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Review Article

Exploring the phytochemical constituents of *Aegle marmelos* (bael) and their therapeutic potential against chronic diseases

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ABSTRACT

Aegle marmelos (Bael), a highly esteemed plant in traditional medicine, is recognized for its remarkable therapeutic properties, attributed to its rich and diverse phytochemical composition. The plant contains bioactive compounds such as alkaloids, flavonoids, tannins, phenolic acids, coumarins and essential oils, which contribute to its pharmacological activities. These compounds exhibit potent antioxidant, anti-inflammatory, antidiabetic, antimicrobial, hepatoprotective and cardioprotective effects, positioning Bael as a promising natural remedy for managing chronic diseases. Bael has demonstrated significant efficacy in regulating blood glucose levels, enhancing insulin sensitivity and protecting pancreatic beta cells, making it an effective agent in diabetes management. Additionally, its strong antioxidant and anti-inflammatory activities are essential in combating oxidative stress and chronic inflammation, which are key drivers of metabolic and neurodegenerative disorders. Bael's antimicrobial properties further expand its potential to address infections and gastrointestinal issues. However, the integration of *Aegle marmelos* into mainstream medicine faces challenges, including variability in its phytochemical composition, lack of standardized formulations and insufficient clinical trials to validate its safety and efficacy. This review aims to comprehensively explore the phytochemical constituents of *Aegle marmelos* and their therapeutic potential, particularly against chronic diseases. By identifying research gaps and future directions, it seeks to support the development of Bael as a reliable, standardized and effective therapeutic agent for modern healthcare.

Keywords: *Aegle marmelos*, Anti-microbial property, Phytochemical constituents

INTRODUCTION

The plant *Aegle marmelos* Correa, commonly known as Bael or Bengal quince, holds a prominent place in traditional medicine systems, particularly in Ayurveda, Siddha and Unani medicine, due to its diverse pharmacological properties. Native to India and Southeast Asia, Bael is revered as a sacred tree and is often associated with religious rituals, underscoring its cultural significance. Its multifaceted therapeutic applications have earned it the designation of a "panacea" for various ailments, making it a subject of growing scientific interest. In traditional practices, every part of the tree leaves, fruit, bark, roots and seeds is utilized to treat an array of

conditions, including gastrointestinal disorders, respiratory diseases, diabetes and fever. The widespread traditional use of Bael has inspired a surge of research in recent years to validate its therapeutic efficacy and explore its bioactive compounds. Phytochemical investigations have revealed that *Aegle marmelos* is a rich repository of bioactive compounds, including alkaloids, flavonoids, tannins, terpenoids, coumarins and essential oils. These compounds are responsible for the plant's diverse pharmacological properties. Notably, marmelosin, aegeline and skimmianine are key constituents that have shown promising therapeutic potential in preclinical studies.¹ These bioactive components have demonstrated anti-inflammatory, antimicrobial, antioxidant and

antidiabetic activities, thereby providing a scientific basis for its traditional uses. The fruit pulp, in particular, is rich in dietary fibre, vitamins and minerals, which contribute to its role in managing gastrointestinal ailments such as constipation and diarrhoea.² The leaves are known for their hypoglycaemic activity, making them an important natural remedy for diabetes management.³



Figure 1: Bael leaf.

Recent studies have further highlighted the antimicrobial properties of *Aegle marmelos*, with its extracts exhibiting significant activity against bacterial and fungal pathogens, including *Escherichia coli*, *Staphylococcus aureus* and *Candida albicans*.⁴ The plant's antiviral potential has also been explored, with encouraging results against viruses such as herpes simplex and dengue, suggesting its utility in managing viral infections.⁵ The antioxidant properties of Bael, attributed to its flavonoid and phenolic content, have garnered attention for their role in mitigating oxidative stress and preventing chronic diseases such as cardiovascular disorders and neurodegenerative conditions.⁶

In addition to its pharmacological attributes, *Aegle marmelos* has been investigated for its safety profile. Acute and sub-chronic toxicity studies have demonstrated that the plant extracts are generally safe within a specified dosage range, with no significant adverse effects observed in animal models.⁷

These findings underscore the plant's potential as a safe and effective natural remedy, paving the way for its inclusion in modern therapeutics. Despite its promising pharmacological profile, challenges remain in translating traditional knowledge into clinically validated interventions. The lack of standardized extraction methods, variability in phytochemical composition and limited clinical trials are significant barriers to its widespread adoption in evidence-based medicine.⁸

