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Research Article

Aegle Marmelos: A Medicinal Plant From A Traditional Indian Perspective

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Abstract
Aegle marmelos (L) Correa may impart health benefits when it is used as functional food products and should be regarded as a potential nutraceutical resource and food additive because of its various attributes like typical colour, flavour and texture in the future. These results are useful for developing and improving the quality of bael leaf. **A**egle marmelos (L) Correa is a valuable medicinal plant with diverse pharmacological activities. The plant has been used for treating jaundice, diarrhea, fever, diabetes, and hepatoprotection. The present study investigated the toxicity of extracts of leaves of A. Marmelos in rats. The crude methanolic and chloroform leaf extracts were evaluated through agar disc diffusion method. Ethanol and aqueous extract of the leaves were tested against selected Gram positive and Gram negative bacteria. Phytochemical screening of the leaf extract revealed the presence of alkaloids, carbohydrates, glycosides, flavonoids, tannins, coumarins and triterpenoids. The anti-inflammatory activity of the crude ethanolic extract of leaves was tested in vitro on isolated target enzymes cyclooxygenase-1 (COX-1) and CYP2 (CX2), lymphocyte proliferation assay (LPA), cytokine profiling in LPS induced mouse macrophage (RAW 264.7) cell line and in vivo carrageenan induced paw edema in mice. In vitro studies showed that the crude extract of leaf extract was found to be more effective against bacterial pathogens. The hepatic and gastrointestinal cytokines were significantly inhibited by the crude leaf extract. It is quite evident from this review that Aegle marmelos contains a number of phytoconstituents which imparts its usefulness for various therapeutic purposes. The extracts of this important medicinal plant can become the main form of health care for not only the poor tribal community of India but can also form an integral part of primary health care or an alternative therapy to the allopathic system of medicine. So, it can be concluded that, In an era when traditional knowledge is gaining recognition, these indigenous plants can serve as healthy, cheap and readily available options in place of more sophisticated, costlier and ill effects causing synthetic medicines.

Keywords: Aegle marmelos, Nutraceutical, Pharmacological Activities, Ethanomedicinal Uses.

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1 Introduction

Aegle marmelos (L) Correa, a spine tree in the Rutaceae family, is also referred to as bael in India. It can reach a height of three to six meters. One of the Hindus' sacred trees is the bael. Since ancient times, people have prayed to Shiva and Parvathi with leaves. Bael is a sacred deciduous tree that is connected to the Gods and has many medical uses, particularly as a cooling agent. This tree can be cultivated in any home and is well-liked in Shiva and Vishnu temples. Its trifoliate leaves, which stand for Brahma, Vishnu, and Shiva, are symbolic of the Threefold Trinity. The spear-shaped leaflets are reminiscent of Lord Shiva's weapon, Thrisoolam (The Trident) (Figure 1).

According to Shiv Puran, Aegle marmelos (Bilva) is considered as an incarnation of Lord Shiva himself and it is one of the sacred trees in Hindu religion having spiritual powers. Aegle marmelos Corr. (Rutaceae), also referred to as Bael or Bengal Quince, is an Indian tree that has been there since prehistoric times. Using bael fruit in daily life offers significant benefits for the environment, nutrition, and commercial significance. This tree's entire life cycle—stem, bark, root, leaves, fruit, and seeds—has therapeutic qualities that have been utilised in ethnomedicine to take advantage of its anti-inflammatory, anti-dysentric, anti-diarroheal, and antipyretic effects. It has been demonstrated that compounds extracted from bael fruit have biological potential in treating a number of illnesses, including hyperlipidemia, diabetes, and stomach ulcers. It should be noted that a small number of isolated compounds have also been shown to exhibit antiviral, antioxidant, antibacterial, and radioprotective properties in their therapeutic activities (1, 2).

In India flowering occurs in April and May soon after the new leaves appear and the fruit ripens in 10 to 11 months from bloom March to June of the following year. Its leaves are oval-shaped, and the blossoms have a nice scent. The therapeutic qualities have been documented in the venerable Ayurvedic literature (3).

