WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

EXPLORING THE ROLE OF BIOACTIVE COMPOUNDS IN *BOSWELLIA SERRATA* ROXB. FOR GLUCOSE REGULATION AND PANCREATIC PROTECTION

Pratik Kumar Vishwakarma*[*1], Vivek Gupta[2], Yogesh Kumar[3], Gyan Singh[4]

Faculty of Pharmacy, PK University, Thanra - 473665, Madhya Pradesh, India.

Corresponding Author

Pratik Kumar Vishwakarma

Research Scholar,

Faculty of Pharmacy,

PK University, Thanra - 473665,

Madhya Pradesh, India.

Email- pksharma893@gmail.com

ABSTRACT :

Background

Diabetes and its complications pose a global health crisis, emphasizing the need for therapeutic approaches that not only regulate glucose but also protect pancreatic function. *Boswellia serrata* Roxb, a traditional medicinal plant, has gained attention for its bioactive compounds that offer dual benefits for glucose regulation and pancreatic protection. This review explores its phytochemical profile, mechanisms of action, and translational potential in diabetes management.

Methods

An in-depth review of studies was conducted to analyze the phytochemistry, pharmacological effects, and therapeutic applications of *Boswellia serrata*. Key bioactive were identified using advanced techniques such as HPLC and GC-MS. Mechanistic insights into glucose modulation, beta-cell protection, and anti-inflammatory pathways were evaluated. The impact of novel drug delivery systems, including nano formulations, on enhancing efficacy was also investigated.

Results

Boswellia serrata is rich in bioactive such as boswellic acids, terpenoids, and flavonoids, which improve glucose homeostasis by enhancing insulin sensitivity, activating AMPK pathways, and inhibiting alpha-glucosidase. Its antioxidant and anti-inflammatory properties protect pancreatic beta cells from oxidative stress and inflammatory damage. Preclinical studies demonstrate significant antidiabetic potential, while early clinical trials suggest safety and efficacy. Innovations in formulations, including nanoparticles, further enhance bioavailability and therapeutic outcomes.

Conclusion

With its multifaceted pharmacological profile, *Boswellia serrata* offers a promising avenue for addressing diabetes and pancreatic dysfunction. Future research should prioritize clinical validation, standardization, and innovative delivery systems to harness its full therapeutic potential.

Keywords: *Boswellia serrata*, glucose regulation, pancreatic protection, bioactive compounds, antidiabetic potential.

1. Introduction

The deciduous tree Boswellia serrata Roxb., sometimes referred to as Indian frankincense, grows in India as well as some of the Middle East countries. Traditionally it has been used for medical ailments including inflammatory problems, arthritis, respiratory diseases and so many more and also Ayurvedic & Unani system of medicines is mainly used the resin of this tree [1]. Srivastava was able to identify chemicals present in large quantity in the resin known as “olibanum,” specifically boswellic acids, terpenoids, and flavonoids; boswellic acid contains specialized antioxidants and anti-inflammatory, antibacterial properties. It has recently rendered importance to metabolic illnesses, particularly diabetes, owing to its capability to modulating crucial tracks in glucose catabolism and insulin signalling, reports suggest. This has made its usage to increase, mainly due to the claims that is an all-natural medicine [2].

The effects of hyperglycemia as well as other complications of diabetes mellitus, a chronic metabolic disease that is known to afflict millions of people around the world include cardiovascular disease, neuropathy, nephropathy, and retinopathy [3]. The lack of ability of the pancreatic beta cells to secrete insulin is a major factor in its progress. To these when chronic inflammation and oxidative stress are added lipid peroxidation the insulin resistance and

the beta cell damage are compounded. Glycaemia regulation and pancreas protection are two parts of diabetes treatment. Natural treatments, especially those made from herbs like Boswellia serrata, have two benefits: They contribute to managing high blood sugar levels and they also guard the organ known as the pancreas. It is hoped that its bioactive components can act on the oxidative stress, inflammation and other important processes involved in the pathogenesis of diabetes mellitus [4].

The objective of this review therefore is to provide a detailed review of Boswellia serrata Roxb. and its role in the management of diabetic patients. The article explores bioactive molecules, their function in controlling of glucose level and their effects towards the pancreas. The medicinal uses of ginger are presented in the study together with the new discoveries about the new compounds and its formulations it also has an analysis of the limitations of the present research and suggests how future investigation could proceed [5]. Altogether, including *Bosewellia serrata* gum resin in currently practising strategies to prevent/ manage diabetes and its complications require data integration from phytochemical studies, pharmacological report, and upcoming trials; hence, this systematic review [6].

