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REVIEW article

Pterocarpus marsupium: An overview of its medicinal properties, phytochemistry, and pharmacology

Snigdha Sreedharan and **Karunakar Hegde** *

Department of Pharmacology, Srinivas College of Pharmacy, Valachil, Post Farangipete, Mangalore, Karnataka, India
* Author to whom correspondence should be addressed

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Abstract: *Pterocarpus marsupium* Roxb., commonly known as Indian kino, is a traditionally important medicinal plant widely used in Ayurvedic medicine for the management of diabetes, obesity, inflammation, and various infections. This review summarizes the ethnomedicinal uses, phytochemical constituents, pharmacological activities, and safety profile of *Pterocarpus marsupium*. The plant is rich in bioactive compounds such as flavonoids, polyphenols, stilbenoids (including pterostilbene), tannins, and terpenoids, which contribute to its therapeutic potential. Preclinical studies demonstrate significant antidiabetic, antihyperlipidemic, antioxidant, antimicrobial, hepatoprotective, anticancer, and anti-metabolic syndrome activities. Mechanistic evidence suggests that these effects are mediated through reduction of oxidative stress, enhancement of glucose uptake, modulation of lipid metabolism, inhibition of aldose reductase, and anti-inflammatory pathways. Acute toxicity studies indicate a high safety margin with no considerable adverse effects at experimental doses. Although experimental findings strongly support its traditional applications, further clinical investigations and standardization studies are required to validate its efficacy and ensure safe therapeutic use. *Pterocarpus marsupium* represents a promising natural candidate for managing metabolic and lifestyle-related disorders.

Introduction

Pterocarpus marsupium Roxb. is an herb in the family Fabaceae, indigenous to India, commonly found in the Western Ghats in Kerala, Karnataka, Maharashtra, and Gujarat [1-5]. The plant, commonly referred to as Malabar kino, Indian kino, or gum kino, has been traditionally used for medicinal purposes for many years. It is a large deciduous plant that can grow up to 30 m tall as a medium-to-large-sized tree (**Figure 1**). The various components of this plant have unique morphological features, including rough and vertically cracked outer bark, golden yellow inner heartwood, light yellow sapwood, compound leaves, yellow flowers, flat circular winged fruits, and blood-like latex (gum) [6].

Figure 1: *Pterocarpus marsupium Roxb.*

It is well known in Ayurvedic medicine because of its curative and lenitive properties. Its flowers are employed against fever and heartwood as depurative, haemostatic, and rejuvenating. The gum (kino) obtained from the tree is used for diarrhoea, pyrosis, and toothache. The water kept in tumblers made from the wood of this plant is said to be beneficial for chest pain and diabetes [7]. The leaf possesses anthelminthic and antioxidant activities. The stem possesses antioxidant, antidiabetic, anti-inflammatory, and antimicrobial activities. The bark possesses anti-inflammatory, analgesic, anticancer, antimicrobial, hepatoprotective, and antidiabetic activities [2]. Researchers recognized the plant *Pterocarpus marsupium* (*P. marsupium*) as a highly abundant source of flavonoids and polyphenolic compounds. All the active phytoconstituents of *P. marsupium* were thermostable. It contains pterostilbene (45.0%), alkaloids (0.4%), tannins (5.0%), and protein. The primary phytoconstituents were liquiritigenin, isoliquiritigenin, pterosupin, epicatechin, catechin, kinotannic acid, kinoin, kino red, β-eudesmol, carsupin, marsupial, marsupinol, pentosan, and p-hydroxybenzaldehyde [3].

