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Review

A Comprehensive Review on Bioactive Properties of Plant *Caesalpinia pulcherrima* (L)

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Abstract

The use of herbal medicine in healthcare has increased, with some extracts showing effectiveness for certain illnesses. Despite the public's misinformation, herbal remedies have potential hazards. More research is needed to determine if herbal treatments are more beneficial than harmful for specific ailments. The plant *Caesalpinia pulcherrima*, commonly used in India's traditional medical systems, has antibacterial, anti-inflammatory, antioxidant, anticancer, and immunosuppressive properties. This article highlights the phytochemical and pharmacological features of the plant.

Keywords: *Caesalpinia pulcherrima, Pulcherrimain A, Cytotoxicity, Antioxidant.*

INTRODUCTION

Caesalpinia pulcherrima (Caesalpiniaceae), also known as Patag or Brazil wood, is a small, prickly tree with a diameter of 15-25 centimetres. It grows up to 6-9 meters and is known for its yellow panicles in gardens and its heartwood, used in South-East Asia for red dye production.[1] Tree is widely distributed across Tamil Nadu, West Bengal, Kerala, Karnataka, and Andra Pradesh.[2] *C. pulcherrima* has compound leaves with small prickles and oblong leaflets, sub compressed woody pods with a recurved beak, yellow flowers, and 3-4 yellowish-brown seeds. Its wood has an orange-red color, straight grain, fine texture, and high weight (1.073 kg/m3) air dry.[3]

Taxonomical Classification

Kingdom	: Plantae-Plants
Sub-kingdom	: Tracheobionta
Super division	: Spermatophyta
Division	: Magnoliophyte
Class	: Magnoliopsida
Sub-class	: Rosidae
Order	: Fabales
Family	: Fabaceae
Genus	: Caesalpiniaceae
Species	: Caesalpinia pulcherrima (L).

Vernacular Names

Kannada	: Kenji gida, Kenjige
Hindi	: Gelutra, Gulutura
English	: Peacock Flower, Pride of Barbados
Telugu	: Pamiditangedu
Sanskrit	: Padangam, Ratnagandhi

Therapeutic Uses

Wood is known for its healing properties, including biliaryness, fever, delirium, ulcers, stranguriy, urinary concentration, and blood problems. It is bitter, dry, sour, and cooling, and is sedative and astringent. Wood infusions have strong astringent and emmenagogue properties. The paste is used to heal wounds, rheumatism, haemorrhages, and atonic diarrhoea and dysentery. Wood extracts have inhibitory effects on cyclic AMP phosphodiesterase, extended sleep duration in mice by the methanolic extract of C. pulcherrima lignum also showed anti-hypercholestermic effects.[4] The trunk wood has demulcent, haemostatic and antibacterial qualities and is beneficial for treating leucorrhoea, anemia, dysmenorrhea, colic, wounds, impetigo, and furnuculosis, and is used in the local medication "Lukol" for treating non-specific leucorrhoea.[5]

Phytochemical Constituents

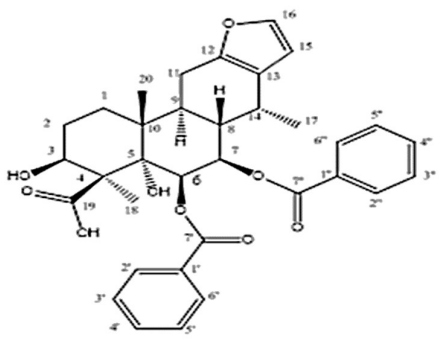

Fig 1: Pulcherrimain A

ß-amyrin, glucose, and free amino acids (alanin, aspartic acid, glycine, praline, valin, leucine, and threonine) as well as free sugars (lactose, galactose, 2-deoxyribose, and glucose) are said to be present in the wood.[6-7] The lignum reports the existence of monohydroxybrazilin and benzyl dihydrobenzofuran derivatives in heartwood, along with various aromatic chemicals such as brazilin, C. pulcherrimachalcone, Caesalpin J, Caesalpin P. proto, C. pulcherrimain A, protoC. pulcherrimain B, and homoisoflavonoids ß-sitosterol. Additionally, it contains C. pulcherrimaol, epiC. pulcherrimaol, 3'-deoxyC. pulcherrimaol, 3'-0-methylC. pulcherrimaol, 3'-0-methylepiC. pulcherrimaol, 3'-0-methylbrazilin, 4-0-methylepiC. pulcherrimaol, C. pulcherrimaon ß, 3-deoxyC. pulcherrimaone ß, 3'-deoxyC. pulcherrimaone ß, and 10-0-methyl-protoC. pulcherrimaion ß. It is also reported that quercetin, rhamnetic, ombuin, 8-methoxy-bonducellin, 4,4'-dihydroxy-2'-methoxychalcone, and rhamnetic acid are present.[8] Three new homoisoflavonoids, 7-hydroxy-3- (4'-hydroxy-benzylidene)3,7-dihydroxy-3-(4'-hydroxy-benzyl), -chroman-4-one3,4,7-trihydroxy-3-(4'-hydroxy-benzyl) and -chroman-4-one. Along with the recognized substances 4,4'-dihydroxy-2'-methoxychalcone, 8-methoxybonducellin, quercetin, rhamnetin, and ombuin was also extracted from the dried heartwood.[9]

