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Phytochemistry and Pharmacology of Santalum Album L.

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ABSTRACT:
Santalum album L. (Santalaceae) , commonly known as Indian sandalwood, is one of the oldest and most valuable sources of natural fragrances of great medicinal and commercial importance. P. Album has been cultivated in India for 25 centuries and is highly valued around the world as a sweet, long-lasting, fragrant oil with medicinal value.Essential oils extracted from sandalwood and sandalwood heartwood are used in various traditional medical systems such as Ayurveda, Siddha medicine, and Unani medicine for the treatment and prevention of various diseases.Sandalwood's versatile therapeutic and health-promoting effects are thought to be due to its rich source of phytochemicals, especially sesquiterpenes. By analyzing globally recognized scientific databases (Pub Med, SciFinder, Scopus, ACS, and Web of Science), recognized books, indexed and non-indexed journals, A thorough bibliographic search was conducted. Modern pharmacological studies have shown a wide range of pharmacological activities, from antibacterial to anticancer effects. Sandalwood oil and its individual ingredients have no significant toxicity. However, to understand the complete phytochemical profile of and the complex pharmacological effects of this plant, further studies on the chemical components of and their mechanisms exhibiting specific biological activities are required. The increasing commercial use of sandalwood and the low productivity of this endangered plant have raised concerns about its conservation and increased productivity with modern tools and techniques. The review discusses the traditional uses, ethnopharmacology, phytochemistry, and biological activities of sandalwood and highlights its medicinal and industrial value as well as gaps requiring future research. I'm doing it.

KEY WORDS: Santalum album,, Phytochemistry, Biological activity,Ethnopharmacology

I. INTRODUCTION :

Santalum album L. Belongs to the Santalum family and is one of the most valuable trees in the world. [1] Commonly known as White Sandalwood (English), Safed Chandan (Hindi) and Sriganda (Sanskrit), this tree is considered a revered gift of the plant world that is woven into Indian culture and tradition. It has been. Sandalwood is one of the oldest fragrances with a history of more than 2,000 years, and has maintained its importance as a popular fragrance from ancient times to modern times.If we look back at history, we find that sandalwood is mentioned in Indian mythology, folklore, and ancient scriptures. Certain cultures value its aroma and medicinal properties.Sandalwood species are generally thought to be native to the Indian peninsula, as their occurrence dates back at least 2,500 years. Sandalwood trees grow under different eco-climatic conditions and are very well adapted in terms of growth, heartwood and oil content [2]. The best wood grows in the driest regions, especially red and stony soils, while on rocky soils the trees often remain small but produce the highest oil yields. The heartwood is moderately hard, heavy and durable, yellow or brown in appearance and oily in texture, making it the perfect material for carving intricate designs. Sculptures of gods and mythical figures are in high demand in the market.A variety of items are made from sandalwood, including boxes, cabinet panels, jewelry boxes, combs, picture frames, fans, pen holders, card cases, letter openers, and bookmarks. Heartwood represents the central part of the tree and is valued for its aroma. However, parts of the tree such as the bark and outer wood (sapwood) have no scent.This plant is primarily used to extract sandalwood oil, which is obtained by steam distillation of the heartwood.The roots also contain essential oils [3]. Oil yield and quality vary depending on location, age of the tree, and distillation method.Sandalwood is commercially known as East India Sandalwood and its oil is known as East India Sandalwood Oil.

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PLANT DESCRIPTION :

Santalum album is an evergreen tree that grows up to 20 m attaining girth of up to 2.4 m with Slender drooping branchlets. There are two major commercial species of Sandalwood named Indian Sandalwood (S. Album) and Australian Sandalwood (S. Spicatum). Australian Sandal Trees are shorter in height. Bark of the tree is tight, dark brown, reddish, dark greyor nearlyIn young trees it is black and smooth, but in older trees it is rough with deep vertical cracks and has a red interior. The sapwood of is white and odorless, while the heartwood is yellowish to dark brown and strongly scented.Leaves are thin, almost opposite, ovate or oval-ovate, 3-8 x 3-5 cm, glabrous and light green above, glassy and slightly paler below. The tip is rounded or pointed. Stem grooved, 5-15 cm long. The veins are clearly reticular. Flowers are purplish-brown, small straw yellow, reddish-green or purple, about 4-6 mm long, up to 6 in small terminal or axillary clusters, odorless in conical secondary or terminal racemes. The fruit is a spherical, fleshy drupe. Is red, purple to black when ripe, about 1 cm in diameter, has a hard, ribbed endocarp, the crown of has a stigma, almost stalkless, smooth, and single-seeded. [4] In India, flower spikes appear from March to April, and fruits ripen during the cold season. In Australia, flowers bloom from December to January and June to August, and fruit ripens from June to September.This species spreads rapidly by dispersal of seeds. Trees produce viable seeds when they reach 5 years of age. Trees over 30 years old will have a circumference of 18 to 38 inches. Sandalwood tolerates a wide range of site conditions and grows naturally in a variety of locations throughout the tropics, although growth is more active in some conditions than others. S. Album grows in well-drained loamy soils, preferably on sunny hillsides.It requires at least 20 to 25 inches of rainfall per year.It does not tolerate frost or waterlogging, but is drought tolerant and requires a lot of light during the seedling stage and later stages. The ongoing drought and fires have killed 4,444 trees. This plant is primarily used for the production of fragrant sandalwood oil.

Historical Background :

There are references to sandalwood in Indian mythology, folklore, and scriptures. He is mentioned in Indian literature in AD and is as old as Milindapana (200 BC), PatanjaliMahabasaya AD (100 BC), Dhammapada, Anguttara and VinayaPitaka (400-300 BC). Thing. Kautilya described a type of sandalwood in his Arthazastra (200 BC). Sandalwood is also mentioned in the epics Ramayana and Mahabharata. It is unlikely that some of the references to sandalwood in ancient Indian texts of refer to his Pterocarpussantalinus, called Red Saunders or Red Sandalwood. There is ample evidence that S.Album was cultivated in India over the past 25 centuries. Sandalwood oil is highly valued all over the world, with India being the main exporter. Sandalwood , known as “sandalwood” in China and “sandalwood” in Japan, is known in ancient Chinese texts as well as ancient Sanskrit texts and manuscripts. It is also used in various forms of initiation ceremonies to open the minds of students.

Origin and distribution:

S. Album is native to the tropical regions of the Indian peninsula, eastern Indonesia, and northern Australia. The main distribution is in the drier tropical regions of India and the Indonesian islands of Timor and Sumba. It is native to the highlands of southern India (), with the main sandal regions being most of Karnataka and adjoining districts of Maharashtra, Tamil Nadu and Andhra Pradesh (). In these regions, this species primarily inhabits dry deciduous forests and shrublands. The vegetation type is a typical monsoon vine thicket growing on pure sand. This record was recorded on a coastal dune just above standard high water mark and near mangroves. It also grows on low lateritic cliffs above beaches. This tree is actually an obligate hemiparasitic plant to various hosts, Cassia siamea, Pongamiaglabra, and Lantana acuminata. It is currently grown in India, China, Sri Lanka, Indonesia, Malaysia, the Philippines, and northern Australia.

Traditional Uses :

S. Album is grown primarily for its timber and aromatic oil.870kg/cubic meter wood is durable and stable. The densely grained heartwood is used for ornaments and carvings. Wood was used as fuel, but is generally considered too valuable for that purpose. Sandalwood oil is distilled from the heartwood and is a pale to yellow viscous liquid with a sweet, aromatic, long-lasting, spicy, warm, woody, animalistic, milky, and nutty note. Have. Widely used in perfume, cosmetics, aromatherapy and pharmaceutical industries. Being an excellent fixative, it is highly valued by the perfume and

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toiletry industry, especially for certain delicate scents that are very rare and fragile.No heavy or oriental perfume composition of type is complete without a generous infusion of sandalwood oil. Most Indian attars use sandalwood oil as a base. This is due to ‘s ability to absorb most of the essential notes of other whole herbs and flowers, which can enhance scent status and stability. This oil is used as a flavoring agent in foods such as frozen dairy desserts, sweets, bread masala, bakery products, gelatin, pudding, alcoholic and non-alcoholic beverages. The United States Food and Drug Administration, the European Council of Flavor and Extract Manufacturers Associations and the FAO/WHO Joint Expert Committee have approved the use of sandalwood oil as a food additive [8].

