

Frankincense: A Comprehensive Review

Sophia Lee^{1*}, Daniel Suh^{2*}, Francis Hong^{3*}, Brandon Yang⁴⁺, Kelly Gu⁵⁺, Jenna Park⁶⁺, Jennifer Nah⁺, Ariel Han⁸⁺, Yejin Cho⁹⁺

*These students contributed equally

+These students contributed equally

¹ sphialeespam@gmail.com

² danielsuh39@gmail.com

³ francis71103@gmail.com

⁴ brandonyang0001@gmail.com

⁶ kellygu15@gmail.com

⁷ jeenapak69@gmail.com

⁸ jennifer02032011@gmail.com

⁹ eriiihan10@gmail.com

¹⁰ goyejincho1020@gmail.com

ABSTRACT

Derived from the *Boswellia* family's resins, frankincense essential oils (FEOs) have long held significance both historically and in modern biochemistry in understanding the terpenoids effect in human bodies and their applications in the medical field. This comprehensive review aims to explore the roles of FEOs primarily in contemporary scientific research in understanding the bioactive components (e.g. terpenoids) found in FEOs, extraction methods, pharmaceutical, and cosmeceutical applications. This review also touches upon some of the challenges posed by the overharvesting of frankincense, leading to its poor bioavailability and the potential ecological threat held to *Boswellia* populations emphasizing more sustainable farming practices and advocating for further research into the enhancement of frankincense in the pharmaceutical field. Holding significant potential in the pharmaceutical field against inflammation, microbial infections, and cancer, frankincense requires further research in promoting higher quality extracts while maintaining ecological sustainability.

1. INTRODUCTION

Frankincense has been known for more than 5000 years and studied for chemical composition, traditional uses, and possible medicinal effects. Many review papers have mainly focused on areas such as boswellic acids, anti-inflammatory activity, anti-cancer effects, anti-bacterial and anti-fungal effects, and other beneficial health effects, yet these topics are often reviewed separately rather than together. This review provides a broader overview of frankincense by connecting chemical compositions and extract methods of frankincense with the biological activities, pharmaceutical applications, and sustainability. This review also examines how frankincense is harvested and extracted, and how it may interact with biological targets, and how frankincense is used in areas such as medicine, aromatherapy, cosmetics, and other possible applications. This review is organized to first introduce the impact, harvesting, extraction, and chemical composition of frankincense. After, we aim to review extraction methods, biological activities, pharmaceutical and other possible applications, and sustainability.

1.1 Impact

In recent years, there have been increasing use of natural oils as treatments for therapeutic benefits (1, 2). Frankincense essential oils, or FEOs, proven to be beneficial in the healthcare industry, showing anti-cancer, anti-inflammation, anti-microbial and other therapeutic uses including aromatherapy (3). In frankincense, the primary chemical is boswellic acid, a pentacyclic triterpene. For such cases, a study funded by the Friedrich Schiller-University Jena in Germany provided a method of liquid chromatography to quantify and extract the amount of boswellic acid within a frankincense formulation (4). With the rise of frankincense's anti-inflammatory properties there remains a differentiation within the effectiveness of said products.

1.2 Harvesting of Frankincense Essential Oils

Traditionally, frankincense has been harvested by injecting frankincense trees with a specialized knife called "Mengaf" (5). Within the 20th century, frankincense had primarily been exported by Indonesia, with frankincense exports reaching 1913 tons in the year 1939; however, as the 21st century approached, the production of frankincense declined (6). In countries like Somalia and India, frankincense harvesting is primarily rooted in generational practices (7). A region in India with the longest tradition of frankincense harvesting had over 50% of harvesters begin the practice since childhood.

1.3 Oil Composition

The main active components of FEOs include a variety of terpenoids, also known as isoprenoids.

The type and amount of terpenoids found in the different *Boswellia* plants differ depending on the plant (8, 9). Nonetheless, *B. sacra* and *B. carteri* were chemically similar, both containing the same triterpenoids and various acids (10, 11).

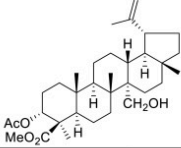
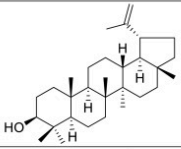
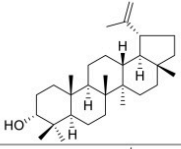
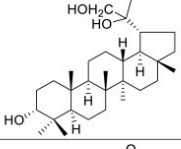
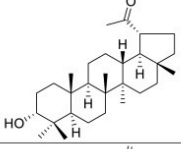
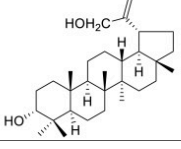
<i>B. papyrifera</i>	3 α -Acetoxy-27-hydroxylup-20(29)-en-24-oic acid (64)		Atta-ur-Rahman et al., 2005
<i>B. frereana</i> , <i>B. carteri</i> , <i>B. serrata</i>	Lupeol (65)		Proietti et al., 1981; Badria et al., 2003ali; Jemmali et al., 2016
<i>B. frereana</i> , <i>B. carteri</i>	3-Epi-lupeol (66)		Proietti et al., 1981; Yoshikawa et al., 2009
<i>B. carteri</i>	Olibanumol H (67)		Yoshikawa et al., 2009
<i>B. carteri</i>	Olibanumol I (68)		Yoshikawa et al., 2009
<i>B. carteri</i>	Lup-20(30)-ene-3 α ,29-diol (69)		Morikawa et al., 2010; Ullah et al., 1999

Figure 1. Table comparing six terpenoid compositions across *B. sacra*, *B. serrata*, and *B. papyrifera*. The columns detail the specific *Boswellia* species each terpenoid is found in, the name of the terpenoid, diagram of the terpenoid, and a reference respectively.

Specifically, diterpenoids and triterpenoids, which are types of terpenoids, are incredibly valuable in the anti-inflammatory and anti-cancer activities of frankincense (8). Byler et al. utilized a reverse docking method to understand the binding abilities of the different diterpenoids and triterpenoids originating from frankincense (7,12). In the process of docking it models the 3D structure of a target protein to predict how strongly it will bind (9,11). By analyzing which protein a compound may potentially prefer, reverse-docking allows people to understand what compound may best relate to the biological pathway (12). By examining which proteins the terpenoids selectively docked on, researchers were able to infer the role of these terpenoids in pharmaceutical uses. For example, diterpenoids were found to have both antimicrobial and neurological effects as they bind to bacterial proteins and acetylcholinesterase, a protein related to memory neurotransmitters and Alzheimer's disease (3,5). In addition, other frankincense triterpenoids were found to have selective binding to cancer-related proteins and inflammation related proteins, showing a wide range of medicinal effects of FEOs for various health conditions (10). More specifically, the triterpenoids were found to affect the cancer-related proteins poly(ADP-ribose) polymerase-1, tankyrase, and folate receptor β , while inflammation-relevant proteins that were affected

included phospholipase A2, epoxide hydrolase, and fibroblast collagenase (12). More specifically these triterpenoids act on cancer-linked targets with chemicals like tankyrase stabilizing β -catenin, polymerase-1 driving Wnt/ β -catenin and leading to anti-cancer activity in hepatocellular carcinoma (13, 14). Furthermore, they act on inflammation-linked targets such as phospholipase which can be linked to arthritis, Crohn's, and colitis (12).

2. LITERATURE SEARCH METHODOLOGY

A literature search was conducted to identify studies relevant to the chemical composition, extraction, biological activities, pharmaceutical applications, non-pharmaceutical applications, and sustainability of frankincense and *Boswellia* species. We used Google Scholar, PubMed, Reaxys, and Web of Science for searching scientific literature. Within the scientific literature search, “ frankincense,” “ frankincense essential oil,” “Boswellia,” “Boswellia serrata,” “Boswellia sacra,” “boswellic acid,” and combinations of these terms with “extraction,” “terpenoids,” “anticancer,” “anti-inflammatory,” “antimicrobial,” “aromatherapy,” “cosmetics,” and “pharmaceutical” are used for our literature review purpose. The literature search covered publications from 2009 through 2025. We identified 135 potentially relevant articles from the scientific literature search and 70 articles were selected for our literature review.

