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Review



## *Aegle marmelos* (L.) Correa from sacred tree to superfruit: A Comprehensive review of its phytochemistry and Therapeutics

Dr. Kannan S<sup>\*1</sup>, Dr. Lakshmi Devi<sup>2</sup>, Sanjai R<sup>3</sup>, Ragul Prasanth T.R<sup>4</sup>, Senthilnathan T<sup>5</sup>, Sharmika P<sup>6</sup>, Sivasangari S<sup>7</sup>, Saiyogi Rajan K<sup>8</sup>

<sup>1,2,3,4,5,6,7,8</sup> Department of Pharmacognosy, College of Pharmacy, Sri Ramakrishna Institute of Paramedical Sciences, Coimbatore, Tamil Nadu, India.

\*Author for Correspondence: Dr kannan S

Email: kannanonline2@gmail.com

	<b>Abstract</b>
Published on: 17.02.2026	<p>Plants are the natural source of food and medicine for both humans and animals, which we have used since the prehistoric era of human civilization. Indigenous plants contain various roles in people's culture and lifestyle. This Review article focuses on the medicinal values and uses of the Indian sacred fruit <i>Aegle marmelos</i> commonly known as Indian Bael fruit. It is an Indian Indigenous plant which is sacred for lord shiva. The nickname of the bael is golden apple which is traditionally used for abdominal disorders, ulcer, cholera, diarrhea, heart diseases, dog bite, jaundice, snake bite etc. <i>Aegle marmelos</i> contains isolated compounds belonging to Alkaloids, Terpenoids, Vitamins, Coumarins, Carbohydrates, Flavonoids, Tannins, Fatty Acids, Essential oils, etc. Hence this review provides concise and standardized information on <i>Aegle marmelos</i> for researchers and students.[8]</p>
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<p><b>Keywords:</b> <i>Aegle marmelos</i>, Phytochemistry, Extraction, pharmacological activity.</p>	

**INTRODUCTION:**

The Evolution and journey of life for birds, animals and humans had started with utilization of plants or plants parts as food. Plant parts such as leaf, stem, branch, fruit, flower, buds, and roots are used by kingdom Animalia for food and survival tools. Ancient Indian medicinal systems like Ayurveda, Siddha also describe the use of plants for the treatment of various health problems.

In last five decades these plants have been extensively studied by advanced scientific techniques and reported used in Treatment for ailments which has properties of Anticancer activity, Antibacterial activity, Antifungal activity, Antidiabetic activity, Haemolytic activity, Larvicidal activity and Anti-inflammatory activity etc. *Aegle marmelos* (Linn) correa, commonly known as bael belonging to the family Rutaceae, is a moderately sized slender and aromatic tree. In India it is abundantly found in the Himalayan tract, Bengal central and South India. It is extensively planted near Lord Shiva temples for wood and leaves which are generally used for worship. The bael has a rich repository of bioactive compounds, including Alkaloids, flavonoids, tannins, terpenoids, coumarins and essential oils. Bael has a high concentration of polyphenol and flavonoids. According to the literature the fruit pulp, leaf, seed, and shell powders of bael could be utilised as a source of nutrients, phytochemicals and antioxidants. The antioxidant activity of methanolic extract had the maximum DPPH radical scavenging behaviour. Methanolic extract of the unripe fruit of bael reduced gastrointestinal ulcers and reversed oxidative stress caused by *Helicobacter pylori*-Lipopolysaccharide in mice. The global demand for nutraceuticals and functional foods is huge and rising these days. The bael fruits have many uses in functional foods also as it has much potential for processing into goods such as powder, jam wine, slab syrup and preservers. In India many of the products are prepared from bael which are sherbet, murabba or syrups. In other countries such as Indonesia and Thailand ripe bael fruits and their sliced pieces are consumed as food and syrups are used in making cake ingredients. The Indian Council of Agricultural Research (ICAR) and agricultural institutes are developing promising varieties of bael through selection in recent years.

