



# **A Review: Medicinal Properties and Health Benefits of Bael (*Aegle marmelos*)**

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## **Authors' contributions**

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## ABSTRACT

In ancient India, the *eagle marmelos*, also known as bael, was associated with folklore. In traditional medical systems such as Ayurveda, every component of the tree, including the root, bark, fruit, leaf, and flower, has therapeutic value for treating various maladies. Current studies have found valuable bioactive substances that support Bael's pharmacological functioning. Bael fruits are rich source in vitamins, minerals and many types of nutrients. Bael fruit has been a major topic for studies in recent years mainly due to its high nutritional (carbohydrates, proteins, minerals, and vitamins) value and presence of various phytochemicals, which attributed to its high medicinal value. These phytochemicals include various compounds, e.g., alkaloids, flavonoids, and phenolic acids (protocatechuic acid, gallic, and ellagic acid). Due to its possible application as an anticancer agent in the treatment of many cancer types and other fatal diseases, this plant is now gaining attention. In this article, we describe the botanical properties of Bael, its traditional use, its phytochemicals, and its pharmaceutical applications in brief.

**Keywords:** *Aegles marmelos*; health benefits; morphological uses; medicinal values; murabba; dietetic purposes.

## 1. INTRODUCTION

The Rutaceae family includes the subtropical fruit *Aegle marmelos*, sometimes referred to as Bael [55]. *Aegle marmelos* (L.) Correa has served as an economically viable culinary and medicinal herb for over 5000 years, making it a highly significant indigenous plant to the Indian subcontinent. The pulp of the bael fruit is used to make desserts like murabba, puddings, and juice. The fruits are useful for dietetic purposes [70]. Although it is indigenous to northern India, it is widely cultivated in Thailand, Bangladesh, Pakistan, Sri Lanka, and Burma, among other places of India [69,70]. Bael fruit is one of several plants that have had extensive therapeutic applications in Indian medicine since antiquity. In India, *A. marmelos* is planted as a temple garden plant, and its leaves are used in prayers to Lord Shiva [55]. Every part of this tree, including the root, bark, leaf, flower, and fruit, can be used in several fields. The wild form of fruit is smaller in size than the cultivated variant and is also less popular for commercial use [55]. Bael is known by various names in different languages, including Bilva, Shivaphala in Sanskrit, Belo in Oriya, Bel in Assamese and Marathi, and Vilva marum in Tamil in India, Be Li in Sinhalese, Matoom in Thai, and Bela in Spanish [88]. Numerous studies and applications have demonstrated *Aegle marmelos*'s natural healing ability [45,82]. The fruit of *Aegle marmelos* is a natural source of useful nutrients and antioxidants.

### 1.1 Rutaceae Family

The Rutaceae phylogeny that was most recently reported shows that 135 genera, or 87.7% of the

family's identified genera, are Haplophylloideae, Amyridoideae, Aurantioideae, Cneoroideae, Rutoideae, and Zanthoxyloideae. The Rutaceae family produces physiologically potent essential oils, which are well-known and present in many of the family's members and ornamental and culinary plants, including orange, lemon, lime, grapes, and satinwood [9]. Numerous plant compounds, such as coumarins, flavonoids, terpenoids, and alkaloids, have been discovered in several investigations [6,22]. High concentrations of coumarins, such as marmelosin and luvangetin, which have antihelminthic, antiulcer, antibacterial, and antispasmodic properties, are found in Rutaceae family plants [84].

