JOURNAL OF PHARMA INSIGHTS AND RESEARCH ISSN NO. 3048-5428

REVIEW ARTICLE

Pharmacological Properties and Therapeutic Applications of *Litchi chinensis*

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Publication history: Received on 15th April 2025; Revised on 11th May 2025; Accepted on 12th May 2025

Article DOI: 10.69613/zbh6mb19

Abstract: *Litchi chinensis* Sonn., belongs to the Sapindaceae family, is a valuable medicinal plant with extensive traditional uses and therapeutic applications. The fruit, characterized by its sweet-aromatic pulp and distinctive reddish pericarp, contains numerous bioactive compounds including flavonoids, phenolics, and triterpenoids. The main compounds isolated from various parts of the plant include epicatechin, procyanidins, and polysaccharides, which are responsible for its pharmacological activities. Scientific studies have shown the plant's antioxidant, anti-inflammatory, hepatoprotective, antidiabetic, and anticancer properties. The fruit pulp is rich in essential nutrients, vitamins, and minerals, while the pericarp and seeds contain unique phytochemicals with therapeutic potential. Modern research has proved several traditional medicinal applications through *in vitro* and *in vivo* studies, particularly in areas of diabetes management, cardiovascular health, and cancer treatment. The plant's antioxidant properties, attributed to its polyphenolic constituents, have shown positive results in various experimental models. Additionally, studies on litchi's effects on lipid metabolism and glucose regulation suggest its capability in managing metabolic disorders. However, systematic clinical trials are needed to establish its therapeutic efficacy and safety profile. The current scientific evidence supporting litchi's medicinal properties makes it as a valuable resource for developing novel pharmaceutical and nutraceutical products.

Keywords: *Litchi chinensis*; Traditional medicine; Phytochemicals; Pharmacological activities; Therapeutic applications.

1. Introduction

Medicinal plants have maintained their pivotal role in global healthcare systems, serving as valuable sources of therapeutic agents [1]. Among these, *Litchi chinensis* Sonn., commonly known as litchi or lychee, has emerged as a significant medicinal plant with substantial therapeutic potential [2]. Native to southern China and northern Vietnam, this subtropical fruit tree has gained worldwide recognition not only for its delectable fruits but also for its medicinal properties [3]. *L. chinensis* belongs to the Sapindaceae family and has been cultivated for over 2000 years. The plant has successfully adapted to various tropical and subtropical regions worldwide, with commercial cultivation now established in more than 20 countries [4]. The tree produces arillate fruits characterized by their distinctive red pericarp, translucent white pulp, and a single large seed [5].

The plant's flowering pattern exhibits unique characteristics, with three distinct flower types: staminate, pistillate, and imperfectly hermaphroditic. These flowers appear in a sequential pattern on the same panicle, contributing to its complex reproductive biology [6]. This flowering pattern has significant implications for fruit production and crop yield [7]. Global commercial production of litchi is concentrated in several regions, with major industries established in China, Taiwan, Vietnam, Thailand, India, Bangladesh, and South Africa. Secondary production centers include Australia, Israel, the United States, Brazil, and various African nations [8]. The widespread cultivation of litchi across different geographical regions demonstrates its adaptability and economic importance. Phytochemical investigations have revealed that various parts of *L. chinensis* contain an array of bioactive compounds. The fruit pericarp, seeds, and leaves are particularly rich in flavonoids, phenolics, and triterpenoids [9].

The main flavonoids identified in the pericarp include epicatechin, epicatechin gallate, and procyanidins B4 and B2, while the seeds contain distinct compounds such as procyanidins A1 and A2, and litchioside D [10]. Modern scientific research has validated many traditional uses of *L. chinensis* through the identification of various pharmacological activities. These include anti-inflammatory, antioxidant, anticancer, antidiabetic, and cardioprotective properties [11]. The diverse range of biological activities exhibited by litchi extracts has attracted significant attention in the fields of pharmacognosy and phytochemistry [12]. The growing interest in natural

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therapeutic agents and the increasing burden of chronic diseases have sparked renewed focus on medicinal plants like *L. chinensis* [13].

