

A REVIEW ON NEPHROPROTECTIVE AND ANTIOXIDANT ACTIVITY OF *SPONDIAS PINNATA* EXTRACT IN ANIMAL MODELS

Devdatta Singh^{1*}, K. Saravanan¹

1. Faculty of Pharmacy, Bhagwant University Sikar Road, Ajmer, Rajasthan-305023

Abstract

In India, *Spondias pinnata* grows in eastern Uttar Pradesh, Belgaum, Chikmagalur, Coorg, Hassan, Mysore, and Nasik, Pune, Raigad, Ratnagiri, and Thane. The plant has been utilized extensively in numerous traditional herbal remedies all over the world. Antimicrobial, antidiabetic, ulcer-protective, anticancer, antidiarrheal, anthelmintic, and hepatoprotective properties are reported to be present. There have also been reports of the plant's various parts being utilized as antitubercular, anti-emetic, and anti-thirst agents. Nevertheless, there is a lack of scientific research on the nephroprotective properties and acute toxicity of various leaf and bark extracts. As a result, an effort has been undertaken to investigate these pharmacological effects and identify the many phytoconstituent groups found throughout the entire plant. Methanolic, aqueous, and petroleum ether fractions will be extracted from the plant. The various extracts will be examined for cytotoxic and nephroprotective properties. The extracts will undergo preliminary phytochemical analyses to detect the presence of several phytoconstituents, which will then be isolated and characterized.

Keywords: *Spondias pinnata*, *Nephroprotective*, *hepatoprotective*, *phytoconstituents* *ulcer-protective*, *anti-cancerous* and *herbal medicines*.

Corresponding Author

Devdatta Singh

Bhagwant University Sikar Road, Ajmer, Rajasthan

Received: 26/02/2026

Revised: 07/03/2026

Accepted: 14/03/2026

DOI: <http://doi.org/10.66204/GJPSR.419-2026-2-3-5>

Copyright Information

© 2026 The Authors. This article is published by Global Journal of Pharmaceutical and Scientific Research

How to Cite

Singh D, Saravanan K. A review on nephroprotective and antioxidant activity of *Spondias pinnata* extract in animal models. *Global Journal of Pharmaceutical and Scientific Research*. 2026;2(3):419-436. ISSN: 3108-0103. <http://doi.org/10.66204/GJPSR.419-2026-2-3-5>

1. Introduction

Numerous chronic illnesses, such as diabetes, hypertension, and nephrotoxicity brought on by medications or environmental pollutants, are significantly accelerated by oxidative stress and renal failure. Because of their cytoprotective, anti-inflammatory, and antioxidant qualities, natural products and plant-based treatments have drawn a lot of interest as possible nephroprotective agents. Novel insights for the prevention and treatment of kidney-related illnesses can be obtained by researching medicinal plants that are highly prized in traditional medicine.

Often referred to as hog plum or wild mango, *Spondias pinnata* (L.f.) Kurz is a significant medicinal tree in the Anacardiaceae family. Ayurveda and other traditional medical systems have made considerable use of *S. pinnata*, which is widely dispersed throughout India, Sri Lanka, Malaysia, the Philippines, and other tropical and subtropical countries (Soumyanath, 2018). The plant's versatility and persistence are demonstrated by its capacity to flourish in a variety of environmental settings, including lush forests and arid plains.

The bark, leaves, fruits, and roots of *S. pinnata* have all historically been used to treat infectious, inflammatory, and digestive disorders (Swathi & Lakshman, 2022). Numerous bioactive substances, including flavonoids, tannins, phenolic acids, saponins, terpenes, β -sitosterol, gallic acid, caffeic acid, and essential oils including α -pinene, caryophyllene, and geraniol, have been discovered by phytochemical research (Ndukwe et al., 2007; Oryema et al., 2011). The antioxidant, anti-inflammatory, antibacterial, and cytoprotective qualities of these components are widely recognized.

While *S. pinnata*'s pharmacological effects have been extensively researched, its nephroprotective potential and antioxidant activity in animal models have received less attention. Because excessive reactive oxygen species (ROS) can harm renal tissues and impede proper kidney function, oxidative stress and kidney injury are intimately related. Therefore, it is essential to investigate the nephroprotective benefits of *S. pinnata* extracts and comprehend their processes through antioxidant pathways in order to validate traditional uses and uncover potential therapeutic applications.

The goal of this review is to compile the most recent information on *S. pinnata* extracts' nephroprotective and antioxidant qualities in animal models. Additionally, it highlights the phytoconstituents that are in charge of these actions, the experimental strategies employed in preclinical investigations, and the potential clinical applications and future research prospects. This review aims to provide a thorough understanding of *S. pinnata* as a possible

nephroprotective agent by connecting traditional knowledge with contemporary scientific evidence.

1.1 *Spondias pinnata* (L.f.) Kurz (Anacardiaceae)

Vernacular Names

There are several colloquial names for *Spondias pinnata* in different parts of the world. It is known as Kincam and Pulima in Tamil and as Wild Mango, Andaman Mombin, Indian Hog Plum, or Indian Mombin in English. It is referred to as Ambatte, Amate, Poondi, or Tindeeka in Kannada and Ambara, Ambari, Amra, Bhringi-phal, Metula, Pashu-haritaki, and Pitan in Hindi. It is called Heining in Manipuri, Amaro in Nepali, and Adavimamidi in Telugu. The plant is known as Ampazham in Malayalam, Aamrata in Assamese, and Khursongthei in Tangkhul.

