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A Review on Pongamia pinnata (Karanj): A Multipurpose Sustainable Tree for Medicinal and Environmental Applications

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Abstract: The traditional medicinal system includes numerous plants with significant therapeutic and pharmacological properties, serving as a valuable source of novel bioactive compounds. Among these, Pongamia pinnata (Linn.) Pierre, commonly known as 'Karanj', is widely distributed across the world. It has been acknowledged in various traditional medicinal systems for its effectiveness in treating a range of human ailments. The plant primarily contains flavonoids and fixed oils as its major phytoconstituents. Traditionally, different parts of *Pongamia pinnata* have been used to manage several conditions such as bronchitis, whooping cough, rheumatism, diarrhea, dyspepsia, flatulence, gonorrhea, and leprosy. Over the past few decades, extensive research has been conducted on this plant, highlighting its medicinal significance. Moreover, the oil extracted from *Pongamia pinnata* serves as a potential source of biodiesel, offering a renewable, eco-friendly, and non-toxic alternative to conventional fuels. This review aims to provide updated and comprehensive insights into the phytochemical composition, pharmacological properties, traditional uses, and biofuel potential of *Pongamia pinnata*.

Key words: Pongamia pinnata, Karanj, Biofuel, Medicinal plant, Sustainability, Environmental protection.

INTRODUCTION:

Traditional medicines play an essential role in addressing global health challenges. Medicinal plants remain a vital source of therapeutic compounds used in both modern and traditional healthcare systems [1]. Due to the side effects often associated with modern pharmaceuticals, traditional remedies are gaining renewed interest, with researchers working to uncover the scientific foundations of their healing properties [2]. The growing body of research on medicinal plants has facilitated valuable information exchange, promoting their scientific validation and reducing reliance on synthetic drugs [3].

Pongamia pinnata (Linn.) Pierre is a medium-sized, glabrous tree commonly referred to as Karanja in Hindi, Indian Beech in English, and Pongam in Tamil [4]. In traditional Indian medicinal systems such as Ayurveda and Siddha, particularly in Tamil Nadu, this plant is extensively used to manage various ailments, including diabetes mellitus [5]. Native to the Western Ghats, Pongamia pinnata predominantly thrives in the tidal forests of India [4]. Also known as Derris indica, it is a monotypic species that grows abundantly along riverbanks and coastal areas in Myanmar and other parts of South Asia.

The tree holds great importance due to its diverse applications and its potential as a sustainable biodiesel source [6]. The seeds of P. pinnata yield approximately 28–34% oil, rich in polyunsaturated fatty acids [7]. Traditionally, various parts of the plant have been used in folk medicine systems such as Ayurveda and Siddha for treating tumors, piles, skin disorders, abscesses, rheumatism, wounds, ulcers, and diarrhea [8,9]. Apart from its medicinal significance, the plant also serves as animal fodder, green manure, timber, and fish poison, and is known for its insecticidal and nematicidal properties. Furthermore, recent studies have highlighted the biomedical potential of P. pinnata, particularly its antimicrobial and therapeutic activities [10]. continue to provide valuable therapeutic agents, both in modern and in traditional medicine [1]. With the associated side effects of the modern medicine, traditional medicines are gaining importance and are now being studied to find the scientific basis of their therapeutic actions [2]. Research work on medicinal plants has intensified and information on these plants has been exchanged. This research will go a long way in the scientific exploration of medicinal plants for the benefit of man and is likely to decrease the dependence on synthetic drugs [3]. Pongamia pinnata (Linn.) Pierre is a medium sized glabrous tree popularly known as Karanja in Hindi,

Indian Beech in English and Pongam in Tamil [4]. Most of the Tamil Nadu physicians of Indian system of traditional medicine Ayurveda and Siddha use Pongamia pinnata to treat various kinds of diseases including diabetes mellitus [5]. It is a medicinal plant native to Western Ghats and chiefly found in tidal forests of India [4].

