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"Aegle marmelos: A Comprehensive Review of Its Historical Roots,Traditional Applications and Pharmacological Properties"

Simran Singh[1], Dipesh Prajapati[2], Nargis Khan[3], Bhawna Kasana[4], Km. Priyanka[5], Sachin Kumar Yadav[6], Kartik Kumar[7]

1. Student, Sunder Deep Pharmacy College, Dasna, Ghaziabad

2, 3, 4, 6. Asst. Professor, Sunder Deep Pharmacy College, Dasna, Ghaziabad

5. School of pharmaceutical Sciences (SGU), Dasna, Ghaziabad

7. Lab Technician, Sunder Deep Pharmacy College, Dasna, Ghaziabad

Abstract

Aegle marmelos is an important medicinal plant with several ethnomedicinal applications in traditional and folk medicinal systems. A. marmelos is used in the treatment of diarrhoea and dysentery also having useful medicinal properties especially as a cooling agent. This tree is popular in Shiva and Vishnu temples also popularly known as temple garden plant and it can be grown in every house. The leaves of Aegle marmelos are trifoliate symbolizing the Thrimurthies- Brahma, Vishnu, Shiva with spear shaped leaflets resembling trisoolam the weapon of Lord Shiva. The tree is also sacred to the Jains. The 23rd Tirthankara, Bhagwan Parasnathji attained enlightenment under a Bael tree. Traditionally used to treat jaundice, constipation, chronic diarrhea, dysentery, stomach-ache, stomachic, fever, asthma, inflammations, febrile delirium, acute bronchitis, snakebite, and abdominal discomfort, acidity, burning sensation, epilepsy, indigestion, leprosy, myalgia, smallpox, eye disorders, ulcers, mental illnesses, swelling, thirst, thyroid disorders, ulcers and upper respiratory tract infections. Studies have shown that the pulp of the bael fruit is rich in bioactive substances like phenolics, alkaloids, coumarins, pectins, tannins, flavonoids, and terpenoids.

Keyword: *Aegle marmelos*, dysentery, cooling agent, tannins, flavonoids etc

INTRODUCTION-

Aegle marmelos (L.) Correa (*A. marmelos*), common name is Bael belonging to the family Rutaceae. Due to its various medicinal properties has been widely used in indigenous systems of Indian medicine. Northern India is the native place for *Aegle marmelos*, but it also grow in Burma, Bangladesh, Indo-China and Thailand [1]. It's size is medium to large and 2.5 cm long alternate trifoliate leaves, short flower and globular fruits [2].

Aegle marmelos is a native plant of India and commonly known as wood apple. The leaves of A. marmelos are used in Indian temple for worship of Lord Shiva. A. marmelos is a significant medicinal plant that is used in various traditional and folk medical systems for ethnomedical purposes. A. marmelos has historically been used to treat dysentery and diarrhea. This plant's leaves are used to induce infertility and abortion in women [3].

Religious connection

Since ancient times, people have presented leaves in adoration of Shiva and Parvathi [4]. The deciduous sacred tree known as Bael is linked to the gods and has beneficial medical characteristics, particularly as a cooling agent. This tree, also known as a temple garden plant and common in Shiva and Vishnu temples, is a plant that may be cultivated in any home. Its trifoliate leaves, which represent the trisoolam, Lord Shiva's weapon, are spear-shaped and represent the three main deities: Brahma, Vishnu, and Shiva. The Jains also regard the tree as holy. Under a Bael tree, Bhagwan Parasnathji, the 23rd Tirthankara, achieved enlightenment. The pamphlets are distributed to worshippers at Shiva temples as prasadam and in Vishnu temples as Tulsi [5].

