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DECODING THE BOTANICAL AND THERAPEUTIC IDENTITY OF CHANDAN (SANTALUM ALBUM L.) AND RAKTA CHANDAN (PTEROCARPUS SANTALINUS L.F.): A COMPARATIVE PHARMACOGNOSTICAL AND PHYTOCHEMICAL PERSPECTIVE

Dr. Neha Yadav[1*], Dr. Sunita D. Ram[2], Dr. Preeti Solanki[3], Dr. Keshori Sharma[4], Dr. Shiromani Mishra[5], Dr. Shivkumar Mishra[6]

[1*]MD scholar, Department of Dravyaguna Vigyana, Government Dhanwantari Ayurved Medical College, Ujjain (M.P.), yneha9810@gamil.com
[2]Professor, Department of Dravyaguna Vigyana, Government Dhanwantari Ayurved Medical College, Ujjain (M.P.), drsunitadram72@gmail.com
[3]MD scholar, Department of Dravyaguna Vigyana, Government Dhanwantari Ayurved Medical College, Ujjain (M.P), preetifly.solanki@gmail.com
[4]MD scholar, Department of Dravyaguna Vigyana, Government Dhanwantari Ayurved Medical College, Ujjain (M.P.), dr.keshoris@gmail.com
[5]Professor & HOD, Department of Dravyaguna Vigyana, Government Dhanwantari Ayurved Medical College, Ujjain (M.P.), shiromishra@gmail.com
[6]Associate Professor, Department of Dravyaguna Vigyana, Government Dhanwantari Ayurved Medical College, Ujjain (M.P.), dr.shivkumarmishra88@gmail.com
*Corresponding author: Dr. Neha Yadav, Email: yneha9810@gamil.com

ABSTRACT

Chandan (Santalum album L.) and Rakta Chandan (Pterocarpus santalinus L.f.) are two botanically distinct species that are highly revered in Ayurveda. Despite their similar common names, they differ significantly in their phytochemical composition, pharmacological properties, and therapeutic applications.

Chandan is primarily characterized by the presence of sesquiterpenoid alcohols, particularly α-santalol and β-santalol1. These compounds are responsible for its characteristic aroma as well as its antimicrobial, anti-inflammatory, calming, and neuroprotective properties. Owing to its fragrant essential oil, Chandan is extensively used in perfumery, cosmetics, and aromatherapy.

In contrast, Rakta Chandan is rich in bioactive constituents such as santalins (A, B, and Y), lignans, and flavonoids2. These phytochemicals impart its distinctive deep red color and contribute to its potent antioxidant, hepatoprotective, anti-inflammatory, and antidiabetic activities. Consequently, Rakta Chandan is widely employed in traditional medicine for the management of liver disorders, blood purification, skin diseases, and other therapeutic applications.

Overall, while Chandan is globally recognized for its fragrance and essential oil production, Rakta Chandan is valued primarily for its medicinal potential. This comparative study highlights the complementary importance of these two species: Chandan serves as an important source of aromatic sesquiterpenes with calming and antimicrobial properties, whereas Rakta Chandan represents a rich reservoir of therapeutic pigments and bioactive compounds with diverse pharmacological benefits.

KEYWORDS: Chandan, Rakta Chandan, phytochemistry

INTRODUCTION

Ayurveda, the traditional system of Indian medicine, has long relied on medicinal plants as a primary source of healthcare. The discipline of Dravyaguna Vigyana, which deals with the identification, properties, and therapeutic applications of medicinal substances, forms the foundation for the rational use of these botanicals. Among the numerous medicinal plants described in Ayurvedic texts, Chandan (Santalum album L.) and Rakta Chandan (Pterocarpus santalinus L.f.) are highly valued for their extensive therapeutic, cultural, and religious significance. Although both species are commonly referred to as "Chandan," they belong to different botanical families and exhibit distinct morphological characteristics, phytochemical compositions, and pharmacological activities. Santalum album is primarily recognized for its aromatic heartwood and essential oil, which are rich in sesquiterpenoid alcohols such as α-santalol and β-santalol. These constituents are responsible for its characteristic fragrance and contribute to its antimicrobial, anti-inflammatory, antioxidant, and neuroprotective properties, making it an important resource for perfumery, cosmetics, aromatherapy, and traditional medicine. In contrast, Pterocarpus santalinus L.f.is characterized by the presence of bioactive compounds, including santalins, lignans, flavonoids, and phenolic constituents, which impart its distinctive red color and are associated with antioxidant, hepatoprotective, anti-inflammatory, antidiabetic, and cardioprotective activities3. Consequently,

Rakta Chandan has been widely employed in Ayurvedic formulations for the management of blood disorders, liver diseases, skin ailments, and inflammatory conditions.
Despite their widespread use in traditional medicine, these two species are frequently confused because of their similar vernacular names. Such confusion may result in the inappropriate substitution or adulteration of herbal raw materials, potentially affecting the quality, safety, and therapeutic efficacy of herbal formulations. Therefore, a clear understanding of their botanical identity, phytochemical composition, and pharmacological properties is essential for ensuring their accurate identification and rational utilization.

