WJPMR, 2026, 12(7), 336-346

Research Article

Impact Factor: 7.533

WORLD JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH

ISSN (O): 2455-3301

ISSN (P): 3051-2557

Coden USA: WJPMBB

www.wjpmr.com

CORRELATION BETWEEN ANTI-INFLAMMATORY AGENTS PRESENT IN PINE TREE AND BOSWELLIA SERRATA TREE- A SYSTEMATIC REVIEW

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DOI: https://doi.org/10.5281/zenodo.20964162

How to cite this Article: [1]Rishiman, [2*]Mahabeer Singh (2026). Correlation Between Anti-Inflammatory Agents Present In Pine Tree And Boswellia Serrata Tree- A Systematic Review. World Journal of Pharmaceutical and Medical Research, 12(7), 336-346.

Article Received on 29/05/2026 **Article Revised on 19/06/2026** **Article Published on 01/07/2026**

1. ABSTRACT

Inflammation is a complex biological response linked to infection, tissue injury, and various chronic diseases. Natural products have attracted significant interest as potential anti-inflammatory agents due to their effectiveness and fewer side effects compared to synthetic drugs. This review examines the relationship between anti-inflammatory compounds found in pine trees (Pinus species) and Boswellia serrata. Pine trees contain multiple bioactive compounds—including flavonoids, phenolic acids, terpenoids, and proanthocyanidins—that show strong anti-inflammatory and antioxidant effects by regulating inflammatory mediators and oxidative stress pathways. Similarly, Boswellia serrata is rich in boswellic acids, especially 3-O-acetyl-11-keto-β-boswellic acid (AKBA), which inhibits key inflammatory enzymes such as 5-lipoxygenase and reduces pro-inflammatory cytokines. Comparative analysis reveals that both pine-derived compounds and boswellic acids exert their anti-inflammatory actions through several molecular mechanisms, including inhibition of inflammatory mediators, reduction of oxidative stress, and modulation of immune responses. These natural agents demonstrate promising therapeutic potential in managing inflammatory conditions like arthritis, asthma, inflammatory bowel disease, and other chronic inflammatory disorders. This review highlights the pharmacological importance of pine tree constituents and Boswellia serrata, underscoring their potential as complementary or alternative anti-inflammatory therapies and encouraging further clinical studies to validate their safety and efficacy.

KEYWORDS: Pinus Species, Pine Tree Constituents, Boswellia Serrate, Boswellic Acids, AKBA.

2. INTRODUCTION

2.1 Pine tree:- Pines are among the most economically valuable trees globally and, along with eucalyptus, dominate commercial forestry. However, the widespread planting of a few species like Pinus pinaster (maritime pine) comes with challenges. These pines are vulnerable to harmful pathogens and insect pests, notably the pinewood nematode (PWN), Bursaphelenchus xylophilus, which causes pine wilt disease (PWD). First identified in Japan, PWD has severely damaged forests in countries including China, Taiwan, Portugal, Spain, and the United States. The spread and progression of PWD are also aided by other organisms such as bacteria, fungi, and bark beetles.[1]

The objective of this study was to evaluate a pine tree substrate (PTS) in terms of decomposition, changes in its physical and chemical properties, and substrate carbon dioxide (CO_2) efflux as an indicator of microbial activity during a long-term production cycle under outdoor nursery conditions. The substrates examined included PTS made using a 4.76-mm hammer mill screen and aged pine bark (PB).[2]

Aleppo pine (Pinus halepensis Mill.) is native to Palestine and other countries surrounding the Mediterranean Sea. Historically, Palestine was abundant in pine forests, especially in the Judean Hills. However, over many centuries, these forests suffered extensive destruction due to human activity, leaving only small remnants of the original forests today.[3]

Aleppo pine (Pinus halepensis Mill.) is native to Palestine and other Mediterranean countries. Historically, Palestine, particularly the Judean Hills, was rich in pine forests. However, centuries of human activity have caused extensive destruction, leaving only small remnants of these original forests today.[4]

The simulation results indicate that a single Merkus Pine tree, when it reaches fifteen years of maturity, can generate an economic value of approximately IDR 47,980.04. Additionally, the developed virtual model of the Merkus Pine tree can function as a green lab, allowing for the analysis of its growth and development in connection with other related factors.[5]

This advancement holds significant implications for the conservation of pine forest resources and supports environmentally sustainable development.[6]

Monitoring pine wilt disease (PWD)-infected wood is essential for disease prevention and control. Early and accurate detection of affected wood is critical to limiting the initial spread of PWD, lowering monitoring and management expenses, minimizing damage, and ultimately strengthening forest protection in epidemic regions. Healthy pine trees have green needles, whereas in diseased pines, the needles gradually change color from green to yellow or reddish-brown due to water deficiency caused by clogged petioles. This lack of water ultimately leads to the death of the tree.[7]

The goal is to maximize the protection and enhancement of ecological environments while supporting the social and economic development of humanity, thereby ensuring the long-term sustainable use of the Earth's natural resources and ecosystems.

