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Mango leaves unveiled: A comprehensive review of their benefits and uses

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Abstract
Mangifera indica L. is a significant fruit from South and Southeast Asia that is a member of the Anacardiaceae family. Among the leading mango-producing nations are Bangladesh, Nigeria, the Philippines, Mexico, Brazil, Thailand, Indonesia, Pakistan, and China. Following a phytochemical analysis of the mango leaf extract, five benzophenones and seventeen flavonoids were isolated and identified. The biological properties of mango leaf (ML) extracts, such as their anti-cancer, antidiabetic, antioxidant, anti-microbial, anti-obesity, lipid-lowering, hepato-protective, and anti-diarrheal properties, have been investigated.

Keywords: Mango leaves, taxonomy, phytochemicals, medicinal importance, pharmacological activity, toxicological activity

Introduction
One of the most economically significant tropical fruit crops in the world and a major traditional crop, the mango (Mangifera indica L.), belongs to the Anacardiaceae family. In addition to its wellknown fruits, the mango tree has several traditional medical uses. In 2018, 55.4 million tons of mangoes (including guavas and mangosteens) were produced globally. Mangoes are native throughout South and Southeast Asia.
Minerals like nitrogen, potassium, phosphorus, iron, salt, calcium, and magnesium, as well as vitamins A, B, E, and C, may be found in mango leaves (MLs). Protein is one of the main biomacromolecules found in mango leaves. As research continues to grow and develop, a variety of mango physiological and pharmacological actions have been discovered [1].
One type of crop waste with a wealth of resources is mango leaves. Comprehensive phytochemical investigations are being conducted to identify anti-inflammatory, antioxidant, and anti-diabetic compounds in the ongoing search for bioactive phytochemicals from high plants. Traditional therapies have used ML extracts to treat scabies, respiratory issues, syphilis, diabetes, bronchitis, diarrhea, asthma, renal disease, and urinary diseases [2]. Mangiferin is the most biologically active component of MLs, followed by benzophenones, phenolic acids, and other antioxidants like tocopherols, flavonoids, carotenoids, quercetin, isoquercetin, and ascorbic acid. The majority of MLs extract's biological actions are mostly attributed to mangiferin. Additionally, the essential oil from MLs has bacteriostatic qualities and contains a number of antimicrobial components, including camphor, αgurjunene, trans-caryophyllene, α-humulene, and α-selinene [3].

Taxonomy description of mangifera indica
Mangifera is a member of the Anacardiaceae family. There are roughly 69 species in the genus Mangifera, with the species that is most common is M. indica. M. indica is a broad-canopy, evergreen tree that can reach heights of 8-40 m. The bark of M. indica is thick, brown-gray, and cracked on the outside [4].
The length of a leaf petiole varies from 1 to 10 cm. Oval, oblong, roundish-oblong, linear-oblong, ovate-lanceolate, and lanceolate are among the different shapes of M. indica leaves (Figure 1). Some mango types have green, red, or yellow leaves, and the upper surfaces of the leaves are often glossy. Male and hermaphrodite M. indica flowers are produced in the same panicle, which can range in diameter from 6 to 8 mm [5].
Although panicles have a lot of blooms, very few of them will turn into fruits. The majority of the flowers are subsessile and have a pleasant scent, and the flowering season typically lasts from January to April.

The drupe fruit of M. indica (Figure 1) comes in a variety of sizes, forms, and colors. Fruit peels can be orange, red, yellow, or green. The hard endocarp, which has a coating of woody fibers, covers the ovoid or oblong seeds [5, 6].

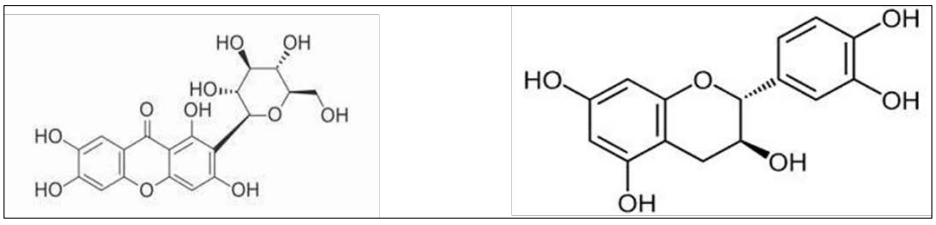
Fig 1: Mango leaf

Taxonomic Classification
Kingdom: Plantae
Subkingdom: Tracheobionta
Supervision: Spermatophyta
Division: Magnolioyta
Class: Magnoliopsida
Subclass: Rosidae
Order: Sapinadles
Family: Anacardiaceae
Genus: Mangifera
Species: Mangifera indica linn [6]