The growing interest in *Aegle marmelos* is reflective of a broader trend towards rediscovering traditional medicinal plants and integrating them into contemporary healthcare systems. Advances in phytochemical analysis, molecular

docking studies and bioinformatics have provided new insights into the mechanisms underlying its therapeutic effects. Moreover, its potential for use in the development of functional foods, nutraceuticals and herbal formulations highlights its versatility and economic value. This review aims to provide a comprehensive overview of the therapeutic potential and traditional uses of *Aegle marmelos*, with a focus on its phytochemical composition, pharmacological properties and prospects. By bridging the gap between traditional knowledge and modern science, this review seeks to contribute to the growing body of evidence supporting the medicinal value of *Aegle marmelos*.

TRADITIONAL USES OF A MARMELOS

Aegle marmelos (L.) Correa, commonly known as Bael, has been extensively utilized in traditional medicine systems, including Ayurveda, Siddha and Unani, due to its remarkable therapeutic potential.³⁰ Traditionally, every part of the Bael tree leaves, fruit, bark, roots and seeds has been employed to treat a variety of ailments. The ripe fruit is valued for its digestive properties and is commonly used to alleviate constipation, while the unripe fruit is a well-known remedy for diarrhoea and dysentery.⁹

In Ayurvedic texts, Bael is classified as a coolant and is frequently recommended for managing gastrointestinal issues, particularly in conditions caused by a pitta imbalance.¹⁰ The pulp of the fruit, when prepared as a sherbet, is also used as a natural summer drink to combat heat-induced dehydration and fatigue.

The leaves of *Aegle marmelos* are considered sacred and are frequently offered in religious rituals in India. Medicinally, leaf extracts are widely used as a natural remedy for diabetes due to their hypoglycemic properties, a practice supported by traditional healers for centuries.¹⁰ The leaves are also crushed and applied as a poultice for skin infections and wounds, reflecting their antimicrobial activity. Similarly, the bark and roots of Bael are used to treat fever and inflammation. Decoctions prepared from the bark are commonly administered in traditional systems to manage intermittent fevers and as a mild analgesic for joint pain.¹¹

The seeds of Bael are less commonly utilized but are known for their anthelmintic properties and are traditionally used to expel intestinal worms.¹² In rural areas, the roots are boiled and consumed as a remedy for respiratory disorders such as asthma and bronchitis, highlighting their expectorant properties.¹³ Furthermore, Bael is also regarded as a cardi tonic in traditional practices, with its fruit and leaf extracts often prescribed to support heart health.

Recent ethnobotanical surveys have documented its continued use in remote communities, underscoring its enduring importance in traditional healthcare systems.¹⁴ These practices reflect the profound cultural and medicinal

significance of *Aegle marmelos*, which remains an integral part of traditional medicine across its native regions.

PHYTOCHEMICAL COMPOSITION OF AEGLE MARMELOS

The phytochemical composition of *Aegle marmelos* (Bael) is extensive and diverse, comprising a range of bioactive compounds responsible for its wide spectrum of therapeutic activities. Among its notable constituents are alkaloids, flavonoids, phenolic compounds, tannins, terpenoids, coumarins and essential oils, which have been identified through various analytical techniques, including GC-MS and HPLC.¹⁴ Marmelosin, a coumarin derivative, is one of the primary bioactive compounds in Bael fruit and has been associated with antioxidant, antidiabetic and hepatoprotective properties. Other coumarins such as imperatorin and psoralen have demonstrated significant antimicrobial and anti-inflammatory effects in preclinical studies.¹⁵

The flavonoid content of Bael, including rutin, quercetin and kaempferol, plays a crucial role in its antioxidant and cardioprotective properties. These flavonoids are potent free radical scavengers that mitigate oxidative stress, thereby preventing the progression of chronic diseases such as cardiovascular disorders and neurodegenerative conditions.¹⁶ Tannins, particularly in the unripe fruit, have been linked to its antidiarrheal and gastroprotective properties, as they help in the contraction of the intestinal mucosa and reduce intestinal fluid secretion.¹⁷

Terpenoids, including aegeline, are another significant group of phytochemicals found in the leaves and fruit of *Aegle marmelos*. Aegeline has shown hypoglycaemic and lipid-lowering activities in recent studies, making it a promising candidate for managing metabolic disorders such as diabetes and hyperlipidaemia.¹⁷ Additionally, the plant contains essential oils, predominantly in the leaves and fruits, which consist of compounds like limonene, citral and eugenol. These volatile compounds exhibit strong antimicrobial and insecticidal activities, which are valuable in both medicinal and agricultural applications.¹⁸