Taxonomy

There are about eighteen species in the genus *Spondias* L., and they are found in many tropical and subtropical areas of the Americas, Madagascar, Asia, and the South West Pacific (Airy Shaw & Forman, 1967; Mabberley, 2017). In addition to being potential decorative plants and wild relatives of cultivated crops, species in this genus have a variety of functions, such as food, medicine, and economic resources (Chandra & Mukherjee, 2000; POWO, 2024). *S. pinnata*, the only species of the genus found in India, grows in deciduous woods at elevations of up to 1650 meters above sea level. The species is found in many parts of China, Malaysia, and the Indian subcontinent.

Description

The fragrant, deciduous *Spondias pinnata* tree can reach a height of 15 meters. Its smooth bark peels in layers of papery material, and its branchlets are glabrous. The imparipinnate, alternating leaves have nine to eleven leaflets and are around thirty centimeters long. The terminal leaflets are obovate, measuring 9–10 × 4–6 cm, cuneate at the base with complete margins, and abruptly acuminate to cuspidate at the apex; all leaflets are glabrous and glaucous beneath. The lateral leaflets are oblong, measuring 5–9.5 × 3–4 cm. There are perhaps 20 pairs of penninerved lateral nerves with noticeable intramarginal veins. Petiolules are around 4 mm in size, while petioles are about 7 cm long. Inflorescences are panicles approximately 25 cm long that are found in terminal axils. They have pedicels that are about 2 mm long and peduncles that are 7.5 cm long. The flowers are pale pink, polygamodioecious, and about 4 mm in diameter. The petals are five oval, 2.5 × 1.8 mm, yellow-pink, with acute apices, while the calyx has five free, ovate-triangular lobes

measuring 1.5×1 mm. Ten stamens with filaments about two millimeters long are positioned beneath a crenate disc. The ovary measures 3×2 mm in size and has a 5-fid style at the 2 mm-long tip. Fruits are oblong-obovoid, drupes, and roughly 1.5×1 cm in size (Figure 1).

Taxonomy (as per APG IV)

Kingdom : Plantae

Clade : Tracheophytes

Clade : Angiosperms

Clade : Eudicots

Clade : Rosids

Order : Sapindales

Family : Anacardiaceae

Subfamily : Spondiadoideae

Genus : *Spondias* L.

Species : *S. pinnata* (L.f.) Kurz



Figure 1. Plant Reference Picture of *Spondias pinnata*

Ethnopharmacology

Individuals in the genus *Spondias* Many conditions, such as stomachaches, diarrhea, diabetes, dementia, anemia, dysentery, and other infections, are treated with *Spondias* in traditional medicine. With significant ethnopharmacological uses in digestive, ophthalmic, cutaneous, and musculoskeletal health, *Spondias pinnata* is a highly prized medicinal plant that is widely utilized in many cultures (Bora et al., 2014). In digestive care, powdered and dried leaves are

commonly employed to manage gastroenteritis, diarrhea, and dysentery, while infusions made from the stem and bark are also used for these ailments. Leaf extracts are used to treat various digestive issues, while fresh leaves eaten with raw sweet candies are used to alleviate acid reflux. In Bangladesh, the fruits are eaten to improve vision and prevent eye infections, while in India, pulverized ripening fruits are used as an antidote against poison arrows. *S. pinnata* fruit paste is applied topically to treat lesions, ulcers, and sores; bark paste is used to treat rheumatism and sprains; and its decoction is used to cure gonorrhea. Fresh leaf decoctions are used to treat skin conditions in places like Nigeria and Belize, while leaf concoctions help with constipation and diarrhea (Sameh et al., 2019). The bark is also used as a rubefacient for sore joints, and root bark solutions are employed to treat gonorrhea and regulate the menstrual cycle. The plant's anti-scorbutic qualities highlight its importance in conventional medicine.

Regarding other species in the genus, fresh *S. purpurea* leaf infusions are used in Mexico to alleviate flatulence and stomachaches, while leaf decoctions are used to treat skin infections, anemia, diarrhea, and dysentery. *S. mombin* leaves are used to treat diarrhea and dysentery in Belize and to enhance memory in Nigeria, Benin, and Togo. The aqueous extract of *S. mombin* leaves is widely used as an abortifacient in Brazil. The leaves are used by traditional healers in Southwest Nigeria to treat diabetes mellitus. These leaves also have significant antiviral and antibacterial properties.

1.2. Phytochemical Constituents

With about 348 kcal per 100 grams, *Spondias pinnata* is a significant source of energy. It also contains a number of phenolic compounds, natural antioxidants, and vital minerals. It is also a significant source of calcium, phosphorus, ascorbic acid, and malic acid. Alkaloids, saponins, tannins, flavonoids, gums, and terpenoids have all been found through phytochemical screening. Gallic acid, salicylic acid, chlorogenic acid, ellagic acid, p-coumaric acid, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid, quercetin, catechin, myricetin, rutin, vitamin E, furfural, phytosterols like campesterol, and different fatty acids are among the specific bioactive substances found in the plant. With a total phenolic and flavonoid concentration equal to gallic acid and quercetin, the leaves in particular are abundant in flavonoids and tannins. Kaempferol has antibacterial and anticancer properties, rutin fortifies blood vessels and enhances vascular integrity, and quercetin regulates inflammatory pathways and prevents lipid peroxidation (Hazra et al., 2008).