According to Charaka (c. 1500 B.C.), bael is the only medication that Indians have used for a longer period of time or are more familiar with than any other medication. It is a widely utilized medicinal plant that is used to treat a wide range of illnesses in the Ayurvedic, Siddha, and traditional medical systems. Bael is known as tridoshhar in Ayurveda, because ofit'suse in treatment for bile, wind, and phlegm disorders (3). Beal possesses antiviral, antiheltinthic, anti-inflammatory, antibilious, antiparasitical, antipyretic, antiscorbatic, digestive, aphrodisiac, aromatic, astringent, febrifuge, hemostatic, antidiarrheal and nutritive properties (4).

2. Geographical Characteristics

Aegle marmelos (L.) Correa, locally known as Bael (Rutaceae family) is a moderate-sized, slender, aromatic tree with a height of 6.0-7.5 m and a girth of 90-120 cm. It is native to the subcontinents of India and is primarily found in tropical and subtropical regions (3). It belongs to Kingdom: Plantae, Order: Sapindales, Family: Rutaceae, Sub family: Aurantioideae, Genus: Aegle, Species: A. Marmelos (Table 1) and is known by the several different names throughout different parts of the country and also outside of the country viz Hindi (Bel, bael, sriphal), English (stone apple, Bengal quince), Sanskrit (Bilva, sriphal), Bengali (Bel). It is cultivated in dry forests on hills and plains of central and southern India, Burma, Pakistan and Bangladesh, also in mixed deciduous and dry dipterocarp forests.

A. marmelos is a subtropical species and grow all over India. It grows up to an altitude of 1,200 m, where the temperature rises to 48.79º C in the shade in summer and descends to-6.67º C in the winter, and prolonged droughts occur. *A. marmelos* plant grows from sea level up to an altitude of 1,200 m. *A. marmelos* is a widely distributed plant and is found in Nepal, Sri Lanka, Myanmar, Pakistan, Bangladesh, India, China, etc. (4). Numerous South East Asian nations, such as Bangladesh, Nepal, Sri Lanka, Pakistan, and Myanmar, Vietnam and Cambodia Philippines, Fiji, Java, Thailand, and Malaysia, are also home to bael trees. Because they release a higher percentage of oxygen into the atmosphere than other trees, they serve as climatic purifiers and are therefore extremely important to the environment. Additionally, they serve as a sink for chemical pollutants, drawing poisonous substances from the environment and neutralising or inerting them in the process. Traditionally, *A. marmelos* is used in diarrhea treatment and any part of plants has medicinal properties such as its fruits, stem, bark, and leaves, and plant leaf is considered one of the highest accumulator components containing bioactive compounds synthesized as secondary metabolites. In traditional and folk medicine, *A. marmelos* has many ethnomedicinal applications.



Figure 1: *Aegle marmelos* (L) Correa (A: Leaves and B: Fruits)

Table 1: Taxonomical Classification

Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopsida
Order	Sapindales
Family	Rutaceae
Genus	Aegle
Species	A. Marmelos

3. Morphological Characteristics

Leaves of this plant are used in females to induce infertility/abortion (5). The roots and fruits of *A. marmelos* are used as an anti-asthmatic agent. *A. marmelos* have anti-amoebic activity and hypoglycemic activity. In the treatment of diseases such as diarrhea, gastric disorders, tonic, and constipation, intestinal, stomach, and laxative, the fruit of *A. marmelos* has several healing properties (6). Medium-sized and slow-growing, A. marmelos can reach heights of 12 to 15 metres. Short, thick, soft, flaking bark and spreading, occasionally spiky branches with drooping lower branches make up the stem. There are many rigid, straight spines on young suckers. This tree has long, pointy axial spikes. The leaflets are 4–10 cm long and 2–5 cm wide, 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. The fruits range in shape from round to oval, pyriform, or oblong, with a diameter of 5 to 20 cm. They can have a soft rind or a thin, hard, woody shell, and they start off grey green before turning yellowish when fully ripe (7, 8).