Geographical Information

The medium-sized, slow-growing Aegle marmelos tree reaches a height of 25 to 30 feet. The short, thick, soft stem has spreading, occasionally spiky branches that droop, and peeling bark. There are many rigid, straight spines on young suckers. This tree has axial spikes that are sharp and one inch long. The leaflets are 4–10 cm long and 2–5 cm broad, with an oval or lancet form. leaves with three to five leaflets each. The terminal leaflet has a lengthy petiole, but the lateral leaflets lack one. From one to two inches length is the petiole. When damaged, mature leaves release an unusual scent. Flowers with four recurved, fleshy petals grow in clusters of four to seven along the immature branchlets [6].

The blooms have a strange scent and are greenish white in color. May and June are the months when flowers appear. Fruit has an oval or spherical form with a diameter of two to four inches. Shells are often thin, hard, and woody. When it's not ripe, it has a greenish hue, but as it ripens, it becomes yellowish. The fruit's pulp is divided into 8 to 15 segments. The pulp is aromatic, pasty, golden, soft, and resinous. May and June are the months when fruition happens. The pulp has the seeds imbedded in it. The tiny (less than 1 cm long), hard, flattened-oblong seeds have fuzzy hairs and are individually encased in an adhesive sac [6].

Natural products are used to prevent and to treat several diseases and improve health because of nutritive and pharmacological importance. These natural products are getting high attention of scientific community and general public. Medicinal Plants with medicinal value are available and offer a cost-effective source which have lesser side effects to prepare new drugs therapy [7]. Plants was used traditionally in whole the world for the health care and for nutritive values. The medicinal components are extracts from different part of plant and methods for the extraction was used such as maceration, Decoction.

The herbal medication shows serious impact on current medicinal practice [8]. Herbal therapeutics have been used in the medication to treat different metabolic disease like diabetes, tumours, cardiovascular sicknesses. Most of metabolic and non-communicable infections are connected with higher mortality [9].

Figure 1: ***Aegle marmelos*** **leaves**

Figure 2: ***Aegle marmelos*** **flowers**

Figure 3: *Aegle marmelos* fruits

Plant profile [10]

Botanical Name: Aegle Marmelos
Sanskrit Name: Bilva
English Name: Bael Tree
Family: Rutaceae
Parts of Plant used: Fruit, leaf, root, bark

Table 1: Scientific classification [10]

Taxonomical Rank	Taxon
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Sapindales
Family	Rutaceae
Sub-family	Aurantioideae
Genus	Aegle
Species	*A. marmelos*
Common name	Bael Patra, Bael

TRADITIONAL USES

Aegle Marmelos has been used as an herbal medicine for the management of diabetes mellitus in Ayurvedic, Unani and Siddha systems of medicine in India. Aegle marmelos is traditionally used to treat jaundice, chronic diarrhoea, constipation, dysentery, stomach-ache, fever, inflammations, asthma, febrile delirium, acute bronchitis, snakebite, acidity, burning sensation, abdominal discomfort, epilepsy, indigestion, leprosy, myalgia, smallpox, spermatorrhoea, leucoderma, eye disorders, ulcers, mental illnesses, nausea, sores, swelling, thirst, thyroid disorders, tumours, ulcers and upper respiratory tract infections. It is also used to treat Anaemia, Swollen Joints, Healing of Wounds, Fractures, Diarrhoea, High Blood Pressure, Healthy Brain, Typhoid Troubles during Pregnancy. A sweet beverage made from fruit pulp has a calming effect on individuals who have recently recovered from bacillary dysentery. Before taking a bath, the body is covered in gingelly oil that has been steeped in the pulp of unripe fruit for a week. It is said that this oil might help get rid of the odd burning feeling in the soles. The tree's bark and roots are made into a decoction that is used to cure fever. To cure ophthalmia, the leaves are prepared into a poultice [11-14].

Distribution

The Aegle Marmelos tree has its origin from Central India and Eastern Ghats. It is indigenous to India and may be found growing wild in central and southern Sub-Himalayan regions that stretch from Jhelum eastward to West Bengal. Bael grows in the Himalayan foothills of Gujarat, Madhya Pradesh, Uttaranchal, Bihar, Chhattisgarh, Jharkhand, and Uttaranchal. Some Egyptian gardens in Trinidad and Surinam also cultivate it [15].

