PHYSIOCHEMISTRY AND PHARMACOLOGY OF PTEROCARPUS SANTALINUS AND ITS ROLE IN DERMATOLOGY

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 geared to 30 August 2021, Revised and Accepted: 25 November 2021

ABSTRACT

The review provides an updated overview of the physicochemical and pharmacological studies on Pterocarpus santalinus. It briefs on the synergistic interactions of P. santalinus with other medicinal plants and its use in Ayurvedic formulations. Phytochemical analysis suggests the presence of triterpenoids, steroids, flavonoids, and phenolic acids. The phytoconstituents and related pharmacological activities of various parts of P. santalinus include antihypertensive, anti-inflammatory, antiallergy, antidiabetic, antiparasitic, and antiulcer activities. Literature survey highlights the dermatological applications of the phytoconstituents such as pterostilbene, savinin, and betulin as potential leads for anti-aging, UV-B protective, and wound healing effects. Undoubtedly, P. santalinus has wide therapeutic value. The dermatologically significant phytoconstituents, namely, pterostilbene, cedrol, elaborin, lupeol, betulin, α-eudesmol, and α-bisabolol, if isolated and used in dermatological formulations, can show promising skin protective effect. The data were compiled using scientific databases, namely, Google Scholar and PubMed, the data made available specifically from 2010 to 2021.

Keywords: Pterocarpus santalinus, Pharmacology, Dermatology, Fabaceae.

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Highlights

- Brief data on the vernacular names, geographical distribution, collection and cultivation, and traditional uses.
- Updated overview of the phytochemical and pharmacological studies on P. santalinus.
- Dermatological applications of the phytoconstituents of P. santalinus.
- Synergistic interactions of P. santalinus with other medicinal plants and its use in Ayurvedic formulations.
- Diverse applications of P. santalinus were discussed.

INTRODUCTION

Pterocarpus santalinus Linn. belongs to the family Fabaceae, popular as “Red Saunders,” it is a deciduous plant growing up to 10–11 m high. Geographical distribution of P. santalinus is in the southern parts of Eastern Ghat. Commercially important part is timber of P. santalinus which has historical and traditional value, used for the production of acoustic instruments, toys, and carvings. Convention on International Trade in Endangered Species of Wild Fauna and Flora has listed P. santalinus as an endangered plant [1].

Santalin, a natural dye in the timber, is used as a pharmaceutical colorant. Correlation of various phytoconstituents with the pharmacological and dermatological applications urges to compile the data.

VERNACULAR NAMES

English: Red Saunders, Red sandalwood, Marathi: Raktchandan, Gujarati: Ratanjali, Lalkhandana, Kannada: Raktachandana, Telugu: Errachandananu, and Assamese: Sandale [2].

GEOPHYSICAL DISTRIBUTION

P. santalinus is distributed in hilly regions with hot and dry climate. It grows well in the tropical regions of India, Sri Lanka, Taiwan, the Philippines, and China. In India, it is predominantly found in the southern parts of the Eastern Ghats, Cuddapah, and Chittoor districts of Andhra Pradesh and Prakasam and Nellore in Tamil Nadu [3].

CULTIVATION AND COLLECTION

The seed and vegetative propagation is the traditional way of propagation of P. santalinus. In seed germination, it needs well-drained red loam soils which are suitable for the cultivation. It regenerates very well in dry hot climate. It requires rainfall ranging from 800 to 1000 mm annually for growth. The seeds are given treatment with GA3 (gibberelic acid) and benzyladenine (parts per million) which help in early germination or seeds can be soaked for 72 h in cold water or in cow dung slurry. The pits [size 45 x 45 x 45 cm are dug at spacing of 4 x 4 m] are filled with topsoil mixed carefully with 10–15 kg farm yard manure and 10 kg of lime dust. It protects the planting stock from attack of soil-borne fungi. March–May months are very much suitable for raising nursery beds from seeds. The best time for planting the crop in the field is end of May–June, that is, onset of rainy season. The irrigation to plants is done immediately after transplantation. Further alternate days up to 15 days irrigation are done [4].