### 1.2 Area and Distribution

It is prevalent throughout South and Southeast Asia, including India, China, Nepal, Myanmar, Pakistan, Bangladesh, Nepal, Vietnam, Laos, Cambodia, Thailand, Indonesia, Malaysia, Tibet, Sri Lanka, Java, the Philippines, and Fiji. [77]. This subtropical plant can grow up to 1200 meters above sea level and can withstand temperatures as low as -7°C. Bael trees can be found in India's Indo-Gangetic Plains, Sub-Himalayan tracts, North-Eastern area, and dry and deciduous forests of the central and southern peninsula [85]. Commercial cultivation of the high-yielding variety Goma Yashi has lately acquired pace in Rajasthan, Uttar Pradesh, Madhya Pradesh, Punjab, Tamil Nadu, and Gujarat states in the form of orchard or border plantation. Trees thrive in soils that are unsuitable for other crops, such as those with stones and limestone, swampy conditions, and

extreme pH levels ranging from 5 to 10 [77,81,70].

### 1.3 Botanical Description

The *Aegle marmelos* tree is a medium sized, aromatic, slender medicinal tree that grows slowly, reaching a height of roughly 762 cm and a diameter of 90–120 cm [30], whereas the bael tree has somewhat prickly stem branches [16].

## 2. NUTRITIVE VALUE OF BAEI (*Aegle marmelos* Linn.)

Numerous bioactive compounds have been isolated from the Indian medicinal plant known as bael, which has been used traditionally to treat a variety of illnesses [12,23]. Bael, which is incredibly rich in vitamins like A, B group, and C, has been shown to function as an antioxidant, reducing rancidity and color loss [63]. Alkaloids (aegeline, fragrine, aegelenine), coumarins (Marmin, Marmelide, Psoralen, Imperatonin), terpenoids (cineol, Caryophyllene), etc. are found to be present in *A. marmelos* [7,22]. According to Sampathkumar [37], unripe fruit has greater

medical benefits than ripe fruit. Fruit juice contains the following: phosphorus (52 mg), potassium (610 mg), calcium (80 mg), fiber (2.9%), protein (1.6%), moisture (61.0%), and carotene (55 mg) [68]. Fruit pulp and leaves have extremely low fat contents [7], with 0.28% and 0.07%, respectively [50]. 34.4% oil, 8.8% stearic acid, 8.1% linolenic acid, 16.6% palmitic acid, and 30.5% oleic acid are found in *Aegles marmelos* seeds [37]. The seed oil is utilized in compressors, cosmetics, and aromatherapy [34]. Oil from *A. marmelo* can be used as an anti-inflammatory, antiseptic, antioxidant, antibacterial, astringent, disinfectant, carminative, and cytophylactic in medicine.





## 3. CONVENTIONAL APPLICATIONS OF BAEI

Bael has been used extensively in traditional medicine and Ayurveda. It has been discovered that every part of the bael tree has the ability to treat a variety of illnesses [4]. The following discusses a few uses as well as the chemical components found in the various portions of *Aegles marmelos* Linn.

**Table 1. Botanical description of *Aegles marmelos***

Parts of a plant	Botanical description	References
Bark	The bark of bael tree observed to be thick in nature. And when the bark thrashed slightly, a sticky gum secretion ooze out that tastes sweet initially and then later on turns out to be unpleasant which gets thick and dangle down in long stands when it comes in the contact with air and thus solidifies.	[16,35,10]
Leaves	It has alternate leaves with serrated leaflets, trifoliate leaves have 3–5 leaflets each leaflet, each measuring 4–10 cm in length and 2.5–5 cm in width. The color of the blossoms is greenish-white. With time, the leaves turns into dark green colour on maturation	[44,72]



Parts of a plant	Botanical description	References	
Flowers	The bale flower is bisexual and hypogynous in nature. May and June are the months when flowers appear. Some lateral panicles, which are supported by leaf axil, hold the greenish-white bael flowers jointly. The hue of the flowers is grewish white in colour. It has an actinomorphic, bisexual, ebracteate, hypogynous stalk with a strong fragrance. In lateral panicles, 10 flowers are seen in leaf axil	[11] [8]	
Fruit	The fruit of A. marmelos is mostly yellowish green in color, with a hard, woody exocarp. Its diameter ranges from approx. 5 to 7 cm, and its approximate weight is 77.2 g, volume is 73 mL, and are spherical or oval in shape. (sphericity is $93.72 \pm 2.78\%$ .)	[86]	
Pulp	The pulp is fragrant, golden, silky, sweet, and resinous. The pulp of the fruit, which has a pale orange color, is pasty, sweet, resinous, and very aromatic. There are a few to fifteen seeds embedded in the pulp. May and June are the months when fruiting happens	[16,4]	
Seed	The seeds are flat, oblong-shaped, and around one centimeter long. Their structures are similar to those of woolly hair. Each seed is surrounded by a sac of sticky, transparent mucus that solidifies when it dries.	[67,55,57,13]	