3. EXTRACTION OF FRANKINCENSE ESSENTIAL OILS

3.1 Hydro-Distillation

FEOs can be readily extracted from *Boswellia* resin using steam distillation, making hydrodistillation as the prominent method is FEO production. This method is desired as it does not require sophisticated apparatus to extract FEOs from the natural plants. According to the research conducted by the National University of Science and Technology (NUST) team, they demonstrated that the steam distillation of mixture between ground frankincense resins and boiling water showed one of the best extractions of FEOs to which 5-9% of the essential oils were distilled from his resins (15, 16, 17). As the solvent evaporates, the remnant oil layer would eventually phase segregate based on their density difference separating valuable FEOs from other undesired natural products.

3.2 Other Extraction Methods

Although the most common method of extracting FEOs from gum resins is hydrodistillation, this process often requires large amounts of solvent to work effectively. More sophisticated methods including solvent extraction aided by liquid chromatography (LC) have been developed as well to increase the yield of FEO (16, 17, 18).

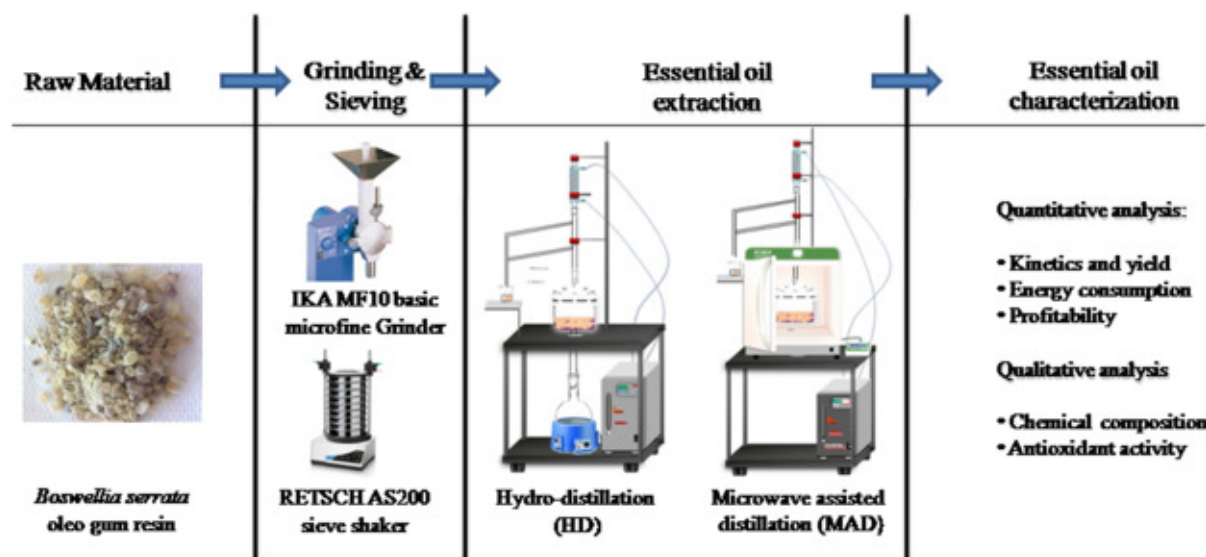


Figure 2. Flowchart of the frankincense extraction process from raw material (*Boswellia serrata*) to essential oil extraction and characterization.

A study conducted by a team in Friedrich Schiller-University Jena deciphered further insights into FEO chemistry. The extraction was conducted by mixing the samples of commercial boswellic acid samples (e.g., Sallaki, BOSWELLIAN, and Ayurmedica) with methanol. This resulting solution was centrifuged to allow the supernatant to be isolated from the solution. The separation was conducted via LC and analyzed with mass spectrometry (MS) to quantify the Boswellic acid content (4, 18).

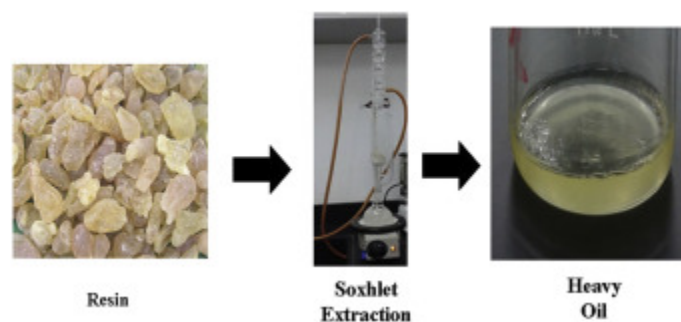


Figure 3. Image of the Soxhlet Extraction process of heavy oil from frankincense resin.

In regards to pure frankincense, derived from *Boswellia*, different species provide a different profile of essential oils, causing a significant amount of variance in the amount of certain active chemicals within the oils. Thus, hydro-distillation acts as the primary method of extracting the oils from *Boswellia* samples.

In an experiment funded by the Aromatic Plant Research Center, the essential oils were distilled in yields of 13% with the usage of the solvent dichloromethane in a filtered environment at room temperature, allowing for evaporation giving extract samples of the resins (9, 19). The primary essential oils that were

found were alpha-thujene showcasing yields around 15% and alpha-pinene showcasing yields of 52.2% of the essential oils in selected groups (10, 20).

4. PHARMACEUTICAL APPLICATIONS

4.1 Anti-Cancer Activity

Frankincense has demonstrated significant pharmaceutical potential across various medical applications (21, 22, 23). Their prominent effect comes from the FEOs ability to bind to cancer-related proteins and ceasing cancer cell proliferation (24, 25, 26). A notable study conducted by Byler, K. G., et. al demonstrated that Boswellia diterpenoids and triterpenoids can selectively bind to proteins that were linked to cancer demonstrating its ability and effectiveness against cancer (12). Furthermore, frankincense bowellic acid derivatives including 3-O-acetyl-11-keto- β -boswellic acid (AKBA) and 11-keto- β -boswellic acid (KBA), which have is especially anti-carcinogenic, allowing it to be a candidate for anti-cancer drugs in the future (27, 28, 29). These active compounds also showcased to be major inhibitors of inflammatory enzymes, which is significant in the reduction of cancer progression (30, 31, 32). Even though these compounds show promising anti-cancer activity, the amount required to have anti-cancer effects is very large. Therefore, we might modify the compound to enhance the anti-cancer activity.

4.1.1 Liver Cancer

FEOs demonstrated their potency in liver cancer treatment due to their ability to subdue the growth of liver cancer cells while protecting healthy liver cells. Bonilla, I. V., et. al conducted a study on 20 women for 11 days before their surgery and compared the tumor growth in groups who took the FEO-based drugs and the control group (33). Those who took the drug exhibited significantly less tumor growth compared to those who did not (33). This works because boswellic acids seem to be associated with the blockage of cancerous proliferation which affects how fast cancer cells can copy themselves (13, 14). Furthermore, compounds found in Boswellic acid may be modulating apoptotic-signaling molecules with caspase, leading to cancerous cell death (13, 34). A further interesting finding is an animal study showing that rats treated with FEOs exhibited protective effects against experimentally induced liver cancer (13, 14, 34). In the study, rats were given a carcinogen associated with liver cancer, the rats that were provided the essential oils had a higher recovery rate from hepatocellular carcinoma which is due to the fact that frankincense oils affect gene expression (13, 14, 34). Within the liver cancer group, the genes of β -catenin, PCNA, and Cyclin D1 were affected; however, each of these chemicals seem to be associated with a function that may limit cancer (13, 14). β -catenin is a key mediator of the canonical Wnt signaling pathway (13, 14). Aberrant stabilization and accumulation of β -catenin can lead to persistent activation of Wnt/ β -catenin signaling, promoting the transcription of genes involved in cell proliferation and tumor progression (13, 14). that causes constant, proliferating cell nuclear antigen (PCNA) is a DNA sliding clamp that plays an essential role in DNA replication and is widely used as a marker of proliferating cells, and Cyclin D1 is a cell that can get hijacked in order to push cells to the replication checkpoint (13, 14). However, with these three cell components being downregulated, FEOs may have practical usage in limiting cancer once we understand what specific components lead to this gene regulation (13, 14, 34).

