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Review Article

A Comprehensive Review on the Phytochemistry, Traditional Uses and Pharmacological Activities of Aegle Marmelos: Current Evidence and Future Perspectives

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ABSTRACT

Aegle marmelos (L.) Correa (Rutaceae), commonly known as bael, is a medicinally important tree widely distributed across the Indian subcontinent and Southeast Asia. Almost every plant part has been used in Ayurvedic, Siddha and Unani medicine. This review systematically examines the botanical profile, ethnomedicinal uses, phytochemical composition and experimental pharmacological evidence for *A. marmelos*. Major bioactive classes include alkaloids (aegeline, skimmianine), coumarins (marmelosin, imperatorin, marmin, and marmesin), flavonoids (rutin, quercetin), phenolic acids and terpenoids. Preclinical studies demonstrate antidiabetic, antioxidant, antidiarrhoeal, anti-inflammatory, hepatoprotective, antidepressant, and antihyperlipidaemic, antimicrobial and antifungal activities. Mechanistic insights implicate inhibition of carbohydrate-digesting enzymes, enhancement of endogenous antioxidant defences, modulation of inflammatory pathways and monoaminergic neurotransmission. Despite robust preclinical data, high-quality clinical trials and standardised phytopharmaceutical development remain limited. This review synthesises current evidence, identifies research gaps and outlines future directions for the translational development of *A. marmelos*-based therapeutics.

Keywords: Aegle marmelos; Bael; Phytochemistry; Traditional medicine; Pharmacological activity; Coumarins; Antidiabetic**ARTICLE INFO:** Received 16 Feb 2026; Review Complete 25 April 2026; Accepted 27 May 2026; Available online 15 Oct. 2026**Cite this article as:**Raval S, Patel D, Dalmati P, Prasad P, Chandel R, A comprehensive review on the phytochemistry, traditional uses and pharmacological activities of Aegle marmelos: current evidence and future perspectives, Asian Journal of Pharmaceutical Research and Development. 2026; 14(5): 55-59 DOI: <http://dx.doi.org/10.22270/ajprd.v14i5.1869>

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INTRODUCTION

Aegle marmelos (L.) Correa, popularly known as bael, is a spiny deciduous tree of the family Rutaceae indigenous to the Indian subcontinent and also occurring in Myanmar, Pakistan, Bangladesh and parts of Southeast Asia. Ancient Ayurvedic literature, including the Charaka Samhita (c. 1500 B.C.), ranks bael among the most valued medicinal plants of the region [1]. The tree holds religious significance in Hinduism and is commonly offered to Lord Shiva; it is therefore also called “Shiva duma”.

More than one hundred secondary metabolites—phenols, flavonoids, alkaloids, cardiac glycosides, saponins, terpenoids, steroids and tannins—have been reported from various plant parts. These constituents underpin a broad spectrum of biological activities relevant to chronic

diseases, including diabetes, cardiovascular disorders, gastrointestinal ailments, inflammation and microbial infections. Traditional preparations of fruit, leaves, bark and roots continue to be used for diarrhoea, dysentery, diabetes, fever, respiratory complaints and skin conditions.

Although numerous experimental studies support the ethnopharmacological claims, the literature remains fragmented. A critical synthesis that integrates phytochemistry with mechanistic pharmacology and translational potential is therefore needed. The objectives of the present review are: (i) to summarise the botanical and ethnomedicinal profile of *A. marmelos*; (ii) to catalogue the principal phytochemical constituents; (iii) to evaluate the experimental evidence for major pharmacological activities together with proposed

mechanisms of action; and (iv) to identify knowledge gaps and future research priorities.

Literature Search Strategy

A comprehensive literature search was conducted using Pub Med/MEDLINE, Scopus, Web of Science, ScienceDirect, Google Scholar and relevant Ayurvedic textual sources up to 2025. Search terms included combinations of “*Aegle marmelos*”, “bael”, “bilva”, “phytochemistry”, “pharmacological activity”, “antidiabetic”, “antioxidant”, “anti-inflammatory”, “hepatoprotective”, “aegeline” and “marmelosin”.