2. Phytochemical Composition of *Boswellia serrata*

2.1 Major Bioactive Compounds

The plant resin of Boswellia serrata consists of several biologically active compounds, of which boswellic acids are the best described and investigated. This compound contains anti-inflammatory, antioxidant, and antidiabetic features mainly due to pentacyclic triterpenoids– acetyl-11-keto-β-boswellic acid (AKBA) and 11-keto-β-boswellic acid (KBA). A typical function of boswellic acids is to downregulate the creation of leukotrienes and inflammation signals using enzymes such as 5-lipoxygenase (5-LOX) [7]. Among the other bioactive constituent, terpenoids are responsible for giving it its antibacterial and antioxidant functionalities thus improving its medicinal properties. Besides the pharmacological activities, flavonoids in resin have reported kaempferol quercetin and other analogs exert significant antioxidant effects to protect the cells from oxidative stress [8]. The anti-inflammatory and analgesic effects of the resin are improved by the volatile's oils the medicinal value of the plant is boosted by the presence of polysaccharides and phenolic acids. This is the reason why *Boswellia serrata* contains a number of these substances: it positively affects carbohydrate metabolism and glucose tolerance, reduces oxidative stress response, and protects pancreatic tissue – all these provide precondition for the plant usage in management of various diseases and illnesses, including diabetes as well [9].

2.2 Isolation and Characterization Methods

There is therefore, a need for advanced analytical techniques for identification and quantification of bioactive compounds present in Boswellia serrata. Being a conventional method, a high-performance liquid chromatography (HPLC) has been adopted to determine the boswellic acids and FLAVs present in the purified resin. Such compounds may be accurately divided and defined by means of this approach, so that an individual is capable of evaluating the density of such compounds in varied gleans [10]. Another powerful technique of world desired used for the identification of terpenoids and volatile oils isolated from Boswellia serrata is Gas chromatography-mass spectrometry (GC-MS). It is devoid of this kind of information, though it is crucial for comprehending the whole phytochemical picture since saponification extracts particular, demonstrated details regarding the nature of the resin by differentiating volatile compounds from the starting sample [11]. Information resulting from investigation of functional groups of bioactive substances employing Fourier-transform infrared spectroscopy (FTIR) is usually beneficial. Nuclear magnetic resonance (NMR) spectroscopy offers information on the molecular identification of the bioactive components and safeguards complete characterisation. The efficiency of compound isolation more or less relies on the extraction techniques used. Some of these strategies include solvent extraction, supercritical fluid extraction, SFE for short, and microwave-assisted extraction, MAE for short. These procedures allow obtaining high yields of bioactive substances needed for further analysis and pharmacological studies by optimising their extraction [12].

2.3 Bioavailability and Pharmacokinetics

The compounds of *Boswellia serrata*, including boswellic acids and a range of other bioactive chemicals, have some fascinating pharmacological effects, but the key challenge in using these reagents is the question of bioavailability. The phenomena mostly associated with the low levels of bioavailability that boswellic acids have due to the fact that these chemical compounds are poorly soluble in water, which in turn restrains their uptake in the GIT as well as their oral administration [13]. These chemicals are even less effective because their metabolism is greatly impacted by first pass through the liver. As a consequence of this, high dosages are required to provide levels of the active drug in plasma that are necessary to bring about therapeutic effects but this severely hinders patient compliance and could also lead to a number of negative effects. Several strategies have however been developed to overcome these restrictions with regard to boswellic acids bioavailability. A lot of focus can be placed on nano formulations consisting of such things as the solid lipid nanoparticles, liposomes, and nanoparticles among others [14]. The advanced techniques in drug delivery make these related compounds both therapeutically more active and pharmacokinetically more favourable, indicating that targeted medication administration and sustained release are getting enhanced by these new formulations. Moreover, research has shown that these formulations can also improve the outcomes of treatments with the help of increasing the time that boswellic acid remains in the organism [15]. Further, pharmacokinetic studies of boswellic acids have also revealed that boswellic acids are substrates of P450 phase I and phase II enzymes and are conjugated with glucuronic acid which may alter their safety and efficacy profile. The possible bio suspensions and pharmacokinetic properties for *Boswellia serrata* substances must be investigated before they are incorporated into clinical practice [16].

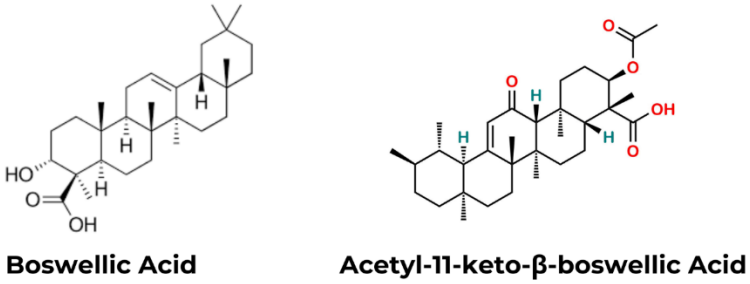

Figure 1: Chemical structures of key bioactive compounds from *Boswellia serrata*. [17]

