IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals
ISSN 2349-7203
HUMAN

Human Journals
Review Article
June 2021 Vol.:21, Issue:3

A Comprehensive Review on Phytochemical Analysis and Biological Activities of *Adenanthera pavonina* L. and *Pongamia pinnata* (L.) Pierre

IJPPR
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Submitted: 25 May 2021
Accepted: 02 June 2021
Published: 30 June 2021

Keywords: *Adenanthera pavonina*, *Pongamia pinnata*, Phytoconstituents, Biological activities, Miscellaneous activities

ABSTRACT

Adenanthera pavonina L. and *Pongamia pinnata* (L.) Pierre are two massive medium sized deciduous trees belonging to the Leguminosae family. They are commonly used as herbal drugs for the treatment of various diseases. Extracts procured from each part of these plants are traditionally claimed to be used for the healing of broad spectrum of illnesses due to the presence of phytoconstituents such as flavonoids, terpenes, tannins and alkaloids. Accordingly, a sizable number of studies are carried out on the basis of the specialties of each part. It includes both the isolation of phytoconstituents as well as the identification of various biological activities such as anti-inflammatory, anticancer, antidiabetic etc. This study provides a comprehensive review on phytochemistry, pharmacological activities, biological activities, medicinal uses together with its role in the biofuel industry. Results suggests that *Pongamia pinnata* is rather more explored than that of *Adenanthera pavonina* which leads to the gaps that can be further investigated with future intervention.

INTRODUCTION

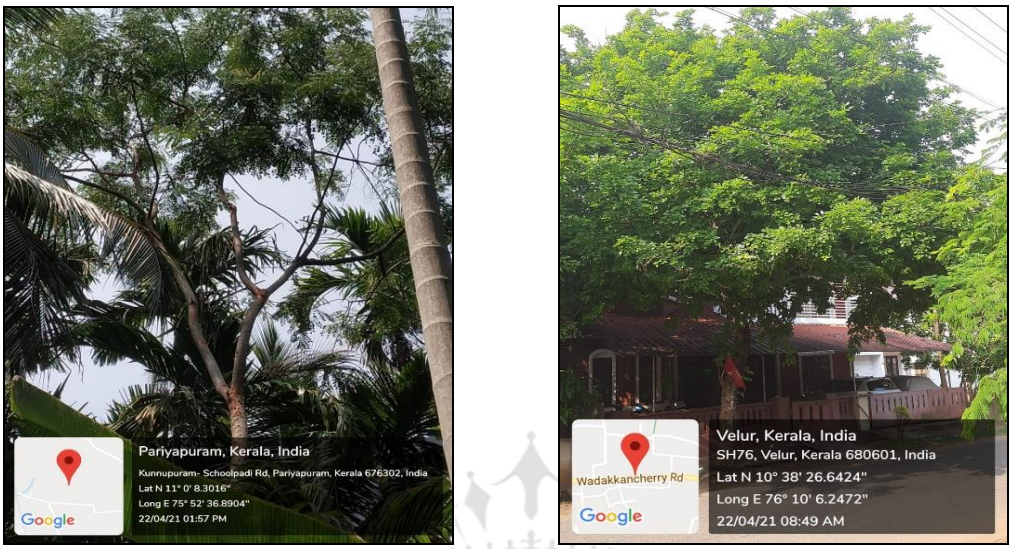
Medicinal plants have been in use from ancient times onwards. Before the introduction of chemical medicines, people relied on the healing properties of plants. Throughout the past, people accustomed to believe that plants were created to provide food for man, treatment and different effects[1]. Plants have exhibited therapeutic properties that assisted people in many ways that are utilized in several conditions to reinforce and maintain human health.

Adenanthera pavonina L. and *Pongamia pinnata* (L.) Pierre belongs to the sub-family Mimosaceae and Papilonaceae respectively within the Leguminosae family was selected for the study. *A.pavonina* is extensively cultivated as a valuable utile agroforestry species that as a shelterbelt, a supply of fodder, manure, construction, flooring, paving blocks and vehicle bodies[2]. *A.pavonina* is employed in ancient Indian drugs, where crushed seeds were accustomed to treat boils and inflammations. It's empirical use for polygenic disorder, lipoid disorders, diarrhea, ulcers, abdomen injury, hematuria, rheumatism, asthma, cardiovascular disease, pneumonic infections and cancer. Flowers of *P.pinnata* are utilized by gardeners as compost, build twine or rope, to treat wounds. Pongame oil has been used as lamp oil, in soap production and as a lubricant, employed as a lotion for rheumatism. Leaves are active against Micrococcus; their juice is employed for colds, coughs, diarrhea, dyspepsia, flatulence, gonorrhea, and infectious disease. Roots are used for improvement gums, teeth, and ulcers. Bark is employed internally for injury piles. Juices from the plant, still because the oil, are antiseptic. Within the ancient system of medicines, like Ayurveda and Unani, the *P.pinnata* plant is employed for medication, anti-plasmodial, antinociceptive, antihyperglycemic, medication, antiulcer, anti-hyperammonic and inhibitor activity[3].

On reviewing these papers on the above categories, it was more convincing to carry out the comparative study between both these plants. Owing to the aforesaid reasons, the objective was to prepare a comprehensive comparative review study on the Phytochemicals and Biological activities of *Adenanthera pavonina* and *P.pinnata* (Figure 1).

METHODOLOGY

The method of collection and assortment was preferentially relying upon the NCBI — Pubmed. The principal objective on the collection was to obtain open access to the papers with all the profounding information related with *Adenanthera pavonina* and *P.pinnata.* The gathered papers are from a timeline of 2000 to the at present. The full-text abstracts were used for the study.