Even though there is evidence of Frankincense being effective against liver cancer, yet more vigorous and detailed human trials are needed. Animal models provide evidence of frankincense having anti-cancer activity but do not provide clinical efficacy in human liver cancer patients yet.

4.1.2 Breast Cancer

Boswellic and lupeolic acids, which are bioactive triterpenoids found in frankincense, are responsible for the medicinal properties which fight against breast cancer (27). In vitro studies show that frankincense nutraceuticals and purified boswellic acid are cytotoxic against triple-negative breast cancer cell lines, including MDA-MB-231, CAL-51, and MDA-MB-453 (35, 36). A study by Schmiech et. al. found correlations between boswellic and lupeolic acid amounts with cytotoxic activity, especially β -boswellic acid, which displayed the highest cytotoxicity, $IC_{50} = 5.9 \mu M$ for MDA-MB-231 cells (35, 36). Drugs with higher FEOs concentrations such as FN9, FN13, and FN16 revealed significantly higher cytotoxicity of $IC_{50} = 6.0\text{--}7.0 \mu g/mL$ (35, 36). This result suggests that a dose-dependent relationship could be present FEO concentration and breast cancer cells viability (35, 37, 36). Further research, however, is necessary to investigate a direct cause-and-effect relationship between the triterpenoid levels in frankincense and cytotoxicity of breast cancer cells.

Frankincense's acids also signal the release of proinflammatory cytokines, including $TNF-\alpha$, IL-6, and IL-8, which are used during tumor progression and metastasis; this inhibition is most defined with higher β -ABA content (35, 36). In vivo, using the chick chorioallantoic membrane model, frankincense nutraceuticals and β -ABA significantly inhibited tumor growth and induced apoptosis in breast cancer xenografts, shown by decreased Ki-67 proliferation marker and increased TUNEL-positive apoptotic cells (35, 36). Acetylated boswellic acids inhibited human topoisomerases and the transcription factor NF- κ B, while lupeolic acid acted as an AKT kinase inhibitor, contributing to anti-proliferative effects (35, 36). In addition, frankincense extracts were found to be more toxic to cancer cells than to normal peripheral blood mononuclear cells, suggesting a potential therapeutic window due to its relative safety and low risk, with only mild gastrointestinal symptoms reported, in contrast to the severe adverse effects of other chemotherapy drugs (such as doxorubicin) (35, 36, 32).

Other studies confirm the anti-inflammatory, anti-proliferative, and pro-apoptotic behavior of frankincense in breast cancer models, including suppression of tumor growth, induction of apoptosis both in vitro and in vivo, and modulation of key oncogenic pathways such as AMPK/mTOR (37). Boswellia serrata extract was overall well-tolerated and led to a significant reduction in tumor cell proliferation in breast cancer patients, with no reported negative reactions to treatments (33, 36). These findings help to support frankincense's potential as a therapy for breast cancer patients, especially for those with aggressive and treatment-resistant subtypes (33, 36). Overall, these studies may show that frankincense-derived compounds can have anti-cancer effects, but perhaps more evidence is still needed. Once again, frankincense extracts do show anti-cancer activities in animal models but do not always show the same results in human-trials. For this reason, scientists need to perhaps at least do in vitro study on human cancer cells. If in vitro study shows promising data, perhaps we can move into more complicated

experiments such as phase I. More deeper studies are needed to confirm those effects are still applicable for humans.

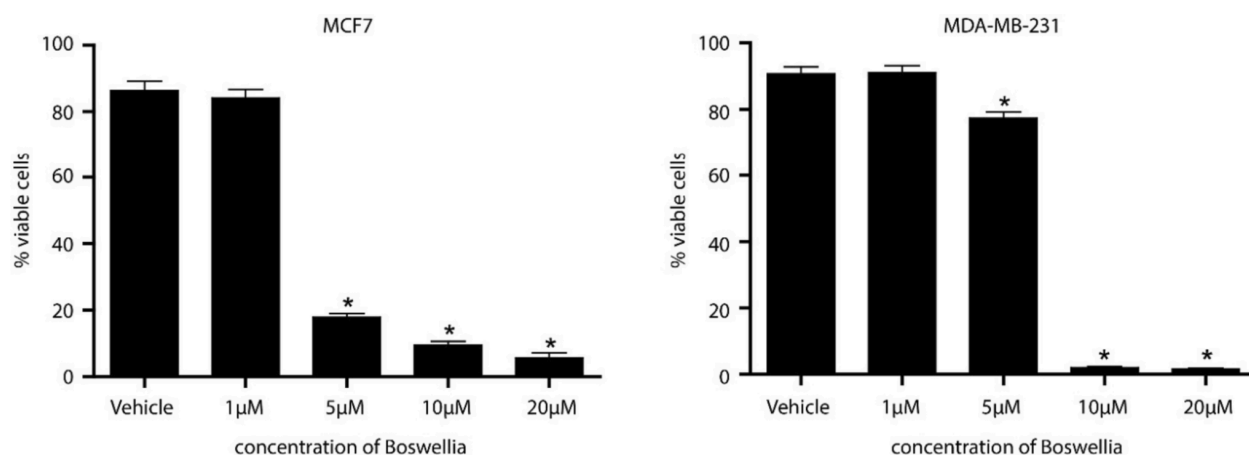


Figure 4. Chart of Boswellia concentration's effects on MCF7 and MDA-MB-231 breast cancer cells

4.2 Anti-Inflammatory Effects

Musculoskeletal pain, encompassing conditions like arthritis and back pain, are related to discomfort that affects muscles, bones, and joints. This pain mainly comes from inflammation, which can either be chronic and cause a more prolonged level of discomfort. Non-steroidal anti-inflammatory drugs (NSAIDs) are mainly given to patients in order to reduce the amount of inflammation and provide pain relief by inhibiting the very enzymes involved in the inflammatory processes present in the body (20, 38). Among these drugs, aceclofenac is shown to treat chronic conditions like osteoarthritis which is the cause of joint stiffness and pain (27,32). Ankylosing spondylitis which is inflammation in the spine and rheumatoid arthritis that is an autoimmune condition affecting joints are also affected by NSAIDs help improve mobility and reduce pain, offering relief for patients dealing with these conditions (38).

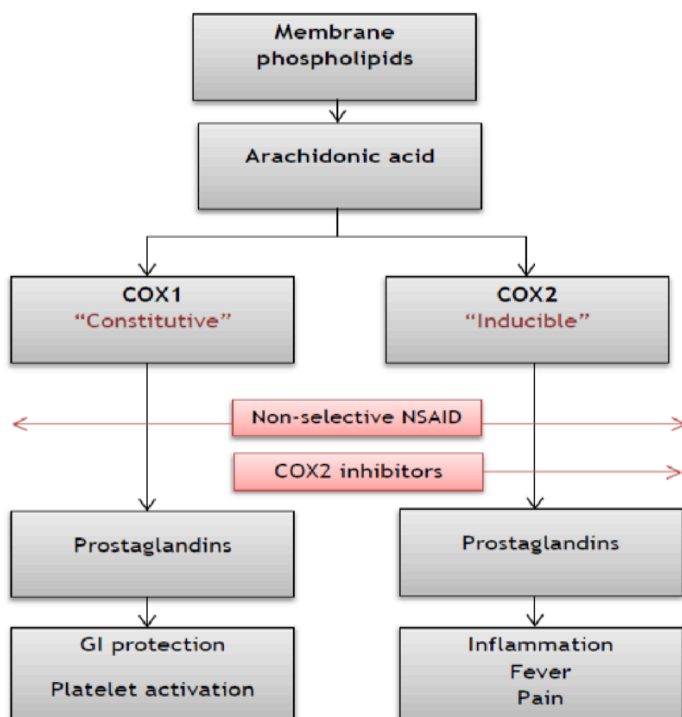


Figure 5. NSAID association with the inhibition of COX-1 and COX-2 enzymes linked with inflammation and physiological function

In addition to that of conventional medications, natural supplements are being investigated for their anti-inflammatory properties and potential to help patients within this field. *Boswellia serrata* which is a plant extract is showing its promise when it comes to reducing inflammation and ameliorating pain (39, 40). Research has demonstrated that *Boswellia* can reduce symptoms and improve joint function to a significant extent, particularly in patients that have osteoarthritis (41, 42). Furthermore, chemicals such as acetyl-11-keto- β -boswellic acid (AKBA), a primary component of *Boswellia*, have been identified for their unique abilities in reducing inflammation in joints by activating the Nrf2/HO-1 pathway, a mechanism or part of the body that helps control oxidative stress and inflammation (38). This event makes *Boswellia* a valuable alternative or supplement which can compare to traditional treatments for issues such as chronic musculoskeletal pain (38, 42).

