

# A Comprehensive Review on Ethnomedicinal Aspects, Phytochemical and Pharmacological Properties of *Limonia acidissima* Linn.

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## ABSTRACT

Fruits and other parts of *Limonia acidissima* Linn. (Wood apple) is edible and used in different cuisines. In folk medicine, various plant parts are utilized to treat various ailments. In addition to being utilized as a folk remedy, the plant was also investigated for its medicinal value. The plant is considered important in Ayurvedic medicine and fruit, leaves, seeds, gum and bark of the plant have medicinal importance. The plant is investigated for different pharmacological properties in preclinical studies. Wood apples are also important for nutritional values. Several phenolic bioactive phytochemicals like kaempferol, catechins, proanthocyanidins, vanillic acid, syringic acid and coumaric acids are characterized in the plant parts. This paper provides an overview of the pharmacological and phytochemical properties of *Limonia acidissima*. This knowledge might help create new formulations or improve current goods by adding additional medicinal or nutritional value.

**Keywords:** *Limonia acidissima*, Nutraceutical value, Folk use, Pharmacological activity, Phytochemicals.

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**Received:** 19-05-2024;

**Revised:** 28-05-2024;

**Accepted:** 14-06-2024.

## INTRODUCTION

Herbal medicine always plays an important role in primary healthcare. Traditional medicine preferred due to its accessibility, lack of adverse effects and affordability compared to allopathic care.<sup>[1]</sup> India is considered as gold mine of medicinal plants and different medicinal traditional knowledge system of India have been practiced since time immemorial.<sup>[2]</sup> *Acidissima limonia* (Family: Rutaceae) commonly known as wood apple or elephant apple found to possess diverse therapeutic properties including antioxidant, hypoglycemic, hepatoprotective, antimicrobial, nephroprotective, neuroprotective properties.<sup>[3]</sup> *Acidissima limonia* Linn. is grown in tropical and temperate Asia, northern Malaysia and Southern America. The monotypic genus *Limonia*, restricted to Sri Lanka, India, Pakistan and Southeast Asia, includes *Limonia acidissima* (L.).<sup>[3-6]</sup> The member of *Limonia acidissima* Linn. belongs to Rutaceae family (Figure 1), also known as *Feronia limonia* Swingle, *Feronia elephantum*, Kath bel, Kaitha, Curd fruit, monkey fruit, Kavath, *Schinus limonia*.<sup>[3-10]</sup> The plant usually grows wild and also cultivated alongside roads, at the edges of fields and occasionally in orchards. The tree *L.*

*acidissima* grows slowly and straight. It has a few upward-reaching branches that split into thin branchlets with drooping tips and curve outward at the crown. Scurvy can be treated and flatulence can be relieved with wood-apple.<sup>[4-7]</sup> *L. acidissima* Linn. found to possess various biological properties, including adaptogenic efficacy against blood impurities, leucorrhoea, dyspepsia and jaundice.<sup>[4,7]</sup> The fruit treats ulcers, diabetes, cancer, diarrhoea and high blood pressure.<sup>[5]</sup> This plant has gained popularity due to its minimal adverse effects and widening range of applications from pharmaceutical to cosmetic.<sup>[5-11]</sup> Fruit pulp protects against skin cancer.<sup>[6,7]</sup> Mashed, seedless fruit pulp can be used to treat dysentery, diarrhoea and piles.<sup>[7,9]</sup> Coumarins in *L. acidissima* exhibited anti-coagulant, astrogenetic, vasodilation, antihelminthic and antibacterial properties. Many photochemical of the plant like alkaloids, anthocyanin and tannin effectively cure many human diseases.<sup>[8-9]</sup> Fruit is also utilized as a liver and heart tonic and is also effective in treating hiccoughs, sore throats and diseases of the gums. The unripe fruit is used as an astringent.<sup>[10,11,13]</sup> Phosphorous in fruits plays a crucial part in the development of bones and iron molecules are effective against anaemia and tuberculosis. The fruit of the plant used to treat blood pressure, diabetes, cancer, diarrhoea and ulcers.<sup>[11]</sup> *L. acidissima* have used in different codified and non-codified medicinal system in the treatment of various diseases, such as root juice used as a remedy for snakebites, bark decoction rich in tannins and alkaloids used to cure malaria and leaf juice combined



