Review Article

# Unravelling the Phytochemical and Pharmacognosy Contour of Traditional Medicinal Plant: Pterocarpus marsupium Roxb

**A. Umamaheswari[1], M. Vijayalakshmi[1], N. Tamilselvan[1], S. Sowntharya[1], R. Thirumurugan[2], S. Lakshmana Prabu[3]**

1. Department of Pharmaceutical Technology, University College of Engineering (BIT Campus), Anna University, India; 2. Department of Pharmaceutical Chemistry, Sree Abirami College of Pharmacy, India; 3. Anna University of Technology, Tiruchirappalli, Tiruchirappalli, India

***Pterocarpus marsupium* Roxb is a traditional medicinal plant commonly acknowledged as "Vengai" and has a long history of usage in the tropical and subtropical regions for a variety of purposes in treating several human diseases. The present objective of this study is to provide its phytoconstituents and pharmacological activities. Extraction and fractionation of this plant highlighted the presence of alkaloids, proteins, carbohydrates, coumarin, gums, mucilage, fixed oils, anthraquinone glycosides, saponin glycosides, tannins, flavonoids, and phenolic compounds. Several investigational studies have demonstrated that this plant has various pharmacological activities such as analgesic, antidiabetic, anti-inflammatory, anticancer, hepatoprotective, antimicrobial, antidiarrhoeal, memory-enhancing activity, antioxidant, and antihyperlipidemic. It is used alone or with other medicinal plants to provide enhanced therapeutic efficacy for treating various ailments. Our present study is an extensive review relating to the plant's phytoconstituents and pharmacological activities such as antidiabetic, antioxidant, antimicrobial, anticancer, anti-inflammatory, memory-enhancing, hepatoprotective, and antihyperlipidemic in order to collate the knowledge that already exists about this plant and to emphasize its many uses as a medication.**

Dr. R. Thirumurugan and Dr. S. Lakshmana Prabu contributed equally to this work.

**Corresponding author:** S. Lakshmana Prabu, slaxmanvel@aubit.edu.in

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# 1. Introduction

Medicinal plants are a major resource for traditional medicine as well as for herbal industries. From ancient times, medicinal plants have been used for treating many diseases [1]. Recently, the World Health Organization highlighted that 80% of people worldwide still depend on herbal medicines for their primary health care needs [2]. India is one of the richest countries in herbal medicine compared to worldwide, and it has 15 agro-climatic zones of medicinal plants [3]. Ayurveda, Siddha, Unani, and Homoeopathy are various systems of medicine, and these systems have been used traditionally in India for several years [4]. The Indian Government is promoting the medicinal plants sector through the Ministry of AYUSH (Ayurveda, Yoga & Naturopathy, Unani, Siddha & Homoeopathy) [5].

The genus *Pterocarpus* is a large deciduous tree species of the angiosperms group (flower) from the *Leguminosae* family. In this family, about 765 genera and approximately more than 20,000 species are widely distributed throughout the world. The genus *Pterocarpus* includes 227 species, of which 46 species are accepted and 30 scientific plant names of intraspecific rank. *Pterocarpus marsupium* Roxb (*P. marsupium*) is a popularly well-known species among the *Pterocarpus* genus. Other vernacular names of this plant in India are kino tree or Malabar kino, Vijayasara, Bijasara, Venga, Bibala, Piashala, Chandan Lal, Vengai, and Yegi [6][7]. *P. marsupium* is native to India, Nepal, Sri Lanka, and is grown in deciduous and evergreen forests of central, western, peninsular India, the sub-Himalayan region, and southern regions of India, Bangladesh, Sri Lanka, and Taiwan [8]. In India, *P. marsupium* is found mostly in the states of Gujarat, Madhya Pradesh, Bihar, and Orissa and is traditionally used in Ayurveda, Siddha, Unani, and Homoeopathy [9].

Earlier phytochemical investigation reports revealed that *P. marsupium* contains alkaloids, protein, carbohydrates, coumarin, gums, mucilage, fixed oils, anthraquinone glycosides, saponin glycosides, tannins, flavonoids, and phenolic compounds [10]. It is a rich source of terpenoids, which include aurone, isoflavonoid glycosides, and associated phenolic compounds such as lupenol, epicatechin, and β-sitosterol [11]. The leaf possesses anthelmintic 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. The heartwood possesses anti-diarrhoeal and antidiabetic activities.

Although there are several earlier reviews on the phytochemistry, ethnobotany, and pharmacological potential of *P. marsupium*, there is very little focus on the relevance of its phytoconstituents and pharmacological activities.

The study was undertaken with the objective of providing baseline information on the potential benefits of the plant by investigating the role of phytoconstituents in the depicted pharmacological activities.

## 2. Botanical Description

*P. marsupium* is a large deciduous tree that can grow up to 30 m in height. The barks are scaly, rough, and longitudinally fissured, with a width range of 10-15 mm in size, which looks like a surface grey or greyish-black, with a pink blaze and whitish markings in colour [4]. Leaves are abundant, alternate without stipules, unequally pinnate with round petioles [12]. Leaflets are generally 5-7 in number, 8-13 cm long, oblong or elliptic or rotund, with 15-20 pairs of lateral veins [13].

The heartwood is golden yellowish-brown in colour, having darker streaks, and occurs as uneven pieces of erratic sizes and thickness [14]. On drenching in water, it gives a yellow-coloured solution with blue fluorescence. It has a strong, hard, and tough fracture with an astringent taste and no odour [13].