Morphologically, pine trees generally have a straight stem and, for their excellent lumber quality, have long been utilized as furniture material or building timbers for ancient palaces, temples.[9]

The area of total forest area in South Korea is 5839 thousand ha, of which the area of pine forest is 1489 thousand ha, which is the largest area (25.5%) based on a single species. Therefore, the amounts of waste or residue, such as pine bark, pine needles, and pine cones, from pine trees are expected to be enormous.[10]

In recent years, the young and dense ponderosa pine forests of northern Arizona have experienced extreme droughts, wildfires, and insect outbreaks .To restore these forests to an ecologically sustainable state, it is necessary to fell a large number of small-diameter pine trees. Heat and power can be generated through combustion; hydrocarbons can be produced in a reformer; and other chemicals can be obtained via pyrolysis. These include essential oils, resins (such as rosin, fatty acids, and fatty acid esters), and terpenes that can be extracted from slash and milling waste. These compounds have numerous high-value commercial applications, .including industrial and household cleaning products, disinfectants, solvents, fragrances, medicines, and aromatherapy.[11]

Nowadays, increasing levels of chemical pollutants in the environment are observed due to urbanization, industrialization, and agricultural activities. Various environmental matrices such as water, air, and soil are being affected by both organic and inorganic pollutants. They have long-term presence and accumulate in the environment due to their rapid and sustained release, capacity for mobilization and dispersion, non-biodegradable and long half-life (Rodriguez etc., 2012, Sun et al., 2010).[12]

Primary chronic inflammation: Develops from the onset of a disease, often caused by immune system disorders such as autoimmune diseases.

The organization of inflammation involves various factors from the immune system, including immune cells, complements, cytokines, inflammatory mediators, enzymes, and more. In recent decades, extracts from the oleo-gum resin of Boswellia serrata (BEs), boswellic acids (BAs), and other compounds have been studied for their effects on different components of the immune system and the cascade of events leading to inflammation.[13]

2.1. Chemical constituent

2.1.1 Terpenes and Terpenoids

Terpenes are hydrocarbons built from isoprene units, forming the basis of essential oils and resins in plants.
Terpenoids are modified terpenes that contain additional functional groups, often oxygen-containing, contributing to plant aroma, flavor, and defense.

2.1.2 Resin Acids

Organic acids primarily found in plant resins; they play a role in plant defense and have antimicrobial properties.

2.1.3. Sterols

Sterol compounds are a subgroup of steroids found in plant cell membranes, helping to regulate fluidity and permeability; examples include sitosterol and stigmasterol.

2.1.4. Fats, Waxes, Fatty Acids

Fats and waxes are lipid molecules used by plants for energy storage, protection, and preventing water loss.
Fatty acids are carboxylic acids that form the building blocks of fats and waxes.

2.1.5. Phenolic Compounds

Flavonoids: Diverse group of polyphenolic molecules involved in pigmentation, UV filtration, and defense.
Simple Phenols: Basic phenolic structures with antioxidant properties.
Tannins: Large polyphenols that bind proteins, contributing to plant defense and astringency.
Stilbenes: Phenolic compounds with antifungal and antioxidant activities.

2.1.6. Other Secondary Metabolites

Sugars: Besides their primary role in energy, some sugars act as signaling molecules or osmoprotectants.

Alkaloids: Nitrogen-containing compounds with potent biological activities, often involved in plant defense and sometimes used medicinally (e.g., morphine, caffeine).[14]

Dichloromethane (p.a., ≥99 purity) was obtained from Fisher Chemicals (Pittsburgh, PA,USA). Pyridine (anhydrous, 99.8%purity), *N*, *O*bis(trimethylsilyl) trifluoroacetamide (derivatization grade), chlorotrimethylsilane (≥99% purity), α-terpineol (90% purity), hexadecenoic acid (99% purity), nonadecan-1-ol (99% purity), stigmasterol (95% purity), tetracosane (99% purity), and vanillin (99% purity) were purchased from Sigma-Aldrich (Madrid, Spain). Betulinic acid (98% purity) was supplied by Chemos (Regenstauf, Germany). Dehydroabietic acid (DHAA) (99% purity) was obtained from Helix Biotech (Vancouver, BC, Canada).

