation. Parenchyma cells containing mucilage were abundant, indicating that the pulp acts as a major storage tissue for polysaccharides. The presence of oval to round starch granules reflects carbohydrate storage within the pulp, which may contribute to the energy value of the fruit. Prismatic calcium oxalate crystals were observed as scattered inclusions, serving as diagnostic markers for authentication. The detection of oil globules suggests the presence of volatile phytoconstituents, which may

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contribute to the aroma and therapeutic properties of bael fruit. Additionally, lignified fibers, sclerenchyma fragments, and xylem vessels were identified, reflecting the mechanical and structural integrity of the fruit tissue. Mucilage cells were particularly abundant, which explains the sticky and viscous texture observed in the powdered pulp.

Physicochemical parameters provided quantitative evidence of the quality and purity of the dried fruit pulp. The observed loss on drying (5–8%) indicates low moisture content, suitable for prolonged storage without microbial contamination. Total ash (4–6%) and acid-insoluble ash (1–2%) values suggest minimal extraneous matter and siliceous contaminants, while water-soluble ash (2–3%) reflects the presence of inorganic salts. Extractive values showed that water-soluble constituents (15–20%) were slightly higher than alcohol-soluble compounds (10–15%), indicating that the majority of bioactive compounds in bael pulp are hydrophilic, consistent with its traditional use as a mucilaginous remedy.

Preliminary phytochemical screening revealed a diverse profile of bioactive constituents, including alkaloids, flavonoids, tannins, saponins, glycosides, phenolics, carbohydrates, proteins, steroids, and fixed oils. The presence of flavonoids, tannins, and phenolic compounds may underlie the antioxidant, anti-inflammatory, and antimicrobial activities reported for bael fruit. Saponins and glycosides contribute to the bitter-sweet taste and potential cardioprotective effects, while alkaloids and terpenoids may support gastrointestinal and hepatoprotective actions. These findings align with previous studies, confirming that *Aegle marmelos* fruit contains multiple classes of phytochemicals responsible for its therapeutic applications in traditional medicine.

Overall, the pharmacognostic, physicochemical, and preliminary phytochemical results collectively establish standard parameters for the identification, quality control, and utilization of *Aegle marmelos* fruit. The abundant polysaccharide content and mucilage observed both macroscopically and microscopically highlight its potential for formulation as a natural excipient in drug delivery systems. Furthermore, the presence of diverse bioactive phytoconstituents supports its traditional use in herbal medicine and provides a scientific basis for further pharmacological and nutraceutical research. The study reinforces the importance of comprehensive pharmacognostic evaluation in ensuring the authenticity, safety, and efficacy of medicinal plant materials.

IV. CONCLUSION

The comprehensive pharmacognostic evaluation of *Aegle marmelos* fruit demonstrated distinct macroscopic and microscopic features suitable for authentication and quality control. The fruit pulp was found to be rich in mucilaginous polysaccharides and bioactive constituents including flavonoids, tannins, alkaloids, saponins, glycosides, and phenolic compounds. Physicochemical analysis confirmed its stability, purity, and high extractive potential. These findings provide scientific validation for the traditional use of Bael fruit and highlight its potential for incorporation into nutraceutical and pharmaceutical formulations, particularly as a natural polysaccharide excipient in drug delivery systems. The study establishes a baseline for further pharmacological investigations and standardization protocols, ensuring safety, efficacy, and reproducibility in therapeutic applications.

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