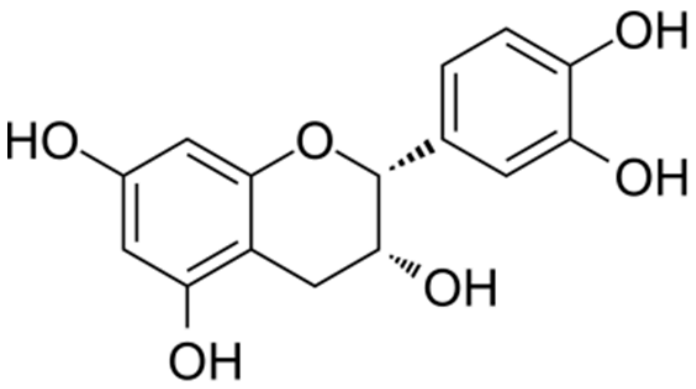
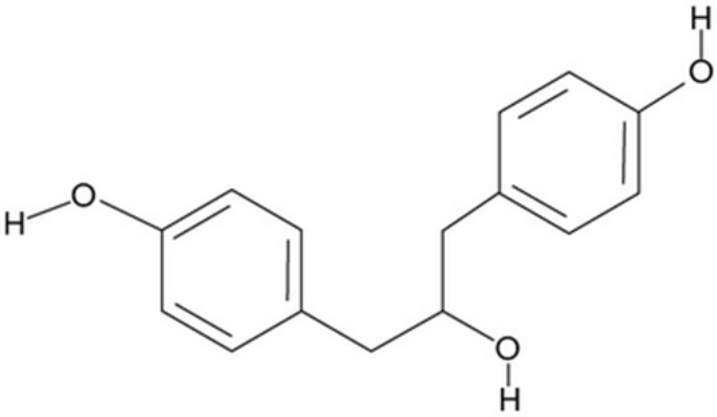
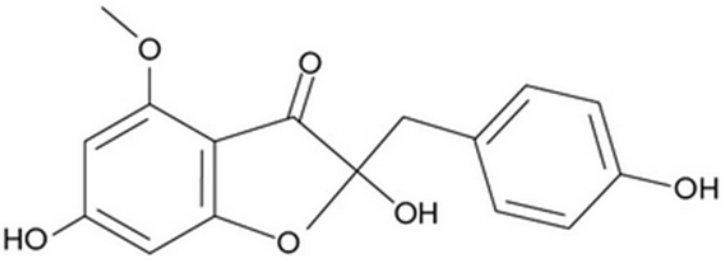
Flowers are fragrant, bisexual, and yellow in colour, which possess about 1-5 cm long large panicles [13]. Pods are flat, orbicular, winged up to 5 cm in diameter, while seeds are 1-3 in number, bony, and convex in shape. Flowering begins in the month of November, then fruiting continues up to March [15]. Normally, the legumes of the plant contain two seeds [16].

## 3. Taxonomic classification

| | |
|---|---|
| **Domain** | Eukaryota |
| **Kingdom** | Plantae |
| **Subkingdom** | Euphyllophytina |
| **Phylum** | Tracheophyta |
| **Infraphylum** | Radiatopsis |
| **Class** | Magnoliopsida |
| **Subclass** | Rosidae |
| **Super order** | Fabanae |
| **Order** | Fabales |
| **Family** | *Fabaceae* |
| **Sub-family** | Papilionaceae |
| **Genus** | Pterocarpus |
| **Species** | marsupium |
| **Botanical Name** | *Pterocarpus marsupium* Roxb[1][4][9][10][14][17]. |

## 4. Phytoconstituents

*P. marsupium* contains a rich source of flavonoids and polyphenolic compounds. Over years of analysis, researchers emphasized that the following bioactive phytochemicals, such as 45% of pterostilbene, 5% of tannins, 0.4% of alkaloids, and proteins, are present [18][19][20][21][22]. Apart from these, there are some primary phytoconstituents such as epicatechin, propterol, marsupin, pterostilbene, resorcinol, trans-stilbene, liquiritigenin, isoliquiritigenin, isoliquiritin, aglycone, pterosupin, catechin, kinotannic acid, kinoin, kino red, $\beta$-eudesmol, carsupin, marsupial, marsupinol, pentosan, and *p*-hydroxybenzaldehyde that were obtained from the heartwood and root [22][13]. Some of the phytoconstituent structures of *P. marsupium* are given in Table 1 , and phytoconstituents associated with different parts of the plant are depicted in Table **2**.