The special focus of this review highlights the morphological, phytochemistry, Extraction methods, Pharmacological Activity of *Aegele marmelos* for its further investigation and development of active

constituents.[3,1]

**ORGANOLEPTIC IMAGES OF *AEGLE MARMELOS*:**

**Figure 2: Bael Fruit**



**Figure 3: Bael Tree**

**COMMERCIAL FOOD PRODUCTS OF AEGLE MARMELLOS:**



Figure 4: Bael sharbat



Figure 5: Bael candy



Figure 6: Bael Fruit Powder

**TAXONOMICAL CLASSIFICATION:**

Table 1:

Kingdom	Plantae
Subkingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
class	Magnoliopsida
Subclass	Rosidae
Order	Sapindales
Family	Rutaceae
Genus	<i>Aegle</i>
Species	<i>Aegle Marmelos</i>

**GEOGRAPHICAL DISTRIBUTION:**

The Beal tree is a semitropical plant that flourishes at an approximate altitude of 1200 meter from the sea level. It is almost found in all over India mainly seen

in Himachal Pradesh, Jammu and Kashmir, Kerala, Karnataka, Andhra Pradesh, Madhya pradesh, Maharashtra, punjab, rajasthan, tamil Nadu, Uttar Pradesh and West Bengal. It is also widely cultivated in several countries such as Nepal,

Myanmar, Vietnam, Tibet, Sri Lanka, Bangladesh, Thailand, Indonesia and also dried areas of Java, Fiji and some parts of Philippines regions.[5,6]

The Bael Tree is a slow growing medium to small size tree about 20 to 30 feet in height which is known as *Aegle marmelos* belongs to family Rutaceae.

## BOTANICAL DESCRIPTION:

Table 2:

Plant part	Organoleptic characteristics
Bark	The bark is brownish or grey in colour, and contains a number of straight long spines. It contains gums which often come out from wounded branches and then become solid. These gums can be explained as a clear, gummy sap. It exhibits an initially sweet taste followed by throat irritation.
Leaf	Trifoliate, round base with pointed tip young leaves are light green and mature leaves are dark green in colour
Flower	Flowers are greenish or yellowish in colour and bisexual in nature.
Fruit	It has a hard outer jacket diameter 5 to 12 cm. It is green in unripe condition and dark brown in ripe. It contains up to 20 pulp inside.
Seed	The seeds are small 1cm in length, hard, flattened, oblong, bearing woolly hairs and each enclosed in an adhesive sac.

## ETHNO MEDICAL USES:

**Leaves:** The leaves are most effective in treating fever, nausea, vomiting, swellings, dysentery, dyspepsia, seminal weakness and intermittent fever.

**Root:** It is effective in treating urinary problems, preventing palpitations and curing fevers. They are also used in treatment of abdominal pain, diarrhea and flatulence.

**Bark:** The decoction of bark was widely used to treat and cure fever and cough. **Flower:** Anesthetic by distilling flowers. Tonic for stomach and intestines were prepared from flowers and it is also used in treatment of epilepsy.

**Fruit:** It is a good source of food used to make delicious items like puddings. Murabba and juice also have medical properties such as scavenging. Antioxidants, Antiulcerative, Gastroprotective, hepatoprotective, antibacterial, antidiarrheal and antiviral properties.

**Seed:** Seed extract possesses antidiabetic and hypolipidemic effects in diabetic rats.

## EXTRACTION OF AEGLE MARMELOS LEAVES:

**Chemicals required:** Pyridine, conc./dil. Sulphuric Acid, CuSo<sub>4</sub>, HgCl<sub>2</sub>, MHA, Lead acetate, ferric chloride, sodium nitroprusside, Mayer's reagent, Benedicts's solution, Ninhydrin solution, NaOH, HNO<sub>3</sub>.

**Glass wares required:** Beaker, Funnel, Glass, Tubes, Rods, Measuring cylinder, pipettes, Round bottom flask, Watch glass, Condenser, etc.

**Instruments required:** Grinder, Digital water bath, Electronic heater, Electronic balance, Soxhlet apparatus, Autoclave, Hot air etc.

### Extraction procedure:

**Step 1 preparation of plant material:** Weight: start

with 500g of dried and powered plant material.

**Step 2 Soxhlet Extraction:** Solvents: use 200ml of ethanol and water separately for successive extraction was carried out using ethanol followed by water. Duration: Perform the extraction using a soxhlet extractor for a period of 5 hours

**Step 3 Filtration and Initial concentration:** Filtration: Filter the resulting extracts. Drying: Concentrate the filtered extracts to dryness using a steam bath maintained at 37°C.

**Step 4 Solvent evaporation:** Rotary Evaporation: The solvent was removed under reduced pressure using a rotary evaporator. This leaves a small yield of extracted plant material in the glass bottom flask which is dark greenish residues.

**Step 5 Storage:** Bottling: place the extracts into sterile bottles. Refrigeration: store the bottles in a refrigerator at 2-4° C until they are needed for further use.