Brazillide A, a novel lactone, was isolated from the heartwood of C. pulcherrima, an oriental crude drug, and its structure was determined using X-ray crystallography and spectroscopic analysis.[10] The NMR signals of Brazillein in ^{1}H and ^{13}C were reported by Dong Seon Kion *et al*. From the heartwood, two novel aromatic compounds that are structurally related to brazilin were extracted and identified. They had the ability to lower hypercholesteremic levels.[11] NeoC. pulcherrimaone is a new dimeric methanodibenzoxocinone. A with an exceptional, never-before-seen carbon framework was separated from the heartwood, and spectroscopic investigation was used to determine its structure. Xanthine oxidase was competitively inhibited by NeoC. pulcherrimaone in a concentration-dependent manner. Together with protoC. pulcherrimain E-2, neoC. pulcherrimaone A, and a previously documented phenolic compound, a novel biogenetically exclusive benzindenopyran with a new carbon structure, neoprotoC. pulcherrimain, and a new compound, protoC. pulcherrimain A dimethyl acetal, were identified.[12]

There is brazilin and brazilein in the woody portion. These are the primary components of Brazilwood that were investigated using vibrational spectroscopy.[13] Brazilein 14%'s ^{1}H and ^{13}C NMR signals were reported by Dong Seon, Kion, *et al*. The combination of sterols (campesterol 11.2, ß-sitosterol 69.9%, and stigmasterol 18.9%) brazilin, brazilein. C. pulcherrimain E isolated from C. pulcherrima heartwood.[14-15] An essential oil that contains saponin, gallic acid, oscimene tannin, and D-aphellandrene.[16] 40% of the pods are made of tannins.[17] The leaves contain the pleasant-smelling essential oil. Oscimene and d-a-phellandrene are present in the oil.[18-19] Protein content in the seeds is 7%. The seed protein contains the following amino acids: valine, alanine, cystine, glycine, isoleucine, lysine, threonone, and trypophan. Orange-colored fixed oil is produced by extracting seeds using petroleum ether (18%). Capric, lauric, myristic, myristoplalmatic, palmitic, palmitoleic, oleic, linoleic, linolenic, and arachidic acids are among the fatty acids present. Paints contain fixed oil as main ingredients.[20]

Two substances, such as protoC. pulcherrima and tetraacetylbrazilin, were extracted from the stem of C. pulcherrima[21] and C. pulcherrimachalcone was extracted from C. pulcherrima. According to Beak NI *et al*., the putative biosynthetic precursor of brazilin,[22] C. pulcherrimachalcon and brazilin were separated from an ethyl acetate extract of C. pulcherrima wood.[23] By using several stages of thin layer chromatography and column chromatography, two substances were separated from C. pulcherrima L. Structures of the two compounds were determined by spectroscopic methods[24] as 1',4'- dihydrospiro[benzofuran-3(2H),3'-[3H-2]benzopyran]- 1',6',6',7'-tetrol and 3-[[4,5-dihydroxy-2(hydroxymethyl)phenyl]- methyl]-2,3-dihydro-3,6 benzofuran diol.[25] Badami. S *et al*. carried out the isolation of the red dye using both the newly devised microwave approach and the old method. The dye yielded 0.656 +/- 0.049 g after conventional heating for two hours. However, after 20 minutes of microwave heating at 540 W, the yield increased to 0.747 +/- 0.047 g.[26] Thin-layer chromatographic methods are used to analyze the natural red dyes found in antique Indian textiles.[27] Several traditional medicines, including C. pulcherrima, include phenolic chemicals, which are primarily flavonoids, tannins, coumarins, lignans, quinones, stilbenes, and curcuminoids.[28]

Pharmacological Activity

Anti-arthritic Activity

Rajaram C. *et al*. studied the anti-arthritic activity of *Caesalpinia pulcherrima* (ECP) in an adjuvant arthritic rat model. After 28 days of treatment, ECP showed significant decrease paw volume and normalize haematological abnormalities in AA rats. Radiological studies showed ECP by preventing cartilage and bone destruction in arthritic joints indicating its potential for treating arthritic conditions.[29]

Anti-asthmatic Activity

Mulik S. S. *et al*. conducted a study on *Caesalpinia pulcherrima* L.'s in-vitro anti-asthmatic activity using the goat tracheal chain method. The study found that the principal constituents were isobonducellin, myricitroside, 6-methoxypulcherrimin, and 8-methoxybonducellin. The study found a significant dose-dependent anti-asthmatic

activity in the ethanolic extract of *Caesalpinia pulcherrima*, while petroleum ether and chloroform extract showed satisfactory activity.[30]

Analgesic Activity

The ethanolic bark extract of *Caesalpinia pulcherrima* was utilized in the study by Afroz T *et al*. to evaluate the plant's analgesic properties in animal models. At an oral dose of 500 mg/kg body weight, the bark extract significantly (P<0.001) reduced acetic acid-induced writhing in mice. The bark extract's writhing inhibition was 47.11%, which was comparable to the standard drug Diclofenac sodium at a dose of 25 mg/kg body weight.[31]

Antibacterial Activity

Osuntokun O T *et al.* conducted a study on the antibacterial activity of *Caesalpinia pulcherrima* leaf and stem bark on various clinical isolates. The extracts inhibited the growth of *Escherichia coli, Staphylococcus aureus*, and *Salmonella typhi*, but not *Klebsiella pneumonia* and *Pseudomonas aeruginosa*. The stem bark also inhibited the growth of *Escherichia coli* but not other isolates. The study suggests that *Caesalpinia pulcherrima* has effective antibacterial properties against various microorganisms.[32]

Anticonvulsant Activity

In this study by Kumar D *et al.,* the ethanol extract of *Caesalpinia pulcherrima* (L.) leaves (CPEE) were investigated for its anticonvulsant effect against maximal electroshock (MES) and pentylenetetrazol (PTZ) induced seizures in rats and mice at dose levels 200 and 400 mg/ kg, i.p., respectively. Diazepam (3 mg/kg, i.p.) was used as a standard anticonvulsant drug for comparison. CPEE was found to be safe up to the dose of 4000 mg/kg in mice when administered intraperitoneally. The extract at 400 mg/kg dose produced significant ($p<0.01$) delayed the onset as well as decreased the duration of hind limb extension seizures (HLES) as compared to control; however, the extract, CPEE, percentage protection of the animals was increased at higher dose (200 mg/kg) in both models. The study's findings indicate that *Caesalpinia pulcherrima* (L.) Sw. leaf ethanol extract possess anticonvulsant properties.[33]