| *Name of Phytoconstituents* | *Structure of Phytoconstituents* | *Reference* |
|---|---|---|
| Epicatechin |  | [10][12][14][15] |
| Propterol |  | [10][12][15] |
| Marsupin |  | [1][10][15] |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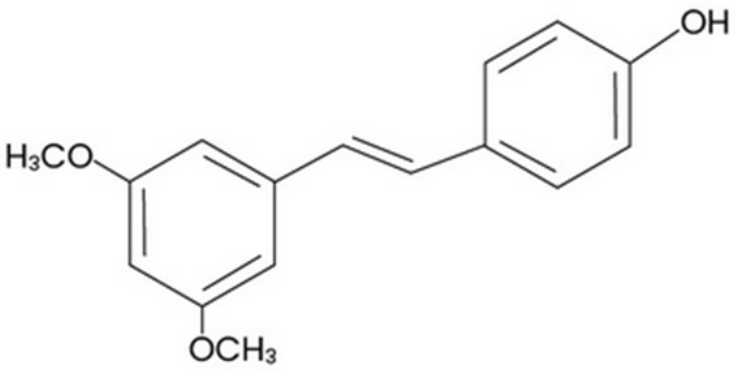
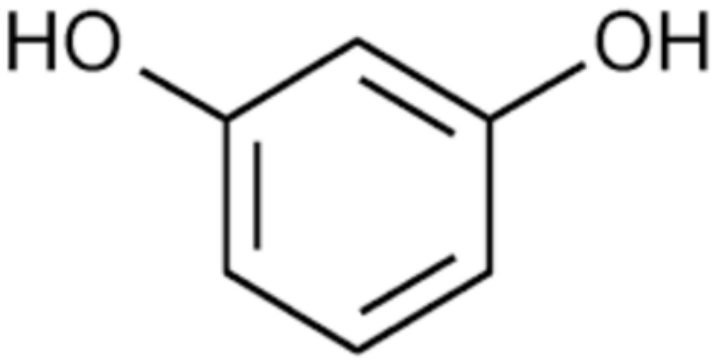
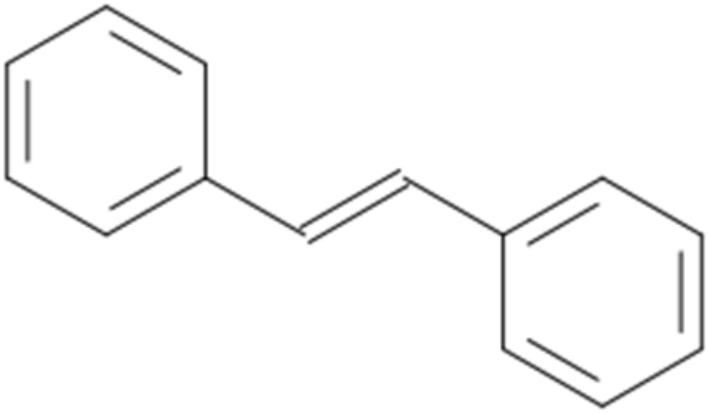
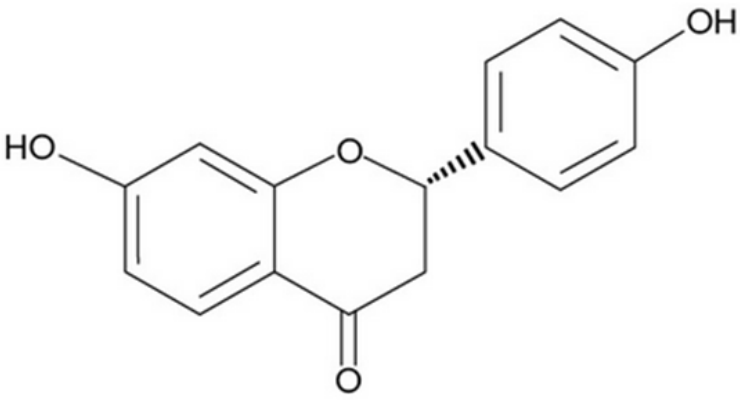
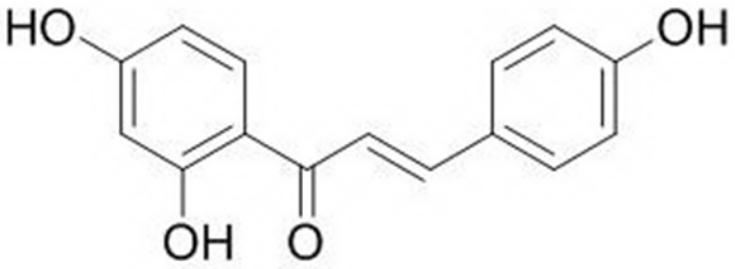
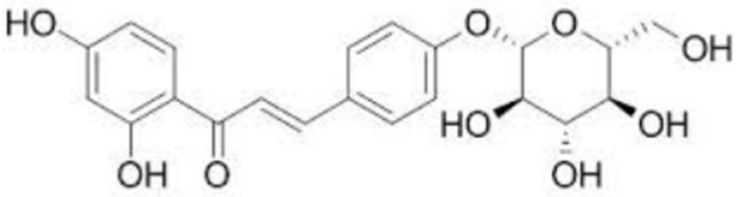
| *Name of Phytoconstituents* | *Structure of Phytoconstituents* | *Reference* |
|---|---|---|
| Pterostilbene |   | [15] |
| Resorcinol |   | [10][12] |
| Trans-stilbene |  | [10][12] |


doi.org/10.32388/4MFJWG.2

| *Name of Phytoconstituents* | *Structure of Phytoconstituents* | *Reference* |
|---|---|---|
| Liquiritigenin |  | [12][14][15] |
| Isoliquiritigrnin |  | [4][10][12][14] [15] |
| Isoliquiritin |  | [4][10][14][15] |


doi.org/10.32388/4MFJWG.2

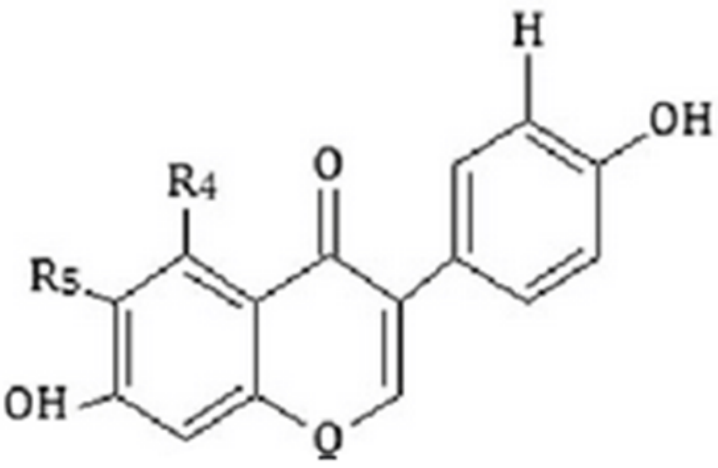
| *Name of Phytoconstituents* | *Structure of Phytoconstituents* | *Reference* |
|---|---|---|
| Aglycone |  | [19] |

**Table 1.** *Chemical structure of Phytoconstituents*

| *Parts of plant* | *Phytoconstituents* | *Reference* |
|---|---|---|
| Flowers | aurone glycosides, 4, 6, 4′-trihydroxyaurone 6-O-rhamnopyranoside and 4,6,4’-trihydroxy-7-methylaurone 4-O-rhamnopyranoside | [10][20] |
| Roots | flavonoid glycosides 7-Hydroxy-6, 8-dimethyl flavanone-7-O-alpha- L-arabinopyranoside and 7, 8, 4′trihydroxy-3′, 5′-dimethoxy flavanone-4′-O-beta-Dglucopyranoside | [10][12] |
| Heartwood | pterostilbene, isoliquiritigenin, liquiritigenin, carpucin, propterol, propterol-B, oleanolic acid, alkaloid and resin 5, 4′-dimethoxy-8-methylisoflavone, essential oil | [6][21] |
| Bark | Nonglucosidal tannins, Kinotannic acid, Kinonin, Kinored, Pyrocatechin, Pyrocatechin acid, resin, pectin and gallic acid | [4][10] |
| Leaves | alkaloids, fixed oils, tannins, proteins, carbohydrates, cardiac glycosides, flavonoids, Isoflavonoids, terpenoids and saponin glycosides. | [10][20] |
| Stem | alkaloids, glycosides, saponins and tannins, proteins, carbohydrates, cardiac glycosides, flavonoids, and terpenoids | [10][20] |

**Table 2.** *Phytoconstituents from different parts of P. marsupium*

From the heartwood of *P. marsupium,* three new isoflavone glycosides viz retusin 7-glucoside, irisolidone 7-rhamnoside and 5, 7- dihydroxy-6-methoxyisoflavone 7-rhamnoside were isolated and reported in several studies [16].

