REVIEW ARTICLE

Pharmacological Insights into *Boswellia serrata*: A Comprehensive Review of Its Therapeutic Potential

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Abstract

Shallaki is the Ayurvedic name for *Boswellia serrata Roxb*., a plant of the *Burseraceae* family. The central peninsular Indian states of Andhra Pradesh, Rajasthan, Madhya Pradesh, Gujarat, Bihar, Assam, and Orissa are home to the plant. Its resin was primarily used for embalming and as incense during cultural occasions by the ancient Babylonian, Egyptian, Roman, Chinese, Greek, and Indian civilizations. This herb is listed in the traditional Ayurvedic pharmacopeia as a remedy for several ailments. Jvara (fever), Svasa (dyspnea), Sarkarameha (glycosuria), Mukharoga (mouth disease), Sula (pain), Pradara (excessive vaginal discharge), and Pittabhisyanda (conjunctivitis caused by pitta dosa). The qualitative phytochemical analysis of *B. serrata* extract reveals the presence of various bioactive constituents, including α-phellandrene. The key active compounds among the boswellic acids are β-boswellic acid, 3-O-acetyl-β-boswellic acid, 11-keto-β-boswellic acid, and 3-O-acetyl-11-keto-β-boswellic acid. In addition, the extract contains a range of terpenoids such as limonene, camphene, myrcene, β-terpene, *p*-cymene, thujene, β-phellandrene, and β-terpineol. tetracyclic triterpene acids have also been identified: 3-ketotirucall-8, 24-dien-21-oic acid, and 3-β-acetoxytirucall-8. Furthermore, the diterpene alcohol serratol is also present, contributing to the plant's pharmacological properties. This article provides a comprehensive evaluation of *B. serrata*, highlighting the convergence between its traditional applications and contemporary pharmacological evidence, while also discussing novel therapeutic potentials not previously described in classical texts.

Key words: Anti-inflammatory activity, Ayurveda, *Boswellia serrata*, resin, Shallaki

INTRODUCTION

The frankincense tree is the source of the gum resin called *Boswellia serrata* extract. For thousands of years, *B. serrata* has also been utilized in traditional Ayurvedic therapy in India. Boswellic acid is the active ingredient of *B. serrata*.[1]

One of the most effective herbal treatments is *B. serrata*, the native olibanum of frankincense, often known as luban. *Boswellia carteri*, *Boswellia sacra*, and *Boswellia papyrifera* are among the more than 25 species that are grown worldwide. *B. serrata* is grown in significant quantities in East Africa and Gulf countries such as Saudi Arabia. For thousands of years, frankincense has been used in traditional medicine by people in China, India, Africa, and Arabia. Around 1500 BCE, the Egyptian Ebbers Papyrus is one of the oldest known uses of frankincense. The resin was promoted as a remedy for fever, asthma, inflammation, and discomfort in addition to healing tumors and edemas. Similar anecdotes can be found in the writings of the Greek scholar Pedanius Dioscorides at the same period as well as in Ayurvedic archives from the first and second centuries CE[2]

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It is frequently grown in the Indian states of Orissa, Bihar, Gujarat, Rajasthan, Uttar Pradesh, and Madhya Pradesh.[3] In Ayurveda, the dried exudate from the bark of *Boswellia* trees is called "Shallaki," an oleo-resin.

To carry out the extraction, various parts of the *Boswellia* plant are required, including the leaves, stem, base, and in some cases, the entire plant. Extracts derived from *Boswellia* are effective in the treatment of numerous inflammatory conditions, such as ulcerations caused by Crohn's disease and colitis.

The essential oils and extracts obtained from *Boswellia* are also commonly used in the formulation of medicines for respiratory conditions such as cough and asthma, as well as in antiseptic mouthwashes.[4]

The resin component of nearly all *Boswellia* species primarily contains boswellic acids and pentacyclic triterpenes. Among these, Acetyl keto β-BA (AKBA) and 11-keto-β-boswellicacid (KBA) are the most potent anti-inflammatory agents. These compounds specifically inhibit leukotriene synthesis by non-redox, enzyme-directed, and non-competitive inhibition of 5-lipoxygenase (5-LOX).[5-7]

The key active boswellic acids in the resin include β-boswellic acid, 3-O-acetyl-β-boswellic acid, 11-keto-β-boswellic acid, and 3-O-acetyl-11-keto-β-boswellic acid. In addition to these acids, the extract contains gum, resin, and approximately 9% volatile oil, which comprises a variety of constituents such as *p*-cymene, limonene, camphene, myrcene, α-terpinene, β-terpinene, α-thujene, α-phellandrene, β-phellandrene, and α-terpineol.