Adenanthera pavonina ***Pongamia pinnata***

Figure No. 1: Habit

RESULTS AND DISCUSSION

1. Phytochemical analysis

Leaves of *Adenanthera pavonina*, *Moringa oleifera* and *Annona squamosa* are used in traditional Thai medicine to treat dysentery and other diseases. This study investigated the antibacterial activity of these plants against six species of foodborne pathogen. *A.pavonina* contained flavonoids, terpines and tannins, and was the most active extract against *Campylobacter jejuni*, inhibiting growth at 62.5–125 µg mL−1. The data presented here show that *A.pavonina* and *A.squamosa* could potentially be used in modern applications aimed at the treatment or prevention of foodborne diseases[4]. A decoction prepared with barks of *Adenanthera pavonina* and *Thespesia populnea* is an herbal formulation which has been prescribed in Sri Lanka in the treatment of cancer

patients for many years. The total phenolics and flavonoids were determined using Folin–Ciocalteau and aluminum chloride colorimetric methods, respectively[5] (Table 1).

Chromatographic separation of a 70% aqueous methanol extract of *P.pinnata* leaves led to the isolation of two isoflavonoid diglycosides and a new rotenoid along with nine known metabolites[6]. A cytotoxic compound was isolated from the leaves by bioassay-guided fractionation and was identified as (-)-deoxypodophyllotoxin (DPT). The results indicate that DPT contributes to the cytotoxic action of the extract from the leaves of *P.pinnata* [7]. Seven flavonoids, pongaflavone (1), karanjin (2), pongapin (3), pongachromene (4), 3,7-Dimethoxy-3',4'-methylenedioxyflavone(5),millettocalyxinC(6),3,3',4',7-tetramethoxyflavone (7), were isolated from 50% EtOH syrup of the bark of *P.pinnata* and structural elucidated on the base of spectral data Phytochemical study of the roots of *P.pinnata* which resulted in the identification of 11 pterocarpanoids and three new compounds[8]. Phytochemical study on the roots of *P.pinnata* yielded 52 flavonoids, four undescribed flavone and four undescribed chalcone derivatives[9]. The root bark of *P.pinnata* has afforded a new biflavonyloxymethane, karanjabiflavone along with a known furanoflavone, Pongapin[10]. Fruits of *P.pinnata* afforded four new furanoflavanoids, pongapinnolA-D, coumestan, pongacoumestan along with 13 known compounds[11]. Pongarotene, a new rotenoid and Karanjin, a known flavonol were isolated from the seeds of *P.pinnata* [12]. Anti-inflammatory constituent in *P.pinnata* is a furanoflavone which was then evaluated by anti-inflammatory active assay and UPLC-HRESIMS chromatography, 22 compounds were isolated from the ethanol extract of *P.pinnata* seedpods[13]. The bioassay-guided fractionation of a semi mangrove, *P.pinnata*, collected from Bangladesh, and isolated a new compound, (2S)-(2″,3″:7,8)-furanoflavanone (1), along with six known flavonoids (2-7)[14]. New therapeutic agents for Age-related macular degeneration (AMD) were evaluated by isolating and comparing the activity of natural flavonoids such as Karanjin, Karanjachromene, Pongachromene and Pongapin from *P.pinnata* [15] (Table 1).

Table No. 1: Phytochemicals in *Adenanthera pavonina* and *Pongamia pinnata*

Name of the plant	Plant part	Phytochemicals
Adenanthera pavonina	Leaves	Flavonoid Terpenes Tannins
	Bark	Phenolics Flavanoids
Pongamia pinnata	Leaves	DPT((-)-deoxypodophyllotoxin)
	Bark	7 flavanoids(pongaflavone,karanjin, pongapin , pongachromene,3,7-Dimethoxy-3',4' methylenedioxyflavone,millettocalyxinC,3,3',4', 7-tetramethoxyflavone)
	Root	11 pterocarpanoids 52 flavonoids, four undescribed flavone and four undescribed chalcone derivatives
	Root Bark	Biflavonyloxymethane,karanjabiflavone furanoflavone, Pongapin
	Fruit	Four new furanoflavanoids, (pongapinnol A-D, coumestan, pongacoumestan)
	Seed	Pongarotene, a new rotenoid and Karanjin, flavonol
	Seedpods	Furanoflavone

2. BIOLOGICAL ACTIVITIES

Table 2 gives the information about the biological activities of *Adenanthera pavonina* L. and *P.pinnata* (L.) Pierre.

Table No. 2: Biological activities of *Adenanthera pavonina* L. and *Pongamia pinnata* (L.) Pierre

Name of the activity	Name of the plant	Plant part	Extract used	Method
Anti-inflammatory activity	*Adenanthera pavonina*	Seed	Methanol extract	Carrageenan-induced paw oedema in the rat, as well as the acetic-acid induced vascular permeability in mice[16]
	Pongamia pinnata	Leaf	70% ethanolic extract	Acute, subacute and chronic models of inflammation was assessed in rats[17]
		Root	Six compounds	Inhibitory effects against NO production and compound five showed best anti-inflammatory activity[8]
		Root	10 compounds produced by this method	Showed good inhibitory effects against no and displayed anti-inflammatory activity comparable to dexamethasone[9]
		Seed	Karanja ketone oxime from Karanjin present in seeds which leads to the formation of two amino acids.leu390 and fly392	Acute anti-inflammatory activity in the rat model[18]

Anticancer activity	*Adenanthera pavonina*	Bark	Decoction	Lactate Dehydrogenase (LDH)release,(3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide)MTT, and Sulforhodamine B (SRB) assays[19]
	Pongamia pinnata	Root	Lonchocarpin	The cytotoxic activities of lonchocarpin were evaluated in 10 lung cancer cell lines and it exhibited 97.5% activity at a dose of 100 μm in the h292 cell line[22]
		Seed	Pongapin and Karanjin was evaluated in comparison with Plumbagin	Differentially inhibit the growth of different cancer cell lines with low inhibitory effect. Pongapin significantly increase and Karanjin could decrease reactive oxygen species (ROS) level[23]
		Fruit	Methanol extract	Bioassay-guided fractionation isolated a new compound, (2S)-(2″,3″:7,8)-furanoflavanone (1), along with six known flavonoids (2-7). Two of the compounds significantly overcame TRAIL-resistance in human gastric adenocarcinoma (AGS) cell lines[14]

