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AEGLE MARMELOS: A Review of Its Chemicals Constituents, Biological Activity, and Potential Health Benefits

Patil Vaishali S.[1,*], Sameer R. Shaikh[2], Divakar R. Patil[2], Akash S. Jain[3], Azam Z. Shaikh[2], Sunil P. Pawar[4]

Abstract

The fruit bael is obtained from the plant name, Aegle marmelos, which is an important medicinal herb found in South Asia. The leaves, stems, bark, and roots are all used in traditional medicine in addition to the fruits. Since ancient times, people have utilized herbs to treat a variety of chronic illnesses. The nutritional and medicinal properties of compounds derived from plants have been confirmed by several scientific investigations. Worldwide concerns over the connection between eating habits and health have led to a surge in interest in plant-derived nutraceuticals. So, to better understand these underutilized fruits and their potential as functional products for the food processing industry, researchers are looking into their functional characteristics. Science-based data on the fruit's nutritional value is given priority in our analysis.

Keywords: Aegle marmelos, chemistry, properties, health benefits, Bael Fruit

INTRODUCTION

Aegle marmelos, commonly known as Bael, is a hardy fruit tree native to the Indian subcontinent, including Bangladesh, Thailand, Nepal, India, and Sri Lanka. This subtropical species, part of the Rosaceae family, thrives in diverse environments, and can grow up to 1200 meters above sea level, with reports of it reaching 1500 meters in Nepal. It is remarkably adaptable to varying temperatures and soil types [1].

***Author for Correspondence**
Patil Vaishali S.
E-mail: patilvaishu590@gmail.com

[1]B. Pharm. Student, Department of Pharmaceutics, P.S.G.V.P. Mandal's College of Pharmacy, Shahada, Maharashtra, India
[2]Assistant Professor, Department of Pharmaceutics, P.S.G.V.P. Mandal's College of Pharmacy, Shahada, Maharashtra, India
[3]Assistant Professor, Department of Quality Assurance, P.S.G.V.P. Mandal's College of Pharmacy, Shahada, Maharashtra, India
[4]Principal, Department of Pharmacognosy, P.S.G.V.P. Mandal's College of pharmacy, Shahada, Maharashtra, India

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This fruit, known for its aromatic and delicious pulp encased in a firm, woody shell, holds a special place in Hindu culture. Often used in religious rituals, it is deeply revered for both its spiritual significance and unique flavor [2]. Aegle marmelos, known informally as bael, holy fruit, or golden apple, is a resilient tree native to India. Reaching heights of 12–15 meters, it thrives in arid, well-drained environments. The tree is characterized by its spiny branches, distinctive leaves with 3–5 pointy leaflets, and clusters of fragrant flowers that grow along its young branches [3].

Bael (Aegle marmelos), the sole species in the genus Aegle, is a hardy, slow-growing subtropical tree known for its resilience and medicinal properties [4]. Bael fruit is known for its medicinal

properties, potentially aiding in the treatment of intestinal issues, diabetes, heart problems, and inflammation. It also shows protective effects against wounds, radiation, bacteria, free radicals, and even depression, making it a valuable natural remedy [5]. Bael fruit comes in four shapes: round, pyriform, oval, or oblong. Its size, ranging from 2 to 8 inches in diameter, depends on the variety and geoclimatic conditions. The tree bears fruit mainly during long, dry seasons, with May and June being peak months in India. Wild bael trees can yield up to 60 kg of fruit, though the fruit is smaller and less economically valuable compared to cultivated varieties [6].

Bael fruit can have a thin or hard woody shell, which changes from gray-green when raw to yellowish when ripe. The shells have tiny aromatic glands, giving them a pleasant scent. The pulp consists of 8–16 orange, triangular segments around a firm core, with a pasty, sweet texture, and a strong fragrance. The pulp contains up to 15 seeds, each covered in a sticky, mucus-like sac that solidifies when dried. Bael fruit varieties, such as Mitzapuri, Rampuri, and Kaghzi Etawah, differ in size and taste, with Mitzapuri being the most prized for its thin rind, fine pulp, and excellent flavor [7].

Despite its excellent flavor, nutritional benefits, and medicinal potential, bael remains underutilized. Its seasonal availability and challenges like a hard shell, sticky pulp, and numerous seeds limit its popularity as table fruit. However, processing bael into products like tea, juice, candy, and jams could enhance its economic value and make it more accessible as a functional food product [8].