Table 1: Taxonomy [2, 3]

Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopsida
Order	Fabales
Family	Fabaceae
Genus	*Pterocarpus*
Species	*P. marsupium*

Table 2: Vernacular names [4, 5]

English	Indian kino, Malabar kino
Malayalam	Venga
Hindi	Bijasal, Vijayasara
Tamil	Vengai
Kannada	Bijasara, Asana

Distribution: *P. marsupium* has been traditionally used for its medicinal value. It is found mostly in deciduous and evergreen forests in the western, central, and southern regions of India, including the states of Bihar, Madhya Pradesh, Gujarat, Kerala, Karnataka, and Uttar Pradesh [3]. This plant is highly tolerant of elevated temperatures, particularly during the intense heat of summer. The maximum temperature ranged from 35°C to 48°C, and the minimum temperature ranged from 0.0°C to 18.0°C. It grows best in deep, clayey loam soil that has plenty of drainage and in geographical situations like quartzite, shale, conglomerate, lateritic, gneiss, and sandstone. The usual rainfall of its habitat ranges from 750 to 2000 mm and even more in Southern India. These species are light-loving, and the young seedlings are frost-tender [5].

Description*: P. marsupium* Roxb. is a moderate to big deciduous tree, usually found in hilly areas, and may grow to a height of up to 30 meters [8-10].

Bark: Its bark is characterized by a brownish-grey colour, peeling off in flakes, and exhibiting a rough, longitudinally fissured, and scaly texture. The bark of the tree displays a pink hue adorned with whitish markings. Abundant leaves adorn the tree, which are arranged alternately without stipules and are unequally pinnate, with round petioles.

Stem: Stem is erect, strong, and crooked. Branches are widely spread.

Flowers: Abundant white flowers, tinged with yellow, fragrant, bisexual, pentamerous, zygomorphic, and regular, calyx-sepal 5, and corolla-petals 5, papilionaceous. Ten stamens unite near the base, eventually dividing into two groups of five, featuring bulbous, bi-lobed anthers.

Heartwood: The heartwood is golden yellowish-brown with darker streaks and occurs as uneven pieces of erratic sizes and thickness. When soaked in water, it produces a yellow solution that fluoresces blue. Strong, hard, and tough fracture. Taste astringent, odour nil.

Leaves: The leaves are intricate and grand, composed of 5 - 7 elongated, rounded leaflets with smooth petioles. These leaflets exhibit diverse shapes, including pine-like, serrated, ovate, or bilobed, and are smooth on both surfaces. Each leaflet, wavy and approximately 5-6 inches long, is stalkless. Panicles are expansive and wide, with leaves distributed bilaterally. Peduncles and pedicels are globular and slightly fuzzy, adorned with small caduceus bracts beneath each panicle subdivision.

Seeds: Seed pods are flat, orbicular, and winged, up to 5.0 cm in diameter, while seeds are 1-3 in number, bony, and convex in shape.

Active constituents: Many important phytochemicals, such as glucosides, sesquiterpene, and Vijayoside, have been isolated from the aqueous extract of the heartwood of *P. marsupium*. The extract of heartwood contains pterostilbene, marsupsin, and liquiritigenin-epicatechin. Bark extract contains several reputed phytochemicals such as 3-o-methyl-D-glucose, n-hexadecenoic acid, 1,2-benzenedicarboxylic acid, tetra-decanoic acid, 9,12-octadecadienoic acid (Z, Z), D-friedoolean-14-en-3-one, and lupeol [10]. Some new flavonoid C-glucosides: 6-hydroxy-2-(4-hydroxybenzyl)-benzofuran-7-C-beta-glucopyranoside(1), 3-(alpha-methoxy-4-hydroxy ben zylidene)-6-hydroxybenzo-2 (3H)- furanone-7-C-beta-d-glucopyranoside(2), 2-hydroxy-2-p-hydroxy benzyl-3(2H)-6-hydroxybenzofuranone-7-C-beta-d-glucopyranoside(4), 8-(C-beta-d-glucopyranosyl)-7,3',4'-trihyd-roxy flavone (5) and 1,2-bis(2,4-dihydroxy,3-C-glucopyranosyl)- ethanedione (6) and two known compounds: Cbeta-d-glucopyranosyl-2,6-dihydroxylbenzene(7) and sesquiterpene (8), were isolated from the heartwood [11].