DOI: 10.5530/pres.16.4.80

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with honey used in fever.<sup>[12,13]</sup> *L. acidissima* is also considered nutraceutically important. Fruit pulps contain 5, 4-dihydroxy-3-(3-methyl-but-2-enyl) flavones, protein (8%), pectin (16%) and volatile oil, O- $\beta$ -D-glucopyranoside, 3,5,6-trimethoxy-flavone-7, stigmasterol content of 0.015%. The fruit is not only important in traditional medicine but also exhibited diverse pharmacological properties and used in different herbal medicinal formulation. This paper highlights the phytochemical, traditional, pharmacological importance of the plant.

## Synonyms

*Feronia limonia* (L.) Swingle, Dadhittha, Dadhiphala, Surabhichhada, Feroniaele phantum Correa and *Schinus limonia* L. Kapittha.<sup>[1-10]</sup> Vernacular names of *L. acidissima* Linn. are mentioned in Table 1 and features of different parts of *L. acidissima* are mentioned in Table 2.

## Taxonomical Classifications<sup>1-4</sup>

Kingdom-Plantae

Sub-kingdom-Tracheobionta

Super division-Spermatophyta

Division-Magnoliophyta

Class-Magnoliopsida

Subclass-Rosidae

Order-Sapindales

Family- Rutaceae.

## Genus-Limonia Ecology

Conditions are required for the growth of *Limonia acidissima* Linn.<sup>[1-3,5]</sup>

*Limonia acidissima* Linn. requires some specific environmental conditions to grow properly. Suitable temperature is 20-29°C. This plant will grow well in the dry season in sandy, loamy and acidic soil. It requires high rainfall (800-1200 mm) and high temperatures (20-29°C). This plant is mostly found in tropical and subtropical areas.

## Distribution

*Limonia acidissima* L. is grown in different locations, including Sri Lanka, Pakistan, Bangladesh, Myanmar, Arunachal Pradesh, West Bengal, Delhi, Tamil Nadu, Andhra Pradesh, Gujarat, Maharashtra, Andaman and Nicobar Islands, Karnataka, Punjab, India, Rajasthan, Madhya Pradesh and Goa.<sup>[1-3]</sup>

## Morphology

*Limonia acidissima* L. is a massive tree with rough, spiky bark that can reach a height of nine metres (30 feet). On particular zigzag twigs, the spines are axillary, small, straight and range in length

from 2 to 5 cm.<sup>[1-3]</sup> Different features of *Limonia acidissima* L. are mentioned in

## Phytochemistry

Diverse phytochemicals present in different parts of the plant were isolated and characterized. Phytochemicals present in *Limonia acidissima* L. are also found to possess diverse medicinal value, which is included in Table 3. Chemical structure of some of the present in *Limonia acidissima* L. are presented in Figure 2.

## Leaves

Phenols, Alcohol, Gum, mucilage, carbohydrates, Saponins, steroids (stigmasterol), glycosides, fixed oils, fats, tannins, carbohydrate, proteins, amino acids, anthocyanin, tannins, Terpenoids, alkaloids, cyanogenetic glycoside, cardiac glycoside, Flavonoids (imperatorin, bergapten and xanthotoxin), acidissimin and acidissiminol, resins, stigmasterol, psoralen, bergapten, orientin, vitedin, essential oil.<sup>[1,5,9,11,13]</sup>

## Fruits

Vitamins such as Vitamin A, Vitamin B and Vitamin C, Mucilage, Saponins, steroids and glycosides, carbohydrates, proteins, amino acids, anthocyanin, tannin, alkaloids, steroids, cyanogenetic glycoside, cardiac glycoside, Flavonoids, calcium, magnesium, iron, zinc, phosphorous. The unripe fruits contain stigmasterol.<sup>[1,3-6,11-14]</sup>

## Heartwood

The flavanone, glycoside, 7-methylporiol- $\beta$ -D-xylopyranosyl-D-glucopyranoside and ursolic acid.<sup>[14]</sup>

## Rind

Alkaloid, Gum, mucilage, amino acid, carbohydrate, Saponins, steroids and glycosides, carbohydrate, proteins, amino acids, anthocyanin, tannins, alkaloids steroids, cyanogenetic glycoside, cardiac glycoside, Flavonoids.<sup>[9,13]</sup>