DIFFERENT NAMES OF BAEL

English (Bael Fruit, Golden Apple, Indian Bael, Bengal Quince, Holy Fruit, Indian Quince, Stone Apple, and Elephant Apple), Hindi (baelputri, bela, sirphal, siri-phal, and kooralam), Gujrati (Bili), Panjabi (Bil), Bengali (Bilbam), Telgu (Maredu, Bilbpandu), Latin (Aeglemarmelos Corr), Tamil (Bilbam), Sindhi (Katori), Oria (Belo), Marathi- (Bael), Synonyms: Bael fruits, Bel, Indian Bael, Bengal Quince, and Belan [9].

- *Biological Source:* Bael is made up of unripe or half-ripe fruits, slices, or irregular pieces of Aegle marmelos Corr., a member of the Rutaceae family [9].
- *Geographical Source:* Sub-Himalayan tract and throughout India, particularly Central and Southern India and Burma, both wild and cultivated [9].

PHYTOCHEMICALS PRESENT IN BAEL

Bael fruit pulp contains important bioactive compounds, such as carotenoids, phenolics, alkaloids, pectins, tannins, coumarins, flavonoids, and terpenoids, offering potential health benefits [10]. Bael fruit contains a wide range of volatile compounds, including acetoin, limonene, linalool, carvone, and citral, along with various coumarins like psoralen, marmelin, and aegeline. These compounds contribute to the fruit's unique aroma and potential therapeutic properties [11]. Bael fruit contains flavon-3-ols, anthocyanins, leucoanthocyanins, tannins, phlobatannins, tartaric acid, and linoleic acid, each contributing to its diverse bioactive profile [12].

Bael Leaf in Medicine

In Ayurveda, bael is highly valued for its therapeutic properties. The leaves, roots, bark, fruit, and seeds are used to treat various ailments. Specifically, bael leaves are effective for alleviating fever, stomachache, urinary tract issues, heart palpitations, and occasional fever [13].

Bael Fruit as a Dietary Agent

Ripe bael fruit, with its sweet, flavorful, and fragrant orange or golden pulp, has been consumed as food on the Indian subcontinent since ancient times In India, mature bael fruit is used to make "bael sherbet," a popular drink made by blending the pulp with milk, sugar, and cardamom. Semi-ripe fruits are also turned into jam with added preservatives, sugar, and citric acid [14].

Nutritive Value of the Bael Fruit

Scientific studies have confirmed that bael leaf has antibacterial properties, validating many of its traditional medicinal uses [15] anti-inflammatory antipyretic [16]. to lower the levels of thyroid hormones [17] anti-fertility effects [18].

Bael Fruit in Traditional Medicine

In Ayurveda, bael fruits are valued for treating diarrhea. Unripe fruits soothe stomach inflammation and aid digestion, while semi-ripe fruits have antidiarrheal and astringent properties. Ripe fruits are particularly effective in preventing sub-acute and chronic diarrhea, offering a cooling effect, pleasant fragrance, and laxative properties.

Medicinal Properties

Bael fruit is renowned for its therapeutic qualities in Ayurvedic medicine, commonly used to treat constipation and diarrhea. It is also believed to have anti-inflammatory and antidiabetic properties [19].

Diarrhea and Dysentery

Bael fruit, especially when unripe or half-ripe, is effective in treating chronic diarrhea. Dried bael fruit powder is ideal for this purpose, and unripe fruits can be roasted and mixed with jaggery for consumption [18].

Antimicrobial Activity

Bael shows exceptional defense against various pathogens, including antibacterial, anticancer, antiviral, anti-inflammatory, and antifungal properties. Marmelide, a compound from bael, exhibits significant antibacterial and antiviral activity, outperforming ribavirin, and acts by inhibiting viruses during the early stages of their replicative cycle [20].

Anticancer Activity

Cancer is a major modern health challenge, with costly treatments. Bael extract contains significant compounds like 6-methyl-4-chromanone, butyl p-tolyl sulfide, and butylated hydroxyanisole, which effectively suppress K562 cells. In vitro studies in Bangladesh also show that bael extract has cytotoxic effects on MDA-MB-231 and MCF-7 breast cancer cells [21].

Anti-ulcer Activity

Ulcers are a common gastrointestinal issue, often caused by oxidative stress, Helicobacter pylori, or impaired blood flow. In rat studies, luvangetin, a pyranocoumarin from bael seeds, has shown protective effects against stomach ulcers induced by pylorus and aspirin [22].

Anti-genotoxic Effects

Genotoxicity refers to the damage substances can cause to DNA and RNA. Bael extract, with its diverse phytochemicals, shows antigenotoxic activity, protecting against genetic damage. Its polyphenolic components are believed to be responsible for these protective effects [23].