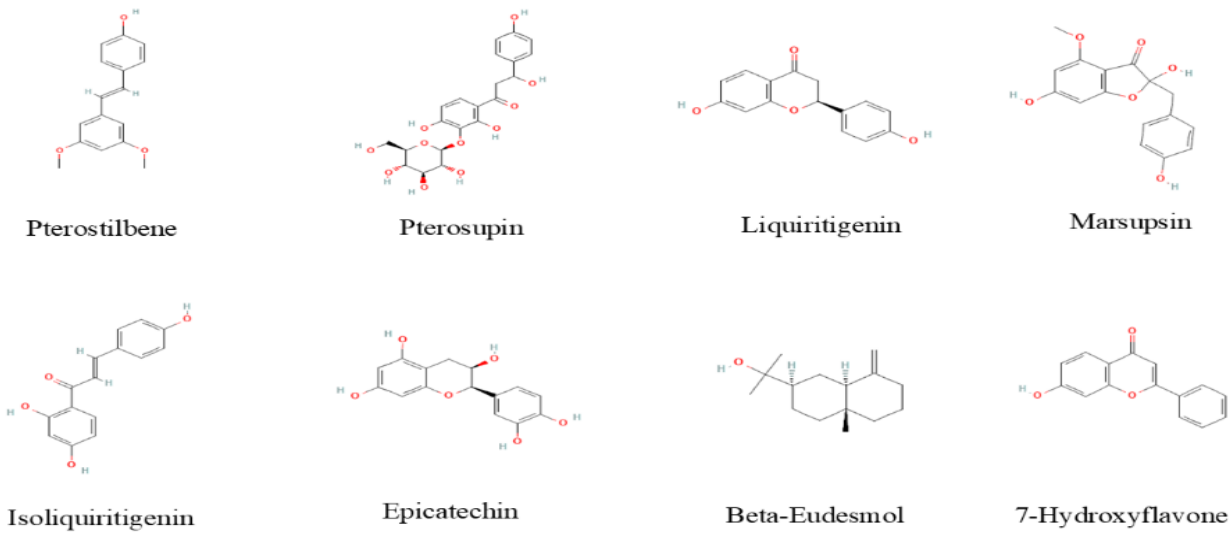

Figure 2: Phytochemical constituents of *Pterocarpus marsupium*

Traditional uses: In the Ayurvedic Pharmacopoeia of India, it has been used for the treatment of Krmiroga (worm infection), Kustha (leprosy), Prameha (diabetes), Pandu (anaemia), and Medodosa (obesity) [12]. Several previous studies have also shown the antioxidant, antimicrobial, antidiabetic, anti-cataract, anti-inflammatory, and analgesic effects of different extracts of *P. marsupium*. Heartwood juice of this plant is known to contain polyphenolic compounds (flavonoids, diphenyl propane derivatives, and sesquiterpenes), which show strong antioxidant, anti-inflammatory, antidiabetic, antimicrobial, and anticancer activities and are used for the treatment of diabetes, jaundice, ulcer, and gastritis [13]. Moreover, the leaves, flowers, gum as well as heartwood of the plant *P. marsupium* have been used as one of the major ingredients in various

Ayurvedic, Homeopathic and Siddha formulations due to its ethnic therapeutic activity against diarrhoea, dysentery, fractures, leprosy, leukoderma, skin diseases, sores, boils, constipation, depurative, rectalgia, ophthalmology, haemorrhages, rheumatoid arthritis, lowering the blood glucose level, diuretic, gastrointestinal tract disorders also aids in the treatment of various neurological problems [4]. The flavonoid phytoconstituents of *P. marsupium,* mainly marsupin, pterosupin, and liquiritigenin, have been shown to have an anti-hyperlipidaemic effect. The experimental observations proved that the extract was able to reduce serum triglyceride, total cholesterol, and low-density lipoproteins, and low-density lipoproteins -cholesterol without any significant effect on the level of HDL cholesterol [14].

Pharmacological properties

Anti-cataract activity: P. marsupium bark extract showed significant anticataract activity in streptozotocin-induced diabetic rats by reducing blood glucose and inhibiting aldose reductase activity (~79%). Treatment downregulated aldose reductase mRNA and protein expression and improved insulin and antioxidant (GSH) levels. This indicated protection against diabetic cataract via polyol pathway inhibition [15].

