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A review: Food, medicinal and nutraceutical properties of bael fruit (*Aegle marmelos*)

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Abstract

Bael, *Aegle marmelos* belongs to family Rutaceae. It is a Indian origin tree having an altitude of 1200 metre. This tree is versatile as all different parts of this tree such as leaves, roots, seed, bark and fruit etc have different dimensions of applications. They contain a large number of coumarins, alkaloids, sterols and essential oils and owing to these, they can be used as anti-microfilarial, antifungal, analgesic, anti-inflammatory, antipyretic, hypoglycaemic, antidyslipidemic, immunomodulatory, antiproliferative, wound healing, anti-fertility, and insecticidal abilities. Apart from using in the aforementioned way, by utilizing post-harvest techniques, this tree can be seen as a income source for the needful farmers. A large number of by products such as candy, panjiri, toffee, jam etc are also made by the fruit by using various post-harvest technologies which also helps to reduce the post-harvest losses and hence increases the shelf life which further helps in value addition and in generation a good income for a needy farmer. Other aspects of potential use of *Aegle marmelos* such as phytochemical, ethnobotanical and pharmacological evaluations have been reported in this literature.

Keywords: *Aegle marmelos*, bael, phytochemical, ethnobotanical, pharmacological, taxonomy

Introduction

Bael (*Aegle marmelos*) belongs to family Rutaceae. It is indigenous fruit of India. In different parts of India, it is known by different names such as Bengal quince (John and Stevenson, 1979) ^[1], Bilva, Indian quince, Golden apple, Holy fruit, Bel, Belwa, Sripthal, Stone apple and Maredo in India. *Aegle marmelos* (L.) tree is a sacred tree for Hindus as they use it to offer in prayers of deities Lord Shiva and thus the tree is also known by the name Shivaduma (The Tree of Shiva). It has tolerance to arid conditions (Chundawat, 1990) ^[2] as well as high rainfall. Exploration undertaken in eastern Uttar Pradesh and adjoining urea of Bihar indicated wide range of variability in thorniness on stem, fruit shape, scull thickness and pulp characteristics. Promising lines in respect to high yield and quality fruits were identified (Rai *et al.*, 1991) ^[3].

The Bael tree has its origin in Eastern Ghats and central India. Most of the population of this tree is found in tropical and sub-tropical regions as it is indigenous to Indian subcontinent. The tree is also found as a wild tree, in lower ranges of Himalayas up to an elevation of 500 meters. Bael is also found growing along foothills of Himalayas, Uttaranchal, Jharkhand, Madhya Pradesh and the Deccan Plateau and along the east coast (Sharma *et al.*, 2007) ^[4]. Bael or *Aegle marmelos* is a sub-tropical, deciduous tree. Bael fruit is globuse with grey or yellowish hard woody shell. It contains soft yellow or orange colored mucilaginous pulp inside it. Inside the dense cover of fibrous hairs, there are numerous seeds. They are embedded in a thick, gluey, aromatic pulp. (Kaushik *et al.*, 2008) ^[5]

Bael or *Aegle marmelos* tree has spiritual, religious and medicinal aspects. It is native of India and Bangladesh and spread throughout South East Asia. The production of Bael in India is 0.08583 MT in 2015-16 (Anonymous, 2015)^[6] from some major production state i.e. Uttar Pradesh, Jharkhand, Uttaranchal, Orissa, Rajasthan, Madhya Pradesh, Chhattisgarh etc. It takes 10-11 months for a Bael fruit to ripe. (Anonymous 2012) ^[7]

The shape of fruit may be round, oval, or oblong, 2 to 8 inches in diameter, may have a thin, hard, woody shell or a more or less soft rind, gray-green until the fruit is fully ripe, when it turns yellowish. It is dotted with aromatic, minute oil glands. Inside, there is a hard central core and 8 to 20 faintly defined triangular segments, with thin, dark-orange walls, filled with aromatic, pale-orange, pasty, sweet, resinous, more or less astringent pulp.

