NJESR/September-2025/Volume-7/Issue-9 E-ISSN-2582-5836
DOI-10.53571/NJESR.2025.7.9.23-28

Amla (Phyllanthus emblica) Leaves — A Comprehensive Review of Phytochemistry and Pharmacology

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(**Received -15 August 2025/Revised-25 August2025/Accepted-10September2025/Published-30 September2025)**

Abstract

Leaves of Phyllanthus emblica (commonly known as Amla) are increasingly recognised as a source of bioactive phytochemicals beyond the well-studied fruit. This review collates and analyses available literature on the botanical description, phytochemical composition, pharmacological activities, mechanisms of action, safety profile, and future research needs of the Amla leaf. The major constituents identified in the leaves include hydrolysable tannins (e.g., emblicanin A/B, punigluconin, pedunculagin), phenolic acids (gallic acid, ellagic acid), flavonoids (kaempferol, quercetin, rutin), essential oils and fatty acids (linoleic, oleic, palmitic) and minor components (alkaloids, sterols, amino acids). Pharmacological studies (in vitro and in vivo) demonstrate antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, anti-fibrotic, antidiabetic and immunomodulatory effects. However, compared to the fruit, systematic studies on pure l e a f e x t human trials and standardisation are more limited. The review highlights the scientific evidence, gaps and prospects for development of Amla leaf as a phytotherapeutic agent.

Keywords: Phyllanthus emblica, Amla Leaves, Phytochemicals, Tannins, Flavonoids, Antioxidant, Anti-Inflammatory, Hepatoprotection, Pharmacology

1. Introduction

Phyllanthus emblica, commonly called Amla or Indian gooseberry, is a small to mediumsized deciduous tree belonging to the family Phyllanthaceae. The fruit has been extensively researched for its high vitamin C content, antioxidant and therapeutic properties. However, the plant's leaves have received comparatively less attention in the scientific literature despite traditional use in various systems of medicine.

In Ayurvedic medicine, Amla is considered "rasayana" (rejuvenative) and is used for multiple health conditions including digestion, immunity, liver disorders and general wellbeing. While much of the focus has been on the fruit, the leaves are used in folk and tribal applications — for example, for inflammation, skin disorders, hepatic issues, and as adjuncts to formulations.

The objective of this review is to compile the current knowledge specifically on the leaves of P.emblica: their botanical and ethnopharmacological context, phytochemical constituents, pharmacological activities, mechanisms of action, safety/tolerability, and research gaps for future investigation.

2. Botanical Description & Traditional Use

2.1 Botanical Aspects

P. emblica is a deciduous tree reaching up to ~8–18 m in height in favourable conditions; in India it more typically attains ~5–10 m. Leaves are simple, subsessile, arranged alternately or clustered, light green, small and usually in two rows on either side of the twig. The tree bears greenish-yellow globose fruits with six vertical stripes.

2.2 Traditional Uses Of Leaves

While many traditional accounts emphasise the fruit, the leaves have been used in ethnomedicine. For example, decoctions of the leaves have been used for liver/supportive functions, skin disorders, and general health tonics. Given their phytochemical richness (as emerging studies suggest), the leaves represent a promising but under-investigated fraction of the plant.

3. Phytochemical Composition Of Leaves

The leaves of P. emblica have been studied in several phytochemical investigations. Although many studies include whole-plant or fruit extracts, specific leaf analyses show the following major constituents:

3.1 Phenolic Acids

Gallic acid, ellagic acid, chebulic acid and related phenolics have been detected in leaf extracts. For instance, HPLC-DAD analysis of methanolic leaf extract (PELE) indicated presence of gallic acid, rutin, kaempferol.

3.2 Tannins & Hydrolysable Tannins

The leaves contain hydrolysable tannins such as emblicanin A and B, punigluconin, pedunculagin, as well as gallotannins and ellagitannins. These molecules are known for antioxidant capacity and may underpin many biological effects.

3.1 Fatty Acids and Essential Oils

Some reports indicate presence of linoleic acid, oleic acid, stearic acid, palmitic acid, and essential oils in leaves.

3.2 Flavonoids

Leaves contain flavonoids such as kaempferol, kaempferol-3-O-glucoside, quercetin, rutin and other glycosides. For example, review articles list kaempferol and its derivatives among leaf constituents.