4. Chemical Constituents of Aegle marmelos (L) Correa

A. marmelos is reported to contain chemical composition like alkaloids (aegeline, fragrine, aegelenine), coumarins (Marmin, Marmelide, Psoralen, Imperatonin), and terpenoids (cineol, Caryophyllene), etc. All the parts of the bael tree are rich in phytochemicals such as coumarins, scoparone, scopoletin, umbelliferone, and marmesin (9). Its fruit has been used for centuries in traditional medicine due to its rich chemical constituents that have various medicinal properties.

One of the key chemical constituents found in Aegle marmelos (L) Correa is marmelosin, a coumarin compound that has been shown to possess anti-inflammatory and antioxidant properties. This compound has been studied for its potential use in treating various inflammatory conditions such as arthritis and asthma.nIn addition to marmelosin, the bael fruit also contains essential oils, tannins, flavonoids, and alkaloids. These chemical constituents contribute to the fruit's antimicrobial, antidiarrheal, and antidiabetic properties. Studies have shown that extracts from Aegle marmelos (L) Correa have potential therapeutic effects on various health conditions (10, 11).

Chemical analysis suggests that Bael contains tannins, skimmianin, essential oils like caryophyllene, cineole, citral, cuminaldehyde, citronella, p-cymene, d-limonene, and eugenol, sterols and/or triterpenoids, including lupeol, β− and γ-sitosterol, α− and β-amyrin, flavonoids like rutin and coumarins, including aegeline, marmesin, umbelliferone marmelosine, marmelin, o-methyl halfordinol, alloimperatorin methyl ether, o-isopentenyl halfordinol, phlobatannins, flavon-3-ols, leucoanthocyanins, and anthocyanins. Most of these chemicals possess beneficial health effects and exhibit diverse pharmacological effects (12).

Cineole:

A common terpene found in many aromatic plants like eucalyptus, mugwort, sweet basil, rosemary, sage, and cardamom is cineole (1,8-cineole), sometimes referred to as eucalyptol. Studies conducted in vitro have shown demonstrated that cineole triggers apoptosis. In human stomach cancer KATO III cells, but not in the human leukaemia cell lines Moult 4B and HL-60 cells. The scientists confirmed that the induction of apoptosis is the mechanism by which 1,8-cineole exerts its antitumor effects and that this action is cell-specific by seeing a concentration- and time-dependent apoptosis (as assessed by the DNA fragments) in both Moult 4B and HL-60 cells (Figure 2a) (13).

Citral:

Recent research has demonstrated that citral (3,7-dimethyl-2,6-octadien-1-al), a crucial component of Bael, can cause apoptosis in a number of haematological cancer cell lines. Activity was similar to staurosporine, a strong antitubercular antibiotic produced from Streptomyces staurosporeus. Citral has been shown to exhibit antiproliferative properties, to hinder cell cycle progression in the G2/M phase, to promote apoptosis in the human breast cancer cell line MCF-7, and to reduce prostaglandin E(2) synthesis (Figure 2b) (14).

d-limonene:

Limonene is a monoterpene found in the peel from citrus fruits, dill, caraway, fennel, and celery. Studies have shown d-limonene possess chemotherapeutic activity against pancreatic, mammary, and prostatic tumors. Mechanistic studies indicate that several pathways are responsible for the observed effects. However, the most important is the observation that monoterpenes inhibit the posttranslational isoprenylation of cell growth-regulatory proteins such as Ras (Figure 2c) (15).

Eugenol:

Eugenol is an allyl chain–substituted guaiacol (2-methoxyphenol) and a member of the phenylpropanoid class of chemical compound in aromatic plants. Cell culture studies have shown that eugenol possess cytotoxic effects against salivary gland tumor cell line

(HSG) and normal human gingival fibroblast (HGF) in vitro.26 Eugenol possesses cytotoxic effects on the malignant HepG2 hepatoma cells, malignant Caco-2 colon cells, and the nonmalignant human VH10 fibroblasts (Figure 2d) (16).

Lupeol:

Lupeol, a triterpene, is shown to possess antineoplastic effects on various human neoplastic cell lines, for example, human melanoma 451Lu cells,18 WM35 cells,18 and B162F2 cells19; human pancreatic adenocarcinoma cells AsPC-120; human epidermoid carcinoma A431 cells21; hepatocellular carcinoma SMMC7721 cells22; and prostate carcinoma cell lines LNCaP,23 CWR22Rγ1,23 and PC-3.24 Its cytotoxicity was selective for neoplastic cells (Figure 2e) (17).