Pongamia pinnata also called as Derris indica, is a monotypic genus and grows abundantly along the coasts and riverbanks in Myanmar. The tree is known for its multipurpose benefits and as a potential source of biodiesel [6]. The seeds are reported to contain on an average about 28– 34% oil with high percentage of polyunsaturated fatty acids [7]. Historically, Pongamia has been used as folk medicinal plant, particularly in Ayurvedha and Siddha systems of Indian medicine [8]. All parts of the plant have been used as a crude drug for the treatment of tumours, piles, skin diseases, itches, abscess, painful rheumatic joints wounds, ulcers, diarrhea etc [8, 9]. Besides, it is well known for its application as animal fodder, green manure, timber and fish poison. It has also been recognized to possess applications in agriculture and environmental management, with insecticidal and nematicidal activity. More recently, the effectiveness of P. pinnata as a source of biomedicines has been reported [10], specifically as antimicrobial and therapeutic age.

TAXONOMY:

The plant *Millettia pinnata* (L.) Panigrahi, commonly referred to as the **Pongame Oil Tree**, is classified under the following taxonomic hierarchy:

- **Kingdom:** Plantae
- **Subkingdom:** Tracheobionta
- **Superdivision:** Spermatophyta
- **Division:** Magnoliophyta
- **Class:** Magnoliopsida
- **Subclass:** Rosidae
- **Order:** Fabales
- **Family:** Fabaceae
- **Genus:** *Millettia* Wight & Arn.
- **Species:** *Millettia pinnata* (L.) Panigrah

GEOGRAPHICAL DISTRIBUTION:

Pongamia pinnata is extensively distributed across tropical regions of Asia, including the Seychelles Islands, Southeast Asia, Australia, and India. Within India, it is locally found throughout the State of Maharashtra, particularly along riverbanks, and is highly common in coastal and tidal forests of the Konkan region as well as along rivers in the Deccan plateau [12]. Its adaptability to diverse climatic and soil conditions contributes to its wide natural occurrence across tropical ecosystems.

CHEMICAL CONSTITUENTS:

Sl No.	Plant Parts	Extraction Solvent	Active Constituents	Activity
1.	Leaf 	Petroleum ether Chloroform Ethyl acetate Methanol Water Ethanol (70%) Hydro alcohol (70%) Acetone	Alkaloids Flavones & flavonoids Glycosides & cardiac glycosides Saponins Carbohydrates Tannins Triterpenoids Steroids Phytosterols Proteins Amino acids Phenolic compounds Sterols Karanjin	Antibacterial [38], Antidiabetic[39], Anti-oxidant [40], Anti-viral[41], Anti-plasmodial[42], Anti-inflammatory[43], Anti-ulcer[44], Anticonvulsant [45] Antihyperammonemic effect [46] & Anti-lice[47] Antinociceptive & antipyretic[48] and Wound healing activities[49]
2.	Root 	Methanol Petroleum ether Dichloromethane Ethyl acetate	Fixed oils Flavonoids & flavones Chalcones β-diketone Karanjin Ponganones Ovilitin B	Anti-ulcer activity[50] Anti-oxidant & Anti-microbial[51]
3.	Bark/Stem 	Petroleum ether Ethanol Aqueous Methanol	Alkaloids, Glycosides, Flavonoids, Tannins, Phenolic compounds, Steroids, Triterpenes, Terpenoids, Volatile oils Carbohydrates	Anti-microbial[52] Cardio protectivity[53] Anti-convulsant[54] Anti-inflammatory and analgesic[55] Anti diabetic[56]
4.	Flower 	Acetone Petroleum ether	Flavonoids Fixed oils	Antibacterial activity[57] Anti-hyperglycaemic & Anti-lipid peroxidative[58] Activity
5.	Fruit 	Hexane Chloroform Water Butanol	Tannins Alkaloids Quercetin Saponin β sitosterol Guggulipid Pinnatin Kanugin Kanjone Kangugin Karanjin Pongamol Pongamin	Anti-dyslipidemia & Antioxidant[59] Anti-hyperglycemic[60] activity
6.	Seed 	Acetone Chloroform Ethanol Methanol Petroleum Ether Aqueous-methanol	Alkaloids Terpenoids Glycosides Flavonoids Saponins Sterols Steroids Phenols	Anti-Microbial[61] Anti-Inflammatory[62] Anti-Gastro duodenal ulcer[63] Anti-oxident[64] Anti-Arthritic[65]

PHYTOCHEMISTRY:

Phytochemical analyses of *Pongamia pinnata* have revealed a rich presence of prenylated flavonoids, including furanoflavones, furanoflavonols, chromenoflavones, furanochalcones, and pyranochalcones [13, 14–16]. Yin et al. [17] successfully isolated two phenylated flavonoid derivatives from the stem bark of the plant — pongaflavanol (1) and tunicatachalcone (2). Among these, pongaflavanol was identified as a novel compound, and its structure was determined through spectroscopic data analysis. It represents the first naturally occurring prenylated flavan-4-ol featuring a modified ring A structure. Meanwhile, tunicatachalcone was also reported for the first time from *Pongamia pinnata* [17]. The molecular structures of these compounds are depicted in Figure 1 [17].