1.1Taxonomical differences4

(Table-1)

Taxonomic Rank	**Santalum album L. (Chandan / White Sandalwood)**	**Pterocarpus santalinus L.f. (Rakta Chandan / Red Sandalwood)**
Domain	Eukaryota	Eukaryota
Kingdom	Plantae	Plantae
Division	Tracheophyta (vascular plants)	Tracheophyta (vascular plants)
Class	Magnoliopsida (dicotyledons)	Magnoliopsida (dicotyledons)
Order	Santalales	Fabales
Family	Santalaceae	Fabaceae (Legume family)
Genus	Santalum	Pterocarpus
Species	Santalum album L.	Pterocarpus santalinus L.f.
Common Names	White sandalwood, Indian sandalwood, Chandan	Red sandalwood, Rakta Chandan, Red sanders
Native Range	India, Southeast Asia, Northern Australia	Native to Southern India, also found in Sri Lanka, Myanmar

1.2 Vernacular Names5

(Table-2)

Language / Region	**Santalum album L. (White Sandalwood / Chandan)**	**Pterocarpus santalinus L.f. (Red Sandalwood / Rakta Chandan)**
Sanskrit	Chandana, Sveta Chandana	Raktachandana, Lohitachandana
Hindi	Chandan	Rakta Chandan, Lal Chandan
Marathi	Chandan	Raktachandan
Gujarati	Chandan	Raktachandan
Kannada	Gandha, Srigandha	Rakta Chandan, Kempugandha
Telugu	Gandham	Erra Chandanam
Tamil	Sandhanam	Sivappu Sandhanam
Malayalam	Chandanam	Rakta Chandanam
Bengali	Chandan	Rakta Chandan
English	White Sandalwood, Indian Sandalwood	Red Sandalwood, Red Sanders

1.3Properties6

(Table-3)

Aspect	**Santalum album L. (White Sandalwood / Chandan)**	**Pterocarpus santalinus L.f. (Red Sandalwood / Rakta Chandan)**
Rasa (Taste)	Madhura (Sweet), Tikta (Bitter)	Tikta (Bitter), Kashaya (Astringent)
Guna (Qualities)	Laghu (Light), Snigdha (Unctuous)	Laghu (Light), Ruksha (Dry)
Virya (Potency)	Shita (Cooling)	Shita (Cooling)
Vipaka (Postdigestive effect)	Madhura (Sweet)	Katu (Pungent)
Prabhava (Specific action)	Manas-shamaka (calms mind), fragrance-related effects	Rakta-shodhaka (blood purifier), pigment-related effects

1.4Classical Inputs

Early Samhita period: In the major Ayurvedic Saṃhitaas, including the Caraka Saṃhita7, Susruta Samhita8, and Aṣṭanga Hṛdaya9, Chandana was primarily described as a cooling, aromatic medicinal drug with applications in conditions such as burning sensation (daha) and other Pitta-related disorders. The early texts generally did not establish the detailed botanical distinction between Sveta Chandana (white sandalwood) and Rakta Chandana (red sandalwood) that became prominent in later lexicographical literature.

Development of the Nighantu tradition: With the emergence of specialized Ayurvedic materia medica texts (Nighantus), descriptions of medicinal substances became more detailed, including their synonyms, properties,

actions, and classifications. Texts such as the Dhanvantari Nighantu10, Kaiyadeva Nighantu11, and Raja Nighantu12 contributed to the increasingly explicit recognition and differentiation of Sveta Chandana and Rakta Chandana in Ayurvedic pharmacognosy. The Dhanvantari Nighantu, for example, contains a dedicated Chandanadi Varga, while later Nighantus further developed the classification and descriptions of Chandana.
Bhavaprakash Nighantu13: The Bhavapraksha Nighantu, attributed to Bhavamisra and generally dated to the 16th century, represents a mature stage in the development of Ayurvedic materia medica. It provides systematic descriptions of medicinal substances, including their synonyms, pharmacodynamic properties, and therapeutic applications. The text contributed to the standardized understanding of different forms of Chandana within the later Ayurvedic tradition.

1.5 Distribution

Sveta Chandan (Santalum album L.)14

- Native to southern India, especially Karnataka, Kerala, and Tamil Nadu.
- Found in dry deciduous forests and cultivated in plantations.
- Prefers well-drained sandy or loamy soils.
- Occurs at altitudes up to 1200 m.
- Widely distributed due to commercial cultivation for sandalwood oil and timber.

Rakta Chandan (Pterocarpus santalinus L.f.)15

Endemic to southern Eastern Ghats of Andhra Pradesh.

- Restricted distribution compared to Sveta Chandan.
- Grows in tropical dry deciduous forests.
- Prefers rocky, gravelly soils with low fertility.
- Occurs at altitudes between 200–900 m.
- An endangered species with a restricted natural distribution in the Eastern Ghats of southern India and is regulated under CITES because of concerns regarding international trade and conservation.

2. MATERIALS AND METHOD

2.1 Pharmacognostical Difference16

Pharmacognostical evaluation plays a crucial role in the accurate identification and authentication of medicinal plants, thereby ensuring the quality, safety, and efficacy of herbal formulations. Sveta Chandana (Santalum album L.) and Rakta Chandana (Pterocarpus santalinus L.f.), although commonly referred to as "Chandana," exhibit distinct macroscopic, microscopic, organoleptic, and phytochemical characteristics that facilitate their differentiation.
Macroscopically, the heartwood of Sveta Chandana is pale yellow to yellowish-brown, fine-grained, moderately hard, and possesses a characteristic pleasant aroma due to the presence of volatile essential oils. In contrast, the heartwood of Rakta Chandana is deep red to reddish-brown, heavy, hard, close-grained, and lacks any characteristic fragrance.
Microscopic examination further distinguishes the two species. Sveta Chandana is characterized by the presence of oil cells containing volatile constituents, predominantly α-santalol and β-santalol, along with resin canals, vessels with simple pits, tracheids, and medullary rays. Conversely, Rakta Chandana lacks oil cells but contains abundant pigment-containing cells rich in santalins (A and B), which impart the characteristic red coloration. It also exhibits thick-walled fibers and vessels with bordered pits. The organoleptic properties of the two species also differ significantly. Sveta Chandana possesses a pleasant, sweet fragrance and a mildly cooling taste, whereas Rakta Chandana is virtually odorless and exhibits a tasteless to slightly bitter taste.

