Journal of Ayurveda & Holistic Medicine

https://jahm.co.in eISSN-2321-1563

Review

Narrative Review on Anti-inflammatory Activity of *Chloroxylon swietenia* DC: Bridging Traditional Claims with Scientific Evidence.

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ABSTRACT:

Background: *Chloroxylon swietenia* DC (CS) or *Bherra* (East Indian Satinwood) is a traditional medicinal plant used in the south-eastern part of India. Different parts of this medium -sized deciduous tree, such as leaves, bark and fruits have been used in folklore medicine to treat pain and inflammatory diseases. In spite of its many ethnomedicinal applications, strong scientific evidences still limited. **Objective:** The purpose of this review is to evaluate the anti-inflammatory activity of CS extracts, along with the phytoconstituents involved in this activity. **Materials and Methods:** The relevant information was gathered from classical Ayurvedic texts such as *Dravyaguna vijnana* by P. V. Sharma and standard reference books like Indian Medicinal Plant and Wealth of India. Also, the electronic databases, including PubMed, Science Direct, Google Scholar and IMPPAT 2.0, were searched to compile scientific work related to phytochemical and pharmacological activities. **Results:** Phytochemical studies indicate that CS extracts contain a wide range of bioactive compounds, which may be responsible for a dose-dependent anti-inflammatory effect in various experimental models. **Discussion:** The anti-inflammatory effect of CS is due to the presence of bioactive components in CS extracts, which can be responsible for modulating key inflammatory pathways, including arachidonic acid through inhibition of lipoxygenase, cyclooxygenase and phospholipase enzymes. Also, it shows a good safety profile with no toxic effects at experimental doses. **Conclusion:** Experimental and phytochemical profiles support the traditional claim and scientific validation of anti -inflammatory potential of CS. However, further research on isolation, standardization and multicentric clinical trials is essential to establish a potent anti-inflammatory drug.

KEYWORDS: Ayurveda, Antioxidant, Bergenin, Caprifoliaceae, Symplocos, *Lodhra*, narrative review

RECEIVED ON:
18-02-2026

REVISED ON:
07-04-2026; 27-04-2026

ACCEPTED ON:
09-05-2026

Access This Article Online:

Quick Response Code:

Website Link:

https://jahm.co.in

DOI Link:

https://doi.org/10.70066/jahm.v14i4.2605

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CITE THIS ARTICLE AS

Smruti M. Shahare, Krati Gautam, Shruti Aggarwal, Monika, Subash Sahu. Narrative Review on Anti-inflammatory Activity of *Chloroxylon swietenia* DC: Bridging Traditional Claims with Scientific Evidence. Journal of Ayurveda and Holistic Medicine (JAHM) 2026; 14(4):62-71.

1. INTRODUCTION

Inflammation is the process of the immune system's response to harmful substances such as microbes, damaged cells, noxious substances or radiation, and acts by removing such substances and initiating the healing process, it is an important core mechanism that is essential in maintaining health. [1] It is a primary process that is necessary for protecting animal cells from certain injury or infection. [2]

The substances that initiate and regulate inflammatory reactions or processes are the inflammatory mediators. [3] These are the chemical substances that work by causing vasodilation, increasing the permeability of blood vessels, causing tissue damage and promoting inflammation, pain and fever. Such mediators include cytokines, prostaglandins, Thromboxane, vasoactive amines like histamine and serotonin. [4]

Non-steroidal anti-inflammatory drugs (NSAIDs) are widely used for anti-inflammatory, analgesic and anti-pyretic effects. They inhibit the enzyme cyclooxygenase, which produces the prostaglandins and thromboxane by the synthesis and action of inflammatory mediators. [5] However, the long-term use of NSAIDs not only creates health issues but potentially increases the risk of GI toxicity, renal toxicity and cardiovascular issues. [6] In this scenario, plant-based alternatives help to reduce the side effects of conventional medicines and evolve a cost-effective and safe alternative to natural anti-inflammatory drugs. The various phytoconstituents present in particular plants regulate the inflammatory signaling pathway and reduce the pro-inflammatory cytokines. [7] Rigorous research is required to study and develop established plant-based anti-inflammatory agents/therapies to counteract the side effects of conventional medicine. [8]