The bark and leaves are rich in tannins, such as gallotannins and ellagitannins, which have potent astringent qualities that aid in wound healing and have antibacterial action. By lowering intestinal inflammation, these substances also help treat diarrhea and dysentery. Important antioxidants found in the bark and fruits include phenolic acids including gallic acid, ellagic acid, and caffeic acid. Ellagic acid prevents the growth of cancer cells, gallic acid exhibits anti-inflammatory, antibacterial, and anticancer actions, and caffeic acid, which is primarily found in leaves, has antioxidant and anti-inflammatory qualities that help prevent chronic illnesses.

Volatile compounds like limonene, α -pinene, and β -caryophyllene are found in essential oils that are extracted from the leaves, bark, and fruits. These compounds have been shown to have antimicrobial, anti-inflammatory, and analgesic properties, making them potential therapeutic agents for the management of pain and inflammation (Bora et al., 2014; Li et al., 2020). Furthermore, the plant's various pharmacological effects, such as antidiabetic, analgesic, antibacterial, and anticancer properties, are attributed to bioactive compounds such as steroids, triterpenoids, saponins, alkaloids, amino acids (glycine, cysteine, serine, alanine, leucine), sitosterol, and β -amyirin (Santos et al., 2023). The plant's capacity to fight oxidative stress, a major factor linked to chronic illnesses including cancer, atherosclerosis, diabetes, and neurological conditions like Alzheimer's and Parkinson's disease, is further strengthened by natural antioxidants like vitamins E and C (Laksemi, 2019).

Table 1: Phytochemical Constituents of *S. pinnata* and Their Activities

Phytoconstituent	Plant Part	Observed Activity	Mechanism / Notes
Gallic acid	Bark, fruit	Antioxidant, anticancer	Induces apoptosis, free radical scavenger
Methyl gallate	Bark	Anticancer, hepatoprotective	Iron chelation, oxidative stress modulation
Quercetin	Leaves	Anti-inflammatory, antioxidant	Inhibits lipid peroxidation, modulates inflammatory pathways
Tannins	Bark, leaves	Antimicrobial, antidiarrhoeal	Astringent properties, reduces intestinal inflammation

α -Pinene, β -Caryophyllene	Leaves, fruits, bark (essential oil)	Antimicrobial, anti-inflammatory	Modulates COX-2, inhibits microbial growth
--	--------------------------------------	----------------------------------	--

1.3. Pharmacological Effects

Different reported pharmacological activities of the genus *Spondias* are detailed below.

Cytotoxic Activity

Numerous research have demonstrated the cytotoxic potential of *Spondias pinnata*, one of the many pharmacological properties exhibited by the genus *Spondias*. According to Ghate et al. (2013), the methanolic extract of *S. pinnata* bark caused apoptosis in human lung adenocarcinoma (A549) and human breast cancer (MCF-7) cell lines, demonstrating considerable cytotoxicity. In their study, A549 cells were seeded at a density of 5×10^4 cells/well, while MCF-7 cells were seeded at 1×10^4 cells/well in a 96-well culture plate and allowed to settle for 2 hours. The methanolic extract was then applied to the cells for 48 hours at doses ranging from 0 to 200 $\mu\text{g/ml}$. With IC₅₀ values of 147.84 $\mu\text{g/ml}$ and 149.34 $\mu\text{g/ml}$, respectively, the 70% methanolic extract inhibited the proliferation of A549 and MCF-7 cells in a dose-dependent manner. Using a microplate ELISA reader, formazan absorbance at 460 nm was used to measure cell viability and proliferation. An increase in the Bax/Bcl-2 ratio was proposed as the mechanism of apoptosis induction. This would activate the caspase cascade, which would then cleave poly(ADP-ribose) polymerase (Ghate et al., 2014).

Chaudhuri et al. (2015) conducted additional research to assess the cytotoxic capability of chemicals extracted from *S. pinnata* bark's ethyl acetate fraction against the human glioblastoma cell line (U87). U87 cells (1×10^2 cells/well) were exposed to isolated compounds at doses of 1–30 $\mu\text{g/ml}$ for 48 hours using the WST-1 in vitro cytotoxicity test. With IC₅₀ values of 59.28 $\mu\text{g/ml}$ and 8.44 $\mu\text{g/ml}$, respectively, gallic acid and methyl gallate showed potential cytotoxic effects. Additionally, it has been documented that gallic acid causes promyelocytic leukemia HL-60RG cells to die (Inoue et al., 1994). Furthermore, via altering the activity of CD4⁺CD25⁺ regulatory T (Treg) cells, methyl gallate has demonstrated anticancer effects in murine tumor models. Methyl gallate decreased Treg cell migration and inhibited effector T-cell inhibitory activity in vitro. In tumor-bearing animals, methyl gallate therapy slowed tumor growth and increased survival via affecting tumor-infiltrating Treg cells (Heekyung et al., 2010).

Together, these results demonstrate the strong cytotoxic qualities of *S. pinnata* bark and its bioactive constituents, bolstering its traditional therapeutic usage and laying the groundwork for more pharmacological research.

Antioxidant Activity

It is generally known that *Spondias* species have antioxidant potential, especially in fruit and bark extracts. The 70% methanolic extract of *S. mangifera* bark is a powerful source of antioxidants, as shown by Hazra et al. (2008). The extract's capacity to scavenge the ABTS radical cation was used to measure the overall antioxidant activity in vitro. The decolorization of the ABTS cation, which was detected spectrophotometrically at 734 nm, was used to quantify the antioxidant capacity of the 70% methanolic extract using trolox as the standard. The extract's trolox equivalent antioxidant value of 0.78 demonstrated a strong capacity to scavenge radicals. The better antioxidant capacity of the plant extract was demonstrated by the fact that, at a concentration of 5 µg/ml, the methanolic fruit extract showed 16% radical scavenging activity while vitamin C only showed 5% activity.