## 5. Pharmacological activities

*P. marsupium* has become an essential source all around the world due to its potential therapeutic properties. It is extensively used in various ethnic systems of medicine for the cure of a number of ailments such as leukoderma, elephantiasis, diarrhoea, cough, discoloration of hair, and rectalgia [23]. It is generally non-hazardous and useful in treating jaundice, fever, wounds, diabetes, stomachache, and ulcers [24]. Moreover, *P. marsupium* heartwood, leaves, flowers, and gum 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, and it also aids in the treatment of various neurological problems [16].

### *5.1. Antioxidant activity*

This plant extract showed not only hypoglycemic activity but also exhibited a promising antioxidant effect. The *in vitro* antioxidant activity of the ethyl acetate leaf extract of *P. marsupium* was studied by hydroxyl radical scavenging activity, ABTS assay, Ferric reducing ability of plasma (FRAP) assay, Nitrous oxide radical scavenging activity, Total reactive antioxidant potential (TRAP) assay, reducing power assay, and hydrogen peroxide ($H_2O_2$) radical scavenging activity. The study results demonstrated that the leaf extract has very good antioxidant activity [25]. Pant *et al.,* investigated the acetone: isopropyl alcohol (1:1) and ethanol extracts of the stem wood of *P. marsupium* for its antioxidant activity at 5, 20, 40, 60, 80, and 100 μg/mL by the 2, 2-diphenyl-1-picrylhydrazyl scavenging method. The study results demonstrated that these extracts showed antioxidant activity in a dose-dependent manner. Among these two extracts, acetone: isopropyl alcohol (1:1) showed a lesser $IC_{50}$ value (36.5 μg/mL), whereas the ethanol extract showed an $IC_{50}$ value of 61.94 μg/mL. In addition, they highlighted that phytoconstituents such as flavonoids, alkaloids, glycosides, phenols, steroids, coumarins, tannins, and terpenoids are responsible for its antioxidant activity [26]. Tippani *et al.,* examined the antioxidant activity of the methanol extract of *P.marsupium* bark by the 2,2-diphenylpicrylhydrazyl (DPPH) method at 0, 10, 20, 40, 80, 100, and 200 μg/mL and compared it with ascorbic acid as a standard. The result revealed that the extract has dose-dependent antioxidant activity with $IC_{50}$ values of 53 μg/mL and 34.0 μg/mL for the extract and ascorbic acid, respectively. They concluded that the extract has closely comparable antioxidant activity with the standard [27]. Bhata and Nayak investigated the various fractions of the heartwood of *P. marsupium* on antioxidant enzymes like protein thiols at 75 mg/kg for 30 days. The study results concluded that after 30 days of treatment, the extract significantly reduced the protein thiol level by neutralizing the free radicals through increased utilization [28].

Singh *et al*., examined the enzymatic and non-enzymatic antioxidant effects of methanol extracts of *P. marsupium* and *Ocimum sanctum* Linn as a mixture of both at a dosage of 500 mg/kg body weight on both non-diabetic and alloxan-induced diabetic adult female Wistar rats through its lipid peroxidation level.

The study results demonstrated that the extracts showed antioxidant activity by re-establishing the endogenous antioxidant levels to the pre-diabetic conditions [29].

### *5.2. Antidiabetic activity*

*P. marsupium* has been used as a potential antidiabetic agent ever since prehistoric times. It aids in lowering blood glucose levels, protecting the beta cells, and also possesses regenerative properties. Various investigational studies have been performed on numerous animal classes (rats, dogs, and rabbits) to study the hypoglycemic effect, and the results have demonstrated that *P. marsupium* repaired the usual insulin secretion by reversing the impairment to the beta cells by repopulating the islets of Langerhans [21][30][31][32][33]. Mohankumar *et al.,* investigated the aqueous extract of the heartwood of *P. marsupium* for its antidiabetic activity using a bioassay method by exposing pancreatic and muscle tissues of mice. The aqueous extract simultaneously increased insulin secretion and glucose uptake in a concentration-dependent manner and concluded that this plant has a potent antidiabetic property in both *in-vitro* as well as *in vivo* [34]. Halagappa *et al*., examined the aqueous extract of *P. marsupium* for antidiabetic activity at 100 and 200 mg/kg. The study results suggested that a 200 mg/kg dose has an effect on postprandial hyperglycemia in type 2 diabetic rats and also improved the body weight of the diabetic animals. In addition, it significantly decreases the Tumor necrosis factor (TNF)-α level in type 2 diabetic rats [35]. Jelastin *et al.,* examined the ethanol extract of *P. marsupium* wood and bark for antidiabetic activity in alloxan-induced diabetic rats. The study has shown that the ethanol extract of *P. marsupium* reduced the blood glucose level and increased plasma insulin levels in diabetic rats and highlighted that it can be used for the management of diabetes [36].

Mishra *et al.,* investigated the ethanol extract of the heartwood of *P. marsupium* for its antidiabetic activity on streptozotocin-induced rats. The crude powder, ethanolic extract, hexane, and n-butanol fractions showed improvement in oral glucose tolerance and increased the serum insulin level in a dose-dependent manner against its antidiabetic activity [37]. Pant and team performed a comparative antidiabetic activity study on the ethanolic extract of *P. marsupium* stem at 200 and 400 mg/kg in mice by oral glucose tolerance test against glimepiride at 0.43 mg/kg. The acute toxicity study results demonstrated that the ethanol extract of *P. marsupium* stem is non-toxic in the dose range of 250-1000 mg/kg. The study results demonstrated that the blood glucose-lowering effect was found to be 57.56%, 51.30%, and 55.13% for the standard, at 200 mg/kg, and 400 mg/kg, respectively, at 180 min. They also concluded that the antidiabetic activity is time- and dose-dependent [26]. Gayathri *et al.,* determined the