Only peer-reviewed original research articles, systematic reviews and authoritative ethnobotanical reports published in English were considered. In-vitro, in-vivo and limited clinical studies were included. Duplicate records, conference abstracts without full data and studies lacking adequate experimental detail were excluded. Reference lists of key papers were hand-searched to identify additional relevant publications.

Taxonomy and morphological description

Taxonomic classification

The accepted taxonomic position of the species is summarised in Table 1.

Table 1: Taxonomic classification of *Aegle marmelos*.

Rank	Name
Botanical name	<i>Aegle marmelos</i> (L.) Correa
Kingdom	Plantae
Division	Magnoliophyta
Order	Sapindales
Family	Rutaceae
Genus	<i>Aegle</i>
Species	<i>A. marmelos</i>



Figure 1: *Aegle marmelos* [3]

Morphological features

A. marmelos is a medium-sized deciduous armed tree reaching 6–15 m in height and bearing sharp straight spines. Key morphological characters are presented in Table 2.

Table 2: Morphological description of the principal plant parts.

Part	Description
Plant	Medium-sized deciduous armed tree, 6–15 m tall, with sharp straight spines.
Leaves	Mainly trifoliate, alternate, exstipulate; leaflets ovate-lanceolate, 4–10 cm long, coriaceous; aromatic when crushed.
Bark	Light grey to pale brown, rough, with longitudinal fissures.
Root	Light brown to greyish.
Flowers	Bisexual, actinomorphic, greenish-white to pale yellow.
Fruit	Berry 5–10 cm in diameter; green when unripe, turning yellow on ripening.

Distribution and vernacular names

A. marmelos is a subtropical species occurring up to approximately 1 200 m above sea level. It thrives in dry woodlands on plains and hills and is distributed throughout India, Sri Lanka, Myanmar, Pakistan, Bangladesh, Nepal, China, Vietnam, Laos, Cambodia, Thailand, Indonesia, Malaysia, the Philippines, Java and Fiji. Within India it ranges from the sub-Himalayan tract eastwards to West Bengal and is present in nearly every state [2]. Vernacular names are listed in Table 3.

Table 3: Vernacular names of *Aegle marmelos*.

Language	Common name(s)
Sanskrit	Shree phal, Bilva, Bilwa
English	Wood apple, Bengal quince, golden apple
Hindi	Beel, Belpaat, Belphal
Gujarati	Billi, Bilva
Tamil	Vilvam, Kuvilam
Telugu	Maredu, Bilvamu

Traditional uses

In Ayurveda, Siddha and Unani medicine, nearly every part of *A. marmelos* is utilised. The mature fruit is employed as a digestive tonic and mild laxative, while the unripe fruit is a classical remedy for diarrhoea and dysentery. Bael is classified as a coolant (sheetavirya) and is recommended for pitta-related gastrointestinal disorders. A sherbet prepared

from the ripe pulp is a traditional summer beverage used to counteract heat exhaustion and dehydration.

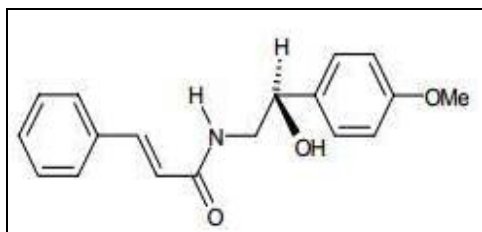
Leaf extracts have been used for centuries as a hypoglycaemic agent. Crushed leaves are applied as poultices for wounds and skin infections. Bark and root decoctions are administered for intermittent fevers and joint pain. Seeds possess anthelmintic properties, and boiled roots are given for asthma and

bronchitis because of their expectorant action. Fruit and leaf preparations are also regarded as cardiogenic.

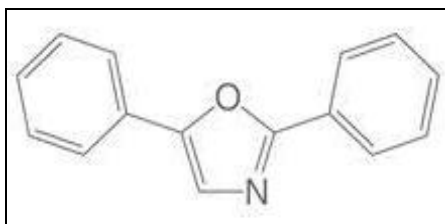
Phytochemistry

Phytochemical investigations have identified a diverse array of secondary metabolites. The principal classes and

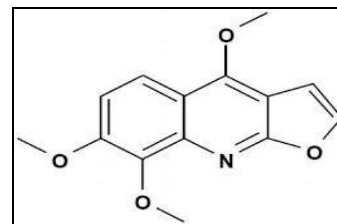
representative compounds are summarised in Table 4 [3]. Coumarins (especially marmelosin) and the alkaloid aegeline are frequently linked to its pharmacological effects.