Table 1: Phytochemical composition of *Boswellia serrata* with reported concentrations and biological activities. [18]

S.No.	Phytochemical	Concentration (mg/g)	Biological Activity
1	Boswellic acids	20-60	Anti-inflammatory, anti-diabetic, anti-cancer
2	Acetyl-11-keto-β-boswellic acid (AKBA)	4-10	Anti-inflammatory, anti-arthritic, neuroprotective
3	11-keto-β-boswellic acid (KBA)	2-5	Anti-inflammatory, anti-diabetic, reduces insulin resistance
4	α-Boswellic acid	5-15	Antioxidant, anti-inflammatory
5	β-Boswellic acid	10-20	Anti-inflammatory, anti-cancer
6	Terpenoids	5-25	Antioxidant, antimicrobial, anti-inflammatory
7	Flavonoids (e.g., quercetin)	0.5-2	Antioxidant, anti-inflammatory, anti-cancer
8	Volatile oils (e.g., limonene, α-pinene)	0.1-1	Analgesic, anti-inflammatory, antimicrobial
9	Triterpenes	1-5	Anti-inflammatory, anti-diabetic, anti-arthritic
10	Phenolic acids (e.g., gallic acid)	0.5-3	Antioxidant, anti-inflammatory
11	Polysaccharides	3-10	Immunomodulatory, anti-inflammatory
12	Resin	50-100	Antioxidant, antimicrobial, anti-inflammatory

3. Mechanisms of Glucose Regulation

3.1 Insulin Sensitization and Secretion

Boswellia serrata has positive effect on glucose metabolism and may be useful for treatment of some pathologies associated with insulin resistance and diabetes of type 2 Boswellic acids are the major active markers of *Boswellia serrata* which has been established to improve insulin sensitivity by modulating signa; ling pathways. These chemicals seemingly enhance accuracy in the nature of insulin receptors and therefore have the capability of modulating insulin's level of sensitivity [19]. In this study, boswellia serrata increases the glucose uptake in the insulin-sensitive tissues such as adipose and muscles via improving the attachment of insulin to its receptors. In support of the Boswellia serrata potential to function as an anti-diabetic drug, the researchers discovered improved stimulation of insulin secretion of pancreatic beta-cells. Just this blood sugar control could be beneficial in those with insulin resistance or decreased pancreas function, since this drug increases insulin production and enhances its sensitivity at the same time [20].

3.2 Alpha-Glucosidase Inhibition

On the matters of how *Boswellia serrata* contributes to the maintenance of normal blood sugar one of the ways is through inhibiting an enzyme called alpha-glucosidase. This enzyme is one that helps to breakdown complex carbohydrates into glucose in the small intestine. Boswellia serrata delays the movement and uptake of carbohydrates by jamming this enzyme and thus stabilizing glucose release into the blood impact [21]. This method is very handy to persons with type II diabetes or persons who are at high risk of developing the disease since it enforces a break on the rate of blood sugar rise. The suppression of alpha-glucosidase by *Boswellia serrata* could help with reinforcing metabolic regulation of glycaemia as well as postprandial glucose control in general [22].

3.3 AMPK Activation Pathways

AMPK is a key energy sensor and controls the glucose homeostasis and energy balance in the cells. Recent work also suggested that, boswellia serrata may enhance the absorption and utilization of glucose in peripheral tissue through increasing the activity of AMPK. Especially, in skeletal muscle and adipose tissue, the increase of glucose transporter proteins such as GLUT4 is enhanced when AMPK activation takes place [23]. Additionally, since AMPK activation suppresses the expression of fine enzymes participating in gluconeogenesis, glucose production in the liver is inhibited. Elimination of increased glucose production in the liver which is characteristic of type 2 diabetes depends on this mechanism. Thus, chemicals from Boswellia serrata that activate the AMPK pathway, glucose uptake in peripheral tissues and decrease glucose production in the liver. This somehow indicates that *Boswellia serrata* can act as drug to prevent elevated blood sugar levels and reduced sensitivity to insulin [24].

4. Protective Effects on the Pancreas

4.1 Antioxidant Properties

Diabetes is characterized by pancreatic beta-cell failure and the major cause is oxidative stress. Among the bioactive compounds of Boswellia serrata there are boswellic acids and flavonoids which have shown the highest antioxidant activity. These chemicals reduce ROS and scavenge free radicals to help in combating oxidative stress to pancreatic cells [25]. The tests also show that *Boswellia serrata* has the potential to scavenge ROS which was good evidence for its ability to reverse or ameliorate the oxidation effect on beta cells and their ability to produce insulin. Based on the free radicals' that are present in the mechanism of action of Boswellia serrata, the researchers believe that diabetics can protect their pancreas against unfavourable changes which can be brought by the disease. *Boswellia serrata's* anti-oxidant potential unfurls therapeutic possibilities to augment the pancreatic health, arrestion of diabetes allied issues and restrict oxidative suppression in pancreatic cells [26].

