INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Article

Sandalwood: A phytochemical and pharmacological Overview

Shivani Wadichar*, Pratik Dhokane, Swapnil Tirmanwarr, Gopal Pondhe, Saurabh Kolaskar, Swejal Tarahane

Priyadarshini J. L. College of Pharmacy, Nagpur, Maharashtra, India – 440016.

ARTICLE INFO

Published: 09 Jan. 2025
Keywords:
Sandlewood, oil, industry, santalols, antiviral, pharmaceutical.
DOI:
10.5281/zenodo.14605347

ABSTRACT

The sandalwood tree, scientifically known as Santalum album L and belonging to the Santalaceae family, is commonly referred to as Chandana in India. The average oil yield from this tree ranges from 4.5% to 5%. Sandalwood oil's sweet, powerful, and long-lasting fragrance makes it highly valuable in the perfume industry. The fragrant components of sandalwood oil primarily consist of α- and β-santalols. Research has shown that sandalwood oil exhibits antiviral activity against herpes simplex viruses 1 and 2, along with anticancer, insect-repellent, antioxidant, anti-inflammatory, antipyretic, and antibacterial properties. Consequently, sandalwood oil has significant potential for use in pharmaceuticals and various other industries, both now and in the future

INTRODUCTION

The Santalum genus includes 30 genera and 400 species in tropical and temperate regions, with about 25 species from India to the Pacific islands. The major species are Santalum album, Santalum pyrularium, Santalum spicatum, and others. Santalum album, also known as Indian sandalwood, is a small evergreen tree native to Southern India, known for its scented heartwood and oil content. It grows at altitudes of 2000–3000 feet and requires a minimum of 20–25 inches of rainfall per year. The tree is cultivated in India and abroad and is known for its distinctive fragrance in oil and wood. Sandalwood is mainly exploited for its oil, obtained through steam distillation of its roots and heartwood. The state of Mysore annually produces 2000 tons of Sandalwood, strictly regulated by the government.

Plant Profile

Kingdom:	Plantae
Clade:	Tracheophytes
Clade:	Angiosperms
Clade:	Eudicots
Order:	Santalales
Family:	Santalaceae

***Corresponding Author:** Shivani Wadichar
Address: Priyadarshini J. L. College of Pharmacy, Nagpur, Maharashtra, India – 440016.
Email ✉: shivaniwadichar00@gmail,.com

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Genus: Santalum Species: S. album

Figure 1. Sandlewood

The plant was primarily used for its fragrant sandalwood oil, which was obtained through steam distillation. It is a small evergreen tree with smooth, drooping branches. The sapwood is white and odorless, while the heartwood is yellowish-brown and strongly scented. The leaves are elliptic-lanceolate, with dimensions of 3.8 – 6.3 by 1.6 to 3.2 cm, and have a thin, acute base. The flowers are slender, brownish-purple, and arranged in terminal and auxiliary panicle clusters that are shorter than the leaves. The fruit is a globose drupe, about 1.3 cm in diameter, and purple-black in color. The seed is solitary and the endocarp is hard-ribbed. [1]

Traditional Uses

Sandalwood is primarily used as a coolant and also has sedative and astringent properties. It is used as a disinfectant in the genitourinary and bronchial tracts, as well as a diuretic, expectorant, and stimulant. The sweet, powerful, and long-lasting odor of sandalwood oil makes it useful in the perfume industry. It is also used as a tonic for the heart, stomach, liver, and as an antidote for poisoning, fever, and for memory improvement. Additionally, it is used as a blood purifier. In Ayurveda, sandalwood is mentioned for the treatment of various other ailments such as diarrhea with bleeding, intrinsic hemorrhage, bleeding piles, vomiting, poisoning, hiccoughs, the initial phase of pox, urticaria, eye infections, and inflammation of the umbilicus. [1,2]

Reported Phytochemicals In Sandalwood

The volatile oil extracted from Santalum album L, derived from the roots and heartwood, is a colorless to yellowish, viscous liquid with a peculiar heavy sweet odor. The chief constituent of the oil is santalol (90% or more), a mixture of two primary sesquiterpene alcohols, C15H24O, namely, a-santalol (boiling point 166–167ºC) and b-santalol (boiling point 177–178ºC). A-santalol is the major component, and the oil has a refractive index of 1.499–1.506, specific gravity of 0.962–0.985, and optical rotation of -19–20º. [3]

The fragrant parts of sandalwood oil a- and b santalols were separated in pure form and a 0.5–0.8% higher yield in sandalwood oil was obtained by extracting wood powder with benzene (Shankaranaryana, 1989). Two minor components namely cyclosantalal (0.21–2.26%) and isocyclo-santalal (0.11–1.47%) new sesquiterpene aldehyde were reported. Also a new acid – ketosantalic (as methyl ester) and gamma – L – glutamyl-S-(trans-1-propenyl)-L-cysteine sulfoxide, an interesting natural sulfoxide diastereoisomers, have been isolatedfrom sandal. Some authors also report the presence of Tricyclosantalal, a-santalene, trans-b-bergamotene, b-santalene (S & E), a-curcumine, a-santalol, beta-santalol (S&E), nuciferol, a-santalal and b-santalal in Santalum album. [4,5]