		Root, leaf, seed	Crude extract	Compared by testable probable biosynthetic pathways for karanjin[24]
Antiparasitic activity	*Pongamia pinnata*	Bark	Methanol extract	*In vitro* method[26]
Antioxidant activity	*Adenanthera pavonina*	Bark	Phenolics and flavanoids	Folin-ciocalteau and aluminium chloride colorimetric method[5]
		Seed	Galactomannans	Isolation and purification of galactomannan[27]
	Pongamia pinnata	Leaf	Leaf extract	Spectroscopy, X-ray diffraction[29]
		Stem	Isochromophilo G	UV, NMR and Mass spectroscopic analysis[31]
		Root, leaf, seed	Crude extract	Biosynthetic pathways[24]
		Decoction prepared	Methanolic extract	*In vivo* anti-oxidant activity[33]
		Root bark	Biflavonyloxymethane,Karanjabiflavone,pongapin	Spectral studies including 2D NMR[34]
		Flower	Ethanolic extract	Free radical scavenging effect[35]
		Bark, leaf, seed	Phenolics, flavanoids	HPLC analysis[36]
Antimicrobial activity	*Pongamia pinnata*	Flower	Ag NPs extract	SEM analysis[38]
		Seed coat	Aq. Seed coat	Broth dilution, checker

			extract	board and time kill method[40]
		Decoction of the plant	Aqueous extract	Inhibition of dextransucrose[39]
		Seed	Fabricated zinc oxide nanoparticles	Antibiofilm activity, x-ray diffraction, spectroscopy[25]
		Seed	Pongarotene and karanjin	Spectral analysis including 2D NMR[12]
		Bark, leaf, seed	Phenolics, flavanoids	DPPH Radical scavenging activity[36]
Antidiabetic activity	*Adenanthera pavonia*	Seed	Adenanthera pavonina seed aqueous extract (APSAE)	Streptozotocin induced in rats[41]
	Pongamia pinnata	Leaf	Petroleum ether, chloroform, alcohol and aqueous extract	Oral glucose tolerance test was performed in the diabetic rats[43]
		Stem bark	Cycloart-23-ene-3β, 25-diol	Molecular docking data clearly indicated cycloart-23-ene-3β, 25-diol bind to the GLP-1 receptor[44]
		Stem bark	Cycloart-23-ene-3β, 25-diol	Oral glucose tolerance test[45]
		Stem bark	Petroleum ether extract	Rats injected with streptozotocin and nicotinamide[32]

		Root, seed, leaf	Crude extract(karanjin)	Several isolation methodologies[24]
Antiviral activity	*Adenanthera pavonina*	Seed	Sulfated polysaccharide	50% cytotoxic concentration was determined by MTT method and the 50% inhibitory concentration was evaluated by plaque reduction assay[47]
		Seed	Sulphated polysaccharide	Dimethylthiazolyl-diphenyltetrazolium bromide method (MTT)[48]
		Seed	Galactomannans	The presence of sulfate groups in galactomannans derivatives was confirmed by their IR spectra[27]
Inhibitory activity	*Adenanthera pavonina*	Leaf	Methanol	The cytotoxicity of the extract was evaluated using the Brine shrimp bioassay[51]
	Pongamia pinnata	Leaf	Alfa amylase	Tyrosinase, collagenase enzymes[52]
Antinociceptive activity	*Adenanthera pavonina*	Leaf	Ethanolic extract	Hot plate and tail immersion test[49]

2.1 Anti-inflammatory activity

A methanol extract of the seeds of *Adenanthera pavonina* was evaluated for pharmacological effects in animal models. The extract produced statistically significant inhibition of the carrageenan-induced paw oedema in the rat, as well as the acetic-acid-induced vascular permeability in mice. The extract exhibited a dose-dependent and significant analgesic activity in the acetic-induced writhing in mice. Acute toxicity studies revealed that the extract produced reduced motor activity. This study demonstrated the anti-inflammatory and analgesic effects of *A.pavonina* extract[16].

In the present study, the anti-inflammatory activity of 70% ethanolic extract of *P.pinnata* leaves (PLE) in acute, subacute and chronic models of inflammation was assessed in rats. Both acute as well as chronic administration of PLE did not produce any gastric lesion in rats. These results indicate that PLE possesses significant anti-inflammatory activity without ulcerogenic activity suggesting its potential as an anti-inflammatory agent for use in the treatment of various inflammatory diseases[17]. Phytochemical study of the roots of *P.pinnata* which resulted in the identification of 11 pterocarpanoids and three new compounds. The result demonstrated that six compounds exhibited inhibitory effects against NO production and compound five showed best anti-inflammatory activity[8]. Phytochemical study on the roots of *P.pinnata* yielded 52 flavonoids, four undescribed flavone and four undescribed chalcone derivatives. The study revealed that ten compounds showed good inhibitory effects against NO and displayed Anti-inflammatory activity comparable to dexamethasone[9]. Effect of Anti-inflammatory activity and molecular modifications of Karanjin (*P.pinnata*) was attempted and evaluated by obtaining a Karanja ketone oxime from Karanjin present in seeds which leads to the formation of two amino acids, Leu 390 and Fly 392. The compounds were evaluated for acute anti-inflammatory activity in the rat model. The study reported that the derivatives exhibited higher Anti-inflammatory activity[18].