2.2 Macroscopic study

Figure 1 and 2; Heartwood of Santalum album L.and Pterocarpus santalinus L.f.

Root17 - The roots of Sveta Chandana are generally slender, woody, and pale brown externally, with a smooth surface and fine longitudinal striations. The inner tissue is lighter in color, aromatic, and shows the presence of oil cells that contribute to its characteristic fragrance. The roots are moderately hard, with a cooling touch, and

when cut, they release a faint sweet odor. In contrast, the roots of Rakta Chandana are thicker, heavier, and distinctly reddish-brown externally, with a rougher texture and prominent longitudinal fissures. The inner tissue is deep red, dense, and non-aromatic, reflecting the presence of pigment cells (santalin) rather than oil cells. Organoleptically, Sveta Chandana roots are fragrant and slightly sweet18, while Rakta Chandana roots are tasteless to mildly bitter and lack fragrance. Thus, the macroscopic difference lies in the color, texture, and aroma19—with Sveta Chandana roots being pale, smooth, and aromatic, and Rakta Chandana roots being dark red, coarse, and non-aromatic

Leaf20 - The leaves of Sveta Chandan (Santalum album L.) are simple, opposite, and decussate in arrangement, meaning each pair is placed at right angles to the next. They are ovate to elliptic in shape with entire margins, measuring about 3–8 cm in length and 1–4 cm in width. The texture is smooth and glabrous, with a shiny green upper surface and a lighter underside. Venation is reticulate, the apex is acute, and the base tapers gradually, supported by a short slender petiole. In contrast, the leaves of Rakta Chandan (Pterocarpus santalinus L.f.) are compound and imparipinnate, arranged alternately along the stem. Each leaf consists of 5–9 ovate or oblong leaflets, each measuring 3–9 cm in length, with entire margins and a smooth, leathery texture. The leaflets are dark green above and pale beneath, with reticulate venation, rounded apices, and asymmetric bases. The petiole is longer and supports the pinnate arrangement. Thus, the key diagnostic difference lies in the simple opposite leaves of Sveta Chandan versus the compound pinnate leaves of Rakta Chandan, which makes them easily distinguishable in macroscopic study. (Fig3,4)

Figure 3 and 4; Leaf of Santalum album L.and Pterocarpus santalinus L.f.

Flower20 - The flowering of Sveta Chandan generally occurs during the hot season, producing small, greenish-white to yellow, fragrant bisexual flowers in axillary cymes. Fruiting follows in the rainy season, yielding small globose drupes that ripen to a purplish-black color, each enclosing a single seed. In contrast, Rakta Chandan blooms in the summer with bright yellow flowers arranged in axillary racemes, which are larger and more conspicuous than those of Sveta Chandan. Fruiting occurs in the post-monsoon period, producing characteristic flat, orbicular pods with winged margins, typical of the Fabaceae family. These pods are indehiscent and usually contain one seed. Thus, while Sveta Chandan is marked by its inconspicuous aromatic flowers and fleshy drupes, Rakta Chandan is distinguished by its showy racemose flowers and winged pods, making their reproductive morphology clearly distinct.

Fruit - The fruits of Sveta Chandan are small, globose drupes measuring about 1–1.5 cm in diameter. They are initially green, turning purplish-black when ripe. The surface is smooth and shiny, enclosing a single hard seed within the fleshy pericarp. These drupes are attractive to birds and animals, aiding natural dispersal. In contrast, the fruits of Rakta Chandan are flat, orbicular pods with a distinctive winged margin, typical of the Fabaceae family. Each pod measures about 3–5 cm across, is indehiscent (does not split open), and usually contains a single hard, flattened seed. The winged structure of the pod facilitates dispersal by wind. Thus, macroscopically, Sveta Chandan fruits are fleshy, globose drupes, while Rakta Chandan fruits are dry, winged pods.

2.3 Microscopic study

Root - The transverse section of Sveta Chandan root reveals a small central pith composed of rounded parenchyma cells, surrounded by a ring of xylem with radially arranged vessels that are relatively fewer in number and lighter in tone. Resin ducts are sparse and small, scattered within the cortex, while the cambium forms a thin boundary separating xylem and phloem. The phloem zone is compact, and the outer periderm shows pale brown cork cells. In contrast, Rakta Chandan root exhibits a prominent central pith with reddish pigmentation, encircled by abundant xylem vessels arranged radially. The cortex is deep red and contains numerous large resin ducts, which

are diagnostic of this species. The phloem is comparatively broader, and the periderm is dark reddish-brown, giving the section a striking appearance. Thus, microscopically, Sveta Chandan is characterized by its lighter tissues and fewer resin ducts, whereas Rakta Chandan is distinguished by its pigmented pith, abundant resin ducts, and darker cortical tissues, making them easily identifiable under the microscope. (Fig 5)