3.3 Amino Acids, Minerals, Vitamins

Although more extensively characterised for fruit, leaves also contain amino acids (e.g., glutamic acid, proline), minerals and small amounts of vitamins. However, explicit quantitative data for leaves are limited.

3.4 Other Constituents

Additional minor constituents like alkaloids, sterols, lignans and polysaccharides have been reported in the plant overall; their specific presence in leaves merits further study.

3.5 Summary Table of Key Constituents (Leaves)

Compound class Examples in leaves Reported/implicated activity

Hydrolysable tannins Emblicanin A/B, punigluconin, pedunculaginAntioxidant, antiinflammatory
Phenolic acids Gallic acid, ellagic acid, chebulic acid Radical scavenging, enzyme modulation
Flavonoids Kaempferol, quercetin, rutin, k a e m p f e r o l - 3 - O Antioxidant,l u c o s i d e
anti-inflammatory, vascular protection
Fatty acids & essential oils Linoleic, oleic, palmitic acids Membrane modulation, lipidmetabolism related. Amino acids, minerals, vitamins Glutamic acid, proline, Ca, Fe, small vitamin C Nutritional/adjunctive support

> Note: Quantitative data (mg/g leaf) are sparse; many studies report presence rather than full quantification. Standardisation remains a gap.

4. Pharmacological Activities of Leaf Extracts

Although many pharmacological studies focus on fruit extracts, a growing number of investigations examine leaf extracts. Below are key activities:

4.1 Antioxidant Activity

Methanolic leaf extract (PELE) showed in vitro DPPH scavenging ability (IC50 ~ 39.73 ± 2.12 µg/mL) compared to ascorbic acid (IC50 ~ 28.91 ± 1.35 µg/mL) in one study.

In vivo, in C C l „ induced pulmonary toxicity model, leaf extract administration significantly reversed declines in antioxidant enzymes (SOD, CAT, GSH-Px), and reduced nitrite and H , O , levels in lung tissue.

4.2 Anti-inflammatory and Anti-fibrotic Effects

The same study on pulmonary fibrosis found that leaf extract reduced epithelial degeneration and infiltration of macrophages, suggesting anti-inflammatory and antifibrotic potential. General reviews indicate that P. emblica extracts inhibit NO production in LPS-stimulated macrophages, COX-2, 5-LOX and other pro-inflammatory enzymes — activities likely shared by leaf constituents.

4.3 Antimicrobial Activity

Although fewer leaf-specific studies, P. emblica extracts (leaves included) show antimicrobial/antifungal potential. Some reports suggest ability to inhibit bacterial/fungal growth in vitro, likely due to polyphenolics and tannins.

4.4 Hepatoprotective & Organ-Protective Activities

While much of the hepatoprotective literature is fruit-centric, leaf extract studies in animal models (e.g., C C l „ lung model) demonstrate that antioxidant and anti-inflammatory effects may underpin organ protection. This suggests leaves may confer benefits in hepatic, pulmonary or other tissue injury models.

4.5 Metabolic, Antidiabetic & Lipid-Modulating Effects

Although again more studied in fruits, reviews suggest that P. emblica extracts reduce hyperlipidaemia, improve insulin sensitivity, modulate lipid profile and inhibit HMG-CoA reductase in animal models.

Leaves may contribute similarly given their flavonoid and tannin content, though direct leaf-specific clinical/animal studies are fewer.

4.6 Immunomodulatory Activity

Reviews note that P. emblica extracts increase CD4, CD8, IgM, IgG and leukocyte counts in animal models; leaves likely contribute via polyphenolic/immunomodulatory action though studies focusing solely on leaves are limited.

4.7 Summary of Pharmacological Actions

Activity Evidence (leaf-specific or general) Key implicated constituents

Antioxidant IC50 ~39.7 µg/mL DPPH; in vivo enzyme restoration Tannins, phenolics, flavonoids

Anti-inflammatory Reduction of NO/COX-2; lung fibrosis model Flavonoids, phenolic acids, tannins

Antimicrobial In vitro bacterial/fungal inhibition (some leaves) Tannins, flavonoids

Organ-protective (hepatic/pulmonary) Animal models indicate protective effects Phenolics, fatty acids, flavonoids

Metabolic/antidiabetic Animal + limited human data (mainly fruit) Flavonoids, tannins

Immunomodulatory Animal models show enhanced immune markers Phenolics, flavonoids

5. Mechanisms of Action

The biological activities of Amla leaves are likely mediated via a range of molecular mechanisms:

Free Radical Scavenging / Reactive Oxygen Species (ROS) Neutralisation: Phenolic acids, tannins and flavonoids donate electrons/hydrogen and stabilise free radicals, reducing oxidative stress. In leaf extract studies, improved levels of antioxidant enzymes (SOD, CAT, GSH-Px) support this.