Documented species distribution:
Native range: India
Exotic range: Bangladesh, Malaysia, Egypt, Pakistan, Myanmar, Sri Lanka, Thailand. [16]

Phytochemistry

Studies have shown that the pulp of the bael fruit is rich in bioactive components such alkaloids phenols, tannins, pectin, flavonoids, coumarin and terpenoids. The most effective solvents for removing the metabolites from this plant are methanol and water, with ethanol coming in second [17–20]. Many physiologically active chemicals have been discovered in A. marmelos after the plant's phytochemistry was thoroughly investigated. Among the important phytochemicals present in A. marmelos are: Numerous plants contain nitrogen-containing substances called alkaloids, which are well-known for their medicinal effects. The leaves and roots of A. marmelos have been shown to contain a number of alkaloids, including aegeline, marmesin, and marmelosin [21].

Within the kingdom of plants, a class of molecules known as tannins is extensively dispersed and possesses both astringent and antioxidant qualities. High concentrations of tannins, which have been demonstrated to have potent anti-inflammatory and antioxidant properties, are present in A. marmelos fruit. Within the kingdom of plants, flavonoids are a class of chemicals that have anti-inflammatory, anti-cancer, and antioxidant properties. The leaves and roots of A. marmelos have been shown to contain flavonoids, some of which have been demonstrated to have antinociceptive (pain-relieving) and antipyretic (lowering fever) properties [22].

Throughout the kingdom of plants, terpenoids are a class of molecules that are well-known for their therapeutic qualities. A. marmelos has been shown to contain terpenoids, some of which have been demonstrated to have antifungal and antibacterial properties.
Within the kingdom of plants, a class of molecules known as saponins is extensively dispersed and possesses emulsifying and foaming abilities. The fruit and leaves of A. marmelos have been shown to contain saponins, some of which have been demonstrated to have antinociceptive and anti-inflammatory properties [23].

Within the kingdom of plants, glycosides are a class of chemicals that are widely dispersed and have been linked to certain medical benefits. The fruit and leaves of A. marmelos have been shown to contain glycosides, some of which have been demonstrated to have antinociceptive and anti-inflammatory properties [24]. By going over and assessing the items from the acquired bibliographic data, the most extensively studied compounds from A. marmelos were identified.

In a study important medicinal plants were investigated on the phytochemical composition including Aegle marmelos and reported highest alkaloids (1.08%), tannins (15.26%), Flavonoid (0.98%) and saponins (2.62%) in Aegle marmelos leaves when compared with other plants.[25]

Some phytochemicals of *Aegle marmelos* are as follows:

Table 2: Major chemical constitute of Aegle marmelos

S. No.	Chemical constituents of *Aegle marmelos*
1	N-2-[4-(3',3'-dimethylallyloxy) phenyl] ethylcinnamide,
2	N-2-hydroxy-2- [4-(3',3'- dimethylallyloxy) phenyl] ethylcinnamide
3	N-4- methoxystyryl cinnamide
4	N-2-hydroxy-2-(4- hydroxyphenyl) ethylcinnamide
5	Aegeline
6	Marmelosin,
7	Marmesinine
8	β- sitosterol-β-D-glucoside
9	7-geranyloxycoumarin [7-(2,6-dihydroxy-7- methoxy-7-methyl-3- octaenyloxy) coumarin]
10	α-Phellandrene
11	p-cymene
12	p-Menth-1-en-3,5-diol