## Seed

Fixed oil, tannin, flavonoids, psoralen, orientin, bergapten, vitexin and saponarin are among the constituents. Proteins and amino acids are also present.<sup>[3,4,9,13]</sup>

## Bark

Contains alkaloid, Gum, mucilage, Saponins, steroids and glycosides, tannins carbohydrates, proteins, amino acids, anthocyanin, tannin, alkaloids steroids, cyanogenetic glycoside, cardiac glycoside, Marmesin (0.016%), feronolide and feronone, aurapten, bergapten and other coumarins, phenol, nitrogen compound, vitamin compound, lignin, sterol and triterpene. Coumarins include 6,7-dimethoxycoumarin "feronolide and feronone," as well as marmesin, bergapten, psoralen, luvangetin, xanthotoxin, scopoletin, isoimperatorin and osthol. Steroid

Alkaloids: beta-d-glucoside and sitosterol-o. Terpenoids: limonin and lupeol Flavones: 5-sitosterol-3-O-β-D-glucopyranoside, 7-dihydroxy-3', 4'-dimethoxy-6,8-di (3-methylbut-2-enyl) stigmasterol.<sup>[1,3-5,9,13,14]</sup>

## Root

Lactones: umbelliferone, frenolin, geranyl and ferronia lactone. Coumarin: 6-methoxy-7-geranyloxy coumarin, osthonol, xanthotoxin, osthonol, bergapten, aurapten and xanthyletin. One methyl-4-methoxy-2-quinolone, or quinolone alkaloid,

Saponins, steroids, glycosides, isopimpinellin, Psoralen, Vitexin, Peronoil.<sup>[1,3,4,9,13]</sup>

## Pulp

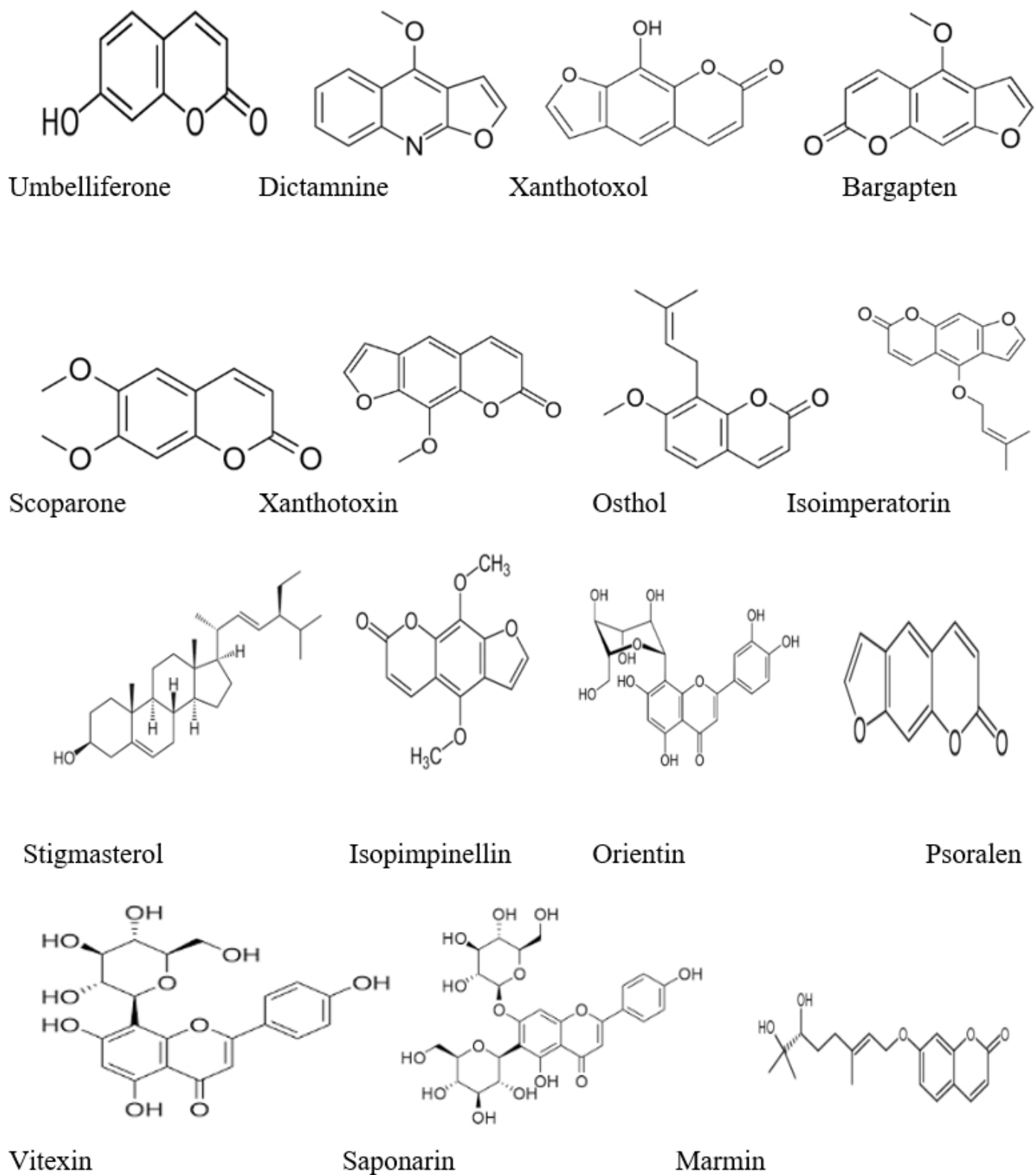
Flavonoids, Gum, mucilage, carbohydrate, Saponins, steroids and glycosides, fixed oils, fats (4.3%), Resins, carbohydrate (70.14%), proteins (13.8%), dietary fibre (1.7%), amino acids, anthocyanin, tannins, alkaloids steroids, cyanogenetic glycoside, cardiac glycoside, citric acid, fruit acids, minerals, Thymol, Dodecanoic acid, α-Pinene, Carvacrol, Camphoric acid, Caryophyllene oxide.<sup>[1,3-5,9,11,13,14]</sup>