TRADITIONAL USES

Ethnobotanical uses of P. santalinus include its application in the treatment of boils, eczema, and wounds in West Bengal [5]. Powder or decoction of heartwood or bark was used to treat piles, diabetes, and hypercholesteremia in Kerala [6]. P. santalinus (tribes in Chittoor district of Andhra Pradesh) used to treat for ulcers. In Malamalar tribes of Kerala used wood paste as a blood purifier and antidote for poisons. The tribes of Kandhas in Kandhamal, Odisha, administered decoction of Calamus tenuis roots, stem bark of Azadirachta indica, and P. santalinus used to treat treating piles [7].

PHYSIOCHEMISTRY OF P. SANTALINUS

Table 1 classifies and enlists the phytoconstituents of P. santalinus [8–10]. Fig. 1 depicts the chemical structures of some of the phytoconstituents.

PHARMACOLOGICAL ACTIVITIES OF P. SANTALINUS

Anticholinesterase (AChE) activity

The methanol extract of bark of P. santalinus possessed in vitro and in vivo AChE activity. In vitro inhibitory assay of AChE by the extract
was evaluated by IC50 value and phystostigmine as a standard. In vivo activity was assessed in scopalamine induced amnesia in Swiss albino mice. In passive shock avoidance test, increasing concentrations of extract exhibited memory enhancement by increased latency time and inhibited brain AChE activity. The terpenoids were found to be responsible for the neuroprotective effects [11].

**Antifungal activity**

Ethyl acetate extract of leaves of *P. santalinus* exhibited significant antifungal activity against *Trichophyton mentagrophytes, Epidermophyton floccosum, Trichophyton rubrum, Trichophyton simii,* and *Magnaporthe grisea.* Complexation of flavonoids in *P. santalinus* with soluble proteins and the fungal cell wall and subsequent dissolution of the cell wall led to the antifungal effect [12].

**Antidiabetic activity**

Aqueous, ethanol, and hexane bark extracts of *P. santalinus* proved to be antihyperglycemic in normal and alloxan monohydrate-induced diabetic male Wistar albino rats. Ethanol extract showed remarkable hypoglycemic activity. Hypoglycemic effect was attributed due to the phytoconstituents β-sitosterol, epicathechin, and lupeol which activated the remnant beta cells, improved insulin response at cellular level, or had insulin-like effect [13].

Oral treatment of ethyl acetate—methanol fraction of the ethanolic extract of *P. santalinus* decreased elevated blood glucose levels, glycylated hemoglobin level (HB1al) by stimulating remnant β-cells in pancreas as a result, increased hexokinasae and glucose-6-phosphate dehydrogenase activity, promoting glycosis, and glucose utilization in diabetic rats. Increase in plasma insulin levels suppressed the activities of hepatic glucogenic enzymes, glucose-6-phosphatase, and fructose-1, 6-biphosphatase [14].

**Antipyretic activity**

Vasudevan *et al.* studied the effect of aqueous extract of heartwood of *P. santalinus* on brewer’s yeast-induced pyrexia in Wistar rats. Increasing concentrations of the extract proved to be antipyretic by reducing the rectal temperature. The phytochemicals mainly flavonoids, alkaloids, and saponins in *P. santalinus* prevent activation of cyclooxygenase and prostaglandin formation and exhibit antipyretic activity [15].

**Antibacterial activity**

Methanol extract of stem bark and leaves possessed dose-dependent antibacterial action against Gram-positive and Gram-negative bacteria. *S. aureus, E. coli,* and *A. faecalis* and *E. aerogenes,* *S. aureus, E. coli,* and *A. faecalis* were the most susceptible to the extract [16].

Gold nanoparticles formulated using *P. santalinus* bark extract showed bacteriostatic effect against pathogenic bacteria *S. aureus* and *P. aeruginosa* [17].

**Anti-inflammatory activity**

*P. santalinus* gel formulation was effective against Complete Freund’s Adjuvant-induced rat hind paw inflammation and pain. Reduction in inflammation was assessed by reduction in the paw volume, body weight due to decreased edema, and paw withdrawal test proved the analgesic activity. Anti-inflammatory effect may be due to savinin, a lignan, which inhibited inflammatory markers such as tumor necrosis factor-α (TNF-α) and T-cell proliferation. *P. santalinus* gel was effective in chronic inflammation and could be used in arthritis-like conditions [18].