Anti-metabolic syndrome activity: Metabolic syndrome is a collection of interconnected disorders linked to central obesity, insulin resistance, dyslipidaemia, and hypertension. The aqueous extract of *P. marsupium* (200 mg/kg/day) showed significant protective effects against high-carbohydrate diet-induced metabolic syndrome in rats. Treatment markedly reduced the body weight, abdominal circumference, blood glucose, and serum triglyceride levels compared to the control group. The effects were comparable to standard therapy (metformin plus atorvastatin), indicating the potential of *P. marsupium* in managing obesity, dyslipidaemia, and insulin resistance associated with metabolic syndrome [14, 16, 17].

Anti-diabetic activity: Methanolic heartwood extract of *P. marsupium* (MPME) exhibits significant antidiabetic activity by reducing oxidative stress and enhancing glucose uptake in HepG2 cells. Metabolic profiling using GC-MS, UPLC-MS, and HPTLC identified phenols, flavonoids, terpenoids, and key antidiabetic compounds such as quercetin. MPME (23.43 - 93.75 µg/mL) was found to be non-toxic and effectively reduced oxyradical generation, cellular damage, and apoptosis. At 93.75 µg/mL, MPME significantly improved glucose uptake, indicating insulin-sensitizing activity. These findings suggest that *P. marsupium* heartwood exerts its antidiabetic effect primarily through attenuation of oxidative stress and enhancement of cellular glucose utilization [18, 19].

Anti-microbial activity: P. marsupium bark extracts exhibited significant antimicrobial activity as evaluated by the disc diffusion method, with zones of inhibition ranging from 11 - 22 mm against selected microbial strains. The methanolic extract showed the highest activity, exhibiting minimum inhibitory concentrations (MIC) of 12.5 µg/mL against *Salmonella typhi* and *Enterococcus faecalis* and 25.0 µg/mL against *Aspergillus niger*, indicating broad-spectrum antimicrobial potential [20].

Anti-oxidant activity: The alcoholic heartwood extract of *P. marsupium* illustrated strong antioxidant activity in multiple *in vitro* assays. The extract showed high total phenolic and flavonoid content and exhibited significant free-radical scavenging activity in DPPH, nitric oxide, superoxide, and hydrogen peroxide assays. It displayed notable reducing power and total antioxidant capacity. These antioxidant properties contribute to the protective role of *P. marsupium* against oxidative stress, which is a key factor in the development of diabetic complications [21]. Phyto-synthesized silver nanoparticles (Pm-AgNPs) derived from *P. marsupium* were positively characterized and exhibited strong antioxidant activity. The nanoparticles showed significant free-radical scavenging potential with an IC_{50} value of 49.7 µg/mL, attributed to bioactive phytochemicals involved in nanoparticle formation. These findings highlight the potent antioxidant capability of *P. marsupium*-mediated AgNPs, supporting their potential application in oxidative stress-related disorders [22-25].

Anti-cancer activity: Gold nanoparticles (Pm-AuNPs) synthesized from the aqueous bark extract of *P. marsupium* demonstrated significant *in vitro* anticancer activity against oral squamous cell carcinoma (OSCC). The Pm-AuNPs exhibited dose-dependent cytotoxicity against SCC29b, SSC154, and OECM-1 cell lines, with IC_{50} values of 25.0 ± 1.2, 45 ± 1.5, and 75.0 ± 2.1 µg/mL, respectively. Mechanistic studies revealed increased intracellular ROS generation, mitochondrial membrane depolarization, and apoptosis induction. Acute toxicity studies in rats confirmed the non-toxic nature of Pm-AuNPs up to 2000 mg/kg, highlighting their potential as safe and effective nanoparticle-based anticancer agents [26].

