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Ethnomedicinal insights into *Sansevieria cylindrica* Bojer ex Hook. : A systematic review of its bioactive properties and therapeutic potential

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Abstract

Medicinal plants have been utilized for centuries, playing a pivotal role in disease management and overall health. They serve as primary therapeutic agents in traditional medicine, providing natural remedies for a wide range of ailments. The bioactive compounds present in these plants contribute to their pharmacological effects, making them valuable sources for drug discovery and development. *Sansevieria cylindrica* Bojer ex Hook., commonly known as the African spear plant, is one such species with significant medicinal potential. Various *Sansevieria species* have been investigated for their diverse pharmacological activities, including antioxidant, antimicrobial, antitumor, and antidiabetic properties, as well as their ability to inhibit capillary permeability. Additionally, *S. cylindrica* has been traditionally used as an antiseptic, for treating snake bites, promoting wound healing, and as a refreshing beverage. This review focuses on *S. cylindrica*, aiming to explore its phytochemical and pharmacological properties, along with its safety profile. Through, a systematic investigation, this study identifies potential lead molecules within *S. cylindrica* that could contribute to natural product-based drug discovery. The findings highlight the plant's rich phytochemical composition and diverse pharmacological activities, further supporting its medicinal applications. Given its promising therapeutic properties, *S. cylindrica* represents a potential candidate for further pharmacological research and drug development. This review underscores the importance of continued exploration of this species to fully unlock its medicinal potential and facilitate the development of novel, plant-based therapeutic agents.

1. Introduction

Medicinal plants have been used as effective herbal medicine worldwide to treat various ailments for centuries. According to Agnew (1974), the use of plants for therapeutic purposes dates back to ancient civilisations, where they were the primary source of medicine. The world health organization (WHO) estimates that more than 3/4th of the global population relies on herbal medicines as their primary healthcare choice due to their accessibility, affordability, and perceived safety (Patan *et al.,* 2024; Banu *et al.,* 2024). Herbal medicines are often considered non-toxic, cost-effective, and associated with greater patient compliance compared to synthetic drugs (Anbarasi *et al.,* 2019). The growing awareness and herbal therapies has significantly increased the demand for herbal products in recent years, leading to a surge in the herbal industry (Antunes Da Silva *et al.,* 2003). Traditional, medicines have been integral to healthcare for centuries, valued for their natural origin, perceived safety, and effectiveness in managing acute and chronic conditions (Ataa Said *et al.,* 2015; Brown, 1915; Khan *et al.,* 2023). Their widespread use, particularly in developing regions, underscores the need for scientific validation to ensure efficacy and safety (Ekor, 2013). However, variations in plant composition, extraction methods, and potential herb-drug interactions necessitate systematic reviews to consolidate knowledge, clarify contradictions, and update research findings (Naaz *et al.,* 2024; Tilburt and Kaptchuk, 2008). Such evaluations bridge research gaps and contribute to evidence-based advancements in phytomedicine, ensuring the safe integration of traditional remedies into modern healthcare.

Sansevieria cylindrica Bojer ex Hook. is commonly known by various names, including Bow-String hemp, Snake plant, Zebra lily, Mother-in-Law's Tongue, and Cow tongue. It belongs to the family Asparagaceae (Buyun *et al.,* 2018). The genus *Sansevieria*, which is native to Africa and South Asia, belongs to a group of xerophytic flowering plants and includes approximately 70 species. These plants are characterized as perennial herbs with stiff, erect leaves and short, thick rhizomes (Chahinian, 2005; Chinasa *et al.,* 2011). The flowers of *Sansevieria* are typically greenish-white, brownish, rose, or lilac-red and are borne on a simple raceme. The fruits are berries that are red or orange in colour. The flowered shoots of *Sansevieria* continue to grow by producing plantlets through their stolons and rhizomes. The genus was named in honour of Count Pietro Sanseverino of Naples, Italy, who was a patron of horticulture in the late 18th century (Coombes, 2012; Dodge, 1893).The leaves of *Sansevieria* are utilized for fiber production while the plant's sap is valued for its antiseptic properties. Additionally, the leaves are traditionally used as bandages in first aid (Ekor, 2013). Many species within the *Sansevieria* genus are widely cultivated as ornamental

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plants (Gledhill, 2008). The NASA Clean Air Study, conducted in collaboration with the associated landscape contractors of America (ALCA), identified certain plant species capable of improving air quality by removing harmful pollutants such as formaldehyde, xylene, and toluene. *Sansevieria*, a genus recognized for its air-purifying properties, employs the crassulacean acid metabolism (CAM) pathway, allowing it to absorb carbon dioxide (CO_2) during the night and release oxygen throughout the day (Wolverton *et al.,* 1989).This unique adaptation makes *Sansevieria* particularly suitable as a bedroom plant, as it improves air quality by reducing CO_2 levels during nighttime (Stuart, 2020).