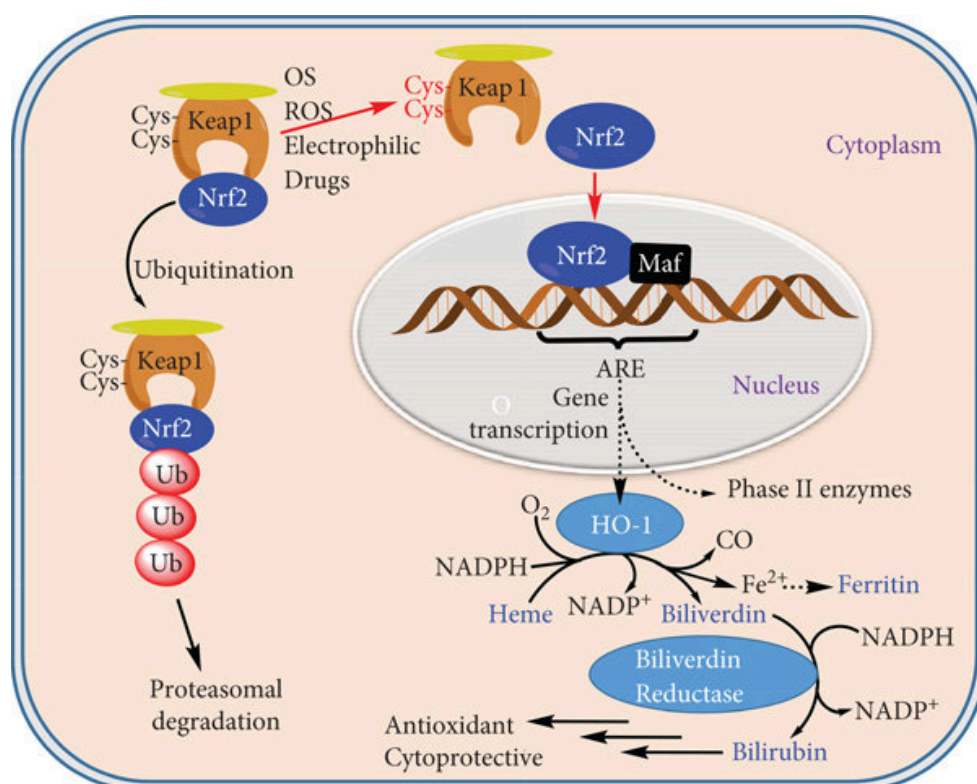


Figure 6. The Nrf2-Keap1-HO-1 pathway which protects cells from stress by releasing Nrf2, activating antioxidant genes.

Recent studies have further explored these effects of combining *Boswellia serrata* with other natural compounds (43). For example, formulations that have both *Boswellia* and curcumin lead to enhanced efficacy in pain reduction and the approval of function in knee osteoarthritis patients compared to the prospect of simply using either supplement alone (43). This idea suggests that combination therapies may offer additional benefits and could be considered within personalized treatment plans.

In conclusion, both aceclofenac and *Boswellia serrata* offer their special benefits when it comes to managing musculoskeletal pain which can be associated with conditions like OA, AS, and RA. While aceclofenac provides effective pain relief with a good safety profile, *Boswellia serrata* is basically that of a natural alternative that holds efficacy in reducing pain and inflammation. Evidence from emerging research gives support to this potential of combination therapies involving *Boswellia* and other natural compounds. By pushing these natural and novel treatments into patient care, it requires careful consideration of individual patient profiles and consultation with healthcare professionals to ensure optimal outcomes.

Most anti-inflammatory, non-steroidal drugs are shown to be related with negative effects on the gastrointestinal and cardiovascular systems present in the human body (1, 42). Frankincense can be

relevant as a herbal alternative that does not provide these effects, but rather directly affects inflammation like that of post-inflammatory bowel disease, rheumatoid arthritis, osteoarthritis, or asthma (42, 44, 45).

Thus, frankincense limits inflammation by inhibiting the following chemicals provided: histamine, prostaglandins, leukotriene, 5-lipoxygenase, human leukocyte elastase, cytokines, tumor necrosis factor, and free oxygen radicals (1, 44, 45). The boswellic acids in frankincense are associated with limits on leukotriene formation, with chronic leukotriene formation indicating a chronic inflammatory disease (42).

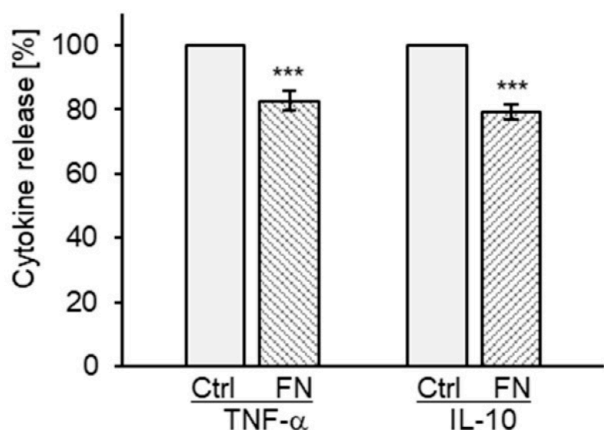


Figure 7. A graph demonstrating frankincense's (FN) inhibitory effects on cytokines TNF-α and IL-10 compared to a control (Ctrl) are shown above. The presence of frankincense consistently shows a decreased cytokine release.

4.3 Anti-Bacterial, Anti-Fungal, and Antioxidant Properties

The triterpenoids in Frankincense's boswellic acids are attributed to the anti-inflammatory and anti-cancer properties; however, frankincense is similarly potent as an anti-microbial chemical. (46, 47). Describing a structure similar to that of steroids, triterpenoids inhibit the enzymes of urease and α-glucosidase (8). To name specific triterpenes that are involved with frankincense's antibacterial properties, trirucallane triterpenes are a primary example connected with frankincense's anti-fungal and anti-bacterial effects. (46, 47).

Frankincense potentially contains antimicrobial effects on the oral microbiome as well targeting two harmful bacteria: *Porphyromonas gingivalis*, which is linked to periodontal disease, also referred to as gum disease, and *Fusobacterium nucleatum*, which is similarly linked to damage in the gums and dental plaque (48). Frankincense is associated with reducing the amount of problematic bacteria in the mouth's microbiome while decreasing the negative side effects attributed with conventional drugs such as liver or cardiac damage.

The terpenoids present in frankincense demonstrate binding tendencies with microbial proteins having an

affinity binding with pathogenic bacteria such as *Serratia marcescens*, *Helicobacter pylori*, *Mycobacterium tuberculosis*, *Escherichia coli*, and *Staphylococcus aureus* (12). Thus, frankincense's affinity in binding with the proteins of bacteria showcase its use for the treatment of pathogenic illnesses (12).

4.4 Other Uses

In addition, more of FEOs pharmaceutical applications can be seen in neurodegenerative diseases like Parkinson's disease, where there is a progressive loss of dopamine-producing brain cells. While research is still in early stages, animal studies suggest that frankincense may protect these cells by reducing inflammation and preventing the harmful protein buildup associated with the disease (49). Beyond neurological applications, frankincense has also been recognized for its antimicrobial properties, as studies indicate its potential to promote oral health by combating bacteria responsible for cavities and gum disease (48). Furthermore, research on peripheral nerve regeneration has also shown potential in nerve repair. A study using a rat model divided 48 Sprague Dawley rats into control and treatment groups receiving varying doses of frankincense extract (50). The high-dose group exhibited significant improvements in the sciatic functional index as early as day 7, with both medium and high-dose groups showing enhanced recovery from day 14 onward (50). Notably, increased expression of GAP-43, a key protein in nerve regeneration, was discovered after day 14 in the high-dose group, encouraging the idea that frankincense extract plays a role in sciatic nerve repair (50).