Subsequent research by Arif et al. (2016) found significant concentrations of phenolics, flavonoids, and acid glycosides, such as propan-1,2-dioic acid-3-carboxyl-β-D-glucopyranosyl-(6'→1'')-β-D-glucofuranoside, in the ethanolic extract of *S. mangifera* fruits. The antioxidant properties of the ethanolic extract and extracted acid glycoside were evaluated in both in vitro and in vivo models of anoxia-stress tolerance, swimming endurance, and immunosuppression produced by cyclophosphamide. When compared to the usual medication Geriforte, the extracts' antioxidant activity showed either similar or improved efficacy. All of these results point to *Spondias* extracts as abundant natural antioxidant sources that can reduce oxidative stress, a major factor linked to a number of chronic and degenerative disorders.

Hepatoprotective Activity

Rats inebriated with CCl₄ show a significant in vivo hepatoprotective effect from the ethyl acetate and methanolic extracts of *Spondias pinnata* stem heartwood. The results showed a dose-dependent protective efficacy when the extracts were given orally at doses of 100, 200, and 400 mg/kg. Serum liver indicators, such as aspartate aminotransferase (AST) and alanine aminotransferase (ALT), significantly decreased as a result, returning to nearly normal levels that were equivalent to those of the common hepatoprotective medication silymarin. The

presence of flavonoids, which are well-known for their antioxidant, anti-inflammatory, and free radical scavenging qualities, has been substantially responsible for the hepatoprotective impact seen in these investigations. Effective defense against CCl₄-induced hepatotoxicity was demonstrated by histopathological analysis of the liver in treated rats, which showed preservation of normal hepatic architecture with no cellular degeneration or necrosis (Rao & Raju, 2010).

The impact of *S. pinnata* stem bark methanolic extract on iron-induced liver injury in rats was assessed by Hazra et al. (2013). Iron overload from intraperitoneal iron dextran injection led to oxidative stress, liver damage, and a marked increase in serum hepatic markers such as bilirubin, ALT, AST, and alkaline phosphatase (ALP). The activity of endogenous antioxidant enzymes, such as glutathione peroxidase (GPx), catalase (CAT), and superoxide dismutase (SOD), was markedly boosted by treatment with the methanolic extract at doses of 50, 100, and 200 mg/kg. The main causes of hepatic fibrosis and cellular damage, lipid peroxidation and protein oxidation, were also inhibited in a dose-dependent manner. Additionally, the extract decreased serum ferritin levels, indicating that it may be used as an iron-chelating agent to treat iron excess and associated oxidative stress (Hazra et al., 2013).

The hepatoprotective effect of the methanolic bark extract against iron-induced liver fibrosis and hepatocellular damage was further investigated by Chaudhuri et al. (2016). Iron and hydrogen peroxide react in iron-overloaded livers to produce extremely reactive hydroxyl radicals, which spread oxidative stress caused by free radicals. Gallic acid and methyl gallate, two bioactive substances, were separated from the extract's ethyl acetate fraction. According to in vivo research, methyl gallate demonstrated exceptional iron-chelation capabilities that successfully reduced oxidative stress, stopped lipid peroxidation, and restored normal liver histology. Although to a lesser degree, gallic acid also aided in hepatoprotection. These findings are consistent with those of Nabavi et al. (2013), who found that gallic acid at doses of 10 and 20 mg/kg reduced oxidative stress and liver damage caused by sodium fluoride, with effects similar to those of silymarin (10 mg/kg).

Together, these studies indicate that *S. pinnata*'s hepatoprotective effect is mediated by a variety of mechanisms, such as chelation of excess iron, scavenging of free radicals, inhibition of lipid peroxidation, enhancement of endogenous antioxidant defenses, and preservation of hepatic cellular integrity. *S. pinnata* is a prospective option for the development of new hepatoprotective medicines because of the presence of flavonoids, gallic

acid, and methyl gallate, which are essential in reducing oxidative stress-induced hepatotoxicity.

Anti-inflammatory Activity

Spondias pinnata exhibits notable anti-inflammatory characteristics, underscoring its potential as a medicinal treatment for conditions associated with inflammation. Nitric oxide (NO), a crucial signaling molecule implicated in the inflammatory response, has been demonstrated to be inhibited in RAW 264.7 macrophage cell lines by the essential oil extracted from the fruit peel (EOSP) without affecting cell survival or proliferation. This implies that the extract does not have lethal effects while modulating inflammatory pathways. The bioactive components of *S. pinnata*, like as tannins, flavonoids, and essential oils, are mostly responsible for its anti-inflammatory properties. These chemicals work together to block pro-inflammatory enzymes like inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2). Additionally, these substances prevent pro-inflammatory cytokines from being released, which lowers the inflammatory response as a whole. *S. pinnata* is widely used in traditional medicine to treat ailments including arthritis, edema, and other inflammatory disorders because numerous *in vitro* and *in vivo* investigations have confirmed its effectiveness in reducing inflammation (Mondal et al., 2021).