4.2 Anti-Inflammatory Effects

Inflammatory changes trigger beta-cell destruction and block insulin response which make type 2 diabetes harder to manage. Boswellia serrata shuts off production of TNF-α and IL-6 inflammation markers to show its strong anti-inflammatory effects. Studies show that these immune response messengers damage both insulin response and pancreas beta cell function. A chronic low-grade inflammatory condition of diabetes can be managed through Boswellia serrata treatment by stopping known inflammatory markers [27]. Boswellia serrata controls pancreas inflammation to help preserve beta-cell function and decrease the risk of getting type 2 diabetes and its related problems. Boswellia serrata eases blood sugar control by calming body wide inflammation at the genetic and immune system levels [28].

4.3 Beta-Cell Regeneration and Protection

Tests show *Boswellia serrata* can help shield and revive pancreatic beta cells. Studies of *Boswellia serrata* demonstrate that beta cell regeneration effects help the plant's biologically active elements restore proper insulin production at pancreatic islets. Studies show that Boswellia serrata stops cell death by apoptosis from destroying beta cells of diabetic patients. By protecting beta cells from damage *Boswellia serrata* helps maintain the pancreas's ability to control blood sugar. Using *Boswellia serrata* lets us find natural ways to repair pancreatic problems and prevent diabetes through beta cell protection [29].

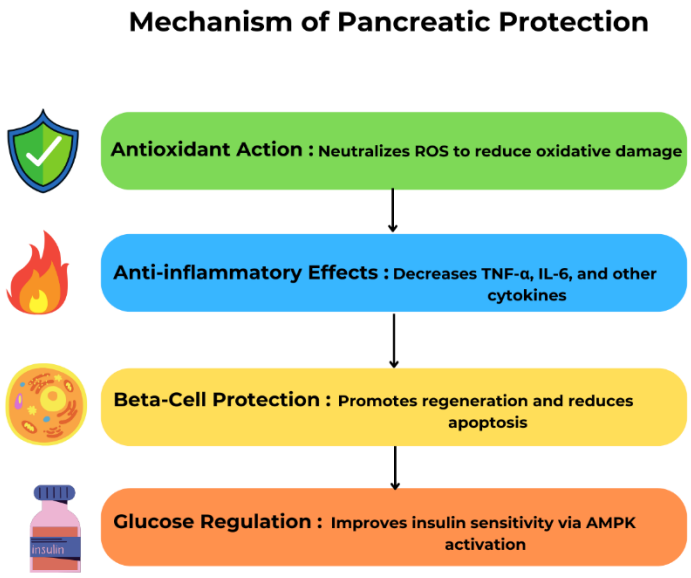

Figure 2: Mechanism of pancreatic protection by *Boswellia serrata* bioactives. [30]

5. Pharmacological Evidence

5.1 Preclinical Studies

Preclinical research shows *Boswellia serrata* protects the pancreas and fights diabetes effectively. Researchers employ multiple diabetic rat models and mouse and rat models with diet-induced obesity to study *Boswellia serrata's* medicinal potential. Research teams use these models to test *Boswellia serrata's* effect on how well diabetes develops by studying glucose control and measuring insulin action in pancreatic tissue [31].

Research with mice demonstrated that *Boswellia serrata* made insulin respond better in diabetic animals and lowered blood sugar levels. Studies prove Boswellia serrata cuts back oxidative stress and drops inflammatory protein release while increasing natural defence mechanism activity. Researchers indicate *Boswellia serrata* protects pancreatic beta-cells from dying and supports new growth while lowering tissue inflammation. The research shows that *Boswellia serrata* can help support diabetes control and safeguard pancreatic health as an adjunct treatment approach [32].

5.2 Clinical Trials

Many preclinical research results exist but studies in actual people must be done to prove if *Boswellia serrata* works well and without harm. Medical researchers currently assess *Boswellia serrata* for its role in blood sugar management and possible diabetes treatment. Blood glucose control improved alongside reduced insulin resistance among type 2 diabetes patients who took *Boswellia serrata* extract supplements. The research showed that when people took *Boswellia serrata* supplements their inflammation markers linked to diabetes problems got lower [33].

Many recent studies that studied *Boswellia serrata* effects on diabetes patients were too small and didn't track participants for long enough to have convincing clinical evidence. Complete studies in multiple medical centres on diabetic people taking *Boswellia serrata* are needed to find the best dose while ensuring safety over time, as initial trials show promise. Large clinical studies are needed to confirm how well Boswellia serrata works with commonly used diabetes medicines [34].