Furthermore, the resin includes tetracyclic triterpene acids such as 3-ketotirucall-8, 24-dien-21-oic acid, and 3β-hydroxytirucall-8. In addition, the diterpene alcohol serratolis present in the extract contributes to its therapeutic profile. Medical uses include Sarkarameha (glycosuria), Jvara (fever), Pradara (excessive vaginal discharge), Sandhisula (pain), Sula (joint soreness), and Mukharoga (mouth disease).[8]

Taxonomical hierarchy[9]

- Kingdom - Plantae
- Subkingdom - Tracheobionta
- Division - Magnoliophyta
- Class - Magnoliopsida
- Order - Sapindales
- Family - Burseraceae
- Genus - *Boswellia*
- Species - Serrata.

One of the oldest and most prized plants in Ayurveda is *B. serrata*, or "Gajabhakshya" in Sanskrit.[10]

CLASSICAL AYURVEDIC FOUNDATIONS AND MEDICINAL USE OF GUGGUL

Susruta's *Susruta samhita* sought to consolidate the medical knowledge of its time, with a particular emphasis on surgical practices. Preceding this, Charaka's *Charaka samhita* had already established itself as one of the earliest and most foundational treatises on internal medicine. Subsequently, the two comprehensive works – Astanga Samgraha and Astanga Hridaya – attributed to *Vagbhata*, synthesized and systematized the teachings of both Charaka and Susruta. Collectively, these three classical texts constitute the cornerstone of traditional Ayurvedic medicine, forming its theoretical and practical framework. Among the earliest remedies detailed in Ayurvedic literature is guggul, a resin obtained from certain tree species. The *C. samhita* and *S. samhita* describe guggul's potent antirheumatic and antiarthritic properties.

Beyond rheumatic disorders, guggul has traditionally been used to treat a wide range of ailments, including Jaundice, Hemorrhoids, Irregular menstruation, Ringworm, Arthritis, Diarrhea, Dysentery, Boils, Fevers, Skin and blood disorders, Cardiovascular diseases, Mouth ulcers, Sore throat, Bronchitis, Asthma, Cough, Vaginal discharges, Hair loss, Liver dysfunction, and Syphilitic conditions. References to guggul also appear in Unani medicine, where its therapeutic scope is similarly extensive. Traditionally, it has been used both internally and externally, functioning as a stimulant, diuretic, astringent, and diaphoretic.

Modern pharmacological research has validated many of guggul's traditional uses. Today, it is recognized for its diverse therapeutic properties, including analgesic (pain-relieving), Hepatoprotective (liver-protecting), anti-inflammatory, anti-hyperlipidemic (reducing blood lipid levels), and antiatherosclerotic (preventing arterial plaque formation). These scientific confirmations highlight the enduring relevance of guggul in both traditional and modern medicine.[9,10]

Boswellic acid, the principal active compound found in *B. serrata*, has demonstrated significant pharmacological efficacy in the treatment of various chronic inflammatory conditions.[11] Among the different boswellic acid derivatives, 3-O-acetyl-11-keto-β-boswellic acid has been identified as a particularly potent inhibitor of 5-LOX, a key enzyme involved in the synthesis of pro-inflammatory leukotrienes.

Numerous studies have confirmed the analgesic and anti-inflammatory properties of *B. serrata* extract.[12-15] Furthermore, *in vitro* research has shown that the extract can downregulate the expression of adhesion molecules and various other inflammatory mediators, suggesting its role in modulating the immune response at the cellular level.

Safety evaluations have indicated that *B. serrata* extract is well tolerated, with no significant adverse effects reported even at

higher doses.[16-18] Among the various bioactive constituents of *Boswellia*, boswellic acids – a group of pentacyclic triterpenoids – have been recognized as the most pharmacologically relevant, particularly in contrast to the essential oils.[12]

Numerous studies examined the anti-inflammatory, anti-cancer, and memory-boosting properties of frankincense without distinguishing between species. The facts surrounding certain medical disorders, such as cancer, inflammatory diseases, osteoarthritis, and Alzheimer's disease, have been the subject of numerous assessments.[12,16] The ability of *B. serrata* extract to treat COVID-19 in older adults has also been evaluated. This study looked at information that supports *B. serrata's* effects are most likely related to COVID-19 because of its capacity to fight off pulmonary lesions, oxidative stress, inflammation, immunological disturbance, viruses, and secondary microbial infections. Most of the evaluations were based on data from *in vitro*, *in vivo*, and clinical studies.[17,18]

PHARMACOLOGICAL ACTIVITIES OF *B. SERRATA*

B. serrata exhibits a wide range of pharmacological activities, including anti-inflammatory, antioxidant, hepatoprotective, antidiabetic, antibacterial, anti-obesity, and anticancer effects. These therapeutic effects are attributed to its bioactive constituents, especially boswellic acids. A summary of these pharmacological activities is presented in Table 1.