The potential of *Sansevieria* extends beyond air purification. As early as 1895, Holtze highlighted the possibility of cultivating *S. zeylanica* and *S. cylindrica* as fiber plants due to their robust and durable leaves (Hnin Thanda Aung *et al.,* 2020). Further studies by Gerome and Labroy in 1903 identified and described 20 of the most important fibre-producing species within the genus, classifying them based on leaf morphology and other vegetative characteristics. Additionally, Dodge (1893) explored the propagation of *Sansevieria* and its potential as a fiber crop, particularly in regions like Florida, where its cultivation was deemed feasible (Kirby, 1899).

Figure 1: *S. cylindrica* (Source: Plantophiles).

Traditionally, various parts of this plant have been used for their medicinal properties, including antitumor, antibacterial, antidiabetic, anti-inflammatory, and free radical scavenging activities (Antunes Da Silva *et al.,* 2003). Beyond its traditional applications, *S. cylindrica* has been found to contain a diverse array of bioactive compounds, including steroidal saponins, flavonoids, alkaloids, and phenolic compounds. These phytochemicals contribute significantly to the plant's pharmacological properties, such as anti-inflammatory, antimicrobial, and antioxidant effects. In addition to its medicinal potential, *S. cylindrica* has a wide range of applications, including air purification, fiber production, and environmental sustainability. Given its diverse uses and promising bioactive profile, a systematic review of *S. cylindrica* is essential to consolidate existing knowledge, identify research gaps, and explore its potential for future therapeutic development. Such a review would provide a comprehensive understanding of this versatile plant and pave the way for innovative applications in environmental, industrial, and medical fields.

2. Phytochemical profile of *S. cylindrica*

S. cylindrica is a rich source of diverse phytochemicals, which contribute to its wide range of medicinal properties. The plant contains a variety of bioactive compounds, including steroidal saponins, flavonoids, alkaloids, sterols, carbohydrates, quinones, and fatty acids (Mimaki *et al.,* 1988; Mohammad Faheem Khan *et al.,* 2017). These compounds have been isolated from different parts of the plant, such as the leaves, roots, and rhizomes, each exhibiting unique phytochemical compositions (Mona Raslan *et al.,* 2015).

A comparative analysis of phytochemical distribution in *S. cylindrica* reveals distinct patterns across its various parts. Steroidal saponins, among the predominant bioactive compounds, are present in high concentrations in the leaves, moderate levels in the roots, and substantial amounts in the rhizomes (Mona Raslan *et al.,* 2015). These glycosidic compounds are widely recognized for their pharmacological potential, particularly in anti-inflammatory and cytotoxic activities (Akinmoladun *et al.,* 2020). Flavonoids, including homoisoflavanone and dihydrochalcones, are predominantly present in the leaves, with trace amounts detected in the rhizomes but absent in the roots. As potent antioxidants, flavonoids contribute to the plant's defense mechanisms by neutralizing free radicals and mitigating oxidative stress (Panche *et al.,* 2016). Additionally, alkaloids and quinones are exclusively found in the roots, suggesting their role in root-specific metabolic pathways. Phenolic compounds, known for their antioxidant properties, are distributed across all parts of the plant, with the highest concentrations observed in the rhizomes.

Table 1: Phytochemicals from *S. cylindrica*

Category	Phytochemicals
Alkaloids	Identified in the root
Sterols	β-Sitosterol
Glycosides	Various steroidal saponins, including: • (25S)-ruscogenin-1-O-α-L-rhamnopyranosyl-(1 → 2)-β-D-glucopyranoside • (25S)-ruscogenin-3-O-α-L-rhamnopyranosyl-(1 → 4)-β-D-glucopyranoside· • (25S)-ruscogenin-3-O-β-D-glucopyranoside • (25S)-ruscogenin-1-O-α-L-rhamnopyranosyl-(1 → 2)-[β-D-xylopyranosyl-(1 → 3)]-α-L-arabinopyranoside· • (25R)-26-O-β-D-glucopyranosyl-furost-5-ene-1β,3β,22α,26-tetrol-1-O-α-L-rhamnopyranosyl-(1 → 2)-[β-D-xylopyranosyl-(1 → 3)]-α-L-arabinopyranoside

Flavonoids	**Homoisoflavanone** ● (3S)-3,7-dihydroxy-8-methoxy-3-(3',4'-methylenedioxybenzyl) chroman-4-one **Dihydrochalcone** ● 2',4'-dihydroxy-3á-methoxy-3,4-methylenedioxy-8-hydroxymethylenedihydrochalcone ● Total flavonoid content: 4.13 mg (QE)/g
Phenolic compounds	Ten phenolic compounds from the rhizomes Various phenolic molecules from the leaves Total phenolic content: 4.82 mg (GAE)/g
Coumarins	Identified in the non-flowering aerial parts
Carotenoids	β-Carotene from the root
Fatty acids (Lipid content)	Lauric, myristic, iso-pentadecanoic, iso-palmitic, palmitic, palmitoleic, iso-stearic, oleic, linolenic, gadoleic, and arachidonic acids
Quinones	Identified in the root
Carbohydrates	Identified in non-flowering aerial parts and in the root