Antidiarrheal Activity

Afroz T *et al.* assessed the anti-diarrheal properties of the ethanolic bark extract of *Caesalpinia pulcherrima* (Family: Caesalpiniaceae) in animal models. When used orally at a dose of 500 mg/kg body weight, the crude ethanolic extract of *Caesalpinia pulcherrima* significantly (P<0.001) reduced the frequency of defecation and increased mean latent period in mice with castor oil-induced diarrhea. This effect was similar to that of the standard medication Loperamide at a dose of 50 mg/kg body weight.[34]

Antidiabetic Activity

The study by Angela B. F. *et al*. investigated the potential benefits of using water extract of *Caesalpinia pulcherrima* flowers to enhance glucose uptake in adipocytes from naturally insulin-resistant chickens. The extract was made by sterilizing the filtrate using vacuum filtration after boiling air-dried CP flowers for five minutes in a water-based modified Krebs Ringer Bicarbonate buffer. When the CP flower water extract was added, glucose uptake was doubled at concentrations as low as 2.8 mg/ml and increased to the rate of insulin-sensitive cells at concentrations as low as 5.6 mg/ml. The findings suggest that the water extract of CP flowers can directly regulate glucose uptake into insulin-resistant cells at concentrations as low as 2.8 mg/ml.[35]

Balasundaram M *et al*. study found that diabetic Wistar albino rats treated with ethanol extract of *Caesalpinia pulcherrima* seeds (CP) showed significant decreases in blood glucose levels even two and a half hours after treatment. At a dose of 250 mg/kg, CP completely stopped the blood glucose rise caused by oral glucose feeding. After ten days, CP reduced blood glucose levels in alloxan-diabetic rats to about 132 mg/100 ml. Histopathological analyses showed higher levels of catalase in diabetic rats treated with CP. The rats showed nearly normal levels of creatinine, uric acid, cholesterol, triglycerides, aspartate aminotransferase (AST), ALT, ALP, and ALT, reduced serum protein levels, and significantly inhibited free radicals produced by 1-diphenyl-2-picryl hydrazyl (DPPH) and lower in vitro lipid peroxidation in rat liver microsomes.[36]

Antifertility Activity

Raj A *et al*. conducted a study on the impact of *Caesalpinia pulcherrima* on uterine morphology and its effect on implantation on female Rattus rattus. The study exposed intact uterine horns to an ethanolic extract for one and four hours, revealing significant changes in the uterus's length, diameter, weight, endometrial width, gland size, nucleus morphology, cell secretary activity, and blood vessel and innervation changes. The study found that the number and shape of uterine glands were severely diminished, and the endometrial lining exhibited noticeable alterations. *Caesalpinia pulcherrima* is suitable for contraception development due to its anti-implantation activity.[37]

Antifungal Activity

Lagos de Melo C M *et al*., carried out this study, where lignin was extracted from the C. pulcherrima leaves and investigated its antifungal activity. The lignin was characterized by FT-IR, UV–Vis, GPC, TGA and nuclear magnetic resonance (1 H and 13C). Antifungal activity was made using Candida spp., *Aspergillus spp*. and *Cryptococcus neoformans* strains. The lignin showed maximal UV–Vis at ~280 nm, 22.27 L/g·cm of absorptivity and, 2,503 kDa of molecular weight. Phenolic compounds (41.33 ± 0.65 mg GAE/ g) and indications of a guaiacyl-syringyl-hydroxyphenyl (GSH)-type composition were found. Lignin showed antifungal potential, especially against Candida spp. (IC_{50} = 31.3 μg/mL) and C. neoformans (15.6 μg/mL). This results indicate that lignin has the potential to be used as antifungal compound.[38]

Anthelmintic Activity

The *in-vitro* anthelmintic activity of crude aqueous and hydroalcoholic extracts of *Caesalpinia pulcherrima* (Caesalpiniaceae) bark by Nilesh S D *et al*., was assessed on adult Indian earthworms, *Pheretima posthuma*. The duration of worm paralysis and death was used to test the anthelmintic potency of extracts at different concentrations (10, 25, and 50 mg/ml) *in vitro*. Earthworms' natural motility (paralysis) was dose-dependently inhibited by *Caesalpinia pulcherrima* bark extracts. The standard medication is albendazole (10 mg/ml). It was discovered that both extracts had greater potency than albendazole. The hydroalcoholic extract caused the earthworm to become paralyzed and die faster than the aqueous extract did. Therefore, this study shows that *Caesalpinia pulcherrima* bark can be classified as an anthelmintic herbal medicine and used as a powerful key ingredient of herbal formulation.[39]

Anti-inflammatory Activity

Rao Y K *et al*. studied the anti-inflammatory properties of five flavonoids from *Caesalpinia pulcherrima* L. in murine peritoneal macrophages. The compounds showed significant and dose-dependent inhibition of nitric oxide and cytokines, specifically TNF-α and IL-12. The order of anti-inflammatory potency was compounds 3 > 5 > 4 > 2 > 1. This study supports traditional medicine's use of *Caesalpinia pulcherrima* to treat inflammatory illnesses and is the first to investigate these properties.[40]