Sandalwood oil was also used in the process of Nardenisation, a technique for separating terpenic components by shaking with two immiscible

solvents. The polar solvent dissolves oxygenated components, while the non-polar solvent holds the non-oxygenated components without santalenes. [6]

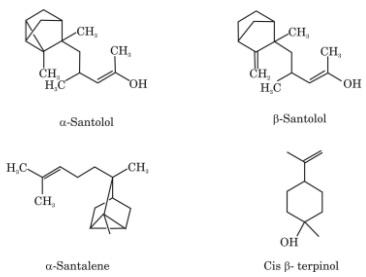

Figure 2. Chemical constituents of Sandlewood

Pharmacological Activities

1. **Tetranychus Urticae Repellent Effect of Santalol from Sandalwood Oil**

In a study, thirty-four essential oils were tested for their repellent effects on the two spotted spider mite, Tetranychus urticae, at a concentration level of 0.1% using choice and no-choice laboratory bioassays. Out of these, 20 essential oils demonstrated significant repellent effects against Tetranychus urticae in the choice tests. When these 20 essential oils were further tested in subsequent no-choice tests, only sandalwood oil showed significant repellent effects against Tetranychus urticae. [7]

2. **The Apoptotic Effects of a-Santalol in Inhibiting the Growth of Human Prostate Cancer Cells**

The apoptotic cell death induced by a-santalol and the activation of caspase-3 were significantly reduced in the presence of pharmacological inhibitors of caspase-8 and caspase-9. A derivative of sandalwood oil, a-santalol, has been found to induce apoptosis in human prostate cancer cells. [8]

3. **Antiviral Activity of Sandalwood Oil Against Herpes simplex Virus-1 and 2 (HSV-1 & 2)**

It has been reported that the replication of Herpes simplex viruses is inhibited in the presence of the oil. The effect was dose-dependent and more pronounced against HSV-1. A slight decrease in the effect was observed at higher levels of infection. The oil was not virucidal and showed no cytotoxicity. [9]

4. **b-Santalol In Vitro Anti-Viral Effect Against Influenza Viral Replication**

b-Santalol demonstrated 86% activity against the influenza A/HK (H3N2) virus at 100 µg/ml with no cytotoxicity, reducing visible CPE formation. [10]

5. **Insect Growth Inhibitor from Bark of S. Album**

Triterpenoid-urs-12-en-3b-yl palmitate (melting point 115-116°C, specific rotation +200, molecular formula C46H80O2) has been isolated from sandalwood. When applied topically to fresh pupae of forest insects such as Atteva fabriciella, Eligma narcissus, and Eupterote geminate, it resulted in the production of morphologically defective adults, indicating the compound's growth inhibition activity. Additionally, it was observed to have chemosterilant activity on freshly emerged moths of Atteva fabricella. [11]

6. **In Vitro Antifungal Activities**

A detailed study was conducted on seven essential oils and their constituents to assess their antifungal properties against eight strains known to be human pathogens. Sandalwood oil was found to be effective against Microsporum canis, Trichophyton mentagrophytes, and T. rubrum, but

ineffective against Candida albicans, Aspergillus niger, and A. fumigatus when compared to tolnaftate and clotrimazole. [6]

7. Clinical Evaluation in Treatment of Various Eye Infections as Herbal Eye-Drop Preparation

An examination was conducted on herbal eye drops that contain Sandalwood, Nimba, Bhringaraj, Nirgundi, Sobhanjana, Punarnava, Satapatri, Madhu, etc., for a period of six months in cases of refractive error and cataracts. Some patients reported improvements in associated symptoms, while a few noted subjective improvements in vision. Notably, no side effects of the medication were reported by any of the patients (Paul et al., 1992).

8. Antibacterial Activities of Oil and Bark

Investigations have revealed that some Indian essential oils, including Sandalwood oil, have antibacterial efficacy against various bacteria. This includes Bacillus anthracis, Bacillus mycoides, Bacillus pumilis, Micrococcus glutamicus, Sarcina lutea, and Staphylococcus albus. The oils also showed inhibition against E.coli, Salmonella paratyphi, Xanthomonas campestris, and Xanthomonas malvacearum at different concentrations ranging from 100% to 10%. Additionally, the aqueous extract of air-dried powdered bark, in concentrations of 25 to 1000 µg/ml in phosphate buffer, demonstrated good inhibition against the virulent species Staphylococcus aureus. [12]

9. Skin Cancer and Chemopreventive Efficacy of a- Santalol

It has been studied that a-santalol, an active component of sandalwood oil, has skin cancer preventive efficacy in murine models of skin carcinogenesis using human epidermoid carcinoma A-431 cells. The study assessed the effect of a-santalol at concentrations of 25–75 µml on cell numbers, showing a time-dependent decrease due to cell death. Mechanistic studies indicated the involvement of caspase-3 activation, poly (ADP-ribose) polymerase cleavage, disruption of mitochondrial membrane potential, and release of cytochrome-C into the cytosol, suggesting the involvement of both caspase-dependent and independent pathways. [13]