Figure 1. Fruits and Leaves of *L. chinensis*

2. Description

2.1. Taxonomical Classification

L. chinensis is a subtropical fruit tree with distinct botanical characteristics. It belongs to the kingdom Plantae, order Sapindales, and family Sapindaceae [14]. The plant belongs to the genus Litchi, with *L. chinensis* being the most economically significant species. The systematic classification reflects its evolutionary relationships and botanical characteristics [15].

2.2. Morphological Features

The litchi tree is an evergreen that typically grows to heights of 10-20 meters with a broad, round canopy. The trunk develops a rough, grayish-brown bark with age, and the tree can remain productive for several decades under optimal conditions [16].

2.2.1. Leaves

The leaves are compound, alternately arranged, with 4-8 pairs of leaflets. Each leaflet is lanceolate to oblong, 5-10 cm long, with a leathery texture and glossy dark green upper surface. Young leaves display a characteristic bronze or copper coloration [17].

Table 1. Phytochemical Constituents of Different Parts of *Litchi chinensis* Sonn.

Plant Part	Major Compounds	Chemical Class
Pericarp	Epicatechin, Procyanidin A2, Cyanidin-3-rutinoside, Quercetin	Flavonoids, Anthocyanins
Seeds	Litchitannin A1, Litchitannin A2, Proanthocyanidins, Saponins	Tannins, Triterpenes
Pulp	Glucose, Fructose, Ascorbic acid, Phenolic acids	Sugars, Vitamins, Phenolics
Leaves	Proanthocyanidins, Flavonol glycosides, Quercetin derivatives	Flavonoids, Glycosides
Flowers	Kaempferol, Isolariciresinol, Stigmasterol	Flavonoids, Lignans, Sterols

2.2.2. Flowers

The inflorescence appears as a terminal panicle, 10-30 cm long, bearing numerous small, inconspicuous flowers. The flowers lack petals and are typically yellowish to greenish in color. The flowering pattern involves three distinct types of flowers appearing in succession: male (staminate), hermaphrodite (perfect), and female (pistillate) [18].

2.2.3. Fruits

The fruit is a drupe, typically round to oval, measuring 2.5-4 cm in diameter. The outer pericarp is thin, tough, and exhibits a distinctive pink to red coloration when ripe. The edible portion (aril) is translucent white, sweet, and surrounds a single dark brown seed [19].

2.3. Geographical Distribution

Originally native to southern China's provinces of Guangdong and Fujian, *L. chinensis* has been cultivated in these regions for over two millennia. Historical records indicate its presence in ancient Chinese agricultural practices dating back to the Han Dynasty [20]. The plant has successfully adapted to various tropical and subtropical regions globally. Major cultivation areas now include:

2.3.1. Asian Region

Countries such as India, Thailand, Vietnam, Bangladesh, and Taiwan have established significant commercial production. In India, primary cultivation occurs in Bihar, West Bengal, and Jharkhand states [21].

2.3.2. Other Regions

Cultivation has expanded to Australia, South Africa, Israel, Madagascar, and parts of the Americas. These regions have developed specialized cultivation techniques adapted to local conditions [22].

2.4. Cultivation

Successful cultivation of *Litchi chinensis* requires specific environmental conditions. The tree requires annual rainfall between 1000-2000 mm and thrives in well-drained, slightly acidic soils with a pH ranging from 5.5 to 7.0. The growing site should be protected from strong winds, and the growing season must be frost-free. For optimal growth and fruit production, temperatures should remain within 20-35°C [23]

3. Phytochemical Constituents

3.1. Primary and Secondary Metabolites

The fruit pulp of *L. chinensis* contains significant amounts of carbohydrates, primarily in the form of glucose, fructose, and sucrose. Protein content varies between 0.8-1.1% of fresh weight, while lipid content remains relatively low at 0.4-0.6%. The high moisture content, approximately 80-82%, contributes to the fruit's succulent nature [24]. Different parts of the plant contain distinct profiles of secondary metabolites. The pericarp is particularly rich in phenolic compounds, including flavonoids and proanthocyanidins. Notable compounds identified include epicatechin, procyanidin A2, and quercetin derivatives. The presence of these compounds correlates with the plant's various biological activities [25].

3.1.1. Leaf

The leaves contain significant amounts of (-)-epicatechin and procyanidin derivatives. Several flavonoid glycosides have been isolated, including quercetin and kaempferol derivatives. These compounds contribute to the leaves' antioxidant properties [26].