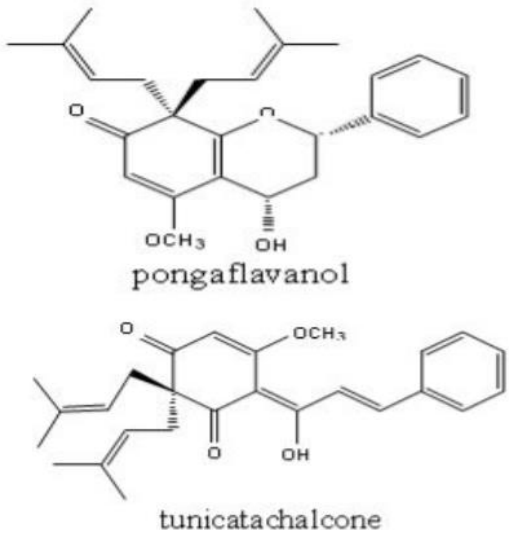


Figure 1. Structures of Pongaflavone and Tunicatachalcone

Yadav et al. [18] reported the isolation of four new furanoflavonoids, named pongapinnol A–D, along with a novel coumestan, pongacoumestan, and thirteen known compounds from the fruits of Pongamia pinnata. The structures of these compounds were determined through detailed spectroscopic analyses [18].

Similarly, Li et al. [19] isolated five structurally unique flavonoids, designated pongamones A–E, together with 16 known flavonoid metabolites from the stem of Pongamia pinnata. Their structural elucidation was carried out using spectroscopic methods and by comparing the spectral data with previously reported related compounds [19].

The seed oil of Pongamia pinnata contains karanjin, a bioactive molecule with significant biological activity [20]. Vismaya et al. [20] developed an efficient method for the recovery of karanjin, which involved liquid–liquid extraction with methanol, followed by chromatography on alumina and crystallization. The purified karanjin achieved a yield of 20% with >95% purity, confirmed by HPLC, and its structure was elucidated through MS and NMR spectroscopy [20].

From the seeds of Pongamia pinnata, six compounds (including two sterols, three sterol derivatives, and one disaccharide) along with eight fatty acids (three saturated and five unsaturated) have been isolated. Structural identification was performed using physicochemical and spectroscopic techniques. Notably, beta-sitosteryl acetate, galactoside, stigma sterol, its galactoside, and sucrose were reported for the first time in this plant. Among the fatty acids, oleic acid was the most abundant (44.24%), followed by stearic acid (29.64%) and palmitic acid (18.58%), while hiragonic and octadecatrienoic acids were present in trace amounts (0.88%).

Additional phytochemicals isolated from seeds include karangin, pongamol, pongagalabrone, pongapin, pinnatin, and kanjone, while immature seeds contain a flavone derivative called pongol. Other flavonoids identified in seeds include glybanchalcone and isopongachromene. The leaves and stems of the plant are rich in flavone and chalcone derivatives such as pongone, galbone, pongalabol, pongagallone A and B [21]. The structures of karangin, isopongachromene, glybanchalcone, and pongol are presented in Figure 2.