Antimalarial Activity

The study by Ogbeide O K *et al*. investigated the *in vivo* anti-malarial activity of pulcherrimin A, a compound isolated from the stem bark of *Caesalpinia pulcherrima*. The compound was characterized using spectroscopic techniques and tested against mice infected with P. berghe. The study found that pulcherrimin A, when given at different doses(50, 200 and 400mg/kg/day), showed a significant suppression of the parasite, with the middle dose showing a maximum suppression of 68.18% and the highest dose of 40.91%, validating the traditional use of plant parts for malaria management.[41]

Ogu G. I. *et al*. conducted a study on the blood schizonticidal effect of aqueous solvent stem bark extract against chloroquine-sensitive *Plasmodium berghei* in albino mice. The extract showed significant anti-plasmodial activity in early infection tests and established infections, with chemosuppression rates of 75.2-86.69%. This suggests the plant's potential for ethnomedicine and potential anti-malarial treatments, making it a promising model for future treatments.[42]

Antimetastatic Activity (Molecular Docking)

The study by Dong T H *et al*. used bioinformatics techniques to investigate the anti-metastatic potential of flower. The researchers identified 471 metastasis targets and predicted protein interactions using Super-PRED and TargetNet. They identified potential core targets such as HSP90AA1, ESR1, PIK3CA, ERBB2, KDR, and MMP9. Six compounds were identified as potential core compounds. The most important metastasis targets and bioactive compounds were ERBB2, HSP90AA1, KDR, and the recently identified 163076213 compound. The study elucidated the primary mechanisms underlying the anti-metastatic properties of , paving the way for further investigation into these substances and proteins to expedite the development of cancer treatments and the use of .[43]

Antinociceptive Activity

Kumbhare M *et al*. conducted a study on *Caesalpinia pulcherrima* pod extracts for their antinociceptive properties. The study involved rats and mice using the tail flick test and acetic acid-induced writhing. The extracts were tested at different doses, with the maximum inhibition observed at 400 mg/kg. However, pet ether and methanolic extracts (400 mg/kg) were found to be more effective in lengthening the latency period in the tail flick method. The results confirm the plant's traditional medicinal application, as *Caesalpinia pulcherrima* pod extracts have analgesic properties that validate its traditional medicinal application. The study highlights the potential of *Caesalpinia pulcherrima* in treating various conditions.[44]

Anti-oxidant Activity

Goat liver was chosen as an *in vitro* model in the current study by Yamuna S T *et al*. to assess the antioxidant effects of the three *Caesalpinia pulcherrima* flowers—orange, pink, and yellow—both in the presence and absence of a common oxidant (H_2O_2). The non-enzymic antioxidants, reduced glutathione and vitamins A, C, and E, as well as the enzymatic antioxidants, catalase, peroxidase, superoxide dismutase, and glutathione reductase, were examined. Goat liver slices treated with hydrogen peroxide had lower antioxidant levels; these levels increased when the flower extracts were added, demonstrating the flowers' ability to act as antioxidants. The results demonstrated that the C. pulcherrima flower methanolic extract significantly protects goat liver from H_2O_2-induced oxidative stress.[45]

Antitubercular Activity

Promsawan N *et al*. isolated two cassane-furanoditerpenoids, 6ß-benzoyl-7ß-hydroxyvouacapen-5a-ol (1) and 6ß-cinnamoyl-73-hydroxyvouacapen-5a-ol (2), by activity-guided fractionation of a root extract of *Caesalpinia pulcherrima*. With a minimum inhibitory concentration (MIC) of 6.25 µg/mL, compound 2 demonstrated potent anti-tubercular activity, while its benzoyl analogue (1) exhibited lower efficacy (MIC of 25 µg/mL).[46]

Antitussive Activity

Umer Gilani S M *et al*. conducted a study on the antitussive properties of *Caesalpinia pulcherrima* aerial parts ethanolic extract. The study used sulfur dioxide induction to induce coughing in four animal groups. The results showed that the extract suppressed coughing, with doses of 200 and 400 mg/kg showing significant results compared to the standard treatment.[47]

Anti-ulcer Activity

H *et al*. conducted a study to determine the antiulcer properties of *Caesalpinia pulcherrima* Linn. bark extracts. The extracts were tested using pylorus ligation models to prevent ulcers caused by aspirin. Results showed that the extracts significantly controlled the development of ulcers induced by aspirin. The ulcer score decreased at 200 and 300 mg/kg. The study concluded that *Caesalpinia pulcherrima* L. bark extracts, both aqueous and hydroalcoholic, have potential applications as herbal medicines with antiulcer properties.[48]

Ayaz S. A.*et al*. study investigated the anti-ulcerogenic properties of *Caesalpinia pulcherrima* leaves in an ethanolic extract. Results showed that the ethanolic extract of *Caesalpinia pulcherrima* was significant at a dose of 500 mg/kg b.wt in a rat ulcer model induced by aspirin. The aspirin-induced model showed increased total protein, glutathione content, and pH of gastric secretion, while decreasing ulcer index, total acidity, and volume.[49]

Antiviral Activity

Chiang LC *et al*. conducted experiments using pure flavonoids and aqueous extracts of *Caesalpinia pulcherrima* Swartz to test their effects on adenoviruses (ADV-3, ADV-8, and ADV-11) and herpesviruses (HSV-1, HSV-1). The selectivity index (SI) was calculated as the ratio of CC50 (concentration of 50% cellular cytotoxicity) to EC50 (concentration needed to achieve 50% protection against virus-induced cytopathic effects). The findings indicated quercetin, a related compound to, and its aqueous extracts had broad-spectrum antiviral activity. The strongest activities against ADV-8 were found in fruit and seed, stem and leaf, and flower extracts, while quercetin showed the strongest anti-ADV-3 activity. This suggests quercetin may be a source of certain C. pulcherrima compounds with antiviral properties.[50]