3.1.2. Fruit

The edible portion contains various organic acids, predominantly malic acid and citric acid. The characteristic aroma compounds include linalool, cis-rose oxide, and geraniol. Additionally, the fruit contains 5-hydroxymethyl-2-furfurolaldehyde and benzyl alcohol [27].

3.1.3. Seed

Litchi seeds contain unique compounds including leucocyanidin, cyanidin glycoside, and malvidin glycoside. Saponins present in the seeds have demonstrated significant biological activities. The seeds also contain substantial amounts of starch and protein [28].

3.1.4. Pericarp

The pericarp contains complex mixtures of phenolic compounds including bis-(8-epicatechinyl) methane, butylated hydroxytoluene, and various flavonoid derivatives. These compounds contribute to the pericarp's potent antioxidant properties [29].

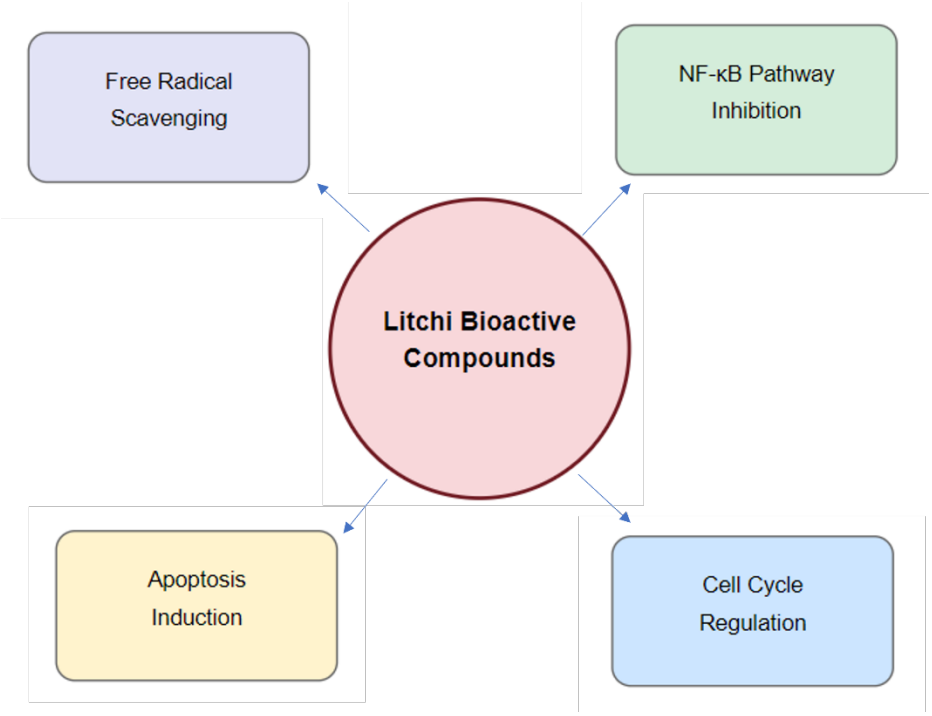

Figure 2. Molecular Mechanisms of Action of Litchi Bioactive Compounds

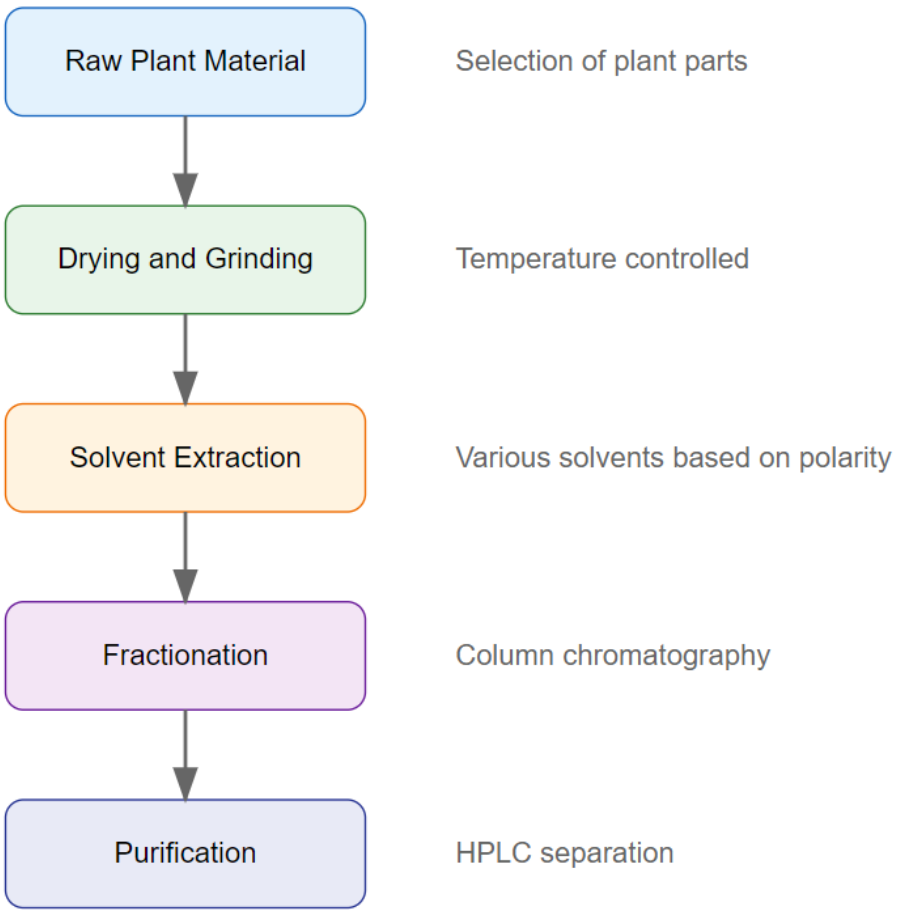

Figure 3. Process for Extraction of Bioactive Compounds from *Litchi chinensis*

3.2. Nutritional Constituents

3.2.1. Macronutrients

Fresh litchi pulp provides approximately 66 kcal per 100g, with carbohydrates being the primary energy source. The fruit contains essential dietary fiber, contributing to its nutritional value [30].

3.2.2. Micronutrients

The fruit is particularly rich in vitamin C, containing approximately 71.5 mg per 100g of edible portion. Other significant vitamins include riboflavin, thiamine, and niacin. Mineral content includes potassium, magnesium, and phosphorus [31].

3.2.3. Bioactive Components

The fruit contains various bioactive compounds including polyphenols and polysaccharides. These components demonstrate significant antioxidant activity and potential health benefits. The concentration of these compounds varies with fruit maturity and environmental conditions [32]