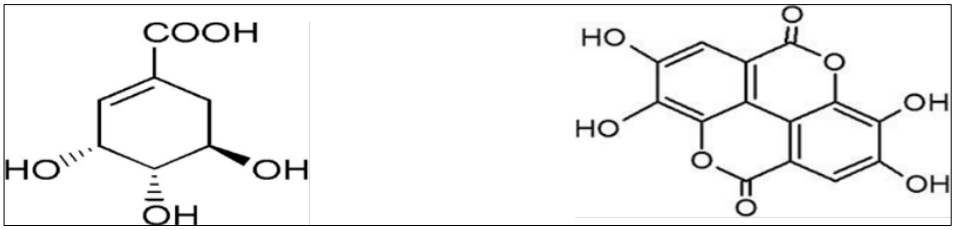
Botanical Description
The leaves are spirally arranged on offshoots, lanceolate-elliptical, linear-oblong, and arranged at both ends.When crushed, they exude an aromatic odor. Typically, leaf blades measure 25 cm in length and 8 cm in width, though they can occasionally be much larger. When they first form, leaves are thinly flaccid and crimson. The lower surface of leaves is glabrous pale green, while the upper surface is dark green and glossy [7].

Phytochemicals

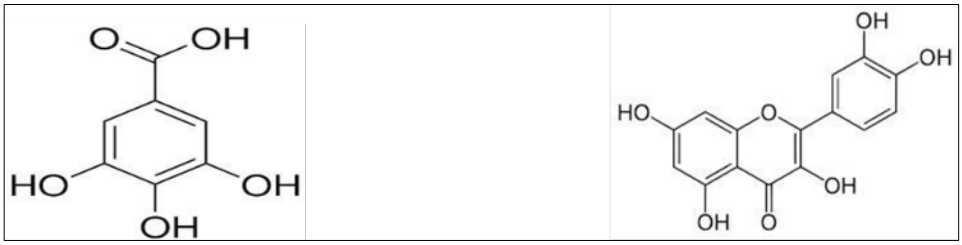
- MLs are often burned or thrown out as agricultural crop waste. Nonetheless, MLs' therapeutic qualities make them a valuable component in traditional folk tea preparation, as well as a treatment for respiratory conditions and diabetes in Asian and African nations [8]. MILs contain 589 mg of K, 480 mg of P, 343 mg of Fe, 98 mg of Mg, 368 mg of Ca, 28 mg of Na, and 14 mg of Zn, Mn (3 mg), and N (2 mg) per 100 g dry weight. Numerous investigations revealed that the total content of MILs extract contained Fe (0.0062-0.034%), P (0.007-0.48%), N (0.003-2.6%), Mg (0.009-1.58%), Zn (0.0024-0.014%), Ca (0.003-4.41%), B (0.0016-0.0042%), S (0.37-0.88), copper (0.0021-0.0029%), Na (0.003-0.23%), cadmium (0.015%), and Mn (0.0028-0.003%). vitamin A (22.60 mg/100 g), vitamin B1 (0.04-0.48 mg/100 g), vitamin B2 (0.06-0.21 mg/100 g), and vitamin B3 (0.38-2.20 mg/100 g).[6]
- Mls extract has saponins,tanins, flavanonids, alkaloids,Benzophenones, such as maclurin and iriflophenone derivatives, were identified in ethanolic and methanolic extracts using UPLC-MS/MS
- (Positive mode). Compounds like maclurin 3-C-β-D-glucoside and 3-glucosyl-2,3',4,4',6 pentahydroxy benzophenone were found in methanol and ethanol extracts (negative mode). Using HRESIMS, four benzophenone compounds were identified in an aqueous extract: acarbose, manindicins A and B, norathyriol, and mangiferin.
- The essential oil of MILs contains 46.98% monoterpenes and 38.17% sesquiterpenes, with GC-MS analysis identifying compounds like 1-terpineol, camphor, and phytol.
- Terpenoids such as lupeol and mangiferonic acid were found via UPLC-MS/MS (positive mode), while cycloartane derivatives were detected in negative mode. Other bioactive compounds, including quercetin glycosides and hypericin, were identified using HR-ESI-TOF-MS on a 70% ethanol-water extract. Aqueous GC-MS analysis revealed compounds like furfural and hydroquinone. The chemical structures of these biologically active compounds are illustrated [6].
- MLs are rich in high-quality bioactive polysaccharides, proteins, lipids, vitamins, and minerals.Significant biological and pharmacological activities, including antioxidant, antidiabetic, antiinflammatory, antimicrobial, antiviral, immunomodulatory, anti-obesity, antiallergic, antifungal, antiparasitic, antidiarrheal, antipyretic, and anti-tumor properties, are exhibited by the diverse bioactive phytochemicals found in their extracts [10].
- Polyphenols, terpenoids, polysaccharides, sterols, carotenoids, vitamins, fatty acids, and amino acids are some of the categories into which the phytochemicals present in MLs can be divided. Particularly prevalent in ML are total phenolic compounds (TPC), which include phenolic acids, xanthones, benzophenones, tannins, terpenoids, and flavonoids. TPC can help prevent chronic diseases such as diabetes, cancer, cardiovascular issues, and neurological disorders, according to numerous epidemiological research. Furthermore, TPC influences a number of physiological functions, including signal transmission, cell division, enzyme activity, and cellular redox potential aiding the management of chronic diseases.