Lignans, savinin, and calcoedrin from *P. santalinus* by the virtue of its α-arylidene-γ-lactone structure could significantly inhibit TNF-α in lipopolysaccharide-stimulated RAW264.7 cells and concanavalin A elicited T-cell proliferation in BALB/c mice splenocytes [19].

**Hepatoprotective activity**

In vitro free radical scavenging activity of the methanol extract of heartwood of *P. santalinus* against oxidative stress induced by DPPH and nitric oxide radicals suggested increased radical scavenging activity dose dependently. In vivo hepatoprotective activity of *PSE* against alcohol-induced oxidative damage in rat liver was demonstrated by normalized levels of liver damage biomarkers, alkaline phosphatase, plasma transaminases, lactate dehydrogenase, and gamma glutamyl transferase. Enhancement of antioxidant enzymes such as glutathione peroxidase (GPX), glutathione S-transferase (GST), glutathione reductase (GR), superoxide dismutase (SOD), and catalase in liver. Phytochemicals such as pterostilbene, lignan, and lupeol possess hepatoprotective action [20].

**Antioxidant activity**

Ghali *et al.* studied the antioxidant and radioprotective effects of chloform extract of *P. santalinus.* Antioxidant potential was significant against ABTS, DPPH, and nitric oxide radicals. In vitro radioprotection of murine splenic lymphocytes against gamma radiation by the extract resulted from inhibition radical propagation, DNA strand breakage, lipid peroxidation, and thiol depletion. It is a radioprotector which is effective in cancer radiotherapy and radiation-induced malignant tumors [21].

**Cytotoxicity against cervical and breast cancer cell lines**

In the study by Donga *et al.*, methanol extracts of stem, leaf, and bark of *P. santalinus* proved cytotoxic against cervical and breast cancer cell lines by MTT [3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyltetrazolium bromide] assay. Maximum cytotoxicity or minimum cell viability of the cancer cell lines was exhibited by bark extract [22].

**Anti-tumor activity**

Oral administration of ethanolic seed extract of *P. santalinus* (300 mg/kg) showed inhibitory effect on 7,12-dimethylbenz(a)-anthracene-induced malignant breast tumor in rats. Anti-tumor activity was assessed by inhibition of tumor growth, reduced malondialdehyde, and reduced serum TNF-α in treated group, suggesting antioxidant action against breast cancer. Histopathological studies on the tumor tissue in extract-treated group suggest the presence of mature fibroblast cells and hence reduced growth of the. Moreover, hypoglycemic effect was observed in treated group. Hepatotoxicity and renal toxicity due to 7, 12-dimethylbenz(a)-anthracene were found to be reversed by decrease in levels of hepatic serum biomarkers (total serum bilirubin, alkaline transaminase, aspartate transaminase, and alkaline phosphate) and kidney serum biomarkers (urea, creatinine, and uric acid) aiding advantage to be used as an anti-cancer agent [23].

**Nephroprotective activity**

In the study by Bulle *et al.*, chronic alcohol consumption caused kidney damage in rats. It was characterized by increased plasma urea and creatinine levels. Hypotenatremia, hypokalemia, hypomagnesemia, hypocalcaemia, and hypochloremia were evident. Kidney damage markers and decreased level of antioxidant enzymes were observed. *P. santalinus* heartwood methanol extract protected against alcohol-induced glomerular damage and decreased plasma urea and creatinine levels. Reversal of Na+/K+/ATPase activity led to decreased Na+, K+, Ca2+, and Cl- loss. Increase in the antioxidant enzymes such as SOD, catalase (CAT), GPx, GR, and GST. Nephroprotective effect was proved [24].