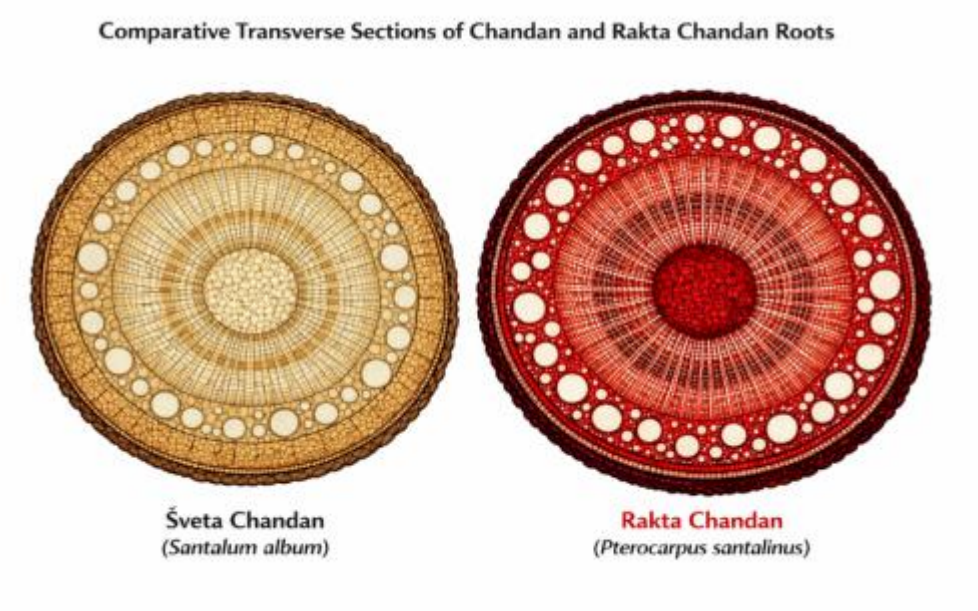
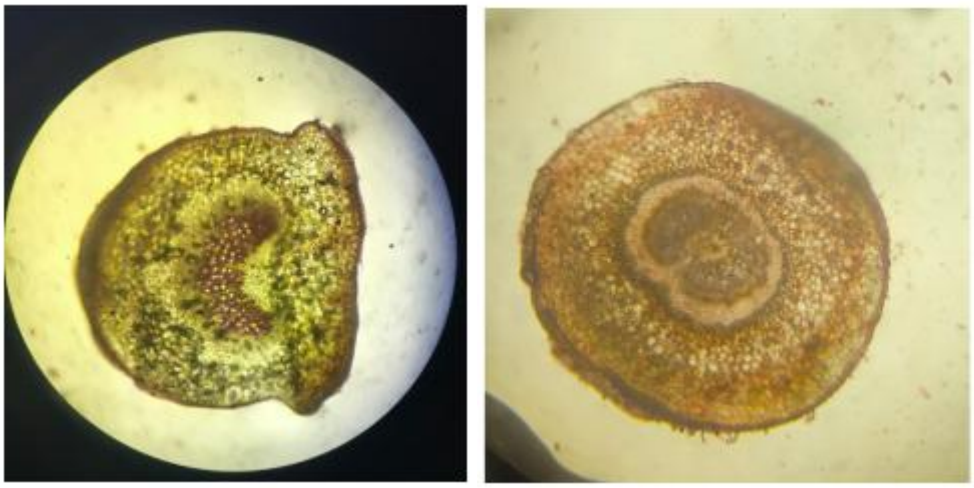


Figure 5

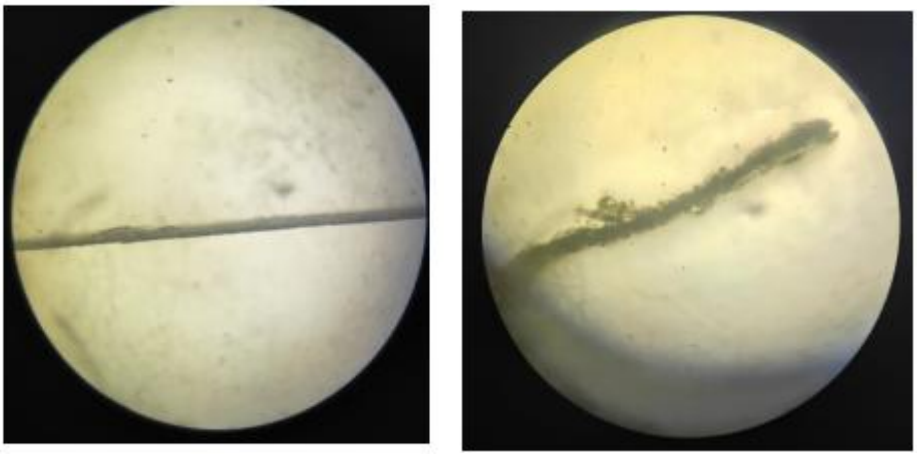
Petiole - The T.S. of Sveta Chandan petiole shows a circular outline with a thin cuticle covering the epidermis. Beneath the epidermis lies a cortex of parenchymatous cells, occasionally containing small resin ducts. The vascular bundles are collateral and arranged in a ring, with xylem towards the center and phloem towards the periphery, surrounded by bundle sheath cells. The pith is small and composed of rounded parenchyma cells. In contrast, the T.S. of Rakta Chandan petiole reveals a more robust structure with a thicker cuticle and epidermis. The cortex is broader and contains numerous large resin ducts, which are diagnostic. Vascular bundles are larger, collateral, and often embedded in sclerenchymatous tissue, forming a stronger ring. The pith is prominent, reddish in pigmentation, and parenchymatous. Thus, Sveta Chandan petiole is lighter, with fewer resin ducts and smaller vascular bundles, while Rakta Chandan petiole is thicker, resin-rich, and has stronger vascular bundles with a pigmented pith (fig 6,7).