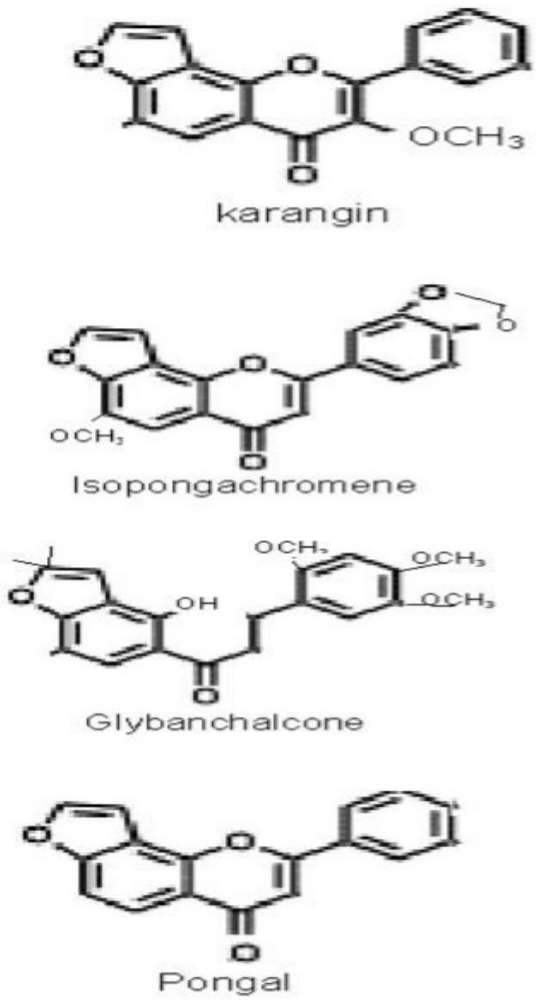


Figure 2. Structures of phytoconstituents isolated from the seeds of *Pongamia pinnata*

BIOLOGICAL AND PHARMACOLOGICAL ACTIVITIES

Over the past several years, *Pongamia pinnata* has attracted considerable attention from researchers due to its wide-ranging therapeutic potential. Numerous pharmacological investigations have been conducted to explore its biological activities. A concise summary of the findings from these studies is presented below, highlighting the diverse medicinal properties of the plant.

ANTIHYPERGLYCEMIC AND ANTILIPIDPEROXIDATIVE EFFECTS

Punitha and Manohar [22] investigated the antihyperglycemic and antilipidperoxidative activities of the ethanolic extract of *Pongamia pinnata* flowers in alloxan-induced diabetic rats. Diabetic rats exhibited hyperglycemia, increased lipid peroxidation (measured as TBARS), and disturbed enzymatic and non-enzymatic antioxidant systems (Vitamin C, Vitamin E, and glutathione). Oral administration of the ethanolic extract at 300 mg/kg body weight significantly reduced blood glucose levels and lipid peroxidation, while enhancing antioxidant defense. No significant changes were observed in normal rats treated with the extract. Notably, the antihyperglycemic effect was comparable to that of glibenclamide (600 mg/kg bw), suggesting that *Pongamia pinnata* may serve as a safe alternative antihyperglycemic agent, likely due to its synergistic bioactive antidiabetic compounds [22].

INFLUENCE ON CIRCADIAN VARIATION OF LIPID PEROXIDATION AND ANTIOXIDANTS

Essa and Subramanian [23] evaluated the effects of *Pongamia pinnata* on lipid peroxidation and antioxidant systems in hyperammonemic rats, considering circadian variations. They analyzed 24-hour rhythms of TBARS, reduced glutathione (GSH), glutathione peroxidase (GPx), superoxide dismutase (SOD), and catalase (CAT). Hyperammonemic rats showed elevated lipid peroxidation (increased TBARS mesor) and decreased antioxidant activities. Treatment with *Pongamia pinnata* modulated these alterations, highlighting its potential role in managing oxidative stress under pathological conditions. The study concluded that understanding circadian rhythms in normal and diseased states can enhance therapeutic strategies [23].

ANTIHYPERAMMONEMIC EFFECT

Essa et al. [24] examined the protective effect of leaf extract of *Pongamia pinnata* on blood ammonia and urea levels in ammonium chloride-induced hyperammonemic rats. Hyperammonemia is associated with oxidative stress, and ammonium salts exacerbate this condition. Administration of the leaf extract significantly reduced blood ammonia, urea, uric acid, non-protein nitrogen, and creatinine levels, without affecting body weight. The antihyperammonemic activity was attributed to nephroprotective effects, antioxidant activity, and free radical scavenging properties. Flavonoids present in the plant, such as kaempferol, quercetin, karanjin, kanjone, pongaglabrone, gammatin, pongaglabol, and kanugin, are likely responsible for these effects [24–27].