**Step 6 Final preparation:** Dilution: Prior to use, dilute the extract with a measured amount of distilled water to reach the required concentration. Extracts were transferred to glass vials and kept at 4°C before use.[2,7]

## PHYTOCHEMISTRY OF AEGLE MARMELOS:

**Alkaloids:** Ethyl cinnamate, O-3, 3-(di methylallyl) halfordinol ethyl N-2-methoxy-

2-[4-(3,3-dimethylallyloxy) phenyl] Ethyl cinnamate, N-2-ethoxy-2-ethyl cinnamon, Halfordino, Marmeline, Anhydromarmeline, Aegelinosides A, Aegelinosides B.

**Terpenoids:**  $\alpha$ -Phellandrene, p-cymene, p-Menth-1-en-3,5-diol, Limonene,  $\alpha$ -pinene,  $\beta$ -Myrcene, Isosylvestrene,  $\delta$ -Carene,  $\beta$ -Ocimene.

**Vitamins:** Thiamin, Riboflavin, Niacin, Ascorbic Acid.

**Coumarins:** Marmelosin, Marmesin, Imperatorin, Marmin, Alloimperatorin. Methyl ether, Xanthotoxol, Scopoletin, Scoparone, umbelliferone, Psoralen, Marmelide.

**Tannins:** 4,7,8-trimethoxyfuro-quinoline, Carbohydrates, Galactose, Arabinose, Uronic Acid, L-rhamnose, Arabinose, D-galacturonic Acid.

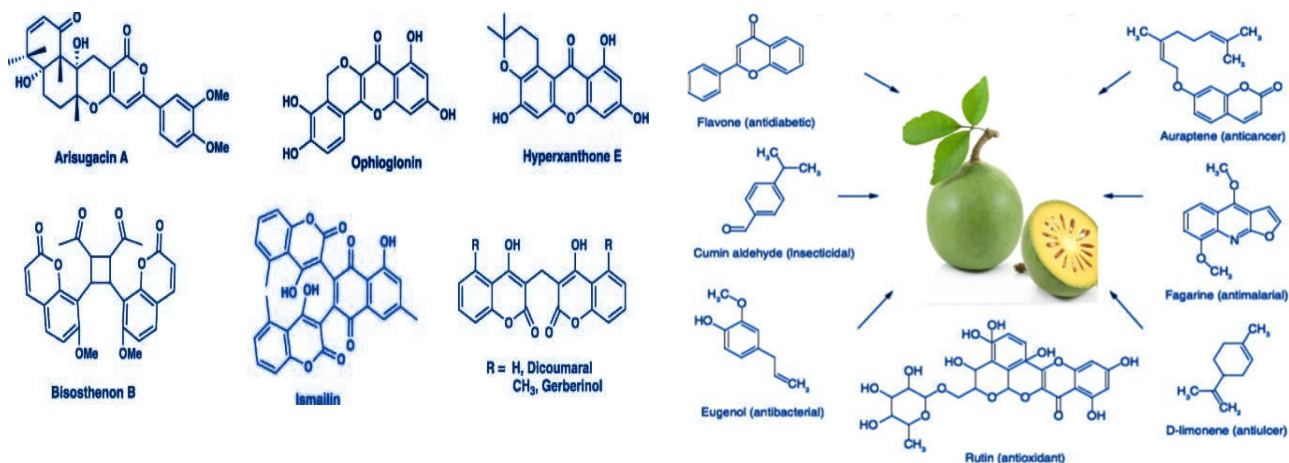
**Flavonoids:** Rutin, Flavone, Flavone-3-ols, Flavone glycosides.

**Fatty Acids:** Palmitic Acid, Stearic Acid, Oleic Acid, Linoleic Acid, Linolenic Acid.

**Essential oils:** Alpha-pinene, Beta-myrcene, Alpha-Phellandrene(56%), P-cymene(17%), Isosylvestrene, Delta-carene, Beta-Ocimene, Terpenolene, linalool, Elemene etc.