Bhillotaka or *Bimbilota* is a plant used in Ayurveda for treating *Raktaabhisyand* (Conjunctivitis) and *Timir* (Refractive Errors). Under the name of *Bhillotaka*, two species have been identified: *Euonymus tingens* (Syn. *E. pendulus* Wall) and *Chloroxylon swietenia* DC (CS). [9] As of now, no studies have been reported that among these is considered a *Bhillotaka*. Multidisciplinary robust research is required to determine the exact botanical source of *Bhillotaka*. *Chloroxylon swietenia* DC, belonging to the Rutaceae family, is a folklore medicinal plant. [10] It is a moderate-sized aromatic tree, distributed mainly in dry, deciduous forests. It is native to India and Sri Lanka and commonly known as East Indian satinwood. [11] Traditionally, various parts of CS have been used in the form of a decoction of bark and leaves as a paste/cream for local application in rheumatism and wounds. The plant is enriched in phytochemicals like alkaloids, flavonoids, tannins, steroids, glycosides, etc., which contribute to its therapeutic effects. [12]

The present review aims to summarize the Ethnomedicinal, Chemical constituents, Anti-inflammatory potential, mechanism of action and safety profile of CS.

2. MATERIALS AND METHODS:

This review has been done by collecting relevant literature on CS from Ayurvedic classical text book such as *Dravyaguna vijnana* by P. V. Sharma and standard reference books including Indian Medicinal Plant, Wealth of India, and Review of Indian Medicinal Plants. We have also gathered information from the scientific web search platforms such as PubMed, Science Direct, and Google Scholar. Keywords and Boolean operators used, such as "*Chloroxylon swietenia*" OR "East Indian Satinwood", "*Chloroxylon swietenia*" AND "Inflammation",etc. Detailed search strategy shown in Table 1. The classification of the plant validated by the IMPAAT PoW (Plant of the World Online) database

Table 1: Search strategy used

Database	Search Strategy (search term used)	Filters Applied	Results Retrieved	Notes
PubMed	"*Chloroxylon swietenia*"[Title/Abstract]	Date range-2000-2025	11	Title/Abstract
	("*Chloroxylon swietenia*"[Title/Abstract]) OR ("East Indian Satinwood [Title/Abstract])	Date range-2000-2025	11	Title/Abstract
	("*Chloroxylon swietenia*") AND ("GC-MS Analysis"[Title/Abstract])	Date range-2000-2026	01	Title/Abstract
	("*Chloroxylon swietenia*"[Title/Abstract]) AND ("Toxicity"[Title/Abstract])	Date range-2000-2026	03	Title/Abstract
Science Direct	"*Chloroxylon swietenia* DC"	Date range- 2000-2025	04	Title/Abstract/ Keywords
	"Chloroxylon swietenia"	Date range- 2000-2025	10	Title/Abstract/ Keywords
	"*Chloroxylon swietenia*" AND "Inflammation"	Date range- 2000-2025	21	Title/Abstract/ Keywords
	"*Chloroxylon swietenia*" AND "Traditional medicine"	Date range-2000-2025	32	Title/Abstract/ Keywords
	"Chloroxylon swietenia"	Date range- 2000-2025	82	Title
	"*Chloroxylon swietenia*" AND "Anti-inflammatory activity"	Date range- 2000-2025	01	Title
Google Scholar	"*Chloroxylon swietenia*" AND "Bioactive compounds"	Date range- 2000-2025	01	Title
	"*Chloroxylon swietenia*" AND "Toxicity"	Date range- 2000-2025	02	Title

Inclusion criteria

- The articles published in between 2000-2025 are included.
- Original research work, review articles on CS are included.
- Studies highlight the phytochemical analysis, anti-inflammatory preclinical studies, toxicity, GC-MS analysis were considered for inclusion criteria.

Exclusion criteria

- The studies before 2000 were excluded.
- Repetition and phytoconstituents (found in CS) involved other than anti-inflammatory activities are excluded.