13	Limonene
14	4, 7, 8-trimethoxyfuro-quinoline [26-31]

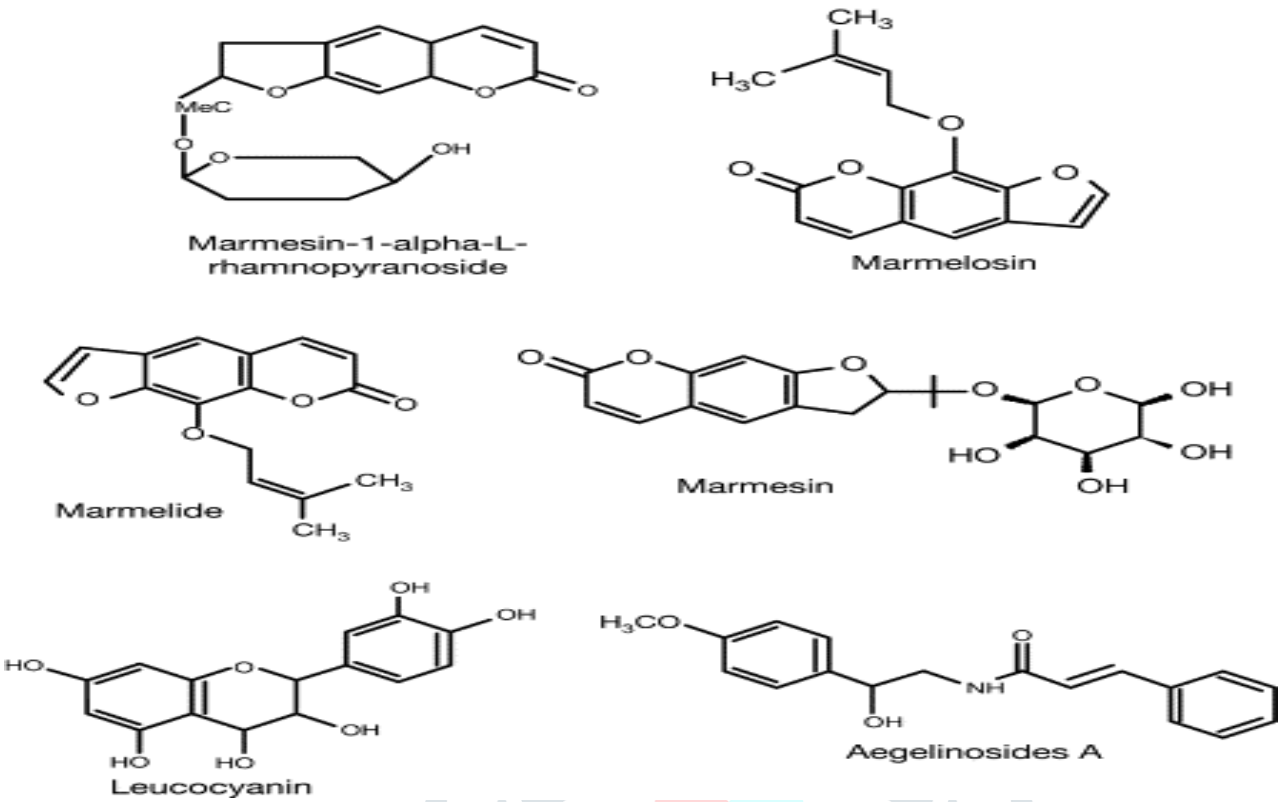

Figure 4: Chemical Structures of some active chemical constituents

Pharmacological Properties of *Aegle marmelos*:

Antioxidant Activity

Antioxidants are the compounds with free radicals scavenging activity and capable of protecting the cells from free radical mediate oxidative stress. The antioxidant compounds can be derived from natural sources such as plants. Antioxidant activity of these plants is due to the presence of flavones, isoflavones, flavonoids, anthocyanin, coumarin lignans, catechins and isocatechins. It has been widely shown that A. marmelos has antioxidant action against a range of free radicals. It has been stated that A. marmelos' fruit has antioxidant properties. We examined the antioxidant and free radical scavenging properties of Aegle marmelos's ripe and unripe fruit. The findings show that, with the exception of glutathione peroxidase, ripe fruit extract had higher levels of enzymatic antioxidants than unripe fruit extract. Additionally, immature fruit had a higher proportion of free radical inhibition than ripe fruit did [32].