2.1.7. Resin Acids

Pimaric acid
Sandaracopimaric acid
Levopimaric acid
Palustric acid
Isopimaric acid
Abietic acid
Dehydroabietic acid
Neoabietic acid
7-Oxodehydroabietic acid
16-Hydroxydehydroabietic acid
8,15-Isopimaridien-18-oic acid

2.1.8. Other Lipophilic Constituents

Various fatty acids
Aliphatic alcohols
Sterols (mainly β-sitosterol)
β-Caryophyllene (a sesquiterpene)
Aromatic compounds such as ferulic acid and vanillin.[15]

2.2. Boswellia Serrata

Extracts from the oleo-gum resin of Boswellia serrata, known as salai guggal in India, have been described in Ayurvedic texts (Charaka Samhita, 1st–2nd century AD, and Astangahrdaya Samhita, 7th century AD) as remedies for treating various inflammatory diseases. seases. Here is a clearer and more concise version of your text on inflammation.

Inflammation is the body's response to tissue damage, aiming to promote healing and restoration. There are three types of inflammation.
Acute inflammation: Typically triggered by infections or injuries.

Chronic inflammation: Results from the persistence of acute inflammation due to insufficient immune defense.

Boswellia serrata Roxb, a member of the Burseraceae family, is commonly known by several names including salai guggal, white guggal, loban, kundur, dhup, Indian olibanum, and most notably as shallaki in Sanskrit. It is one of the most important herbal medicines traditionally used to treat a variety of ailments and diseases. Its resin is valued for its anti-inflammatory, analgesic, and other therapeutic properties in traditional medicine systems Boswellia serrata is sometimes referred to as “Gajabhakshya,” a Sanskrit name meaning that elephants enjoy this herb as part of their diet. It is also known as Indian Fran kincense, where “Frankincense” comes from the French term meaning “pure incense.” The term “olibanum” is derived from the Arabic word “al-Luban,” meaning “milk” or “white,” referring to the resin’s appearance.

The Boswellia serrata tree has been traditionally used in various countries’ medicinal systems to treat a range of diseases. The Boswellia genus includes nearly 25 species, with some notable ones being Boswellia sacra, Boswellia carterii, Boswellia papyrifera, Boswellia neglecta, Boswellia frereana, Boswellia rivae, and Boswellia ovalifoliolata.

The plant formulation of Boswellia serrata is beneficial when applied externally for conditions such as stiffness of blood vessels, joint pain, inflammatory conditions, leg pain, pus formation, various types of wounds, and stomach problems. Additionally, it has been used in the treatment of eye cancer. Boswellia serrata is also traditionally employed in managing diseases related to the eye, tooth, tongue, and in preventing contamination of the birth canal.[16]

Clinical evidence has demonstrated that chronic inflammation can contribute to the development of certain types of cancers, neurodegenerative disorders, and rheumatoid arthritis. This highlights the importance of managing inflammation to potentially reduce the risk or severity of these diseases. Gum resin extracts of Boswellia serrata (BSE) have long been recognized as an anti-inflammatory herbal remedy. They have been used for centuries in traditional Ayurvedic medicine in India to treat various inflammatory conditions. This traditional use is supported by studies such as Kimmatkar et al. (2003), which highlight the therapeutic potential of BSE in managing inflammation.[17]

Boswellic acids selectively inhibit leukotriene synthesis by targeting the enzyme 5-lipoxygenase (5-LOX) through an enzyme-directed, non-redox, and noncompetitive mechanism. This inhibition contributes to their anti-inflammatory effects.

Salai guggal (Boswellia serrata) contains approximately 8-9% essential oil, 20-23% gum, and about 50% resin.[18]

Coronavirus disease 2019 (COVID-19) is a type of viral pneumonia caused by the novel coronavirus known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). The emergence of the COVID-19 pandemic has posed a significant global health threat, affecting millions worldwide and leading to widespread social and economic impacts. The deadly uncontrolled systemic inflammatory response, often referred to as a "cytokine storm," results from the excessive release of large amounts of pro-inflammatory cytokines and chemokines. This overwhelming immune reaction can cause severe tissue damage, organ failure, and is a critical factor in the severity of diseases such as COVID-19.[19]

Boswellia serrata (BS) is a proven antioxidant. Phytochemical analysis has revealed that it contains many valuable compounds, including lignans, flavonoids, hydrolysable tannins (ellagitannins), polyphenols, triterpenes, sterols, and alkaloids. These compounds contribute to its therapeutic properties, including antioxidant and anti-inflammatory effects.[20]