Ethnopharmacology :

Therapeutically, sandalwood has a calming and relaxing effect. It is said to reduce stress, depression, anxiety, nervous fatigue, restlessness, fatigue, insomnia, and promote meditation. It was believed to promote spiritual practices, peaceful relaxation, openness, and grounding.[6] Sandalwood is used in various traditional medicine systems such as Ayurveda, Siddha medicine, and Unani medicine to treat various ailments. In Ayurveda, India’s traditional medical system, sandalwood is primarily used as a sedative, diuretic, and mild stimulant. In Ayurveda, sandalwood is considered an antiseptic, antipyretic, antiscabies, diuretic, expectorant, and stimulant, and its antibacterial and antifungal properties can treat bronchitis, urinary disorders, urinary tract infections,andgonorrhea. It is prescribed for the treatment of. [12] Other therapeutic uses mentioned in Ayurveda include bile, fever, papules, diarrhea with internal bleeding, eye infections, hemorrhage, hiccups, omphalitis, poisoning, early stages of smallpox, hives, etc. Including its use in the treatment of various diseases.[3,8]

PHYTOCHEMISTRY :

Sandalwood, the most valuable wood and the main source of essential oils, has been extensively studied for its chemical composition. Sandalwood oil accumulates in the heartwood only after it has grown for 30 years under natural conditions. [37] The yield and composition of all essential oils are strongly influenced by tree age, heartwood color, organ maturity, individual tree, location within the tree, and environmental and genetic factors of the plant. [38-40] Traditionally, according to ancient customs, steam distillates of heartwood are sold as marketable sandalwood essential oil. [41] Additionally, the composition of the oil extracted from young and mature sandalwood trees is different, [43] while the content and composition of the oil from the heartwood, which is extracted in varying amounts from the tree, is different. [44]. Sandalwood oil has been extensively studied for its chemical composition and its isolation, synthesis, and quantitative estimation.[45-57] Shankaranarayana and his colleagues have carried out extensive research on the phytochemical and other related aspects of sandalwood. Chromatographic separation of □- and □-santalol [58] α- and β-santalole by column chromatography [59] Simple method for high-yield extraction of sandalwood oil by rectification of benzene extract , [60] Sodium santarubate dimethyl sulfate inclusion complex, [61] Estimation of oil content in sandalwood depot-based sapwood, [62] Possibility of developing fragrant products from low-odor sandalwood oil [41] Estimation of oil content and composition from sandalwood Central and transitional regions of sandalwood slices [63], Use of sandalwood extract [64], Hydrolyzed Depleted Sandalwood Powder (HESP)extraction of essential oil from [65-66], isolation of santalol from sandalwood oil [67].
The main components of commercially available sandalwood oil are sesquiterpene alcohols such as α- and β-santalol (C15H24O), bergamotol, and several stereoisomers thereof, while minor components include lansol, Includes sesquiterpene hydrocarbons such as pherol, bisabolol, and α-. Φ-santarene (C15H24), bergamotene, α-, ϕ-, and ϖ-curcumene, ϕ-bisabolene [68-72], and phenylpropanoids [73]. A-santalol is usually more common than Õ-santalol.

[74] With VergheseCollaborators reported the sesquiterpene alcohols cis-□-santalol and cis-□-santalol, □-trans—bergamotol and epi-cis-□-santalol as the maincomponents of essential oils [75]. Minor components include trans-□-santalol and cis-lantheol, [72] hydrocarbon santarene (C9H14), □-santarene, □- santarene, □-bergamotene, epi-□-santarene, □-curcumene, □-Curcumene, □-Curcumene, □- Bisabolene, □-Bisabolol [72,76] and heterocycles. Other ingredients mentioned in sandalwood oil include alcohol, sunthenol (C9H16O), and telecentalol (C10H16O). Aldehydes, nor-tricycloecasantral (C11H16O) and isovaleraldehyde. The ketones L-santenone (C9H14O) and Santalone (C11H16O), the acids telesanthalic acid (C10H14O) (partially

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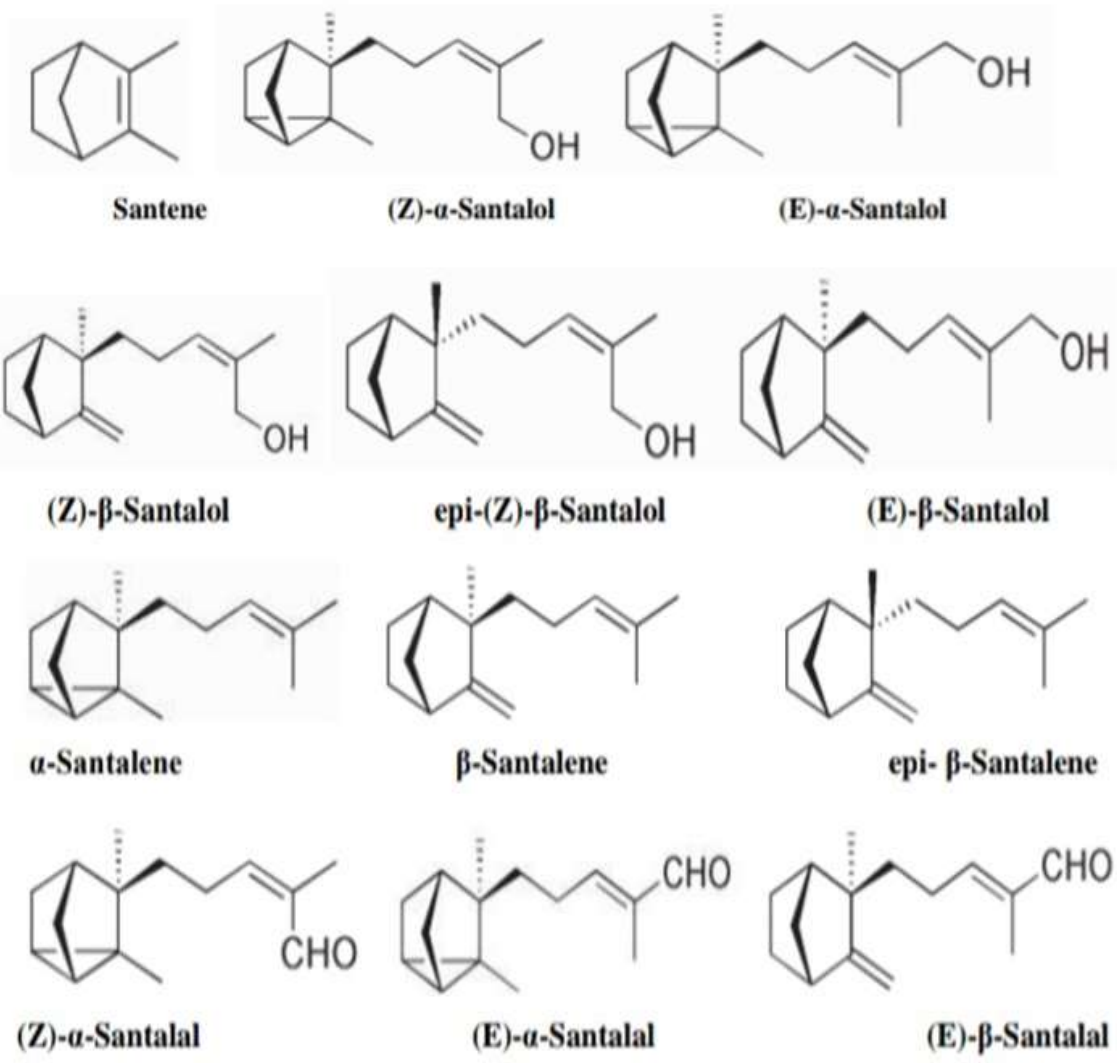
free and partially esterified form of), α- and β-santhalic acid (C15H22O2). The genetic diversity among sandal populations from different localities in India [78] and the relationship between abundance and heartwood/oil yield in sandal localities [2] were investigated. Indian Sandalwood Oil and Australian Sandalwood Oil contain similar ingredients, but the concentrations of these ingredients are different, resulting in two similar but completely different oils.The main components of in Australian sandalwood oil are sesquiterpenes, with the two major sesquiterpene alcohols □-santalol and □-santalol, and E, E-farnesol and □-bisabolol being the predominant occupies . It is worth mentioning here that the content of secondary metabolites depends on the intrinsic properties of the plant material, environmental and genetic aspects, or external aspects such as extraction methods. [80] also noted that the amount of santhyl acetate and santarene in 10-year-old trees was slightly higher than in 30-year-old trees [81]. Roots of Indian sandalwood tree yeast were also tested for yield and essential oil composition. By solvent extraction of sandalwood, oil recovery from the roots of was determined to be 10.3%. GC and GC/MS analysis of the oil revealed that it accounts for 99.9% of the total oil, including 30 sesquiterpenols (78.5%), 9 sesquiterpenes (7.8%), and 1 terpene acid (0.4%). Compounds of 53 types were detected. . Five sesquiterpenoid isomers (4.4%);



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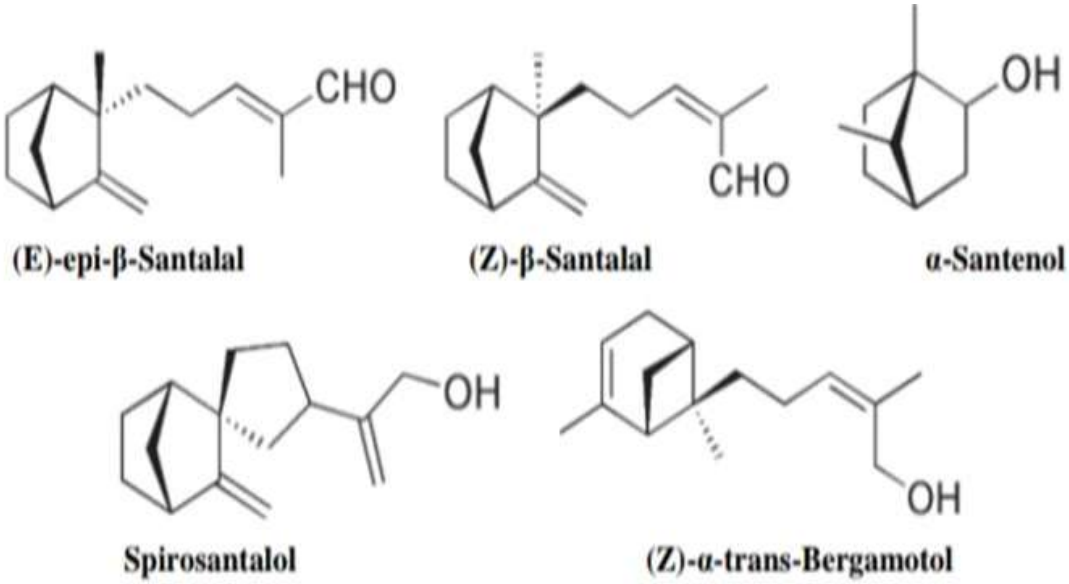