Anxiolytic Activity

Balakrishna V *et al*. conducted a study on the anti-anxiety activity of *Caesalpinia pulcherrima* leaves using an elevated plus maze model. The mice were given different doses (200 and 400 mg/kg) of various extracts-hexane, chloroform, ethyl acetate and methanol, and their behavior was monitored. The methanol extract showed a dose-dependent effect on EPM, similar to diazepam. The Actophoptometer model showed a reduction in locomotor activity at different dosages. The phytochemical screening of the methanol extract suggested polyphenols may be responsible for *'s* potential anxiolytic effects, suggesting the plant could be used to create an effective anti-anxiety medication.[51]

Arginase Inhibition Activity

Zalsabela L T *et al*. conducted a study on (L.) Sw. stem bark extracts, including n-hexane, ethyl acetate, and methanol, to inhibit arginase activity. The most active extract was found to be the methanolic extract, with an IC_{50} value of 21.969 µg/mL, surpassing the IC_{50} value of 3.994 µg/mL for standard N(omega)-hydroxy-nor-L-arginine acetate. The methanol extract contained flavonoids, tannins, saponins, and triterpenoids, suggesting it could be a useful source for creating arginase inhibitors.[52]

Cytotoxicity Activity

Cytotoxic activity by Refahy L A *et al*. evaluated via using preliminary brine shrimp lethality test and toward liver cancer cell line; HepG2. This study verified that the extracts and butanol fraction from C. pulcherrima showed appreciable cytotoxic activity via HEPG2 assay, the IC 48.6 µg/mL.[53]

Immunosuppressive Activity

Chinese medicine uses C. pulcherrima heartwood to treat immune-mediated pathologies and inflammatory illnesses. Using the plaque-forming cell (PFC) test, Ye M. *et al*. demonstrated immunosuppressive activity. Brazilein, found to suppress humoral immune response in mice, and ethanol extract and betainein prevent T lymphocyte proliferation. Brazilein can induce apoptosis in mouse spleen lymphocytes, potentially decreasing immune-competence. These findings suggest that heartwood has potential immunosuppressive properties.[54]

Immunomodulatory Activity

Khan F *et al*. studied the anti-inflammatory properties of fractions of fresh pods and extracts from *Caesalpinia pulcherrima*. They extracted every component of using methanol, acetone, and water. The extracts were further processed to yield separate phases of hexane, ethyl acetate, butanol, and aqueous. The chemiluminescence technique was used to investigate the effects of these plant extracts on neutrophils, murine macrophages, and whole blood phagocytes. The results showed that whole blood phagocytes' production of reactive oxygen species (ROS) was inhibited, with IC_{50} values lower than standard ibuprofen.[55]

Insecticidal Activity

Erharuyi O *et al*. studied the insecticidal activity of oil derived from C. pulcherrima root. The oil showed a 20% and 40% mortality rate against Tribolium castaneum and Callosbruchus analis, respectively, using gas chromatography-mass spectrometry.[56]

Larvicidal Activity

Govindarajan M *et al*. evaluated the larvicidal activity of crude benzene and ethyl acetate extracts of *Caesalpinia pulcherrima* leaves against three major vector mosquitoes: Culex tritaeniorhynchus, Aedes albopictus, and Anopheles subpictus. The highest larval mortality was observed in the benzene extract. The study suggests that leaf solvent extracts could be an environmentally friendly mosquito control method. This is the first report on the plant *Caesalpinia pulcherrima*'s larvicidal effect on mosquitoes.[57]

Leishmanicidal Activity

A study by Erharuy *et al*. found that 10 known furanocassane diterpenoids, including vouacapen-5α-ol (1), 8,9,11,14-didehydrovouacapen-5α-ol (2), 8,9,11,14-didehydrovouacapen-5α-ol (3), pulcherrin A (4), pulcherrin B (5), pulcherrin J (6), pulcherrimin A (7), pulcherrimin B (8), pulcherrimin C (9), and pulcherrimin E (10), were found to have leishmanicidal activity against Leishmania major promastigotes.Compounds 6β-hydroxyisovouacapenol C (11), 6β-cinnamoyl-7β-acetoxyvouacapen-5α-ol (12), and pulcherrimin D (13), originated from the chemical transformation of 3 and 7. The compounds 3, 9, and 13 showed significant activity against these promastigotes, with IC_{50} values of 65.30 ± 3.20, 58.70 ± 2.80, and 55.90 ± 2.40 µM, respectively.[58]

Hepatoprotective Activity

Pooja *et al*.'s study explores the hepatoprotective properties of *Caesalpinia pulcherrima* in STZ induced diabetic rats. After a 45-day oral treatment, the methanolic extract (200 and 300 mg/kg) restored body weight and decreased blood glucose levels, liver marker enzymes (ALT, AST, ALP), and carbohydrate metabolizing enzymes. This suggests that *Caesalpinia pulcherrima* fruit extract has beneficial hepatoprotective activity by reducing blood sugar values.[59]

Purgative Activity

The current study by Tamil S. A. *et al*. displays the purgative properties of several extracts made from dried *Caesalpinia pulcherrima* leaves. In albino rats, the extracts showed significant ($p<0.001$) purgative activity at the 300 mg/kg, p.o. dose level.[60]

Silver Nanoparticles

Moteriya P *et al*.'s study presents an environmentally friendly, quick, and economical method for synthesizing AgNPs stem extract. The resulting AgNPs, with an average size of 8 nm and a spherical shape, showed strong antioxidant, antibiofilm, and synergistic antimicrobial activity. Although genotoxicity study showed nontoxic at lower concentrations, their cytotoxicity against the HeLa cancer cell line was dose-dependent, indicating potential biomedical applications.[61]