Antimicrobial Activity

Spondias pinnata is a useful plant for treating bacterial and fungal diseases because of its potent antibacterial qualities. According to studies, the plant's methanolic extracts exhibit strong bactericidal action against pathogenic bacteria like *Salmonella typhi*, *Vibrio cholerae*, and *Escherichia coli*. The bioactive chemicals responsible for the antibacterial action are more effectively extracted in organic solvents, as evidenced by the mild antimicrobial activities of aqueous extracts against the same infections. Although they are less effective against Gram-negative bacteria and the yeast *Saccharomyces cerevisiae*, the resin exudates of *S. pinnata* also exhibit antibacterial activity, particularly against *Bacillus subtilis*. Furthermore, root extracts made with ethyl alcohol and chloroform show strong antibacterial action, particularly against *Vibrio cholerae* and *Salmonella typhi* (Li et al., 2020; Jain et al., 2013). *S. pinnata*'s rich phytochemical composition, which includes tannins, flavonoids, phenolic acids, and essential oils, is responsible for its antimicrobial potential. These compounds disrupt microbial cell walls, inhibit enzyme activity, and obstruct microbial replication. This provides a scientific foundation for the plant's traditional use in the treatment of infections.

Antidiabetic Activity

The substantial antidiabetic potential of *Spondias pinnata* has been shown by research, underscoring its importance in the treatment of hyperglycemia and associated metabolic disorders. Within four days, a methanolic extract of *S. pinnata* given at a concentration of 400 mg/kg dramatically lowered blood glucose levels in non-diabetic Wistar rats, exhibiting an effect similar to that of glibenclamide, a common antidiabetic medication. In a similar vein, within 4 hours of ingestion, the aqueous extract at the same dose significantly lowered glucose levels. The trichloromethane extract, on the other hand, showed no discernible hypoglycemia impact, suggesting that the active antidiabetic chemicals are more soluble in polar solvents. Additionally, both the methanolic and aqueous extracts successfully reduced blood glucose levels within an hour during glucose tolerance tests, but the chloroform extract had no discernible impact (Mondal et al., 2021). *S. pinnata*'s rich phytochemical makeup, which includes flavonoids, phenolic acids, tannins, and terpenoids, is probably responsible for its antidiabetic action. These compounds may improve insulin sensitivity, regulate the metabolism of carbohydrates, and lessen oxidative stress linked to hyperglycemia.

Anticancer Activity

The substantial anticancer potential of *Spondias pinnata*, especially its bark and trunk, which show noteworthy anticarcinogenic properties, has been highlighted in recent studies. The cytotoxic activity of a 70% methanolic extract of *S. pinnata* bark was assessed using human lung cancer (A549) and breast adenocarcinoma (MCF-7) cell lines (Chaudhuri et al., 2015). With IC₅₀ values of 147.84 ± 3.74 µg/mL for A549 cells and 149.34 ± 13.30 µg/mL for MCF-7 cells, the extract showed a remarkable ability to induce apoptosis in these malignant cells. The extract demonstrated preferential cytotoxicity towards cancer cells, as evidenced by its significantly higher IC₅₀ value of 932.38 ± 84.44 µg/mL against normal human lung fibroblast cells (WI-38). The extract caused apoptosis by modifying pro-apoptotic and anti-apoptotic pathways, such as the upregulation of the Bax/Bcl-2 ratio, the activation of caspase cascades, and the subsequent cleavage of poly (ADP-ribose) polymerase, according to mechanistic investigations using flow cytometry and confocal microscopy (Ghate et al., 2014). These results imply that *S. pinnata* bark contains bioactive substances that can specifically target cancer cells, making it a viable option for more research and development as a natural anticancer drug.

Table 2: Pharmacological Activities of *Spondias pinnata* Extracts

Plant Part	Type of Extract	Animal/Cell Model	Dose/Concentration	Observed Activity
Bark	Methanolic	A549 (lung cancer), MCF-7 (breast cancer) cell lines	0–200 µg/mL	Cytotoxic, induces apoptosis
Stem Heartwood	Ethyl acetate & Methanolic	CCl4-induced rats	100–400 mg/kg, p.o.	Hepatoprotective, reduced ALT & AST
Bark	Methanolic	Iron-induced liver injury in mice	50–200 mg/kg	Antioxidant, reduced lipid peroxidation
Fruit Peel	Essential oil	RAW 264.7 macrophages	–	Anti-inflammatory, inhibits NO production
Leaves	Aqueous	Wistar rats	400 mg/kg	Antidiabetic, lowers blood glucose
Bark	Methanolic	WI-38 (normal) & A549, MCF-7 (cancer)	–	Selective cytotoxicity to cancer cells

2. Toxicity

The plant extracts are generally safe at moderate doses, according to toxicological analyses of *Spondias* species, especially *S. mombin* leaves. In mice and rats, oral administration of aqueous, methanolic, and ethanolic leaf extracts at concentrations ≤ 5 g/kg did not result in any harmful effects (Jain et al., 2013). The aqueous extract was also non-toxic when administered intraperitoneally at levels of less than 200 mg/kg. Higher concentrations of ethanolic and methanolic extracts (>100 mg/kg), however, caused noticeable toxic effects.

When the extracts were injected intraperitoneally at a concentration of 3.2 g/kg, lethal effects were observed in mice and rats. According to Jain et al. (2013), the LD50 values in mice were 480 mg/kg for the ethanolic extract, 1.1 g/kg for the methanolic extract, and 1.36 g/kg for the aqueous extract. The LD50 values for the ethanolic extract, methanolic extract, and aqueous extract in rats were 620 mg/kg, 1.08 g/kg, and 1.42 g/kg, respectively (Ayoka et al., 2006). Over the course of a continuous 48-hour observation period, these conclusions were made.