Table 2. Nutritional Composition of Litchi Fruit (per 100g fresh weight)

Component	Content	Component	Content
Energy	66 kcal	Vitamin C	71.5 mg
Carbohydrates	16.5 g	Potassium	171 mg
Protein	0.8-1.1 g	Magnesium	10 mg
Fat	0.4-0.6 g	Phosphorus	31 mg
Dietary Fiber	1.3 g	Calcium	5 mg
Moisture	80-82%	Iron	0.31 mg

4. Pharmacological Activities

4.1. Antioxidant Properties

L. chinensis extracts demonstrate significant antioxidant activity through multiple mechanisms. The polyphenolic compounds present in various plant parts effectively neutralize free radicals, including DPPH, superoxide, and hydroxyl radicals. The pericarp extract shows particularly potent antioxidant effects, attributed to its high concentration of flavonoids and phenolic compounds [33]. Studies have shown that polysaccharide-enriched fractions from litchi pulp exhibit remarkable metal ion chelating abilities. These fractions demonstrate dose-dependent antioxidant activities, with LFP-III fraction showing superior chelating properties compared to other isolated fractions [34].

4.2. Anti-inflammatory Activity

Hydroalcoholic extracts of litchi leaves significantly reduce carrageenan-induced paw edema in experimental models. The anti-inflammatory effect becomes most pronounced four hours post-administration, comparable to standard anti-inflammatory drugs [35]. The anti-inflammatory activity involves modulation of pro-inflammatory mediators and cytokines. Studies indicate that litchi extracts suppress the expression of inflammatory markers and reduce the production of inflammatory mediators in various experimental models [36].