**Action against atopic dermatitis**

*P. santalinus* and *Buddleia officinalis* exhibited synergism in treating skin inflammation, especially atopic dermatitis by inhibition of thymic stromal lymphopoeitin and interleukin (IL)-4/polyinosinic-polycytidylic acid. Inhibition led to reduction in inflammation and pro-inflammatory cytokines and inflammatory markers [25].
Table 1: Phytochemistry of *P. santalinus* [8-10]

| Part                  | Chemical class of phytocomponents                        | Names of phytocomponents                                                                 |
|-----------------------|-----------------------------------------------------------|------------------------------------------------------------------------------------------|
| Bark                  | Terpenoids, steroid                                       | β-amyrone, betulin, lupinone, β-sitoster                                                  |
| Leaves                | Triterpenes, steroids                                     | Lupenone, lupeol, β-amyrone, epilupen, β-amyrin, stigmasterol, β-sitoster                  |
| Stem and heartwood    | Carbohydrates, flavonoids, terpenoids, alkaloids, saponins, tannins, glycosides, stilbene, lignin and lignans, isoflavones, sesquiterpenes, coumarins, aurone glycosides | Santalin A, santalin B, santalin C, cryptomeridol, oleanolic acid, pterocarpol, pterocarpotriol, pterocarpolide, pterosterol, savinin, calcoedin, eudesmin, neoflavones I and II, isoliquiritigenin, liquiritigen, eudesmol α,β,γ isomers, β-santalol, pterocarpol, isopoterocarpolone, pterocarpotriol, cryptomeridol, canesol K, canesolol L, 12,15-Dihydroxy-Curcumene, 5-Hydroxy-7-O-[3-methyl]-but-2-enykoumarin, 3-aryl coumarin, 6-Hydroxy-7-methoxy-2H-chromen-2-one, 6-Hydroxy-5-methyl-3',5',6'trimethoxy aurone-4-O-α-L-rhamnopyranoside, 6,4'-dihydroxy aurone-4-O-rutinoside Syringic acid, 2,4-Dihydroxy-benzoic acid ferulic acid, 2H-1-Benzopyran-2-one |
| Various parts         | Phenolic acids                                             |                                                                                                                                               |

*P. santalinus* ethanol extract decreased the degranulation of IgE-sensitized rat basophilic leukemia-2H3 mast cells and release of allergic mediators such as histamine and β-hexosaminidase in a dose-dependent manner. Extract treatment further inhibited the production of the pro-inflammatory cytokines (TNF-α and IL-1) and prostaglandin E2 production contributing to action against atopic dermatitis. 2,4-dinitrochlorobenzene-induced atopic dermatitis model in NC-Nga mice proved *P. santalinus* extract to reduce inflammatory cell infiltration, skin hypertrophy, and epidermal thickening. Flavonoids, namely, taxifolin, quercetin, and protocatechuic acid have anti-inflammatory activity may be responsible for the activity [26].

Protection against UV-B radiation

Ethanol extract of *P. santalinus* exhibited protective and anti-photoaging effect against UV-B irradiated human dermal fibroblasts by regulating the levels of matrix metalloproteinases, interleukin-6 (tissue destruction and inflammatory response mediators), checked phosphorylation of extracellular signal-regulated kinase, Jun N-terminal kinase, and p38 mitogen-activated protein kinase and activated AP-1 transcription factors which aided tissue regeneration [27].

Anti-tyrosinase activity

Inhibition of tyrosinase, tyrosinase-related protein 1 (TRP-1), TRP-2, and microphthalmia-associated transcription factor (MITF). *In vitro* studies on B16F0 melanoma cells proved the inhibitory effect of santalin by downregulation of tyrosinase, tyrosinase-related protein 1 (TRP-1) and tyrosinase-related protein 2 (TRP-2) and MITF (precursors for melanogenesis) and thereby proposed the role in treating hyperpigmentation [28].

Wound healing activity

Wound healing potential of *P. santalinus* gel formulation was studied by Biswas et al. on male Charles Foster rats. Significant wound contraction, less period of epithelization, enhanced hydroxyproline content, and collagen content in the gel treated group. *P. santalinus* was found to stimulate the generation of proteins and factors which regenerated the extracellular matrix and potentiated wound healing [29].

Anti-ulcer activity

Protective effect of the ethanol extract of heartwood of *P. santalinus* against gastric ulcers induced by ibuprofen was proved in rats as it normalized the sodium and potassium ion concentration and thus regulated gastric acid stimulation [30]. Ethanol extract of heartwood of *P. santalinus* inhibited the growth of *Helicobacter pylori* in rat gastric epithelial cells and reduced urease activity which promoted its growth [31].