**Table 1: Vernacular Names of *Limonia acidissima* Linn.**<sup>[1,2,4]</sup>

Sl. No.	Languages	Vernacular Names
1	Assamese	Koth Bel
2	Bengali	Kapittha
3	English	Wood Apple, Elephant Apple, Monkey Fruit, Indian Wood and Curd Fruit.
4	Gujarati	Kothu
5	Hindi	Kath bel, kapitth, kavit, kaitha, Dadhiphal, Dantasath, Kabeet.
6	Kannada	Kapithha, Dadhiphala, Manmathamara, Damtasata.
7	Malayalam	Vilam kai, Vilavu, Vilarmaram, Belingai.
8	Marathi	kapith, kavat, kavant, kavanti.
9	Oriya	Koyito, Kaitha
10	Sanskrit	Kapithama, kapitya, kapityama, pushpaphala, Dadhirra, Dadhistha.
11	Tamil	Vilam Palam, kapittam, kavittam, vilampazam, vilamaram.
12	Telegu	Kapitthhamu, Vellaga Pandu.

**Table 2: Different features of every part of *Limonia acidissima* L.**

Sl. No.	Plant parts used	Features	References
1	Rind	The woody has a tough outer shell (called a rind). The rind is 6 mm thick and greyish-white.	[7]
2	Pulp	The pulp has a lot of tiny white seeds and is sticky, brown, mealy, fragrant, resinous, astringent and sour or sweet.	[1,3,7]
3	Leaves	With five to seven leaflets, the leaves are pinnate. Each leaflet is 25-35 mm long, 10-20 mm wide and when crushed, releases a citrus aroma. Pairs of opposing leaflets and a terminal leaflet are present. 1-3 in a cluster, imparipinnate, alternating, estipulate leaves; Leaflets 4-7, opposite, sessile, estipellate; broad, glabrous and frequently somewhat winged rachis; lamina 1.3-3.8×1.3 cm, obovate, base cuneate or acute, apex obtuse, margin entire, glabrous, pellucid-punctate, coriaceous; lateral nerves pinnate, inconspicuous.	[3,4,12]
4	Fruit	The fruit, a berry with a 5 to 9 cm diameter, can be sour or sweet. It is 6 mm thick and is a greyish-white colour. The fruit is a berry with a strong, woody skin, many seeds and a globose, whitish-brown fruit with a 5-7.6 cm diameter.	[1,3,4,12]
5	Bark	Deciduous trees up to twenty meters in height have widely split longitudinal bark that is dark grey or black in appearance.	[4]
6	Flowers	Flowers in axillary cymes, polygamous, dull red and 1.3 cm in diameter; Small, flat, 5-toothed, pubescent-free and deciduous calyx; five free-flowing petals; Inserting stamens 10-12 around the disc causes the filaments below to dilate and the face and edges are villous; Anthers are linear-oblong, the disc is thick, annular and pubescent, the pistillode is short and the ovary is superior with numerous ovules and an oblong, fusiform stigma.	[4]