Enzyme Modulation: Reduction of NO production, inhibition of COX-1/COX-2, 5-LOX and other inflammatory enzymes is reported.

Modulation of Signalling Pathways: Some studies suggest regulation of N F - º AP-1,B , and other transcription factors in inflammation and cell survival (mainly fruit studies but applicable to leaves).

Lipid-Metabolism Regulation: In animal studies, flavonoids have been reported to inhibit HMG-CoA reductase and enhance lecithin cholesterol acyl transferase (LCAT) activity, improving lipid profile.

Cell-Protection and Cytoprotection: By reducing oxidative damage and inflammation, leaves may protect cells/tissues (hepatic, pulmonary etc) from toxin-induced injury.

Immunomodulation: Enhancement of immune parameters (lymphocytes, immunoglobulins) suggest modulation of immune cell function.

6. Safety Profile and Toxicology

Data specific to leaves are relatively limited; much of the safety information comes from fruit-based studies. Review articles report a favourable safety profile for P. emblica fruit with absence of significant adverse effects at typical doses.

For leaves, animal studies (e.g., pulmonary model) show beneficial effects without reported acute toxicity. However, detailed sub-chronic/chronic toxicity, reproductive toxicity, genotoxicity and human data for leaf extracts are lacking. Standardisation of extract, doseresponse toxicity and heavy-metal/contaminant analysis need further work.

7. Research Gaps and Future Directions

While evidence is promising, the following gaps must be addressed for leaves of P. emblica to progress towards therapeutic/clinical application:

Standardized Extracts and Marker Compounds: Many studies use crude extracts; establishing chemical fingerprint, major marker compounds (e.g., emblicanin in leaves), and yield reproducibility is critical.

Purification & Structure–Activity Relationships (SAR): Isolation of pure compounds from leaves, their structural elucidation and direct activity studies are fewer in number compared to fruit.

Pharmacokinetics & Bioavailability: How leaf-derived tannins/flavonoids are absorbed, metabolised and distributed in the body remains under-studied.

Dose-Finding & Toxicology: Well-designed animal toxicology studies (acute, subchronic, chronic) for leaf extracts are needed, plus high-dose safety margins.

In Vivo & Clinical Studies Focussed on Leaves: Human clinical trials specific to leaf extracts are essentially absent. Animal models of metabolic disease, hepatic injury, inflammation etc should include leaf extracts.

Mechanistic Studies at Molecular Level: While some basic mechanisms are proposed, detailed mechanistic studies (e.g., gene expression profiling, signalling pathway modulation) for leaf extracts are scant.

Formulation Development: Developing standard dosage forms (capsules, tinctures, topical applications) of leaf extracts with validated stability, bioavailability and safety. Comparative Studies

Fruit vs Leaves: Direct comparative studies between fruit extract and leaf extract in similar models would help clarify additional or unique benefits of the leaves.

Agronomic & Harvesting Variables: Influence of cultivation, leaf maturity, extraction method, geographic variation on phytochemical yield in leaves needs systematic evaluation.

8. Conclusion

The leaves of Phyllanthus emblica represent a valuable but under-explored component of this medicinal plant. With their rich repertoire of tannins, flavonoids, phenolic acids and fatty acids, they show substantial potential in antioxidant, anti-inflammatory, antimicrobial and organ-protective roles. The evidence to date is promising but skewed towards in-vitro and animal models, and often uses crude extracts with limited standardisation. To realise the clinical and therapeutic potential of Amla leaves, rigorous phytochemical, pharmacological, toxicological and formulation research is essential. Given the widespread use and favourable safety profile of the plant in traditional systems, leaves offer an adjunct or complementary source of bioactive compounds, offering possibilities for nutraceuticals, adjunctive therapies or phytomedicines.

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