2.2 Anti-cancer activity

A decoction composed of *Adenanthera pavonina* L. and *Thespesia populnea* L. is currently being used in the treatment of cancer patients. Lactate Dehydrogenase (LDH) release, (3-(4, 5-Dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide) MTT, and Sulforhodamine B (SRB) assays were carried out to study cytotoxicity and anti-proliferative activity against the HEp-2 cells, 24 h post-treatment with the decoction. These results suggest that the decoction prepared with *Adenanthera pavonina* L. and *Thespesia populnea* L. exhibits anti-proliferative activity and induces apoptosis on the HEp-2 cancer cells but no toxicity against *Artemia salina* [19].

A novel depsipeptide (PM181110) was purified from an endophytic fungus *Phomopsis glabrae* isolated from the leaves of *P.pinnata*. The chemical structure of PM181110 was elucidated using physicochemical properties, 2D NMR and other spectroscopic methods. PM181110 is very close in structure to FE399. The compound exhibited *in vitro* anticancer activity against 40 human cancer cell lines with a mean IC50 value of 0.089

μM and ex vivo efficiency towards 24 human tumor xenograft[20]. Expression of cytochrome P450-1A1 (CYP1A1) is suppressed under physiologic conditions but is induced (a) by polycyclic aromatic hydrocarbons (PAHs) which can be metabolized by CYP1A1 to carcinogens, and (b) in majority of breast cancers. Hence, phytochemicals or dietary flavonoids, if identified as CYP1A1 inhibitors, may help in preventing PAH-mediated carcinogenesis and breast cancer. Herein, we have investigated the cancer chemopreventive potential of a flavonoid-rich Indian medicinal plant, *P.pinnata* (L.) Pierre. Pongapin/lanceolatin B and the methanolic extract of *P.pinnata* seeds protect CYP1A1-overexpressing HEK293 cells from B[a]P-mediated toxicity. Remarkably, they also block the cell cycle of CYP1A1-overexpressing MCF-7 breast cancer cells, at the G0-G1 phase, repress cyclin D1 levels and induce cellular-senescence. Molecular modeling studies demonstrate the interaction pattern of pongapin/lanceolatin B with CYP1A1. The results strongly indicate the potential of methanolic seed-extract and pongapin/lanceolatin B for further development as cancer chemopreventive agents[21].

Antitumor effect of lonchocarpin from traditional herbal medicine *P.pinnata* (L.) Pierre and to reveal the underlying mechanism. The cytotoxic activities of lonchocarpin were evaluated in 10 lung cancer cell lines and it exhibited 97.5% activity at a dose of 100 μM in the H292 cell line. A field-based quantitative structure-activity relationship (3D-QSAR) study of 37 flavonoids from *P. pinnata* was also performed, and the results obtained showed that the hydrophobic interaction could be the crucial factor for the antitumor activity of lonchocarpin. These results suggest that lonchocarpin is a potentially useful natural agent for cancer treatment[22].

Antitumor activity of two furanoflavanoid derivatives, Pongapin and Karanjin was evaluated in comparison with Plumbagin, a plant-derived polyphenol with antitumor activity which differentially inhibit the growth of different cancer cell lines with low inhibitory effect. Pongapin significantly increase and Karanjin could decrease reactive oxygen species (ROS) level. The study revealed that Pongapin and Karanjin maybe potential natural anticancer agents[23]. In a search for natural products with activity to overcome tumor necrosis factor-related apoptosis-inducing ligand (TRAIL)-resistance, we performed the bioassay-guided fractionation of a semi mangrove, *P.pinnata*, collected from Bangladesh and isolated a new compound, (2S)-(2″,3″:7,8)-furanoflavanone (1), along with six known flavonoids (2-7). Two of the compounds significantly overcame

TRAIL-resistance in human gastric adenocarcinoma (AGS) cell lines [14]. The crude extracts from root, leaf and seed were evaluated and compared by testable probable biosynthetic pathways for Karanjin. The study revealed that Karanjin exhibits evident anticancer property [24]. This study was focused on the anticancer activity of *P.pinnata* seed extract-fabricated zinc oxide nanoparticles (Pp-ZnO NPs) on human MCF-7 breast cancer cells and antibiofilm activity against bacteria and fungi. Nanoparticles were characterized by UV-Vis spectroscopy, X-ray diffraction, Fourier transform infrared spectroscopy. This study concludes that the synthesized Pp-ZnO NPs may be used as effective antimicrobial and antibreast cancer agents[25].

2.3 Antiparasitic activity

In vitro antiplasmodial activities in leaf, bark, flower and root of *P.pinnata* against *Plasmodium falciparum* and also for the *in vivo* study against *P.berghei* for antimalarial activity was conducted by preparing methanol extract from each part. The study exhibited that the methanol extract of the bark showed both good antimalarial activity *in vitro* and activity against *P.berghei*[26].

2.4 Antioxidant activity

This study was designed to investigate its phytochemical and antioxidant properties. The total phenolics and flavonoids were determined using Folin–Ciocalteau and aluminum chloride colorimetric methods, respectively. These investigations suggested that the decoction prepared with *A. pavonina* and *T. populnea* can be a potential source of nutraceuticals with antioxidant activity[5]. Galactomannans isolated from *Adenanthera pavonina* L., *Caesalpinia ferrea* Mart., and *Dimorphandra gardneriana* were chemically sulfated in order to evaluate the antioxidant, and antiviral activities and the role in the inhibition of virus DENV-2 in Vero cells. The results are very promising and suggest that these sulfated galactomannans from plants of Caatinga biome act in the early step of viral infection [27].