Plant description: Taxonomic position

Kingdom – Plantae **Division –** Streptophyta

Class – Equisetopsida **Sub-class –** Magnoliidae **Order –** Sapindales **Family** – Rutaceae **Genus** – Chloroxylon

Species - Chloroxylon swietenia *Chloroxylon swietenia*

- **Geographical Distribution:**

CS mostly occurs in dry as well as deciduous forests of peninsular India, extending to the Satpura hills and Chota Nagpur. It grows over metamorphic rocks and areas with rocky grounds characterized by black cotton soil and poor soil. [13] The species is widespread across globally including India, Sri Lanka, and Madagascar. In India, it occurs in central, southern, and south-eastern states. (Fig 1) [14]

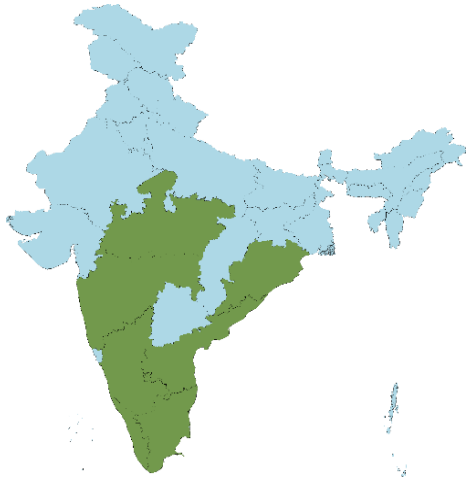

Fig 1. Distribution of *Chloroxylon swietenia* DC in India

- **Botanical Characterization:**

CS is a small to medium-sized tree. It reaches a height of 9-12 meters, along with a girth of 1.0-1.2 meters. It has a spreading crown characterized by a straight, cylindrical bole. (Fig 2 i) The bark is yellowish or greyish brown with a rough and corky texture. (Fig 2 ii) The leaves of CS are paripinnate, measuring 15-23 cm in length, comprising 10-20 pairs of leaflets. These leaflets are oblong in shape with obtuse apices, glabrous, glaucous and typically sub-opposite or alternate in appearance. (Fig 2 iii) The tree produces small white or cream-colored flowers arranged in terminal or axillary panicles. The fruit is glabrous and an oblong capsule divided into three segments, which measure about 2.5-4.5 cm long. Upon maturation, it exhibits dark brown coloration and contains 1-4 seeds. (Fig 2 iv) [13, 15]

(i)  (ii)  (iii)  (iv) 

Fig 2. Botanical Morphology of Chloroxylon swietenia DC- (i) Tree (ii) Bark (iii) Leaves (iv) Fruit & seeds

- **Vernacular Names:**

CS is recognized by many vernacular names. In India, it is called Bhirra, Bherul, Rakata-rohidhi (Hindi), Mammarai, Karumboraju, Poraju (Tamil), Bittula, Hurugulamare (Kannada), Bheru gatcho (Oriya), Bheria, Halda (Marathi), *Bhillotaka, Bimbilota* (Sanskrit), Varimaram (Malayalam), Billu (Telugu). In Sri Lanka, it is referred to as Buruta (Sinhalese), while in English known as East Indian Satinwood. [12, 15, 16]

- **Traditional uses**

CS is very well known for its various applications in traditional medicine, which have been getting attention from many studies on ethno botanical uses. Table 2 consolidates the findings of the common uses in folk medicine.

Traditionally, leaves of CS, in the form of paste, are applied for rheumatism, wounds, burns, cuts, various skin ailments, snakebites and constipation. Likewise, decoction prepared from leaves is used to get relief from ulcers and skin abrasions. A Combination of Leaves and roots, and making a paste, is applied to relieve headaches. The stem bark is given in jaundice, chest pain, fever, as a general tonic, as an antiseptic, for various skin conditions, and dandruff. Additionally, a decoction made up of stem bark is used for managing contusions and painful joints, cataracts, and ophthalmic infections. The gum obtained from the plant is used to manage diabetes and urinary disorders. The root bark, mixed with milk, is used to treat impotency; also, the root is recognized for its analgesic properties. [11, 12, 16, 17]

Table 2: Ethnobotanical uses of *Chloroxylon swietenia* DC Used part

	Mode of Preparation	Traditional uses	References
Leaves	Decoction	Ulcers, healing abrasions of skin	[11]
	Paste	Rheumatism, wounds, cuts, burns, skin diseases, Snakebites, constipation, Inflammation	[12]
Leaves and Roots	Paste	Headache	[16]
Stem bark	-	Jaundice, Fever, chest pain, antiseptic, as a tonic, on itches, Dandruff	[16]

	Decoction	Contusions and painful joints, chest pain	[11]
	-	Ophthalmic infection, Cataract, cough, cold	[12]
Gum	-	Diabetes and urinary disorders	[16]
Root	-	Relieve pain	[16]
Root bark	Adding with milk	Impotency	[16,17]

Phytoconstituents of *chloroxylon swietenia* dc:

The CS contains a broad range of phytochemicals that have been reported across different plant parts. The leaves have a significant number of secondary metabolites, including flavonoids, carbohydrates, alkaloids, cardiac glycosides, coumarins, lignin, phytosterols, quinones, phenolic compounds, saponins and diterpenes, suggesting notable antioxidants and anti-inflammatory properties. [18] The bark has a high concentration of tannins, glycosides, phenols, flavonoids, steroids, anthraquinones, triterpenoids, carbohydrates, and phenolic compounds, highlighting its potential role in antimicrobial properties. [19, 20] The roots are reported to have glycosides, saponins, flavonoids, phytosterols, triterpenoids, tannins, amino acids, alkaloids, and carbohydrates. [21]

The quantitative evaluation of key phytochemicals presents in the leaf and bark was established by analytical methods. For phenolic content, it uses the Folic-Ciocalteau method, and for alkaloids, using methanolic and oil-based extracts and the Bromocresol Green (BCG) assay method. The phenolic content was measured at about 26.38 ± 0.18 µg/mg and alkaloids at 30.28 ± 0.38 µg/mg in the methanolic extracts. [22] Whereas phenolic content was 236.94 ±11.85 µg/mg in the oil extracts. The levels of flavonoid in the leaves were found to be 19.92 ±1.00 µg/mg with oil and 2.90 ± 0.14 µg/mg with methanol extraction. The phenolic content in the bark was found to be higher in methanolic (47.53 ± 2.38 µg/mg) as well as oil extracts (146.18 ± 7.31 µg/mg). The flavonoid content observed was 19.94 ± 1.00 µg/mg in oil and 5.46 ± 0.27 µg/mg in methanol extracts. This suggests a marked phytochemical profile between plant parts and solvent systems. [23]

Through analytical techniques like GC-MS, several marker compounds have been identified that show anti-inflammatory activity and have been summarized in Table 3.

Pharmacological profile:

CS has a variety of pharmacological properties, and there are substantial evidences which support its traditional medicinal uses. The plant indicates notable antimicrobial activities, with the presence of essential oils in leaves and stem bark, which show moderate to high activities against bacterial and fungal infectious agents. [24] Its significant anti-inflammatory effect has been proven by animal studies, using carrageenan induced paw edema model. [25] The species shows hepatoprotective effect with the ethanol extract (250-500 mg/kg), diminishing acetaminophen-induced liver toxicity by restoration of high serum enzyme (ALT, AST, ALP) and bilirubin level, alongside improving antioxidant enzyme activities. [26] Both in vitro and in vivo studies have stated antidiabetic effects; leaf extracts of CS have shown α-amylase and α-glucosidase inhibitory effects. [27] As well as reducing blood sugar levels in streptozotocin-induced diabetic rats significantly. [28] The plant exhibits larvicidal and mosquitocidal activity by essential oils, which shows a high level of fumigant toxicity to Aedes aegypti, Anopheles gambiae, and Culex quinquefasciatus. [29] Also, it shows relevant wound healing and analgesic effects. [30, 31]

Table 3: Marker compounds having Anti-inflammatory activity isolated from *Chloroxylon swietenia* DC through GC-MS technique

Plant part	Extract used	Marker compounds showing anti-inflammatory Activity	References
Leaves	Methanol and Ethanol extract	L-(+)-Ascorbic acid 2,6-Dihexadecanoate, Octadecanoic acid 1-hexyl-1-Nitro cyclohexane, Tridecanoic acid, octadecanal, 2-Bromo-	[18]
	Hexane extract	N-Nitroso-2,4,4-Trimethyl oxazolidine, Tri tetracontane, Triacontane, Pentatriacontane, 2,6,10,14,18,22-Tetracosahexaene, Lupeol, 3-O-Acetyl-6-Methoxy cycloartenol, 2, 6, 10,15,19,23-Hexamethyl-, (All-E).	[18]
	Ethyl acetate	1-Hexyl-1-Nitrocyclohexane, Octadecanal	[18]

Toxicity and safety profile:

Pre-clinical toxicological studies show a consistent safety margin for CS. In an acute toxicity experiment, using methanol and aqueous bark extracts, no toxic effect or mortality was observed with doses up to 1000 mg/kg body weight in rats. [32] Likewise, acute toxicity evaluation extracts demonstrate that no adverse response at doses of 2000 mg/kg body weight, and the LD50 result was above this level. [33] Sub-acute toxicological study of chloroform extracts at doses (50-200 mg/kg/day for 14 days) did not produce any toxic effects on hematological parameters or hepatorenal functional marker toxicity. [34] Furthermore, acute toxicity studies on fruit extract were proven safe at a maximum dose of 2000mg/kg without any mortality. [35]

The wood of CS contains chloroxylonine alkaloid, which can lead to skin irritation; caution must be taken. [13]

Even so, comprehensive toxicological evidence supports that the plant is relatively safe in experimental doses, which confirms its traditional use and determines therapeutic indices to be used in future pharmaceutical development.