**Figure 2:** Some key Phytoconstituents present in *L. acidissima* Linn.

## Pericarp

These include umbelliferone, dictamnine, xanthotoxol, scoparone, xanthotoxin, isopimpinellin, isoimperatorin, sterols, fatty acids and alkaloids.<sup>[1,3,4]</sup>

## Nutritional and Folk Medicinal Importance

*Limonia acidissima* Linn. is a source of carbohydrates, fat, protein and minerals, as mentioned in Table 4. This plant also has different traditional uses, as mentioned in Table 5.

The properties and actions of Kapitha in Ayurveda.<sup>[2,4,21]</sup>

Rasa (taste on tongue): Amla (sour), Madhura (sweet), Kashaya (astringent); Unripe Pulp: Kashaya (astringent), Amla (sour).

Guna (Medicinal Action): Laghu (Light), Guru (Heavy) for Unripe Pulp.

Sita (cooling); Ushna (hot) (unripe pulp).

Unripe pulp: Amla (sour); Vipaka (condition modified after digestion): Madhura (sweet). Take Action Pitta-har Vata; Rakta-pitta-har.

## Pharmacological Activities

The plant parts were investigated for diverse pharmacological activities, including anti-diabetic, anti-hyperlipidemic, anti-inflammatory, hypouricemic, anticancer, antiulcer and wound healing, hepatoprotective, antibacterial, antifungal, cardioprotective, neuroprotective activities. Table 6 includes different pharmacological activities of the plant.

## Antidiabetic activity

A study using fructose supplementation induced insulin resistance rat model reported that oral administration of hydroalcoholic fruit pulp extract of *L. acidissima* (100, 200 and 400 mg/kg) exhibited anti-hyperglycemic effect.<sup>[23]</sup> Methanolic fruit extract of *L. acidissima* showed antidiabetic effect by reducing the glucose



**Figure 1:** *Limonia acidissima* (A) Leaf (B) Bark (C) Fruit and Flower.

**Table 3: Medicinal properties of different chemical constituents of *Limonia acidissima* L.**

Sl. No.	Active constituents	Medicinal uses
1	Kaempferol	Reducing the risk of cancer, antioxidant.
2	Catechins	antioxidant, anti-viral, anti-microbial, anti-inflammatory, anti-allergenic and anticancer.
3	Proanthocyanidins	antioxidant, anticancer, antidiabetic, neuroprotective and antimicrobial.
4	Coumaric acids such as ferulic acid and m-coumaric acid.	Diabetes, obesity, hyperlipidemia, gout, antioxidant, anti-cancer, antibacterial, antiviral, anti-inflammatory, anti-platelet aggregation, anxiolytic, antipyretic, analgesic and anti-arthritis properties.
5	Vanillic acid	Vanillic acid has pharmacological actions like neuroprotective, antioxidant, immuno-stimulating, cardioprotective, anti-hepatoprotective, inflammatory and antiapoptotic.
6	Syringic acid	Alzheimer's disease, cerebrovascular accidents, cancer, liver and neurodegenerative diseases, antioxidant, antibacterial, anti-inflammatory and antiendotoxic properties.
7	Mucilage	Heart disease, intestinal motility, colon health and colorectal cancer risk.