Anti-hyperlipidaemic activity: The antihyperlipidemic potential of the hydroalcoholic extract of *P. marsupium* (HAPM) was evaluated in high-fat diet–induced hyperlipidaemic rats. Chronic hyperlipidaemia was induced by oral administration of a high-fat diet for 21 days, resulting in significant elevation of serum cholesterol and triglyceride levels. Treatment with HAPM (300 and 500 mg/kg) significantly reduced serum total cholesterol, triglycerides, LDL-C, and VLDL-C, while markedly increasing HDL-C levels compared to the vehicle control. The lipid-lowering effect was comparable to that of atorvastatin (10.0 mg/kg). Histopathological examination of cardiac tissue showed marked regression of lipid-associated changes in treated groups. These findings demonstrate the significant antihyperlipidemic activity of *P. marsupium* hydroalcoholic extract [27].

Anti-fungal activity: Leaf extracts of *P. marsupium* have demonstrated significant antifungal activity against various pathogenic fungi. The activity was evaluated using parameters such as MIC, minimum fungicidal concentration (MFC), and zone of inhibition. Among different solvent extracts, the methanolic extract exhibited the highest antifungal efficacy, showing a larger zone of inhibition and lower MIC and MFC values compared to ethanol and aqueous extracts. The antifungal potential is attributed to the presence of bioactive phytoconstituents such as phenolic compounds and tannins, which may disrupt fungal cell membrane integrity and inhibit essential enzymatic pathways. These findings suggest that methanolic leaf extracts of *P. marsupium* possess promising antifungal properties and may serve as a potential source for the development of novel antifungal agents [28].

Hepatoprotective activity: The ethanolic extract of *P. marsupium* leaves demonstrated hepatoprotective activity against paracetamol-induced liver damage in rats. Pretreatment, particularly at 400 mg/kg, markedly reduced elevated liver enzymes (ALT, AST, ALP), bilirubin, and lipid peroxidation levels while restoring antioxidant enzymes such as SOD, GSH, and CAT. The extract also improved total protein and albumin levels. Its protective effect was comparable to that of silymarin, suggesting that the hepatoprotective action is primarily mediated by antioxidant and membrane-stabilizing mechanisms [24, 29].

Toxicity properties: *Acute toxicity studies:* Acute oral toxicity study of the aqueous heartwood extract of *P. marsupium* was carried out in rats at graded doses of 1000, 2000, and 5000 mg/kg. The animals were observed continuously for the first two hours, intermittently for 48 hours, and then daily for 14 days for any behavioural, neurological, or autonomic signs of toxicity. No mortality or visible toxic symptoms were observed at any dose level. Although a dose-dependent change in body weight gain was noted, it was not associated with clinical toxicity. The median lethal dose (LD_{50}) was greater than 5000 mg/kg, indicating a wide margin of safety and confirming that the extract is practically non-toxic under acute exposure conditions [30-32].

***Future perspectives*:** Despite extensive preclinical evidence supporting the pharmacological potential of *P. marsupium*, further studies are required to translate these findings into clinical applications. Advanced molecular studies focusing on pathways (AMPK activation, PPAR modulation, oxidative stress regulation, and adipogenesis inhibition) will help clarify its precise mechanism of action. Bioactivity-guided isolation of lead compounds and investigation of synergistic interactions among flavonoids and polyphenols may facilitate the development of standardized phytopharmaceutical formulations. Chronic toxicity studies, herb-drug interaction assessments, and pharmacokinetic profiling are essential to ensure safety. The development of nano-formulations and nutraceutical products may enhance their bioavailability and therapeutic efficacy.

Conclusion: Pterocarpus marsupium Roxb. is a significant medicinal plant used in traditional systems of medicine for the management of diabetes, metabolic disorders, inflammatory conditions, gastrointestinal disorders, and infectious diseases. Studies support its traditional claims, demonstrating antidiabetic, antihyperlipidemic, antioxidant, antimicrobial, anticancer, anti-cataract, and anti-metabolic syndrome activities. These are attributed to its rich phytochemical profile, including flavonoids, polyphenols, stilbenoids, and other bioactive constituents. Preclinical studies indicate a favourable safety profile with low acute toxicity, suggesting a wide therapeutic margin. Overall, *Pterocarpus marsupium* holds a remarkable potential as a natural therapeutic agent and phytopharmaceutical candidate for the treatment of metabolic and lifestyle-related disorders, warranting further systematic scientific exploration.

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