ANTI-INFLAMMATORY EFFECTS

Rheumatoid arthritis is one inflammatory disease that *B. serrata* resin has been used to treat. It was discovered that boswellic acids, the most well-known active component in *B. serrata* resin, have anti-inflammatory properties. Among these, 3-O-acetyl-11-keto-β-boswellic acid is particularly potent. It exerts its effects by inhibiting cyclooxygenase-1and suppressing the expression of lipoxygenases, specifically 5-LOX and 12-lipoxygenase. Through these mechanisms, boswellic acids effectively reduce the production of pro-inflammatory mediators.[12-15] Interference with the interleukin (IL)-1β-mediated IL-1 receptor-associated kinase 1 (IRAK1) signaling pathway – by preventing the phosphorylation of IRAK1 and signal transducer and activator of transcription 3 – has been shown to reduce T-helper 17 cell differentiation. This suggests a potential regulatory mechanism of IL-1β signaling in modulating inflammatory immune responses.[19]

It has been demonstrated that boswellic acid inhibits the conversion of prostaglandin (PG) H2 to PGE2 by microsomal PG E2 synthase-1 (mPGES-1).[20] Along with boswellic acids, other known triterpene acids that were extracted from *B. serrata*, including 3α-acetoxy-8,24-dienetirucallic acid and 3α-acetoxy-7,24-dienetirucallic acid, also dramatically reduced mPGES-1[20] By reducing the activity of bacterial lipopolysaccharide (LPS), ß-boswellic acid may have anti-inflammatory effects, according to pull-down tests and the selective suppression of bacterial LPS-induced inducible nitric oxygen synthesis synthesis.[21] Incensole acetate prevented LPS-induced cytokine production and Nuclear Factor-κB activation by blocking IκB kinase phosphorylation.[22]

In mice with closed head injuries, incensole acetate removed the macrophages and reduced the activation of glial cells and nuclear factor-κB, as well as the expression of tumor necrosis factor-α (TNF-α) mRNA, IL-1β, and Transforming Growth Factor-β.[23] According to the previously mentioned research, incensole acetate may reduce inflammation, shield

Table 1: Pharmacological activities of *Boswellia serrata* ROXB

S. No.	Pharmacological activity	Plant part	Test model	References
1.	Anti-inflammatory activity	Gum resin	Carrageenan-induced paw edema in rats	[46]
2.	Analgesic activity	Gum resin	Acetic acid-induced writhing response Formalin-induced pain in rats, Eddy's Hot Plate, and Tail Flick Method in Rats	[47]
3	Anti-arthritic activity	Gum resin	Mycobacterium-induced poly arthritis in rats	[48]
4	Anti-asthmatic activity	Gum resin	Double-blind, Placebo control study on 40 patients of 18–75 year old	[49]
5	Immunomodulatory activity	Gum resin	Passive paw anaphylaxis and 48/80 compound degranulation of mast cell in rats	[50-52]
6	Anticancer activity	Gum resin	Ahrlic ascites carcinoma and S-180 tumor in mice	[53,54]
7	Hypolipidemic and Hepatoprotective activity	Gum resin	Galactosamin/endotoxin-induced liver damage in mice	[38,55]
8	Anti-ulcer activity	Gum resin	Burn wound	[56,57]
9	Antimicrobial activity	Gum resin	Filter paper disc diffusion	[58,59]
10	Anti-diarrheal activity	Gum resin	Acetylcholine, barium chloride, croton and castor oil-induced diarrhea in mice	[60,61]
11	Anti-diabetic activity	Gum resin	Streptozocin induced diabetic rat	[62,63]

neurons, and stop ischemia and reperfusion. Moreover, 3α-acetoxy-28-hydroxy-lup-20(29)-en-4β-oic acid inhibited cytosolic phospholipase-A2α, which decreased the synthesis of eicosanoids from COX, 5-LOX, and 12-lipoxygenases, hence suppressing eicosanoid biosynthesis in intact cells.[24]

ANTIOXIDANT EFFECTS

The antioxidant potential of *B. serrata* has been evaluated through various extracts, including alcohol-based fractions and specific compounds such as 3-O-acetyl-9, 11-dehydro-β-mastic acid.[25,26] The reported antioxidative effects include the inhibition of 5-LOX activity,[24] scavenging of oxygen-free radicals,[27] and prevention of elevated levels of malondialdehyde, a key biomarker of lipid peroxidation and oxidative stress.