Rutin:

Rutin (3,3′,4′,5,7-pentahydroxyflavone-3-rhamnoglucoside) is a flavonol, abundantly found in plants, such as passion flower, buckwheat, tea, and apple. It is a vital nutritional component of food stuff. Rutin, also called as rutoside, quercetin-3-rutinoside, and sophorin is a citrus flavonoid glycoside found in buckwheat. The name 'rutin' comes from the plant Ruta graveolens, which also contains rutin. Chemically it is a glycoside comprising of flavonolic aglycone quercetin along with disaccharide rutinose. It has demonstrated a number of pharmacological activities, including antioxidant, cytoprotective, vasoprotective, anticarcinogenic, neuroprotective and cardioprotective activities (Figure 2f) (18).

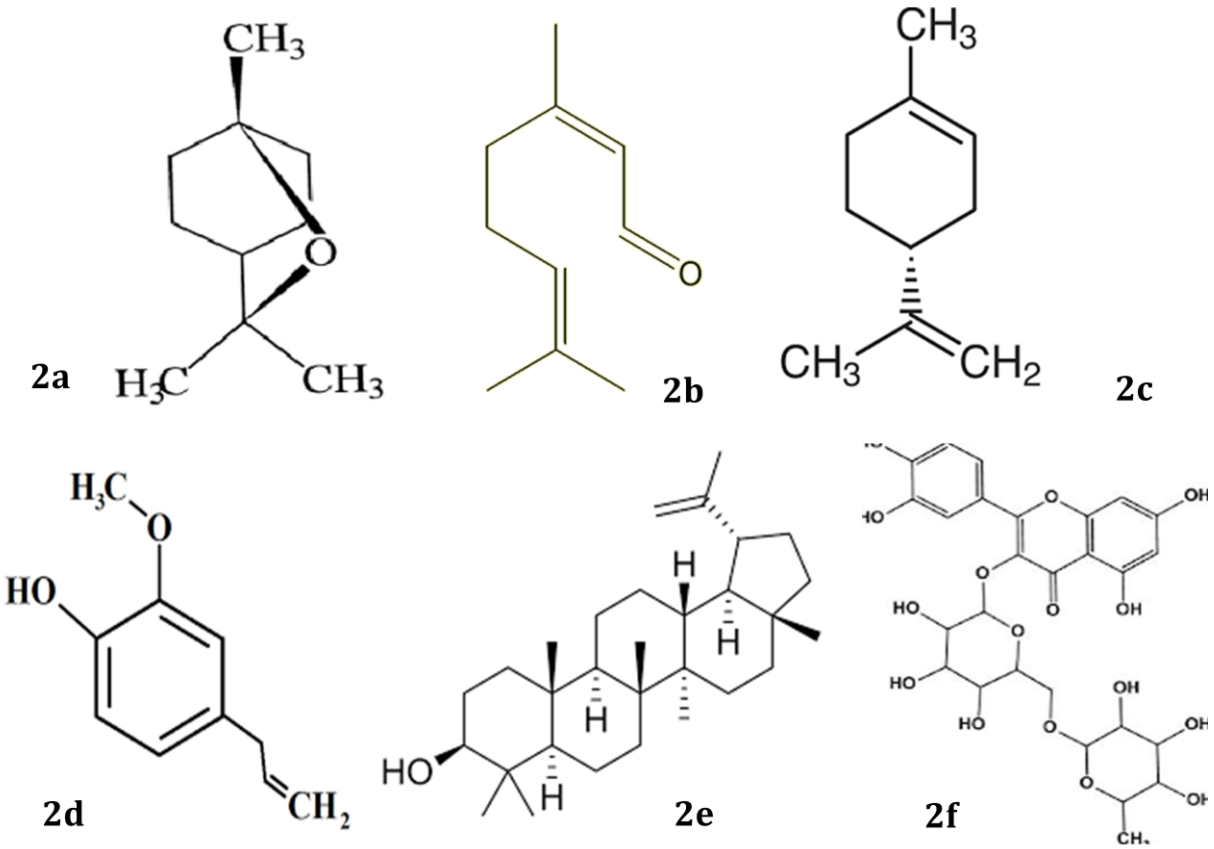


Figure 2(a-f): Major Chemical Constituents of Aegle marmelos (L) Correa
(2a: Cineole, 2b: Citral, 2c: d-limonene, 2d: Eugenol, 2e: Lupeol and 2f: Rutin)