10. The Evaluation of Nitric Oxide Scavenging Activity

The extracts of Indian medicinal plants including S. album were examined for their possible regulatory effect on nitric oxide (NO) levels using sodium nitroprusside as an NO donor in vitro. Most of the plant extracts demonstrated direct dose dependant scavenging on NO and exhibited significant activity. [14]

11. Antioxidant Activity

Santalum album, along with other medicinal plants used in Ayurvedic Rasayana such as Embellica officinalis, Curcuma longa, Mangiferra indica, Momordica charantia, Swertia chirata, and Withania somniferra, have been studied for their historical, etymological, morphological, phytochemical, and pharmacological properties. These studies have shown that these plants contain antioxidant principles, which support their traditional medicinal use in the past as well as in the present. [15]

12. Anti-Ulcerogenic Activity

The herbal preparation UL-409, containing six medicinal plants (Santalum album L, Glycyrrhiza glabra L, Saussurea lappa C.B Clarke, Aegle marmelos Corr, Foeniculum vulgare Mill, Rosa damascena Mill) at a dose of 600 mg/kg, showed significant anti-ulcerogenic activity. It effectively prevented ulcerations induced by stress, aspirin, and alcohol in Wister albino rats. (Venkataranganna et al., 1998).

13. Effect on Central Nervous System

The sedative effect of sandalwood oil and HESP oil was studied on albino mice of either sex using doses of 500/600 mg/kg and 600/800 mg/kg,

respectively. A 0.2% tween 80 was used as a control. Severe depression occurred, leading to death at LD50 of 558 mg/kg and 747.6 mg/kg, respectively. [16]

14. **Antipyretic Effect**

The sedative effect of sandalwood oil and HESP oil was studied on albino mice of either sex using doses of 500/600 mg/kg and 600/800 mg/kg, respectively. A 0.2% tween 80 was used as a control. Severe depression occurred, leading to death at LD50 of 558 mg/kg and 747.6 mg/kg, respectively. [16,17]

15. Effect on Blood Pressure/Respiration

A prolonged fall in carotid BP, increase in heart rate and respiration has been observed while investigating effect of sandalwood oil (8 mg/ kg) and HESP (10 mg/kg) in adult, healthy mongrel dogs (10–12 kg anaesthesised with 35 mg/kg pentobarbitone). [16,17]

16. Anti-Inflammatory Effect

Investigations have revealed that sandalwood oil and HESP oil have an anti-inflammatory effect against formalin-induced paw edema in albino rats at a dose of 200 mg/kg. A control using 0.2% tween 80 and a standard using 150 mg/kg of phenyl butazone were also used for comparison. A significant reduction in edema was observed in the case of HESP. [16,17]

17. **Toxicology**

The oil has been found to be irritating in both mouse and rabbit skin test models. The santalols and related compounds that inhaled sandalwood fumes under experimental conditions have been identified in the blood of mice, indicating that systemic absorption of these compounds can occur. [18]

Marketed Formulations

There are many sandalwood products popular around the world. Many brands and companies use sandalwood in cosmetics and medicinal products.

Table 1. Different uses of Sandlewood

Sr. no.	Uses	Products
1.	Cosmetics	1. Blush 2. Body wash 3. Eye shadow 4. face powder 5. Fairness creams 6. Fragrance 7. oil 8. Perfumes 9. Shampoo 10. Soaps 11. Sunscreen cream
2.	Medicinal uses	1. Anti-bacterial agent 2. Anti-cancer agent 3. Anti fungal 4. Anti inflammatory 5. Anti pyratic 6. Anti-Ulcerogenic 7. Aromatherapy 8. CNS stimulant 9. Im treatment of Herpes 10. Insect repellent 11. Protection from UV 12. To regulate blood pressure 13. Used to cool the body from heat

		14. Viral repellent
3.	Other	1. As a relaxant 2. As support logs 3. Essence sticks 4. Face paint 5. Symbolism

CONCLUSION:

Based on the provided information, it can be concluded that sandalwood is a remarkable plant. It is cultivated both in India and other countries, and is well-known for the distinctive fragrance of its oil and wood. Sandalwood is primarily harvested for its oil, which exhibits various pharmacological properties that could be beneficial in medical and pharmaceutical research and development. With a wide range of sandalwood products used globally, further experimentation and study can enhance the understanding of this extraordinary plant and contribute to the development of economic infrastructure.

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HOW TO CITE: Shivani Wadichar*, Pratik Dhokane, Swapnil Tirmanwarr, Gopal Pondhe, Saurabh Kolaskar, Swejal Tarahane, Sandalwood: A phytochemical and pharmacological Overview, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 01, 334-341. https://doi.org/10.5281/zenodo.14605347