Subramanyam D *et al*.'s study demonstrates the cytotoxicity of synthesized silver nanoparticles on the HCT116 cell line and the bioactivities of extracts. The aqueous extract showed a higher concentration of phenolic compounds and DPPH quenching activity, matching the IC50 values of methanolic and ascorbic acid. The extracts also showed 4.6% hemolytic activity, indicating their non-toxic and protective properties. The extract was used to synthesize silver nanoparticles, which were examined using various methods. The silver nanoparticles showed a crystalline structure, a highly stable colloidal form, and a spherical shape. The silver nanoparticles demonstrated a strong cytotoxicity effect of 77.5% on a human colon cancer cell line, indicating acceptable cytotoxic properties in the anticancer mechanism.[62]

Wound Healing Activity

The study by Kavith a N, *et al*. evaluated the methanolic extract of *Caesalpinia pulcherrima* leaves for wound healing. Four groups of healthy animals were treated with different treatments, including nitrofurazone ointment, ointment base, and formulation. The extract group showed significant wound healing, with 100% epithelization occurring in 14 days compared to the control group. This was attributed to the plant's analgesic, anti-inflammatory, antibacterial, and antioxidant properties.[63]

CONCLUSION

With 30+ activities being proved in the various parts of *Caesalpinia pulcherrima* (L) Sw., it can be said to be the most useful plant for the treatment of various diseases. In times where the research is being done in the look for natural plant-based medication, plants like these can be of most beneficial for the mankind. It can be concluded that *Caesalpinia pulcherrima* is not just an ornamental decorative plant but also very good medicinal plant. Further investigation on other activities can support the plant's extensive therapeutics use.

REFERENCES

1. Varier P S. Indian Medicinal Plants: A compendium of 500 species. Vol I. Orient Longman; 1994: 315-323.
2. Guha D N, Pal D C. A Lexicon of Medicinal Plants in India. Vol-I. 1999:335-336
3. The Wealth of India: A Dictionary of Indian Raw Materials and Industrial Products-Raw Materials Series. Vol. II. *Publication and Information Directorate.* CSIR. New Delhi;1988: 14-16.
4. Pawar C R, Amol D L, Sanjay J S. Phytochemical and Pharmacological Aspects of *Caesalpinia pulcherrima*. *Journal of Pharmaceutical Research.* 2008; 1(2): 135-143.
5. Kirtikar K R, Basu B D. Indian Medicinal Plants. Vol I. *International Book Distributors.* Dehradun (India) 1987:847.
6. Rajyalaxmi R, Ravikanth V and Jansi Lakshmi VV. Pharmacological study of caesalpiniceae species. *Probe.* 1982; 22: 35-83.
7. Moon C K, Park K S, Kim S G, Won H S. Chung JH. Phytochemical evaluation of C. pulcherrima. *Planta Med*. 1985, 66
8. Nigam P, Kannan E, Bhojraj S. Compounds from *Caesalpinia pulcherrima*. *Indian Journal of Pharmacology*. 1977; 39:85-88
9. Namikoshi M, Nakata H, Tamotsu S. *Chemical and Pharmaceutical Bulletin*. 1987; 35: 2761-3615.
10. Namikoshi M, Nakta H, Tamotsu S. Homoisoflavonoids from *Caesalpinia pulcherrima*. *Phytochemistry*.1987; 26:1831-33.
11. Bo Ou Yang, Chang-Qiang Ke, Zhi-Sheng He, Yi-Ping Yang. Brazilide A. A Novel Lactone with an Unprecedented Skeleton from C. pulcherrima. *Tetrahedron*. 2002; 43:1731-33.
12. Chiaki Fuke, Johji Yamahara, Takashi Shimokawa, Junei-Kinjo. Aromatic compounds related to brazilin from *Caesalpinia pulcherrima*. *Phytochemistry*.1985;24: 2403-05.
13. Thanh M, Ngyen T, Awale S, Tezuka Y, Tran OL and Kadota S, Xanthine Oxidase Inhibitors from the Heartwood of Vietnamese *Caesalpinia pulcherrima*, *Tetrahedron*. 2004; 45: 8519-8522.
14. Luiz F C, de Oliveira, Eudes S, Velozo M. Vibrational spectroscopic study of brazilin and brazilein, the main constituents of Brazilwood from Brazil. *Vibrational spectroscopy*. 2002; 28: 243-249.
15. Kim D S. Baek N I. Jung K Y. NMR assignment of brazilein. *Phytochemisry*.1997; 46: 177-17.
16. Oh S R, Kim D S, Lee I S, Jung K Y. Isolation of brazilin & brazilein from. *Planta Med*.1998; 64: 456-458.
17. Prajapati Purohit, Sharma Kumar. A Handbook of Medicinal Plants: A Complete Source Book. Agrobios (India). 2003: 101.
18. Quraishi and Khan. Industrial application of Brazil Wood. *Pakistan Journal For*. 1965;15:250.
19. Hikino P H, Freisleben H J, Rumampuk R J. Anti-inflammatory principles of wood and of Haematoxylon campechianum wood. *Planta Med.* 1977; 31: 214.