5. Ethanomedicinal uses of Aegle marmelos (L) Correa

The ethnic community was essential in maintaining the traditional knowledge of this herb, which was utilised to treat a variety of illnesses. Both mature and immature fruit have been utilised in conventional medicine to treat dysentery and persistent diarrhoea.

When a patient has chronic diarrhoea, fresh fruit pulp juice is made and taken twice. The green fruit is cut into slices and sun-dried; the powdered dry fruit is consumed for diarrhoea and dyspepsia. To alleviate constipation, ripe fruit sharbat made with pulp, milk, and sugar is consumed. Intestinal parasites such as Entamoeba histolytica are treated by consuming a finely ground unripe fruit powder mixed with water (19).

The trifoliate leaves (bilva-patra) of this tree are offered to Lord Shiva since prehistoric times. This signifies the importance of leaves and even today is being used to cure diabetes, abscess, eye diseases, backache etc. Ripe fruit juice is very useful in treating inflammation of rectum. To treat an abscess, apply bael leaves paste to the affected area and cover it with a bandage. Leaf poultices are used to treat eye conditions such as opthalmia. Bael tea made from healthful leaves and is used to treat children's chronic digestive ailments, cough, and flatulence (20).

Backache and abscess are treated with leaves. Leaf decoction is used to treat fever and aids in clearing the bronchial tubes of mucus secretions. A small quantity is used to manage diabetes. Grinded leaves are taken with

one glass of water in the morning for a few days (21). The leaves are soaked in water overnight to treat gastric ulcers; the water is then strained and consumed in the morning for a few weeks. Leaf juice is drank by mixing it with warm water and a small amount of pepper to relieve cold and cough symptoms (22, 23).

One table spoon juice extracted from bael leaves is taken daily on a regular basis is used by tribes of Jharkhand to cure diabetes (24). Extract of bael root, pyaz and haldi are mixed in equal proportion and is put in ear to relive carache (25). Dry powder of fruit mixed with mustard oil (1:2) is applied externally to treat burn cases (26). An ethno-botanical survey of Gujjar community inhabiting Rajaji National Park, Uttarakhand was conducted by us which revealed that A. marmelos is being used for treating jaundice, diarrhea, fever, diabetes. Leaves juice taken in early morning having empty stomach is effective in diabetes while leaf juice taken with honey is helpful in prevention of fever. A teaspoon of dried and powdered bael leaves taken for three days help in increasing appetite (27). Bael leaves extract taken with honey for one week is used to cure jaundice (28). Jaundice can also be cured by consuming a teaspoon of crushed bael leaves added with a pinch of black pepper and then drink a cup of butter milk (29). The treatment is to be followed three times a day. Moreover, fruit juice is useful in the treatment of diarrhea and dysentery (30).

6. Pharmacological Activity of Aegle marmelos (L) Correa

The pharmacological activity of Aegle marmelos (L) Correa is attributed to its bioactive compounds such as alkaloids, flavonoids, tannins, and essential oils. These compounds exhibit antioxidant, anti-inflammatory, antimicrobial, and antidiabetic properties. Studies have shown that extracts from different parts of the plant possess significant pharmacological activities. For example, the leaf extract has been found to have hypoglycemic effects and can help in the management of diabetes. The fruit extract has been shown to have antioxidant properties and can help in preventing oxidative stress-related diseases. Aegle marmelos (L) Correa is a valuable medicinal plant with diverse pharmacological activities. Further research is needed to explore its full potential and develop new therapeutic applications.