**Miscellaneous:** Hamycin, Oxalic Acid, Carotene, Psoralin, Auraptine, Marmin, Umbelliferone, Lupeol, Scopoletin, Marmesin, Skimmlamine, Luvsngetin, Imperatorin, Xanthotoxin.[3,2,1,4]

## STRUCTURES:



## PHARMACOLOGICAL ACTIVITY:

### 1. Antimicrobial Activity:

Aegle marmelos Linn exhibits broad-spectrum antimicrobial activity against a wide range of Gram-positive bacteria, Gram-negative bacteria, and pathogenic fungi. This activity has been demonstrated using different extracts prepared from leaves, fruits, bark, and seeds, employing solvents such as ethyl acetate, petroleum ether, ethanol, and aqueous media. Experimental studies using disc diffusion and tube dilution methods have shown that leaf and fruit pulp extracts effectively inhibit the growth of *Escherichia coli*, *Staphylococcus aureus*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Candida albicans*, *Aspergillus niger*, and *Aspergillus fumigatus*. The minimum inhibitory concentration (MIC) values indicate particularly strong activity against *Staphylococcus aureus* and *Candida albicans*, suggesting potential usefulness against both bacterial and fungal infections. Interestingly, petroleum ether and ethyl acetate extracts often showed greater antimicrobial efficacy than standard antibiotics like streptomycin, particularly against multidrug-resistant strains. This supports the traditional use of bael in treating diarrhea, dysentery, and gastrointestinal infections, where microbial pathogens play a central role.[2,6,5]

### 2. Antioxidant Activity:

Oxidative stress plays a critical role in the development of chronic diseases such as diabetes, cancer, hepatic disorders, and inflammatory conditions. Aegle marmelos is recognized as a powerful natural antioxidant, capable of scavenging reactive oxygen species (ROS) and preventing oxidative damage to biomolecules. Antioxidant assays (DPPH, FRAP, and radical scavenging models) have shown that fruit pulp, leaves, and bark extracts exhibit significant antioxidant activity. Notably, marmelosin, a major coumarin isolated from bael fruit, demonstrated antioxidant potential comparable to or even superior to standard antioxidants like gallic acid and ascorbic acid. By reducing malondialdehyde (MDA) levels and enhancing endogenous antioxidant enzymes such as superoxide dismutase (SOD) and catalase, A. marmelos contributes to cellular protection and disease prevention. This antioxidant property underpins many of its other pharmacological activities, including antidiabetic, hepatoprotective, and anti-inflammatory

effects.[5,6,2]

### 3. Anti-constipating Activity:

The anticonstipating and gut-regulatory effect of Aegle marmelos is closely related to the maturity stage of the fruit. While unripe fruits are traditionally used as antidiarrheal agents due to high tannin content, ripe fruits act as a mild natural laxative, making bael useful in constipation. Ripe bael fruit pulp contains Pectins and mucilage – increase stool bulk and improve bowel motility, Dietary fibers – enhance intestinal transit, Natural sugars and organic acids – promote osmotic water retention in the colon. These components soften stool consistency and stimulate peristalsis without causing irritation or dependency, unlike synthetic laxatives. Traditional formulations using ripe bael pulp mixed with warm water or milk have been employed for centuries to manage chronic constipation and digestive sluggishness. Additionally, the prebiotic effect of bael supports beneficial gut microbiota, indirectly improving bowel regularity and intestinal health.[6,5]

### 4. Antidiabetic Activity:

Aegle marmelos Linn has been extensively investigated for its antidiabetic potential using both in-vitro and in-vivo experimental models, and the results strongly validate its traditional use in diabetes management. Aqueous and alcoholic extracts of the fruit, leaves, and seeds have demonstrated significant hypoglycemic effects in streptozotocin-induced diabetic animals. The reduction in blood glucose levels is primarily attributed to enhanced insulin secretion through partial regeneration of pancreatic  $\beta$ -cells and improved insulin sensitivity in peripheral tissues. Additionally, bael extracts inhibit key carbohydrate-digesting enzymes such as  $\alpha$ -amylase and  $\alpha$ -glucosidase, thereby reducing post-prandial hyperglycemia. In vitro studies using HepG2 cells further revealed increased glucose uptake and reduced intracellular reactive oxygen species, indicating protection against oxidative stress-induced insulin resistance. Bioactive compounds such as aegeline, rutin, flavone, and fruit lectins play a crucial role in mediating these effects, making A. marmelos a promising natural source for the development of antidiabetic therapeutics.[2,6]