Treatment of menorrhagia (Dysfunctional uterine bleeding)

In the study by Mishra et al., *P. santalinus* along with *Berberis aristata*, *Rasanjana* (extract of *B. aristata* in milk), *Swertia chirita*, *Cyperus rotundus*, *Aegle marmelos*, *Calotropis procera*, and *Adhatoda vasica* in the form of decoction (Drayya kadikalhay) and intrauterine instillation of Drayya Tail were evaluated in women suffering from menorrhagia. Results suggested decreased duration and magnitude of menstrual blood loss, normalized consecutive menstrual cycles. Attenuation of raised biomarker serum vascular endothelial growth factor-A (VEGF-A) improved the symptoms of menorrhagia by decreased fibrinolytic and vasodilatory effects on the endometrium [32].

Treatment of acne vulgaris

Herbal formulation containing *Emblica officinalis*, *Citrus aurantium*, *Psidium guajava*, *Aloe vera*, *Curcuma longa*, *A. indica*, *P. santalinus*, and *Ocimum sanctum* can be used for acne treatment due to its bacteriostatic effect on acne causing *S. aureus* and *E. coli*. *P. santalinus* possesses soothing and cooling effect on the skin and relieved from symptoms such as pain and redness [33].

Treatment of neonatal jaundice

Amruta Abheervadi drops are used for treating neonatal jaundice in Ayurveda. Amruta Abheervadi drops contain *Tinospora cordifolia*, *Asparagus racemosus* (Abbeuru), *Tinospora cordifolia*, *A. indica*, *P. santalinus*, and *Hemidesmus indicus*. [34].

Protective action against gamma radiation

Polyphenols extracted from *P. santalinus* hydroalcoholic extract, namely, vanillic acid, chlorogenic acid, protecatechuic acid, rosmarinic acid, eudesmin, and astragalin protected against gamma radiation-induced inflammation, cytotoxicity, and lipid peroxidation *in vitro* and *in vivo* studies [21].

Anticancer activity

Methanol extract of *P. santalinus* stem-induced apoptosis in human cervical adenocarcinoma cell line (HeLa cell line) dose-dependently. Proteolytic cleavage of poly-ADP ribose polymerase-activated caspase-3,8,9, leading to apoptosis and loss of cell viability, DNA fragmentation, chromatin condensation, DNA fragmentation, and sub-G1 phase accumulation [35].

Anti-adiopenetic and associated inflammation

*In vitro* anti-adiopenetic and anti-inflammatory potential of chloroform extract of *P. santalinus* heartwood at 200 μg/ml was evident on 3T3L1 cell line due to downregulation of PPAR-γ and SREBP-1c-mediated decreased lipid accumulation, triglyceride accumulation, and inflammatory markers, TNF-α and IL-6. Enhanced adiponectin
and mRNA expression of fat burning protein UCP-1 improved effective against adipogenesis, insulin resistance, inflammation, and obesity [36].

Pharmacological activities of various parts of *P. santalinus* are given in Table 2.

**DERMATOLOGICAL APPLICATIONS OF PHYTOCONSTITUENTS OF *P. SANTALINUS***

Pterostilbene and cream formulation with 0.4% pterostilbene protected against UV-induced sunburn (erythema), photoaging, tanning, and mutagenicity. Sunscreen protection factor indicated the protection against UV-B rays. Pterostilbene scavenges free radicals produced due to oxidative stress caused by UV-B radiation exposure. Pterostilbene proves to have vital role in sunscreen formulations [37]. Promising UV-B rays protective effect of liposomal formulation of pterostilbene was seen in a study by Sirerol *et al.* on female SKH-1 hairless mice. Pterostilbene treatment protected from photoaging, inflammation, and skin wrinkling after acute UV-B radiation (360 ml/cm²) and prevented skin carcinogenesis in mice due to chronic UV-B irradiation (180 ml/cm²; three doses in a week for 30 weeks) by upregulation of antioxidant enzymes, glutathione, CAT, superoxide, and glutathione peroxidase, as a result of transcription factor nuclear factor erythroid 2-related factor 2 (Nrf2) activation, the antioxidant response element (ARE) causing expression of antioxidant enzymes [38].