Anti-inflammatory properties:

Anti-inflammatory activity of CS has been studied in both in vivo and In vitro models which are summarized in Table 4.

Table 4: The Anti-inflammatory studies on different parts of *Chloroxylon swietenia* DC

Plant part	Method used	Grouping and Duration of study	Key Findings	References
Leaves	**Extract**- Chloroform extract **Method** – In vivo **I.** (Acute)- Carrageenan-induced rat paw oedema. **II.** (Chronic)- Cotton pellet-induced granuloma. **Animal/Model**- Swiss albino mice or Albino Wistar rats.	**Group-5** I: Control (Carrageenan) II: Standard Control- Diclofenac 12.5 mg/kg III: Treatment control (50 mg/kg) IV: Treatment control (100 mg/kg) V: Treatment control (200 mg/kg) **Duration:** Up to 4 hrs. (Acute) 7 days (Chronic)	Inhibition of 55.32 % was observed at a dosage of 200 mg/kg as assessed 3 hours post administration of the drug, reducing paw edema nearly comparable to the standard drug	[34]
	Extract- Hydro-alcoholic **Method**-In vivo- Carrageenan-induced paw edema **Animal / Model** -Swiss albino rats of either sex.	**Group-4** I: Negative Control (Carrageenan) II: Standard control {Diclofenac (10 mg/kg)} III: Treatment control (100 mg/kg) IV: Treatment control (200 mg/kg)	Extract reduced paw edema dose-dependently (max 74.78% inhibition at 200 mg/kg	[25]

		Duration: 1-4 hrs.		
Fruit	**Extract-** Ethanol **Method-**In vivo-Carrageenan-induced paw edema. **Animal / Model-** Wistar albino rats	**Group-4** I: 1% CMC suspension. II: Standard control {Indomethacin (10 mg/kg body weight)} III: Treatment control (200 mg/kg body weight) IV: Treatment control (500 mg/kg body weight) **Duration: 240 min** (4 hrs.)	500 mg/kg dose showed the strong inhibition; Paw edema reduced to 0.46±0.03 in 240 min nearly comparable to the standard drug	[31]
	Extract- Ethanol, Petroleum ether, Chloroform **Method-** In vitro I. BSA (Bovine serum albumin) Denaturation Assay II. HRBC (human red blood cell) in vitro inflammatory assay.	Control (PBS) Standard (Diclofenac sodium) Fruit extracts -Petroleum ether, Chloroform, Ethanol At doses of 100 µg/mL, 200 µg/mL, 300 µg/mL	**I.** Showed significant anti-denaturation activity of 65.74% on BSA at a concentration of 300µg/ml (IC50=201.05µg/mL) significantly, exhibiting a considerable inhibition of heat-induced BSA denaturation **II.** Showed the maximum inhibition of 87.92% at 300µg/ml (IC50=132.94µg/mL)	[30]

3. DISCUSSION

CS is a deciduous tree, presently categorized as Vulnerable in the IUCN Red List due to continuous exploitation and habitat loss. It is commonly used in folklore medicine to treat rheumatism, fever, wounds, and burns, etc. It has gained pharmacological importance, particularly in the context of its traditional uses in managing inflammation and inflammatory conditions. Ethnomedicinal report supports its uses in treating pain, reducing inflammation, and related disorders. CS has a rich phytochemical profile, containing flavonoids, alkaloids, phenolics, and tannins, which leads to its ability to modulate inflammatory pathways through the inhibition of pro-inflammatory mediators such as prostaglandins and cytokines. These compounds also contribute to the plant's anti-microbial, antioxidant and hepatoprotective activities. These findings validate its traditional uses with its ethnomedicinal relevance. Thereby, it highlights the need for its conservation and sustainable utilization. [12]