In the plant kingdom, the Burseraceae family is characterized by 17 genera and approximately 600 species, which are widely distributed across tropical regions worldwide. This family includes many resin-producing trees and shrubs, such as Boswellia and Commiphora species, known for their medicinal and aromatic properties.[21]

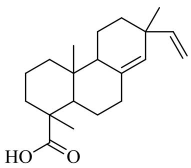
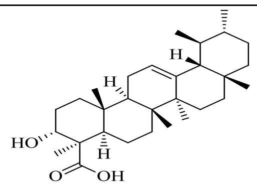
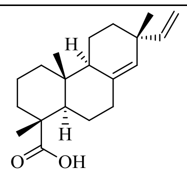
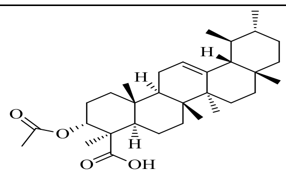
2.2.1 Chemical Constituents

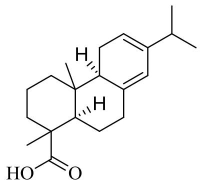
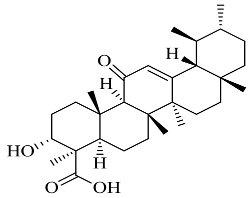
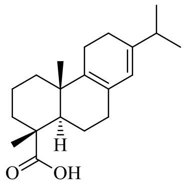
The resinous part of Boswellia serrata contains various compounds including monoterpenes, diterpenes, triterpenes, tetracyclic triterpenic acids, and four major pentacyclic triterpenic acids: β-boswellic acid, acetyl-β-boswellic acid, 11-keto-β-boswellic acid, and acetyl-11-keto-β-boswellic acid. These boswellic acids are responsible for inhibiting pro-inflammatory enzymes. Among them, acetyl-11-keto-β-boswellic acid is the most potent inhibitor of 5-lipoxygenase (5-LOX), the enzyme that plays a key role in inflammation.[22]

ABA, Acetyl-boswellic acid; AESG, Alcoholic Extract of Salai Guggul; AKBA, Acetyl-keto-boswellic acid; BA, Boswellic acid; BS, Boswellia serrata; BSA, Bovine Serum Albumin; BSE, Boswellia serrata Extract; CHP, Cumene hydroperoxide; EGR, Extract of Gum Resin; ESR, Erythrocyte Sedimentation Rate; GC, Gas Chromatography; HDL, High Density Lipoprotein; HPLC, High Performance Liquid Chromatography; ILs, Interleukins; KBA, Keto-boswellic acid; 5-LOX, 5-Lipoxygenase; LPs, Lipopolysaccharides; LTs, Leukotrienes; MAPK, Mitogen Activated Protein Kinase; MS, Mass Spectroscopy; PC, Pyruvate carboxylase; PEPCK, Phosphoenol Pyruvate Carboxy Kinase; PI3-K, Phosphatidyl Inositol-3-Kinase; PMNLs, Polymophonuclear Leukocytes; PTs, Pentacyclic Triterpenes; TNFα, Tumor Necrosis Factor α.[23]

1. Acetic Acid
2. AKBA: Acetyl-11-keto-β-boswellic Acid
3. Aβ: Amyloid beta-peptide
4. BAs: Boswellic Acids
5. BS: Boswellia serrata
6. BSE: Boswellia serrata Extract
7. COX-2: Cyclooxygenase-2
8. DNA: Deoxyribonucleic Acid
9. DOX: Doxorubicin
10. EO: Essential Oils
11. GC: Gas Chromatography
12. GC-MS: Gas Chromatography-Mass Spectrometry
13. 1H-NMR: Proton Nuclear Magnetic Resonance
14. HbA1c: Hemoglobin A1c
15. IL-6: Interleukin 6
16. iNOS: Inducible Nitric Oxide Synthase
17. KBA: 11-keto-β-boswellic Acid
18. 5-LOX: 5-Lipoxygenase
19. LPS: Lipopolysaccharide Extraction
20. MAPK: Mitogen-Activated Protein Kinase
21. NF-kB: Nuclear factor-kappa B
22. Nrf2/HO-1: Nuclear factor erythroid-2-related factor 2 / heme oxygenase-
23. TNBS: 2,4,6-TrinitroBenzene Sulfonic Acid.[24]

Table 1: Chemical constituents of pine tree and boswellia sarrata.