Antibacterial Activity

Aegle marmelos (L) crude methanolic and chloroform leaf extracts was evaluated through agar disc diffusion method. Two Gram-positive (Bacillus subtilis, Staphylococcus aureus) and three Gram-negative bacteria (Pseudomonas aeruginosa, Klebsiella pneumonia, Escherichia coli) were used for the study. The zone of inhibitions obtained from the agar diffusion disc method showed that methanolic and chloroform leaf extracts exhibited maximum (15 mm) activity against P. aeruginosa and 18 mm against S. aureus, respectively. Both extracts were partially active against B. subtilis and K. pneumonia. The activity was maximum at higher concentration (100mg/ml) and decreased gradually with the decrease in the concentration of the extracts against all the test pathogens (31).

The antimicrobial activity of leaf extracts from *Aegle marmelos* (L.) Corr. Petroleum ether, Dichloromethane, Chloroform, Ethanol and Aqueous extract of the leaves were tested against selected Gram positive and Gram negative bacteria. Results depict that phytochemical extracts of *A. marmelos* exhibited significant anti-bacterial activity. However, the inhibitory activity was found to be both organism and solvent dependent. Ethanol and chloroform leaf extracts of *Aegle marmelos* were found to be more active towards the bacterial species tested. The leaf extracts inhibited the growth of both Gram-positive and Gram-negative bacterial species. Further, the aqueous leaf extract was moderately active followed by dichloromethane extract. However, petroleum ether extract was not effective against any of the organisms tested. Growth of *Lactobacillus bulgaris* and *Bacillus cereus* was not inhibited by any of the tested leaf extracts of *A. marmelos* (32).

Methanolic and aqueous extract of bael fruit have shown strong action against multi resistant Salmonella typhi. The methanolic extract is more potent than the aqueous extract. The Minimum Inhibitory Concentration (MIC) value of methanolic extract is around 256µg/ml. Thus it is evident that bael fruit has antibacterial activity and the mechanism of action may be the blockade of protein synthesis either at transcription or at translational level and/or peptido-glycan synthesis at membrane level (33).

Anti Viral Activity

In a study, the IC50 values of leaves, stem, stem bark, fruit, root, root bark and purified compound Marmelide were reported to be 1000, 500 to 1000, 250 to 500 and 62.5 µg/ml, respectively, whereas, the IC50 of Ribavirin (a standard antiviral agent) was 2000 µg/ml for the same viruses and at the same time period. Thus, marmelide is the most effective virucidal agent interfering with early events of its replicative cycle. The mechanism of action is that bael extracts act upon the early stages of viral replication with minimum host cytotoxicity opposite to a virucidal chemotherapeutic agent, ribavirin, acting during the later stages of viral replication accompanied with side effects (34).

Anti Fungal activity

Essential oil extracted from the bael leaves shows potent antifungal activity against animal and human fungi like: Trichophyton mentagrophytes, T. rubrum, Microsporum gypseum, M. audouinii, M. cookie, Epidermophyton floccosum, Aspergillus niger, A. flavus and Histoplasma capsulatum. The germination of any spore (bacterial or fungal) is associated to free Ca+2 ion available in the medium as well as within the cytoplasm of microbes. Bael leaf essential oil may inhibit spore germination via interference with the Ca+2–dipicolonic acid metabolism pathway (35).

Anti Malarial activity

Malaria caused by Plasmodium falciparum causes about 2 million deaths annually. Also, the species gradually get resistant to existing anti-malarial drugs which complicates the treatment of this dreadful disease. The alcoholic extracts of the bael leaves have been tested for

antimalarial activity against the NK65 strain of Plasmodium berghei. The leaves have shown activity in the in-vitro system (36).

Antiulcer Activity

A daily dose of 1 gm/kg body weight of the aqueous extract of leaves of Aegle marmelos was administered orally for 21 days. The volume of the gastric secretion, ulcer lesion count, pepsin content, PH, total acidity, hexose and hexosamine content were the parameters to estimate. The observation indicated a significant reduction in the ulcer lesion count, volume of gastric juice, acidity (increase in pH) and hexosamine after treatment with aqueous extract. However there was no significant alteration in pepsin and hexose content (37).