The aqueous extract seems to be the safest of the investigated extracts based on these findings. Furthermore, the aqueous extract supported its ethnopharmacological application by

exhibiting a broad range of pharmacological actions in both in vitro and in vivo settings. The aqueous extract of *Spondias* species is a viable option for the creation of safe herbal medications due to its therapeutic efficiency and low toxicity.

3. Traditional Uses in Ayurveda

Because it may balance the three doshas—Pitta, Kapha, and Vata—*Spondias pinnata* is highly prized in Ayurveda. It is categorized as an astringent and cooling herb that has long been used to treat a variety of illnesses. The fruit and bark are frequently used to treat digestive issues such as indigestion, dysentery, and diarrhea (Sai et al., 2021). The astringent qualities of the tannins in the bark help thicken the intestinal lining and lessen inflammation, while the fruit functions as a digestive tonic, improving appetite and digestion. Using the plant's antibacterial and anti-inflammatory phytochemicals to aid in healing, the bark and leaves are applied topically to treat wounds, psoriasis, and eczema (Patathananone et al., 2019).

With essential oils and saponins helping to reduce inflammation and remove mucus from the respiratory system, the leaves and bark are also used to treat respiratory conditions like bronchitis, colds, and coughs. Furthermore, *S. pinnata* is used to treat rheumatic pain and arthritis because of its anti-inflammatory qualities; decoctions of the bark are frequently used to reduce joint pain and inflammation. Furthermore, the leaves and bark have analgesic and antipyretic properties that lower fever and ease discomfort. In traditional Ayurvedic medicine, the plant's therapeutic value is attributed to flavonoids, essential oils, and saponins.

4. Future Perspectives

Even though Ayurveda has long acknowledged *Spondias pinnata*'s many therapeutic benefits, more research is necessary to fully grasp the plant's therapeutic potential (Figure 2). Future studies should concentrate on the structural characterisation and isolation of novel bioactive compounds utilizing sophisticated analytical methods including nuclear magnetic resonance (NMR) spectroscopy, mass spectrometry (MS), and high-performance liquid chromatography (HPLC). Validating its traditional usage and finding novel therapeutic targets would require an understanding of the molecular mechanisms underlying its pharmacological activity, which include antioxidant, anti-inflammatory, nephroprotective, and anticancer properties.

Furthermore, research on *S. pinnata*'s genome and transcriptome may shed light on the biosynthesis of its bioactive metabolites, allowing for more precise manipulation and increased synthesis of pharmacologically significant substances. To assess safety, efficacy, and potential toxicity while figuring out the best dosage schedules, preclinical research

utilizing in vitro cell lines and in vivo models like zebrafish or rodents is required. Translating these discoveries into human applications will require clinical studies. Consistent treatment results will also be guaranteed by the creation of standardized formulations, improved extraction methods, and tactics to raise the bioavailability and stability of active ingredients. All things considered, there is great potential for using *S. pinnata* as a source of innovative and potent herbal remedies by combining traditional knowledge with contemporary pharmacological research.