**Table 2. Nutritive values of *Aegles marmelos***

Components	Value (%)	Components	Value (%)
Mineral	1.5	Vitamin B1	0.01
Fiber	2.2	Nicotinic acid	0.9
Fat	0.2	Vitamin A (IU)	186
Protein	1.8	Iron 0.3	0.3
Phosphorus	0.05	Calorific value	129
Carbohydrate	30.6	Riboflavin	1.2
Calcium	0.09	Vitamin C	0.01
Water (moisture)	64.2	Potassium 0.6	0.6

Source: Shankar and Garg [80,52]

**Table 3. Chemical components along with their uses in Bael (*Aegles marmelos*)**

Parts	Chemical constituents	Uses	References
Leaves	Rutin, Flavone, Cineol Glycoside, O-Halfordiol, Marmeline, Lupeol, Citronellal, Tannins, Marmesinin, Aeglin, Phenylethyl Cinnamamides, Citral, Skimmianine, Eugenol, and Isopentenyl alpha and beta sitosterol and Cuminaldehyde.	<ul style="list-style-type: none"> <li>Fever, nausea, vomiting, swellings, diarrhea, dyspepsia, seminal weakness, and intermittent fever are the conditions for which the leaves are most beneficial.</li> <li>It is also used to treat cholera, bronchitis, beriberi, sore throat, stomach issues, wound healing, Jaundice, Asthama and stomach ulcers.</li> </ul>	[16,51,33,39]
Bark	Marmin, Coumarins and Fagarine	<ul style="list-style-type: none"> <li>Traditionally, the inhabitants cure fever and cough with a bark decoction.</li> <li>It is one of the components that makes up chyavanprash.</li> <li>While bark decoction, leaf extract with honey, and bael extract are used to cure fever, febrifuge, and intermittent fever, root bark may also be utilized as a fish poison and fever therapy.</li> </ul>	[17,29,28,42,48]
Fruit	Tannin, gallic acids, Psoralen, Aurapten, Marmelide, Luvangetin, and Marmelosin -- tocopherol, $\gamma$ -tocopherol, $\delta$ -tocopherol, Cobalamins, $\beta$ -tocopherol, Vanillic acid, Malic acid, Propionic acid, Succinic acid, 2,3-dihydroxy benzoic acid, Chlorogenic Acid, pcoumaric acid, lactic acid,	<ul style="list-style-type: none"> <li>It is used as an astringent, for stomach problems, diarrhea, gonorrhoea, epilepsy, ulcers, anti-diabetic, anti-cancer, antioxidant, and antimicrobial purposes.</li> <li>The fruit consumption lowers the blood sugar and boosts the secretion of insulin</li> <li>Pulp of a fruit is very helpful in urino-genital disorders when mixed with milk and sugar</li> </ul>	[36,68,33,24]
Flower	xanthotoxol, imperatorin, alloimperatorin, $\beta$ -sitosterol	<ul style="list-style-type: none"> <li>Flowers can be distilled to create a local anesthetic, antidiabetic, diaphoretic, and anti-dysenteric drug.</li> </ul>	[43,2]