5.3 Comparative Analysis with Other Antidiabetic Agents

When we take *Boswellia serrata*, it reduces blood sugar, helps our cells respond better to insulin, and keeps our pancreas working well. Current studies suggest that *Boswellia serrata* helps manage blood sugar, but its effects don't replace traditional options for treating diabetes like metformin or insulin treatment. Research shows *Boswellia serrata* lowers glucose like metformin but can also protect pancreas beta cells from harmful stress and inflammation [35].

More studies show that *Boswellia serrata* has the same effect as two other well-known plants used to lower blood sugar, Gymnema sylvestre and Curcuma longa. While *Boswellia serrata* has antioxidant strength that equals other plant medicines, early research shows it may fight inflammation better. Taking *Boswellia serrata* also helps boost its blood sugar-lowering power when combined with other natural treatments or diabetes pills, making it easier to control blood sugar and preserve healthy pancreatic function [36].

6. Challenges and Limitations

6.1 Variability in Bioactive Compound Concentration

Natural climate and soil differences control how much bioactive substances grow in distillates made from Boswellia serrata. The way these variables act together causes major differences in how much boswellic acid remains in the extract [37]. Phytochemical levels often change a lot when plants grow in different countries or react to different kinds of environmental pressure. The mixed effects of seasonal changes and farming methods contribute to unexpected results. Medical effectiveness of *Boswellia serrata* extract depends on how it is made, and between batches can change greatly because of varied ingredients. Science teams must look into what best helps plants grow while standardizing how they collect these plants to deal with quality inconsistencies [38].

6.2 Standardization Issues

The chemical compounds in *Boswellia serrata* are hard to bring to standard levels, keeping herbs from becoming a widely accepted therapy. All three parts of the extraction process - how it's done, what solvent is used, and what steps are taken - influence what goes into the final extract. Bioactivity in real-world treatment keeps changing because Boswellia extracts can't be made uniform [39]. If *Boswellia serrata* is to become a widely used medicine, we must find consistent methods to collect and bring boswellic acids into consistent levels in their pure form. Getting the same results from treatment every time is essential for doctors and getting medicines approved, and these methods must guarantee that all extracts stay consistent [40].

6.3 Long-Term Safety and Efficacy

Boswellia serrata provides evidence of benefits for blood sugar control and pancreatic health in the early tests, but we don't know for sure what would happen if it was used over many years. Based on current evidence, we don't know if using these supplements for a long time could pile up negative impacts inside our bodies or interact badly with our other medicines [41]. Because research on how *Boswellia serrata* works over time for managing diabetes and other long-lasting health problems is very limited, we do not understand how it affects diseases like diabetes that need ongoing care. Studies are needed to see how Boswellia serrata affects health over extended usage times. Tests must be used to uncover any risks and find the right dosage safe to use over many years [42].

7. Future Perspectives

7.1 Clinical Validation

Before using *Boswellia serrata* widely in medicine, researchers need to prove clearly that it helps control blood sugar and protects the pancreas in scientific tests with people. To discover how well it works and determine what amount to use in patients, large random studies with humans are needed, even with promising early results from animal tests [43]. Randomized controlled trials (RCTs) will better help us find the right dose, watch for side effects, see how well Boswellia works, and compare it to standard diabetes medications. Since these studies work, they can both help regulators through the approval process and help insert the findings into current medical standards for diabetes and other metabolic problems [44].

7.2 Novel Drug Delivery Approaches

We need better ways to deliver *Boswellia serrata* drugs to increase how well they work and how much they reach the body. To make treatments work better, we must develop ways to send bioactive materials directly where they're needed most, particularly the pancreatic cells, using little carrier particles known as liposomes or nanoparticles [45]. The development of slow-release Boswellic acid medicines could lengthen the drug's working time, keeping boswellia active for longer periods and reducing the need to take a pill daily. The therapeutic combination of Boswellia serrata with other diabetes treatments helps medication work better and causes less side effects. Scientists can now use new drug delivery systems to improve how Boswellia serrata works in medication [46].

7.3 Integration in Functional Foods and Nutraceuticals

The plant *Boswellia serrata* offers important benefits as an ingredient in functional foods and nutraceutical products. People looking for natural ways to improve their body's ability to manage blood sugar and physical health can take *Boswellia serrata* plant parts as add-ins for dietary supplements, pre-made foods, or drinks [47]. These dietary products fighting type 2 diabetes work well because of shown effects against inflammation, free radical damage, and blood sugar imbalances. People with a heightened risk for metabolic diseases might find it helpful to add Boswellia serrata to their daily food as a natural, simple way to keep their blood sugar controlled [48].