antidiabetic activity of the aqueous bark extract of *P. marsupium* at 500 mg/kg in streptozotocin-induced diabetic rats and measured various parameters like plasma insulin, cholesterol, glycosylated haemoglobin, triglycerides, aspartate transaminase (AST), alanine transaminase (ALT), alkaline phosphatase (ALP), a-glutamyl transferase (a- GT), and creatine kinase (CK). The study results demonstrated that the extract normalized the cholesterol, triglycerides, plasma insulin, and glycosylated haemoglobin levels and also decreased the AST, ALT, ALP, a-GT, and CK from their elevated levels in the diabetic rats. They concluded that the aqueous bark extract of *P. marsupium* showed a remarkable antidiabetic effect in metabolic alterations [38]. Mohankumar *et al.*, isolated the insulinotrophic activity-enriched fraction (AEF) from the aqueous extract of *P. marsupium* and investigated it for its antidiabetic activity by bioassay method. The study results showed that AEF modulated the biosynthesis of insulin by mimicking sulphonyl urea, also prolonged the responsiveness effects on glucose, and combated the hyperglycemia adverse effects by increasing and sustaining the glucose-dependent insulin secretion [39]. Singh *et al*., examined the antidiabetic effect of methanol extracts of *P. marsupium* and *Ocimum sanctum* Linn as a mixture of both at a dosage of 500 mg/kg body weight to both non-diabetic and alloxan-induced diabetic adult female Wistar rats. Parameters such as tissue lipids along with corticosterone, oestrogen, and progesterone profiles were assessed during the study. The study results demonstrated that the extract mixture ameliorated the diabetic-associated manifestations by restoring the endogenous antioxidant levels [40]. Radhika *et al*., made a comparative evaluation of the methanol extract of *P.marsupium* for its antidiabetic activity at the doses of 200 mg/kg and 400 mg/kg in streptozotocin-induced diabetic rats with glibenclamide at 2.5 mg/kg as a reference standard. Serum biochemical parameters such as triglycerides, Low Density Lipoprotein (LDL), Very Low Density Lipoprotein (VLDL), and High Density Lipoprotein (HDL) were also assessed. The extract showed significant diabetic activity by improving the peripheral utilization of glucose and extra pancreatic effect. In addition, the extract showed significantly decreased triglycerides ($p<0.01$), LDL ($p<0.01$), VLDL ($p<0.001$), and increased HDL ($p<0.05$) and concluded that the extract has potent antidiabetic activity [41]. Dhanabal *et al*., prepared an alcohol extract from the bark of *P. marsupium*, subsequently fractioned with different solvents like chloroform, butanol, toluene, and ethyl acetate. These fractions were investigated for their antidiabetic activity along with their related metabolic alterations in alloxan-induced diabetic rats. The study results demonstrated that among the different fractions, the butanol fraction showed more activity than the other fractions; in addition, it controlled the diabetic metabolic parameters such as total protein,

triglyceride, cholesterol, Serum glutamic oxaloacetic transaminase (SGOT), Serum glutamate pyruvate transaminase (SGPT), and alkaline phosphatase [42].

### *5.3. Antimicrobial activity*

Kachhawa and coworkers investigated the antibacterial activity of *P. marsupium* (Stem) methanol extract at the concentrations of (200, 100, 50, and 25 mg/mL) against gram-positive *Bacillus coagulans* and gram-negative *Escherichia coli* (*E. coli*) and compared it with ciprofloxacin as a standard (0.001 mg/mL) by the disc diffusion method. The study results demonstrated that the extract showed antibacterial activity against both bacteria, and the results were comparable with the standard [43]. Singh *et al.,* investigated the acetone: isopropyl alcohol (1:1) and ethanol extract of *P. marsupium* stem (50 mg/mL) for its antibacterial activity against Gram-positive bacteria such as *Staphylococcus aureus (S. aureus), Bacillus cereus* (*B. cereus*) and Gram-negative such as *E. coli, Salmonella typhi* and compared it against ofloxacin 50 μg/mL. Their study results demonstrated that the acetone: isopropyl alcohol (1:1) showed a zone of inhibition (8 mm) against gram-positive bacteria; no activity was observed against gram-negative bacteria. In addition, the ethanol extract didn't show any antibacterial activity against both gram-positive and gram-negative bacteria [40].

A comparative antimicrobial activity study between ethanol and aqueous extracts of fresh barks of *P. marsupium* by the cup plate agar diffusion method against gram + ve bacteria like *S. aureus, Bacillus sterothermophilus* and gram – ve bacteria like *E. coli*, *Klebsiella pneumoniae* at 400 and 800 µg/mL of extract and compared with ciprofloxacin at 20 µg/mL as a standard. The study results concluded that both extracts showed concentration-dependent antibacterial activity, whereas the alcohol extract was more potent than the water extract. In addition, they highlighted that the presence of tannin and flavonoids may contribute to its antimicrobial activity [44].

Kalaivani *et al*, examined the antimicrobial activity of the ethanol leaf extract of *P. marsupium* against *E. Coli, S. aureus, Aspergillus niger* (*A. niger*) and *Candida albicans* (*C. albicnas*) and compared it with Ciprofloxacin 5µg/disc for bacteria and Fluconazole 100 units/disc for fungi by the disc diffusion method. The study results outlined that the extract has both antibacterial and antifungal activity and also highlighted that *E. coli* had the highest (22 mm) and *C. albicans* had the lowest (12 mm) zone of inhibition [45].

Londonkar and Hugar have done the extraction from *P. marsupium* bark with different solvents such as distilled water, methanol, chloroform, and petroleum ether. The extracts were investigated for their

antimicrobial activity against gram + ve bacteria such as *S. aureus* and *Enterococcus faecalis (E. faecalis*), gram – ve bacteria such as *Salmonella typhimurium*, *E. coli*, *Enterobacter aerogenes*, and *Shigella dysenteriae*, and a fungus *A. niger* at the concentration of 100 mg/mL and compared with standard Cefixime (30µg) for +ve and piperacillin (30µg) for -ve bacteria, and amphotericin B (20mcg) for fungi, respectively. The study results demonstrated that the order of antimicrobial activity was found to be methanol > aqueous > petroleum ether > chloroform, respectively [46]. Deepa *et al.,* investigated the ethanol extract of *P. marsupium* stem bark for its antimicrobial activity at 0.1, 0.3, 0.6, 1.25, 2.5, 5 mg per mL by the agar well diffusion method against *Bacillus polymyxa (B. plymyxa), Vibrio cholera* (*V. cholera*), and *C. albicans* using Gentamycin and Amphotericin as controls. The ethanol extract showed significant antimicrobial activity at 1.25 mg/mL for *B. plymyxa, V. cholera* and at 25 mg/mL against *C. albicans*. From the study, they concluded that the antimicrobial activity might be due to its phytoconstituents such as alkaloids, tannin, glycosides, steroids, and flavanoids of the extract [47]. Gayathri and Kannabiran examined the antimicrobial activity of the aqueous extract of *Hemidesmus indicus* root, *Ficus bengalensis* bark *and P. marsupium* bark. The study emphasized that aqueous extracts of *P. marsupium* had the minimum inhibitory concentration range between 0.04 and 0.08 mg and concluded that the extract showed significant antimicrobial activity against all the microorganisms. They also suggested that secondary metabolites such as saponins and tannins could be responsible for its antibacterial activity [48]. Another research analysis revealed the antimicrobial activity against the gram-positive bacteria such as *Enterococci* and *S. aureus*, and negative bacteria such as *E. coli* and *Pseudomonas aeruginosa* (*P. aeruginosa*), and a fungal strain *C. albicans* [49].