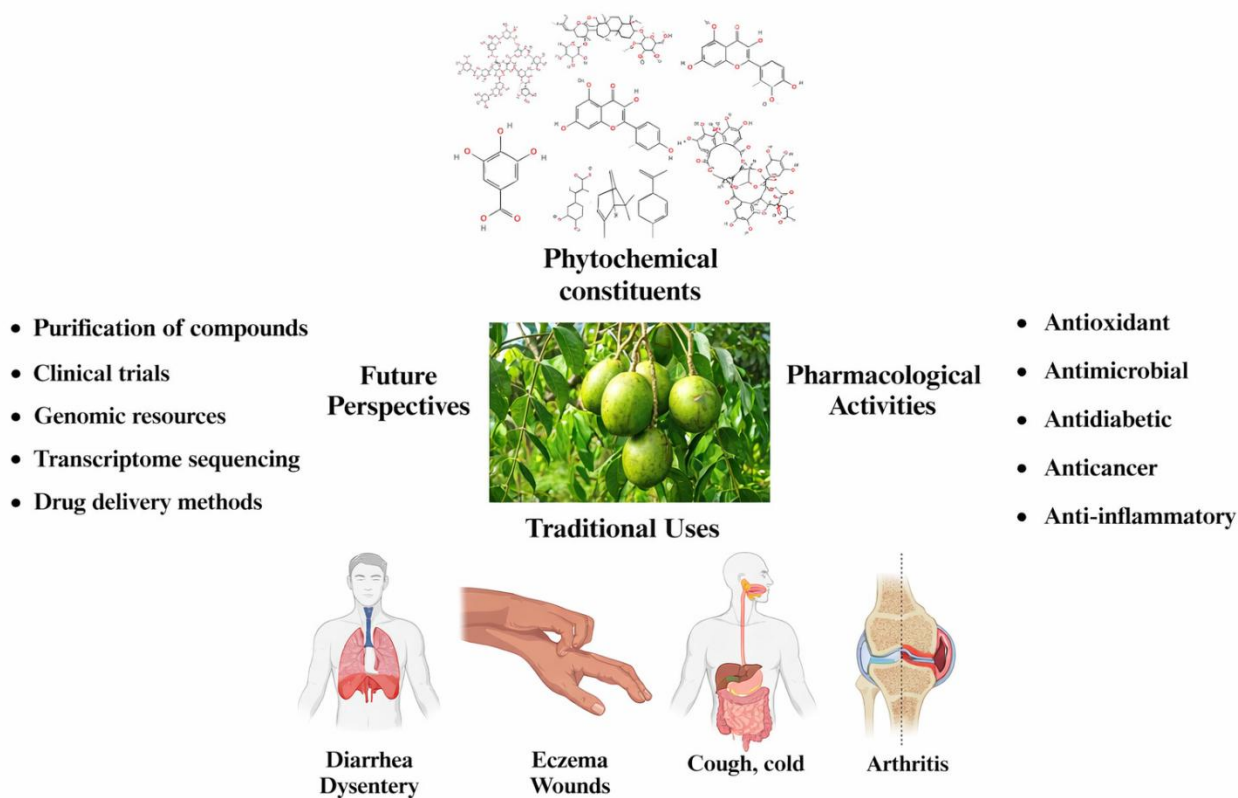


Figure 2. Applications and Significance of Spondias pinnata

5. Conclusion

Natural cures are becoming more and more popular worldwide, and herbal medications are becoming acknowledged as an alternative or supplement to pharmaceutical drugs. However, in order to confirm their pharmacological actions and guarantee safety, their extensive use requires thorough laboratory research. Oxidative stress is intimately linked to a number of degenerative diseases, including as cancer, diabetes, cardiovascular disease, and neurological ailments. This underscores the need for safe, readily available, and efficient antioxidants derived from natural sources. Because of its many bioactive phytoconstituents, including phenolics, flavonoids, tannins, and terpenoids, plants in the genus *Spondias*, especially

Spondias pinnata, have been widely utilized in traditional medicine. These substances have strong anti-inflammatory, nephroprotective, antibacterial, and antioxidant properties that provide protection against a range of chronic and degenerative illnesses.

This review provides a thorough grasp of *S. pinnata*'s bioactive components and pharmacological mechanisms by combining the most recent research on its phytochemistry and pharmacology. The plant is a viable option for the creation of novel medications or herbal formulations because of its diverse medicinal potential, which is supported by its rich phytochemical profile. *S. pinnata* can become a useful tool in current healthcare by bridging the gap between ethnomedicine and modern pharmacology through the integration of ancient Ayurvedic knowledge with contemporary scientific validation. To fully realize its benefits for human health and well-being, more study on its pharmacological activity, mechanisms of action, toxicological profile, and clinical efficacy will be essential.

6. Acknowledgement

The authors sincerely thank all researchers, institutions, and database providers whose work contributed to this bibliometric review. We also appreciate the guidance and support of colleagues during the preparation of this manuscript.

7. Conflict of Interest

The authors declare that they have no conflicts of interest.

8. Source of Funding

None.

9. References

1. Soumyanath, A. (2018). *Review of plants with anti-diabetes mellitus properties*. CRC Press.
2. Swathi, S. S., & Lakshman, K. L. (2022). Phytopharmacological and biological exertion of *Spondias pinnata*: A review. *Oriental Journal of Chemistry*.
3. Ndukwe, I. G., Bello, A. I., Habila, J. D., & John, C. (2007). Phytochemical and antimicrobial screening of the crude petroleum spirit and methanol extracts of the stem bark, leaves, and roots of *Ficus thoningii* (Blume). *African Journal of Biotechnology*, 6, 2645–2649.
4. Oryema, C., Ziraba, R. B., Odyek, O., Omagor, N., & Opio, A. (2011). Phytochemical properties and toxicity to brine shrimp of medicinal plants in Erute County, Lira District, Uganda. *Journal of Medicinal Plants Research*, 5, 5450–5457.

5. Airy Shaw, H. K., & Forman, L. L. (1967). The genus *Spondias* L. (Anacardiaceae) in tropical Asia. *Kew Bulletin*, 21, 1–19.
6. Chandra, D., & Mukherjee, S. K. (2000). Anacardiaceae. In N. P. Singh, J. N. Vohra, P. K. Hajra, & D. K. Singh (Eds.), *Flora of India* (pp. 435–510). Botanical Survey of India.
7. Mabberley, D. J. (2017). *Mabberley's plant-book: A portable dictionary of plants, their classification, and uses* (pp. 474–482). Cambridge University Press. <https://doi.org/10.1017/9781316335581>
8. POWO. (2024). *Plants of the World Online*. Royal Botanic Gardens, Kew. Retrieved August 29, 2024, from <https://powo.science.kew.org/>
9. Bora, N. S., Kakoti, B., Gogoi, B., & Goswami, A. K. (2014). Ethno-medicinal claims, phytochemistry, and pharmacology of *Spondias pinnata*: A review. *International Journal of Pharmaceutical Sciences and Research*, 5, 1138–1145.
10. Sameh, S., Al-Sayed, E., Labib, R. M., & Singab, A. N. B. (2019). Comparative metabolic profiling of essential oils from *Spondias pinnata* (Linn. F.) Kurz and characterization of their antibacterial activities. *Industrial Crops and Products*, 137, 468–474.
11. Hazra, B., Biswas, S., & Mandal, N. (2008). Antioxidant and free radical scavenging activity of *Spondias pinnata*. *BMC Complementary and Alternative Medicine*, 8, 63.
12. Li, R., Yang, J.-J., Song, X.-Z., Wang, Y.-F., Corlett, R. T., Xu, Y.-K., & Hu, H.-B. (2020). Chemical composition and the cytotoxic, antimicrobial, and anti-inflammatory activities of the fruit peel essential oil from *Spondias pinnata* (Anacardiaceae) in Xishuangbanna, Southwest China. *Molecules*, 25(2), 343.
13. Santos, É. M. D., Ataíde, J. A., Coco, J. C., Fava, A. L. M., Silvério, L. A. L., Sueiro, A. C., ... Mazzola, P. G. (2023). *Spondias* sp: Shedding light on its vast pharmaceutical potential. *Molecules*, 28(4), 1862.
14. Laksemi, D. A. A. S. (2019). Biological activity of *Spondias pinnata*: A review. *Indonesia Journal of Biomedical Science*, 13(2).
15. Ghate, N. B., Hazra, B., Sarkar, R., & Mandal, N. (2014). In vitro anticancer activity of *Spondias pinnata* bark on human lung and breast carcinoma. *Cytotechnology*, 66(2), 209–218.
16. Chaudhuri, D., Ghate, N. B., Singh, S. S., & Mandal, N. (2015). Methyl gallate isolated from *Spondias pinnata* exhibits anticancer activity against human