A cream formulation with 0.4% w/w pterostilbene possessed *in vitro* anti-melanogenic activity and *in vivo* skin brightening and anti-aging effect. *In vitro* study proved inhibition of tyrosinase, collagenase, and elastase enzymes. The cream was found to hydrate, repair, rejuvenate the skin, and reduce fine lines and wrinkles in healthy male and female volunteers. The activation of cytoplasmic and surface membrane estrogen receptors by pterostilbene maintains skin elasticity and collagen content, reduced wrinkles, and promoted hydration [39].

Savinin was found to downregulate UV radiation-induced expression of metalloproteinases by blocking the DNA binding site of photo-induced

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**Table 2: Pharmacological activities of *P. santalinus* [9-13,16,19,22,23,25]**

| S. No. | Pharmacological actions         | Part used        | Extract     | Mechanism of action                                                                 |
|-------|--------------------------------|------------------|-------------|-----------------------------------------------------------------------------------|
| 1     | Anticholinesterase              | Bark             | Methanol    | Inhibition of brain acetylcholinesterase and enhancement in memory in mice         |
| 2     | Antifungal                      | Leaves           | Ethyl acetate | Disruption of the fungal cell wall by flavonoids                                  |
| 3     | Hypoglycemic effect             | Bark             | Aqueous, ethanol, hexane | Activation of the remnant beta cells and improvement in insulin response at cellular level |
| 4     | Antipyretic                     | Heartwood        | Aqueous     | Prevention of activation of cyclooxygenase and prostaglandin formation             |
| 5     | Antibacterial                   | Bark and leaves  | Methanol    | Inactivation of microbial enzymes, transport proteins and adhesins, loss of cell membrane integrity |
| 6     | Hepatoprotective effect         | Heartwood        | Methanol    | Enhancement of antioxidant enzymes in the liver in rats                           |
| 7     | Nephroprotective effect         | Heartwood        | Methanol    | Enhancement of antioxidant enzymes SOD, CAT, GPx, GR, and GST in the kidney in rats. |
| 8     | Antityrosinase                  | Heartwood        | Acetone extract | Downregulation of tyrosinase, TRP-1TRP-Z, and MITF (precursors for melanogenesis)       |
| 9     | Wound healing                   | Stem powder      | -           | Stimulation of generation of proteins and factors which regenerated the extracellular matrix |
| 10    | Anti-ulcer                      | Heartwood        | Ethanol     | Anti-*Helicobacter pylori*                                                        |

SOD: Superoxide dismutase, CAT: Catalase, GPx: Glutathione peroxidase, GR: Glutathione reductase, GST: Glutathione S-transferase
of AP-1 transcription factor in an in silico study. Downregulation of metalloproteinases may restore the skin integrity, elasticity, and tensile strength by decreased degradation of collagen and extracellular matrix proteins and protect from photaging of the skin [40]. Cedrol isolated from Pterocarpus genus proved to be a promising anti-wrinkle agent by enhancing dermal fibroblast cell proliferation, leading to increased collagen and elastin synthesis through intracellular signaling pathways [41].

In addition, cedrol can be used as a fragrance material in cosmetics and non-cosmetic preparations [42]. Topical application of cedrol (200 mg/kg) ameliorated cyclophosphamide-induced hair damage and alopecia. Restoration of hair growth and normal hair follicles with abundant melanin content in cedrol-treated mice was attributed to suppression of p53 protein transcription-induced hair follicle apoptosis, activation of MAPK, and ERK intracellular signaling pathways prevent apoptosis and protect dermal fibroblasts [43].

Betulin, a terpenoid, found in P. santalinus modulated 7,12-dimethylbenzanthracene and 12-O-tetradecanoylphorbol 13-acetate (TPA)-induced skin cancer in vivo and ex vivo studies in mice as evident from spectral signatures of surface-enhanced Raman spectroscopy [44]. Betulin oleaginous formulation showed promising anti-inflammatory and anti-tumor potential against actinic keratoses [45]. Betulin also showed promising candidate as a wound healing agent by promoting reepithelization of wounds in a Phase-III clinical trial [46]. Isoquiritigenin and beta-sitosterol found in the heartwood and bark proved to be useful in atopic dermatitis by suppressing inflammatory cytokines, chemokine, and IgE antibody production [47].