(E)-epi-β-Santalal (Z)-β-Santalal α-Santenol

Spirosantalol (Z)-α-trans-Bergamotol

The main components of the essential oil were □-santalol and □-santalol, and their percentages were 19.6% and 16.0%, respectively.□-Santalol content was below the recommended range of 41–55%. However, in , the □-santalol content was close to the specification of 18%. The total content of 4,444 bisabolenol A, B, C, D and their isomers was also high, being 25.0% of the oil [82]. In another study, GC-MS studies identified a total of 32 active phytocompounds in stem extracts of Santalum album. In another study, his GC-MS analysis detected 4,444 volatile metabolites in the heartwood of 15-year-old trees. [84] Bioassay-controlled fractions of Santalum album heartwood were performed and seven □-Santas including (9R,10E)-9-hydroxy-□-Santaral, (10R,11R)-10,11 Role derivative was isolated.Dihydroxy-□-santalol, (9E)-11,13-dihydroxy-□-santalol, and (10E)-12-hydroxy-□-santalol acid . Their structures were determined by spectroscopic analysis.[85] HPTLC-based evaluation of sesquiterpenoids from sandalwood oil was developed to profile metabolites such as n-alkanes, sesquiterpenes, sesquiterpenoids, fatty acids, alcohols, and hydrocarbons in sandalwood oil. Ta. Srivastava et al. Studied the functional characterization of a novel -sesquiterpene synthesis from Indian sandalwood. The possibility of reliably identifying wood based on its anatomical structure, color of the hot water extract, chemical composition of the oil (mainly santalol content), and DNA fingerprints was investigated. [87] The structure-activity relationship of sandalwood-derived odorant compounds was studied. [88- 89] Furthermore, the relationship between the structure and odor of (Z)-α-santalol, the main component of sandalwood essential oil, which has a unique wood odor derivative, was also studied. , focused on the relationship between the side chain structure and odor of types of compounds. This study found that the odor of the Z isomer is similar to that of the corresponding saturated compound of , but significantly different from that of the corresponding E isomer of (odorless, fresh or oily). Did. These results indicated that the relative configuration of the side chain to the santalol backbone plays an important role in the odor of α-santalol. The E configuration of the side chain eliminates the woody aroma character of α-santalol and its studied derivatives, but the Z configuration or the saturation of the carbon side chains do not [90]. Studies on sandalwood tree seeds and seed oil [91], partial hydrogenation of sandalwood seed oil [92], removal of unsaponifiable components from sandalwood seed oil, fatty acid composition of seed coat [93], and seed Overstorage of petroleum has also been reported [94]. Isolation of betulinic acid from sandalwood seed coat and its reduction by Baggins have been reported.The use of bark and seeds of depleted sandalwood was investigated. [91,96] Flavonoid components vicenin-2, vitexin, isovitexin, orientin, isoorientin, chrysin-8-C-□-D-glucopyranoside, chrysin-configuration 6- C -□-D- glucopyranoside and isorhamnetin was isolated from the leaves of S. And characterized. Albums. [97-98] Sandalwood oil research, synthetic substitutes, industrial and therapeutic uses were summarized by Ranade.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

Furthermore, Makoto published a research report on natural and synthetic fragrances of sandalwood [100]. The synthesis of sandalwood odor derivatives from camporenic aldehyde has been reported [101]. Process of synthesizing fragrances with similar propertiesFlavor patented oxidation of santalol with MnO2 in hexane to give Z-□-santalal, which isomerized with 0.5-2% glacial acetic acid to produce the product E-□- santalal . [102] Safety evaluation of oils in food has been studied [103]. A comparative study of the chemical composition of fragrant sandalwood species including S. Album, S.Spicatum, and S. Austrocaledonicum was conducted.[104] The use of many essential oils , including sandalwood oil, in aromatherapy was described by Setzer. Gleason discussed the possibilities and prospects for using Indian sandalwood oil as an ingredient in luxury perfumes. Methods have been developed to identify and detect adulterants.[107-108]

Pharmacology :

Sandalwood and its oil have demonstrated a wide range of pharmacological activities, in addition to its relevance in perfumery and cosmetics. S. The album has been extensively studied to confirm traditional therapeutic claims and reveal additional biological activities. Her series of 4,444 pharmacological studies on sandalwood and its oil reported biological effects ranging from antibacterial to anticancer. The reported pharmacological activities of his sandalwood and its oil are summarized below.

Hepatoprotective activity :

Hydroalcoholic extract from leaves of S. Album shows significant hepatoprotective activity against CCl4 and paracetamol and induces hepatotoxicity by reducing the activities of serum marker enzymes, bilirubin and lipid peroxidation. And showed a significant increase in glutathione levels. Superoxide dismutase, catalase and protein decreased in a dose-dependent manner, which was further confirmed by the decrease in total liver weight and histopathological studies. [109]

CNS Effect :

Santarum Album L It is known to be effective in improving memory. [110-111] Studies on the sedative effects of have shown that inhalation of East Indian sandalwood oil reduced motility in mice by 40-78% compared to 0% controls. [112] The soothing effects of sandalwood oil and aqueous extracts have already been demonstrated. [113-114] Sandalwood oil is said to have a relaxing effect on the nerves and is used for hot or excited emotional states that cause headaches, insomnia, and nervous tension. . [32] Santalol, as a bioactive ingredient , has been reported to affect the central nervous system (CNS). Accordingly, the effects of depression have been shown to have a 4,444 impact on patients with sleep disorders [115]. The first study of its kind explores the sense of smell.Receptor neurons specifically stimulated by four synthetic sandalwood compounds and oil were identified. Additionally, solvent extracts of heartwood have been shown to have neuroleptic effects in mice. A-santalol and β-santalol significantly increase the concentrations of homovanillic acid, 3,4-dihydroxyphenylacetic acid, and/or 5-hydroxyindoleacetic acid in the brain of mice when administered intragastrically and intracerebroventricularly. I let it happen. [113] α-Santalol is a potent dopamine D2 antagonist – and serotonin 5-HT2A- receptor binding. Furthermore, the effects of α-santalol were similar to those of chlorpromazine as an antipsychotic. [117] Alpha-santalol caused significant physiological changes such as relaxing and sedative effects, whereas sandalwood oil caused physiological inactivation after transdermal absorption but no behavioral activation. Ta.Recently, TLC254 bioautograph studies have shown that alpha-santalol, the main component of this essential oil, is a potent inhibitor of both tyrosinase and cholinesterase in vitro, and therefore this essential oil may be associated with Alzheimer's disease. It has been shown that it has great potential for use in the treatment of The same is true for skin care [119].

Anti-ulcer effect :

Oral treatment of hydroalcoholic extract of S. Album strain through effective inhibition of physical (stress) and chemical (bothlocal irritants and pharmaceutical NSAIDs) induce gastric exposure. , was reported to induce good levels of gastroprotection in rats. Ulcer. [120]

Antifungal Activity :

Sandalwood oil is reported to have antifungal activity against Microsporumcanis, Trichophytonmentagrophytes, and T. Rubrum. Sandalwood oil was found to be effective against human pathogenic fungal strains Microsporumcanis,Trichophytonmentagrophytes , and T. Rubrum, but not against Candida albicans,

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

Aspergillusniger, and fumigated A. It was ineffective against [132]

Antioxidant Activity :

Phytochemical and pharmacological studies have demonstrated the existence of principles that justify the traditional medicinal properties of antioxidant . S. Album and other Indian medicinal plants were tested in vitro for possible regulatory effects on nitric oxide (NO) levels using sodium nitroprusside as the NO donor. Most plant extracts showed significant direct, dose-dependent scavengingactivity towards NO. [140] Reported to have nitrous oxide scavenging activity and DPPH antioxidant activity. [140] [141] Santalum album can protect cardiac tissues from cell damage and lipid peroxidation caused by oxidative stress, and also prevents DOX-induced inflammation and induction of apoptosis. [142] Recently, the anthocyanin pigment cyanidin-3-glucoside from S.Album was shown to have antioxidant properties and be nutritionally important. Furthermore, in a comparative study, nine in vitro antioxidant assays were performed and in vitro cultured callus cells were shown to exhibit antioxidant activity comparable to sandalwood oil. Sandalwood oil increased glutathione S-transferase (GST) activity and acid-soluble sulfhydryl (SH) levels in the livers of adult male Swiss albino mice. [145] Increased GST activity and acid-soluble SH levels suggested a possible chemopreventive effect of sandalwood oil on carcinogenesis through a blocking mechanism.