SN.	Pine tree chemical constituents	Boswelia sarrata chemical constituents
1	 **Pimaric acid**	 **Beta- boswellic acid**
2	 **Sandaracopimaric acid**	 **Acetyl-beta-boswellic acid**

3	 **Levopimaric acid**	 **11-keto-beta-boswellic acid**
4	 **Palustric acid**	

Other chemical constituents of pine tree are as Abietic acid, Dehydroabietic acid, Neoabietic acid,7-oxodehydroabietic acid, 16-hydroxydehydroabietic acid, 8,15-isopimariden-18-oic acid, chlorotrimethylsilan, hexadecenoic acid, Alpha- pinene, Beta- piene, Limonene, Camphene, Myrcene, Bormyl acetate and α-Pinene.Whereas myrcene and Acetyl- 11-keto-beta-boswellic acid are in Boswellia serrata tree.

3. AIM:- To study the correlation of anti-inflammatory agents present in Pine tree and Boswellia serrata.

4. OBJECTIVES

- To identify the major anti-inflammatory phytoconstituents present in Pine tree and Boswellia serrata.
- To study the pharmacological activities of bioactive compounds responsible for anti-inflammatory effects in both plants.
- To evaluate the therapeutic potential of Pine tree and Boswellia serrata in the treatment of inflammatory disorders.
- To review published scientific literature related to the anti-inflammatory activity of Pine tree and Boswellia serrata.
- To establish a correlation between the anti-inflammatory properties of Pine tree and Boswellia serrata.

5. Literature Review

5.1 Pine tree

BY Zhao 2024-Compared to other pine product extracts (hexane/water), the ethyl acetate extract of fermented pine needle (EAE-FPN) has a higher phenolic/flavonoid concentration. Compared to ordinary pine needles, EAE-FPN exhibited significantly higher levels of free radical scavenging activity (H2O2) and antioxidant indices (TEAC, DPPH). ROS and several inflammatory markers (NO, PGE2, TNF-α, and IL-1β/6) levels.[32]

L Karrat, MY Abajy, R Nayal Hellion, 2022:- The anti-inflammatory and analgesic effects of Cedrus libani and Pinus brutia leaves were investigated. Anti-inflammatory activity was assessed using the Human Red Blood Cells (HRBC) membrane stabilization assay and the albumin denaturation assay, with sodium diclofenac serving as the positive control. Inhibition of hemolysis was observed at concentrations of 2.5–12.5 µg/ml for P. brutia and 2.5–25 µg/ml for C. libani. Additionally, the albumin denaturation assay demonstrated protective effects for both plant extracts, with IC_{50} values of 47.74 µg/ml for C. libani and 81.50 µg/ml for P. brutia, respectively.[29]

Seung A Kim 2021:-An ethanol extract (Pd-EE) of Pinus densiflora Siebold and Zucc was derived from the branches of pine trees. According to the Donguibogam, pine resin has the effects of lowering the fever, reducing pain, and killing worms.[26]

EK Akkol, H Taştan 2018:-The antioxidant, anti-inflammatory, and wound healing activities of Maritime Pine (Pinus pinaster Ait.) have been widely studied for their potential therapeutic applications. The composition of essential oils and the quantities of both lipophilic and hydrophilic extracts were analyzed.[28]

XL Zhang, 2015:-he main components of Antrodia cinnamomea include polysaccharides, terpenoids, benzenoids, and nucleic acids. Among these, triterpenoids are particularly important, comprising a diverse range of tetracyclic compounds. These components contribute to the fungus's notable properties such as anti-inflammatory effects, liver protection, and immunoregulation. If you need more detailed information or specific aspects about these compounds or their effects Inflammatory biomarkers include cytokines, nitric oxide, enzyme activities, and various other molecules related to inflammation. These biomarkers play key roles in the body's inflammatory response and are often measured to assess the extent and nature of inflammation in tissues or the bloodstream.[33]

KH Lee, AJ Kim, EM Choi 2009: The antioxidant and anti-inflammatory activities of the ethanol extract of pine. 1,1-diphenyl-2-picrylhydrazyl (DPPH) radicals and hydrogen peroxide. The levels of malondialdehyde and protein carbonyls formed in liver homogenates were measured. Similar to its antioxidant activity, PPE also demonstrated excellent reducing power.[30]

Bakkali et al. Citation2008; Essential oils (EOs) derived from various plants, including different species of Pinus (pine trees), have been studied for their anti-inflammatory and anticancer properties. These oils contain bioactive compounds such as monoterpenes, sesquiterpenes, and phenolic compounds that contribute to their therapeutic effects.[25]

DW Huang, 2008-he protective effects of pine (Pinus morrisonicola Hay.) needle extract on low-density lipoprotein (LDL) oxidation and nitric oxide production in macrophages, as well as its bioactive compounds, were investigated.The ability to scavenge free radicals an d the levels of total flavonoids and polyphenols.[31]

CEM Choi EunMi – 2007:-- The antinociceptive and anti-inflammatory activities of pine (Pinus densiflora) have been investigated for their potential therapeutic benefits. Anti-inflammatory effects were evaluated using carrageenan- and formalin-induced paw edema modele effects of pine (Pinus morrisonicola Hay.)