20. Yadava V, Dinda B and Saha S. Isolation of Oils from *Ceasalpinia pulcherrima*, *Indian Perfumer*. 22,1978, 73.
21. Oswal and Garg. Nutritional important of Brazil wood. *Seifen ole fatte Wachs*. 1984; 110: 577.
22. Xu H, Zhou Z H, Yang J S. Compounds from L. *Chinese Medical and Research*. 1994; 9 (8): 485-486.511.
23. Nagai M, Nagumo S, Eguchi I, Lee SM and Suzuki T. Pulcherrimachalcone from *Caesalpinia pulcherrima* L., the proposed biosynthetic precursor of brazilin. *Yakugaku Zasshi*.1984; 104(9): 935- 938.
24. Beak N I, Jeon S G, Ahn E M, Bahn J H. Anticonvulsant compounds from the wood of L. *Archives of Pharmacal Research*. 2000; 23(4): 344- 348.
25. Safitri R, Tarigan P, Freisleben H J, Rumampuk R J. Antioxidant activity *in vitro* of two aromatic compounds from L. *Biofactors*. 2003; 19(1-2): 71-77.
26. Niranjan Reddy V L, Ravikanth V, Jansi Lakshmi V V. Suryanarayan Murty U. Venkateswarlu Y. Inhibitory activity of homoisoflavonoids from against Beauveria bassiana. *Fitoterapia*. 2003; 74(6): 600-602.
27. Badami S, Geetha B, Sharma S V, Rajan S. Suresh B. Microwave-assisted rapid extraction of red dye from heartwood. *Natural Products and Research*. 2007; 21(12):1091-1098.
28. Kharbade B V, Agrawal O P. Identification of natural red dyes in old Indian textiles. Evaluation of thin-layer chromatographic systems. *Journal of Chromatography*. 1985; 347: 447-454.
29. Cuddapah Rajaram, Kandula Ravindra Reddy, Kothapalli Bonnth Chandra Sekhar. Evaluation of anti-arthritic activity of *Caesalpinia pulcherrima* in freund's complete adjuvant induced arthritic rat model. *Journal for Young Pharmacist*. 2015; 7(2): 128-132.
30. Mulik S S, Patil V M, Patil S S. Isolation, Characterisation and Evaluation of Anti-Asthmatic Activity of *Caesalpinia pulcherrima* L. *International Journal of Scientific Research in Science and Technology*. 2022; 9(6): 503-07.
31. Afroz T, Ramproshad S, Mondal B, Haque A, Khan R. Antidiarrhoeal and Analgesic Activity of Barks of Medicinal Plant *Caesalpinia pulcherrima*. *International Journal of Pharmaceutical Sciences and Research*. 2013; 4(5): 1946-1949.
32. Osuntokun O T, Julianah J U and Thonda O A. Bioprospective Screening of Antibacterial and Phytochemical Activity of *Caesalpinia pulcherrima* (Pride of Barbados) on Selected Clinical Isolate. *Bioequivalence & Bioavailability International Journal*. 2017; 1(3): 01-11.
33. Kumar D, Singh J, Baghotia A, Kumar S. Anticonvulsant effect of the ethanol extract of *Caesalpinia pulcherrima* (L.) Sw., Fabaceae, leaves. *Revista Brasileira de Farmacognosia Brazilian Journal of Pharmacognosy*. 2010; 20(5): 751-755.
34. Afroz T, Ramproshad S, Mondal B, Haque A, Khan R. Antidiarrhoeal and Analgesic Activity of Barks of Medicinal Plant *Caesalpinia pulcherrima*. *International Journal of Pharmaceutical Sciences and Research*. 2013; 4(5): 1946-1949.
35. Angela B F. Carrington-Dyall, Shekaib A I, Nickelia E, Clarke-Jordan. Water Extract of *Caesalpinia pulcherrima* Flowers Increases Glucose Uptake in Insulin Resistant Adipocytes in A Dose-Dependent Manner. *Era's Journal of Medical Research*. 2020; 7(2): 172-75.
36. Balasundaram M, Dhanesh Gandhi A, Kavitha P, Babujanarthanam R. Effect of *Caesalpinia pulcherrima* (L.) Sw. seeds on serum glucose and other metabolic parameters of normal and alloxan - induced diabetic rats. *Diabesity*. 2018; 4(3): 9-16.
37. Raj A, Sharma A, Singh N, Kumar P, Singh A, Bhatia V and Sharma S K. Studies on Anti-Fertility Activity of Peacock Flower (*Caesalpinia pulcherrima*) On Uterine Morphology of Rat (Rattus rattus). *Applications in Research*. 2011; 7-15.
38. Cristiane Moutinho Lagos de Melo a, Iranildo José da Cruz Filho a, Georon Ferreira de Sousa a, *et al*. Lignin isolated from *Caesalpinia pulcherrima* leaves has antioxidant, antifungal and immunostimulatory activities. *International Journal of Biological Macromolecules*. 2020; 162: 1725–1733.
39. Satwadhar N D, Mehta P, Patil S R, Mute V M. Evaluation of Anthelmintic Activity of *Caesalpinia pulcherrima* (L). Bark Against Pheretima posthuma. *International Journal of Pharmacy and Pharmaceutical Sciences*. 2012; 4(1): 76-77.
40. Rao Y K, Fang S H, Tzeng Y M. Anti-inflammatory Activities of Flavonoids Isolated from *Caesalpinia pulcherrima*. *Journal of Ethnopharmacology*. 2005; 100: 249–253.
41. Ogbeide O K, Akhigbe I U, Unuigbe C A, Erharuyi O. Isolation, Characterisation And In Vivo Anti-Malarial Investigation of Pulcherrimin A from *Caesalpinia pulcherrima* Stem Bark. *GSC Biological and Pharmaceutical Sciences*. 2020; 12(2): 056-063.
42. Ogu Gi, Aisuodionoe Me and Nwachukwu Pu. Anti-Plasmodial Activity of *Caesalpinia pulcherrima* (Swarts) Stem Bark Extract Against Plasmodium berghei in Albino Mice. *International Journal of Biology, Pharmacy and Allied Sciences*. 2012; 1(2): 168-178.
43. Donga T H, Wen Ninga A Y and Tang Y Q. Network Pharmacology-Integrated Molecular Docking Analysis of Phytocompounds of *Caesalpinia pulcherrima* (Peacock Flower) as Potential Anti-Metastatic Agents. *Journal of Biomolecular Structure and Dynamics*. 2023; 42(4): 1778–1794.