(Magnerferin) (Catechin)



(Shikimic Acid) (Ellagic Acid)



(Gallic Acid) (Quercetin)

Extraction of magneferin

- For the first time, mangiferin is extracted from Mangifera indica leaves using water as a solvent in this work, which makes it more cost-effective than previous extraction techniques that have been researched too far. Numerous extraction techniques, such as sequential batch extraction and microwave assisted extraction, have been tested and their effects refined. In connection with the impacts of microwave irradiation time, solute to solvent ratio, microwave power, and soaking time, the yield of the targeted component was investigated and adjusted.
- At ideal microwave-assisted extraction circumstances, such as using water as the extracting solvent, extracting for 5 minutes, using a solid-to-solvent ratio of 1:20, and using a microwave power of 272 W, the highest extraction yield of 55 mg/g was achieved. The microwave extraction yield was contrasted with that of soxhlet and sequential batch extraction. Comparing microwave to conventional procedures, it was discovered that the former lowered the amount of solvent used and quickly boosted the extraction yield [12, 15].
- Therefore, the current study examined how mood and cognitive performance were affected by a single dosage of mango leaf extract that was standardized to include more than 60% mangiferin (Zynamite®) [13].

Technique	Description
Soxhlet Extraction	A conventional technique that entails heating a sample with a solvent over an extended period of time, then evaporating and recovering the solvent
Preparative High-Performance Liquid Chromatography (HPLC)	Uses the variations in the physicochemical characteristics of the target compound and other extract constituents to separate and purify the target compound.
Ultrasonic-Assisted Extraction	Increases solvent penetration and breaks down plant cell walls using ultrasonic waves to improve extraction efficiency.
Microwave-Assisted Extraction	Increases the extraction yield by using microwave irradiation to accelerate the target compound's diffusion and encourage solvent penetration.
Supercritical Fluid Extraction (SFE)	Extracts the target chemical using supercritical fluids (like CO2), which has benefits like great selectivity, minimal toxicity, and no residue.
Liquid-Liquid Extraction (LLE)	Divides the target chemical between two immiscible solutions with distinct polarities in order to separate it from the plant extract.

Nutritional health benefits

- Prebiotic dietary fiber, vitamins, minerals, and polyphenolic flavonoid components are all present in mango fruit. Vitamin A and flavonoids (beta-carotene, alphacarotene, and beta-cryptoxanthin) are abundant in mangos.
- To keep skin and mucous membranes healthy, vitamin A is essential. It is well known that eating natural fruits high in carotenes can shield the body from malignancies of the mouth and lungs.
- Potassium is abundant in fresh mango. Potassium is a crucial element in bodily fluids and cells that aids in blood pressure and heart rate regulation. Additionally, it is an excellent source of vitamins C, E, and B6 (pyridoxine). Eating meals high in vitamin C helps the body scavenge dangerous oxygen free radicals and build tolerance against pathogenic agents.
- The brain's synthesis of GABA (neurotransmitters) depends on vitamin B-6, also known as pyridoxine. Additionally, it regulates blood homocysteine levels, which could otherwise damage blood vessels and cause stroke. Many essential enzymes, such as cytochrome coxidase and superoxide dismutase, require copper as a co-factor; manganese and zinc are other minerals that are necessary for this enzyme to operate.
- Additionally, red blood cell formation requires copper. Additionally, mango peels are a great source of phytonutrients, including antioxidant pigments like carotenoids and polyphenol [14].

Medicinal importance of mango leaves

1. Properties of diabetes medications
2. Improve amnesia and memory qualities
3. Antioxidants' ability to scavenge free radicals
4. Acts as a hypotensive agent to lower blood pressure

5. cures complex respiratory conditions
6. Antiviral activity
7. Anti-inflammatory
8. combats malignant cells
9. regulates cholesterol
10. Treating kidney disease [14, 16, 17]

Pharmacological activity

Antioxidant activity and Anti inflammatory

Reactive oxygen species are intercepted by antioxidant activity in order to prevent or reduce radicals and to create less aggressive chemical species that are more likely to damage tissue. Because antioxidants can guard against the negative effects of reactive oxygen species, their use has attracted a lot of attention [20].