ANTIFUNGAL AND ANTIBACTERIAL ACTIVITY

Wagh et al. [28] evaluated the antimicrobial activity of *Pongamia pinnata* oil against Aspergillus niger, A. fumigatus, Staphylococcus aureus, and Pseudomonas aeruginosa using MIC determination and the dry-weight method. Gas chromatography (GC) and GC-MS analysis confirmed the presence of fatty acids. The study suggested that the fatty oil of Pongamia pinnata has potential as a plant-derived antimicrobial agent [28].

ANTI-INFLAMMATORY ACTIVITY

Singh and Pandey [29] investigated the anti-inflammatory potential of various root extracts of *Pongamia pinnata*. All root extracts showed significant activity in carrageenan- and PGE1-induced edema models, comparable to phenylbutazone. The mechanism was primarily attributed to prostaglandin inhibition, especially in ethanolic and acetate extracts. Butanol extracts were effective in carrageenan-induced but not in PGE1-induced edema. Petroleum ether seed extracts exhibited potent acute anti-inflammatory effects, whereas aqueous suspensions demonstrated pro-inflammatory activity. Maximum effects were observed in bradykinin-induced edema, possibly due to inhibition of prostaglandin synthesis and reduced capillary permeability. Both petroleum ether and aqueous extracts inhibited histamine- and 5-hydroxytryptamine-induced inflammation, likely through lipophilic constituents acting in early inflammation stages. However, none of the extracts showed efficacy in Freund's adjuvant-induced arthritis, indicating limited utility in rheumatoid arthritis [29].

ANTI-INFLAMMATORY ACTIVITY

Singh and Pandey [29] evaluated the anti-inflammatory potential of various root extracts of *Pongamia pinnata*. All root extracts demonstrated significant anti-inflammatory activity, comparable to phenylbutazone, in carrageenan- and PGE1-induced edema models. The observed effects were mainly attributed to prostaglandin inhibition, particularly by the ethanolic and acetate extracts. The butanol extract was effective in the carrageenan model but showed no activity in the PGE1-induced model, indicating that the anti-inflammatory activity primarily resides in intermediate polar constituents, rather than in highly lipophilic or extremely polar fractions.

In addition, petroleum ether seed extracts exhibited potent acute anti-inflammatory effects, while aqueous suspensions showed pro-inflammatory activity. Maximum anti-inflammatory activity was observed in bradykinin-induced edema, likely due to prostaglandin synthesis inhibition and reduced capillary permeability. Both petroleum ether and aqueous extracts also inhibited histamine- and 5-hydroxytryptamine-induced inflammation, suggesting that lipophilic constituents may act during the early stages of inflammation. However, none of the extracts showed efficacy in the Freund's adjuvant-induced arthritis model, indicating limited utility in rheumatoid arthritis [29].

ANTIVIRAL ACTIVITY

White Spot Syndrome Virus (WSSV) is a highly virulent and contagious pathogen responsible for white spot syndrome in shrimp, leading to significant mortality in most commercially important cultured marine crustaceans worldwide [30]. Rameshthangam and Ramasamy [30] evaluated the antiviral potential of bis(2-methylheptyl) phthalate, isolated from *Pongamia pinnata* leaves, against WSSV in Penaeus monodon. Oral administration of the ethanolic leaf extract and the purified compound significantly increased survival of WSSV-infected shrimp. Shrimp were fed pelletized feed containing 200 and 300 µg extract/g body weight/day before and after infection, resulting in survival rates of 40% and 80%, respectively, demonstrating the effectiveness of *P. pinnata* in enhancing resistance against WSSV [30].

ANTIFILARIAL POTENTIAL

Uddin et al. [31] investigated the antifilarial activity of fruit and leaf extracts of *Pongamia pinnata* against the cattle filarial parasite Setaria cervi. Both aqueous and alcohol extracts of fruits and alcohol extracts of leaves inhibited spontaneous movements of the whole worm and nerve-muscle preparations. The minimum concentrations required to inhibit whole worm movement were 250 µg/mL (aqueous fruit extract), 120 µg/mL (alcohol fruit extract), and 270 µg/mL (alcohol leaf extract). Equivalent inhibition in the nerve-muscle preparation was achieved at 25 µg/mL, 5 µg/mL, and 20 µg/mL, respectively, suggesting the presence of a cuticular permeability barrier [31].