In addition, *B. serrata* extracts exhibited significant antioxidant activity *in vitro*, as evidenced by their performance in DPPH and ABTS free radical scavenging assays. Interestingly, in animal models with damaged epithelial tissues, the methanolic fraction of mastic-containing compounds displayed both antioxidant and anti-inflammatory properties. This fraction also promoted epithelial regeneration and angiogenesis, suggesting therapeutic potential in tissue repair.

Overall, the antioxidant properties of frankincense (*Boswellia* spp.) are believed to contribute to its ability to mitigate oxidative stress, a key factor involved in the aging process and various degenerative diseases.[28]

ANTITUMOUR EFFECTS

Components and extracts of *B. serrata* have demonstrated therapeutic potential against several age-related malignancies, including glioblastoma, prostate cancer, fibrosarcoma, neuroblastoma, bladder cancer, leukemia, colon cancer, breast cancer, and liver cancer.[29-31] The anticancer effects of *B. serrata* are mediated through modulation of multiple cellular and molecular signaling pathways.

Notably, *B. serrata* extracts have been shown to regulate the p21/FOXM1/cyclin B1 axis, enhance the p53 signaling pathway, and downregulate Aurora B, thereby promoting cell cycle arrest and apoptosis in cancer cells.[31] One of its active compounds, acetyl-lupeolic acid, specifically binds to the pleckstrin homology domain of Akt, leading to potent inhibition of Akt signaling. This results in several downstream effects, including: Loss of mitochondrial membrane potential, Inhibition of mTOR pathway targets such as p70S6 kinase, β-catenin, p65/NF-κB, and c-Myc, Suppression of phosphorylation events associated with Akt pathway activation.[30]

Moreover, *B. serrata* has been shown to significantly reduce Sp1-stimulated androgen receptor promoter activity by impairing Sp1 DNA-binding capacity and suppressing c-Myc expression.[32,33] Another key compound, AKBA, has been found to phosphorylate Akt at Ser473 and Thr308, indicating its role in modulating Akt-related cancer progression pathways.[34]

In addition, β-boswellic acid has been reported to interact with several protein targets involved in oncogenesis, including proteases, 14-3-3 proteins, heat shock proteins, and ribosomal proteins.[35,36] These interactions suggest a multi-targeted mechanism by which *Boswellia* compounds may exert broad-spectrum anticancer effects.

ANTI-DIABETIC EFFECTS

The aqueous extract of *B. serrata* has demonstrated significant antidiabetic properties. In diabetic rat models, oral administration of the extract at doses of 200, 400, and 600 mg/kg led to a notable reduction in blood glucose levels, suggesting that *B. serrata* may serve as a promising natural source for the development of antidiabetic agents.[37]

Furthermore, clinical studies have shown that supplementation with *B. serrata* gum resin can help slow disease progression. Patients were administered 300 mg of gum resin orally, 3 times daily for 6 weeks. The treatment resulted in multiple beneficial effects, including:

- A significant reduction in blood cholesterol, low-density lipoprotein (LDL), fructosamine, serum glutamate pyruvate transaminase, and serum glutamate oxaloacetate transaminase levels.
- A marked increase in high-density lipoprotein levels.[38]

These findings indicate the potential of *B. serrata* not only in glycemic control but also in improving lipid metabolism and liver function in diabetic conditions.

ANTI-OBESITY EFFECTS

B. serrata extract has shown promise in the management of obesity. Studies conducted on obese rat models revealed that treatment with *B. serrata* extract significantly reduced body weight gain and visceral white adipose tissue mass.

In addition to weight reduction, the extract also led to a notable decrease in several metabolic and inflammatory markers, including:

- Triglycerides
- Total cholesterol
- Serum glucose
- Free fatty acids
- LDL cholesterol
- Insulin
- Leptin
- Pro-inflammatory cytokines such as IL-1β and TNF-α.[39]

These findings suggest that *B. serrata* may exert anti-obesity effects through the modulation of lipid metabolism, glucose homeostasis, and inflammatory signaling pathways.