Phenolic acids, including gallic acid, caffeic acid and ferulic acid, are abundant in the Bael fruit and are known for their anti-inflammatory and anticancer activities. These compounds inhibit pro-inflammatory cytokines and oxidative pathways, contributing to their therapeutic potential in conditions like arthritis and cancer.¹⁹ Furthermore, the seeds of Bael are rich in fatty acids and proteins, with linoleic acid being the most prominent. These components add nutritional value to the plant, supporting its traditional use in managing malnutrition and related disorders.²⁰

Recent advancements in analytical techniques have facilitated a more detailed understanding of the phytochemical diversity of Bael. Studies employing metabolomics approaches have revealed the presence of

several secondary metabolites that may synergize to produce the plant's observed therapeutic effects.¹⁸ However, variations in phytochemical content due to factors such as geographical location, harvesting time and extraction methods remain a significant challenge. Efforts to standardize extraction protocols and identify bioactive markers are critical for the development of Bael-based nutraceuticals and pharmaceuticals.²¹ These findings underscore the phytochemical richness of *Aegle marmelos* and its immense potential as a source of natural therapeutics.

THERAPEUTIC POTENTIAL OF AEGLE MARMELOS

Antimicrobial and antiviral activity

The antimicrobial properties of *Aegle marmelos* have been extensively studied, demonstrating its efficacy against a range of bacterial, fungal and viral pathogens. Phytochemicals such as tannins, flavonoids, alkaloids and essential oils contribute to its antimicrobial activity. Recent research shows that ethanolic extracts of Bael inhibit the growth of bacterial pathogens such as *Escherichia coli*, *Staphylococcus aureus* and *Salmonella typhi*.²² These findings underline its potential in managing gastrointestinal infections. Similarly, studies have revealed its antifungal properties, with activity against strains like *Candida albicans* and *Aspergillus niger*.²³

The antiviral activity of Bael is linked to its bioactive compounds, particularly eugenol and marmelosin, which disrupt viral replication. Extracts of the fruit have shown potential against RNA viruses such as dengue and influenza, making it a promising candidate for the development of novel antiviral agents.²⁴ These properties position Bael as a valuable natural resource for combating infectious diseases.

Antidiabetic activity

Bael has long been utilized in traditional medicine for managing diabetes and modern studies validate its antidiabetic potential. Its hypoglycaemic activity is primarily attributed to compounds such as *Aegeline marmelos* and coumarins, which enhance insulin secretion and improve glucose uptake in peripheral tissues.²⁵ Bael leaf extracts inhibit α -amylase and α -glucosidase enzymes, reducing postprandial blood glucose levels by delaying carbohydrate digestion.²⁶

In preclinical models, Bael extracts significantly reduced fasting blood glucose, glycosylated haemoglobin (HbA1c) levels and oxidative stress markers in diabetic rats. Clinical studies further validate these findings; patients consuming Bael-based formulations have reported improved glycaemic control, reduced lipid peroxidation and decreased insulin resistance.²⁷ These studies highlight Bael's multifaceted role in diabetes management,

including its ability to prevent complications such as neuropathy and nephropathy.

Antioxidant and Anti-inflammatory Activity

Bael is a rich source of antioxidants, including phenolic acids, flavonoids and carotenoids, which effectively neutralize free radicals and reduce oxidative stress. Oxidative stress is a key factor in the pathogenesis of numerous chronic diseases and Bael's antioxidant properties make it a valuable therapeutic agent.²⁸ The fruit and leaf extracts of Bael enhance the activity of endogenous antioxidant enzymes such as superoxide dismutase, catalase and glutathione peroxidase.

The anti-inflammatory activity of Bael is mediated through the inhibition of pro-inflammatory cytokines, including tumour necrosis factor-alpha (TNF- α) and

interleukins (IL-6, IL-1 β). These actions are beneficial in conditions like arthritis, inflammatory bowel disease and cardiovascular disorders.²⁹ Recent studies also suggest that the combination of antioxidant and anti-inflammatory effects of Bael could be leveraged in the treatment of age-related degenerative diseases.

Table 1: Taxonomical classification of *A marmelos*.⁸

Kingdom	Plantae
Division	Tracheobionta
Class:	Magnoliopsida
Subclass	Rosidae
Order	Sapindales
Family	Rutaceae
Genus	Aegle
Species	<i>Aegle marmelos</i>

Table 2: Various parts of *A marmelos* according to their therapeutic potential are described by below.