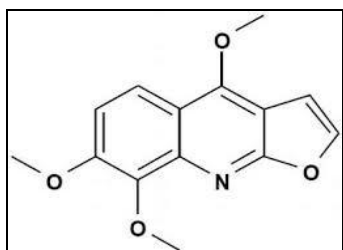
Aegeline



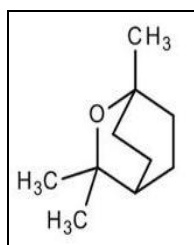
Aeglemarmelosine



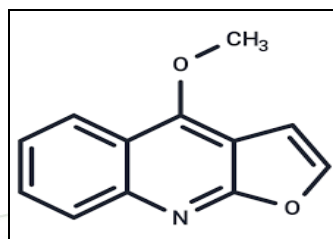
Skimmianine



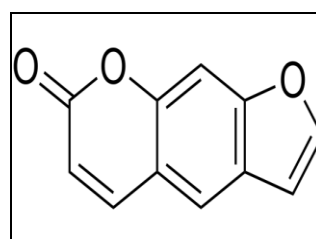
Cineol



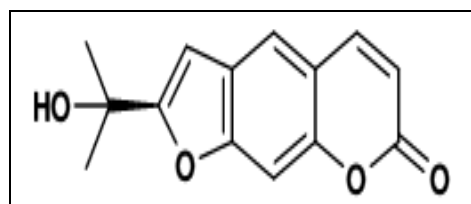
Imperatorin



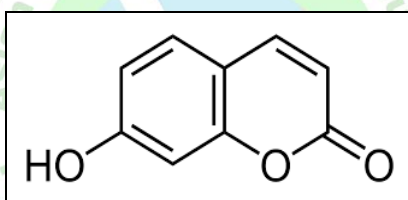
Eugenol



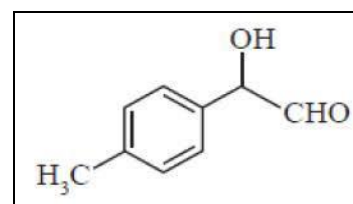
Psoralen



Diacetamine



Marmesin



Umbelliferon p-cymene

Table 4: Major phytochemical classes and representative constituents of *Aegle marmelos*.

No.	Class	Representative compounds
1	Alkaloids	Aegeline, skimmianine, diacetamine, fragrine
2	Coumarins	Marmelosin, imperatorin, marmin, marmesinin, psoralen, umbelliferon, Marmesin
3	Phenolic acids	Gallic acid, caffeic acid, ferulic acid
4	Flavonoids	Rutin, quercetin, kaempferol
5	Terpenoids	Lupeol, cineole, citral, citronellal, p-cymene
6	Others	Eugenol, aegelin

Pharmacological activities

Antidiabetic activity

Multiple studies support the traditional antidiabetic use of *A. marmelos*. Aqueous seed extract (250 mg/kg) produced significant hypoglycaemic and antihyperglycaemic effects in diabetic and non-diabetic rats, improving glucose tolerance and reducing urine sugar and lipid abnormalities after 14 days of treatment [4]. Fruit and leaf extracts inhibit α -amylase and α -glucosidase, thereby delaying carbohydrate digestion and attenuating post-prandial

hyperglycaemia. Coumarins such as marmelosin, Marmesin and Aegeline display favourable binding affinities to these enzymes in molecular-docking studies and also interact with DPP-4 catalytic residues. Additional proposed mechanisms include stimulation of insulin secretion, enhancement of peripheral glucose uptake via GLUT-4 and PPAR- γ pathways, free-radical scavenging and β -cell protection [5,6].

Antioxidant activity

Methanolic leaf extract exhibits potent free-radical scavenging activity and protects against carbon-

tetrachloride-induced hepatic oxidative stress. The extract lowers serum ALT, AST and ALP, reduces lipid peroxidation and restores catalase, superoxide dismutase and glutathione levels [7]. Marmelosin itself shows an IC₅₀ of approximately 15.4 μ M in antioxidant assays. The antioxidant effect is largely attributed to phenolic and flavonoid constituents that act both by direct radical quenching and by up-regulation of endogenous defence systems.