Figures 6 and 7; Microscopic TS of petiole of Santalum album L.and Pterocarpus santanilus

Leaf - The transverse section of Sveta Chandan leaf shows a dorsiventral structure with a thin cuticle covering the upper epidermis. The upper epidermis is made of a single layer of compact cells, beneath which lies a palisade tissue of elongated parenchyma cells rich in chloroplasts. The spongy parenchyma is loosely arranged with large intercellular spaces, aiding gaseous exchange. Vascular bundles are small, collateral, and surrounded by bundle sheath cells, while secretory structures are absent. In contrast, the transverse section of Rakta Chandan leaf reveals a thicker cuticle and more robust epidermal cells. The palisade tissue is well-developed, often in two layers, while the spongy parenchyma is denser and more compact compared to Sveta Chandan. Vascular bundles are larger, collateral, and embedded within bundle sheath cells, with occasional secretory cavities present in the mesophyll.

Thus, microscopically, Sveta Chandan leaves are thinner with a single palisade layer and loose spongy tissue, whereas Rakta Chandan leaves are thicker, with double palisade layers, denser mesophyll, and stronger vascular bundles (fig 8,9).



Figures 8 and 9; Microscopic TS of leaf Santalum album L. and Pterocarpus santalinus L.f.

2.4 Phyto- chemistry

The phytochemical investigation of Sveta Chandana (Santalum album L.) and Rakta Chandana (Pterocarpus santalinus L.f.) reveals a diverse range of secondary metabolites distributed among different parts of the plants. These include terpenoids, phenolics, flavonoids, lignans, stilbenes, tannins, fatty acids, and other bioactive constituents. The phytochemical composition varies considerably according to the plant part examined, geographical origin, extraction method, and analytical technique employed. These constituents are considered to contribute to the traditional medicinal applications and reported pharmacological activities of both species.

Root21

The roots of Santalum album L. contain a variety of secondary metabolites, including phenolic compounds, flavonoids, lignans, fatty acids, and terpenoid constituents. Flavonoid and phenolic compounds may contribute to the antioxidant potential of root extracts, while lignans and related phenolic compounds have been investigated for their potential anti-inflammatory and cytoprotective activities. Terpenoid constituents, including sesquiterpenes and sesquiterpenoid derivatives, may also occur in the root, although the concentration and composition differ from those of the aromatic heartwood. The characteristic sesquiterpenoid alcohols α-santalol and β-santalol, which are responsible for the characteristic fragrance and much of the pharmacological interest in sandalwood, are predominantly associated with the heartwood essential oil rather than the root.

The roots of Pterocarpus santalinus L.f. contain several classes of secondary metabolites, including phenolics, flavonoids, tannins, lignans, terpenoids, and other polyphenolic constituents. Compounds belonging to the pterocarpan and stilbene groups have been reported from the species, while phenolic constituents contribute to the antioxidant properties of extracts. The phytochemical profile of the root complements that of the characteristic red heartwood, which is particularly rich in santalins and related phenolic pigments responsible for its characteristic coloration.

Leaf

The leaves of Santalum album L. contain several classes of phenolic and flavonoid compounds. Reported constituents include flavonoids and flavonoid glycosides such as vitexin, orientin, isoorientin, isovitexin, isorhamnetin, and related compounds. These constituents may contribute to the antioxidant and anti-inflammatory potential reported for leaf extracts22.

The leaves of Pterocarpus santalinus L.f. contain a diverse range of phytochemicals, including flavonoids, phenolic compounds, tannins, glycosides, and other secondary metabolites. These compounds have been associated with antioxidant, anti-inflammatory, antimicrobial, and hepatoprotective activities in experimental studies. However, the specific phytochemical composition may vary according to geographical origin and extraction conditions23.

Bark

The bark of Santalum album L. has been reported to contain several classes of phytochemicals, including phenolics, flavonoids, tannins, saponins, steroids, triterpenoids, alkaloids, and glycosidic compounds. The presence of these constituents may contribute to the antioxidant and antimicrobial activities observed in various extracts. Nevertheless, the phytochemical composition of the bark is less extensively characterized than that of the heartwood and its essential oil.

The bark of Pterocarpus santalinus L.f. contains tannins, flavonoids, phenolic compounds, saponins, alkaloids, and terpenoid constituents. The high content of phenolic and tannin compounds may contribute to the antioxidant and antimicrobial properties of bark extracts. These phytochemicals may also contribute to some of the traditional medicinal applications of the plant.

Fruit

The fruits and seeds of Santalum album L. contain lipids, fatty acids, sterols, phenolic compounds, and flavonoids. The seed oil contains fatty acids, including oleic and linoleic acids, together with other lipid constituents. These compounds may contribute to the nutritional and biological properties of the seed and fruit preparations.

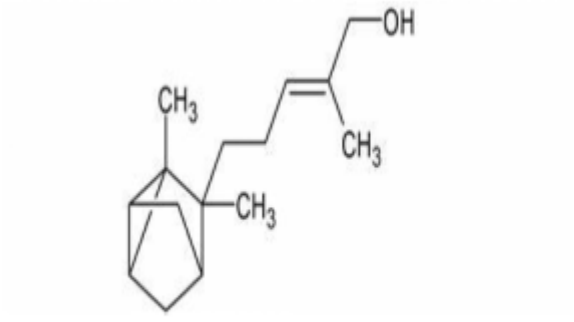
The fruits and seeds of Pterocarpus santalinus L.f. have been less extensively investigated than the heartwood. Available studies indicate the presence of phenolic compounds, flavonoids, tannins, and other secondary metabolites, although the characteristic santalin pigments are primarily associated with the heartwood. The phytochemical profile of the fruit and seed therefore differs from that of the red heartwood and should not be assumed to be identical.