Methods

The anti-oxidant and anti-inflammatory properties were assessed *in vitro* using DPPH radical scavenging activity and lipoxygenase (LOX) inhibition tests, respectively. Together with the corresponding reference standards, the methanolic extract (MEMI), successive water extract
(SWMI), ethyl acetate fraction (EMEMI), n-butanol fraction (BMEMI), and water soluble fraction (WMEMI) of MEMI were assessed [21].

Antiviral activity

In vitro research was conducted to determine the impact of mangiferin, a tetrahydroxy pyrrolidone saponin that was isolated from mango (Mangifera indica) leaves, on herpes simplex virus type 2 (HSV-2). 111.7 micrograms.ml-1 was its 50% effective concentration (EC50) against the development of HSV-2 plaque in HeLa cells. The viral replicative yields were decreased by 90% (EC90) and 99% (EC99) at doses of 33 and 80 micrograms.ml-1, respectively. 8.1 was the therapeutic index (IC50/EC50). Mangiferin did not immediately make HSV-2 inactive. Mangiferin appears to suppress the late event in HSV-2 replication, according to the results of the drug addition and removal studies [18].

Antifungal activity

Five flavonoids, including 5-hydroxy-3-(4-hydroxylphenyl) pyrano [3,2-g] and (-)-epicatechin-3-O-β-glucopyranoside (1)4-(8H)-one (2), 6-(p-hydroxybenzyl) chromeneQuercetin-3-O-α-glucopyranosyl-(1 → 2), and taxifolin-7-O-β-D-glucoside (tricuspid) (3)Mango (Mangifera indica L.) leaves were used to isolate -β-D-glucopyranoside (4) and (-)-epicatechin(2-(3,4-dihydroxyphenyl)-3,4-dihydro-2H-chromene-3,5,7-triol (5). Alternaria alternata (Fr.) Keissler, Aspergillus fumigatus Fresenius, Aspergillus niger van Tieghem, Macrophomina phaseolina (Tassi) Goid, and Penicillium citrii were the five fungal species against which the antifungal activity of these compounds was assessed [22].

Anticancer activity

Antioxidants such as quercetin, isoquercitrin, astragalin, fisetin, gallic acid, and methylgallat have anti-cancer properties found in mangos shield the body from breast and colon cancer [14].

Anthelmintic and anti allerginic activity

The anti-allergic and anthelminthic properties of stem bark constituents Mice experimentally infected with Trichinella spiralis nematodes were used to study vimang and mangiferin. The main component of Vimang, mangiferin, was found to contribute to the extract's antiallergic properties [14].

Toxicological activity

Mango leaves (from *Mangifera indica*) have been studied for their potential toxicological effects. Some studies indicate that mango leaf extracts contain compounds such as mangiferin, tannins, flavonoids, and phenolic acids, which may exhibit various bioactivities. Toxicological assessments reveal the following key points:

Acute Toxicity: Mango leaf extracts generally demonstrate low acute toxicity in animal studies, with high doses required to cause any adverse effects. This suggests they are relatively safe at moderate dosages.

Cytotoxicity: Some components in mango leaves, such as tannins and certain flavonoids, may exhibit cytotoxic effects in specific cell lines at high concentrations. However, this effect is typically concentration-dependent and not observed at low, nutritionally relevant levels.

Allergic Reactions: Certain mango leaf constituents have been linked to allergic reactions, especially in sensitive individuals. For example, mangiferin may trigger allergic dermatitis or contact sensitivity in rare cases.

Hepatotoxicity and Nephrotoxicity: In high doses or prolonged use, some mango leaf compounds can potentially cause mild liver or kidney stress in animal models, though this is usually reversible once the exposure is stopped [23].

Conclusion

The review of mango leaves highlights their impressive range of health benefits and applications. Rich in bioactive compounds such as antioxidants, flavonoids, and phenolic acids, mango leaves offer promising potential in traditional and modern medicine alike. Their documented effects include anti-inflammatory, anti-diabetic, antimicrobial, and antioxidant properties, making them useful for conditions such as diabetes, respiratory issues, and skin problems. Although traditional practices have long used mango leaves for various ailments, scientific research is now beginning to validate and expand on these uses. Further studies are needed to determine optimal dosages and fully understand their mechanisms, but the existing evidence supports the potential of mango leaves as a natural, affordable, and sustainable remedy. As awareness grows, mango leaves may gain a stronger place in both health and wellness spaces and as a subject of continued scientific exploration.

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