Similarly, methanol extract of sandalwood demonstrated inhibition of acetyl-cholinesterase, DPPH and superoxide radical scavenging activity in albino mice, indicating the potential of to combat dementia and memory loss associated with Alzheimer's disease. Was shown. Recently, an in vivo study investigated the antiglycemic and antioxidant effects of sandalwood oil and its main component □-santalol in an alloxan- and D-galactose-mediated model using oxidative stress-induced diabetic male Swiss albino mice. Possibilities have been evaluated.

Antibacterial activity :

Some studies have focused on the antibacterial properties of East Indian sandalwood oil [121], while many other studies have focused on Australian sandalwood oil [122]. A comparative study conducted with 26 essential oils that evaluated their antibacterial activity against bacteria in the axilla showed the strongest activity against sandalwood oil and its synthetic analogs [123]. Sandalwood oil is an effective antibacterial agent against methicillin-resistant Staphylococcus aureus and antifungal-resistant Candida species. [124] Crude extract of sandalwood oil and α- and β-santalol compounds exhibit antibacterial activity against Helicobacter pylori, a Gram-negative bacterium closely associated with the development of duodenal, gastric, and gastric ulcers. . Sandalwood oil also shows activity against herpes simplex virus type 1 [125], and □-santalol shows anti-influenza activity against H3N2 virus. Another study found the greatest inhibitory effect of sandalwood oil on Bacillus mycoides and Escherichia coli. [126] Methanol extract from S.Album is said to be effective against Bacillus subtilis, Salmonella typhi, Staphylococcus aureus, and Staphylococcus aureus.Very effective against Pseudomonas aeruginosa and Candida albicans. [127]Sandalwood oil showed antidermatophyte activity against Microsporumcanis, Trichophytonrobrum, and Trichophytonmentagrophytes. [128] Furthermore, the sandalwood oil components □- and □-santalol were found to be effective against Salmonella typhimurium and Staphylococcus aureus, and epi-□-santalole was found to be effective against Salmonella typhimurium. Did. [128] Santalbic acid (trans-11-octa-decene-9-ynoic acid), the main component of seeds, was found to inhibit Gram-positive bacteria and some pathogenic fungi. Santalol was found to be effective against yeast and Gram-positive and negative bacteria at high and/or medium concentrations, and showed better antibacterial activity even at low concentrations. Furthermore, immature tree buds have also been shown to have antibacterial effects against 4,444 13 different bacterial strains [130].

Antiviral Activity :

Sandalwood's antiviral activity has also been proven by biological studies.Rephrase Sandalwood oil has been proven to be used in the prevention and treatment of warts, age spots, and other skin tumors caused by viruses. [133-134] Traditional medical systems, including Ayurveda and Chinese medicine, also mention the antiviral effects of sandalwood oil. [135] An in vitro study showed that sandalwood oil has dose-dependent antiviral activity against herpes simplex virus (HSV)-1 and 2 by inhibiting the replication of the virus. Ta. Sandalwood oil was also thought to help protect cells by regulating the levels of glutathione, S-transferase, and acid-soluble sulfhydryls in the

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liver. [136] Sandalwood oil showedan inhibitory effect on herpes simplex virus type 2 (HSV-2) on RC-37 cells in vitro. Interestingly, before being adsorbed to cells, sandalwood oil affected the virus only through non-specific inhibition of the interaction between the virus and host cells [25]. The components of sandalwood oil, alpha- and beta-santalol, their mixtures and derivatives, are relevant for the treatment of human warts, especially HPV and DNA poxviruses that cause warts.Molluscumcontagiosum is said to be a treatment for HIV and other RNA viruses, as well as for seborrheic dermatitis, psoriasis, and the dryness, scaling, and desiccation associated with allergic and eczematous rashes. , is said to be a treatment for acne lesions on the face body and removal of pustular acne – lesions caused by staphylococcal acne and streptococcal infections. Additionally, sandalwood oil and santalol derivative are said to be used in the treatment of cold sores and cold sores [137]. Recently, single cell and somatic embryo suspension cultures of Indian sandalwood have been shown to be an alternative and renewable source of shikimic acid, a precursor for the industrial scale synthesis of Tamiflu, the only commercially available neuraminidase inhibitor against influenza A. It has been shown . Virus. [138]

Antioxidant Activity :

Phytochemical and pharmacological studies have demonstrated the existence of principles that justify the traditional medicinal properties of antioxidant . S. Album and other Indian medicinal plants were tested in vitro for possible regulatory effects on nitric oxide (NO) levels using sodium nitroprusside as the NO donor. Most plant extracts showed significant direct, dose-dependent scavenging activity towards NO. [140] Reported to have nitrous oxide scavenging activity and DPPH antioxidant activity. [140] [141] Santalum album can protect cardiac tissues from cell damage and lipid peroxidation caused by oxidative stress, and also prevents DOX-induced inflammation and induction of apoptosis. [142] Recently, the anthocyanin pigment cyanidin-3-glucoside from S. Album was shown to have antioxidant properties and be nutritionally important. Furthermore, in a comparative study, nine in vitro antioxidant assays were performed and in vitro cultured callus cells were shown to exhibit antioxidant activity comparable to sandalwood oil. Sandalwood oil increased glutathione S-transferase (GST) activity and acid-soluble sulfhydryl (SH) levels in the livers of adult male Swiss albino mice. [145] Increased GST activity and acid-soluble SH levels suggested a possible chemopreventive effect of sandalwood oil on carcinogenesis through a blocking mechanism. Similarly, methanol extract of sandalwood demonstrated inhibition of acetyl-cholinesterase, DPPH and superoxide radical scavenging activity in albino mice, indicating the potential of to combat dementia and memory loss associated with Alzheimer's disease. Was shown. Recently, an in vivo study investigated the antiglycemic and antioxidant effects of sandalwood oil and its main component □-santalol in an alloxan- and D-galactose-mediated model using oxidative stress-induced diabetic male Swiss albino mice. Possibilities have been evaluated.

Hemolytic Activity :

The hemolytic activity of any compound is an indicator of general cytotoxicity to normal healthy cells. One study found that a leaf extract of this plant caused the lysis of 4,444 red blood cells. However, this hemolytic activity occurs only when administered parenterally. Studies have shown that the leaves of this plant contain saponins, which are responsible for hemolytic activity on blood. [148]

Anticancer Activity :

studies have demonstrated the chemopreventive effects and molecular mechanisms of □- santalol on skin cancer development in both animal models and skin cancer cell lines.Rephrase Anticancer effects of the oil were demonstrated in chemically induced skin carcinogenesis in CD—1 and SENCAR mice, UV-B-induced skin carcinogenesis in SKH-1 mice, and in vitro models of melanoma, non-melanoma, breast and melanoma. It has been reported. Prostate cancer and its ability to induce cell cycle arrest and apoptosis in cancer cells has also been demonstrated. [150] □-Santalol, a component of sandalwood oil , delayed the development of papillomas in both strains of mice. [151] α—santalol at concentrations of 25–75 μM was found to induce apoptotic death of human epidermal carcinoma A431 cells through caspase activation, along with loss of mitochondrial potential and cytochrome release. [152] In a similar study in female hairless mice of the SKH-1 strain, topical application of □-santalol showed chemopreventive effects due to reductions in ornithine decarboxylase activity, tumor incidence, and proliferation. Has been proven. Furthermore, □-santalol slows skin tumor development, reduces

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

tumorproliferativeness, and inhibits lipid peroxidation in skin and liver microsomes in vitro, possibly by acting as an antioxidant. , and thus has been shown to prevent UVB—induced skin tumor development. [154] α-Santalol significantly upregulated apoptosis-related proteins, caspases 3 and 8, and tumor suppressor protein p53 through the extrinsic pathway in a UV-B-induced skin tumor development model in SKH-1 mice. It has been reported that it increases. -Santalol induced apoptosis in human prostate cancer cells through activation of caspase-3. [156] Approximately six novel sesquis were assayed for in vitro activation of Epstein-Barr virus early antigen (EBV-EA) in Raji cells to assess their antitumor-promoting activity. Terpenoids, two aromatic glycosides and several neolignans were identified. Furthermore, in vivo two-step carcinogenesis assays of demonstrated a strong inhibitory effect on EBV-EA activation and a strong inhibitory effect of on two-step carcinogenesis in mouse skin. [157] Furthermore, a derivative of □-santalol showed tumor-selective cytotoxicity in human HL-60 promyelocytes.Leukemia cells and normal human diploid TIG-3 fibroblasts. [158] Two lignans obtained from heartwood samples showed tumor cell apoptosis-inducingcytotoxicity against HL- 60 human promyelocyticleukemia cells and A549 human lung adenocarcinoma cells. Alpha- santalol, an active ingredient in sandalwood essential oil, has been studied for its protective effects against skin cancer in mouse models of skin carcinogenesis. [159]

Antipyretic effect:

Sandalwood oil at a dose of 200 mg/kg showed a highly significant antipyretic effect on yeast-induced fever in albino rats.