Sterols, such as β-sitosterol, and fatty acids, including lauric, myristic, palmitic, and oleic acids, are primarily concentrated in the leaves. These compounds are associated with various physiological functions, including membrane stability, anti-inflammatory activity, and cholesterol-lowering effects (Güçlü-Ustündað and Mazza, 2007). Carbohydrates, which play essential roles in energy storage and structural integrity, are universally present across all plant parts. The specificity of certain bioactive compounds to particular tissues emphasizes the plant's adaptive metabolic strategies. Notably, quinones are exclusive to the roots, reinforcing their potential role in defense mechanisms against soil-borne pathogens (Moustafa *et al.,* 1986). The differential distribution of phytochemicals in *S. cylindrica* underscores its pharmacological relevance and emphasizes the need for targeted extraction techniques to optimize the yield of bioactive compounds for medicinal applications.

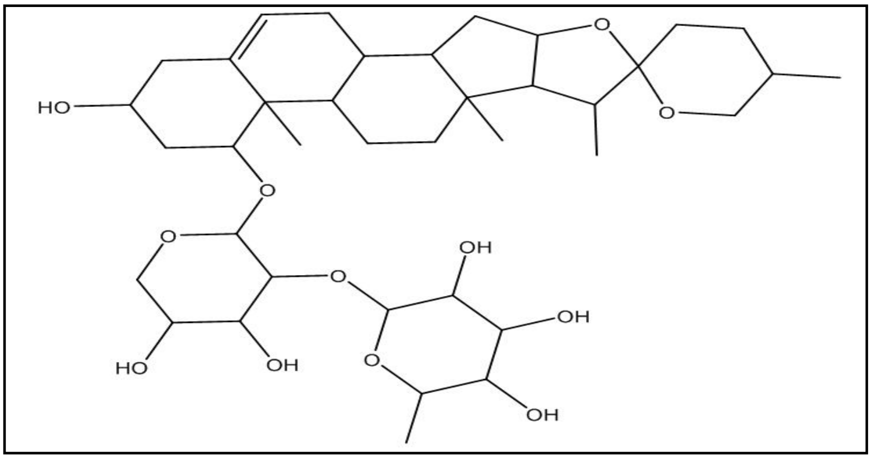


Figure 2: (25S)-ruscogenin-1-O-α-L-rhamnopyranosyl-(1 → 2)-β-D-glucopyranoside.

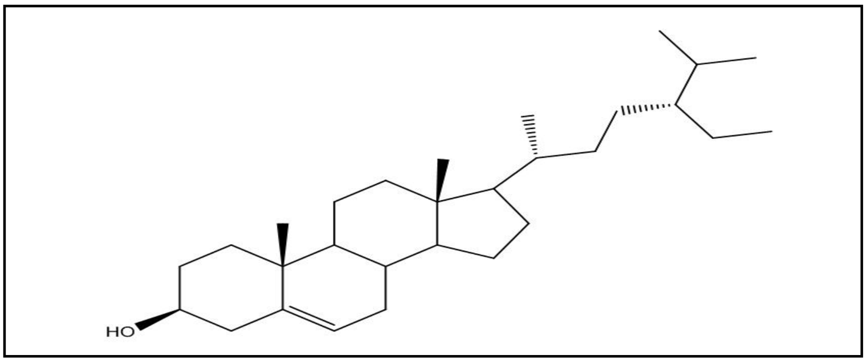


Figure 3:β-Sitosterol.