Ferulic acid acts as an antioxidant against UV-A and UV-B radiation in keratinocytes and fibroblasts by scavenging reactive oxygen species preventing carcinogenesis and elastosis. Decrease in metalloproteinases supports its role as anti-photaging agent. It has shown to accelerate wound healing by enhancing collagen [48]. α-Bisabolol, a sesquiterpene alcohol, isolated by Jiang et al., from P. santalinus has a role in cosmetic formulations as a depigmentation agent by inhibiting melanocyte-stimulating hormone-induced CAM and tyrosinase activation and as a permeation enhancer [49,50]. β-eudesmol was found to inhibit nuclear factor-kappa B (NF-κB) and metalloproteinases activation in human dermal fibroblasts. DPPH radical scavenging activity assay, glutathione (GSH) estimation proved its anti-inflammatory and antiaging potential [51].

Syringic acid found in P. santalinus inhibited UV-B-induced skin cancer in vitro and in vivo by inhibition of inflammatory responses (cylooxygenase-2, matrix metalloproteinase-1, and prostaglandin E2 expression), inhibition of phosphorylation of mitogen-activated protein kinases. Akt 11 signaling pathways, epidermal growth factor receptor, and protein-tyrosine 13 phosphatase-κ activity [52].

Lupeol and its ester derivatives have skin damage healing property and in vivo studies prove its use as a wound and burn healing agent [53,54].

DIVERSE APPLICATIONS OF P. SANTALINUS

Santalin as a histological stain

Histological stain of santalin isolated from the heartwood of P. santalinus to stain histological tissues was prepared by Sengupta et al. Santalin was found to be remarkable nuclear material stain Santalin stained striations on the voluntary tissues, Nissl granules, and cranial nerve fibers in the pons, thin elastic fibrils and thick elastic fibers in the skin tissue, and chromatin bars and nucleus in Entamoeba histolytica cysts [55].

Antidote for snake and scorpion bite

Stem bark of P. santalinus along with garlic and pepper is ground together and infusion is prepared and given orally as an antidote for snakebite [56]. In India, the heartwood is used as an antidote for scorpion bite [57].

TOXICITY STUDIES

Azamthulla et al. studied the acute toxicity profile of ethanol and chloroform extract in five groups of adult male Wistar rats, at doses 50, 500, 1000, and 2000 mg/kg, respectively, no mortality and toxic effects were seen up to the dose of 2 g/kg in 24 h. Adult male Wistar rats were orally administered ethanol and chloroform extract of four groups at doses 100, 400, and 750 mg/kg, respectively, twice daily and for 28 for subacute toxicity study. No behavioral, locomotor, and biochemical toxic effects were observed in the toxicity studies [58].

However, allergic contact dermatitis was observed in a woman in India, after applying P. santalinus bark powder paste for 2 months. Symptoms included itchy erythema and edema over the post-chickenpox scars were found to diminish after topical corticosteroid treatment [59].

CONCLUSION

This review entails brief description on the phytoconstituents and pharmacological activities of P. santalinus. Phytoco constituents, namely, terpenoids, flavonoids, and pterostilbene are responsible for the neuroprotective, antimicrobial, hypoglycemic, antipyretic, anti-inflammatory, and hepatoprotective activities. Santalin plays a peculiar role in the holistic utilization of P. santalinus in the fields of dyeing staining, therapeutic, and cosmetics. Indeed, P. santalinus is a treasure of health.

ACKNOWLEDGMENTS

Authors are thankful to Dr. Pravin. D. Chaudhari, Professor and Principal, Modern College of Pharmacy, Nigdi, Pune, for their constant guidance, motivation, and being supportive during project.

AUTHORS’ CONTRIBUTIONS

Dr. Mohini Chetan Kuchekar conceptualized the idea, writing, and reviewed the manuscript. Vijay Navghare wrote, reviewed, and finalized the manuscript. Amrita Milind Kulkarni, Aishwarya Avinash Zamhare, and Bharti Jagdish Choudhary contributed in information collection and writing the paper. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

All authors declare that we have no conflicts of interest.

AUTHORS’ FUNDING

No funding for article writing needed.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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