Anti-inflammatory effects :

Santalol has been reported to have significant anti-inflammatory effects in several experimental models. [33] Santalum album had anti-inflammatory and anti-ulcer effects as evidenced by significant inhibition in carrageenan-induced paw edema, cotton pellet-induced granulomas, and pyloric ligation-induced ulcers. These findings may support the inclusion of this plant in the effective treatment of inflammatory diseases such as ulcers in traditional medicine. Methanol extracts from heartwood have been shown to have in vitro antioxidant effects (and in vivo analgesic and anti-inflammatory effects) in mice. [160]

antihyperglycemic and antihyperlipidemic effects :

Effect of long-term oral administration of the petroleum ether fraction of sandalwood in streptozotocin-induced A study on the antihyperglycemic and antihyperlipidemic effects of long-term oral administration of the petroleum ether fraction of sandalwood in streptozotocin-induced diabetic rats showed a reduction in blood glucose levels.A decrease in blood glucose levels was also observed in the metformin treatment group (), whereas an increase in blood glucose levels was observed in the diabetic control group. Additionally, total cholesterol (TC), low-density lipoprotein (LDL), and triglyceride (TG) levels were decreased in treated diabetic rats , whereas cardioprotective high-density lipoprotein (HDL) was increased . A significant improvement in the atherogenic index was observed around , leading to the conclusion that S. album has potential antihyperglycemic and antihyperlipidemic effects. [161]

Cardioprotective activity :

Aqueous extract of sandalwood has been reported to significantly inhibit cardiac tissue damage by reducing lipid peroxidation in doxorubicin-induced cardiotoxicity in a rat model [162] and ISO in albino Wistar rats .It has been reported that it has a significant protective effect against induced myocardial infarction. Dependent way.

Physiological Effects:

Sandalwood oil and its main component □-santalol have been shown to influence several physiological functions and sensory stimulation. The oil reportedly increases pulse rate, skin conductance and systolic blood pressure, while □-santalol produces higher levels of alertness and mood than the oil. [163] Inhaling sandalwood oil has been reported to improve hearing.[164] [] Recently, sandalwood tea significantly increased myocardial contractility and heart rate in isolated and dysfunctional frog hearts, while having excellent anti-fatigue effects on smooth muscle contraction in isolated rabbit aortic strips. It has been shown to be effective. [165] Sandalwood oil did not show phototoxicity, but irritation and sensitization reactions in humans have been occasionally reported. [166]

Metabolic Effects :

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

Sandalwood oil has been reported to exhibit changes in neonatal hepatic xenobiotic-metabolizing enzymes in lactating mouse pups upon transmammaryexposure.It was also observed that sandalwood oil and its constituents passed through milk and altered xenobiotic metabolizing enzymes in the liver, including a decrease in soluble sulfhydryl content and hepatic cytochrome P 450 content.

II. CONCLUSION:

Santalum album is one of the most famous and widely used plants in perfumery and cosmetics. Apart from its perfume and cosmetic uses, sandalwood has a wide range of pharmacological activities and this plant is considered one of the important medicinal plants. Although this plant has been extensively studied since the past 20 years, there is still much scope to realize the full potential of using sandalwood for humanity. For more than a century, researchers around the world have focused on the study of interesting chemical constituents, especially the sesquiterpenoids of sandalwood, in terms of structure, synthesis, and pharmacological activity. There has been a recent surge in research activity validating the traditional medical uses of essential oils and their components through modern experimental approaches, driven by thorough pharmacological and mechanistic studies. Various studies have demonstrated the pharmacological activities of sandalwood and its oil, ranging from antibacterial to anticancer properties. It also showsprominent activity in various skin diseases. There are few toxicological studies on Sandalwood. It is necessary to summaries all activities reported about this plant. This review Consolidates different reported activities of sandalwood plant as well as its oil.

REFERENCE:

[1]. Fox JE, Sandalwood: Royal Tree. The Biologist (London), 2000. 47: 31-34.
[2]. Jain SH, Angadi VG, Shankaranarayana KH, Edaphic, Environment and Genetics Factors related to growth and adaptability of sandal (Santarum album L) in origin. Sandalwood Research Newsletter, 2003. 17: 6-7. 3.
[3]. Kirtikar KR, Basu BD, Santaram Album Medicinal Plants of India, BD. 3.llAufrage, (L M Basu, 49, Leader Road, Allahabad), 1933. 2184-2188.
[4]. Benencia F, Courrèges MC, Antiviral activity of sandalwood oil against herpes simplex viruses 1 and 2, Plant Medicine, 1999. 6(2): 119-123.
[5]. Sensarma PK, Sandalwood – Its cultivation and uses. In: Attal CK, Kapoor BM, eds. Cultivation and use of medicinal and aromatic plants.RRL Jammu, 1977. 287- 297.
[6]. Joshi SG, Medicinal Plants, Oxford & IBH Publishing Co.Pvt. Ltd., New Delhi, 2003. 157-158
[7]. Arun Kumar AN, Joshi G, Mohan Ram HY, Sandalwood: History, uses, current status and future of . Current Science, 2012. 103(12): 1408-1416.
[8]. Desai VB, Hirenath RD, Pharmacological screening of HESP and sandalwood oil. Indian Perfumer, 1991. 35: 69-70.
[9]. James A Duke, Mary Jo Bogenschutz-Godwin, Judi duCellier, Peggy-Ann K Duke, Handbook of Medicinal Herbs, 2nd edition, 2002. 646-647.
[10]. Benencia F, Courrèges MC, Antiviral activity of sandalwood oil against herpes simplex viruses 1 and 2, Plant Medicine, 1999. 6(2): 119-123.
[11]. Pande MC, Medicinal Oils and Their Importance. Medicine and Surgery, 1977. 17: 13-16.
[12]. Dikshit A, Hussain A, Antifungal effects of some essential oils against animal pathogens. Phytotelapia, 1984. 55: 171-176.
[13]. Paul S, Plant Profile. In Ayurvedic Medicine: Principles of Traditional Practice. USA: Churchill, 2006.
[14]. Nadkarni KM, Indian MateriaMedica. Mumbai: Mumbai Popular Prakashan, 2009. 1099.
[15]. Jamal A, Siddiqui A, Tajuddin Jafri MA, Review of anti-ulcer agents used in the Unani medical. system. Nat Prod Rad.、2006; 5: 153 -159。
[16]. Kausar H, Jahan N, Ahmed K, Aslam M, Ahmed P, Ahmed S, Unani Perspectives and Recent Studies on Sandal Safed (Santalum Album Linn.): Review. World Journal of Pharmacy and Pharmacy, 2014. 3(8): 2133-2145.
[17]. Chavda R, Vadalia KR, Gokani R, Hepatoprotective activity of the root bark of Calatropisprocera R.Br (Asclepiadaceae). Internal. J Pharmacol, 2010; 6(6): 937-934.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

[18]. Shankaranarayana KH, Venkatesan KR, chemical aspects of sandalwood oil. Cultivation and Utilization of Aromatic Plants (edited by CK Atal and BM Kapoor), Regional Institute, Jammu, 1982. 138-141.
[19]. Brunke E, Fahlbusch K, Schmaus G, Volhardt J, Sandalwood fragrance chemistry – Review of the past 10 years. RivistaItaliana EPPOS (Specification number, 15. JourneesInternationalesHuilesEssentielles, 1996; 48-83.
[20]. Lawless J, The Encyclopedia of Essential Oils: is a complete guide to the use of aromatic oils in aromatherapy, herbalism, health and wellness. Thorsons Publishers, USA, 2002.
[21]. Mojay G, Aromatherapy for Healing the Mind. Hodder and Stoughton, 1996,
[22]. Davis P, Aromatherapy: From A to Z. 2nd edition, Daniel, C.W. Company Limited, UK, 1999.
[23]. Misra B, Dey S, Quantitative and qualitative evaluation of essential oils and sesquiterpenoids from in vitro somatic embryos of East Indian sandalwood tree (Santrum album) by HPTLC and GC. Journal of Medicinal and Aromatic Plants, 2013a; 4(1): 1-9.
[24]. Kim TH, Ito H, Hatano T, Takayasu J, Tokuda H, Nishino H, Machiguchi T, Yoshida T, Novel antitumor sesquiterpenoids from Santalum album of Indian origin. Tetrahedron, 2006; 62: 6981-6989.
[25]. Koch C, Reichling J, Schneele J, Schnitzler P, Inhibitory effects of essential oils on herpes simplex virus type 2. Phytomedicine, 2008. 15: 71-78.
[26]. Ochi T, Shibata H, Higuti T, Kodama K, Kusumi T, Takaishi Y, Santalum album anti-Helicobacter pylori compound. Natural Products Journal, 2005. 68: 819-824.
[27]. Matsuo Y, Mimaki Y, Santalum album lignans and their cytotoxic activity. Chemistry. Pharm. Bull. , 2010; 58: 587-590.
[28]. Handa KL, Kapoor LD, Chopra IC, Current status of herbal medicines used in indigenous medicine. Indian Journal of Pharmacy, 1951. 13: 29-48.
[29]. Kazuya Okazaki, Shun Oshima, Antibacterial activity of higher plants XXV: Antibacterial effect of essential oils VI. Journal of the Pharmaceutical Society of Japan (Japan), 1953. 73: 344-347.
[30]. Winter AG, The importance of essential oils in the treatment of urinary tract infections. Planta Medica, 1958. 6: 306.
[31]. Jainism SK, Medicinal Plants. National Book Trust, New Delhi, 1968. 123-125.
[32]. Battaglia S, The Complete Guide to Aromatherapy, International Center of Holistic Aromatherapy, Brisbane, 2007. 263.
[33]. Sindhu RK, Upma, Kumar A, Arora S, Santalum Album Lin: Overview of Morphology, Phytochemical and Pharmacological Aspects. International J PharmTech Res, 2010. 2: 914 – 919.
[34]. Rohadi D, Aryani RM, Belcher B, Perez M, Widnyana M, Can sandalwood survive in East Nusa Tenggara?Lessons learned from policy implications for resource sustainability . Sandalwood Research Newsletter, 2004. 10: 3-6.
[35]. Holmes P, The Energy of Western Herbs Volume II, Artemis 481 Press, USA. 1989.
[36]. Blumenthal M, Busse WR, Goldberg A, The Complete Commission E Monographs: Herbal Medicine Treatment Guide. Integrative Medicine Communications, Boston, MA , USA, 1998. 199.
[37]. Howes MJR, Simmonds MSJ, Kite GC, Evaluation of the quality of sandalwood essential oil by gas chromatography-mass spectrometry, Journal of Chromatography A, 2004. 1028: 307-312.
[38]. Sangwan NS, Farooqi AHA, Sabih F, Sangwan RS, Regulation of essential oil production in plants. Journal of Plant Growth Control, 2001. 34: 3-21.
[39]. Figueiredo A, Barroso J, Pedro L, Scheffer J, Factors influencing the production of secondary metabolites in plants: volatile substances and essential oils. Flavors and Fragrances Journal, 2008. 23: 213-226.
[40]. Arun Kumar AN, Srinivasa YB, Joshi G, Seetharam A, Variation and relationship between tree growth, heartwood and oil content of sandalwood (Santalum album L.). Kare. Science, 2011. 100: 827-830.
[41]. Shankarnarayana KH, Kamala BS, Fragrance products made from