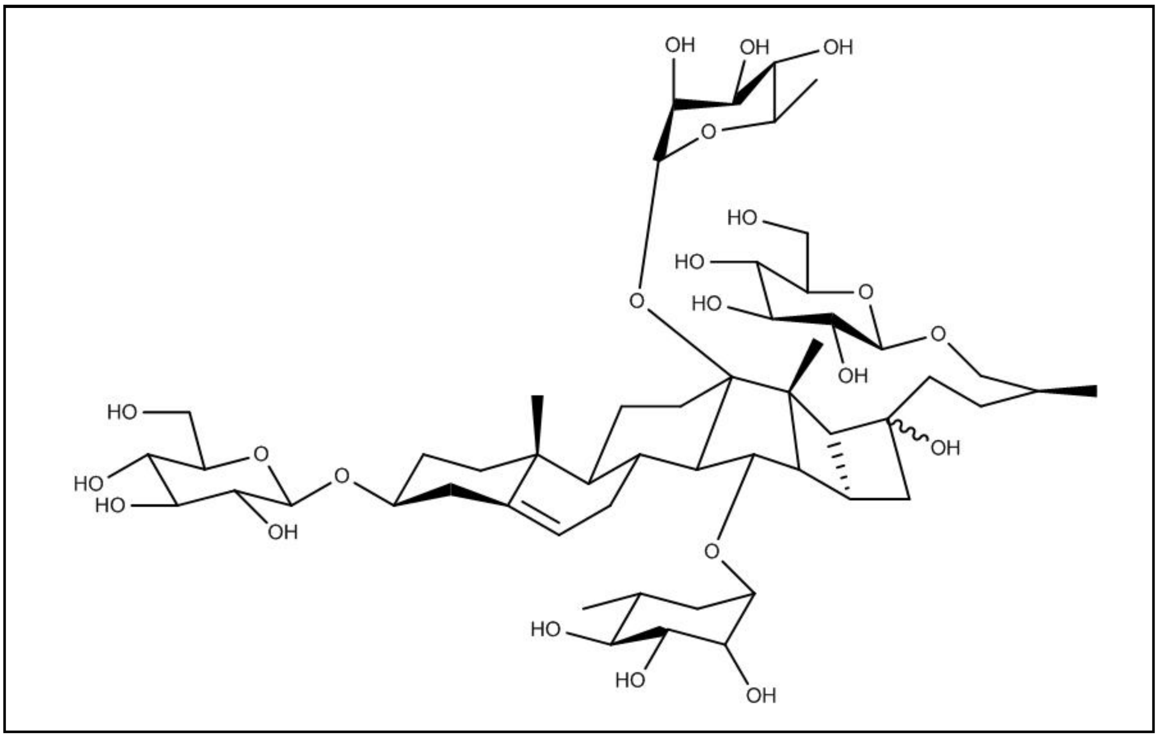


Figure 4: Steroidal saponin from *S. cylindrica*.

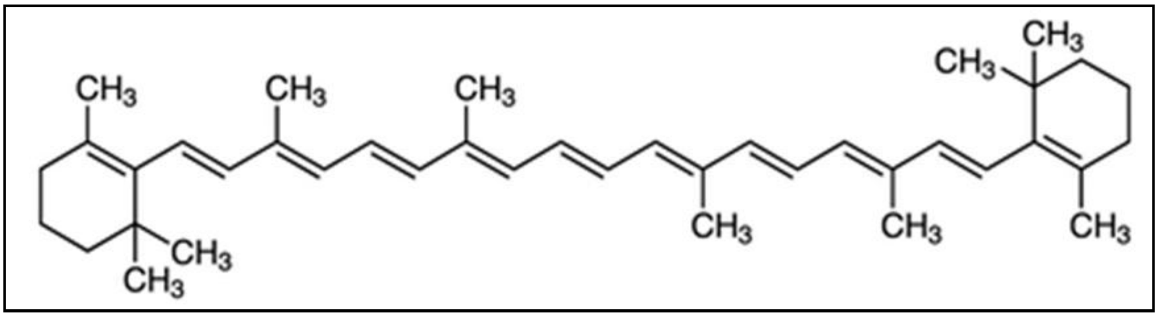
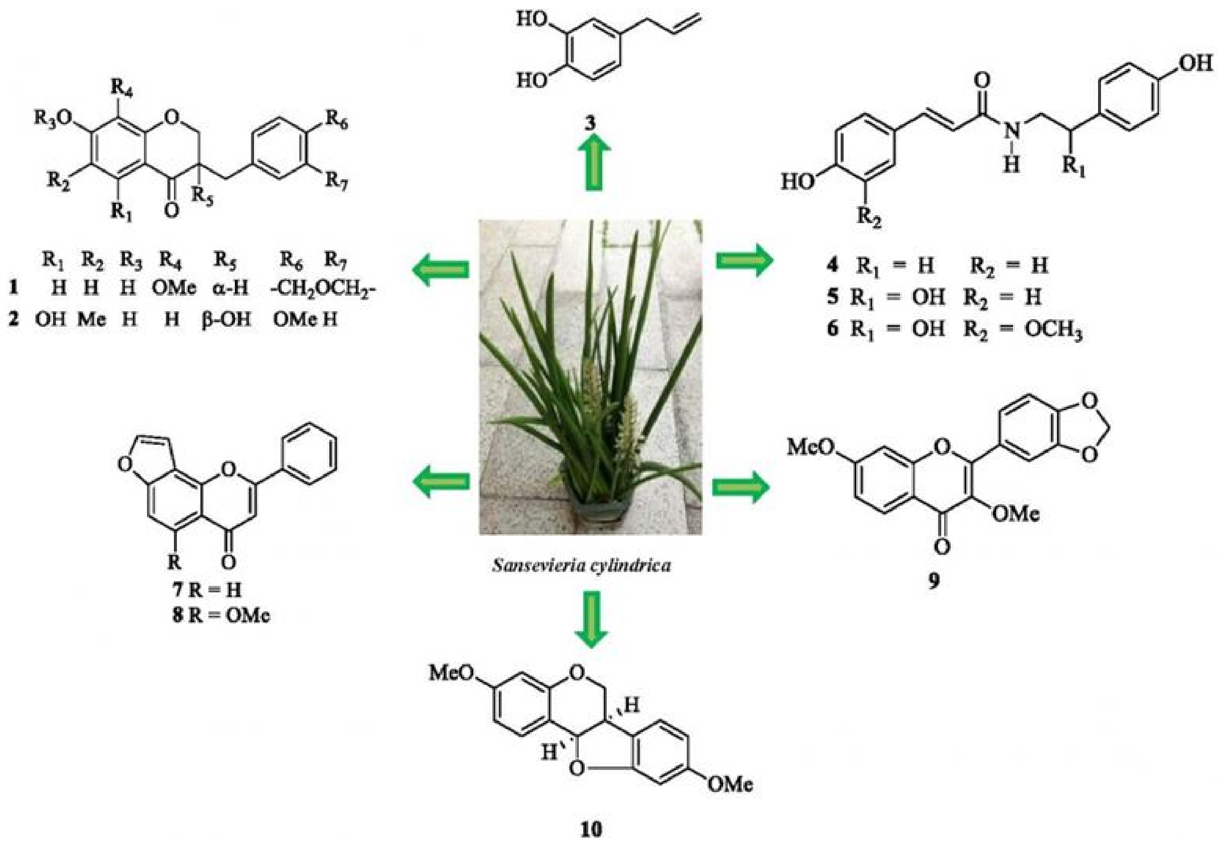