44. Kumbhare M and Thangavel S. Anti-inflammatory and Antinociceptive Activity of Pods of *Caesalpinia pulcherrima*. *Journal of Applied Pharmaceutical Science*. 2011; 1(7): 180-184.
45. Yamuna S T, Padma P R. Antioxidant potential of the flowers of *Caesalpinia pulcherrima*, Swartz in an in vitro system subjected to oxidative stress. *Journal of Pharmacy Research*. 2013; 7: 661-665.
46. Pomsawan N, Kittakoop P, Boonphong S, Nongkunsarn P. Antitubercular Cassan Furanoditerpinoids from the Roots of Ceasalpinia pulcherrima. *Planta Med*. 2003; 69: 776-777.
47. Gilani S M U, Roshan R, Ahemd S, Mohtasheem M H. Antitussive Effect of Aerial Parts of *Caesalpinia pulcherrima* L. by Sulfur Dioxide Induced Cough in Rats. *RADS Journal of Pharmacy and Pharmaceutical Science*. 2021; 9(2): 111-114.
48. Takawale H, Mute V, Awari D, Hukkeri V I, Mehta P and Vawhal P. Screening of Antiulcer Activity of *Caesalpinia pulcherrima* L. Bark. Against Aspirin Induced Ulcer in Rat. *World Journal of Medical Sciences*. 2011; 6 (4): 168-172.
49. Ayaz S A, Mujahid S, Aatif S, Mukhtar M, Iftequar S. Antiulcerogenic Activity of *Caesalpinia pulcherrima* Leaves. *International Journal of Pharmaceutical Research and Allied Sciences*. 2015; 4(2): 74-78.
50. Chiang L C, Chiang W, Liu M C and Lin C C. In Vitro Antiviral Activities of *Caesalpinia pulcherrima* and its Related Flavonoids. *Journal of Antimicrobial Chemotherapy*. 2003; 52: 194–198.
51. Vuyyala B, Senthil K D, Thakkalapally L. Evaluation of Anxiolytic Potential of Various Extracts of *Caesalpinia pulcherrima* Leaves. *Research Journal of Pharmacy and Technology*. 2021; 14(11): 5625-5628.
52. Zalsabela L T, Elya B, Noviani A. Arginase Inhibition Activity of Stem Bark Extract of *Caesalpinia pulcherrima*. *Journal of Young Pharmacists*. 2018; 10(2): 111-113.
53. Refahy L A, Farghaly T A, Abdel-Aziz M S and Mohamed T S. Antimicrobial, Antioxidant and Cytotoxic Potential of *Caesalpinia pulcherrima* Flower. *Global Journal of Pharmacology*. 2015; 9 (2): 150-158.
54. Min Y, Xie W D, Fan L, Zhen M, Zhao Y N. Brazilein, An Important Immunosuppressive Component from L. *International Immuno Pharmacology*. 2006; 6: 426-432.
55. Khan F, Dastagirb N, Lateefc M, Yousufd M, Miranic Z A, Mesaikb A, Faizid S and Kazmi S U. Immunomodulatory Activities of Extracts of *Caesalpinia pulcherrima*. *Journal of Herbs, Spices and Medicinal Plants*. 2018; 24(3), 245–256.
56. Erharuyi O, Imieje V O, Oseghale I O, Ubhenin A E, Falodun A, Choudhary M I. Identification of Compounds and Insecticidal Activity of the Root of Pride of Barbados (*Caesalpinia pulcherrima* L). *Journal of Applied Science and Environmental Management*. 2017; 21(2): 281-287.
57. Govindarajan M, Rajeswary M and Amsath A. Larvicidal Properties of *Caesalpinia pulcherrima* (Family: Fabaceae) Against Culex tritaeniorhynchus, Aedes albopictus and Anopheles subpictus (Diptera: Culicidae). *International Journal of Pure and Applied Zoology*. 2013; 1(1): 15-23.
58. Erharuyi O, Adhikari A, Falodun A, Jabeen A, Imad R, Ammad M, Choudhary M I, Nezhun Gören. Cytotoxic, Anti-inflammatory, and Leishmanicidal Activities of Diterpenes Isolated from the Roots of *Caesalpinia pulcherrima*. *Planta Med*. 2016; 83(01/02): 104-110.
59. Pooja, Mazumder A, Das S. Hepatoprotective Nature of Aerial Parts of *Caesalpinia pulcherrima* in STZ Induced Diabetic Rat Model. *Research Journal of Pharmacy and Technology*. 2012; 14(7): 3716-3720.
60. Tamil S A, Suthakar R, Muthu V S B, Kumara S S K. Purgative Activity of *Caesalpinia pulcherrima* (L) Sw Leaves Extracts. *Research Journal of Pharmacy and Pharmacodynamics*. 2013; 5(3): 164-165.
61. Moteriya P, Chanda S. Biosynthesis of Silver Nanoparticles Formation from *Caesalpinia pulcherrima* Stem Metabolites and Their Broad-Spectrum Biological Activities. *Journal of Genetic Engineering and Biotechnology*. 2018; 16: 105–113.
62. Subramanyam D, Chinnadurai I S, Roopan S M. Screening Bioactivities of *Caesalpinia pulcherrima* L. Swartz and Cytotoxicity of Extract Synthesized Silver Nanoparticles on HCT116 Cell Line. *Materials Science and Engineering C*. 2020; 106.
63. Kavith A N, Naira N. Formulation and Evaluation of the Methanolic Extract of *Caesalpinia pulcherrima* Leaves for its Wound Healing Activity. *Asian Journal of Pharmaceutical Research and Health Care*. 4 (3) 90- 94.