Rajgovind and team photo-synthesized copper nanoparticles from *P. marsupium* and evaluated their antimicrobial activity against gram + ve (*S. aureus, Staphylococcus epidermidis, B. cereus*) and gram – ve (*E. coli, Proteus vulgaris, K. pneumoniae*) bacteria by the agar diffusion method and compared with gentamycin as a standard. The synthesized nanoparticles showed antimicrobial activity against all the microbes, whereas they had the maximum zone of inhibition for *K. pneumonia* [50].

Shrestha *et al*., extracted *P. marsupium* bark with methanol and performed antimicrobial activity tests against four American type culture collection (*E. coli, K. pneumonia, S.Typhimurium, and S. aureus*) and eight Multidrug resistant strains (*E. coli, methicillin-resistant S. aureus, K. pnemoniae, Acinetobacter baumannii, Citrobacter freundii, Xanthomonas species, Morganella morganii, P. aeruginosa)* by the agar well diffusion technique. The study results revealed that *P. marsupium* exhibited good antibacterial activity against the clinical isolates of MDR bacteria [51]. Bhat and team evaluated the antimicrobial activity of the

alcohol extract of the heartwood of *P. marsupium* against gram + ve (*Enterococci and S. aureus*) and negative (*E. coli and P. aeruginosa*) bacteria and a fungal strain *C. albicans* at 25, 50, and 100 µg/mL. The study results revealed that the extract showed dose-dependent antibacterial activity against the examined bacteria and didn't show any antifungal activity against *C. albicans*. Also, they highlighted that secondary metabolites such as triterpenes, tannins, saponins, and flavonoids could be responsible for its antimicrobial activity [52]. The antibacterial effect of the methanol extract of *P. marsupium* bark was investigated against *B. cereus, E. coli, K. pneumoniae*, and *V. cholera* and compared with Streptomycin sulphate as a standard and concluded that the extract showed higher antibacterial activity against *K. pneumonia* [53].

### *5.4. Anticancer activity*

Vijayarekha *et al*., performed the extraction of *P. marsupium* bark with three different solvents such as ethanol, chloroform, and aqueous and evaluated its anticancer activity against the Human prostate cancer cell line (PC-3) and Human cervical cancer cell line (HeLa) by the DNA fragmentation assay method. The study results demonstrated that ethanol and chloroform extracts showed an apoptosis effect by lysis of cells bound with the apoptotic bodies [54]. Diabetes mellitus can lead to cell damage and apoptosis through oxidative stress. Dar and team investigated the glucose uptake and apoptosis in HepG2 cells under oxidative stress conditions. The apoptosis effect of the methanol extract of *P. marsupium* heartwood was assessed through a fluorescence microscope. The study results revealed that the extract reduced cell damage and the apoptosis effect in HepG2 cells at 93.75 µg/mL [55].

Pterostilbene, a stilbenoid (Polyphenolic compound), was isolated from the heartwood of *P. marsupium* by Chakraborty *et al*., and investigated for its anticancer activity against breast (MCF-7) and prostate (PC3) cancer cell lines. The isolated pterostilbene showed anticancer activity by fragmenting the DNA, formation of apoptotic bodies, and distortion of the cell membrane. They highlighted that the mechanism behind its apoptosis effect is by preventing the cell proliferating factors such as Akt, Bcl-2, and improving apoptotic signals like Bax and caspases in mitochondria. In addition, it prevents the two metastasis inducers such as Matrix metalloproteinase 9 (MMP9) and a-methyl acyl-CoA racemase (AMACR) [56].

Gosetti *et al.,* identified volatile, non-volatile, and metal components in the aqueous extract of *P. marsupium* heartwood and examined its anticancer potential in different cell lines such as A431, HeLa, REN, and PC-3, and compared it with Imatinib mesylate as a positive control. The observed results

concluded that the aqueous extract of *P. marsupium* heartwood has anticancer activity against all the cell lines with $IC_{50}$ values of 8.7, 9.8, 12.5, and 13.4 µg/mL for A431, HeLa, REN, and PC-3 cell lines, respectively [57].

### *5.5. Anti-inflammatory activity*

Londonkar *et al*., performed a comparative anti-inflammatory activity study by the protein denaturation method between aqueous and methanol extracts of *P.marsupium* bark using diclofenac sodium as a standard. The study results revealed that both extracts have distinct anti-inflammatory activity which was comparable with the standard. The $IC_{50}$ values were found to be 45±1.6, 45±0.94, and 55±0.24 µg/mL for the methanol extract, aqueous extract, and diclofenac sodium, respectively [58]. Pant *et al.,* investigated the acetone: isopropyl alcohol (1:1) extract of *P. marsupium* stem wood for its anti-inflammatory activity in Swiss albino mice at 200 and 400 mg/kg/oral and compared it with indomethacin as a standard at 5 mg/kg/oral for 6 h. The paw edema was induced by administering 0.05 mL of undiluted fresh egg white in the sub-plantar region. The study results revealed that the extract has anti-inflammatory activity by decreasing the elevated TNF-α in serum in a time- and dose-dependent manner, with the inhibition activity at 5 h being 52.96%, 45.18%, and 47.03% for the standard, 200, and 400 mg/kg, respectively [26].