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

sandalwood oil with low fragrance. Perfumer and Flavorist, 1989. 14: 19-20.
[42]. Lex AJT, Santalumaustrocaledonicum, and S. Yasi (Sandalwood). Pacific Islands Agroforestry Species Profile, 2006. 2(1): 1-21.
[43]. Shankaranarayana KH, Parthasarathi K, Differences in the composition of sandal oils that change color on standing . Indian Perfumer, 1984. 28: 138-141.
[44]. Shankaranarayana KH, Parthasarathi K, On the content and composition of oils from his heartwood at different levels of sandals. Indian Perfumer, 1987. 31: 211-214.
[45]. Guha PC, Bhattacharya SC, Separation of Santalore and Santarem. J. Ind. Chem. Society 1944; 21:261.
[46]. Dasgupta S, Chakravarti KK, Bhattacharya SC, IR spectra of compounds containing cyclopropane rings and their application to quantitative evaluation of sandalwood oil. Indian soap. , 1956. 21: 217.
[47]. Gaggei BB, Bhattacharya JC, Isolation of Santaremes from sandalwood oil. Perfume.Butt. Oil. Record, 1956. 47: 35.
[48]. Karawya MJ, Wahba SK, Chromatographic analysis of sandal oil, Egypt Pharm. Bull., 1962; 44: 23.
[49]. Kishore I, Thermal pyridine phthalation method for the determination of primary alcohols in essential oils. Soap. Perfume. Cosmetics. 1962. 35: 446.
[50]. Nigam IC, Devi L, GLPC of sesquiterpene compounds. Can.j.chem,1962;40:2083
[51]. Kamat SY 、 Chakravarthi KK 、 Bhattacharya SC、Synthese von Santalen 、 Santaloland santabic 、 aacid tetrahedron, 1967 ; 223: 4487.
[52]. Walker GT, Chemistry of Sandalwood Oil. Perfume. Eat. Oil. Record, 1968. 59: 778.
[53]. Bhati A, Recent developments in the chemistry of sandalwood oil. Flavor Industry, 1970; 1(4): 235-251.
[54]. Kumar S, Kartha ARS, Estimation of total alcohol and phenols in essential oils. Ind. J. Agri.Science, 1974. 44: 79.
[55]. Chaurasi LO, Nair KNG, Mathew TV, Quasi-method for estimation of free santalol in sandalwood oil. Indian Perfumer, 1975. 19: 19.
[56]. Demole EC, Enggist P, Chemical study of volatile components of sandal oil. HELB. Chim. Actor, 1976. 59: 737.
[57]. Yadav VK, Bisarya SC, Synthetic aspects of santalol in santarene. Scientific Journal and Industrial Research, 1982. 41:650.
[58]. Shankaranarayana KH, Separation of α-santalol and β-santalol by column chromatography. Indian Perfumer, 1979. 23(1): 65-66.
[59]. Shankaranarayana KH, Chromatographic separation of alpha and beta Santarene. Indian Perfumer, 1980. 24(1): 40-42.
[60]. Shankaranaryana KH, Venkatesan KR, Purification of benzene extract: A simple method to obtain sandal oil with higher yield. Indian Perfumer, 1981. 25: 31-34.
[61]. Shankaranarayana KH, Krishna Rao GS, Sodium Santalubate Dimethyl Sulfate Inclusion Complex Complex. It gets crowded. Petrochemical Society (USA) 1982. 59(5): 240-241.
[62]. Shankaranarayana KH, Ravikumar G, Rangaswamy CR, Thegarajan, KS, Sandal Sapwood Based Depot Oil. My Forest, 1997. 33 (3): 581-582.
[63]. Shankaranarayana KH, Ravikumar G, Rangaswamy CR, Theagarajan KS, Content and the composition of oils from the central and transitional zones of the sandal disc. (International Sandals Seminar, Dez. 97) Sandals and Products, Australia. Cent. Für Inter Agri.Resolutionproz. No. 84, Canberra, Australia, 1998. 86-88.
[64]. Shankaranarayana KH, Theagarajan KS, Ravikumar G, Rajeevalochan AN, Importance and Benefits of Sandalwood Extract. FAFAI Journal, 1999. 1(4): 65-67.
[65]. Shankaranarayana KH, Parthasarathi, K. HESP – A new essential oil from acidic hydrolyzate of usedsandalwood heartwood. Perfumer and Flavorist (USA) 1986;10: 60-61.
[66]. Shankaranarayana KH, Ravikumar G, Rajeevalochan AN, Theagarajan KS, New essential oils from depleted sandalwood powder. Non-Wood Products Journal, 2000. 7 (3&4): 233-234.
[67]. Shankaranarayana KH, Ravikumar G, Rangaswamy CR, On the isolation of Santarolene from sandalwood oil. Indian Perfumer, 2001. 45(2): 79-80.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

[68]. Adams DR, Bhatnagar SP, Cookson RC, Sesquiterpenes of Santalum album and Santalum spicatum, Phytochemistry 1975. 14: 1459-1460.

[69]. Demole, E., Demole, C., and Enggist, P, "Chemical study of the volatile constituents of East Indian sandalwood oil (Santalum album L.)", Helvetica ChimicaActa, 1976. 59: 737-747.

[70]. Christenson P, Secord N, Willis BJ, Identification of trans-ϕ-santalol and epicis-ϕ- santalol in East Indian sandalwood oil, Phytochemistry 1981. 20: 1139-1141.

[71]. Ranibhai P, Ghatge BB, Patil BB, Bhattacharya SC, Ketosantharic acid, a new sesquiterpene acid from Indian sandalwood oil. Indian Journal of Chemistry, 1986: 25B: 1006-1013.

[72]. Jones CG, Ghisalberti EL, Plummer JA, Barbour EL, Quantitative co-occurrence of sesquiterpenes. Tools to elucidate their biosynthesis in Indian sandalwood, album Santarum . Phytochemistry, 2006. 67: 2463-2468.

[73]. Gibbard S, Schoental R, Simple semi-quantitative estimation of sinapyr and certain related aldehydes in wood and other materials. Journal of Chromatography A, 1969. 44: 396-398.

[74]. Anonis DP, Sandalwood and Sandalwood Compounds, Perfumers and Flavorants 1998. 23: 19-24

[75]. Verghese J, Sunny TP, Balakrishnan, KV, (Z)-(+)-□-santalol and (Z)-(-)-□-santalol concentration, a new quality factor for East Indian sandalwood oil. Flavor and Fragrance Journal, 1990. 5: 223-226.

[76]. Brown NA, Meyer M, Pickenhagen W. Isolation and chiral GC analysis of trace components of □-bisaborolene- from the essential oil of Santalum album L. (Santalum family).Essential Oil Research Journal, 2003. 15: 63-65.

[77]. Bhattacharyya DK, Perfume Materials, Production and Applications. Studium Press LIC, Houston, Texas, 2009. 40-41.

[78]. Angadi VG, Jain SH, Shankaranarayana KH, Ravikumar G, Genetic diversity among sandal populations of different origins in India. Sandalwood Newsletter from Australia, 2003. 17: 4-5.

[79]. India's wealth. Dictionary of Indian Raw Materials and Industrial Products, Raw Materials, CSIR, New Delhi, 2004. 5(R-Z): 49-50.