Plant Part	**Santalum album L. (Sveta Chandana)**	**Pterocarpus santalinus L.f. (Rakta Chandana)**
Root	Phenolics, flavonoids, lignans, fatty acids, and terpenoids; aromatic sesquiterpenoids are primarily characteristic of heartwood.	Phenolics, flavonoids, tannins, lignans, and terpenoids.
Leaf	Flavonoids and flavonoid glycosides, including vitexin and orientin derivatives.	Flavonoids, phenolics, tannins, glycosides, and other secondary metabolites.
Bark	Phenolics, flavonoids, tannins, saponins, steroids, triterpenoids, alkaloids, and glycosides	Tannins, flavonoids, phenolics, saponins, alkaloids, and terpenoids
Fruit/Seed	Fatty acids, lipids, sterols, phenolics, and flavonoids; seed oil contains oleic and linoleic acids	Phenolics, flavonoids, tannins, and other secondary metabolites; less extensively studied than heartwood
Major characteristic constituents	α-Santalol and β-santalol, predominantly in heartwood essential oil	Santalins and related phenolic pigments, predominantly in heartwood

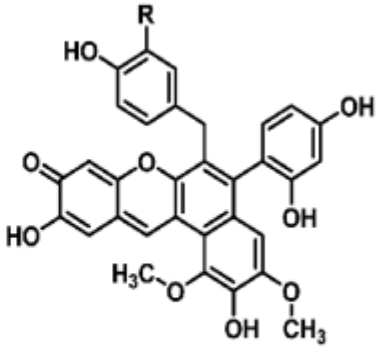
3. Chemical Constituents24

The chemical constituents of Sveta Chandana (Santalum album L.) are predominantly characterized by sesquiterpenes and sesquiterpene alcohols, particularly α-santalol, β-santalol, and epi-β-santalol, together with other volatile constituents such as α-santalene, β-santalene, and santalenones. These compounds, especially the santalols, are primarily responsible for the characteristic fragrance of sandalwood and contribute substantially to its reported biological activities, including antioxidant, antimicrobial, anti-inflammatory, and anxiolytic effects. Other phytochemical classes, including phenolic compounds and flavonoids, have also been reported in different extracts and plant parts, although the chemical profile varies considerably according to the plant part and extraction method.

In contrast, Rakta Chandana (Pterocarpus santalinus L.f.) is characterized by a chemically diverse profile dominated by phenolic compounds, isoflavonoids, pterocarpans, stilbenes, and related polyphenolic constituents. The characteristic red colour of its heartwood is primarily attributed to santalins, particularly santalin A and santalin B, together with other phenolic pigments. Additional compounds reported from the species include pterostilbene and lignan-related constituents, as well as tannins and other phenolics [5–8]. These phytochemicals have been associated with antioxidant, anti-inflammatory, hepatoprotective, and metabolic activities in experimental studies.



α- Santalol



Santalin

(Table-5)

Parameter	Chandan (Santalum album L.)	Rakta Chandan (Pterocarpus santalinus L.f.)
Main Class of Compounds	Sesquiterpenes and sesquiterpene alcohols; other terpenoids and phenolic constituents	Phenolics, isoflavonoids, pterocarpans, stilbenes, lignans, tannins, and related polyphenols.
Key Constituents	α-Santalol25, β-Santalol, epi-β-Santalol, santalene, santalenones.	Santalin A, santalin B, other santalin pigments, pterostilbene, and other phenolic constituents
Characteristic Feature	Volatile sesquiterpene alcohols, particularly α- and β-santalol, are responsible for the characteristic sandalwood aroma.	Santalin pigments and other polyphenolic compounds are responsible for the characteristic red colour of the heartwood.

4. Therapeutic uses

Sveta Chandana (Santalum album L.)

Sveta Chandana (Santalum album L.), commonly known as Chandan, is highly valued in Ayurvedic medicine for its Sita Virya (cooling potency) and Pitta-pacifying properties. Classical Ayurvedic literature describes Chandana as useful in conditions associated with Daha (burning sensation), Jvara (fever), and Pitta aggravation. It is traditionally regarded as Daha-prasamana (relieving burning sensation), Varnya (supporting complexion), Hrudya (beneficial to the heart), and Medhya (supportive of cognitive and mental functions). It has also been traditionally employed in skin disorders, inflammatory conditions, and urinary complaints such as Mutrakriccha. The cooling and aromatic properties of Sveta Chandana have contributed to its use in a variety of Ayurvedic preparations and external applications. The heartwood paste is traditionally applied to the skin for its cooling and soothing effects and is used in certain cosmetic and dermatological preparations. Formulations containing Chandana or related cooling drugs are traditionally used in Pitta-dominant disorders and conditions associated with heat and burning sensations. The pharmacological activities reported in modern studies are largely associated with the sesquiterpene-rich essential oil of sandalwood, particularly α-santalol and β-santalol. Experimental investigations have reported antioxidant, antimicrobial, anti-inflammatory, and anxiolytic or CNS-related activities associated with sandalwood oil and its major constituents. However, these experimental findings should be distinguished from established clinical efficacy

Rakta Chandana (Pterocarpus santalinus L.f.)

Rakta Chandana (Pterocarpus santalinus L.f.) is an important Ayurvedic medicinal plant traditionally recognized for its Sita (cooling) properties and its use in Pitta-associated disorders. Classical Ayurvedic texts and later Nighantu literature describe its applications in conditions involving Rakta (blood), Pitta, skin disorders, burning sensations, and inflammatory conditions. It is traditionally described as Rakta-sodhaka (associated with purification of blood) and is used in the Ayurvedic management of conditions such as Raktapitta and certain skin disorders. The powdered heartwood and aqueous preparations have traditionally been used internally and externally, while paste preparations have been applied to the skin in conditions involving inflammation, wounds, and pigmentation. The therapeutic use of Rakta Chandana is particularly associated with its characteristic red heartwood, which contains santalin pigments and other phenolic constituents. Modern phytochemical and pharmacological investigations have identified several bioactive constituents in Pterocarpus santalinus, including santalin pigments, pterostilbene, phenolic compounds, and related polyphenolic constituents. Experimental studies have reported antioxidant, anti-inflammatory, hepatoprotective, and antidiabetic activities associated with extracts or isolated constituents of the plant. These findings provide pharmacological support for some of its traditional applications; however, further clinical studies are required to establish therapeutic efficacy and appropriate clinical dosing.