The antiulcer activity of methanolic extract of leaves of Aegle marmelos on gastric ulcer induced rats by aspirin plus pylorus ligation. Indomethacin induced ulcer in rats, water immersion stress test induced ulcer in rats. In aspirin plus pylorus ligation model, Aegle Marmelos when given in doses of 200 and 400 mg/kg produced significant reduction in gastric volume, free acidity and ulcer index compared to control (38).

Antiulcer activity of ethanolic extract of Aegle marmelos against aspirin induced gastric ulcer in albino rats. Gastric volume, pH of gastric content, free acidity and total acidity, total carbohydrate content such as total protein, hexoses, hexosamine, fucose and sialic acid were the various biochemical parameters which were estimated in alcoholic precipitate of gastric juice and examined on the test and control group of animals. A protective effect on ulcer induced models was exhibited by the extract in a dose dependent manner and was comparable with the standard drug Lansprazole. As a result gastric volume, free and total acidity and ulcer index were significantly reduced due to the extract of Aegle marmelos. When compared with the standard drug, it was concluded that the extracts possess significant gastroprotective activity (39).

the efficacy of A. marmelos leaf to prevent ethanol induced gastric ulcer in a rat model. Thirty two Wister albino rats were adminiatered dose of 200 mg/kg or 400 mg/kg aqueous extract of A. marmelos leaves. The animals were sacrificed after one hour and then ulcer scores, index and Percentage protection of ulcer were determined. They concluded that extracts of A. marmelos leaves have potential ability to prevent experimentally induced peptic ulcer formation (40).

Antiulcer effect of Aegle marmelos which were determined in aspirin induced gastric mucosal injury in cannulated free-moving rats. As a result, pretreatment significantly prevented the development of gastric mucosal lesion and decreased the gastric toxicity produced by ulcerogen. Aegle marmelos exhibits antisecretory and cytoprotective property that protects the gastric mucosa against ulceration (41, 42).

Antioxidant Activity

Leaf extract (dose-200 mg/kg) was found to be as effective as natural antioxidant alpha tocopherol (60mg/kg) in isoproterenal (ISO)-treated rats. The antioxidant activity or free radical scavenging activity in the leaf is attributed to the presence of phytochemical such as flavonoids, alkaloids, sterols, tannins, (45phlobatannins and flavonoid glycosides (43). The antioxidant potential of bael leaves increases the level of (GSH) in erythrocyte and decrease of plasma glutathione-S-transferase (GST) and malondialdehyde (MDA) in male albino rats The antioxidant potential of bael leaves brings back the level to normal (44).

Anti Diabetic Activity

Phytochemical screening of A. marmelos fruit extract revealed the presence of alkaloids, carbohydrates, glycosides, flavonoids, tannins, coumarins, sterols and triterpenoids. Results of the biological study reported that alloxan-induced diabetic group exhibited hyperglycemia, hyperlipidemia, elevation in malondialdehyde (MDA) level accompanied with weight loss and reduction in high density lipoprotein cholesterol (HDL-C) level, reduced glutathione (GSH) level and superoxide dismutase (SOD) enzyme activity when compared to control group. Treatment with A. marmelos fruit extract at the three dose levels reported improvement in the biological evaluation, lipid profile, glucose, insulin, MDA and GSH levels and SOD enzyme activity when compared to the diabetic group. The improvement was most pronounced in 500 mg/kg A.marmelos treated group (45).

The present study shows the hypoglycemic effect of extracts of leaf and callus against STZinduced diabetes. It appears that the leaf and callus extracts possess the ability to stimulate the insulin secreting cells of pancreas. This would, in turn, decrease the blood sugar as would do the leaf extract of A. marmelos11. All these findings suggest that both the leaf and callus extracts may be acting, through some mechanism, to improve the receptor-responsiveness to insulin causing increased sugar uptake by the tissue (46).

Leaf extracts of Aegle marmelos are reported to have hypoglycemic and anticancer effects. While a lot of information is available about the antioxidant activity of fruit of A. marmelos not much information is available about the antioxidant activity of the leaf of A. marmelos. AME was evaluated for total phenolic content (TPC) and total flavonoid content (TFC) by Folin-Ciocalteau reagent method and by aluminium chloride method, respectively. Antioxidant activity of AME was assessed by FRAP assay, DPPH assay, ABTS cation scavenging activity and by reducing power determination. Results: High levels of TPC and TFC were found in AME which showed antioxidant activity comparable to vitamin C. Significant correlation between TPC, TFC and antioxidant activity of AME was found when Pearson's correlation is applied (47).