Jerez et al., 2007-Enzogenol is rich in proanthocyanidins and is a more concentrated source of procyanidins compared to PYC (Jerez et al., 2007). It possesses multiple beneficial properties, including antioxidative, anti-inflammatory, anticancer, cardioprotective, and neuroprotective effects.[34]

The extract demonstrated antioxidant activity as evidenced by chemical assays: 2,2-diphenyl-1-picrylhydrazyl (DPPH) with a value of 58.4 ± 1.1%, and ferric ion reducing antioxidant power (FRAP) measured at 575 ± 17 mg Eq Fe(II) per gram of extract. It also contained high levels of flavonoids and phenolic compounds. In cytotoxicity tests, the P. radiata extract showed no toxicity up to 100 mg/mL in the CHSE-214 salmonid embryo cell line. Furthermore, its antioxidant activity at 50 µg/mL was confirmed by a dichlorofluorescein (DCFH) assay in the SHK-1 salmon cell line exposed to oxidative stress (H2O2), showing 58.9% activity.[35]

5.2 Boswellia serrata

Arif Jamal Siddiqui 2026:-Inflammation and oxidative stress are central contributors to the pathophysiology of lipopolysaccharide (LPS)-induced cardiac injury. LPS, a component of the outer membrane of Gram-negative bacteria, triggers a strong immune response that leads to the release of pro-inflammatory cytokines and the generation of reactive oxygen species (ROS). This inflammatory cascade and oxidative damage together cause cardiac tissue injury, impairing heart function. Targeting both inflammation and oxidative stress is therefore critical in managing and preventing LPS-induced cardiac damage.[44]

T Golakoti2020:-5-Lipoxygenase (5-LOX) is a key enzyme involved in the inflammatory process, making it a significant target in conditions like osteoarthritis (OA). LI13019F1, also known as Serratrin®, is a unique composition that has been studied for its anti-osteoarthritis efficacy. This formulation contains acidic boswellic acids, which are known to inhibit 5-LOX, thereby reducing the production of pro-inflammatory leukotrienes. By targeting the inflammatory pathways mediated by 5-LOX,[42]

MM Abouzied2020;-Boswellic acids—including α-, β-, and γ-boswellic acid—as well as their derivatives acetyl-β-boswellic acid, 11-keto-β-boswellic acid, and acetyl-11-keto-β-boswellic acid, are a group of triterpenic acids known not only for their anti-inflammatory effects but also for their ability to reduce oxidative stress. Additionally, these compounds have been reported to exhibit anti-cancer properties.

Their multifunctional bioactivity is linked to their capacity to modulate key molecular pathways involved in inflammation, oxidative damage, and cancer cell proliferation, making boswellic acids promising candidates for therapeutic applications beyond inflammation, including cancer prevention and treatment.[43]

G Yu, W Xiang, 2020: Current research indicates that 3-O-Acetyl-11-keto-β-boswellic acid (AKBA) is the boswellic acid with the strongest pharmacological activity. Notably, AKBA exhibits a powerful inhibitory effect on 5-lipoxygenase (5-LOX), a key enzyme involved in the inflammatory process. Clinical studies have demonstrated that Boswellia serrata extract, rich in AKBA, possesses significant anti-inflammatory and anti-arthritis properties, making it a promising natural therapeutic option for managing inflammatory conditions such as arthritis.[45]

K Saritha 2012

1. DPPH Free Radical Scavenging Assay: This method evaluates the extract's ability to neutralize the stable free radical 1,1-diphenyl-2-picryl-hydrazyl (DPPH), indicating its free radical scavenging potential.

2. Nitric Oxide Assay: This assay measures the extract's capacity to inhibit or scavenge nitric oxide radicals, which are reactive species involved in inflammation and oxidative stress.

3. Reducing Power Method: This test assesses the electron-donating ability of the extract, reflecting its potential antioxidant power by reducing oxidized intermediates.