Using the DPPH radical scavenging technique, reducing power assay, superoxide radical scavenging assay, nitric oxide scavenging assay, ABTS radical scavenging assay, and H2O2 radical scavenging assay, methanol and aqueous extract of A. marmelos fruit pulp was tested for antioxidant activity.
Both aqueous and alcoholic extract exhibited good antioxidant activity [33].The antioxidant activity of the fruit of A. marmelos was reported. The aqueous extract of A. marmelos fruit was screened for antioxidant activity by the DPPH radical scavenging. The extract showed efficient antioxidant activity [34].

Antimicrobial Activity

A. marmelos has long been used to treat a variety of infectious disorders and has a broad spectrum of harmful microorganism inhibition documented. Numerous in vitro investigations demonstrated the antibacterial ability of A. marmelos extracts against bacteria and fungus, among other harmful pathogens. The agar well diffusion

method was used to test A. marmelos's leaves' antibacterial properties. Effective antibacterial activity was demonstrated by the aqueous, petroleum ether, and ethanol extract of Aegle marmelos leaves against Salmonella typhi, Escherichia coli, Streptococcus pneumoniae, Klebsiella pneumoniae, and Proteus vulgaris. The petroleum ether and aqueous extract exhibits action against Fusarium oxysporum, whereas the ethanolic extract exhibits activity against Penicillium chrysogenum [35].
The antimicrobial activity was checked by disc diffusion method. The petroleum ether extract of leaves was checked against multi resistant strains of Staphylococcus aureus, Bacillus subtilis, Escherichia coli, Salmonella typhi, Proteus vulgaris, Pseudomonas aeruginosa and Klebsiella pneumoniae. The antimicrobial activity against gram-negative strains was higher than that of gram-positive strains [36].

It has been documented that Aegle marmelos leaves has antifungal properties against dermatophyte clinical isolates. It was discovered that A. marmelos leaf fractions and extracts have fungicidal effect against Trichophyton mentagrophytes, T. rubrum, Microsporum canis, M. gypseum, Epidermophyton floccosum [37].

It has been documented that A. marmelos' fruit has antifungal and antibacterial properties. The tube dilution MIC technique was used to measure the antibacterial activity. Fruit decoction demonstrated efficacy against Aspergillus niger, Aspergillus fumigatus, Candida albicans, and Staphylococcus aureus; corresponding minimum inhibitory concentrations (MIC) were 19.5 µg/ml, 39 µg/ml, 625 µg/ml, and 1.25 mg/ml and respectively [34].
The antibacterial activity of the leaves, fruits and barks of Aegle marmelos was reported. The antimicrobial activity of chloroform, methanol and water was performed by disc diffusion method. The antimicrobial activity was checked against Bacillus subtilis, Staphylococcus aureus, Klebsiella pneumoniae, Proteus mirabilis, Escherichia coli, Salmonella paratyphi A and Salmonella paratyphi B. Compared to the other extracts, the methanol extract shown much higher effectiveness against the aforementioned microorganisms [38].

The antibacterial activity of the leaves of Aegle marmelos was reported. The antibacterial activity of the different extracts was evaluated by agar well diffusion method. The hexane, cold methanol, hot methanol and ciproflaxacine extracts showed high antibacterial activity against Escherichia coli, Klebsiella pneumoniae, Proteus vulgaris, Micrococcus luteus, Enterococcus faecalis and Streptococcus faecalis [39].

It has been documented that A. marmelos leaves possess antimicrobial properties. Five pathogenic bacterial strains were tested using the disc diffusion technique on various solvent extracts of A. marmelos' leaves. When tested against the test species, methanol extract exhibited strong antibacterial activity [40].

It was reported that the different solvent extracts of Aegle marmelos leaves exhibited antibacterial activity. Using a modified disc diffusion assay, the antimicrobial activity of the different solvent extracts was screened. Streptococcus faecalis, Micrococcus glutamicus, Micrococcus luteus, Staphylococcus aureus, , S. pyogenes, Bacillus stearothermophilus, E. coli, and Pseudomonas denitrificans were among the bacteria against which various extracts exhibited antibacterial activity. The extract of petroleum ether showed no activity, whereas the extract of ethanol and chloroform showed the highest activity [41].