S. no	Plant parts	Therapeutic potential
1.	Leaves	Bael leaves are acetic, laxative and an expectorant that is used to treat diseases like ophthalmia, deafness, inflammations, cataracts, diabetes, diarrhea, dysentery, heart palpitation and asthmatic difficulties. ¹⁰ It is vital to concentrate on the particular phytochemical intensifies liable for hepatoprotective impact or to control liver diseases. ³³
2.	Fruits	Fruits are effective for one's health and the organic product mash is utilized to plan delights like murabba, puddings and juice. ¹ It is mainly used as a treatment for diarrhea. ³ It helps in curing scurvy and healing ulcerated intestinal surfaces. ² It acts as an antibacterial, antifungal and antiviral activity and fights against microorganisms like <i>E. coli</i> , <i>Bacillus subtilis</i> , etc. ⁶
3.	Flower	Traditional medical systems have employed flower distillation to create a medicine used as a tonic for the stomach and intestines. ⁴
4.	Bark and root	The root of this plant can be utilized against diarrhea, fever, a seminal shortcoming, ear infection, dysentery, cardiopalmus, uropathy, gastric irritability in infants, stomachalgia, vitiated conditions of vata, vomiting, increased fertility power of men and bark decoction is used to cure malaria. ^{9,34}
5.	Seed	Bael seeds are a rich source of good quality protein and are used as protein dietary and food supplements. ¹⁴ Seeds are successful within the treatment and anticipation by CC14-induced hepatic cytotoxicity. ³⁴

Table shows the various parts of the Beal plant show high sources of bioactive constituents

Hepatoprotective and cardioprotective effects

Bael demonstrates hepatoprotective effects through its ability to mitigate oxidative damage and inflammation in the liver. Experimental studies using animal models have shown that Bael extracts significantly reduce serum markers of liver damage, such as alanine transaminase (ALT), aspartate transaminase (AST) and bilirubin, in conditions of drug-induced hepatotoxicity.²⁶

The hepatoprotective action is linked to compounds like aegeline and marmelos in, which prevent lipid peroxidation in hepatocytes. The cardioprotective effects of Bael are equally noteworthy. Its ability to improve lipid

profiles, reduce blood pressure and decrease myocardial oxidative stress makes it beneficial in managing cardiovascular diseases. Flavonoids in Bael reduce LDL cholesterol levels and enhance HDL cholesterol, while its antioxidant properties prevent atherosclerosis and ischemic heart disease.²³ These findings underscore Bael's potential as a natural remedy for liver and heart health.

Gastroprotective and antidiarrheal effects

Bael has been extensively used in traditional medicine to treat gastrointestinal disorders, including diarrhoea, dysentery and peptic ulcers. The unripe fruit of Bael, rich in tannins, acts as an astringent and reduces intestinal motility, making it effective against diarrhoea and dysentery caused by infections.³² Additionally, the mucilage content in Bael provides a protective layer over

the gastric mucosa, preventing damage from gastric acid and NSAID-induced ulcers.³⁴ In clinical trials, Bael fruit pulp has shown efficacy in managing irritable bowel syndrome (IBS) by improving stool consistency and reducing abdominal pain. The gastroprotective effects are attributed to its ability to stimulate mucus secretion and reduce gastric acid output, thus aiding in the prevention and healing of ulcers.¹⁸ These properties make Bael a vital therapeutic agent for managing digestive ailments.

Neuroprotective potential

The neuroprotective effects of Bael are attributed to its antioxidant and anti-inflammatory properties, which help mitigate oxidative damage and inflammation in neuronal tissues. Flavonoids such as rutin and quercetin found in Bael enhance synaptic plasticity and reduce the production of neuroinflammatory mediators like IL-1 β and TNF- α .¹²

Preclinical studies have demonstrated that Bael extracts inhibit acetylcholinesterase activity, a key enzyme involved in the degradation of acetylcholine, thereby enhancing cholinergic transmission in the brain. This action is particularly beneficial in neurodegenerative diseases like Alzheimer's disease.²³ Additionally, Bael has shown potential in preventing amyloid-beta aggregation, a hallmark of Alzheimer's pathology. Its neuroprotective effects extend to improving cognitive function and memory, making it a promising candidate for the treatment of age-related cognitive decline.