- glioblastoma by induction of apoptosis and sustained extracellular signal-regulated kinase 1/2 activation. *Pharmacognosy Magazine*, 11(42), 269–276.
17. Inoue, M., Suzuki, R., Koide, T., Sakaguchi, N., Ogihara, Y., & Yabu, Y. (1994). Antioxidant gallic acid induces apoptosis in HL-60RG cells. *Biochemical and Biophysical Research Communications*, 204(2), 898–904.
18. Heekyung, L., Hyojung, L., Youngjoo, K., et al. (2010). Methyl gallate exhibits potent antitumor activities by inhibiting tumor infiltration of CD4+CD25+ regulatory T cells. *The Journal of Immunology*, 185(11), 6698–6705.
19. Hazra, B., Biswas, S., & Mandal, N. (2008). Antioxidant and free radical scavenging activity of *Spondias pinnata*. *BMC Complementary and Alternative Medicine*, 8, 63.
20. Arif, M., Fareed, S., & Rahman, M. A. (2016). Stress relaxant and antioxidant activities of acid glycoside from *Spondias mangifera* fruit against physically and chemically challenged albino mice. *Journal of Pharmacy and Bioallied Sciences*, 8(1), 58–63.
21. Rao, B. G., & Raju, N. J. (2010). Investigation of hepatoprotective activity of *Spondias pinnata*. *International Journal of Pharma Sciences and Research*, 1(3), 193–198.
22. Hazra, B., Sarkar, R., & Mandal, N. (2013). *Spondias pinnata* stem bark extract lessens iron overloaded liver toxicity due to hemosiderosis in Swiss albino mice. *Annals of Hepatology*, 12(1), 123–129.
23. Chaudhuri, D., Ghate, N. B., Panja, S., & Mandal, N. (2016). Role of phenolics from *Spondias pinnata* bark in amelioration of iron overload-induced hepatic damage in Swiss albino mice. *BMC Pharmacology & Toxicology*, 17(1), 34.
24. Nabavi, S. F., Nabavi, S. M., Habtemariam, S., et al. (2013). Hepatoprotective effect of gallic acid isolated from *Peltiphyllum peltatum* against sodium fluoride-induced oxidative stress. *Industrial Crops and Products*, 44, 50–55.
25. Mondal, S., Bhar, K., Panigrahi, N., Mondal, P., Nayak, S., Barik, R. P., & Aravind, K. (2021). A tangy twist review on hog-plum: *Spondias pinnata* (L.f.) Kurz. *Journal of Natural Remedies*, 21(1), 1–25.
26. Chaudhuri, D., Ghate, N. B., Singh, S. S., & Mandal, N. (2015). Methyl gallate isolated from *Spondias pinnata* exhibits anticancer activity against human glioblastoma by induction of apoptosis and sustained extracellular signal-regulated kinase 1/2 activation. *Pharmacognosy Magazine*, 11(42), 269–276.

27. Ghate, N. B., Hazra, B., Sarkar, R., & Mandal, N. (2014). In vitro anticancer activity of *Spondias pinnata* bark on human lung and breast carcinoma. *Cytotechnology*, 66(2), 209–218.
28. Jain, P., Hossain, R. R., Mishu, T. R., & Reza, H. M. (2013). Antioxidant and antibacterial activities of *Spondias pinnata* Kurz leaves. *European Journal of Medicinal Plants*, 4(2), 183–195.
29. Ayoka, A. O., Akomolafe, R. O., Iwalewa, E. O., Akanmu, M. A., & Ukponmwan, O. E. (2006). Sedative, antiepileptic, and antipsychotic effects of *Spondias mombin* L. (Anacardiaceae) in mice and rats. *Journal of Ethnopharmacology*, 103(2), 166–175.
30. Sai, K., Chhetri, S. B. B., Devkota, S. R., & Khatri, D. (2021). Evaluation of the hypoglycemic potential of leaves extract of *Spondias pinnata* (L.f.) Kurz from Nepal. *Scientific World Journal*, 2021, 3230351.
31. Patathananone, S., Daduang, J., Koraneekij, A., & Li, C. (2019). Tyrosinase inhibitory effect, antioxidant, and anticancer activities of bioactive compounds in ripe hog plum (*Spondias pinnata*) fruit extracts. *Oriental Journal of Chemistry*, 35(3).