4.3. Hepatoprotective Effects

Litchi pulp extract demonstrates significant hepatoprotective activity against CCl_4-induced hepatotoxicity. Treatment with the extract normalizes serum levels of liver enzymes including glutamate-pyruvate transaminase, glutamate-oxalate transaminase, and alkaline phosphatase [37]. The hepatoprotective mechanism involves both antioxidant and antiapoptotic effects. The extract's ability to prevent lipid peroxidation and maintain cellular integrity contributes to its liver-protective properties [38].

4.4. Cardiovascular Effects

Lychee flower water extract significantly impacts cardiovascular health by normalizing lipid profiles. The extract modulates LDL receptor gene expression and influences lipid metabolism pathways [39]. Studies show that litchi extracts enhance endothelial function and possess anti-atherosclerotic properties. The compounds present in the extract help maintain vascular health through multiple mechanisms [40].

4.5. Antidiabetic Activity

Litchi seed extracts show promising antidiabetic effects through the inhibition of protein tyrosine phosphatase 1B. This mechanism helps reduce postprandial hyperglycemia and improves insulin sensitivity [41]. The extracts demonstrate multiple beneficial effects on glucose metabolism, including reduced glycogenesis and improved lipid profiles in diabetic models. The presence of specific glycosides contributes to these antidiabetic properties [42].

4.6. Anticancer Properties

Litchi fruit pericarp extract exhibits significant anticancer activity against various cancer cell lines. Studies have demonstrated particular efficacy against breast cancer cells, both estrogen receptor-positive and negative variants [43]. The anticancer activity involves multiple pathways including apoptosis induction and cell cycle regulation. The extract upregulates pro-apoptotic genes while downregulating genes involved in cell proliferation and invasion. Key genes affected include CYP1A1, BIRC3, and ADAM9 [44].

4.7. Antimicrobial Activity

Various extracts from *L. chinensis* demonstrate broad-spectrum antibacterial activity against both gram-positive and gram-negative bacteria. The phenolic compounds present in the pericarp contribute significantly to this activity [45]. Studies have shown that litchi extracts possess moderate to significant antifungal activity against various pathogenic fungi. This activity is particularly notable in the pericarp extracts [46].

4.8. Neuroprotective Effects

Litchi extracts show promising effects on cognitive function and neuroprotection. The antioxidant compounds present in the fruit help protect neural cells from oxidative stress-induced damage [47]. Studies indicate potential benefits in memory enhancement and prevention of age-related cognitive decline through multiple mechanisms including cholinesterase inhibition [48].

4.9. Immunomodulatory Activity

The polysaccharides and other bioactive compounds in litchi demonstrate significant immunomodulatory effects. These compounds enhance both cellular and humoral immune responses [49]. Research shows that litchi extracts possess anti-allergic properties through the modulation of inflammatory mediators and immune cell function [50].

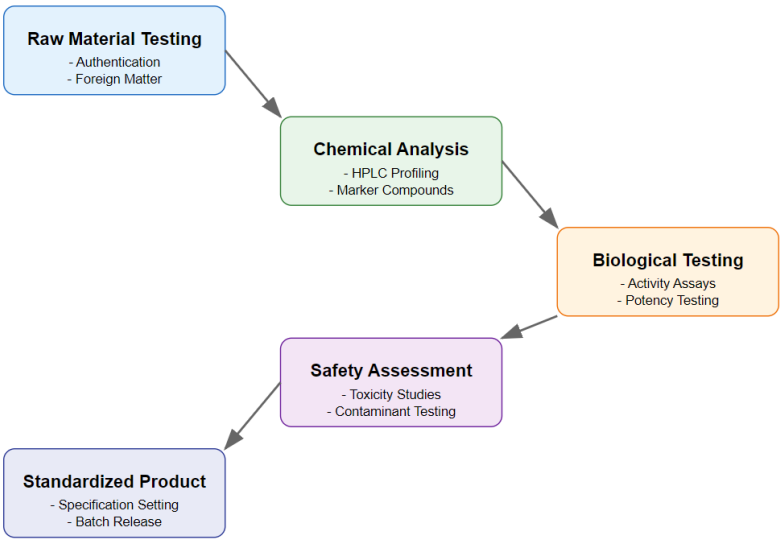

Figure 4. Quality Control and Standardization of Litchi Preparations

4.10. Other Pharmacological Effects

Litchi flower water extract shows promising anti-obesity effects through lipase inhibition and modulation of fat metabolism. The extract significantly reduces adipose tissue accumulation and liver lipid levels [51]. Studies demonstrate protective effects on the gastrointestinal system, including anti-ulcer properties and improvement in digestive function [52-54].