[80]. Muzika RM, Campbell CL, Hanover JW, Smith AL, Comparison of extraction techniques for volatile compounds from coniferous trees. Journal of Chemical Ecology 2006; 16: 2713-2722.

[81]. Battaglia S, The Complete Guide to Aromatherapy, International Center of Holistic Aromatherapy, Brisbane, 2007. 263.

[82]. Zhang XH, Jaime A, da Silva T, Jia YX, Jian Y, Ma, GH, Essential oils composition from Roots of Santalum album L. Journal of Essential Oil-Bearing Plants, 2012 15(1): 1-6.

[83]. Ashok K, Jayaprakash P, Screening of active plant compounds and antibacterial activity of Santalum album stems by GC-MS study. International Journal of Current Pharmaceutical Research, 2012. 4(3): 43-44.

[84]. Bisht SS, Hemanthraj KPM, Gas Chromatography Mass Spectrometry (GC-MS) Profiling of Kernel Oil Composition of 15-Year-Old Sandalwood . International Journal of Pharmacological and Phytochemical Research , 2014. 6(2): 387-392.

[85]. Matsuo Y, Mimaki Y, Alpha-santalol derivative from Santarum album and its cytotoxic activity. Phytochemistry, 2012.77: 304-311.

[86]. Srivastava PL, Daramwar PP, Krithika R, Gangashetti SB, Pandreka A, Shankar SS, Thulasiram HV, Functional characterization of a novel sesquiterpene synthase from Indian sandalwood, Santalum Album, Sci. Bericht, 2015. 5: 10095 DOI: 10.1038/srep10095.

[87]. Crovadore J, Schalk M, Lefort F. Selection and mass production of Santarum album L. In potash for the induction of sesquiterpenes. Biotechnology and Biotechnological Equipment, 2012; 26(2): 2870-2874.

[88]. Pande BS, Relationship between structure and odor of sandalwood fragrance. Chemistry Industry Digest, 1996. 9(4): 83-86.

[89]. Constanze B, Marcus E, Anja F, Current developments in the chemistry of sandalwood fragrances. Chemistry and Biodiversity, 2008. 5(6): 1000-1010.

International Journal of Pharmaceutical Research and Applications
Volume 9, Issue 1 Jan-Feb 2024, pp: 588-604 www.ijprajournal.com ISSN: 2249-7781

[90]. Satoshi Hasegawa, Hiroshi Izumi, Hiroshi Tajima, Hiroshi Yamada, Relationship between structure and odor of α- santalol derivatives with modified side chains. Molecules, 2012, 17, 2259-2270.
[91]. Shankaranarayana KH, Chemical and utilization studies on depleted sandalwood bark and seeds. My Forest, 1987. 23(4): 239-240.
[92]. Shankaranarayana KH, Partial hydrogenation of sandalwood oil. J. Oil Tech. Assn. India, 1979b; 3(1): 116-118.
[93]. Shankaranarayana KH, Removal of unsaponifiables from sandalwood seed oil and fatty acids Composition of seed coat. Van Vigian, J. For Social India, 1988. 26(1&2): 43.
[94]. Anantapadmanabha HS, Shankaranarayana KH, Nagaveni HC, Compositional changes during storage of sandal seeds. Indian Forestry Journal, 1989. 12(2): 157-158.
[95]. Shankaranarayana KH, Venkatesean KR, On the occurrence of betulinic acid in the seed coat of Sandal , its isolation and reduction by Baggins. Van Vigian, (J. Soc. For India), 1985; 23(3&4): 73-74.
[96]. Desai VB, Shankaranarayana KH, On the usage aspects of sandalwood seed oil. Research & Industry, 1990; 35: 232-233.
[97]. Yan C, Lin L, Liu H, Lin Z, Chen P, Cai C, Zheng L. Unteruchiung von FlavonoidenausBlättern von Santalum Album. ZhongguoZhong Yao ZaZhi, 2011; 36(22): 3130- 3133.
[98]. Yan C, Liu H, Lin L. Simultaneous determination of vitexin and isovitexin in rat plasma after oral administration of Santalum album L. Leaf extract by liquid chromatography tandem mass spectrometry. Biomed Chromatogr., 2012; 27(2): 228-232.
[99]. Ranard GS, Chemistry of Sandalwood Scent. Indian Perfumer, 2002. 46(1): 59-61.
[100]. E Makoto, A new approach to the scent of fragrant wood. Goryeo, 2003. 218: 113-124.
[101]. Chunli Li, Mao Haifang, Xianhua P, Ping Ai, Research development on the synthesis of sandalwood odor derivatives from camporenic aldehyde.
[102]. How to synthesize perfume using XiangchunGu, Fan, Xinlei, Fragrance Santalum Album Faming ZhuanliShenqing. 2012; Patent number CN 102584550 A 20120718.
[103]. George AB, Carabin IG, Safety evaluation of sandalwood oil (Santalum album L.) Food and chemical toxicology, 2008. 46(2): 421-432.
[104]. Nicolas B, Celine D, Daniel J, Phytochemistry of the fragrant Santalum species of heartwood: a review of . Flavor and Fragrance Journal, 2011: 26(1): 7-26.
[105]. Setzer WN, Essential oils and anti-anxiety aromatherapy. Natural Products Communications, 2009. 4(9): 1305-1316.
[106]. Gleason AJ, Comparative Notes: Formulated with coumarin, sandalwood, and ethyl linalool. Perfumer and Flavorist, 2009, 34(4), 26-29.
[107]. Bhat KV, Balasundaran M, Balagopalan M, KFRI Research Report No. 307. Identification of Santalum album and Osiris lanceolata using morphological and biochemical characteristics and molecular markers for impurity checking (KFRI Project 509/ 06 of Final Report), 2006.
[108]. Sankappan Analyst, 2010, 135, 2676-2681.
[109]. Hegde K, Deepak TK, Kabitha KK, Hepatoprotective potential of the hydroalcoholic extract of Santalum album Linn . Leaf. International Journal of Pharmaceutical Sciences and Drug Research 2014, 6(3), 224-228.
[110]. Jackson DD, Siju L, Jevasin D, Huxley VAJ. Memory-improving potential of Santalum album extract in albino mice. Journal of Theory and Experiment Biology. 2009, 5, 3.
[111]. Biradar SS, Rasal VP, Ashok P. Sandalwood oil treatment during growth spurt improves learning and enhances memory. Pharmacologyonline, 2009, 3, 142.
[112]. Khanna A, Singh VK, Govil JN. Aroma. Therapy.So, recent advances in medicinal plants: Aesthetics.USA: Stadium Press, 2004, 125.
[113]. Okugawa H, Ueda R, Matsumoto K, Kawanishi K, Kato A, Effects of sandalwood-derived alpha-santalol and beta-santalol on the central nervous system of mice. Influence. Plant Medicine, 1995, 2, 119-126.

[114]. Joshi MP, Satarkar SR, Desai VH, Comparative Study of Central Nervous System Effects , Santalum Album Linn. Comparison of fragrance paste and water extract in Wistar albino rats. American Journal of Phytomedicine and Clinical Therapeutics, 2013, 1(8), 661-671.
[115]. Virkung of Ohmori A, Shinomoto K, Utsu Y, Tokunaga, S, Hasekawa Y, Kamei C, Santalol on the snow monitoring cycle of snow-covered rats. Japan ShinkeiBiopharmacology Journal, 2007, 27, 167-171.
[116]. Bieri S, Monastyrskaia K, Schilling B, Profiling of olfactory receptor neurons exposed to sandalwood fragrance. Chemical Senses, 2004, 29, 483-487.
[117]. Okugawa H, Ueda R, Matsumoto K, Kawanishi K, Kato K, Effects of sesquiterpenoid from "Oriental Incense" on acetic acid-induced writhing and D2 and 5-HT2A receptors in rat brain.Plant Medicine, 2000, 7, 417-422.
[118]. Hongratanaworakit T, Heuberger E, Buchbauer G, East Evaluation of the effects of Indian sandalwood oil and α-santalol on humans after dermal absorption. Planta Medica, 2004, 70, 3-7.
[119]. Misra BB, Dey S, TLC bioautograph evaluation of in vitro antityrosinase and anticholinesterase potential of sandalwood oil. Natural Product Communications, 2013b, 8, 253-256.
[120]. Ahmed N, Ali Khan MS, Matt Jace AM, Mortaluddin N, Ranjibar M, Amjad MS, Nagaraju B, Faraz M, Pathan F, Chincholi A, Anti-ulcer activity of sandalwood stems (Santarum album L.).Hydroalcoholic extracts in his three gastric ulcer models of Wistar rats. BoletínLatinoamericano y del Caribe de PlantasMedicinales y Aromáticas, 2013, 12(1), 81-91.
[121]. Jirovitz L, Buchbauer G, Denkova Z, Stoyanova A, Murgo, I., Gearon V, Birkbeck S, Schmidt E, Geissler M, Comparative study on the antibacterial activity of various sandalwood essential oils of different origins.Flavor and Fragrance Journal, 2006, 21, 465-468.
[122]. Beylier MF, Givaudan SA, Bacteriostatic activity of some Australian essential oils. Perfumer and Flavorist, 1979, 4, 23-25.
[123]. Viollon C, Chaumont JP, Antifungal properties of essential oils and their main constituents against Cryptococcus neoformans. Mycopathology, 1994, 128, 151-153.
[124]. Warnke PH, Becker ST, Podschun R, Sivananthan S, Springer IN, Russo PA, Wiltfang J, Fickenscher H, Sherry E, Combating multidrug-resistant strains: Antimicrobial essential oils as a promising force. Renaissance measures against nosocomial infections. J. Carnio Maxillofacial Surgery, 2009, 37(7), 392-397.
[125]. Schnitzler P, Koch C, Reichling J. Susceptibility of drug-resistant clinical herpes simplex virus type 1 strains to essential oils of ginger, thyme, hyssop, and sandalwood. Antibacterial agents AgentsChemother、 2007、 51、 1859-1862。
[126]. Antibacterial activity of essential oils of Chourasia OP, Santalum album and Glossogynepinnatifida. Indian Perfumer, 1978, 22, 205-206.
[127]. Bakkiyaraj S and Pandiyaraj S, Evaluation of the potential antibacterial activity of medicinal plants against common foodborne pathogenic microorganisms, International Journal of Pharma and Bio Science. 2011, 2(2), 484-491.
[128]. Simanjuntak P, Antibakterierer Test von Sandelholzextrakt (Santalum album L.). Indonesian Pharmacy Journal, 2003, 14, 326-332.
[129]. Jones GP, Rao KS, Tucker DJ, Richardson B, Barnes A, Rivett DE, Antibacterial activity of Santalbic acid from the oil of Santalumacuminatum (Quandong). Pharmaceutical Biology, 1995, 33, 120-123.
[130]. Misra BB, Dey S, Phytochemical analysis and comparison of antibacterial efficacy of in vitro and in vivo extracts from East Indian sandalwood tree (Santalum album L.). Letters of Applied Microbiology , 2012a, 55, 476-486.
[131]. Chaumont JP, Bardey I, Activities Antifongques In-Vitro de Sept HuilesEssentielles. Phytotelapia, 1989, 60: 263-266.
[132]. Chourasia OP, Tirumala RJ, Antibacterial activity of some Indian essential oils. Perfume and Cosmetics, 1987, 68 (volume, no. 9/87), 564-566.