Other therapeutic applications

Beyond its antimicrobial, antidiabetic and neuroprotective properties, *Aegle marmelos* exhibits several other therapeutic benefits. Its anticancer potential has been highlighted in recent studies, where Bael extracts induced apoptosis and inhibited the proliferation of cancer cells, including breast and colon cancer cell lines.²⁶ The anticancer activity is linked to compounds such as marmelosin and psoralen, which modulate key signalling pathways involved in cell growth and survival.

Bael also exhibits immunomodulatory properties, enhancing the production of immune cells and cytokines. This makes it effective in boosting overall immunity and combating infections.²⁹ Furthermore, Bael is widely used in wound healing due to its antimicrobial and anti-inflammatory properties. Traditional applications involve the use of Bael leaf poultices to promote the healing of cuts and burns and recent studies confirm these effects, attributing them to the plant's bioactive constituents.³²

PHARMACOLOGICAL AND TOXICOLOGICAL STUDIES

Extensive pharmacological and toxicological studies have been conducted to evaluate the safety and efficacy of *Aegle marmelos* (Bael), a medicinal plant revered for its therapeutic potential. These studies encompass both in

vitro and in vivo experiments, providing insights into its pharmacological activities and toxicity profile.

Pharmacological studies

The therapeutic properties of Bael have been validated through numerous pharmacological investigations. In vitro studies have highlighted its antimicrobial, antioxidant and anti-inflammatory activities, attributed to its diverse phytochemicals, including alkaloids, flavonoids and tannins.²⁹ For example, Bael extracts demonstrate potent inhibition of bacterial growth against *Escherichia coli*, *Staphylococcus aureus* and *Pseudomonas aeruginosa*.³² Its antifungal and antiviral properties are equally noteworthy, with activity against *Candida albicans* and dengue virus.

In vivo studies corroborate these findings and extend the therapeutic relevance of Bael to systemic health benefits. Animal models have shown that Bael significantly reduces oxidative stress markers, lipid peroxidation and pro-inflammatory cytokine levels, underscoring its potential in managing chronic diseases.²⁷ Bael's neuroprotective effects are particularly promising; preclinical studies in rodent models demonstrated improved cognitive function and reduced amyloid-beta aggregation, suggesting potential applications in neurodegenerative diseases like Alzheimer's.²³

The antidiabetic efficacy of Bael has also been extensively studied. In diabetic rat models, Bael leaf extracts improved fasting blood glucose levels, insulin sensitivity and glycemic control by modulating carbohydrate metabolism enzymes such as α -amylase and α -glucosidase.³⁴ Clinical studies complement these findings, revealing reductions in HbA1c and fasting glucose levels in diabetic patients supplemented with Bael-based formulations.

Toxicological studies

Toxicological evaluations of Bael have focused on determining its safety profile and identifying safe dosage limits. Acute toxicity studies conducted on rodents indicate that aqueous and ethanolic extracts of Bael are well-tolerated at doses up to 5,000 mg/kg body weight, with no observable adverse effects.¹⁸ Sub-chronic toxicity studies over 90 days have shown that Bael does not cause significant alterations in haematological, biochemical or histopathological parameters at doses of up to 1,000 mg/kg.

Despite its overall safety, some studies have reported dose-dependent toxicity at higher concentrations. For instance, extremely high doses of Bael extracts may induce mild gastrointestinal disturbances, such as diarrhoea and nausea, likely due to its tannin content.³⁴ However, these effects are typically transient and resolve upon discontinuation of treatment.

Reproductive toxicity studies have revealed no teratogenic or embryotoxic effects of Bael at therapeutic doses,

supporting its safe use during pregnancy. Additionally, genotoxicity and mutagenicity assays, including the Ames test and chromosomal aberration test, have consistently shown negative results for Bael extracts.¹⁹

Safe dosage recommendations

Based on toxicological data, the safe dosage of Bael varies depending on the extract type and route of administration. For aqueous and ethanolic extracts, doses up to 500 mg/kg are considered safe for long-term use in animal models.⁹ In humans, therapeutic doses of 250–500 mg/day of Bael extract are generally recommended for managing conditions such as diabetes and gastrointestinal disorders. However, individual factors such as age, weight and underlying health conditions should be considered when determining the optimal dosage.

Overall, the pharmacological and toxicological evidence underscores the therapeutic potential and safety of *Aegle marmelos* when used within recommended dosages. Its multifaceted pharmacological activities, coupled with a favourable safety profile, make it a promising candidate for the development of novel herbal therapeutics. Future studies should aim to elucidate its long-term safety and efficacy in diverse populations through well-designed clinical trials.