Table 3. Pharmacological Activities of *Litchi chinensis* Extracts

Activity	Part Used	Experimental Model	Findings	References
Antioxidant	Pericarp, Pulp	DPPH, FRAP assays	Strong free radical scavenging activity	[31, 33]
Anti-inflammatory	Leaves, Seeds	Carrageenan-induced edema	Reduced inflammation markers	[35, 36]
Anticancer	Pericarp	Breast cancer cell lines	Inhibited cancer cell proliferation	[29, 43]
Antidiabetic	Seeds, Pulp	Diabetic rat models	Improved glucose tolerance	[41, 42]
Hepatoprotective	Pulp, Seeds	CCl_4-induced liver injury	Reduced liver enzyme levels	[37, 38]

5. Therapeutic Applications

5.1. Traditional Medicine

5.1.1. Chinese Medicine

In traditional Chinese medicine, litchi has been utilized for centuries to treat various conditions including gastrointestinal disorders, cough, and diabetes. Different parts of the plant are employed for specific therapeutic purposes [55]. The fruit and seeds are particularly valued for their warming properties and ability to nourish blood and promote circulation.

5.1.2. Ayurveda

The integration of litchi in Ayurvedic practices focuses on its use as a rejuvenating tonic and for managing digestive disorders. The fruit is considered beneficial for improving blood circulation and strengthening the body [56]. Traditional preparations often combine litchi with other herbs to enhance therapeutic efficacy.

5.2. Modern Therapeutic Uses

5.2.1. Metabolic Disorders

Modern applications in metabolic disorders encompass various therapeutic approaches. The management of type 2 diabetes benefits from improved glucose regulation mechanisms through litchi extracts. Treatment protocols for obesity incorporate lipase inhibition properties, while lipid metabolism disorders are addressed through multiple pathways influenced by bioactive compounds [57, 58].

5.2.2. Cardiovascular Health

Contemporary cardiovascular applications utilize litchi's beneficial properties for preventing atherosclerosis through modulation of lipid profiles and inflammatory markers. The management of hypertension involves multiple mechanisms, including vascular tone regulation and antioxidant effects. Overall cardiac function improvement is achieved through combined actions on various cardiovascular parameters [59].

5.2.3. Hepatic Protection

Clinical applications in hepatic protection focus on preventing drug-induced hepatotoxicity through antioxidant and anti-inflammatory mechanisms. Management of alcoholic liver disease benefits from hepatoprotective properties, while viral hepatitis treatment protocols incorporate supportive therapy with litchi extracts [60].

Table 4. Traditional and Modern Therapeutic Applications of *Litchi chinensis*

System	Traditional Uses	Modern Applications	Supporting Evidence
Cardiovascular	Blood circulation enhancement	Anti-atherosclerotic, Antihypertensive	[39, 40]
Metabolic	Diabetes management	Glucose regulation, Anti-obesity	[41, 51]
Digestive	Gastrointestinal disorders	Hepatoprotection, Anti-ulcer	[52, 59]
Immune	General tonic	Immunomodulation, Anti-allergic	[49, 50]
Nervous	Cognitive enhancement	Neuroprotection, Memory improvement	[47, 48]

6. Conclusion

L. chinensis is a valuable medicinal plant with significant therapeutic potential for various multiple diseases. The phytochemical profile, including flavonoids, polyphenols, and polysaccharides, are responsible for its distinct pharmacological activities. Scientific evidence has validated many traditional uses of litchi through experimental studies and clinical observations. The hepatoprotective, antidiabetic, cardiovascular, and anticancer properties of the fruit show its potential in combating various contemporary health problems. The favorable safety profile of litchi extracts, combined with their therapeutic efficacy, makes this plant as an ideal

candidate for developing novel pharmaceutical and nutraceutical products. The growing body of scientific evidence with increasing interest in natural therapeutic agents, suggests a viable future for this traditional medicinal plant in modern healthcare systems.

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