Antidiarrheal Activity

One of A. marmelos' main therapeutic qualities is its antidiarrheal action, which has historically been widely used to treat dysentery and chronic diarrhea. Recently, several in vitro and in vivo studies have been conducted to confirm the antidiarrheal property of A. marmelos. The in vitro antidiarrheal activity of dried fruit pulps of A. marmelos was reported. Antidiarrheal activity was performed by MIC method against the causative organisms of diarrhea. The ethanolic extract showed good activity against Shigella boydii, S. sonnei and S. flexneri, moderate against S. dysenteriae [42]. Unripe A. marmelos fruit crude aqueous extract was evaluated for diarrhea-causing chemicals. The antibacterial, antigiardial, and antirotaviral properties of the extract were examined. While none of the six tested bacterial strains' viability was impacted, the extract showed inhibitory action against rotavirus and Giardia [43].

Antidiabetic Activity

In conventional medicine, A. marmelos has been used to manage diabetes. A. marmelos fresh juice and various organic extracts have been tested for their anti-diabetic properties in numerous in vivo scientific investigations using animal models. The leaves and callus of A. marmelos have been shown to have antidiabetic properties in

streptozotocin-induced diabetic rabbits. In streptozotozin-diabetic rabbits, all of the extracts decreased blood sugar levels; however, the leaf and callus methanol extracts had the strongest anti-diabetic effects [44].

In rats with alloxan diabetes, the anti-diabetic properties in Aegle marmelos leaves were observed. Blood sugar is lowered by the methanolic extract of Aegle marmelos leaves (120 mg/kg body weight, ip). After taking the extract continuously for six days, there was a noticeable drop in blood sugar levels. By the twelveth day, the levels had dropped by 54%. [45].

Antiproliferative activity

It has been reported that the various solvent fractions of the ethanolic extract of A. marmelos' stem barks have antiproliferative effects on human tumor cell lines. The findings demonstrated that human tumor cell lines, such as leukemic K562, melanoma Colo38, T-lymphoid Jurkat, erythroleukemic HEL, Blymphoid Raji, and breast cancer MCF7 and MDAMB-231 cell lines, were inhibited in vitro from proliferating [46].

Cytoprotective Effect

Freshwater fish exposed to heavy metals, Cyprinus carpio, showed the cytoprotective effect of Aegle marmelos leaves. After being exposed to heavy metals, C. carpio was treated with Aegle marmelos leaf powder that had been dried. Through the stabilization of the plasma membrane and the modulation of the antioxidant enzyme system, the treatment had a cytoprotective effect [47].

Hepatoprotective Effect

The hepatoprotective effect of the leaves of A. marmelos and were reported in alcohol induced liver injury in Albino rats. Rats were administered with 30% ethyl alcohol for a period of 40 days. The induced rats were fed with leaves of A. marmelos for 21 days. The TBARS values of healthy, alcohol intoxicated and herbal drug treated animals were 123.35, 235.68 and 141.85 µg/g tissue respectively. This indicates the excellent hepatoprotective effect of the leaves of A. marmelos [48].

Antifertility Effect

Aegle marmelos leaf aqueous extracts were found to have an antifertility effect in male albino rats. For forty-five days, aqueous extracts of Aegle marmelos leaves (250 mg/kg body weight) were given to the rats. Testicle, epididyme, and seminal vesicle weights decreased as a result of treatment. Additionally, the extract decreased the number of abnormal sperm, testicular sperm, and epididymal sperm motility [49].

Insect controlling properties

Callosobruchus chinensis (L.), Sitophilus oryzae (L.), Rhyzopertha dominica (F.) and Tribolium castaneum are the four stored grain insect pests that the essential oil from the leaves of A. marmelos has been shown to exhibit insecticidal activity against. Test insects were used in the study to infect grains, and 500 µg/mL of A. marmelos essential oil was used to fumigate the grains. With the exception of T. castaneum, all insect species' fumigated grain samples showed a significant reduction in weight loss and grain damage following the oil treatment. In treated cowpea seeds, the essential oil at various concentrations dramatically decreased C. chinensis oviposition and adult emergence [50].