**Table 4: Nutritional Influence of *L. acidissima* Linn.**

Sl. No.	Constituent	Function	References
1	Protein fiber (13.8%) Carbohydrates (70.14%)	A healthy body with a good source of energy 375.18 kcal	[5,7,11]
2	Fat (4.38%)	A good diet for an overweight person.	[5,7,11]
3	Vitamins B9 and B12, Vitamins (A, B <sub>2</sub> , B <sub>3</sub> , C), Mg (852.5 µg/g), Zn (23.84 µg/g), Ni (23.1µg/g), Calcium (711.8 µg/g), Phosphorus (1137.35 µg/g)	Vitamins B9 and B12 are required for the development and maturation of RBC. Vitamin A is required for good skin and eyes. Minerals such as Ca, Mg, P, Zn and others maintain the development of bones, teeth and mucous membranes. Calcium maintains rigidity in the skeleton.	[15-18]
4	Iron (23.1µg/g)	Required for haemoglobin formation, it protects against anaemia.	[18]
5	Sugar molecule	Used to manufacture Dairy-Based Sweets. Pulp is used to make drinks. Fruit powder is utilized to make herbal biscuits enhanced with phenols with nutritional and antioxidant potential.	[4,19]
6	Anthocyanin from fruits.	Used as preservatives. Fruit shell used as biosorbent.	[20]

content by 19.2 and 27.5% at oral doses of 200 and 400 mg/kg b.w., respectively in experimental rats.<sup>[24]</sup> In another study, methanolic extract of the fruit pulp of *L. acidissima* Linn. (200 and 400 mg/kg) reduced the glucose level on day 21 of diabetic rats.<sup>[25]</sup> Methanolic leaf extract of *L. acidissima* showed antidiabetic and antioxidant action through enhanced glycogenesis, enhanced glucose transport and direct effects on islet regeneration or repair in Alloxan-induced diabetic Wister albino rats. Alcohol and aqueous extract of the stem bark of *L. acidissima* tend to show antidiabetic effect by reducing the glucose content to 90.4 mg/kg and 99.8 mg/kg, respectively, on the 14th day at an oral dose of 200 mg/kg in alloxan induced diabetic rats.<sup>[27]</sup>

### Antihyperlipidemic activity

At a dosage of 200 mg/kg, the alcohol and water extract of *Limonia acidissima* Linn's stem bark dramatically reduced cholesterol levels in patients with diabetes-induced hyperlipidemia.<sup>[27]</sup>

### Anti-inflammatory activity

Aqueous extracts of *L. acidissima* fruits at five different concentrations of the protein denaturation assay (200, 400, 600, 800 and 1000 µg/mL) were tested. 1000 µg/mL demonstrated a 74.55% reduction in protein denaturation.<sup>[28]</sup>

### Hypouricemic effect

Ethanol extract of *L. acidissima* fruits causes reductions of serum uric acid in 200 mg/kg and 400 mg/kg doses in potassium oxonate-led hyperuricemic rodents. Extract causes inhibition of URAT1, possibly due to fatty acids in the extract.<sup>[29]</sup>

### Anticancer activity

Ethanol extract of the plant *L. acidissima* Linn. was evaluated to find the protective effect in breast cancer. A concentration of 100 µg/mL fraction extract line was used in SKBR3 and MDAMB-435 cell lines. Following 48 hours of treatment, it was seen that both cancer cells' cell proliferation had significantly diminished.<sup>[30]</sup>

### Hepatoprotective activity

*L. acidissima* L. fruit methanolic extract (200 and 400 mg/kg, p.o.) showed hepatoprotective action against CCl<sub>4</sub> induced hepatotoxic rats. Protective activity was measured by estimating AST, ALP and ALT levels.<sup>[31]</sup>

### Cardioprotective activity

In a rat model, the cardioprotective efficacy against doxorubicin-induced cardiotoxicity and oxidative stress was estimated using three functional foods: water spinach, wood apple and linseed. After a further fifteen days of the trial, heart function and oxidative stress were found to have improved and blood Cardiac Biomarkers (CK-MB and LDH) and stress markers (MDA) were shown to have decreased.<sup>[32]</sup>

### Wound healing activity

In models with incision, excision and dead space wounds, the methanol extracts of *L. acidissima* fruits exhibit noteworthy dose-dependent wound healing and antioxidant properties at 200 and 400 mg/kg dosages.<sup>[16]</sup>