The effect of *P.pinnata* leaf extract in circulatory lipid peroxidation and antioxidant status was evaluated in ammonium chloride induced hyperammonemic rats which was accompanied by decrease in the levels of Vitamin A, Vitamin C, Vitamin E, GSH, glutathione peroxidase, superoxide dismutase and catalase. The results indicate that leaf extract modulates by reversing oxidant-antioxidant during ammonium chloride induced

hyperammonemic due to its antihyperammonemic effect and antioxidant property[28]. Biosynthesis of AgNPs is evaluated using *P.pinnata* leaf extract as reducing agent which is characterized with the help of UV-Vis spectroscopy, Photoluminescence, FTIR, X-ray diffraction and dynamic light scattering. The *in vitro* antioxidant activity of AgNPs showed significant effect on scavenging of free radicals. The results suggest that the silver nanoparticles from *P.pinnata* can be potent antioxidants and can be used against degenerative diseases[29]. The antioxidant activity of HBPP was investigated in rats with liver injury induced by oral administration of carbon tetrachloride: olive oil.HBPP exhibited statistically significant antioxidant activity, as shown by increased levels of glutathione peroxidase (GPX), glutathione S-transferase (GST), glutathione reductase (GRD), superoxide dismutase (SOD) and catalase (CAT) and decreased level of lipid peroxidation (LPO). HBPP performed equally well as silymarin, a well-established antioxidant preparation used to protect against liver injury [30]. Phytochemical study on the endophytic fungus *Diaporthe perseae sp*. isolated from the stem of the Chinese mangrove *P.pinnata* led to the isolation of one new chlorinated *isochromophilone G* along with six known azaphilones. The structures isolated were elucidated by UV, NMR and Mass spectroscopic analysis. The results showed that all the isolated compounds were having antimicrobial and antioxidant activities[31].

The aim of the present investigation was to evaluate the antidiabetic activity of cycloart-23-ene-3beta, 25-diol (called as B2) isolated from stem bark of *Pongamia pinnata* in streptozotocin-nicotinamide induced diabetic mice. The mechanism of B2 appears to be due to increased pancreatic insulin secretion and antioxidant activity [32]. The crude extracts from root, leaf and seed were evaluated and compared by testable probable biosynthetic pathways for Karanjin. The study revealed that Karanjin exhibits evident antioxidant property[24]. Methanolic extracts of *Pongamia pinnata* were studied for wound healing efficiency and was assessed for antimicrobial and antioxidant activity in wistar rats. Antimicrobial activity against ten microorganisms and *in vivo* antioxidant activity was performed to understand the mechanism of wound healing. The results indicated that *P.pinnata* has potent wound healing capacity and posses potent antioxidant activity [33].

The root bark of *P.pinnata* has afforded a new biflavonyloxymethane, karanjabiflavone along with a known furanoflavone, Pongapin. The structure of biflavonyloxymethane was determined by spectral studies including 2D-NMR. The study shows that both these

compounds possess antioxidant activity[34]. Ethanolic extract of flowers of *P.pinnata* was studied for its protective effect against cisplatin and gentamicin induced renal injury in rats. The extract had a marked NO free radical scavenging effect giving it antioxidative property. Two flavonoids known for their antioxidant activity were isolated from the extract. The results suggest that the flower had a protective effect and has antioxidant property[35]. The antioxidant and antimicrobial attributes of various solvent extracts from bark, leaves and seeds of *P.pinnata* were evaluated in which bark extract obtained the greater levels of phenolics, total flavonoids, inhibition of linoleic acid peroxidation and DPPH radical scavenging activity, followed by leaves and seed extracts. Bark extract also revealed the strongest antimicrobial activity. The study concludes that the tested parts especially bark of *P.pinnata* is a potential antioxidant and antimicrobial agent[36].

2.5 Antimicrobial activity

This study investigated the antibacterial activity of these plants against six species of food borne pathogen. Phytochemical analysis of the optimised extracts was performed by thin layer chromatography (TLC). The data presented here show that *A.pavonina* and *A.squamosa* could potentially be used in modern applications aimed at the treatment or prevention of foodborne diseases [4]. Phytochemical study on the endophytic fungus Diaporthe perseae sp. isolated from the stem of the Chinese mangrove *P.pinnata* led to the isolation of one new chlorinated *isochromophilone G* along with six known azaphilones. The structures isolated were elucidated by UV, NMR and Mass spectroscopic analysis. The results showed that all the isolated compounds were having antimicrobial and antioxidant activities[31].

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To develop an easy and eco-friendly method for the synthesis of Ag-NPs using extracts from the medicinal plant, *Millettia pinnata* flower extract and investigate the effects of Ag-NPs on acetylcholinesterase (AChE), butyrylcholinesterase (BChE), antibacterial and cytotoxicity activity. UV-Vis peak at 438 nm confirmed the Ag-NPs absorbance. The SEM analysis results confirmed the presence of spherical shaped Ag-NPs by a huge disparity in the particle size distribution. The highest antibacterial activity was found against Escherichia coli (20.25 ± 0.91 mm). These nanoparticles showed cytotoxic effects against brine shrimp (*Artemia salina*) nauplii with a LD50 value of 33.92[38].

Streptococcus mutans is responsible for causing dental caries in humans and utilizes sucrose for its growth. The dextransucrase is responsible for sucrose metabolism, which exhibits both hydrolytic and glucosyltransferase activities. In this study, we examined the effects of the plant phenols, namely gallic, tannic and syringic acids and aqueous extracts of certain traditionally used chewing sticks (*Acacia arabica, Azadirachta indica*, *P.pinnata* and *Salvadora persica*) for prevention of dental caries on hydrolytic activity of dextransucrsae in *S. mutans*. Gallic acid (4-5 mM) produced 80-90% inhibition of the enzyme, while tannic acid (0.2 mM) and syringic acid (5 mM) inhibited the enzyme activity 80% and 48%, respectively in vitro. The aqueous extracts of chewing sticks produced 35-40% inhibition of dextransucrase activity at 5 mg phenol concentration. These results suggest that plant polyphenols may find potential applications in the prevention and control of dental caries by inhibiting dextransucrase activity in *S. mutans*[39]. Aqueous extracts of the seed coat of *P.pinnata* with antibacterial effects was combined with antibiotics against methicillin-resistant *Staphylococcus aureus* (MRSA) were tested by broth dilution, checkerboard and time-kill methods. The study revealed that the aqueous seed coat extracts of *P.pinnata* have excellent *in vitro* synergistic inhibitory effects and have good potential as an antimicrobial agent[40].