While research into frankincense and its potential benefits for Parkinson's disease has shown, especially in animal studies where it appeared to protect dopamine-producing brain cells and reduce harmful protein buildup, there are still notable side effects and limitations to consider (49). For example, frankincense's ability to ease inflammation and cellular stress is important to note, as these are major contributors to the progression of Parkinson's (49). Though, when looking into the unseen consequences of it, the research is still in its early stages and has largely been limited to animal models, not humans, making it difficult to draw definitive conclusions about its safety and effectiveness in clinical settings.

5. NON-PHARMACEUTICAL APPLICATIONS

Along with pharmaceutical applications, frankincense oils have long been used for other applications, including aromatherapy and skincare.

5.1 Aromatherapy, Pain/Fatigue Relief

Frankincense essential oils may have benefits towards pain relief and disability reduction. Lower back pain, or dorsal pain is a common problem, with most adults having a probability upwards of 60% of developing the problem. The experiment conducted with frankincense oils in comparison to Myrrh oils and a Placebo group, FEO-treated group demonstrated significantly lower back pain compared to other groups (51). A three-month study involving 232 osteoarthritis patients treated with a combination of *Curcuma longa* and *Boswellia serrata* extract revealed significant pain reduction as early as six weeks,

with continued improvement over time, an 80% patient satisfaction rate, and only 1.3% reporting side effects, suggesting this combination may offer a safer and more sustainable alternative for managing chronic inflammation-related pain conditions (52).

Additionally, FEOs were able to remediate the fatigue to individuals for more than 5 months after an individual was infected with the virus (53). In an experiment conducted at the Franklin Health Research Center, the experiment surveyed female patients who reported low energy levels 5 months after being infected with the virus (53). The study purported that individuals who inhaled an essential oil blend containing thyme, orange, clove bud, and frankincense managed to boost the energy levels against fatigue (53).

Although the quality of life and fatigue metric is quite difficult to consistently quantify, as in the case of this study, the researchers had to make metrics to understand how socio-economics and mental health variables may affect fatigue, the research concluded that the difference within those who consumed the essential oil blend twice per day for 2 weeks had an improvement substantial enough to clarify its benefits towards energy level.

5.2 Cosmetics

Frankincense is most often found in anti-aging products, valued for its calming scent and healing properties. In today's skincare, researchers study FEOs and their bioactive compounds for its strong anti-inflammatory properties which can help calm irritated or sensitive skin. Inflammation plays a big role in many skin issues, such as acne, rosacea, and premature aging. A study found that frankincense oil had significant anti-inflammatory and tissue-regenerating effects, making it good for skin health and wound healing (54).

Frankincense also has important antioxidant properties. Antioxidants fight free radicals that can damage skin cells and speed up aging. A study on frankincense essential oil found protective effects against UVB-induced skin damage and showed antioxidant and anti-aging effects (55). A study evaluating frankincense essential oil also showed antimicrobial activity against tested microorganisms (56). Because of its soothing and rejuvenating effects, frankincense is often included in modern skincare products like serums, moisturizers, and facial oils. However, dermatologists advise doing a patch test before using essential oils, including frankincense, due to the possibility of irritating sensitive skin types.

One of these side effects is that some individuals have experienced skin irritation, rashes, or dermatitis, especially when diffused or applied topically, raising concerns about its suitability for broader use (57). Furthermore, when looking into even more sources, extracts of *Boswellia* have generally been found to be well tolerated by the human body, with no major adverse effects reported, further reinforcing its promise as a viable therapeutic agent (58). As a widely used essential oil within the skincare industry, in comparison to most other essential oils, frankincense is generally not attributable to most contact allergies, and only in rare cases does frankincense showcase allergenic properties. However, frankincense is potentially attributable to allergenic effects for those who are atopic, as in one case study, an older 68

year-old woman developed spongiotic dermatitis in response to creams diffused with frankincense oil (59).

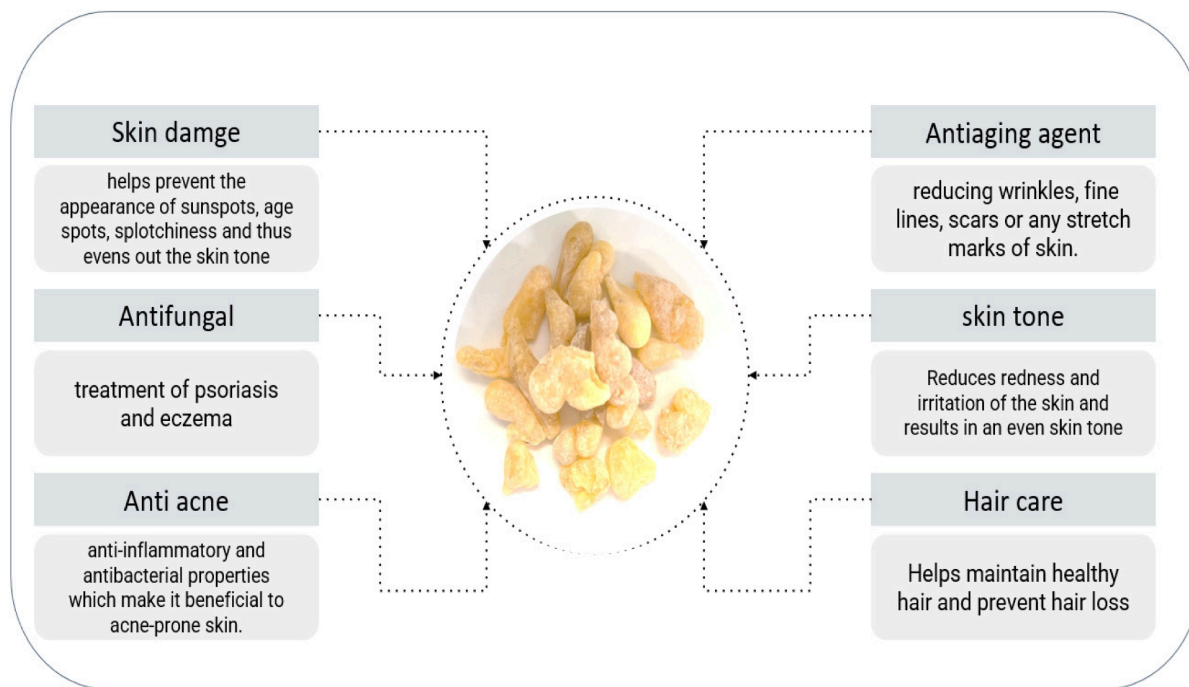


Figure 8. Frankincense resin's various cosmetic uses include preventing skin damage, acne, hair damage, as well as aging.

6. RECENT ADVANCES IN FRANKINCENSE ESSENTIAL OILS

6.1 Advances in Cancer Research and Drug Delivery

Recent advances in cancer research have focused on improving the delivery of frankincense compounds and studying the anticancer effects in experimental and clinical studies. A 2025 study found that using FEO in nanoemulsions (tiny droplets that improve absorption) can cause cancer cells to die, showing strong potential for treating lung and other cancers (60). Clinical trials have also shown promise: in 2024, breast cancer patients who took frankincense before surgery had slower tumor growth than those who didn't, proving its anticancer effects and safety in humans (33). Lastly, even advancements in processing techniques have been shown. For example, one study successfully encapsulated frankincense oil using the coprecipitation method, achieving a 78% encapsulation efficiency and forming stable host-guest inclusion complexes, which significantly improved the oil's thermal stability (65).

6.2 Advances in Wound Healing and Regeneration

Another study from the same year showed that FEO helps wounds heal faster by blocking a protein called caspase-3, which allows the tissue to move from inflammation to healing (54).