Anti-Microfilaria

Bael leaf extract, along with Vitex negundo L root extract, effectively reduces motility loss in microfilaria at a concentration of 100 ng/mL. This dosage is fully effective against Brugia malayi, a cause of filariasis [24].

Antihistaminic Effect

Bael's antihistaminic effect was tested on rat mast cells using RBL-2H3 and RPMC cell lines. Skimmianine from bael effectively suppresses histamine release triggered by DNP24-BSA, ionomycin, and thapsigargin in these cells [25].

Antimalarial Activity

Bael root extract shows anti-malarial activity against Plasmodium falciparum (K1, multidrug-resistant), with an IC50 of 48.2 μg/mL. In vitro studies using Trager and Jensen's approach and [3H]-hypoxanthine regulation demonstrate a 50% reduction in parasite growth. Decoction of bael root bark could be a potential malaria treatment [26].

Nephroprotective Activity

Bael leaf extract has shown nephroprotective properties in Wistar rats, counteracting gentamicin-induced nephrotoxicity by lowering MDA levels and raising glutathione and catalase levels. It also effectively mitigates cisplatin-induced nephrotoxicity [27].

Anthelmintic Activity

Bael fruit extract demonstrates anthelmintic action in an Indian earthworm model. When administered in doses of 1, 2, 10, and 20 mg/mL, the extract shows significant differences in paralysis and death times at a 1 mg/mL concentration compared to the control group [28].

Anti-asthmatic Activity

Bael leaf infusion effectively reduces phlegm in colds and asthma attacks. Research shows that bael leaf's aegeline prevents histamine release by inhibiting mast cells, while skimmianine in bael roots also influences histamine release from rat mast cells [29].

Antithyroid Activity

Bael leaf contains scopoletin, which lowers thyroid hormone levels in animals with hyperthyroidism. Scopoletin (1 mg/kg) and the antithyroid drug propylthiouracil show similar effects. Additionally, extracts from Aegle marmelos (1 g/kg), Bacopa monnieri (200 mg/kg), and aloe vera (125 mg/kg) also exhibit anti-thyroid activity [30].

Nutritional Profile

Bael fruit is rich in vitamins A, B, and C, and contains minerals like calcium and iron. It provides dietary fiber, aids digestion, and supports gut health. The fruit also has antioxidants, fatty acids, amino acids, and a significant amount of carbohydrates, including fiber, sugar, and glucose. Methods, such as Soxhlet extraction and micro Kjeldahl's distillation are used to measure its nutritional content, including crude protein levels [31]. Unripe bael fruit is considered more medicinally beneficial than ripe fruit. Its juice contains 61% moisture, 1.9% minerals, and key nutrients: 52 mg phosphorus, 610 mg potassium, 80 mg calcium, 2.9% fiber, 1.6% protein, and 55 mg beta-carotene. Edible parts of the fruit provide essential minerals like iron, calcium, potassium, and phosphorus [32].

Health Benefits

Regular consumption of bael fruit may boost the immune system, support heart health by lowering cholesterol, and aid in weight management due to its high fiber content [33].

Bael Juice and Beverages

Bael juice is a popular summer drink often mixed with other fruits or herbs for enhanced nutrition and flavor. Its blends are increasingly favored in the beverage industry as health drinks [33].

Bael in Modern Medicine

Recent studies are exploring bael fruit's potential anticancer properties, its effectiveness in regulating blood sugar levels, and its antibacterial and antimicrobial benefits [33].

Bael in Cosmetics

Bael fruit extracts are used in skincare products for their antioxidant properties, enhancing skin texture and hydration. They are also featured in formulas targeting acne and blemishes.

Consumer Education

To expand the market for bael fruit, it's essential to educate customers on its uses and health benefits through social media, cooking demos, and workshops. Collaboration with medical experts can further promote bael as a superfood.

Culinary Uses

Bael fruit can be enjoyed raw or used in drinks and pastries. Bael sharbat, or juice, is a popular beverage, and its pulp also enhances the flavor of jams, jellies, and ice creams.

CONCLUSIONS

Plants are becoming more and more important globally, in both developed and developing nations, because of the expensive cost of synthetic medications and their frequent negative side effects. Because they are inexpensive and have no negative effects, herbal medications are widely accessible. Consumers' shifting preferences for healthful eating and lifestyle choices have fueled the market's expansion of functional food products, potential medicinal properties that make them worthy of flavonoids, phenols, coumarins, essential oils, and their extraordinary ability to heal a wide range of ailments naturally. Clinical medicine investigations have confirmed that bael demonstrates non-toxic behavior, guaranteeing the patient's safety. Macology applications have no risk at all. Furthermore, the plant requires very little maintenance and is quite easy to cultivate.

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