This study was focused on the anticancer activity of *P.pinnata* seed extract-fabricated zinc oxide nanoparticles (Pp-ZnO NPs) on human MCF-7 breast cancer cells and antibiofilm activity against bacteria and fungi. Nanoparticles were characterized by UV-Vis spectroscopy, X-ray diffraction, Fourier transform infrared spectroscopy. This study concludes that the synthesized Pp-ZnO NPs may be used as effective antimicrobial and antibreast cancer agents[25]. Pongarotene, a new rotenoid and Karanjin, a known flavonol were isolated from the seeds of *P.pinnata*. The structures were determined by spectral

analysis including 2D-NMR. The study exhibits the antifungal, antibacterial and phytotoxicity of these compounds[12]. The antioxidant and antimicrobial attributes of various solvent extracts from bark, leaves and seeds of *P.pinnata* were evaluated in which bark extract obtained the greater levels of phenolics, total flavonoids, inhibition of linoleic acid peroxidation and DPPH radical scavenging activity, followed by leaves and seed extracts. Bark extract also revealed the strongest antimicrobial activity. The study concludes that the tested parts especially bark of *P.pinnata* is a potential antioxidant and antimicrobial agent[36].

2.6 Antihyperglycemic activity

Antihyperglycaemic and lipid lowering effect of *Adenanthera pavonina* seed aqueous extract (APSAE) was evaluated using streptozotocin induced diabetes in rats. After induction of diabetes, APSAE was administered for 30 days p. o. and simultaneously different biochemical parameters like plasma glucose, HbA1c, serum triglyceride, cholesterol, LDL-cholesterol and HDL-cholesterol were estimated. Hence, from the result obtained in the present study, it can be confirmed that *Adenanthera pavonina* has the potential to treat diabetes condition and associated lipid disorders[41]. The aim of the present study was to investigate the renal protective effect of *Adenanthera pavonina* seed aqueous extract, in streptozotocin -induced diabetictic rats. *Adenanthera pavonina* seed aqueous extract was given daily to diabetic rats for 13 weeks. Blood glucose, serum parameters and urine parameters were examined. Kidney histopathology was also done. The results suggested that *Adenanthera pavonina* seed aqueous extract has reduced development of diabetic nephropathy in streptozotocin-induced diabetic rats and could have beneficial effect in reducing the progression of diabetic nephropathy[42].

The antidiabetic activity of *P.pinnata* leaf extracts was evaluated in alloxan-induced albino rats. The comparison was made between different extracts of *P.pinnata* obtained by simple maceration method and a known antidiabetic drug Glibenclamide. An oral glucose tolerance test was performed in the diabetic rats. Results clearly demonstrated that ethanolic and aqueous extract showed antidiabetic activity and can be used as a drug [43]. We have reported cycloart-23-ene-3β, 25-diol is an active antidiabetic constituent isolated from stem bark of *P.pinnata* (L.) Pierre. The objective of the present investigation was to evaluate cycloart-23-ene-3β, 25-diol stimulates glucagon like peptide-1 (GLP-1) (7-36) amide secretion in streptozotocin-nicotinamide induced diabetic

Sprague Dawley rats. In acute study, active GLP-1 (7-36) amide release, plasma glucose and insulin were measured during oral glucose tolerance test. The docking data clearly indicated cycloart-23-ene-3β, 25-diol bind to the GLP-1 receptor. It decreased plasma glucose level, increased plasma and pancreatic insulin level as well as increased plasma and colonic active GLP-1 (7-36) amide secretion in streptozotocin-nicotinamide induced diabetic Sprague Dawley rats[44].

The aim of the present investigation was to evaluate the antidiabetic activity of cycloart-23-ene-3beta, 25-diol (called as B2) isolated from stem bark of *P.pinnata* in streptozotocin-nicotinamide induced diabetic mice. The mechanism of B2 appears to be due to increased pancreatic insulin secretion and antioxidant activity[45]. Cardiomyopathy in diabetic rats was investigated on the basis of the effect of petroleum ether extract from the stem bark of *P.pinnata* (PPSB-PEE) which resulted in decreased glucose level, improved electrocardiographic parameters and hemodynamic parameters, controlled levels of cardiac biomarkers and improved oxidative stress in diabetic rats. The result demonstrated that PPSB-PEE is a promising remedy against diabetic cardiomyopathy[32]. The crude extracts from root, leaf and seed were evaluated and compared by testable probable biosynthetic pathways for Karanjin. The study revealed that Karanjin exhibits evident antidiabetic property[24]. Antihyperglycemic and antilipidperoxidative effect was evaluated in the ethanolic extract of *P.pinnata* flowers (PpEt) in normal rats and alloxan-induced diabetic rats. The oral administration of ethanolic extract showed significant antihyperglycemic and antilipidperoxidative and enhancement in antioxidants defense system. These results suggest that PpEt could be used as a safe alternative antihyperglycemic drug for diabetic patients[46].