6.3 Advances in Neurological and Other Therapeutic Applications

Frankincense may also help protect the brain; a 2024 study found it could reduce inflammation and preserve dopamine-producing brain cells in models of Parkinson's disease (49). Following this, another study demonstrates frankincense's advancements in an application form, not thought of before, when a study was done on renal health with a dosage of frankincense at 150mg/kg/day, significantly raising the prevention of kidney stones of rats, an idea not entirely suggested beforehand, becoming more effective than Uralyt-U in reducing fibrosis without adverse effects (64).

6.4 Advances in Extraction, Resin Production, and Sustainability

New extraction methods using sub- and supercritical CO₂ were introduced in 2024, which increased the amount of resin collected and preserved important compounds better than traditional steam-based methods (61). Meanwhile, a 2025 report from Oman highlighted threats to the *Boswellia sacra* trees, like overharvesting and climate stress, and called for better conservation practices to ensure the long-term sustainability of this valuable resource (62). In addition, recent research as far back as 2020 demonstrates that through constant experimentation, frankincense demonstrates new advancements. An example is shown in a study, the combined application of Ethrel and methyl jasmonate significantly increased resin output, suggesting a safe method for artificially enhancing resin yields through hormone treatments (63).

Limitations

This review has several limitations. Many studies and researches on frankincense are based on in vitro or animal studies while lack in human clinical studies which limits further studies on frankincense. In addition, differences in *Boswellia* species, geographic origin, and extraction methods can result in different chemical composition and different amounts of each chemical in frankincense. Research on the long-term sustainability of frankincense-producing *Boswellia* needs to be further studied to go beyond limits.

7. FUTURE DIRECTIONS

There are significant concerns regarding the sustainability of frankincense farming processes (66, 67). Considering the process of harvesting the essential oils including tapping the tree with a knife, the process of harvesting the frankincense resins can be damaging (68, 69). According to A. Ibrahim's 2023 article detailing the issues present within the industry of harvesting FEOs in Somalia, there is not a significant amount of literature in regards to the conservation of frankincense trees (70). However, the study details a method to protect the populations of frankincense through an enforcement of field assessments. The trees'

health was examined thoroughly to determine if it recovered properly since its past harvests, with the results concluding that overharvested trees should be put in waiting periods for up to 3 years (70). Future advancements in the application of FEOs must consider the consequences of overharvesting and develop sustainable ways to extract the valuable oils.

8. CONCLUSION

The recognition received by frankincense in ancient therapeutic medicine has shown support through modern medical practices. In pharmaceutical circumstances, frankincense extracts enhance the expression of GAP-43 which indicates an acceleration of regeneration. Furthermore, Boswellic acids contain compounds like AKBA which inhibit enzymes that minimize the progression of cancer; similarly, this limitation of enzymes extends to the inhibition of inflammatory agents like that of histamines and leukotrienes, which contribute to chronic inflammation.

In addition, frankincense has a variety of non-pharmaceutical applications. Frankincense is used in aromatherapy, and is associated with reduced fatigue and improved energy levels in studies of Post-COVID patients. Similarly, the Boswellic acids in frankincense are associated with the limitation of enzymes that degrade collagen, allowing individuals to have better skin. Many of the anticancer and biological effects discussed in this review are only supported by in vitro and animal studies; therefore, more human clinical studies are needed for further data.

Current evidence supports the biological activity of frankincense, but deeply designed human clinical studies and trials are needed before many effects of frankincense can be acknowledged for clinical use. FEOs show medicinal potential, especially in the field of cancer, making it crucial to continue research into the future regarding its properties and uses. While FEOs remain lauded for its anti-cancer, anti-inflammation, and wound healing practices, the threatened state of the *Boswellia Sacra* tree can not be ignored: future research must aim to retain sustainable practices if FEOs will be further developed for pharmaceutical use in the future.

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REFERENCES

1. Efferth T, Oesch F. Anti-inflammatory and anti-cancer activities of frankincense: targets, treatments and toxicities. *Semin Cancer Biol.* 2022;80:39-57. doi:10.1016/j.semcancer.2020.01.015.
2. Gordon S. 5 health benefits of frankincense oil—and how to use it [Internet]. Health.com; 2026 [cited 2026 Aug 29]. Available from: <https://www.health.com/frankincense-8671705>
3. Khalifa SAM, Kotb SM, El-Seedi SH, Nahar L, Sarker SD, Guo Z, et al. Frankincense of *Boswellia sacra*: traditional and modern applied uses, pharmacological activities, and clinical trials. *Ind Crops Prod.* 2023;203:117106. doi:10.1016/j.indcrop.2023.117106.
4. Börner F, Werner M, Ertelt J, Meins J, Abdel-Tawab M, Werz O. Analysis of boswellic acid contents and related pharmacological activities of frankincense-based remedies that modulate inflammation. *Pharmaceuticals (Basel).* 2021;14(7):660. doi:10.3390/ph14070660.
5. Pullaiah T, Ratnam KV, Swamy MK, Bhakshu LM, editors. *Frankincense - Gum Olibanum: Botany, Oleoresin, Chemistry, Extraction, Utilization, Propagation, Biotechnology, and Conservation*. 1st ed. Palm Bay (FL): Apple Academic Press; 2023.
6. Miran M, Amirshahrokhi K, Ajanii Y, Zadali R, Rutter MW, Enayati A, et al. Taxonomical investigation, chemical composition, traditional use in medicine, and pharmacological activities of *Boswellia sacra* Flueck. *Evid Based Complement Alternat Med.* 2022;2022:8779676. doi:10.1155/2022/8779676.
7. Soumya KV, Shackleton CM, Setty SR. Harvesting and local knowledge of a cultural non-timber forest product (NTFP): gum-resin from *Boswellia serrata* Roxb. in three protected areas of the Western Ghats, India. *Forests.* 2019;10(10):907. doi:10.3390/f10100907.
8. Ur Rehman N, Rafiq K, Avula SK, Gibbons S, Csuk R, Al-Harrasi A. Triterpenoids from frankincense and *Boswellia*: a focus on their pharmacology and ¹³C-NMR assignments. *Phytochemistry.* 2025;229:114297. doi:10.1016/j.phytochem.2024.114297.
9. Johnson S, DeCarlo A, Satyal P, Dosoky NS, Sorensen A, Setzer WN. The chemical composition of single-tree *Boswellia frereana* resin samples. *Nat Prod Commun.* 2021;16(9). doi:10.1177/1934578X211043727.
10. Johnson S, DeCarlo A, Satyal P, Dosoky NS, Sorensen A, Setzer WN. The chemical composition of *Boswellia occulta* oleogum resin essential oils. *Nat Prod Commun.* 2019;14(7). doi:10.1177/1934578X19866307.
11. Mertens M, Buettner A, Kirchhoff E. The volatile constituents of frankincense - a review. *Flavour Fragr J.* 2009;24(6):279-300. doi:10.1002/ffj.1942.
12. Byler KG, Setzer WN. Protein targets of frankincense: a reverse docking analysis of terpenoids from *Boswellia* oleo-gum resins. *Medicines (Basel).* 2018;5(3):96. doi:10.3390/medicines5030096.
13. Lu X, Mao J, Wang Y, Huang Y, Gu M. Water extract of frankincense and myrrh inhibits liver cancer progression and epithelial-mesenchymal transition through Wnt/ β -catenin signaling. *Mol Clin Oncol.* 2023;19(4):77. doi:10.3892/mco.2023.2673.