**Table 5: Ethno pharmacological applications of *Limonia acidissima* L.**

Sl. No.	Plant Parts	Ethno Pharmacological Uses	References
1	Fruit	Tonic for the liver and lungs Astringent; Effective against diarrhoea Dysentery; Throat and diseases of gums Heart weakness; Hepatitis; Wounds; Respiratory disease Carcinomas; Lowering cholesterol levels.	[5,7,9,11]
2	Leaves	Antiemetic Antimicrobial Hepatoprotective Antivenom Carminative Dysentery Anti-allergic Cure peptic ulcer Treatment for uterine cancer, breast cancer, infertility, progesterone shortage, respiratory illnesses and the flu Traditional use in snake bites.	[5,9,11]
3	Seeds	Cure heart diseases Headache.	[9,11]
4	Pulp	Detoxification Decrease weight because.	[5,11]
5	Gum	Demulcent Constipation Anti-diarrheal Anti-haemorrhoidal properties.	[5,11]
6	Bark	Venomous wounds.	[5,22]

### Neuroprotective activities

Methanolic extract of *Limonia acidissima* Linn. exhibits anti-Alzheimer activity at 200 mg/kg and 400 mg/kg against the scopolamine-produced amnesia model. This extract inhibits the acetylcholinesterase enzyme, increases the concentration of Ach in the brain and increases locomotor activity.<sup>[33]</sup>

### Antifungal Activity

Petroleum ether, chloroform and ethanol extract of stem bark, root bark and fruit shells of *Limonia acidissima* L. were successfully tested for antifungal activity against *Cladosporium cladosporioides*. Every extract shows distinctive zones of inhibition.<sup>[34]</sup>

### Antibacterial activity

Extract of *Limonia acidissima* exhibited the antibacterial activity against *Staphylococcus epidermidis*, *Staphylococcus aureus* and *Bacillus subtilis* at a 500 mg/mL dosage. Compared to rind extract, it was discovered that pulp's methanolic extract exhibited the most potent antibacterial activity against *Staphylococcus epidermidis*, *Bacillus subtilis* and *Staphylococcus aureus*.<sup>[7]</sup> An investigation found that biogenic zinc oxide and silver oxide nanoparticles made from *L. acidissima* leaves were tested for antibacterial activity against test bacterial species. Compared to erythromycin, the results showed that the most significant zone of inhibition for silver nanoparticles against *S. aureus*, *S. typhi* and *P. aeruginosa* was 15.16, 15.5 and 13.33 mm at 400 µg/mL.<sup>[8]</sup> By using the agar-well-diffusion method, the leaf extracts of *Limonia acidissima* in hexane, chloroform and methanol showed a high