ACTION AGAINST INFECTIOUS DIARRHEA

Diarrhea, primarily caused by gastrointestinal infections, is responsible for approximately 1.8 million deaths annually, mostly in children from developing countries [32]. The main cause of mortality is dehydration resulting from electrolyte loss [33]. Traditionally, the leaves of *Pongamia pinnata* (syn. *P. glabra* Vent.) have been used as a remedy for diarrhea [34]. Shoba and Thomas [35] reported that *P. pinnata* effectively controlled castor oil-induced diarrhea. While medicinal plants have been studied for their effects on intestinal motility and antibacterial activity, there is limited information regarding their action on diarrheal pathogenicity, including colonization of intestinal epithelial cells and enterotoxin activity. Brijesh et al. [33] evaluated the crude decoction of dried leaves of *Pongamia pinnata* for its effects on these mechanisms, supporting its traditional use as an antidiarrheal agent.

ANTIMICROBIAL ACTIVITY

The crude decoction of *Pongamia pinnata* has been evaluated for its effects on bacterial, giardial, and rotaviral infections, as well as on enterotoxin production (cholera toxin, CT; *Escherichia coli* labile toxin, LT; and *E. coli* stable toxin, ST), adherence of enteropathogenic *E. coli*, and invasion by enteroinvasive *E. coli* and *Shigella flexneri* to epithelial cells [33]. While the decoction did not exhibit direct antibacterial, antigiardial, or antirotaviral activity, it was found to reduce cholera toxin production and inhibit bacterial invasion of epithelial cells. These results suggest that *P. pinnata* exerts a selective antidiarrheal effect, particularly against cholera and enteroinvasive bacterial strains, likely via antimotility, antisecretory, and antimicrobial mechanisms [33].

NOOTROPIC ACTIVITY

Singh et al. [36] reported that various seed extracts of *Pongamia pinnata* reduced pentobarbitone-induced sleeping time in rats, likely through stimulation of the hepatic microsomal enzyme system. Further studies on root extracts revealed that the petroleum ether extract (PEE) prolonged pentobarbitone sleeping time, possibly due to CNS depression [37]. Additionally, PEE of seeds showed nootropic effects in an Alzheimer's disease model induced by ibotenic acid lesions of the basal magnocellular nucleus, reversing both cognitive deficits and cholinergic dysfunction, suggesting modulation of cholinergic pathways as the mechanism [38].

ANTINOCICEPTIVE ACTIVITY

Srinivasan et al. [39] examined the analgesic activity of various root extracts of *Pongamia pinnata*. The PEE, n-butanol extract (BE), and ethanol extract (EE) demonstrated significant analgesic effects in the tail-flick test. Additionally, PEE and EE of seeds exhibited notable analgesic activity at doses above 100 mg/kg [39]

PROTECTIVE EFFECT AGAINST NEPHROTOXICITY

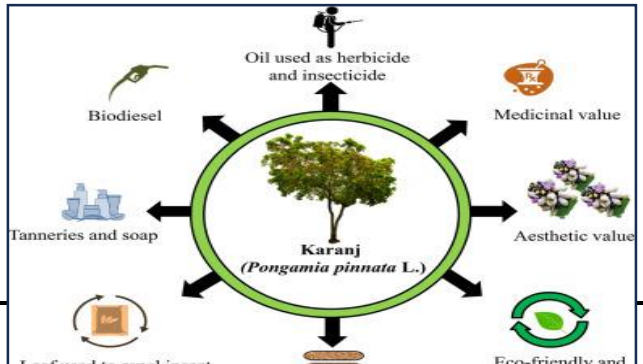
Shirwaikar et al. [40] studied the protective effects of ethanolic flower extract of *Pongamia pinnata* against cisplatin- and gentamicin-induced renal injury in rats. Oral administration of the extract at 300 and 600 mg/kg for 10 days following cisplatin treatment (5 mg/kg, i.p.) conferred significant nephroprotection, attributed to the antioxidant properties of the extract [40].

ULCEROPROTECTIVE ACTIVITY

The aqueous extract of *Pongamia pinnata* roots significantly reduced gastric juice volume, acid output, and peptic activity in acetylsalicylic acid-induced ulcers, without affecting mucin activity. Methanolic root extracts enhanced mucosal defenses by increasing mucin secretion, mucosal cell lifespan, glycoprotein content, cell proliferation, and preventing lipid peroxidation, while altering hexose and fructose levels. These effects contribute to the ulceroprotective activity of the plant [41, 42].