4. HRBC (Human Red Blood Cell) Membrane Stabilization Method: This in vitro assay measures the extract's ability to stabilize human red blood cell membranes against hemolysis induced by hypotonic solution or heat, which is indicative of its potential to inhibit inflammatory processes.[41]

JN Kolla, 2011- Boswellia serrata, a traditional medicinal plant, contains bioactive compounds such as

3-O-acetyl-11-keto-β-boswellic acid (AKBA), which have shown significant potential as therapeutic agents against inflammatory diseases.[36]

MZ Siddiqui 2011:- Boswellia serrata contains a variety of bioactive compounds, including monoterpenes, diterpenes, triterpenes, tetracyclic triterpenic acids, and notably four major pentacyclic triterpenic acids: β-boswellic acid, acetyl-β-boswellic acid, 11-keto-β-boswellic acid, and acetyl-11-keto-β-boswellic acid. These boswellic acids are primarily responsible for the inhibition of pro-inflammatory enzymes.Among these, acetyl-11-keto-β-boswellic acid (AKBA) stands out as the most potent inhibitor of 5-lipoxygenase (5-LOX), a key enzyme involved in the inflammatory process. By effectively inhibiting 5-LOX, AKBA reduces the synthesis of inflammatory mediators, thereby playing a crucial role in controlling inflammation and contributing to the therapeutic potential of Boswellia serrata in inflammatory diseases.[38]

M Schubert-Zsilavecz 2011;-This limited bioavailability can reduce their therapeutic efficacy in vivo despite their potent anti-inflammatory activity demonstrated in vitro. As a result, improving the delivery and absorption of boswellic acids is a key area of research to enhance their clinical effectiveness in treating inflammatory conditions.[39]

M Abdel-Tawab2011;-β-Boswellic acid (βBA) has been suggested to possess anti-inflammatory properties by targeting specific enzymes involved in inflammation. It acts through the inhibition of serine protease cathepsin G (catG) and microsomal prostaglandin E synthase (mPGES).[40]

M. D. Kharya 2010:-Boswellic acids (BAs), including β-boswellic acid, acetyl-β-bos wellic acid, keto-β-boswellic acid, and acetyl-11-keto-β-boswellic acid (AKBA), are the main active compounds found in Boswellia serrata. These compounds act as novel and specific non-redox inhibitors of the enzyme 5-lipoxygenase (5-LOX).

5-LOX is an enzyme present in neutrophils that catalyzes the conversion of arachidonic acid into inflammatory mediators such as 5-HETE and leukotrienes. Leukotrienes contribute to various inflammatory responses including vasoconstriction, bronchoconstriction, increased vascular permeability, and chemotaxis (the movement of immune cells towards inflammation sites).

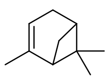
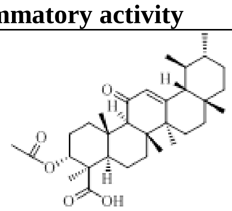
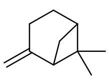
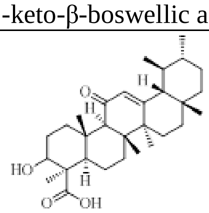
By inhibiting 5-LOX, boswellic acids reduce the production of these pro-inflammatory leukotrienes, thereby mitigating inflammation and the associated pathological effects. This mechanism underlies the therapeutic potential of boswellic acids in treating inflammatory diseases such as asthma, arthritis, and other conditions involving leukotriene-mediated inflammation.[37]

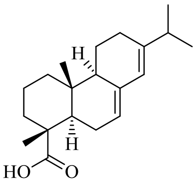
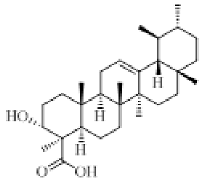
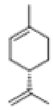
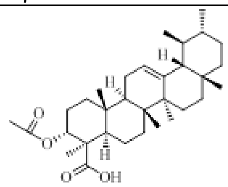
6. DISCUSSION

inflammatory agents for pine tree are Alpha- pinene, Beta- pinene, Abietic acid, Limonene, and for Boswelia sarrata are Acetyl-11-keto-β-boswellic acid (AKBA), 11-keto-β-boswellic acid (KBA), β-Boswellic Acid, Acetyl-β-boswellic Acid.

1. Acetyl-11-keto-β-boswellic acid (AKBA) is more potent anti-inflammatory agent between Alpha-pinene.[46]
2. 11-keto-β-boswellic acid (KBA) is more potent anti-inflammatory agent between beta- pinene.[47]
3. β-Boswellic Acid is more potrnt anti-inflammatory agent between Abietic acid.[48]
4. Acetyl-β-boswellic Acid is more potent inti-inflammatory agent between Limonene.[49]

Table 2: Known chemical contituents for potent anti-inflammatory activity.