It has been reported that the essential oil extracted from A. marmelos' leaves has insect-repelling properties against Tribolium castaneum and Sitophilous oryzae. Nevertheless, the essential oils of A. marmelos did not exhibit 100% repellent activity against the test insects [51].

Analgesic activity

It has been reported that A. marmelos leaves have analgesic properties. Swiss mice were used to test the analgesic potential of a methanol extract of A. marmelos leaves using an acetic acid-induced writhing test. The outcomes showed that the writhing brought on by acetic acid was greatly decreased by the methanol extract. Methanol extract (200 and 300 mg/kg body weight) demonstrated a notable analgesic effect in the tail flick test [52].

Antiarthritis activity

Antiarthritis activity of A. marmelos leaves against collagen-induced arthritis in Wistar rats has been reported. Rats treated with methanol extract had reduced paw swelling and arthritic index. Rats treated with methanol extract also showed a significant reduction in radiological and histopathological alterations [53].

Anti-inflammatory activity

It has been reported that A. marmelos's unripe fruit pulp has anti-inflammatory properties. 0.1 ml of 1% λ carrageenan was injected into the subplaner side of the left hind paw of Sprague Dawley rats to cause inflammation. The carrageenan-induced inflammation in the inflamed rats was significantly reduced by extract treatment [54].

CONCLUSION

Aegle marmelos, commonly known as bael, is a spiny tree belonging to the family Rutaceae. The medicinal properties of this plant have been described in the Ayurveda also. According to Charaka (1500 B.C.), the Aegle marmelos has been a drug that Indians have known and valued for longer than any other. In diabetic rats, aegle leaf extract has been shown to regenerate injured pancreatic s-cells. It has been discovered to be just as successful as insulin in bringing blood sugar and body weight back to normal.

This review makes it very clear that A. marmelos is a significant medicinal herb that is used widely in Siddha, Ayurveda, and other healing systems. A. marmelos has several phytoconstituents, which are essential to the plant's therapeutic value. Nearly every component of this plant, including the leaves, fruits, seeds, bark, and roots, is used to treat a wide range of illnesses. The development of contemporary medications from A. marmelos can be highlighted for the management of diverse diseases, as pharmacologists anticipate creating new pharmaceuticals from natural sources. It is important to conduct systemic research and development to create products that can be used more economically and therapeutically.
To finish up, this exhaustive survey article has introduced a careful outline of the helpful capability of *Aegle marmelos*, otherwise called Bael. Through a broad investigation of different examinations, the survey features the large number of pharmacological exercises exhibited by this restorative plant.

The discoveries show that *Aegle marmelos* displays outstanding cancer prevention agent, mitigating, antimicrobial, anticancer, antidiabetic, hepatoprotective, neuroprotective, and cardiovascular impacts. These helpful properties are credited to the presence of bioactive mixtures, including alkaloids, flavonoids, phenols, and terpenoids, inside the plant. The audit underlines the conventional utilization of *Aegle marmelos* for overseeing different sicknesses and highlights its true capacity for future medication improvement. Moreover, the article gives bits of knowledge into the basic components of activity and the security profile related with *Aegle marmelos* removes.

Nonetheless, further exploration is important to acquire an extensive comprehension of the sub-atomic systems included and to streamline the suitable measurements and detailing of treatments in view of *Aegle marmelos*. Thorough clinical preliminaries are fundamental to approve the adequacy and wellbeing of this plant in human subjects. In outline, the remedial use of *Aegle marmelos* shows guarantee as a characteristic other option or reciprocal treatment for a large number of sicknesses. With proceeded with examination and investigation, this important plant can possibly make huge commitments to the field of medication and upgrade the wellbeing results of people around the world.

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