**Table 6: Scientific studies conducted on *Limonia acidissima* L.**

Sl. No.	Pharmacological activity	Plant parts used	Extract	Chemical Constituent	Dosing	Disease inducing agent	References
1	Anti Diabetic	Fruit pulp	Methanolic and Aqueous	Flavonoids	400, 200 and 100 mg/kg.	Fructose Induced insulin resistance rat model.	[23]
2	Anti Diabetic	Fruit	Methanolic	Flavanone, Phenolic Compound	200 and 400 mg/kg.	Streptozotocin-induced male Albino diabetic rats.	[24]
3	Anti Diabetic	Fruit pulp	Methanolic	Flavanone, Phenol	200 and 400 mg/kg.	Alloxan (120 mg/kg, ip)-induced diabetic rats.	[25]
4	Anti Diabetic	Leaves	Methanolic	Flavanone, Phenolic Compound	100 mg/kg, 200 mg/kg and 400 mg/kg.	Alloxan-induced diabetic Wister albino rats.	[26]
5	Anti Diabetic	Stem bark	Alcoholic	Flavanone	200 mg/kg	Alloxan (150 mg/kg))	[27]
6	Antihyperlipidemic activity	Stem bark	Alcoholic	Flavanone	200 mg/kg	Diabetes-induced hyperlipidemia	[27]
7	Anti-inflammatory activity	Fruit	Aqueous	Flavonoids, Phenols, Saponins	1000 µg/mL	Albumin Denaturation Assay	[28]
8	Hypouricemic	Fruit	Ethanolic	Fatty Acids, Phytosterol, Triterpenoid.	200 and 400 mg/kg.	Potassium oxonate-induced hyperuricemic rats.	[29]
9	Anticancer activity	Fruit	Ethanolic	Glycosides, Saponins	100 µg/mL	SKBR3 and MDAMB-435 cell line.	[30]
10	Antiulcer and wound healing activities	Fruits	Methanolic	Fatty Acids, Phytosterol, Triterpenoid	200 and 400 mg/kg,	Models of incision, excision and dead space wounds.	[16]
11	Hepatoprotective activity	Fruits	Methanolic	Flavanone, Lignan, Coumarins	200 and 400 mg/ kg	Ccl <sub>4</sub>	[31]
12	Anti-bacterial Activity	Leaves	Milli-Q water	Phenolic Compound	400 µg/mL	Microplateamar blue assay technique.	[8]
13	Anti-bacterial Activity	Pulp and rind	Methanolic	Phenolic Compound	500 mg/mL	Staphylococcus aureus and Staphylococcus epidermidis.	[7]
14	Cardioprotective Activity	Water spinach, Wood apple and Linseed	Crude drug	Omega-3 Fatty Acids, Phenols, Glycosides, Gum Mucilage, Tannins, Saponins, Alkaloids, Flavonoids, Terpenoids, Myricetin, Quercetin, Lutein.	Laboratory diet with Wood apple, Water spinach and Linseed	Doxorubicin-induced cardiotoxicity.	[32]



Sl. No.	Pharmacological activity	Plant parts used	Extract	Chemical Constituent	Dosing	Disease inducing agent	References
15	Neuroprotective	Leaves and fruit pulp	Methanolic	Alkaloids, Flavonoids, Carbohydrates, Glycosides, Saponins.	200 mg/kg and 400 mg/kg.	Rats with an amnesia model produced by scopolamine.	[33]
16	Antifungal	Stem bark, root bark and fruit shells.	Petroleum ether, chloroform and ethanol	White Crystalline Solid	<i>In vitro</i>	TLC-Bioassay technique	[34]
17	Anti-bacterial Activity	Leaves	Hexane, chloroform and methanol.	Steroids, Alkaloids, Triterpenoids, Saponins, Tannins, Flavonoids and Phenols.	<i>In vitro</i>	Agar well diffusion method.	[35]

zone of inhibition against five gram-positive bacteria (*Bacillus subtilis*, *Enterococcus faecalis*, *Micrococcus luteus*, *Staphylococcus aureus* and *Streptococcus pneumoniae*) and four gram-negative bacteria (*Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Proteus vulgaris*). Because of their inherent qualities, silver nanoparticles have the potential to be employed as antibacterial agents. The hexane extract was found to have low activity and chloroform extract to have mild to moderate antibacterial activity. However, methanol extract showed good antibacterial activity with significant inhibition zones. The leaves of *Limonia acidissima* contain secondary metabolites such as steroids, alkaloids, phenols, flavonoids, coumarins, saponins, tannins and triterpenoids. These compounds may be used to treat infectious diseases caused by *E. coli*, *P. vulgaris* and *S. pneumoniae*.<sup>[35]</sup>

## CONCLUSION

*Limonia acidissima* L. is an important medicinal plant in traditional medicine which are also supported by different preclinical studies. Bioactive phytoconstituents present in this plant have exhibited therapeutic efficacy. Leaf, fruit, seed, bark and root of the plant are important source of bioactive phytochemicals which may use to treat various illnesses. A thorough review of the literature on *L. acidissima* revealed that the plant is also important to investigate new drug molecules and further clinical trials require to confirm their therapeutic importance. More scientific research is required to confirm the potential of *Limonia acidissima* L. in the treatment of metabolic diseases, cardiovascular diseases and neurodegenerative diseases and develop medicinal herbal formulations.

## ACKNOWLEDGEMENT

Authors are thankful to Assam Down Town University, Guwahati for the opportunity and infrastructure facilities.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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**Cite this article:** Khatun S, Sen S. A Comprehensive Review on Ethnomedicinal Aspects, Phytochemical and Pharmacological Properties of *Limonia acidissima* Linn. Pharmacog Res. 2024;16(4):688-97.