Figure 5: β-carotene.

Alkaloids and quinones are predominantly localized in the roots of *S. cylindrica*, where they exhibit potent antimicrobial properties. The presence of these bioactive compounds indicates that root extracts may possess significant antibacterial and antifungal properties, suggesting their potential application in the management of infectious diseases. Additionally, phenolic compounds, known for their potent antioxidant and antidiabetic activities, are widely distributed throughout the plant, with the highest concentrations detected in the rhizomes (Aung *et al.,* 2020). Their capacity to neutralize free radicals highlights their medicinal significance, particularly in preventing oxidative stress-related disorders. Additionally, sterols such as β-sitosterol, along with fatty acids like oleic and palmitic acids, are primarily concentrated in the leaves, where they contribute to lipid metabolism regulation and exhibit anti-inflammatory properties (Antunes Da Silva *et al.,* 2003; Dewatisari and To'bungan, 2023). Carbohydrates, essential for energy storage and structural integrity, are universally present across all plant parts, playing a crucial role in metabolic functions and potentially serving as prebiotic agents.

The key bioactive compounds in *S.cylindrica* include steroidal saponins, flavonoids, phenolic compounds, alkaloids, and fatty acids, each synthesized through distinct biosynthetic pathways. Steroidal saponins originate from the triterpenoid biosynthesis pathway and are widely recognized for their cytotoxic and anti-inflammatory properties, contributing to the plant's pharmacological significance (Wolverton *et al.,*1989). Flavonoids, such as homoisoflavanone and dihydrochalcones, are synthesized through the flavonoid biosynthesis pathway and exhibit potent antioxidant and anti-inflammatory activities, protecting cells from oxidative damage and modulating inflammatory responses. Similarly, phenolic compounds, derived from the phenylpropanoid pathway, play a crucial role in scavenging free radicals and enhancing the plant's defense mechanisms.

Alkaloids, characterized by their antimicrobial and analgesic properties, are biosynthesized through the decarboxylation of amino acid precursors. This biochemical process enhances the plant's ability to combat microbial threats while contributing to its therapeutic potential (Petrovska, 2012). Fatty acids, including oleic and palmitic acids, contribute to anti-inflammatory and lipid-regulating activities, supporting metabolic balance and reducing inflammatory responses in biological systems. The synthesis and distribution of these bioactive compounds within *S. cylindrica* highlight its medicinal potential, making it a valuable source of natural therapeutic agents. A well-labeled Figure 7 illustrating the chemical pathways of these compounds and their interactions provides deeper insight into their biosynthetic origins and pharmacological significance.