2.7 Antiviral activity

The antiviral effect of sulfated polysaccharide of *Adenanthera pavonina* against acyclovir resistant and sensitive herpes simplex virus strains. The 50% cytotoxic concentration was determined by MTT method and the 50% inhibitory concentration was evaluated by plaque reduction assay. The antiviral activity was performed in Balb/c mice infected by skin scarification and treated with topical 0.5% Sulfated Polysaccharide from *Adenanthera pavonina* formulations. Our results demonstrated that mice treated with Sulphated Polysaccharides from *Adenanthera pavonina* presented a delay in the development and progression of skin lesions compared with the control group[47]. In this

work, Galactomannans isolated from *Adenanthera pavonina* L., *Caesalpinia ferrea* Mart., and *Dimorphandra gardneriana* were chemically sulfated in order to evaluate the antioxidant, and antiviral activities and the role in the inhibition of virus DENV-2 in Vero cells. The sulfated galactomannans showed binding to the virus surface, indicating that they interact with DENV-2. The results are very promising and suggest that these sulfated galactomannans from plants of Caatinga biome act in the early step of viral infection[27]. The present study aimed at evaluating the activity of sulfated polysaccharides from the *Adenanthera pavonina* seeds against poliovirus type in HEp-2 cell cultures. The Sulphated Polysaccharide from *Adenanthera pavonina* presented a cytotoxic concentration of 500 in HEp-2 cell culture. The Sulphated Polysaccharide from *Adenanthera pavonina* exhibited a significant antiviral activity [48].

2.8 Antinociceptive activity

The aim of this study was to evaluate the antinociceptive activity of ethanol extract of leaves of *Adenanthera pavonina*. Ethanol extract of *Adenanthera pavonina* was investigated using various nociceptive models induced thermally or chemically in mice. The results have demonstrated that Ethanol Extract of *Adenanthera pavonina* produced a significant and dose-dependent increment in the hot plate latency and tail withdrawal time. The results prove the antinociceptive activity of the leaves of *Adenanthera pavonina* and support the traditional use of this plant[49].

The antinociceptive activity of a 70% ethanol extract of *P.pinnata* leaves (PLE) was investigated in different models of pain in mice and rats. The PLE exhibited a significant antipyretic response in Brewer's yeast induced pyrexia in rats. The results demonstrated that PLE possesses marked antinociceptive as well as antipyretic activities[50].

2.9 Inhibitory activity

The methanol extract of the leaves was sequentially extracted with petroleum ether and thereafter was partitioned between EtOAc, and water. The antioxidant activities were measured using the DPPH free radical scavenging activity and the total phenolic content using Folin-Ciocalteu's reagent. The cytotoxicity of the extract was evaluated using the Brine shrimp bioassay. The leaf extracts of *Adenanthera pavonina* exhibit remarkable α-amylase inhibitory activity in the crude methanolic extract[51]. This article describes the inhibitory effects of extracts from 25 plants harvested in Sri Lanka against tyrosinase and

collagenase. Inhibitors of these enzymes are common ingredients in cosmetics and medications, which help protect the skin against hyperpigmentation and premature aging[52].

The pie chart given below represents the Biological and miscellaneous activities of *Adenanthera pavonina*(Figure 2)and *Pongamia pinnata* (Figure 3).