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14. Elmoslemany AM, Elzallat M, Abd-Elfatah MH, Mohammed DM, Abd Elhady EE. Possible therapeutic effect of frankincense (Gum olibanum) and myrrh (Commiphora myrrha) resin extracts on DEN/CC14-induced hepatocellular carcinoma in rats. *Phytomed Plus*. 2024;4(1):100517. doi:10.1016/j.phyplu.2023.100517.
15. Al Amri AS, Jesil A, Salim A, Saravanan AM. Extraction of essential oil from frankincense using steam distillation. *Int J Trend Res Dev*. 2019;6(1):87-89.
16. Bhakshu LM, Ratnam KV. Extraction of oleogum resin (frankincense/olibanum) from Boswellia species. In: Pullaiah T, Ratnam KV, Swamy MK, Bhakshu LM, editors. *Frankincense - Gum Olibanum*. Palm Bay (FL): Apple Academic Press; 2023. p. 41-68. doi:10.1201/9781003348016-3.
17. Ni X, Suhail MM, Yang Q, Cao A, Fung KM, Postier RG, et al. Frankincense essential oil prepared from hydrodistillation of Boswellia sacra gum resins induces human pancreatic cancer cell death in cultures and in a xenograft murine model. *BMC Complement Altern Med*. 2012;12:253. doi:10.1186/1472-6882-12-253.
18. Kataoka H. Sample preparation for liquid chromatography. In: Fanali S, Haddad PR, Poole CF, Schoenmakers P, Lloyd D, editors. *Liquid Chromatography*. 2nd ed. Amsterdam: Elsevier; 2017. p. 1-37. doi:10.1016/B978-0-12-805392-8.00001-3.
19. Niebler J, Buettner A. Identification of odorants in frankincense (Boswellia sacra Flueck.) by aroma extract dilution analysis and two-dimensional gas chromatography-mass spectrometry/olfactometry. *Phytochemistry*. 2015;109:66-75. doi:10.1016/j.phytochem.2014.10.030.
20. Camarda L, Dayton T, Di Stefano V, Pitonzo R, Schillaci D. Chemical composition and antimicrobial activity of some oleogum resin essential oils from Boswellia spp. (Burseraceae). *Ann Chim*. 2007;97(9):837-844. doi:10.1002/adic.200790068.
21. Khan AJ. Medicinal properties of frankincense. *Int J Nutr Pharmacol Neurol Dis*. 2012;2(2):79. doi:10.4103/2231-0738.95925.
22. Hussain H, Rashan L, Hassan U, Abbas M, Hakkim FL, Green IR. Frankincense diterpenes as a bio-source for drug discovery. *Expert Opin Drug Discov*. 2022;17(5):513-529. doi:10.1080/17460441.2022.2044782.
23. Nwachukwu EC. Frankincense: biological activities and therapeutic properties [thesis]. Nicosia (Cyprus): Near East University; 2020.
24. Al-Balushi RA, Chaudhuri A, Kandimalla R, Haque A, Alenezi KM, Saeed M, et al. In vitro anticancer effects of frankincense and its nanoemulsions for enhanced cancer cell targeting. *Front Pharmacol*. 2025;16:1403780. doi:10.3389/fphar.2025.1403780.
25. Hakkim FL, Al-Buloshi M, Al-Sabahi J. Frankincense-derived heavy terpene cocktail boosting breast cancer cell (MDA-MB-231) death in vitro. *Asian Pac J Trop Biomed*. 2015;5(10):824-828. doi:10.1016/j.apjtb.2015.06.008.
26. Suhail MM, Wu W, Cao A, Mondalek FG, Fung KM, Shih PT, et al. Frankincense oil derived from Boswellia carteri induces tumor cell specific cytotoxicity. *BMC Complement Altern Med*. 2009;9:6. doi:10.1186/1472-6882-9-6.

27. Bini Araba A, Ur Rehman N, Al-Araimi A, Al-Hashmi S, Al-Shidhani S, Csuk R, et al. New derivatives of 11-keto- β -boswellic acid (KBA) induce apoptosis in breast and prostate cancer cells. *Nat Prod Res*. 2021;35(5):707-716. doi:10.1080/14786419.2019.1593165.
28. Pang X, Yi Z, Zhang X, Sung B, Qu W, Lian X, et al. Acetyl-11-keto-beta-boswellic acid inhibits prostate tumor growth by suppressing vascular endothelial growth factor receptor 2-mediated angiogenesis. *Cancer Res*. 2009;69(14):5893-5900. doi:10.1158/0008-5472.CAN-09-0755.
29. Poeckel D, Werz O. Boswellic acids: biological actions and molecular targets. *Curr Med Chem*. 2006;13(28):3359-3369. doi:10.2174/092986706779010333.
30. Hamidpour R, Hamidpour S, Hamidpour M, Shahlari M. Frankincense (Rǔ Xiāng; *Boswellia* species): from the selection of traditional applications to the novel phytotherapy for the prevention and treatment of serious diseases. *J Tradit Complement Med*. 2013;3(4):221-226. doi:10.4103/2225-4110.119723.
31. Al-Yasiry ARM, Kiczorowska B. Frankincense-therapeutic properties. *Postepy Hig Med Dosw (Online)*. 2016;70:380-391. doi:10.5604/17322693.1200553.
32. Frankincense and cancer: inflammation, research, and safety [Internet]. *Medical News Today*; 2023 [cited 2026 Aug 29]. Available from: <https://www.medicalnewstoday.com/articles/314366>
33. Bonilla Valente IV, Garcia D, Abbott A, Spruill L, Siegel J, Forcucci J, et al. The anti-proliferative effects of a frankincense extract in a window of opportunity phase Ia clinical trial for patients with breast cancer. *Breast Cancer Res Treat*. 2024;204(3):521-530. doi:10.1007/s10549-023-07215-4.
34. Zheng P, Huang Z, Tong DC, Zhou Q, Tian S, Chen BW, et al. Frankincense myrrh attenuates hepatocellular carcinoma by regulating tumor blood vessel development through multiple epidermal growth factor receptor-mediated signaling pathways. *World J Gastrointest Oncol*. 2022;14(2):450-477. doi:10.4251/wjgo.v14.i2.450.
35. Schmiech M, Lang SJ, Ulrich J, Werner K, Rashan LJ, Syrovets T, Simmet T. Comparative investigation of frankincense nutraceuticals: correlation of boswellic and lupeolic acid contents with cytokine release inhibition and toxicity against triple-negative breast cancer cells. *Nutrients*. 2019;11(10):2341. doi:10.3390/nu11102341.
36. Suhail MM, Wu W, Cao A, Mondalek FG, Fung KM, Shih PT, et al. *Boswellia sacra* essential oil induces tumor cell-specific apoptosis and suppresses tumor aggressiveness in cultured human breast cancer cells. *BMC Complement Altern Med*. 2011;11:129. doi:10.1186/1472-6882-11-129.
37. Al-Balushi RA, Haque A, Saeed M, Al-Harthy T, Al-Hinaai M, Al-Hashmi S. Unlocking the anticancer potential of frankincense essential oils (FEOs) through nanotechnology: a review. *Mol Biotechnol*. 2024;66(11):3013-3024. doi:10.1007/s12033-023-00918-5.
38. Elias AN. Synthesis, characterization and anti-inflammatory evaluation of new potentially active naproxen hydrazones [master's thesis]. *ResearchGate*; 2015. doi:10.13140/RG.2.1.4159.2402.
39. Yu G, Xiang W, Zhang T, Zeng L, Yang K, Li J. Effectiveness of *Boswellia* and *Boswellia* extract for osteoarthritis patients: a systematic review and meta-analysis. *BMC Complement Med Ther*. 2020;20(1):225. doi:10.1186/s12906-020-02985-6.