8. Conclusion

Boswellia serrata is emerging as a very useful plant for protecting and regulating glucose utilization in the pancreas. The boswellic acids found in Boswellia serrata activate body systems that help control blood sugar by responding to insulin, stopping carbohydrates from breaking down too fast, and

switching on pathways that affect glucose processing. Using *Boswellia serrata* helps preserve healthy pancreatic function and fights diabetes by reducing inflammation and stopping oxidative damage.

Therapeutic potential of *Boswellia serrata* in diabetes management and pancreatic health is supported by the preclinical and clinical trials reviewed in this article. Nevertheless, there are still obstacles to overcome, such as the lack of data on long-term safety, extract standardisation, and concentration variability of bioactive compounds. In order to use *Boswellia serrata* into therapeutic practice successfully, it is vital to overcome certain hurdles.

Exploring *Boswellia serrata* as a component in functional foods and nutraceuticals, conducting large-scale randomised clinical trials, and developing new drug delivery methods such as sustained-release systems and Nano formulations should all be priorities for future study. *Boswellia serrata* has the potential to improve the lives of people with metabolic illnesses by filling in these knowledge gaps and satisfying the demands for clinical validation. It could provide a natural and effective supplemental therapy for diabetes control and pancreas protection.

REFERENCES:

1. Thombare N, Kumari U, Sakare P, Chowdhury AR, Lohot VD, Prasad N. Indigenous technical knowledge on the medicinal uses of natural resins and gums in India. Indian Journal of Traditional Knowledge (IJTK). 2023 Jun 28;22(2):340-9.
2. Solanki N, Gupta G, Chellappan DK, Singh SK, Gulati M, Paudel KR, Hansbro PM, Dua K, Bhan S, Saini M, Dureja H. Boswellic acids: A critical appraisal of their therapeutic and nutritional benefits in chronic inflammatory diseases. Endocrine, Metabolic & Immune Disorders-Drug Targets (Formerly Current Drug Targets-Immune, Endocrine & Metabolic Disorders). 2024 Jan 1;24(1):116-29.
3. Mishra S, Tiwari P, Yadav R, Patel PS. An extensive analysis of diseases associated with diabetes. Journal of Pharma Insights and Research. 2024 Jun 14;2(3):174-87.
4. Newsholme P, Keane KN, Carlessi R, Cruzat V. Oxidative stress pathways in pancreatic β-cells and insulin-sensitive cells and tissues: importance to cell metabolism, function, and dysfunction. American Journal of Physiology-Cell Physiology. 2019 Sep 1;317(3):C420-33.
5. Mahdian D, Abbaszadeh-Goudarzi K, Raoofi A, Dadashizadeh G, Abroudi M, Zarepour E, Hosseinzadeh H. Effect of Boswellia species on the metabolic syndrome: A review. Iranian Journal of Basic Medical Sciences. 2020 Nov;23(11):1374.
6. Chatterjee A, Jayaprakasan M, Chakrabarty AK, Lakkaniga NR, Bhatt BN, Banerjee D, Narwaria A, Katiyar CK, Dubey SK. Comprehensive insights into rheumatoid arthritis: Pathophysiology, current therapies and herbal alternatives for effective disease management. Phytotherapy Research. 2024 Mar 24.
7. Ragab EA, Abd El-Wahab MF, Doghish AS, Salama RM, Eissa N, Darwish SF. The journey of boswellic acids from synthesis to pharmacological activities. Naunyn-schmiedeberg's Archives of Pharmacology. 2024 Mar;397(3):1477-504.
8. Saladino R, Gualandi G, Farina A, Crestini C, Nencioni L, Palamara AT. Advances and challenges in the synthesis of highly oxidised natural phenols with antiviral, antioxidant and cytotoxic activities. Current medicinal chemistry. 2008 Jun 1;15(15):1500-19.
9. Truzzi E, Vanti G, Grifoni L, Maretti E, Leo E, Bilia AR. Plant Resin Delivery by Nanovectors as an Emerging Approach to Boost Solubility, Permeability and Bioavailability. Pharmaceutics. 2025 Jan 3;17(1):53.
10. Asteggiano A, Curatolo L, Schiavo V, Occhipinti A, Medana C. Development, validation, and application of a simple and rugged HPLC method for boswellic acids for a comparative study of their abundance in different species of Boswellia gum resins. Applied Sciences. 2023 Jan 17;13(3):1254.
11. 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 Jan 1;109:66-75.
12. Singh KS, Majik MS, Tilvi S. Vibrational spectroscopy for structural characterization of bioactive compounds. InComprehensive analytical chemistry 2014 Jan 1 (Vol. 65, pp. 115-148). Elsevier.
13. Kosolapov D, Jáč P, Riasová P, Poušková J, Polášek M, Nováková L. Advances and challenges in the analysis of boswellic acids by separation methods. Critical Reviews in Analytical Chemistry. 2024 Feb 1:1-27.
14. Du Z, Liu Z, Ning Z, Liu Y, Song Z, Wang C, Lu A. Prospects of boswellic acids as potential pharmaceutics. Planta medica. 2015 Mar;81(04):259-71.
15. Montaser MM, El-Sharnouby ME, El-Noubi G, El-Shaer HM, Khalil AA, Hassanin M, Amer SA, El-Araby DA. Boswellia serrata resin extract in diets of Nile tilapia, Oreochromis niloticus: Effects on the growth, health, immune response, and disease resistance to Staphylococcus aureus. Animals. 2021 Feb 8;11(2):446.
16. JC Furtado NA, Pirson L, Edelberg H, M. Miranda L, Loira-Pastoriza C, Preat V, Larondelle Y, André CM. Pentacyclic triterpene bioavailability: An overview of in vitro and in vivo studies. Molecules. 2017 Mar 4;22(3):400.
17. Ahmed HH, Abd-Rabou AA, Hassan AZ, Kotob SE. Phytochemical analysis and anti-cancer investigation of Boswellia serrata bioactive constituents in vitro. Asian Pacific Journal of Cancer Prevention. 2015;16(16):7179-88.
18. Sharma A, Chhikara S, Ghodekar S, Bhatia S, Kharya M, Gajbhiye V, Mann A, Namdeo A, Mahadik K. Phytochemical and Pharmacological investigations on Boswellia serrata. Pharmacognosy Reviews. 2009;3(5):206.
19. Gomaa AA, Farghaly HA, Abdel-Wadood YA, Gomaa GA. Potential therapeutic effects of boswellic acids/Boswellia serrata extract in the prevention and therapy of type 2 diabetes and Alzheimer's disease. Naunyn-Schmiedeberg's Archives of Pharmacology. 2021 Nov 1:1-9.
20. Prasad M, Jayaraman S, Eladl MA, El-Sherbiny M, Abdelrahman MA, Veeraraghavan VP, Vengadassalapathy S, Umapathy VR, Jaffer Hussain SF, Krishnamoorthy K, Sekar D. A comprehensive review on therapeutic perspectives of phytosterols in insulin resistance: a mechanistic approach. Molecules. 2022 Feb 28;27(5):1595.
21. dev Sharma A. Phytochemical profile using GC-FID and diverse in-vitro biological activities of essential oil extracted from Boswellia serrata. Arabian Journal of Medicinal and Aromatic Plants. 2023 Oct 17;9(2):1-37.