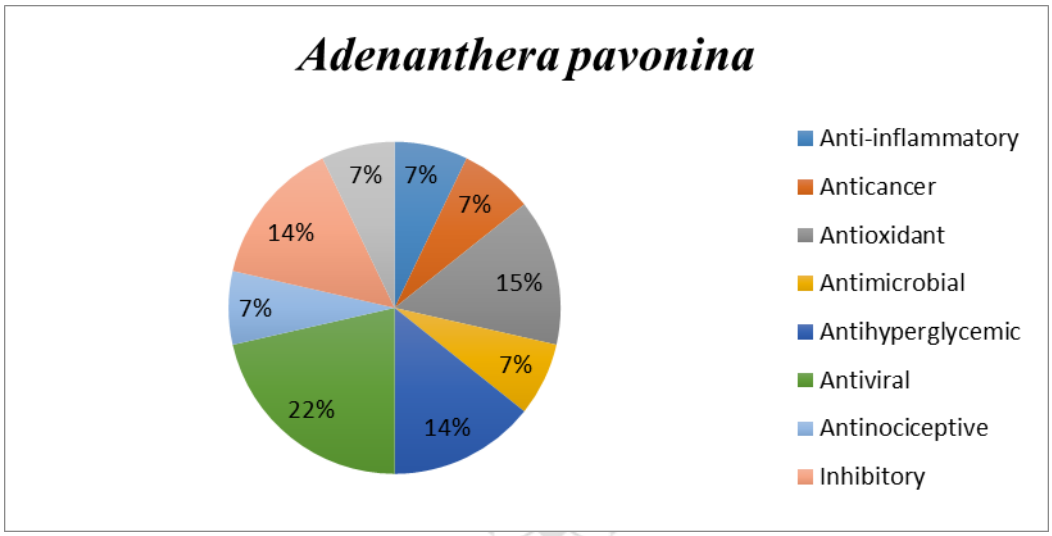

Figure No. 2: Biological and miscellaneous activities of *Adenanthera pavonina*

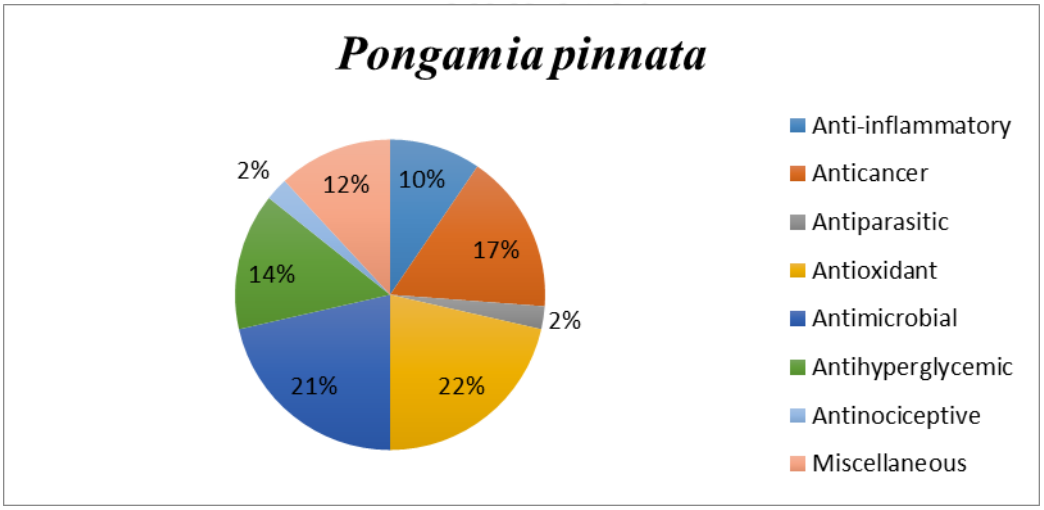

Figure No. 3: Biological and miscellaneous activities of *Pongamia pinnata*

3. MISCELLANEOUS ACTIVITIES

3.1 Neuroprotective activity

Neuroprotective activity of ethanol extract of *P.pinnata* stem bark was evaluated in Monosodium glutamate-induced neurotoxicity in rats. Ethanol extract was orally administered after the monosodium glutamate treatment which altered the behavioural, locomotor activity. Further histopathological studies revealed that *P.pinnata* has neuroprotective effect due to the presence of phytoconstituents such as flavonoids and chalcones[53].

3.2 Regeneration

In vitro nodal explants of *P.pinnata nata* was used to evaluate the regeneration system for micropropagation and genetic manipulation by culturing in a Woody Plant Medium (WPM) containing different kinds of cytokinin. The result demonstrated that, with the establishment of the protocol for multiple shoot bud induction, regeneration, rooting and acclimatisation, micropropagation can be performed [54].

A reproducible protocol developed for in vitro regeneration of *Milletia pinnata* using hypocotyl segments. Multiple shoots were induced from hypocotyl explants through direct adventitious shoot bud regeneration. The proximal end of hypocotyls was responsive for shoot bud induction. Silver nitrate and adenine sulphate had a positive effect on shoot bud induction and elongation. The maximum response and number of shoot bud produced in media supplemented with 8.88 µM BAP with 108.6 µM adenine sulphate and 11.84 µM silver nitrate. Elongated shoots were harvested and successful rooting of microshoots achieved on MS media supplemented with 9.84 µM IBA, with 81.1 % rooting. Remaining shoot buds sub-cultured for further multiplication and elongation. Each subculture produced eight to nine elongated microshoots up to four subcultures. The rooted microshoots were successfully hardened and transferred to field[55]. The basal cut end of coppice shoot cuttings of *P.pinnata ata* was treated for 24 h with 0 (water treated control) or 5.0 mmol/L of KMnO4, KCI, and KH2PO4 or 2.5 mmol/L of K2HPO4 and K2SO4. Inorganic salts of P, S, Cl and Mn significantly influenced IAA ionization and adventitious rhizogenesis. P and S salts had lower IAA ionization potential, but more pronounced effect on adventitious rhizogenesis than Cl and Mn salts. The linear regression analysis also established negative correlations between salt induced

IAA ionization with various characteristics of adventitious rhizogenesis such as sprouting, root number and root length. The implication of IAA ionization in adventitious rhizogenesis has been discussed and the possible role of inorganic salts therein suggested [56].

3.3 Biofuel

Non-edible oilseed residual waste of *P.pinnata* used as sustainable solid biofuel (whole seed, kernel, and hull). These biomasses showed good carbon contents, whereas, fewer sulfur, chlorine, nitrogen and ash contents. Their volatile matter and calorific values (17.68-19.98 MJ/kg) were found to be comparable to coal. The pellets prepared without any additional binder, showed better compaction ratio, bulk density and compressive strength. XRF analysis carried out for determination of slagging-fouling indices, suggested their ash deposition tendencies in boilers, which can be overcome significantly with the optimization of the blower operations and control of ash depositions[57].

The optimum reaction conditions for interesterification of the oils with ethyl acetate were 10% of Novozym-435 (immobilized Candida antarctica lipase B) based on oil weight, ethyl acetate to oil molar ratio of 11:1 and the reaction period of 12h at 50 degrees C. The maximum yield of ethyl esters was 91.3%, 90% and 92.7% with crude jatropha, karanj and sunflower oils, respectively under the above optimum conditions. Relative activity of lipase could be well maintained over twelve repeated cycles with ethyl acetate while it reached to zero by 6th cycle when ethanol was used as an acyl acceptor [58].

CONCLUSION

The present comprehensive review on the phytochemical analysis and the biological activity helps us to understand the significance and properties of *Adenanthera pavonina* and *P.pinnata*. The isolation of several phytochemicals such as flavonoids, terpenes, alkaloids and so on lead to the discovery of healing and therapeutic medication which included Ayurveda and Unani. Mostly the extracts from leaf, bark, root and oil from seed were used for the purpose of determination. Scholarly papers included studies on biological activities such as antidiabetic, anticancer, anti-alzheimer, anti-inflammatory, antihyperglcemic, antioxidant, anticolitis, antiulcer and also have discussed the broad-spectrum pharmacological and biopesticidal properties which were evaluated by the crude extraction of root, leaf and seed. Biochemical and toxicological study lead to the isolation

of a biopesticide from the seed oil of *Pongamia*. Special types of activities held by the plants were easily evaluated. The estimated phytochemicals were arranged and tabulated for ease of observation. Therefore, this study helped to knot a relationship between the respective plants and their biochemical as well as biological properties. Hence, this comparative study on the phytochemical and biological activities between *A.pavonina* and *P.pinnata* lead to revelation of knowledge in the present modern expansion of studies.

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