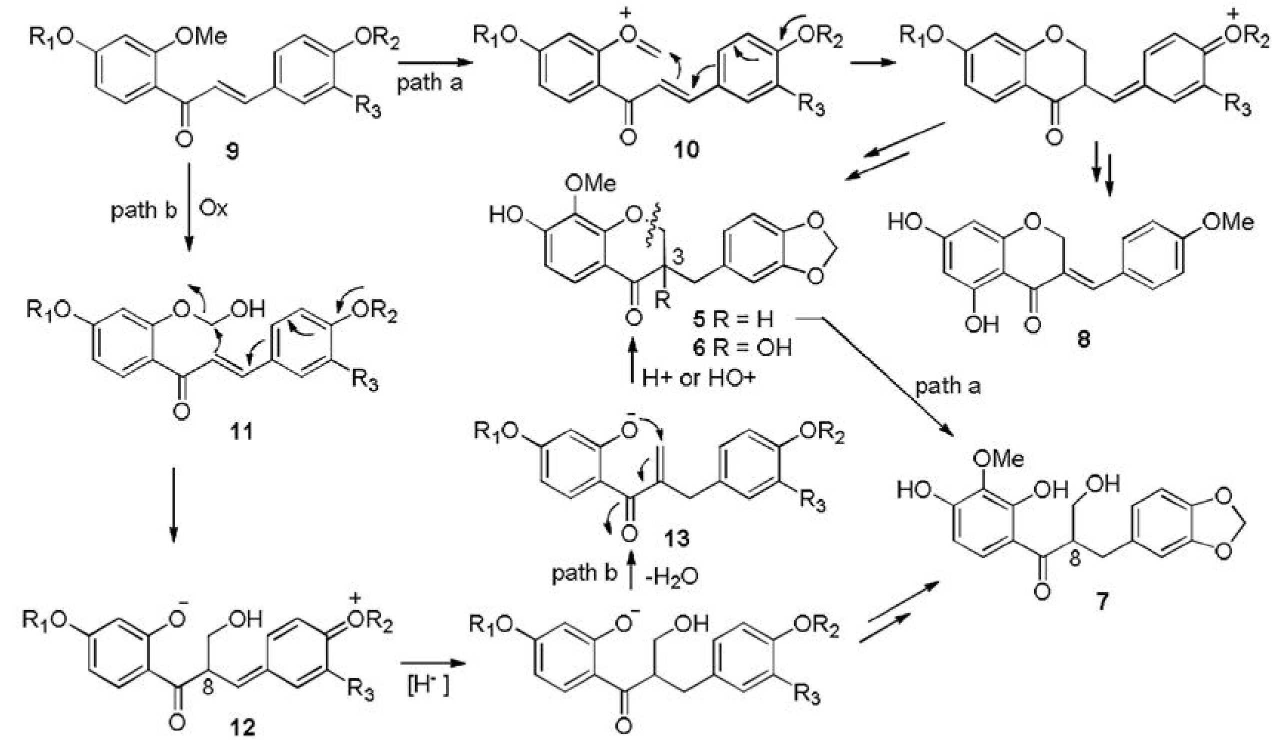


1. (–) - Trifasciatine A (Homoisoflavanone),
2. (–)-(3R)-Cambodianol (Homoisoflavanone)
3. Hydroxychavicol (3,4-Dihydroxyallylbenzene, a phenylpropane derivative)
4. Trans-N-p-CoumaroylTyramine(N-(p-Hydroxy phenyl)ethyl p-hydroxycinnamide, an alkaloid)
5. (–)-Trans-N-p-CoumaroylOctopamine (Alkaloid)
6. (–)-Trans-N-FeruloylOctopamine (Alkaloid)
7. Lanceolatin B (Furanoflavone)
8. Pongaglabol Methyl Ether (Furanoflavone)
9. De(s)methoxyKanugin (3-Methoxyflavone)
10. (–)-(6aR,11aR)-Homopterocarpin (Pterocarpan)

Figure 6: Compounds isolated from *S. cylindrica*.

Table 2: Phytochemicals in various parts of *S. cylindrica*

Phytochemical class	Key compounds	Location in plant
Steroidal saponins	Ruscogenin derivatives	Leaves, rhizomes
Flavonoids	Homoisoflavanone, dihydrochalcone	Leaves, rhizomes
Phenolic compounds	Gallic acid, caffeicacid	Rhizomes, leaves
Alkaloids	Alkaloid-rich extracts	Roots
Sterols	β-Sitosterol	Leaves
Fatty Acids	Palmitic, oleic, linolenicacids	Leaves
Quinones	Anthraquinones	Roots



Trifasciatine A-(5); (+)-Trifasciatine B (6); Dihydrochalcone (+)-(7); 3-Benzylchroman-4-one eucomin(8).

Figure 7: Biosynthetic pathway of few chalcone derivatives of *S. cylindrica*.

Table 3: Pharmacological properties of *S. cylindrica*

Phytochemical category	Major phytochemicals	Pharmacological activities
Alkaloids	Identified in the root	Antitrypanosomal and cytotoxic activity
Sterols	β-Sitosterol	Capillary permeability inhibition.
Glycosides (Steroidal saponins)	Various steroidal saponins (*e.g.,* (25S)-ruscogenin derivatives)	Analgesic, anti-inflammatory, antiulcer, hepatoprotective, antibacterial, antifungal.
Flavonoids	Homoisoflavanone, dihydrochalcone	Antioxidant, cytotoxic, anti-inflammatory.
Phenolic Compounds	Ten phenolic compounds, various phenolic molecules	Antioxidant, cytotoxic, antiradical, antidiabetic.
Coumarins	Identified in the non-flowering aerial parts	Potential anti-inflammatory and anticoagulant effects.
Saponins	Steroidal saponins from aerial parts	Antibacterial, antifungal, cytotoxic.
Carotenoids	β-Carotene from the root	Antioxidant activity, potential immune support.
Fatty Acids	Lauric, myristic, iso-pentadecanoic, iso-palmitic, palmitic, oleic, etc.	Anti-inflammatory, cardiovascular benefits.
Quinones	Identified in the root	Antibacterial, antifungal.
Carbohydrates	Identified in non-flowering aerial parts and roots	Potential prebiotic and metabolic benefits.