Antidiarrheal activity

Leaf and unripe-fruit extracts reduce the frequency of defecation, intestinal transit and faecal output, delay the onset of diarrhoea and decrease the proportion of wet stools in experimental models. These findings validate the classical use of unripe Bael fruit in the management of diarrhoea and dysentery [8].

Anti-inflammatory activity

Aqueous root extract produced approximately 69 % inhibition of acute inflammation relative to indomethacin, with milder activity in chronic models. Marmin, lupeol and other coumarins are considered the principal anti-inflammatory constituents, acting through modulation of pro-inflammatory mediators [9].

Hepatoprotective activity

Leaf powder and extracts normalise elevated ALP, bilirubin, SGOT and SGPT in carbon-tetrachloride-intoxicated rats, with efficacy comparable to the standard preparation Liv-52 and minimal observed toxicity at experimental doses [10]. The hepatoprotective effect is closely linked to the antioxidant capacity of the plant.

Antidepressant activity

Ethanol leaf extract produces dose-dependent antidepressant-like effects in the forced-swim and tail-suspension tests. The activity appears to be mediated via monoaminergic pathways involving serotonin, noradrenaline and dopamine [11].

Antihyperlipidemic activity

Aqueous, ethanolic and chloroform leaf extracts significantly reduce total cholesterol, triglycerides, LDL and VLDL while elevating HDL in Triton WR-1339-induced hyperlipidaemic rats. Alkaloids, flavonoids, tannins and phenolic compounds are implicated in the lipid-lowering action [12].

Antimicrobial and antifungal activities

Leaf essential oil, rich in α -phellandrene and α -pinene, exhibits broad-spectrum antibacterial and antifungal activity, including synergistic effects among its constituents. These findings support further development of the oil as a natural antimicrobial agent [13].

Discussion

The collective experimental evidence confirms that *A. marmelos* possesses a multi-target pharmacological profile consistent with its traditional indications. The antidiabetic activity is particularly well documented and appears to involve both pancreatic and extra-pancreatic mechanisms,

including enzyme inhibition, insulin sensitisation and antioxidant protection of β -cells. Coumarins (marmelosin, Marmesin) and the alkaloid Aegeline emerge as key bioactive scaffolds worthy of further structure-activity and pharmacokinetic investigation.

Antioxidant and anti-inflammatory effects provide a rational mechanistic basis for the observed hepatoprotective, gastroprotective and cardioprotective actions. Nevertheless, several limitations must be acknowledged. Most studies have been conducted with crude extracts rather than purified markers, hindering dose standardisation and regulatory development. Clinical data remain scarce, and long-term safety, herb-drug interactions and bioavailability of the major constituents have not been adequately characterised. In addition, variability in phytochemical content arising from geographical origin, harvest season and extraction method complicates reproducibility.

Future research should prioritise: (i) bioassay-guided isolation and characterisation of active principles; (ii) detailed pharmacokinetic and toxicological profiling of lead compounds; (iii) well-designed randomised controlled trials in relevant patient populations; and (iv) development of standardised, quality-controlled extracts or phytopharmaceutical formulations. Integration of network pharmacology, multi-omics approaches and advanced delivery systems may further accelerate the translational pathway.

CONCLUSION

Aegle marmelos is a scientifically validated medicinal plant whose traditional uses are supported by a substantial body of preclinical pharmacological evidence. Its rich repertoire of alkaloids, coumarins and flavonoids underpins antidiabetic, antioxidant, anti-inflammatory, hepatoprotective, antidepressant, antihyperlipidemic and antimicrobial activities. While the existing data are encouraging, rigorous clinical evaluation, standardisation of bioactive markers and mechanistic elucidation at the molecular level are essential before *A. marmelos*-based products can be confidently integrated into evidence-based modern therapeutics. The plant remains a promising and underexploited resource for the discovery of novel natural-product drug candidates.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author contributions

S.R. conceptualised the review, performed the literature search and drafted the manuscript. D.P., P.D. and P.P. critically revised the content for intellectual accuracy and approved the final version.

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