22. Ajiboye OM, Ogunwenmo KO, Adewumi AG, Mohanye CC. Parkia biglobosa Jacq.(Locust Bean) leaves and seeds extracts attenuates diabetic-linked cognitive dysfunction in streptozotocin-induced male wistar rats. Metabolic Brain Disease. 2024 Dec 23;40(1):76.

23. Chadt A, Al-Hasani H. Glucose transporters in adipose tissue, liver, and skeletal muscle in metabolic health and disease. Pflügers Archiv-European Journal of Physiology. 2020 Sep;472(9):1273-98.

24. Khan A, Khan I, Halim SA, Rehman NU, Karim N, Ahmad W, Khan M, Csuk R, Al-Harrasi A. Anti-diabetic potential of β-boswellic acid and 11-keto-β-boswellic acid: Mechanistic insights from computational and biochemical approaches. Biomedicine & Pharmacotherapy. 2022 Mar 1;147:112669.

25. Kherouf A, Kherouf M, Aouacheri O, Doghmane A, Saka S, Adem Ş. Boswellia serrata Powder Regimen Provides Significant Protection Against Renal Damage and Blood Imbalances in Diabetic Rats. Chemistry & Biodiversity. 2024:e202402200.

26. Al-Matubsi H, Rashan L, Aburayyan W, Al Hanbali O, Abuarqoub D, Efferth T. Antidiabetic and antioxidant properties of Boswellia sacra oleo-gum in streptozotocin-induced diabetic rats. Journal of Ayurveda and Integrative Medicine. 2024 Jul 1;15(4):101014.

27. Ansari MA, Chauhan W, Shoaib S, Alyahya SA, Ali M, Ashraf H, Alomary MN, Al-Suhaimi EA. Emerging therapeutic options in the management of diabetes: recent trends, challenges and future directions. International Journal of Obesity. 2023 Dec;47(12):1179-99.

28. Mahdian D, Abbaszadeh-Goudarzi K, Raoofi A, Dadashizadeh G, Abroudi M, Zarepour E, Hosseinzadeh H. Effect of Boswellia species on the metabolic syndrome: A review. Iranian Journal of Basic Medical Sciences. 2020 Nov;23(11):1374.