3. Pharmacological properties

S. cylindrica has demonstrated a diverse range of pharmacological activities, including antioxidant, anti-inflammatory, analgesic, antimicrobial, and cytotoxic effects. These therapeutic properties are largely attributed to its rich composition of bioactive compounds, such as steroidal saponins, flavonoids, phenolic compounds, and alkaloids. To enhance the clarity and accessibility of this information, a comparative table summarizing different extracts, their active constituents, and corresponding pharmacological effects can be included. This would facilitate a structured understanding of the plant's medicinal potential (Missouri Botanical Garden, 2023). Further discussion on the underlying mechanisms of these bioactivities is crucial to establishing their therapeutic relevance. For instance, steroidal saponins exert anti-inflammatory effects by inhibiting the production of pro-inflammatory cytokines, while their cytotoxic activity is associated with the induction of apoptosis in cancer cells. Flavonoids play a significant role in antioxidant defense by scavenging free radicals and regulating oxidative stress pathways. Additionally, alkaloids contribute to antimicrobial effects by disrupting bacterial cell membranes and inhibiting microbial growth. Despite promising pharmacological findings, several research gaps remain. The majority of existing studies focus on *in vitro* and *in vivo* models, with limited investigation into clinical applications. Notably, no clinical trials have validated the traditional medicinal uses of *S. cylindrica*, highlighting the need for further pharmacokinetic and pharmacodynamics profiling.

Phytochemicals present in various parts of *S. cylindrica* exhibit diverse pharmacological activities. Alkaloids, primarily found in the roots, have demonstrated antitrypanosomal and cytotoxic properties (Mona Raslan *et al.,* 2015). Sterols, particularly β-sitosterol, contribute to the inhibition of capillary permeability and may play a role in vascular health. Steroidal saponins, including (25S)-ruscogenin derivatives, are associated with multiple therapeutic properties, including analgesic, anti-inflammatory, antiulcer, hepatoprotective, antibacterial, and antifungal activities (Moustafa *et al.,* 1986). Flavonoids such as homoisoflavanone and dihydrochalcone exhibit strong antioxidant, cytotoxic, and anti-inflammatory effects. Similarly, phenolic compounds, comprising at least ten distinct phenolic molecules, have demonstrated antioxidant, cytotoxic, antiradical, and antidiabetic properties. Coumarins, found in the non-flowering aerial parts, are known for their anti-inflammatory and anticoagulant potential (Petrovska, 2012).The plant also contains bioactive compounds such as saponins, primarily steroidal saponins found in the aerial parts, which demonstrate antibacterial, antifungal, and cytotoxic properties. Additionally, carotenoids, including β-carotene extracted from the roots, contribute to antioxidant activity and may play a role in supporting immune function. (Missouri Botanical Garden, 2023; Saw Bawn, 2020). Fatty acids, including lauric, myristic, iso-pentadecanoic, iso-palmitic, palmitic, and oleic acids, have been associated with anti-inflammatory and cardiovascular benefits. Quinones, localized in the roots, exhibit antibacterial and antifungal activities (Sissi Wachtel-Galor and Iris Benzie, 2011). The carbohydrates, present in both the non-flowering aerial parts and roots, may serve as prebiotics and play a crucial role in metabolic functions (Royal Botanic Gardens, Kew, 2023).

4. Safety and toxicity data

S. cylindrica has long been valued in traditional medicine; however, comprehensive toxicological evaluations remain limited. Acute toxicity studies indicate that the plant is generally safe at doses up to 2000 mg/kg, but its long-term safety profile is not well understood. Future research should focus on evaluating specific toxicity endpoints, including hepatotoxicity, nephrotoxicity, hematological effects, genotoxicity, and teratogenicity. Assessing biomarkers such as liver enzymes (ALT, AST) and kidney function markers (BUN, creatinine) will be essential in determining potential organ toxicity. Furthermore, investigations into its effects on blood cell counts and DNA integrity are crucial to establishing its long-term safety profile (Saw Bawn, 2020).

Another critical aspect that warrants attention is the potential for herb-drug interactions. Given that *S. cylindrica* contains steroidal saponins, it may influence the metabolism of drugs processed by cytochrome P450 (CYP450) enzymes, particularly those involved in hepatic metabolism. Similar saponin-rich medicinal plants, including *Tribulusterrestris* and *Panax ginseng,* have been reported to interact with anticoagulants, anti-inflammatory agents, and hypoglycemic drugs. Therefore, pharmacokinetic studies examining these interactions will be vital for ensuring the safe medicinal use of *S. cylindrica* (Sissi Wachtel-Galorand Iris Benzie, 2011).

5. Ethnopharmacological and industrial relevance

S. cylindrica holds significant ethnopharmacological and industrial value, extending beyond traditional medicinal uses to applications in fiber production, air purification, and sustainable industries.

5.1 Traditional and industrial fiber applications

Historically, *Sansevieria* species, including *S. cylindrica*, have been valued for their strong and durable fibers, which have been traditionally used in rope-making, mats, and textiles. Early records, such as those by Holtze (1895), recognized its potential as a fiber-producing plant. However, contemporary research should further investigate advancements in fiber yield, mechanical properties, and innovative processing techniques to optimize its industrial applications. Contemporary studies have examined fiber composition, tensile strength, and its potential role in eco-friendly textile production. The increasing demand for biodegradable and sustainable materials further highlights the relevance of *S. cylindrica* fibers in industrial applications.