TRADITIONAL USES OF *PONGAMIA PINNATA*

Pongamia pinnata has been widely used in traditional medicine across India. Its seed oil is applied for itching, abscesses, and skin disorders [28]. Flowers are used for glycosuria and diabetes management [4], while bark treats bleeding piles, beriberi, diabetes, and possesses antimicrobial activity [43–45]. The seeds have antiviral activity against herpes simplex virus types 1 and 2, and exhibit hypoglycemic, antioxidant, anti-ulcer, anti-inflammatory, and analgesic properties [20]. Other therapeutic applications include treatment for bronchitis, whooping cough, rheumatic pain, diabetes-related thirst, and digestive or skin ailments. Leaves serve as digestive aids, laxatives, anthelmintics, and are used for wounds, piles, and rheumatic pain. Root and bark extracts aid in gum and tooth cleaning, ulcers, and bleeding piles. Powdered seeds are used as a febrifuge, tonic, and remedy for bronchitis and whooping cough, while flowers are prescribed for diabetes, and bark for beriberi [27, 43, 46, 47].



ROLE OF *PONGAMIA PINNATA* IN THE BIOFUEL INDUSTRY

The mature seeds of *Pongamia pinnata* (karanja) have recently attracted significant commercial attention due to their high oil content, making them a promising alternative source of fuel and energy [48]. The oil of karanja is rich in furan flavones, including karanjin, pongapin, kanjone, and the diketone pongamol. While traditionally the plant has been used to treat scabies, leprosy, piles, ulcers, chronic fever, and liver disorders, its oil is now increasingly recognized for its biofuel potential. Notably, karanjin exhibits anti-scabies and anti-leprotic activity [48].

Oil-yielding plants play a crucial role in economic growth, particularly in the energy and agricultural sectors. Seeds containing polyunsaturated fatty acids are considered excellent sources of biodiesel [49, 50]. Compared to conventional diesel, these organic seed oils offer superior physico-chemical properties and biodegradability [51]. Among such species, *Pongamia pinnata* stands out as a dual-purpose crop for biodiesel and biomedicine, though further research is needed to maximize its potential.

To enhance oil yield, selecting elite genotypes is critical. Candidate Plus Trees (CPTs) are individual *P. pinnata* trees exhibiting superior morphological traits, such as girth, height, leaf number, flower and seed production, compared to other individuals of the species [52].

Kesari et al. [53] analyzed seed oil from an elite genotype of *P. pinnata*, reporting the highest oil yield of 33% using n-hexane extraction. Gas chromatography–mass spectrometry (GC–MS) analysis showed that oleic acid (46%) predominated among mono-unsaturated fatty acids, while polyunsaturated fatty acids comprised 33% of the oil. The seed oil also demonstrated concentration-dependent antimicrobial activity against tested fungal and bacterial strains. These findings validate the use of well-characterized elite genotypes of *P. pinnata* for biodiesel production and pharmaceutical applications [53].

With the growing global concern over declining fossil fuel reserves, biofuels are expected to play a pivotal role in meeting domestic and commercial energy demands. *Pongamia pinnata* contributes significantly by providing oil that can be converted to biodiesel, which is environmentally friendly, greenhouse gas neutral, and reduces diesel engine emissions [54–56]. The seeds contain 30–40% oil, which can be transesterified with methanol in the presence of KOH to produce fatty acid methyl esters (FAMEs). The oil composition is mainly oleic acid (C18:1; 45–55%), with notable amounts of palmitic acid (C16:0; 5–15%), stearic acid (C18:0; 5–10%), and linoleic acid (C18:2; 15–20%), along with trace amounts of arachidic (C20:0), eicosanoic (C20:1), behenic (C22:0), and lignoceric (C24:0) acids [57].

CONCLUSION

An extensive review of the literature highlights that *Pongamia pinnata* L. is a valuable medicinal plant with a broad spectrum of pharmacological activities. The plant contains numerous bioactive chemical constituents responsible for its diverse therapeutic properties. In addition to its medicinal significance, *P. pinnata* plays a crucial role in the biofuel industry, emerging as one of the most promising oil-yielding crops for sustainable energy production. Despite the progress made, further scientific investigations and clinical evaluations are required to uncover its full potential and translate its traditional and pharmacological uses into practical applications for the betterment of human health.

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