10-15 seeds are Embedded in the pulp, flattened-oblong, about 3/8 in (1 cm) long, bearing woolly hairs and each enclosed in a sac of adhesive, transparent mucilage that solidifies on drying. (Julia and Miami, 1987)^[8]

Plants have been utilised as a natural source of medicinal compounds since thousands of years. In last five decades, these plants are extensively studied by advanced techniques and reported for various medicinal properties viz, anticancer activity, antioxidant activity, antifungal activity, antidiabetic activity, antibacterial activity, hepatoprotective activity, haemolytic activity, larvicidal activity and anti-inflammatory activity etc. It is normally used for lord Shiva in temples. Taxonomy for this plant is given in table 1.

Table 1: Taxonomy

Kingdom	Plantae
Order	Sapindales
Family	Rutaceae
Sub family	Aurantioideae
Genus	Aegle
Species	A. marmelos

It is also known as Bengali quince, Indian quince, holy fruit, golden apple in English, Bael and bilwa in hindi. Other local names are given in table 2.

Table 2: Names of *Aegle marmelos* in different languages

Name	Language
<i>Aegle marmelos</i>	Latin
Wood apple, Bengali quince, Indian quince	English
Mbau Nau, Trai Mam	Vietnamese Bel
Gudu	Nepali
Toum	Lao (Sino-Tibetan)
Bnau	Khmer
Modjo	Javanese
Oranger du Malabar	French
Ohshit, Opesheet	Burmese
Mojo tree	Indonesian
Pokok Maja Batu	Malay
Mapin, Matum, Tum	Thai
Shreephal, Bilva, Bilwa	Sanskrit
Sir Phal	Old Hindi
Bel, Shreefal	Bengali
Kaveeth	Marathi
Vilva Maram, Vilva Pazham	Tamil
Maredu	Telugu
Bel	Urdu

Chemical constituents of *Aegle marmelos*

Alkaloids:

The alkaloids comprise the largest single class of secondary plant substances. From the leaves of *Aegle marmelos*, new alkaloids were reported viz., ethyl cinnamamide, O-3,3-(di methylallyl) harfordinol, N-2-methoxy-2-[4-(3',3'-dimethylallyloxy) phenyl] ethyl cinnamamide etc. (Riyanto, 2001)^[9]

Terpenoids

In India study of the essential oil of *Aegle marmelos* leaves was done very much extensively in India by various workers since 1950. a-Phellandrene was the common constituent of the essential oil found from leaves, twigs and fruits. a-Phellandrene (56%) and p-cymene (17%) were reported from leaf oil. Later, similar report was published on leaf essential oil by many workers. P-menth-1-en-3,5-diol was isolated and characterized from *Aegle marmelos* leaves. (Hema, 1999)^[10]

Coumarins

Marmelosin, marmesin, imperatorin, marmin, alloimperatorin, methyl ether, xanthotoxol, scopoletin scoparone, umbelliferon, psoralen, maemelide has also been reported in *Aegle marmelos*. (Bramhachari and Reddy, 2010)^[11]

Phenylpropanoids

These are naturally occurring phenolic compounds, having an aromatic ring to which three carbon side chain is attached. Hydroxycoumarines, phenylpropenes and lignans are included among the Phenylpropanoids. Coumarine, the most widespread plant, is the parent compound which occurs in over twenty-seven plant species. (Kurian, 1992)^[12]

Tannins

In January month, the maximum tannin content was recorded in Bael fruit. There is as much as 9% tannin in the pulp of wild fruit, less in cultivated type. Tannin is also present in leaves as skimmianine, it is also named as 4,7,8-trimethoxyfuro-quinoline. (Daniel, 2006)^[13]

Polysaccharides

Galactose, arabinos, uronic acids and L-rahamanos are obtained on hydrolysis. (Laphookhieo, 2011)^[14]

Flavonoids

Mainly includes Rutin, Flavone, flavan-3-ols, flavone glycosides. (Sivraj and Balakrishnan, 2011)^[15]

Table 3: Nutritional value of Bael Fruit (% or per 100 g)