5.2 Air-Purifying properties and environmental benefits

Beyond its role in fiber production, *S. cylindrica* has gained prominence for its air-purifying properties. According to NASA clean air study, the plant effectively removes airborne toxins, including formaldehyde, xylene, and toluene, making it a valuable addition to indoor spaces for improving air quality (Stover, 1983). Its ability to perform crassulacean acid metabolism (CAM) allows it to absorb carbon dioxide at night, making it an ideal eco-friendly plant for urban environments, green buildings, and sustainable indoor spaces.

5.3 Commercial potential and future applications

The industrial relevance of *S. cylindrica* extends to commercial applications, including patented formulations and eco-friendly innovations. Research into *S. cylindrica*-derived extracts, bioactive compounds, and fiber applications could enhance its commercial viability. Patents related to its use in medicinal formulations, biodegradable textiles, and air purification systems demonstrate its potential in diverse industries. Furthermore, integrating its air-purifying capabilities into green building designs and sustainable urban planning initiatives could create new opportunities for commercialization.

An integrated examination of both traditional and contemporary applications highlights *S. cylindrica* as a multifunctional species with significant industrial and pharmacological potential. Future research should prioritize the optimization of fiber extraction methods, the expansion of its utilization in sustainable material production, and the exploration of its broader applications in environmental management.

6. Future research directions

To fully harness the medicinal and industrial potential of *S. cylindrica*, future research should focus on optimizing its bioactive properties, improving standardization processes, and addressing regulatory challenges. Advancements in nanotechnology, biotechnology, pharmacokinetics, and regulatory compliance will be crucial in enhancing its therapeutic and commercial viability.

6.1 Nanotechnology for enhanced therapeutic potential

One promising avenue is the application of nanotechnology to improve the bioavailability and stability of *S. cylindrica*'s active compounds. Nanoformulations of flavonoids and steroidal saponins could enhance their therapeutic efficacy by facilitating targeted drug delivery, controlled release, and increased cellular uptake. Encapsulation techniques, such as liposomes and polymeric nanoparticles, should be explored to protect these bioactive molecules from degradation and improve their pharmacological effects.

6.2 Biotechnological approaches for standardization

Biotechnological innovations, including tissue culture and genetic engineering, offer potential solutions for optimizing phytochemical yields and standardizing growth conditions. Micropropagation techniques could be employed to ensure the mass production of genetically uniform plants with consistent bioactive profiles. Additionally, metabolic engineering could be used to enhance the biosynthesis of key therapeutic compounds, making large-scale cultivation more efficient and economically viable.

6.3 Pharmacokinetics, pharmacodynamics, and clinical studies

Pharmacokinetic and pharmacodynamic profiling of *S. cylindrica*'s bioactive compounds should be prioritized to understand their absorption, distribution, metabolism, and excretion (ADME) in the human body. Preclinical studies should establish effective dosing regimens, toxicity thresholds, and potential drug interactions. Despite its wide range of reported pharmacological activities, *S. cylindrica* has not been extensively evaluated in human clinical trials. Conducting well-designed, randomized, and placebo-controlled clinical studies is essential to establish its safety and efficacy, ultimately supporting its integration into mainstream medicine.

6.4 Regulatory challenges and global market compliance

For *S. cylindrica* to gain acceptance in evidence-based medicine, regulatory challenges must be addressed. Standardization of herbal extracts is crucial to ensure batch-to-batch consistency in phytochemical composition, which is a prerequisite for regulatory approvals in global markets. Adhering to guidelines set forth by regulatory agencies such as the U.S. food and drug administration (FDA) and the european medicines agency (EMA) will facilitate its acceptance as a therapeutic agent. Establishing pharmacopoeial standards, validated analytical methods, and good manufacturing practices (GMP) will further enhance its credibility and market potential.By integrating these advanced research approaches, *S. cylindrica* can transition from traditional medicine to a scientifically validated therapeutic and industrial resource. Addressing these research gaps will ensure its safe, effective, and sustainable utilization in diverse fields, from pharmaceuticals to environmental applications.

7. Conclusion

S. cylindrica is a versatile plant with significant medicinal, industrial, and environmental applications. Its rich phytochemical profile, including steroidal saponins, flavonoids, alkaloids, phenolic compounds, and fatty acids, contributes to its pharmacological properties such as antioxidant, anti-inflammatory, antimicrobial, cytotoxic, and analgesic effects. Furthermore, the air-purifying properties and fiber-producing potential of *S. cylindrica* underscore its broader ecological and economic significance. However, despite its promising bioactivity, comprehensive studies on its pharmacokinetics, pharmacodynamics, and clinical efficacy remain limited. Future research should prioritize detailed toxicological evaluations, clinical validation, and formulation development to ensure its safe and effective therapeutic application. Standardization and regulatory advancements will be essential for integrating its traditional uses into modern medicine and industrial applications.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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