Parts	Chemical constituents	Uses	References
		<ul style="list-style-type: none"> <li>It is used as an intestinal and stomach tonic.</li> <li>It helps with epilepsy and can be taken as an expectorant as well.</li> </ul>	
Root	Marmesin, Marmelosin, Caryophyllene, $\alpha$ -zingiberene, $\beta$ -funebrene, Betulinic acid, and Cis-piperitol O-(3,3-dimethylallyl) halofordinol, O-methylhalfordinine, and Aegeline	<ul style="list-style-type: none"> <li>Bael roots are said to be useful in managing fevers, preventing heart palpitations, and addressing urinary issues.</li> <li>They are supposed to help with stomach pain as well.</li> <li>The root of dashamula has therapeutic qualities that include treating fever, diarrhea, and flatulence.</li> </ul>	[46,79,54]
Seed	Scopoletin, Dictamine, Umbelliferone, Cineol, Sitosterol, $\alpha$ -amyrin, Citral, D-limonene, Marmelosin, Aegeline, Limonene, Citronellal, Psoralen, Skimmianine, Marmelide, Marmenol, A-D-phellandrene, 7-geranyloxy coumarin Cumin aldehyde, P-Cyrene.	<ul style="list-style-type: none"> <li>Seed oil contains antibacterial qualities and stops the growth of several pathogens, including Escherichia coli, Staphylococcus aureus, and Vibrio cholera</li> </ul>	[34,83,14]

#### 4. MEDICINAL VALUES OF BAEL (*Aegles marmelos*)

Several studies have found that *Aegles marmelos* have many health benefits and medicinal values. The fruit can treat numerous health problems related to digestion, respiration, depression, skin related disorders and many other problems. Some of the medicinal effects has been discussed in this review.

##### 4.1 Diabetes

- The hypoglycemic effect of bael leaf aqueous extract has been reported by Upadhy et al. [74]. This is corroborated by analysis based on plasma urea, glutathione-S-transferase, and glucose, as well as levels of malondialdehyde (MDA) and glutathione (GSH), checked for erythrocytes in diabetic rats induced with alloxan [74].
- Bael's dietary fiber and amino acid content help with sugar absorption to a moderate extent [62]. At a dosage of 250 mg/kg, it

has been proven to be superior to the antidiabetic medication glibenclamide [49].

##### 4.2 Anti-Cancer Activity

- Leukemic K562, T-lymphoid Jurhat, Beta-lymphoid Raji, and Erythro leukemic HEL20 were among the human cancer cell lines whose in vitro proliferation was suppressed by bael. Although *A. marmelos* extract is antiproliferative, it only affects MCF-7 and MDA-MB-231 breast cancer cell lines at high concentrations [47].
- Fruit extract from *A. marmelos* significantly decreased the tumor yield as well as the tumor burden (Group IV-3.7, 2.6; Group V-4.6, 2.3), indicating the fruit extract's potential as a chemopreventive strategy against DMBA-induced skin tumorigenesis in mice [5].
- The Bael fruit extract contains the phytochemicals marmesin and marmelosin, which interact with HSULF-2 at its active site, possibly blocking it and producing anticancer action [25].

### 4.3 Anti-ulcer activity

The *H. pylori* bacteria is the cause of peptic ulcers. Further research is necessary to ascertain *A. marmelos*'s impact on *Helicobacter pylori* because there is little to no literature on the subject. If it effectively lowers AMR, it will be a fantastic natural medication that treats abscesses without causing any side effects [38].

### 4.4 Anti-inflammatory Activity

Tiwari [87] found that the increased extract of *A. marmelos* fruit exhibited strong anti-inflammatory and anti-diabetic properties due to the presence of marmelosin and marmesin. *A. marmelos* fruit demonstrated anti-inflammatory, antioxidant, and mast cell stabilizing capabilities with significantly higher SOD and lower MDA levels as well as defense against mast cell degranulation [15].