S. No	Constituents	Composition(Per 100 g)
1.	Moisture	54.96-61.5 g
2.	Carbohydrates	28.11-31.8 g
3.	Protein	1.8-2.62 g
4.	Ash	1.04-1.7 g
5.	Fat	0.2-0.39 g
6.	Carotene	55 mg
7.	Ascorbic Acid	8-60 mg
8.	Tartaric Acid	2.11 mg
9.	Riboflavin	1.19 mg
10.	Niacin	1.1 mg
11.	Thiamine	0.13 mg

(Source: Julia and Miami, 1987)^[8]

Pharmacological Properties of *Aegle marmelos*

Antibacterial activity

Antimicrobial activity of different leaf extracts such as Petroleum ether, Dichloromethane, Chloroform, Ethanol and Aqueous extract of *Aegle marmelos* leaves are tested against selected Gram-positive and Gram-negative bacteria. Phytochemical extracts of *Aegle marmelos* exhibited significant anti-bacterial activity as depicted from results. Ethanol and Chloroform leaf extracts of *Aegle marmelos* were found to be more active towards the bacterial species tested. (Rajasekaran and Meignanam, 2008)^[16]

Antihistaminic activity

From the roots of *Aegle marmelos*, skimmianine is isolated which is quinoline alkaloid. In the study the effects of skimmianine on the histamine release from rat mast cells are tested. The study was performed by using two cell lines, rat basophilic leukemia (RBL-243) cell line, and rat peritoneal mast cell (RPMCs) DNP24-BSA, thapsigargin, ionomycin, compound 48/80 were used as inducers for release of histamine from rat mast cell. Skimmianine markedly inhibited

the histamine release from RBL-243 cells induced by DNP24-BSA, thapsigargin and ionomycin. (Nugroho and Riyanto, 2010) ^[17]

Anti-inflammatory, antipyretic and analgesic activity

For anti-inflammatory property, the extracts of leaves of *Aegle marmelos* were investigated. The antipyretic and analgesic activities are also evaluated. The most extracts derived from the plant *Aegle marmelos* caused a significant inhibition of carrageenan induced paw oedema and cotton-pellet granuloma in rats. The extract also produced marked analgesic activity by reducing the early and late phase of paw-licking in mice. By most of the extracts, a markedly decrease in hyperpyrexia in rats was also produced. Anti-inflammatory, antipyretic and analgesic activities of *Aegle marmelos* was established by this study. (Rao, 2003) ^[18]

Heptoprotective activity:

Leaves of *Aegle marmelos* were reported in alcohol induced liver injury in Albino rats for heptoprotective purpose. Rats were administered with 30% ethyl alcohol for a period of 40 days. The induced rats were fed with leaves of *Aegle marmelos* for 21 days. The TABRS values of healthy, alcohol intoxicated and herbal treated drug treated animals were 123.35, 235.68 and 141.85 µg/g tissue respectively. This indicates the excellent heptoprotective activity of leaves of *Aegle marmelos*. (Singanan, 2007) ^[19]

Antifertility activity:

In male Albino rats, leaves of *Aegle marmelos* plant were investigated for antifertility activity. The rats were administered with aqueous extract (250mg/kg body weight) of leaves of *Aegle marmelos* for 45 days. Treatment resulted in reduction of testies, epididymis and seminal vesicle. The extract also resulted in reduction of testicular sperm count. (Sathiyaraj *et al.*, 2010) ^[20]

Insect controlling properties:

Essential oil from the leaves of *Aegle marmelos* was reported for showing insecticidal activity against four stored grains insect pests included *Callosobruchus chinensis* (L.), *Rhyzopertha dominica* (F.), *Sitophilus oryzae* (L.) and *Tribolium castaneum*. In the study grains were infected with test insects and were fumigated with essential oil of *A. marmelos* (500µg/mL). Except *T. castaneum*, grain damage as well as weight loss in fumigated grain samples infested with all insects are reduced significantly by the oil treatment. The essential oil at different doses significantly reduced oviposition and adult emergence of *C. chinensis* in treated cowpea seeds. (Kumar *et al.*, 2008) ^[21]