- Chandan = cooling, mind-calming, complexion-enhancing, urinary relief
- Rakta Chandan = blood-purifying, skin-healing, fever & liver support.

5. Clinical Evidence and Research

Pharmacological researches validate literature viewpoint and establish evidence in advancement of clinical and therapeutic usage of both Santalum album L. and Pterocarpus santalinus L.f.

1. Santalum album L. (Sveta Chandana)

- Antimicrobial activity: Sandalwood essential oil, particularly its major sesquiterpene alcohols α-santalol and β-santalol, has demonstrated antimicrobial activity against several pathogenic microorganisms, including Staphylococcus aureus, Pseudomonas aeruginosa, and Candida species. This activity may contribute to the traditional use of sandalwood in topical and dermatological preparations26.
- Anti-inflammatory activity: Experimental studies indicate that α-santalol and sandalwood oil may exert anti-inflammatory effects by modulating inflammatory signaling pathways and mediators. These findings provide a possible pharmacological basis for the traditional use of sandalwood in inflammatory and skin-related conditions27.

- Anticancer potential: Sandalwood oil and its constituents have demonstrated antiproliferative and pro-apoptotic effects in experimental cancer models, including cultured skin and breast cancer cell lines. However, these findings should be described as preclinical anticancer potential, as they do not establish clinical efficacy in cancer patients28.
- Anxiolytic and sedative activity: Experimental studies have reported that sandalwood aroma and its major constituents may influence the central nervous system and produce calming, anxiolytic, and potentially sedative effects. These findings are consistent with the traditional use of sandalwood for mental relaxation and emotional well-being29.
- Dermatological applications: Sandalwood oil and preparations containing sandalwood have been investigated for their potential use in inflammatory and dermatological conditions, including acne and other skin disorders. The reported antimicrobial and anti-inflammatory properties may contribute to these applications30.

Rakta Chandan (Pterocarpus santalinus L.f.)

- Antimicrobial activity: Extracts of Pterocarpus santalinus L.F.,particularly those obtained from the bark and heartwood, have demonstrated antimicrobial activity against various Gram-positive and Gram-negative bacteria. This activity may be associated with the presence of phenolic compounds, tannins, flavonoids, and other secondary metabolites31.
- Antioxidant activity: The heartwood of Pterocarpus santalinus L.F. is rich in santalin pigments and other phenolic compounds, which exhibit antioxidant activity in experimental assays. These constituents can scavenge free radicals and may contribute to the protective effects observed in experimental models32.
- Hepatoprotective activity: Experimental studies have reported hepatoprotective effects of Pterocarpus santalinus L.F. extracts and isolated constituents in animal models of chemically induced liver injury. These effects have been associated with its phenolic, flavonoid, and related polyphenolic constituents33.
- Antidiabetic activity: Extracts and isolated constituents of Pterocarpus santalinus L.f. have demonstrated antihyperglycemic and metabolic effects in experimental models. These findings suggest potential antidiabetic activity, although clinical studies are required to establish efficacy and safety in humans34.
- Wound-healing activity: Traditional preparations of Rakta Chandana have been used externally for skin disorders and wounds. Experimental investigations suggest that extracts may support tissue repair and reduce inflammatory responses, providing preliminary pharmacological support for its traditional topical applications35.

6. Contraindications and Precautions

Chandan (Santalum album L.)

- Use cautiously in individuals with pronounced Kapha aggravation or excessive coldness.
- Exercise caution in individuals with Manda Agni (low digestive capacity) according to Ayurvedic principles.
- Avoid unnecessary prolonged or high-dose internal administration because comprehensive long-term safety data are limited.
- Pregnancy and lactation: insufficient safety data; use only under qualified medical or Ayurvedic supervision.

Rakta Chandan (Pterocarpus santalinus L.f.)

- Use cautiously in individuals with significant Vata aggravation and pronounced dryness.
- Exercise caution in patients with severe debility or emaciation, based on its traditional Ruksa and Kaṣaya properties.
- The safety of prolonged or high-dose internal use has not been adequately established.
- Specific contraindications in hypotension, anemia, or impaired nutrient absorption are not sufficiently supported by current evidence and require further investigation.

7. DISCUSSION

The comparative study of Chandan (Santalum album L.) and Rakta Chandan (Pterocarpus santalinus L.f.) demonstrates the importance of integrating classical Ayurvedic knowledge with contemporary pharmacognostical, phytochemical, and pharmacological evidence for the proper identification and therapeutic evaluation of these two botanically distinct drugs. Although both are traditionally referred to as Chandana and share certain cooling and therapeutic applications, the findings of the present comparative assessment indicate clear differences in their botanical identity, morphology, microscopy, chemical composition, and pharmacological profiles.

7.1 Taxonomical perspective

Santalum album belongs to the family Santalaceae and order Santalales, whereas Pterocarpus santalinus belongs to the family Fabaceae and order Fabales. This fundamental botanical difference is reflected in their external morphology and anatomical characteristics. Santalum album is recognized by its simple, opposite leaves and aromatic, pale-coloured heartwood, while Pterocarpus santalinus possesses compound, imparipinnate leaves and characteristic deep red, non-aromatic heartwood. These differences provide important diagnostic parameters for distinguishing the two drugs and are particularly relevant in pharmacognostical authentication, where substitution and adulteration may compromise the quality and therapeutic reliability of herbal preparations.