### 4.5 Anti-depressant Activity

Depression is one among the mood-related disorders. Synthetic medications have been discovered to be successful in treating depression, but they also have certain negative side effects. Natural antidepressants, on the other hand, have fewer adverse effects [32]. Using the tail suspension test and the elevated plus maze test, researchers have documented the antidepressant action of bael in mice treated with anxiolytic medications. After taking into account a number of characteristics, it was determined that bael had increased the antidepressant activity of fluoxetine and imipramine [71]. The antidepressant efficacy of bael is derived from its agonistic action on the serotonin receptor [42].

### 4.6 Anthelmintic Activity

For bael's anthelmintic action, the Indian earthworm model is employed. Earthworms are given distilled water to rinse them, and then they are given aqueous dry bael fruit extract at various concentrations of 1, 2, 10, and 20 mg/mL. Comparing the 1 mg/mL concentration group to the vehicle control group, a difference in paralysis and death time is seen [3].

### 4.7 Cyto Protective Effect

- The integrity of the plasma membrane and the control of the antioxidant enzyme system are indicative of Bael's

cytoprotective effects [53]. Bael may effectively shield red blood cells from oxidants, suggesting that it possesses cytoprotective qualities. Bael's cytoprotective impact is demonstrated by the stabilization of the plasma membrane and the modification of the antioxidant enzyme system [61].

### 4.8 Anti-stress activity

Research indicates that immobilization stress can cause oxidative harm to the liver, kidney, and plasma. The amount of glucose has grown and non-enzymatic antioxidants are being depleted as plasma corticosterone levels rise. Bael extract can raise glucose levels, decrease non-enzymatic antioxidants, and raise plasma cortisol. Fruit contains vitamins C and E, which can help to alleviate stress [41].

### 4.9 Anti- Thyroid Activity

- Aloe vera, *Bacopa monnieri* (200 mg/kg), and *Aegle marmelos* (1.00 g/kg) have all been researched for hyper thyroidism. Scopoletin (7-hydroxy-6-methoxy coumarin) is a compound found in bael leaves. Leaf extracts containing 125 mg/kg of scopoletin have been shown to exhibit effective anti-thyroid activity [1].
- Animals treated with thyroxine are given 1 mg/kg for 7 days, which lowers the level of thyroid hormones in the serum. The antithyroid medication propylthiouracil functions similarly to bael extract [27].

### 4.10 Insecticidal Activity

- Bael extract and *Andrographis paniculata* have demonstrated a noteworthy effect as a possible repellent, ovicidal, and oviposition deterrent against *Culex tritaeniorhynchus* [20].
- Acetone extract of bael at a dosage of 250 ppm has demonstrated 100% efficacy [75]. Methanolic bael leaf extract has the ability to moderately inhibit *Aedes aegypti* and *Anopheles stephensi* mosquito larvae [20].

### 4.11 Anti-oxidant Activity

- It was found that marmelosin had superior antioxidant qualities to regular gallic acid [60].

- Bael has been found to have antioxidant properties because of phytochemicals such as flavonoids and phenolic acids [42]. Different substituents are present in the aromatic ring of phenolic acid, and as a result, different phenolic acids have varying antioxidant activity [18].
- The radical scavenging activity of the hydroalcoholic extract of bael is demonstrated against 2, 2'-azino-bis (3 ethylbenzothiazoline-6-sulphonic acid) and DPPH radicals. Bael extract can stop the oxidation caused by the 2, 2'-azobis (2-amidinopropane) dihydrochloride radical that occurs in biomolecules such as plasmid DNA, bovine serum albumin, and lipids [26].

#### 4.12 Anti-ocular Hypertension Activity

Bael leaf chloroform extract, at doses of 150 and 300 mg/kg body weight, has been used to treat cataracts by lowering osmotic stress, suppressing lens aldose reductase (AR), and raising glutathione, catalase, and superoxide dismutase [76,90].