### 5. Antiproliferative Activity:

The antiproliferative activity of Aegle marmelos has been well documented through studies conducted on various human cancer cell lines and animal tumor

models. Methanolic, ethanolic, and aqueous extracts of bael fruit pulp and leaves exhibited significant cytotoxic effects against breast cancer (MCF-7, MDA-MB-231), HEp-2, and Ehrlich ascites carcinoma cells. The observed antiproliferative action is mediated through the induction of apoptosis, cell cycle arrest, and inhibition of uncontrolled cell division. In vivo studies demonstrated a marked reduction in tumor volume and a significant increase in survival time in tumor-bearing animals treated with bael extracts. These effects are largely attributed to phytochemicals such as marmelosin, auraptene, flavonoids, and coumarins, which modulate oxidative stress, inflammatory signaling pathways, and tumor biomarkers. The selective toxicity toward cancer cells, with minimal effect on normal cells, highlights the chemopreventive and therapeutic potential of *A. marmelos* in cancer management.[6,2]

## 6. Hepatoprotective Activity:

*Aegle marmelos* exhibits pronounced hepatoprotective activity, as evidenced by experimental studies conducted in toxin- and drug-induced liver injury models. Administration of fruit pulp and leaf extracts resulted in a significant reduction in elevated hepatic biomarkers such as alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase, indicating restoration of normal liver function. Histopathological examinations revealed regeneration of hepatocytes and reduced necrosis in treated groups. The hepatoprotective effect is primarily mediated through antioxidant mechanisms, including inhibition of lipid peroxidation, scavenging of free radicals, and enhancement of endogenous antioxidant enzymes. Phytoconstituents such as marmelosin, rutin,  $\beta$ -sitosterol, and flavonoids stabilize hepatocyte membranes and protect liver tissue from oxidative and inflammatory damage. These findings support the traditional use of bael in the treatment of jaundice and other hepatic disorders.[6,5,2]

## 7. Anti-inflammatory Activity:

The anti-inflammatory activity of *Aegle marmelos* has been substantiated through various experimental models, including carrageenan-induced paw edema, cotton pellet granuloma, and inflammatory bowel disease models in laboratory animals. Extracts obtained from leaves, flowers, and unripe fruits significantly reduced edema formation, inflammatory cell infiltration, and hyperpyrexia in a dose-dependent manner. The mechanism of action

involves inhibition of pro-inflammatory mediators such as prostaglandins and cytokines, stabilization of mast cells, and suppression of oxidative stress-mediated inflammatory pathways. Notably, increased levels of endogenous antioxidants and reduced lipid peroxidation further contribute to the anti-inflammatory effect. Bioactive compounds including marmelosin, rutin, flavonoids, and coumarins are responsible for modulating these responses, thereby validating the traditional application of *A. marmelos* in inflammatory conditions such as arthritis, colitis, and fever.[5,2,6]

## CONCLUSION:

Scientific evaluations of *Aegle marmelos* reveal a remarkably diverse range of pharmacological properties, including antidiabetic, anticancer, antimicrobial (encompassing antibacterial and antifungal), antiviral, anti-inflammatory, antioxidant, and antipyretic activities. The plant also functions as a potent antidiarrhoeal, antidyenteric, anti-ulcer, and gastroprotective agent. Additionally, it has been found to possess hepatoprotective, cardioprotective, radioprotective, antimalarial (including antiplasmodial), antifertility, and hypolipidemic properties. Other documented biological activities include analgesic (antinociceptive), antispasmodic, anthelmintic, diuretic, wound healing, insecticidal, antigenotoxic, chemopreventive, sedative, and anticonvulsive effects. The therapeutic profile of *Aegle marmelos* is driven by a diverse array of bioactive molecules, including the alkaloids aegeline, skimmianine, marmeline, and fagarine, which are joined by potent coumarins such as marmelosin, luvangetin, psoralen, and auraptene. The plant's antioxidant capacity is bolstered by flavonoids like rutin, quercetin, kaempferol, and flavone, while its aromatic and medicinal properties are further enhanced by terpenoids and volatile oils, specifically cineol, citral, limonene, and eugenol. Additionally, the presence of sterols and other compounds such as  $\beta$ -sitosterol, lupeol, tannins, and pectins rounds out the complex chemical matrix that provides its wide-reaching health benefits. *Aegle marmelos* represents a highly valuable medicinal resource that bridges ancient traditional knowledge with modern pharmacology. The paper concludes that while its therapeutic potential is immense—particularly in managing diabetes, cancer, and infectious diseases—further clinical trials and standardized extraction methods are essential to fully integrate its bioactive molecules into evidence-based modern medicine.

As global demand for natural remedies and health foods increases, Bael stands out as a promising candidate for the development of new, targeted therapeutic drugs with limited adverse

effects.[8,6,4,5,]

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