7.2 Ayurvedic literature

It provides an important basis for understanding the therapeutic distinction between Sveta Chandana and Rakta Chandana. Sveta Chandana is predominantly associated with Sita Virya, cooling action, relief of burning

sensations, Pitta-pacifying activity, and applications in conditions such as Daha, Jvara, skin disorders, and urinary discomfort. Its aromatic nature and traditional association with mental calmness further distinguish it therapeutically. Rakta Chandana, on the other hand, is traditionally described in relation to Rakta and Pitta disorders, with applications in conditions involving burning, skin disorders, and Rakta-pitta. The traditional description of Rakta Chandana as Rakta-sodhaka is particularly consistent with its historical use in blood- and skin-related disorders. Thus, although both drugs share the general property of cooling, their traditional therapeutic emphasis differs.

7.3 Pharmacognostical findings

The pale yellowish to yellow-brown and characteristically fragrant heartwood of Santalum album is associated with its volatile essential oil, whereas the dense, reddish heartwood of Pterocarpus santalinus is associated with its characteristic pigment constituents. The difference in colour and aroma represents a simple and useful macroscopic diagnostic feature. Similarly, differences observed in the leaves, roots, petioles, and microscopic structures provide additional parameters for authentication. However, the diagnostic anatomical characters should be interpreted carefully and verified against authenticated botanical specimens, as features may vary according to plant age, geographical origin, and the specific plant part examined.

7.4 Phytochemical comparison

Santalum album is particularly distinguished by its sesquiterpene-rich heartwood essential oil, with α-santalol and β-santalol serving as important characteristic constituents. These compounds are closely associated with the characteristic fragrance of sandalwood and have been investigated for antimicrobial, anti-inflammatory, antioxidant, and anxiolytic activities. In contrast, Pterocarpus santalinus is characterized by phenolic and polyphenolic constituents, including the characteristic santalin pigments responsible for the red colour of its heartwood, along with other stilbenes, pterocarpan-related compounds, and phenolic constituents. This difference in chemical composition provides a plausible basis for the distinct pharmacological profiles and traditional applications of the two drugs.

7.5 Pharmacological evidence

Studies on Santalum album have reported antimicrobial, anti-inflammatory, antioxidant, and anxiolytic activities, which may provide scientific support for its traditional use in inflammatory, dermatological, and calming applications. However, the available evidence is predominantly experimental, and the therapeutic effects observed in laboratory studies should not be equated directly with proven clinical efficacy. Similarly, Pterocarpus santalinus has demonstrated antioxidant, antimicrobial, hepatoprotective, antidiabetic, and anti-inflammatory potential in various experimental models. These findings are relevant to its traditional use in systemic and skin-related disorders, although further clinical investigation is necessary to establish the magnitude and clinical relevance of these effects.

8. CONCLUSION

The comparative study of Sveta Chandana (Santalum album L.) and Rakta Chandana (Pterocarpus santalinus L.f.) demonstrates that, despite sharing the common name Chandana and certain traditional cooling properties, the two medicinal plants are distinct botanical, pharmacognostical, phytochemical, and pharmacological entities. Their taxonomic differences are reflected in their macroscopic and microscopic characteristics, which provide valuable diagnostic parameters for accurate identification and authentication.

The study further highlights significant differences in their organoleptic and phytochemical profiles. Santalum album is characterized by its pale, aromatic heartwood and sesquiterpene-rich essential oil, particularly α-santalol and β-santalol, whereas Pterocarpus santalinus possesses dense, reddish, non-aromatic heartwood containing characteristic santalin pigments and other phenolic and polyphenolic constituents. These differences provide a scientific basis for distinguishing the two drugs and may also contribute to their differing therapeutic profiles.

The classical Ayurvedic descriptions of Sveta Chandana and Rakta Chandana are broadly supported by contemporary pharmacognostical and pharmacological findings. Sveta Chandana is predominantly associated with cooling, soothing, aromatic, anti-inflammatory, antimicrobial, and anxiolytic properties, while Rakta Chandana is traditionally and experimentally associated with antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, and metabolic activities. However, much of the modern pharmacological evidence remains preclinical, emphasizing the need for further well-designed clinical studies to establish therapeutic efficacy and safety.

Thus, the present study emphasizes the importance of integrating classical Ayurvedic literature with modern taxonomy, pharmacognosy, phytochemistry, and pharmacology for the correct identification, authentication, quality control, and rational therapeutic use of these two drugs. The findings also highlight the need to maintain a clear distinction between Santalum album and Pterocarpus santalinus in Ayurvedic practice and herbal drug formulations to prevent substitution or adulteration. Further multidisciplinary research, including standardized phytochemical profiling and clinical validation, may strengthen the scientific understanding and therapeutic application of both Sveta Chandana and Rakta Chandana.

9. CONTROVERSY

Rakta Chandana is sometimes incorrectly equated with "red sandalwood" or Santalum rubrum. However, in the Ayurvedic materia medica, Rakta Chandana traditionally refers to Pterocarpus santalinus L.f. This nomenclatural

confusion may contribute to misidentification, adulteration, and substitution of the genuine drug in pharmacognostical and clinical practice. Therefore, clear differentiation based on botanical identity, morphological and microscopic characteristics, and phytochemical markers is essential for the proper authentication and quality control of Rakta Chandana.

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