29. Konda PY, Nagalapuram R, Venkateswarlu JK, Mohammad SA, Chippada AR. Pathophysiology of STZ-induced pancreatic β cell injury and dysfunction: traditional role of Boswellia ovalifoliolata Bal. & Henry on diabetes and dyslipidemia. Comparative Clinical Pathology. 2020 Jun;29:609-19.

30. Ragab EA, Abd El-Wahab MF, Doghish AS, Salama RM, Eissa N, Darwish SF. The journey of boswellic acids from synthesis to pharmacological activities. Naunyn-schmiedeberg's Archives of Pharmacology. 2024 Mar;397(3):1477-504.

31. Zaitone SA, Barakat BM, Bilasy SE, Fawzy MS, Abdelaziz EZ, Farag NE. Protective effect of boswellic acids versus pioglitazone in a rat model of diet-induced non-alcoholic fatty liver disease: influence on insulin resistance and energy expenditure. Naunyn-Schmiedeberg's Archives of Pharmacology. 2015 Jun;388:587-600.

32. Shehata AA, Yalçın S, Latorre JD, Basiouni S, Attia YA, Abd El-Wahab A, Visscher C, El-Seedi HR, Huber C, Hafez HM, Eisenreich W. Probiotics, prebiotics, and phytogenic substances for optimizing gut health in poultry. Microorganisms. 2022 Feb 8;10(2):395.

33. Karimi M, Vakili K, Rashidian P, Razavi-Amoli SK, Akhbari M, Kazemi K. Effect of boswellia (Boswellia serrata L.) supplementation on glycemic markers and lipid profile in type 2 diabetic patients: a systematic review and meta-analysis. Frontiers in Clinical Diabetes and Healthcare. 2024 Oct 10;5:1466408.

34. Lindler BN, Long KE, Taylor NA, Lei W. Use of herbal medications for treatment of osteoarthritis and rheumatoid arthritis. Medicines. 2020 Oct 28;7(11):67.

35. Sharma P, Rani N, Gangwar A, Dahiya RS, Verma N. Chemical constituents based approach for the management of diabetes. Current Diabetes Reviews. 2023 Jun 1;19(5):18-26.

36. Kumar V, Sharma C, Taleuzzaman M, Nagarajan K, Haque A, Bhatia M, Khan S, Salkini MA, Bhatt P. Neuroprotective Effect of Boswellia serrata against 3-NP Induced Experimental Huntington's Disease. Current Bioactive Compounds. 2024 Jul 1;20(6):64-77.

37. Alam T, Khan SA, Najam L. Chemistry, Biological Activities, and Uses of Resin of Boswellia serrata Roxb. InGums, Resins and Latexes of Plant Origin: Chemistry, Biological Activities and Uses 2021 Oct 29 (pp. 1-43). Cham: Springer International Publishing.

38. 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. 2021 Jul 10;14(7):660.

39. Srujana TS, Konduri RB, Rao BS. Phytochemical investigation and biological activity of leaves extract of plant Boswellia serrata. The pharma innovation. 2012 Jul 1;1(5, Part A):22.

40. Abdel-Tawab M, Werz O, Schubert-Zsilavecz M. Boswellia serrata: an overall assessment of in vitro, preclinical, pharmacokinetic and clinical data. Clinical pharmacokinetics. 2011 Jun;50:349-69.

41. Ammon HP. Modulation of the immune system by Boswellia serrata extracts and boswellic acids. Phytomedicine. 2010 Sep 1;17(11):862-7.

42. Tiwari G, Yadav D, Singh B, Kumar A, Wal P, Tiwari R. Development and assessment of phytophospholipid nanovesicular systems for treatment of diabetic neuropathy. Pharmacognosy Research. 2022;14(4).

43. Vishwakarma PK, Moharana A, Behra SR, Choudhury P, Jayronia S, Tripathi SM. Diabetes Management: Herbal Remedies and Emerging Therapies. Current nutraceuticals. 2024 Jan;5(1):E100524229823.

44. Euler D. Chinese herbal medicine for pain. Integrative Pain Medicine: The Science and Practice of Complementary and Alternative Medicine in Pain Management. 2008:471-93.

45. Shirsath NR, More MP, Deshmukh PK, Bagul VS, Patel JK, Bhavsar BV, Patil PB. Novel Drug Delivery Systems in the Treatment of Cancer: A Better Future Hope. InNovel Drug Delivery Systems in the Management of Chronic Diseases (pp. 199-254). Apple Academic Press.

46. Ibrahim BM, Darwish AB, Taleb SA, Mourad RM, Yassen NN, Hessin AF, Gad SA, Mohammed MA. Appraisal terpenoids rich Boswellia carterri ethyl acetate extract in binary cyclodextrin oligomer nano complex for improving respiratory distress. Scientific Reports. 2024 Jul 22;14(1):16779.