40. Mohsenzadeh A, Karimifar M, Soltani R, Hajhashemi V. Evaluation of the effectiveness of topical oily solution containing frankincense extract in the treatment of knee osteoarthritis: a randomized, double-blind, placebo-controlled clinical trial. *BMC Res Notes*. 2023;16(1):28. doi:10.1186/s13104-023-06291-5.
41. Shi X, Jie L, Wu P, Mao J, Wang P, Liu Z, Yin S. Comprehensive network pharmacological analysis and in vitro verification reveal the potential active ingredients and potential mechanisms of frankincense and myrrh in knee osteoarthritis. *Nat Prod Commun*. 2022;17(8). doi:10.1177/1934578X221116984.
42. Ammon HPT. Boswellic acids and their role in chronic inflammatory diseases. *Adv Exp Med Biol*. 2016;928:291-327. doi:10.1007/978-3-319-41334-1_13.
43. Bannuru RR, Osani MC, Al-Eid F, Wang C. Efficacy of curcumin and Boswellia for knee osteoarthritis: systematic review and meta-analysis. *Semin Arthritis Rheum*. 2018;48(3):416-429. doi:10.1016/j.semarthrit.2018.03.001.
44. Lu W, Liu Z, Song Z, Wang C, Yu Z, Peng S, et al. Vinegar-processed frankincense ameliorates ulcerative colitis by targeting BSH-active bacteria preference-mediated GDCA hydrolysis. *J Ethnopharmacol*. 2025;348:119845. doi:10.1016/j.jep.2025.119845.
45. Su S, Duan J, Chen T, Huang X, Shang E, Yu L, et al. Frankincense and myrrh suppress inflammation via regulation of the metabolic profiling and the MAPK signaling pathway. *Sci Rep*. 2015;5:13668. doi:10.1038/srep13668.
46. Prakash B, Mishra PK, Kedia A, Dubey NK. Antifungal, antiaflatoxin and antioxidant potential of chemically characterized Boswellia carterii Birdw essential oil and its in vivo practical applicability in preservation of Piper nigrum L. fruits. *LWT Food Sci Technol*. 2014;56(2):240-247. doi:10.1016/j.lwt.2013.12.023.
47. Man A, Santacroce L, Jacob R, Mare A, Man L. Antimicrobial activity of six essential oils against a group of human pathogens: a comparative study. *Pathogens*. 2019;8(1):15. doi:10.3390/pathogens8010015.
48. Vang D, Moreira-Souza ACA, Zusman N, Moncada G, Dakafay HM, Asadi H, et al. Frankincense (Boswellia serrata) extract effects on growth and biofilm formation of Porphyromonas gingivalis, and its intracellular infection in human gingival epithelial cells. *Curr Issues Mol Biol*. 2024;46(4):2991-3004. doi:10.3390/cimb46040187.
49. Calabrese V, Osakabe N, Khan F, Wenzel U, Modafferi S, Nicolosi L, et al. Frankincense: a neuronutrient to approach Parkinson's disease treatment. *Open Med (Wars)*. 2024;19(1):20240988. doi:10.1515/med-2024-0988.
50. Jiang X, Ma J, Wei Q, Feng X, Qiao L, Liu L, et al. Effect of frankincense extract on nerve recovery in the rat sciatic nerve damage model. *Evid Based Complement Alternat Med*. 2016;2016:3617216. doi:10.1155/2016/3617216.
51. Özdemir Alkanat H, Özdemir Ü, Kulaklı F. The effects of massage with frankincense and myrrh oil in chronic low back pain: a three-arm randomised controlled trial. *Explore (NY)*. 2023;19(5):761-767. doi:10.1016/j.explore.2023.04.004.

52. Henrotin Y, Dierckxsens Y, Delisse G, Maes N, Albert A. Curcuma longa and Boswellia serrata extract combination for hand osteoarthritis: an open-label pre-post trial. *Pharm Biol.* 2022;60(1):2295-2299. doi:10.1080/13880209.2022.2147550.
53. Hawkins J, Hires C, Keenan L, Dunne E. Aromatherapy blend of thyme, orange, clove bud, and frankincense boosts energy levels in post-COVID-19 female patients: a randomized, double-blinded, placebo-controlled clinical trial. *Complement Ther Med.* 2022;67:102823. doi:10.1016/j.ctim.2022.102823.
54. Venkatesan K, Sivadasan D, Al Weslati MA, et al. Protective effects of frankincense oil on wound healing: downregulating caspase-3 expression to facilitate the transition from the inflammatory to proliferative phase. *Pharmaceuticals (Basel).* 2025;18(3):407. doi:10.3390/ph18030407.
55. Kotb EA, El-Shiekh RA, Abd-Elsalam WH, El Sayed NS, El Tanbouly N, El Senousy AS. Protective potential of frankincense essential oil and its loaded solid lipid nanoparticles against UVB-induced photodamage in rats via MAPK and PI3K/AKT signaling pathways: a promising anti-aging therapy. *PLoS One.* 2023;18(12):e0294067. doi:10.1371/journal.pone.0294067.
56. Hamzah KN, Romulo A. Evaluation of antimicrobial activity of Pickering emulsion essential oil of frankincense, patchouli, and lemongrass. *IOP Conf Ser Earth Environ Sci.* 2025;1488(1):012111. doi:10.1088/1755-1315/1488/1/012111.
57. McIntyre C. Frankincense - uses, side effects, and more [Internet]. WebMD; 2025 [cited 2026 Aug 29]. Available from: <https://www.webmd.com/vitamins-supplements/frankincense>
58. Al-Harrasi A, Hussain H, Csuk R, Khan HY. Biological activities of Boswellia extract. In: *Chemistry and Bioactivity of Boswellic Acids and Other Terpenoids of the Genus Boswellia*. Amsterdam: Elsevier; 2019. p. 111-125. doi:10.1016/B978-0-08-102441-6.00004-9.
59. Buonomo M, Hylwa S. Allergic contact dermatitis from Boswellia carterii (frankincense) oil. *Contact Dermatitis.* 2021;85(4):465-467. doi:10.1111/cod.13881.
60. Abd-Rabou AA, Edris AE. Frankincense essential oil nanoemulsion specifically induces lung cancer apoptosis and inhibits survival pathways. *Cancer Nanotechnol.* 2022;13:22. doi:10.1186/s12645-022-00128-9.
61. Guta M, Tan H, Zhao Y. Selectively extracting oleoresin from Boswellia papyrifera frankincense resin by sub- and supercritical CO₂ processes. *J Supercrit Fluids.* 2024;204:106135. doi:10.1016/j.supflu.2023.106135.
62. Johnson S, Bait Said A, Vahalik P, Karas L, Sarrouf Willson M, Bongers F. Rapid conservation assessment of Boswellia sacra in Oman reveals complex threat and population patterns. *J Arid Environ.* 2025;229:105368. doi:10.1016/j.jaridenv.2025.105368.
63. Yamamoto F, Iwanaga F, Al-Busaidi A, Yamanaka N, et al. Roles of ethylene, jasmonic acid, and salicylic acid and their interactions in frankincense resin production in Boswellia sacra Flueck. *trees. Sci Rep.* 2020;10:16760. doi:10.1038/s41598-020-73993-2.
64. Al-Marhoon MS, Al-Harrasi A, Siddiqui K, et al. Effects of frankincense on experimentally induced renal stones in rats. *BJUI Compass.* 2023;4(4):437-445. doi:10.1002/bco2.227.

65. Parbuntari H, Etika SB, Mulia M. Molecular encapsulation of frankincense oil (*Boswellia serrata*) in β -cyclodextrin as a preliminary of the stability study. *Int J Adv Sci Eng Inf Technol*. 2020;10(6):2606-2612. doi:10.18517/ijaseit.10.6.9388.
66. Khan AL, Al-Harrasi A, Wang JP, Asaf S, Riethoven JJM, Shehzad T, et al. Genome structure and evolutionary history of frankincense producing *Boswellia sacra*. *iScience*. 2022;25(7):104574. doi:10.1016/j.isci.2022.104574.
67. Hido A, Tolera M, Lemma B, Evangelista PH. Population status and resin quality of frankincense *Boswellia neglecta* (Burseraceae) growing in South Omo, southwestern Ethiopia. *J Sustain For*. 2020;39(6):620-634. doi:10.1080/10549811.2020.1721302.
68. Ali AH, Fadl KEM, Adam IM. Effect of position of tapping, tree stem diameter and tapping tools on frankincense yield of *Boswellia papyrifera* in South Kordofan State, Sudan. *For Trees Livelihoods*. 2009;19(1):19-26. doi:10.1080/14728028.2009.9752651.
69. Negussie A, Gebrehiwot K, Yohannes M, Norgrove L, Aynekulu E. Continuous resin tapping for frankincense harvest increases susceptibility of *Boswellia papyrifera* (Del.) Hochst trees to longhorn beetle damage. *Heliyon*. 2021;7(2):e06250. doi:10.1016/j.heliyon.2021.e06250.
70. Ibrahim AA. Local knowledge and attitudes of frankincense communities in northeastern Somalia. *Glob Ecol Conserv*. 2023;48:e02748. doi:10.1016/j.gecco.2023.e02748.