Antiarthritis Activity

Study has shown that leaves of *Aegle marmelos* have ability to possess antiarthritis activity against collagen induced arthritis in Wistar rats. Paw swelling and arthritic index has reduced from the methanol extract treatment of rats. Radiological and histopathological changes were also significantly reduced in methanol extract treated rats. (Trivedi *et al.*, 2011) ^[22]

Cytoprotective Activity

The cytoprotective activity of leaves of *Aegle marmelos* was reported in *Cyprinus carpio* (freshwater fish) exposed to heavy metals. *C. carpio* was exposed to heavy metals followed by the treatment with dried powder of *Aegle*

marmelos leaves. The treatment resulted in cytoprotective activity by stabilization of plasma membrane and modulation of antioxidant enzyme system. (Vinodhini and Narayanan, 2009) ^[23]

Antidiarrheal activity:

Antidiarrheal activity is one of the most important medicinal properties of *A. marmelos* and traditionally it is used to control chronic diarrhea and dysentery. Recently, several *in vitro* and *in vivo* studies have been conducted to confirm the antidiarrheal activity of *A. marmelos*. The *in vitro* antidiarrheal activity of dried fruit pulps was reported. Against the causative organism of diarrhea, study of antidiarrheal activity was performed by MIC method. The ethanolic extract showed good activity against *Shigella boydii*, *S. sonnei* and *S. flexneri*, moderate against *S. dysenteriae*. (Joshi *et al.*, 2009) ^[24]

Crude aqueous extract of unripe fruits of *A. marmelos* was screened for causative agents of diarrhea. The extract was analyzed for antibacterial activity, anti-giardial activity and antirotaviral activity. The extract exhibited inhibitory activity against *Giardia* and rotavirus whereas viability of none of the six bacterial strains tested was affected. (Brijesh *et al.*, 2009) ^[25]

Antidiabetic activity

A. marmelos has been used to control diabetes in traditional medicinal system. To evaluate the anti-diabetic activity of different organic extracts and fresh juice of *A. marmelos*, many *in vivo* scientific studies have been conducted in animal models. Antidiabetic potential of the leaves and callus of *A. marmelos* was reported in streptozotocin induced diabetic rabbits. All the extracts reduced the blood sugar level in streptozotocin diabetic rabbits, however, among the various extracts, the methanol extracts of the leaf and callus brought about the maximum anti-diabetic effect. (Arumugam, 2008) ^[26]

The anti-diabetic activity of the leaves of *Aegle marmelos* was reported in alloxan diabetic rats. The methanolic extract (120mg/kg body weight, ip) of the leaves of *Aegle marmelos* reduces the blood sugar level. Reduction in blood sugar level could be seen from 6th day after continuous administration of the extract and on 12th day sugar levels were found to be reduced by 54%. (Sabu and Kuttan, 2003) ^[27]

Bael fruit products

Various process technology for production of value added preserved products from Bael fruit. Fresh Bael fruit can be stored for 15 days at 30°C when harvested at full maturity, for 1 week at 30°C when harvested ripe, for 3 months at 9°C. Fruit pulp can be stored for 6 months, when stored in heat-sealed containers. Fruit powder can be stored for a year when packed in 400-gauge polypropylene pouches and stored under dark, cool place, while fruit jam, squash and preserve can be stored for several months. There are many functional and bioactive compounds such as carotenoids, phenolics, alkaloids, coumarins, flavonoids, and terpenoids in Bael fruit pulp and has innumerable traditional medicinal uses (Karunanayake *et al.*, 1984; Singh, 1986; Nagaraju and Rao, 1990) ^[28-30]. Thus, by using aforementioned processing technology, value added products can be produced and post-harvest losses can be managed. Process technology could be used to increase shelf life, value addition and increase the income.

Bael products and uses

A large number of Bael processed products (Preserve, candy, panjiri, toffee, jam etc.) are prepared and some scientist and researcher have already worked on their processed products (Rakesh *et al.*, 2005)^[31].