Patil and team developed a hydrogel from the hydroalcoholic extract of *P. marsupium* heartwood and evaluated its anti-inflammatory activity in carrageenan-induced rat hind paw edema for 8 h and compared it with a marketed formulation (Enacgel). The investigational results revealed that the formulated hydrogel showed more significant anti-inflammatory activity (43.70%) than the marketed formulation (17.03%) [59].

Yadav performed an anti-inflammatory activity assessment based on the individual and combined bark extracts of *P. marsupium* and *C. nurvala* bark at 250 µg/mL each and compared it with diclofenac sodium at 100 µg/mL as a standard. Anti-inflammatory activity was assessed based on hypotonicity-induced membrane lysis of human red blood cells. The observed results demonstrated that anti-inflammatory activity was found to be 74.49%, 42.88%, 38.26%, and 59.52% for the standard, *P. marsupium, C. nurvala*, and combined extract, respectively. The study results suggested that the combination of these extracts produced a synergistic effect and that phytoconstituents such as phenols, flavonoids, and alkaloids are mediating the anti-inflammatory activity by preventing numerous inflammatory enzymes [60].

Elevated inflammatory cytokines were observed during hyperglycemic conditions. A study performed by Halagappa and team examined the anti-inflammatory effect of the aqueous extract of the heartwood of *P. marsupium* at doses of 100 and 200 mg/kg in Type 2 diabetic rats for 4 weeks. Diabetes was induced in a neonatal rat by administering streptozotocin (90 mg/kg, i.p). The results showed that the extract significantly decreased the elevated TNF-α level in serum ($P<0.001$). Also, they highlighted that the presence of flavonoids in the extract might be responsible for its anti-inflammatory activity. In addition, they evaluated the bioactive fraction (2.5% and 5%) of *P. marsupium* extract for its anti-inflammatory activity by measuring TNF-α and Interleukin-6 (IL-6) in diabetic rats for 45 days at 50, 100, and 200 mg/kg body weight. The study results demonstrated that the bioactive fraction at 5% in the dose of 200 mg/kg body weight showed significant anti-inflammatory activity by reducing oxidative stress, TNF-α, and IL-6 as inflammatory cytokines [35].

Rageeb *et al*., examined the methanol and aqueous extracts of *P.marsupium* stem bark for their anti-inflammatory activity at 100 mg/kg and compared them with Ibuprofen 60 mg/kg as a standard. Paw oedema was induced in albino rats by carrageenan. The results revealed that both extracts showed significant anti-inflammatory activity and outlined that the presence of flavonoids in the extracts could be responsible for their anti-inflammatory activity [61].

### *5.6. Memory enhancing activity*

Dementia is a syndrome usually characterized as a mental disorder that leads to deterioration in intellectual ability and involves impairment of memory. It is considered a major influencing factor in causing the specific brain disease known as Alzheimer's disease. Chauhan *et al.,* investigated the methanol extract of *P. marsupium* for its memory-enhancing activity in albino mice at 25 and 50 mg/kg p.o by elevated plus-maze and Morris water maze tests. In the elevated plus-maze model, administration of the extract significantly increased the inflexion ratio and reduced the transfer latency, whereas in the Morris water maze model, it enhanced the impairment in learning and memory. The study outlined that the extract showed memory-enhancing potential by facilitation of cholinergic transmission [62].

Vangalapati *et al*., assessed the memory-enhancing activity of the aqueous extract of *P.marsupium* heartwood on diabetic rats at 250 mg/kg and 500 mg/kg b. w. based on the Morris water maze. Diabetes was induced by intraperitoneal injection of Streptozotocin (STZ) and Nicotinamide (NA). The investigational results revealed that the extract showed beneficial learning and memory effects in diabetic rats [63].

### *5.7. Hepatoprotective activity*

Mankani and team investigated $CCl_4$-induced hepatotoxicity in rats with methanol and aqueous extracts of *P. marsupium* stem bark as hepatoprotective agents at 25 mg/kg/day based on its liver function biochemical parameters such as total bilirubin, serum protein, alanine aminotransaminase, aspartate aminotransaminase, alkaline phosphatase activities, and histopathological studies of the liver, and compared with standard silymarin at 100 mg/kg/day for 14 days. The study results revealed that both extracts restored the liver function biochemical parameters and showed normal hepatic cords, absence of necrosis, and lesser fatty infiltration. However, among these two extracts, the methanol extract showed more potent activity than the aqueous extract. In addition, they concluded that the presence of a higher content of flavonoids could be responsible for its hepatoprotective activity [23].

Saidurrahman and team evaluated the hepatoprotective effect of ethanol leaf extract of *P. marsupium* against paracetamol-induced liver damage in rats at 200 mg/kg/day and 400 mg/kg/day by measuring various biochemical markers such as AST, ALT, ALP, total cholesterol, bilirubin, and liver weight. The study results were compared with 100 mg silymarin/kg/day as a standard. The study results demonstrated that the extract showed potent hepatoprotective activity by inhibiting oxidative stress and altering the biochemical markers [64].

Devipriya *et al.,* conducted a study on the hepatoprotective activity of the *P.marsupium* extracts at 100 mg/kg orally against the $CCl_4$-induced hepatotoxicity model and measured various marker enzymes like ALT, AST, ALP, lactate dehydrogenase (LDH), and bilirubin. The study results revealed that the extract significantly increased the marker enzyme levels in the $CCl_4$-induced hepatotoxicity model [65].

Gupta and team examined the hepatoprotective activity in streptozotocin-induced diabetic rats at 100 and 300 mg/per/kg-b.wt for 21 days and assessed hepatic LPO, glutathione (GSH), superoxide dismutase (SOD), serum AST, ALT, and creatinine as hepatoprotective parameters. The study determined that the plant extract reduced hepatic LPO, increased GSH, SOD, AST, ALT, and creatinine content, and concluded that the extract showed a hepatoprotective effect in diabetic rats [66].

Jadhav and Dhikale developed a polyherbal formulation comprising the extracts of *Bauhinia variegate, Pterocarpus marsupium*, and *Oxalis corniculate.* Subsequently, they investigated its hepatoprotective activity in $CCl_4$ induced hepatotoxicity in female Albino Wistar strain rats for 4 days. Changes in the histopathology of the liver and quantification of SGOT, SGPT, alkaline phosphatase (ALP), and serum bilirubin were considered as hepatoprotective assessment parameters and compared with marketed

tablets Liv-52 as a standard. The study determined that the polyherbal formulation was a hepatoprotective agent by increasing SGOT, SGPT, ALP, and serum bilirubin and also showed less hepatocyte cell damage [67].