CURRENT CHALLENGES

Limited standardization and quality control

One of the major challenges in utilizing *Aegle marmelos* in clinical settings is the lack of standardization in terms of its active ingredients, dosage and quality control. The therapeutic effects of Bael are highly dependent on the plant's extraction methods, the specific parts of the plant used (leaves, fruits or bark) and the preparation form (e.g., powder, extract or decoction).

There is a need for standardized protocols to ensure the consistency and potency of Bael-based products. This would not only improve the efficacy of the plant in clinical applications but also ensure safety, particularly in commercial products.²⁶

Insufficient clinical evidence

Although preclinical studies (in vitro and in vivo) have provided promising results regarding the therapeutic properties of *Aegle marmelos*, there is still a lack of robust clinical trials involving human subjects.

Most of the available research is based on animal models, which limits the generalizability of the results to human populations. Human clinical trials are necessary to confirm the plant's effectiveness and safety in the treatment of various diseases. Furthermore, clinical studies would help determine the appropriate dosages, treatment regimens and long-term effects of Bael.²²

Variability in phytochemical composition

The therapeutic potential of Bael is attributed to its rich composition of bioactive compounds, including alkaloids, flavonoids, tannins and glycosides. However, the phytochemical profile of *Aegle marmelos* can vary significantly depending on the geographical region, environmental conditions and plant maturity. This variability makes it difficult to assess the plant's true therapeutic efficacy and complicates the process of developing standardized extracts for medicinal use.²⁷

Lack of comprehensive toxicological studies

While Bael has shown a favourable safety profile in preclinical studies, comprehensive toxicological studies, including long-term toxicity, genotoxicity and carcinogenicity, are still lacking.²³ The current toxicological data primarily focus on acute toxicity and hepatotoxicity, but detailed studies on chronic toxicity, especially when used over extended periods, are needed. There is also a need to assess the interactions between Bael and other pharmaceutical agents to avoid any potential adverse effects when combined with conventional drugs.²⁰

FUTURE PROSPECTS

Development of standardized extracts

Future research should prioritize the development of standardized Bael extracts that can be utilized in clinical trials and pharmaceutical products. Advances in analytical techniques such as high-performance liquid chromatography (HPLC) and mass spectrometry (MS) can help identify and quantify the key bioactive compounds in Bael. Standardized extracts would ensure the consistency of therapeutic effects and enable the creation of reliable dosage forms for medical use.

Clinical trials for efficacy and safety

Conducting well-designed, randomized controlled clinical trials (RCTs) is essential to establish the therapeutic efficacy and safety of Bael in humans.

These trials should focus on a variety of conditions, including diabetes, gastrointestinal disorders, inflammation and infections. Furthermore, clinical studies should explore the optimal dosage, administration route and duration of treatment to maximize therapeutic outcomes while minimizing risks.

Exploration of synergistic effects

Given its wide range of bioactive compounds, Bael may exhibit synergistic effects when combined with other herbal medicines or conventional pharmaceutical agents. Future research could focus on the potential synergism of Bael with other traditional plants, enhancing its therapeutic effects and reducing potential side effects. Investigating

Bael's role in polyherbal formulations could open up new avenues for its clinical applications.

Biotechnological advances

With the advent of biotechnology, there is potential to optimize the production of Bael's bioactive compounds through plant tissue culture and genetic modification. This could provide a more sustainable and controlled method of producing high-quality Bael extracts, making them more accessible to pharmaceutical and nutraceutical industries.

Nanotechnology for drug delivery

Nanotechnology holds promise in enhancing the bioavailability and targeted delivery of Bael's active compounds. Nano-formulations could improve the absorption of Bael's bioactive components, increase their therapeutic efficacy and reduce any potential toxicity. The use of nanocarriers for drug delivery could make Bael a more potent and safe therapeutic agent in the treatment of various diseases.

CONCLUSION

Aegle marmelos (Bael) presents a wealth of therapeutic potential, with evidence supporting its use in the treatment of various conditions such as gastrointestinal disorders, diabetes, inflammation and infections. While Bael holds promise, the current challenges in terms of standardization, clinical evidence, phytochemical variability and toxicological safety must be addressed to realize its full potential in modern medicine. Future research should focus on developing standardized extracts, conducting clinical trials, exploring synergistic effects with other medicinal agents and utilizing biotechnological and nanotechnological advances. With continued research and innovation, *Aegle marmelos* has the potential to become a significant player in both traditional and modern therapeutic landscapes, offering natural solutions to a variety of health concerns.

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