DIURETIC EFFECTS

An *in vivo* study was conducted to assess the diuretic potential of *B. serrata* using albino rat models. The crude aqueous extract, administered intraperitoneally at a dose of 50 mg/kg, demonstrated approximately 44% diuretic activity. These findings indicate that *B. serrata* may serve as a potent natural diuretic agent, supporting its traditional use in the management of fluid retention and related disorders.[40]

ANTI-BACTERIAL EFFECTS

B. serrata has demonstrated broad-spectrum antibacterial activity against a variety of pathogenic microorganisms. The plant and its methanolic extract have shown efficacy against both Gram-positive and Gram-negative bacteria, including:

- *Salmonella* Typhimurium
- *Salmonella* Typhi
- *Staphylococcus epidermidis*
- *Proteus vulgaris*
- *Escherichia coli*
- *Staphylococcus aureus*
- *Klebsiella pneumoniae*
- *Enterobacter aerogenes*
- *Pseudomonas aeruginosa.*[41]

The methanolic extract was particularly effective in suppressing the growth of *Salmonella* Typhi, *S. aureus*, and *S. epidermidis*. It also exhibited notable antibacterial activity against *Salmonella* Typhimurium, *P. aeruginosa*, *E. coli*, and *E. aerogenes*. However, its effectiveness was comparatively lower against *P. vulgaris*.

Further studies identified that the phenolic compounds in the gum resin of *B. serrata* contributed significantly to its antibacterial properties. These phenolics exhibited strong inhibitory effects against Bacillus subtilis, *Streptococcus pneumoniae*, and *P. vulgaris*, with phenols being more potent than fatty acids in antimicrobial action.[42]

These findings highlight *B. serrata* as a promising natural source of antibacterial agents, potentially useful in combating drug-resistant bacterial infections.

MEMORY ENHANCING PROPERTY

B. serrata has been traditionally regarded for its cognitive-enhancing properties, particularly in improving memory. In one study, the effects of *B. serrata* were evaluated in 24-month-old male Wistar rats, focusing on spatial learning abilities and dentate granule cell morphology. The rats received an intragastric administration of an aqueous extract of *B. serrata* at a dose of 100 mg/kg daily for 8 weeks. The results demonstrated a significant enhancement in both memory function and the size of dentate granule cells, indicating a potential neuroprotective effect.[43]

In another study, researchers investigated the combined effects of *B. serrata* and *Melissa officinalis* on memory using scopolamine-induced memory-impaired rat models. When administered at doses of 200 and 400 mg/kg body weight, both plant extracts significantly improved memory performance, suggesting synergistic cognitive benefits.[44]

These findings support the potential use of *B. serrata* as a natural nootropic agent for managing age-related cognitive decline and memory impairments.

HEPATOPROTECTIVE EFFECTS

An *in vivo* investigation has demonstrated the hepatoprotective potential of *B. serrata*. In the study, liver damage was experimentally induced in animal models using thioacetamide, carbon tetrachloride (CCl_4), and paracetamol. Treatment with the hexane extract of *B. serrata* oleo-gum-resin, administered orally at a dose of 87.5 mg/kg, significantly reduced elevated levels of liver marker enzymes and decreased liver weight in all treated groups. These findings indicate that *B. serrata* exerts protective effects on the liver and may be a promising candidate for the development of natural hepatoprotective agents.[45]

CONCLUSION

The resin of *Boswellia* species, commonly known as frankincense, has been used since ancient times as incense in religious and cultural ceremonies. Beyond its ceremonial importance, it is well-known for its medicinal properties, particularly in the treatment of inflammatory diseases, wound healing, and even certain malignant conditions, largely due to its antibacterial and anti-inflammatory effects.

Despite its long-standing historical, cultural, and traditional significance, *Boswellia* remains underexplored in modern scientific research. There is still a noticeable gap between its traditional applications and the current scientific understanding of its therapeutic value. Traditional medicine continues to be widely relied upon for various reasons, especially in regions with limited access to modern healthcare.

To fully harness the potential of *Boswellia*, there is a pressing need for further research including the identification of active constituents, development of novel therapeutic agents, and the standardization and validation of herbal remedies.

Indeed, the time has come for focused scientific advancement to help protect humanity from the growing burden of diseases through the integration of traditional wisdom and modern medicine.

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