[133]. Haque MH, Haque AU, Use of sandalwood oil for the prevention and treatment of warts, skin wounds and other virus-related tumors. 2000, U.S. Patent 470 6132756.
[134]. Haque MH, Haque AU, Use of □- and □-santalol, the main components of sandalwood oil, in the treatment of warts, skin wounds and other virus-induced tumors, . 2002; US Patent 6406706.
[135]. Chattopadhyay D, Sarkar MC, Chatterjee T, Sharma Dey R, Bag P, Chakraborti S, Khan MT, Recent advances in the evaluation of antiviral activity of natural products. New Biotechnology, 2009, 25, 347-368.
[136]. Benencia F, Courrèges MC, Antiviral activity of sandalwood oil against herpes simplex viruses 1 and 2, Plant Medicine, 1999, 6(2), 119-123.
[137]. Singh CU, Nulu JR, Derivatives of sandalwood oil and santalol for the treatment of cold sores and cold sores. US Patent No. 7858126, 2010.
[138]. Misra BB, Day S, Production of shikimic acid (Tamiflu precursor) in suspension culture of East Indian sandalwood (Santrum album) in an airlift bioreactor. Postdoctoral Research Journal Research, 2013c: 1: 1-9.
[139]. Scartezzini P, Speroni E, Review of some plants of Indian traditional medicine with antioxidant activity. J. Ethnopharmacol., 2000; 71: 23-43.
[140]. Jagetia GC, Baliga MS, In vitro evaluation of nitric oxide scavenging activity of selected Indian medicinal plants: preliminary study. J Med Food, 2004. 7: 343-348.
[141]. Patrick LO, Timothy J, Antioxidants in drugs and spices as cardioprotective agents in Tibetan plateau populations. Pharmaceutical Biology, 2002. 40: 346-357.
[142]. Khan, MS, Singh M, Khan, MA, Ahmed S, Protective effect of Santalum album against doxorubicin-induced cardiotoxicity in rats. 2014; 3(2): 2760-2771.
[143]. Pedapati SHS, Khan MI, Prabhakar P, Giridhar P, Cyanidin-3-glucoside, nutritionally important constituent and in vitro antioxidant activity of Santalum album L. Berry. Food Research International, DOI: http: //dx.doi.org/10.1016/j.foodres.2012.10.024, 2012.
[144]. Misra BB, Dey S, Phytochemical analysis and evaluation of antioxidant activity. -vitro callus extract from the East Indian sandalwood tree (Santalum album L.). Journal of Pharmacology and Phytochemistry, 2012b; 1: 8-18.
[145]. Banerjee S, Ecavade A, Rao AR, Regulatory effects of sandalwood oil on mouse liver glutathione S-transferase activity and acid-soluble sulfhydryl levels.Cancer Letters, 1993. 68: 105-109.
[146]. Misra BB, Dey S, Evaluation of in vivo antiglycemic activity and antioxidant capacity of □-santalol and sandalwood oil. Plant Medicine, 2013d; 20: 409-416.
[147]. Da Silva E, Shahgaldian P, Coleman AW, Hemolytic properties of some water-soluble para-sulfonato-calix-[n]-arenes. Internal. J. Pharmacy, 2004. 273(1-2): 57-62.
[148]. DeepakTK, Hegde K, HassainarA, Devi S, Phytochemical screening and hemolytic activity of hydroalcoholic extract of Santarumalbum.L leaves, International Journal of Pharma Sciences and Research, 2014. 5(8): 514-517.
[149]. Zhang X, Dwivedi C, Chemoprevention of skin cancer with □-santalol. Frontiers in Bioscience (Schol ed.), 2011. 3: 777- 787.
[150]. Santha S, Dwivedi C, Anticancer effects of sandalwood (Santalum album). International Journal of Cancer Research and Treatment, 2015. 35 (6): 3137-3145.
[151]. Dwivedi C, Guan Cancer Epidemiology Biomarkers and Prevention, 2003 12: 151-156.
[152]. Kaul M, Agarwal C, Singh RP, Guan potential and cytochrome C release.Carcinogenicity, 2005. 26: 369-380.
[153]. Dwivedi C, Valli HB, Guan. Carcinogenicity, 2006. 27: 1917-1922.
[154]. Bommareddy A, Hora J, Cornish B, Dwivedi C, Chemoprevention with α-santalol against UV-B radiation-induced skin tumor development in mice. Anticancer Research, 2007. 27: 2185-2188.
[155]. Arasada BL, Bommareddy A, Zhang Anticancer Research, 2008. 28: 129-132.

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[156]. Bommareddy A, Rule B, VanWert AL, Santha S, Dwivedi C, □-santalol, a derivative of sandalwood oil, inhibits apoptosis in human prostate cancer cells by causing activation of caspase-3 . I will guide you. Plant Medicine, 2012. 19: 804-881.
[157]. Kim TH, Ito H, Hatano T, Takayasu J, Tokuda H, Nishino H, Machiguchi T, Yoshida T, Novel antitumor sesquiterpenoids from Santalum album of Indian origin. Tetrahedron, 2006; 62: 6981–6
[158]. Matsuo Y, Mimaki Y, α-santalol derivatives from Santalum album and their cytotoxic activity. Phytochemistry, 2012.77: 304-311.
[159]. Kaur M. □-santalol, a skin cancer chemopreventive drug, inhibits apoptosis in human epidermoid carcinoma A431 cells via caspase activation with mitochondrial membrane lysis and cytochrome C release. Induce death. Carcinogenicity, 2005 26: 369-380.
[160]. Saneja A, Kaushik P, Kaushik D, Kumar S, Kumar D, Antioxidant, analgesic and anti-inflammatory effects of Santarum albumin. Planta Medica, 2009. 75: 102.
[161]. Kulkarni CR, Joglekar MM, Patil SB, Arvindekar AU, Antihyperglycemic and antihyperlipidemic effects of Santalum album in streptozotocin-induced diabetic rats. Pharmaceutical Biology, 2012. 50: 360-365.
[162]. Khan, MS, Singh M, Khan MA, Ahmad S, Protective effect of Santalum album against doxorubicin-induced cardiotoxicity in rats. World Pharmaceutical Research Journal, 2014; 3(2): 2760-2771.
[163]. Heuberger E, Hongratanaworakit T, Buchbauer G, East Indian sandalwood and alpha—santalolodors increase physiological and self-rated arousal in humans. Planta Medica, 2006; 72: 792-800
[164]. Yuko Sugawara, Yuko Hino, Masaki Kawasaki, C Hara, Kazuya Tamura, Naoya Sugimoto, Yuko Yamanishi, Masato Miyauchi, Takashi Masushima, Takashi Aoki, Changes in perceived aroma of depending on the type of essential oil work: Aroma A simple screening test for effectiveness.Chemistry, 1999; 24: 415-421.
[165]. Qin M, Xie J, Zhou H, Li A, Zhou F, Experimental study of the effects of ethanol precipitate from sandalwood tea on cardiovascular function and anti-fatigue.Genomics and Applied Biology, 2010. 29: 962-968.
[166]. Safety evaluation of burdock GA, carabine IG, and sandalwood oil (Santalum album L.). Food and Chemical Toxicology, 2008. 46: 421-432.