Preserve and candy

Preserve and candy are prepared from mature (tender green fruit), hole or large pieces of fruits in which sugar is impregnated till it becomes tender and transparent minimum fruit portion and minimum total soluble solids in preserves should be 55 and 70%, respectively (Lal *et al.*, 1960)^[32]. Fruits in general contain more than 75% water and get spoiled quickly if not stored properly. Removal of water from fruits is known to help in longer period of storage. The osmotic dehydration techniques not only enables the storage of fruits for a longer period but also preserve the flavor, colour and texture of the product to a great extent and prevents its microbial spoilage (Bongirwar, 1997)^[33].

“A fruit of its pieces impregnated with sugar or glucose syrup, sub piquantly drained free of syrup and dried is known as candied fruit”. To prevent fermentation, the total sugar content of the impregnated fruit is kept at about 75%. In case of Bael candy, the fruit slices are drained subsequently free of syrup and dried at 55-60°C for 8-10 hrs in oven.

Bael fruit squash

An ideal composition of Bael fruit squash was found to be 50 per cent extracted pulp, 50° Brix and 1 per cent acidity. The squash was chemically preserved by addition of 300 ppm SO₂ (Roy and Singh, 1979)^[34]. Fruit beverages commercially contain at least 25 per cent fruit pulp or juice and 40-50 per cent TSS, besides 1 per cent acid (Srivastav and Kumar, 1993)^[35]. The squash from Bael fruit pulp was prepared by adjusting the TSS and by adding the preservatives like sodium metabisulphite @ 350 ppm SO₂. The squash was then filled in sterilized bottles, crowned and pasteurized at 80 °C for 30 minute followed by cooling and wax sealing to insure air tightness. (Bhat and Kaul, 2006)^[36]

Bael RTS (Ready To Serve)

The ripe fruit were washed with tap water and broken by striking against hard object.

The fruit pulp along with its seeds and fibres was scooped with the help of stainless steel spoon. Amount of water equal to the weight of pulp was added. The mixture of pulp and water was then heated up to 80 °C for 1 minute and cooled. Pulp free from seeds and fibres was then obtained by passing through 20 mesh stainless steel sieve. The Bael fruit pulp was improved by adjusting the TSS by addition of sugar and acidity by the addition of citric acid (Chand and Gehlot, 2006)^[37].

Coffee

Fruit toffees generally are more nutritious than ordinary toffees, and Bael fruit pulp will provide even better toffees because of its nutritional and medicinal properties. Bael fruit toffees was successfully prepared by mixing 40 parts of cane sugar, 10 rparts of skim milk powder, 4.5 parts of glucose, and 6 parts of hydrogenated fat to 100 parts of extracted pulp. The final moisture content of the toffee was kept at 8.5 per cent (Roy and Singh, 1979)^[34]. Slab

It is also known as leather or paper. Ripe fruits are used in its preparation. Wash ripe fruits and collect fruit pulp by breaking fruits and removing its hard shell. At 200-300ml of

water for each one kg of fruit pulp, mix well and heat it up to 800C. Collect fruit pulp free of seeds and fibers by straining heated mass through stainless steel sieve. Add sugar, citric acid and potassium meta-bisulphite (KMS) to this pulp so that treated pulp contains 35% total soluble solids, 0.5% total acidity and 0.07% KMS. Boil treated pulp and spread on aluminum trays smeared with butter. Dry at 55-60°C for 15-16 hrs to a moisture content of 14.5%. Cut slaves of dried pulp in aluminum trays, wrap in butter paper and pack in polyethylene. Before drying the pulp to a moisture content of 14.5%, addition of up to 10 per cent sugar to the extracted pulp was found to be ideal. (Roy and Singh, 1979)^[34].

Conclusion

From the aforementioned analysis, it is quite evident from this review that *A. marmelos* is an important medicinal herb and is extensively used in Ayurveda, Siddha and other medicinal systems. Owing to the presence of key factor phytoconstituents, *A. marmelos* has medicinal values. Almost every part of this plant such as leaf, fruit, seed, bark and root are used to cure many diseases. As the pharmacologists are looking forward to develop new drugs from natural sources, development of modern drugs from *A. marmelos* can be emphasized for the control of various diseases. A systemic research and development work should be undertaken for the development of products for their better economic and therapeutic utilization.

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