SN.	Pine tree chemical constituents as Anti-inflammatory activity	Boswelia sarrata chemical constituents as Anti-inflammatory activity
1	 Alpha- pinene	 Acetyl-11-keto-β-boswellic acid (AKBA)
2	 Beta- pinene	 11-keto-β-boswellic acid (KBA)

3	 Abietic acid	 β-Boswellic Acid
4	 Limonene	 Acetyl-β-boswellic Acid

7. RESULTS

A comprehensive review of published literature revealed that both Pine tree (Pinus species) and Boswellia serrata possess significant anti-inflammatory properties due to the presence of various bioactive phytoconstituents.

In Pine tree, major anti-inflammatory compounds identified were α-pinene, β-pinene, limonene, abietic acid, flavonoids, phenolic compounds, and proanthocyanidins. These constituents demonstrated anti-inflammatory activity through inhibition of inflammatory mediators, reduction of oxidative stress, and antioxidant mechanisms. Several studies reported that pine extracts effectively reduced the production of nitric oxide (NO), prostaglandin E2 (PGE2), tumor necrosis factor-alpha (TNF-α), and interleukins involved in inflammatory responses.

Boswellia serrata was found to contain potent anti-inflammatory constituents including Acetyl-11-keto-β-boswellic acid (AKBA), 11-keto-β-boswellic acid (KBA), β-boswellic acid, and acetyl-β-boswellic acid. Among these, AKBA exhibited the strongest anti-inflammatory activity by selectively inhibiting the enzyme 5-lipoxygenase (5-LOX), thereby reducing leukotriene synthesis and inflammatory reactions. Clinical and preclinical studies demonstrated the effectiveness of Boswellia serrata in inflammatory disorders such as osteoarthritis, rheumatoid arthritis, asthma, and inflammatory bowel disease.

Comparative evaluation showed that both Pine tree and Boswellia serrata exert anti-inflammatory effects through modulation of inflammatory pathways and antioxidant activity. However, Boswellia serrata demonstrated comparatively stronger and more targeted anti-inflammatory action due to the presence of boswellic acids, particularly AKBA.

The reviewed studies support the therapeutic potential of both plants as natural anti-inflammatory agents and suggest their possible use as complementary or alternative treatments for chronic inflammatory conditions.

Overall, the literature indicates that while both plants possess substantial anti-inflammatory potential, Boswellia serrata exhibited greater efficacy due to its highly active boswellic acid constituents.

8. CONCLUSION

Both plant products of pine and boswellia are selectively works as anti-inflammatory agents with anti-oxidant properties. In future perspectives they might work with or without NSAIDs.

Comparison of Pine Tree to more potent the Boswellia serrata chemical constitution.

9. SUMMARY

Inflammation is a natural biological response of the body to injury, infection, or tissue damage. However, prolonged or chronic inflammation is associated with several diseases, including arthritis, asthma, inflammatory bowel disease, cardiovascular disorders, and neurodegenerative conditions. Due to the adverse effects associated with long-term use of synthetic anti-inflammatory drugs, there has been growing interest in natural products as safer and effective alternatives.

This systematic review was conducted to investigate the correlation between the anti-inflammatory agents present in Pine tree (Pinus species) and Boswellia serrata. Both plants have a long history of traditional medicinal use and are rich sources of bioactive phytochemicals with significant pharmacological activities.

The review revealed that pine trees contain several anti-inflammatory constituents such as α-pinene, β-pinene, limonene, abietic acid, flavonoids, phenolic compounds, and proanthocyanidins. These compounds exert anti-inflammatory effects through antioxidant activity, inhibition of inflammatory mediators, and modulation of immune responses. Similarly, Boswellia serrata contains boswellic acids, particularly Acetyl-11-keto-β-boswellic acid (AKBA), 11-keto-β-boswellic acid (KBA), β-boswellic acid, and acetyl-β-boswellic acid, which are well known for inhibiting 5-lipoxygenase (5-LOX) and reducing the production of pro-inflammatory cytokines and leukotrienes.

Comparative analysis of the literature demonstrated that both pine-derived compounds and boswellic acids possess potent anti-inflammatory and antioxidant properties. However, boswellic acids, especially AKBA, showed stronger and more specific anti-inflammatory activity due to their direct inhibition of key inflammatory pathways. The findings indicate that both plants may serve as valuable natural therapeutic agents for the management of inflammatory disorders.

In conclusion, Pine tree and Boswellia serrata exhibit significant anti-inflammatory potential through different but complementary mechanisms. Their bioactive constituents may provide safer alternatives or adjunct therapies to conventional anti-inflammatory drugs. Further experimental and clinical studies are recommended to validate their efficacy, safety, and potential synergistic effects in the treatment of chronic inflammatory diseases.

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