#### 4.13 Anti-asthmatic Activity

The primary cause of phlegm and asthma is histamine release. Phlegm in cold and asthma cases can be effectively reduced by using bael leaf decoction. Research using the ileum of guinea pigs reveals that histamine has an opposing influence on contraction [89,73]. Bael leaves contain aegeline, which inhibits mast cell histamine release [40]. Because leaves of *A. marmelos* successfully lower histamine production, they are beneficial for asthma management.

#### 4.14 Wound Healing Activity

The wound healing process involves three distinct stages: inflammation, cell proliferation, and collagen lattice formation contraction. Basic wound symptoms including reddening, pain, and edema also occur during inflammation. It has been discovered that reactive oxygen species emission serves as a defense mechanism [31].

Methanolic *A. marmelos* seed extract ointment was shown to have the ability to completely heal wounds in an experiment conducted on Wistar albino rats [59]. *A. marmelos* functions similarly to the medication nitrofurazone in terms of

wound healing [92]. As they can boost antioxidant activity, the phytochemicals included in *A. marmelos* are particularly beneficial for wound healing [12].

#### 4.15 Cardio Protective Effect

- It has been discovered that bael fruit protects against cardiovascular illnesses. Lipid peroxidation can be reduced by the bioactive compound marmesinin, also known as linear furanocoumarin, which is found in bael. Serum LDH and CK levels are elevated in isoprenaline-induced myocardial rats, but they are lowered when bael leaf extract (200 mg/kg) is administered. In addition, it is discovered that a few other biochemical parameters rise [56].
- Using various dilutions of bael extract, the cardiotoxic activity of bael has been tested on a frog heart assembly that has been extracted. Digoxin is outperformed by bael extract [21].

#### 4.16 Anti-microbial Activity

- According to reports, *A. marmelos* possesses antibacterial, anticancer, antiviral, anti-inflammatory, and antifungal properties that enable it to provide protection against a broad range of pathogenic organisms [55]. The inhibition rate of *A. marmelos* extract varies according to concentration; for example, a 0.05% extract dose can prevent 100% of fungus, whereas a 0.04% dose may prevent 90% of them and a 0.03% dose can prevent 75% of them [65].
- The quinine component was found in the ethyl acetate extract of *A. marmelos* leaf, and it had good antibacterial action against both gram-positive and gram-negative bacteria [66].

#### 4.17 Diarrhoea and Dysentery

- Bael fruit, particularly unripe or half-ripe fruit, can be used to treat chronic diarrhea. The ideal powder for this purpose is dried bael fruit. Unripe fruits can be roasted, then combined with jaggery to be consumed [91].
- The pulp of unripe fruit may be active against enterotoxins. Moreover, it can stop



the production of colonies from the intestinal epithelium [19].

- The astringent qualities of the tannin in bael make it a miraculous cure for diarrhea [58,78].
- Current investigations have concentrated on enhancing the effectiveness of *A. marmelos*-derived medications for dysentery and diarrhea. It has been noted that bael root extract containing chloroform has the same antibacterial properties as ciprofloxacin, but without any negative side effects [64].

## 5. CONCLUSION AND FUTURE ASPECTS

These studies have demonstrated the therapeutic potential of *A. marmelos* and the presence of components that may be utilized to create novel drugs for the treatment, mitigation, or prevention of diabetes, cancer, and other pathogenic diseases. Bael's non-toxic behavior has been confirmed by clinical research, ensuring that the pharmacological application is completely safe and devoid of any negative consequences. Many allopathic medicines actions can be carried out by various *A. marmelos* components and extracts. As it has no side effects, this lowers the cost of medications while reducing the probability of developing new diseases. This is a significant benefit over allopathic medications and is also practically feasible economically.

Since *A. marmelos* contains powerful phytochemicals that are responsible for a variety of therapeutic effects, further study and research are needed to understand the molecular functions of these constituents in order to develop more effective medical treatments. Even though bael has been used extensively in traditional medicine from ancient times, it is now necessary to learn more about the bioactive components in the fruit and encourage its use globally in order to fully utilize its remarkable health advantages.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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