### *5.8. Anthelmintic activity*

Helminthic diseases are worm infections caused by parasitic worms. Panda *et al.,* performed an investigation of various extracts such as ethanol, ethyl acetate, n-butanol, and petroleum ether of leaves of *P. marsupium* at 20, 40, and 60 mg/mL and determined the paralysis and death time in Indian earthworms Pheretimepasthuma as the test worm and compared it with albendazole 10 mg/mL as the standard. The study determined that petroleum ether, ethanol, and the standard showed paralysis in 7.14, 8.41, and 6.33 min respectively; death in 15.33, 16.17, and 14.27 min respectively. The strategic and hypothesized study concluded that the extracts petroleum ether and ethanol showed substantial dose-dependent and significant anthelmintic activity which was comparable with the standard [68].

### *5.9. Antihyperlipidemic activity*

Many natural herbs and shrubs, including *P.marsupium* extracts, are continuously screened for their potential hypolipidemic effect or antihyperlipidemic activity. Singh *et al.,* carried out an extensive study by the combination therapy with the methanol extract of *O. sanctum* leaves and *P. marsupium* heartwood against the non-diabetic and oxidative stressed alloxan-induced diabetic rats for 15 days and measured serum triglycerides, VLDL, HDL, and hepatic cholesterol as parameters for lipidemic activity. Wistar female rats were given a dosage of 500 mg/kg (combination therapy) and revealed that *P. marsupium* heartwood exhibited a potential anti-lipidemic effect by maintaining the serum triglycerides, VLDL, HDL, and hepatic cholesterol. The study results concluded that the combination of these two extracts showed the greatest lipid-lowering potential, which can be used as corrective measures on the metabolic machinery responsible for diabetic dyslipidemia [40]. Jahromi and Ray investigated the antilipidemic effect of ethyl acetate from the heartwood of *P. marsupium* in diet-induced and Triton-induced hyperlipidemic model rats for 14 days at 75 mg/kg/b.w and measured lipidemic parameters such as serum triglyceride, total cholesterol, and LDL and VLDL cholesterol levels. The study results revealed that the extract reduced all lipidemic parameters significantly in both animal models [69]. Mohire performed a comparative study between the aqueous extract of the heartwood of *P. marsupium* at 0.25, 0.5, 1, 2, and 4 mg/mL and digitoxin at 0.25, 0.5, and 1.0 mg/mL for its cardiotonic effect in an isolated heart perfusion

technique. The study results showed that at a low concentration (0.25 mg/mL), there was an increase in the height of force of contraction and a decrease in heart rate, whereas at higher concentrations, a significant increase in the height of force of contraction and a decrease in heart rate were observed. Also, they concluded that the extract showed a narrow therapeutic window, very good cardiotonic activity, and a wide margin of safety [70].

### *5.10. Neuroprotective activity*

A study performed by Gunasekaran *et al*., observed the neuroprotective effect of an aqueous extract of *P. marsupium* at 100 mg and 200 mg/day on the pain threshold response in streptozotocin-induced diabetic neuropathic pain for 8 weeks. At the end of 8 weeks, a formalin-evoked pain model was followed, and parameters such as TNF-α, IL-1β, IL-6, and pain threshold response were measured. The study results demonstrated that the extract significantly prevented the increase in TNF-α, IL-1β, and IL-6 levels and significantly increased the pain threshold response. Further, they highlighted that the extract showed a neuroprotective effect due to its anti-inflammatory and neuroregeneration mechanisms in STZ-induced neuropathic pain [71].

### *5.11. Nephroprotective activity*

Gupta *et al*., examined the alcoholic extract of *P. marsupium* heartwood at (100, 200, and 400 mg/kg) for its nephroprotective activity in diabetic nephropathy rats. Various parameters such as kidney weight, serum creatinine, blood urea nitrogen, serum uric acid, urea, urine volume, urine albumin, oxidative stress markers such as lipid peroxidation, catalase, superoxide dismutase, and creatinine clearance were estimated during the study. The study results concluded that at a higher dose, the extract showed a significant reduction in kidney weight, serum creatinine, blood urea nitrogen, uric acid, and total protein, remarkably decreased urine volume and urine protein, and increased urine creatinine and creatinine clearance; whereas it significantly increased SOD, GSH, and catalase. The histopathological results confirmed that the extract prevented kidney damage. They also concluded that the extract showed dose-dependent nephroprotective activity [72].

## 6. Conclusion

In recent years, ethnomedicinal studies have received much attention as they bring light to the numerous little-known and unknown medicinal virtues, especially of plant origin. *P. marsupium* can aid as an

effective remedy for the detrimental effects posed by the synthetic derivatives and drugs prevalent in this modern age. Various investigational studies have been carried out to shed light on the recent progress of the plant's bioactive phytochemicals and diverse pharmacological effects. The presence of bioactive phytoconstituents in the extracts of *P. marsupium* is very well scrutinized and documented by various researchers; however, there is very little clear information about its phytoconstituents and their related pharmacological activities. Our present review summarized its high biomedical activities such as antioxidant, antidiabetic, antimicrobial, anticancer, anti-inflammatory, memory-enhancing activity, hepatoprotective, anthelmintic, antihyperlipidemic, neuroprotective, and nephroprotective activities. Various pharmacological screenings of *P. marsupium* revealed its therapeutic potential and represent that it is a valuable pharmaceutical plant with several medicinal properties. As pharmacologists are looking forward to developing new drugs from natural sources, the development of modern drugs from *P. marsupium* can be emphasized for the control of various diseases. In the near future, further investigational studies are needed to isolate and characterize the bioactive compounds as lead molecules in the drug discovery research process. Also, a systematic research and development effort should be undertaken for the conservation of *P. marsupium* and the development of products for their better economic and therapeutic utilization.

## Statements and Declarations

### *Data Availability*

Not applicable.

### *Author Contributions*

A. Umamaheswari, M. Vijayalakshmi, N. Tamilselvan, S. Sowntharya, R. Thirumurugan, and S. Lakshmana Prabu contributed equally to this work. Correspondence and requests should be addressed to Dr. S. Lakshmana Prabu.

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