The aim of this review was to evaluate the anti-inflammatory potential of CS through various studies and identify the key phytoconstituents responsible for the activity. Preclinical studies indicate that CS possesses significant anti-inflammatory properties in acute as well as chronic inflammatory models. A study conducted on the carrageenan-induced paw edema model, leaf extracts exhibit a significant inhibitory effect on acute inflammation, (Table 4) which can be attributed to the presence of flavonoids and tannins. [25] Flavonoids and tannins are the major phenolic compounds present in CS leaf extract; [18] flavonoids play a major role in interfering with inflammatory mediators by inhibiting cyclooxygenase (COX) and lipoxygenase (LOX) pathways, thereby reducing the synthesis of prostaglandins and leukotrienes. Additionally, they inhibit enzymes like protein kinase, NADH oxidase and phospholipases, which contribute in reduction of inflammatory responses. [36] Similarly, ethanolic fruit extracts of CS have shown the inhibitory effect

on histamine, serotonin or prostaglandin synthesis. (Table 4) [31] In addition to the effect of CS leaves chloroform extract on chronic inflammation, it significantly reduces the granuloma formation by inhibiting the fibroblast proliferation and collagen deposition. (Table 4) [34] Another in vitro study demonstrated that fruit extracts of CS inhibit protein denaturation and stabilize erythrocyte membranes, (Table 4) which indicates their ability to preserve cellular integrity and prevent secondary inflammatory damage. [30]

Collectively, these findings provide evidence that CS exerts significant anti-inflammatory effects. And can be explained mechanistically by the presence of its phytochemical composition. Octadecanoic acid identified in CS leaf extract may support its anti-inflammatory potential (Table 3) as it has been reported to suppress the production of inflammatory mediators such as prostaglandins, nitric oxide and cytokines like TNF- α and IL-6. This effect may be mediated through the down regulation of inducible nitric oxide synthase (iNOS) and cyclooxygenase-2 (COX-2). [37] Lupeol is a pentacyclic triterpene, also identified in leaf extract of CS through GC-MS analysis (Table 3) and is known to exhibit anti-inflammatory activity through various multi-target mechanisms. Lupeol inhibits the production of pro-inflammatory mediators such as cytokines like TNF-α and IL-6, and reduces inflammatory response. Also suppresses immune cell activity and oxidative stress, regulating NF-kB and PI3K pathways, leading to a reduction in inflammation. [38] Taken together, these findings may support that the presence of key phytoconstituents in different extracts of CS exerts anti-inflammatory potential.

However, even with these observations, experimental studies have shown that the anti-inflammatory efficacy of CS is comparatively lower than that of standard NSAIDs such as Diclofenac sodium and Indomethacin. In spite of this, an important advantage lies in its safety profile; acute and sub-acute toxicity studies indicate no adverse effect at experimental doses. [32, 34] This offers a plant serve as a safer alternative drug over conventional NSAIDs.

Despite these promising findings, several limitations and research gap remain. As its efficacy is lower compared to the standard drug, this highlights the need for rigorous investigations, like dose optimization, isolation of bioactive compounds and clinical validation. Detailed mechanistic studies at the molecular level are limited. Also, there is insufficient data on long term toxicity and the absence of well-designed clinical trials. Therefore, future research should focus on isolation and characterization of bioactive compounds along with validation at molecular level.

4. CONCLUSION:

CS has been used traditionally in the management of inflammatory conditions, and the ethnomedicinal claim is supported by phytochemical and preclinical evidence. The experimental studies have indicated that various extracts of CS can be effective in reducing inflammation through several mechanisms. Including inhibition of pro-inflammatory mediator synthesis, modulating cytokine pathways and suppression of fibroblast proliferation, which is related to chronic inflammation. And the activity may be attributed to bioactive compounds present in CS. Preliminary toxicity experiments indicate that it is relatively safe, which supports its potential for therapeutic use.

Even with such promising findings, most evidence is still limited to preclinical investigations. However, Further research is needed to isolate and standardize bioactive compounds and well-designed metacentric clinical trials are essential to establish their therapeutic applicability as a safe and effective anti-inflammatory drug.

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Reviewing & Editing: SS, KG, MK, SS

Approval of final manuscript: All Authors

Declaration of Generative AI

The authors declare this manuscript was written without the use of generative artificial intelligence tools. All the content, including text generation, data analysis and references was developed and reviewed by the author without assistance from AI technologies.

Conflict of Interest – The authors declare no conflicts of interest.

Source of Support – The authors declare no source of support.

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