Anti-Inflammatory Activity

A total of 191 extracts (petroleum ether, ethyl acetate, ethanol and aqueous) of roots, stems and leaves of A. marmelos were tested for anti-inflammatory effects in vitro on isolated target enzymes cyclooxygenase-1 (COX-1), cyclooxygenase-2 (COX-2) and 5-lipoxygenase (5-LOX), lymphocyte proliferation assay (LPA), cytokine profiling in LPS induced mouse

macrophage (RAW 264.7) cell line and in vivo carrageenan induced paw edema in mice. Of 191 extracts, 44 extracts showed COX-2 inhibition and 38 extracts showed COX-1 inhibition, while none showed 5-LOX inhibition. Cytokine analysis of the 44 extracts showing inhibition of COX-2 suggested that only 17 extracts modulated the cytokines by increasing the anti-inflammatory cytokine IL-2 and reducing the pro-inflammatory cytokines like IL-1β, MIP1-α and IL-6. The young (2 and 3 years) roots of Bilva plants from Gujarat and young (1 yr) roots from Odisha showed the most potent anti-inflammatory activity by suppressing the pro-inflammatory cytokines and inducing anti-inflammatory cytokines. These three extracts have also shown in vivo anti-inflammatory activity comparable to that in adult stem and root barks (48).

Antipyretic Activity

the antipyretic property of Aegle marmelos (L.) Correa leaves (Family: Rutaceae) on Brewer's yeast-induced pyrexia in albino rats. It reveals that the ethanolic extract, at dose of 200 mg kg-1 body wt. and 400 mg kg-1 body weight, produced significant (p.o.), a standard antipyretic agent (49).

Hepatoprotective Activity

The study investigated the hepatoprotective effect of A. marmelos leaves' crude ethanolic extract on mice induced by carbon tetrachloride (CCl4). The extract showed significant protective effects, lowering enzyme levels and increasing high density lipoprotein levels. It also increased antioxidant enzyme levels and reduced lipid peroxidation. Further research is needed to develop a lead molecule for hepatoprotection (50).

A study investigated the hepatoprotective effect of Aegle marmelos Roxb fruits against carbon tetrachloride (CCl4)-induced hepatotoxicity in rats. The rats were divided into six groups and treated with extracts of fruit pulp/seeds and CCl4 before or after administration. Results showed that the extracts significantly reduced CCl4-induced elevation in plasma enzyme and bilirubin concentration, suggesting that CCl4-induced liver damage can be ameliorated (51).

Toxicity Profile

The study investigated the toxicity of Aegle marmelos plant extracts in rats. The extracts were tested on various animals, including dead animals and postmortem subjects. Histopathological studies revealed no significant changes in vital organs after chronic administration of A. marmelos for 14 days. The study found a broad therapeutic window and high therapeutic index value for A. marmelos extracts. Intraperitoneal administration of A. marmelos extracts at doses of 50, 70, 90, and 100 mg/kg body weight did not induce short-term toxicity, demonstrating high drug safety margins (52).

7. Conclusion

Because of its many qualities, including its usual colour, flavour, and texture, aegle marmelos should be considered a possible nutraceutical resource and food additive in the future. It may also provide health advantages when employed in functional food items. The development and enhancement of bael leaf quality can be facilitated by these results. This review makes it quite clear that Aegle marmelos has a variety of phytoconstituents, which contribute to its value for a range of medicinal reasons. The valuable medicinal plant extracts have the potential to serve as the primary source of healthcare not just for the impoverished Indian tribal people, but also as an adjunct to primary care and an alternative to the allopathic medical system. In a time when traditional knowledge is becoming more widely accepted, these locally grown herbs can be used as safe, affordable, and easily accessible alternatives to more complex, expensive, and potentially harmful pharmaceutical medications.

8. Conflict of Interest

None

9. Reference

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