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A NARRATIVE REVIEW OF AGASTYA (*SESBANIA GRANDIFLORA* (L.) PERS.): ETHNOMEDICINAL, NUTRITIONAL AND PHYTO-PHARMACOLOGICAL EVIDENCE

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ABSTRACT

Sesbania grandiflora (L.) Pers (SG) commonly known as 'Agastya 'is a nutritionally and medicinally important plant widely used in traditional healthcare systems. Rich in bioactive phytoconstituents and essential nutrients, it has demonstrated diverse pharmacological activities. However, despite its extensive traditional use, comprehensive clinical evidence and modern formulation development remain limited. Data were collected from classical texts of Ayurveda, ethnobotanical records, scientific databases, and published articles. Information related to its plant characteristics, traditional uses, nutritional content, phytochemical compounds, pharmacological effects, toxicity studies, combined effects, and commercial uses was summarized. The review showed that SG has significant nutritional value and contains various bioactive compounds such as flavonoids, phenolic compounds, alkaloids, terpenoids, and glycosides. Experimental studies have demonstrated a broad range of biological effects, including antioxidant, anti-inflammatory, antidiabetic, and anticancer properties. Available toxicity studies suggest a favorable safety profile when used as recommended. Additionally, growing scientific interest has led to its use in functional foods, health supplements, herbal products, and commercially available health items. The combination of traditional knowledge and modern scientific findings shows that SG is a multifunctional medicinal plant with significant therapeutic, nutritional, and commercial value. Despite its extensive traditional use, SG requires further clinical validation and formulation development to establish its evidence-based therapeutic and nutraceutical applications. SG is a valuable medicinal and nutraceutical plant with diverse health-promoting properties and significant potential for application in functional foods and evidence-based healthcare.

Keywords: Hummingbird, Fabaceae, Functional Foods, Nutraceuticals, Ayurveda.

INTRODUCTION

Medicinal plants represent an important reservoir of natural products with diverse pharmacological properties and continue to provide lead molecules for the development of novel pharmaceuticals.[1] One such plant is *Sesbania grandiflora* Linn. Pers. (SG), commonly known as 'Agastya'or 'Hummingbird Tree'. Belonging to Fabaceae family it is a rapidly growing leguminous tree.[2] SG is widely distributed, cultivated, and naturalized in the tropical and subtropical regions of India. It is commonly found in South, West, East, North, and North-Eastern India, as well as the Andaman and Nicobar Islands, where it is cultivated for its nutritional, medicinal, and fodder value. The plant is important for its nutritional, medicinal, agricultural, and economic value. In traditional medicine, especially Ayurveda, SG has been recognized for its laxative (rechana), diuretic (mutrala), antipyretic/fever-reducing (jwaraghna), and tonic and strength-promoting (rasayana/balya). Beyond its medicinal use, the edible leaves, flowers, and pods are commonly eaten as vegetables. They are rich in proteins, dietary fibres, vitamins, minerals, and other nutrients, making the plant a key part of traditional diets.[3] Phytochemical analysis demonstrated that, SG has a wide range of bioactive compounds such as alkaloids, steroids, flavonoids, tannins, glycosides and others.[4]

Recent pharmacological studies have confirmed many traditional claims about SG. They showed a wide range of biological activities, including Hepatoprotective Activity[5], Immunomodulatory activity[6], anti-diabetic activity[7], anti-inflammantory activity[8], analgesic and anti-pyretic activity[9] and antiproliferative and Apoptotic Effects[10]in both lab and animal models. Additionally, new evidence suggests its potential use in combination therapies and synergistic formulations. This means plant-based bioactive compounds could improve treatment effectiveness while reducing side effects. The plant is now recognized as a valuable ingredient in functional foods, nutraceuticals, dietary supplements, herbal formulations, and other enhanced products. Moreover, many commercially available products featuring different parts of the plant have been launched to promote nutrition and health. This reflects its importance in the industrial and commercial sectors.

In the present review an attempt has been made to compile an inclusive analysis of available literature on SG from classical texts of Ayurveda, ethnomedicinal records, phytochemical investigations, nutritional studies and recent pharmacological research. It has rich medicinal as well nutraceutical use, still there is a need of SG based modern formulations like tablets, capsule, gummies, etc. to make it consumable and ready to use in daily life. This highlights an important research gap and the need to bridge traditional knowledge with modern scientific evidence.

This review integrates available evidence to summarize the nutritional and therapeutic potential of SG and identifies key areas for future research. The results can be a starting point for further clinical studies and stimulate the development of new phytopharmaceutical and nutraceutical products of this valuable medicinal plant.

An extensive literature survey has been carried out to gather the available data on SG from classical texts of Ayurveda as well as scientific literature. Classical texts of Ayurveda like Charaka Samhita, Sushruta Samhita, Ashtanga Hridaya and Nighantus were studied to extract the information regarding nomenclature, properties, indications and usage of SG in ayurveda. Classical and contemporary reference books such as The Wealth of India, Review on Indian Medicinal Plants and other published literature on medicinal plants were referred for gathering information.
Electronic databases such as Science Direct, Scopus, Google Scholar, Research Gate, Ayush Research Portal, PubMed and Cochrane Library have been extensively used to gather scientific information regarding the nutritional, phytochemistry, pharmacology, analytical and therapeutic aspects of SG.

Keywords used for the database search included "*Sesbania grandiflora*" "Agastya" "Agati" "Vegetable Hummingbird "Fabaceae" "nutritional composition" "antioxidant" "anti-inflammatory", "traditional medicine", and "Ayurveda", Phytochemistry, Nutraceuticals, Toxicity, Functional Foods, Market products.

A manual survey of classical texts of Ayurveda, references of published articles and ethnomedical information was also done for gathering the relevant information. The gathered information was critically analyzed and systematically arranged into various headings, which include botanical description, vernacular names, geographical distribution, Ayurvedic perspective, nutritional value, phytochemistry, analytical studies, pharmacology, therapeutic uses and safety profile of *Sesbania grandiflora*.

Vernacular Name: Agasthya, Agathiya, Hatiya in Hindi, Agathiyo in Gujarati, Hadaga in Marathi[11].

Synonyms: Agastya, Munivriksa, Vangasen, Surpriya, Munipushpa, Munidruma, Sighrapuspa, Dirghaphala, Vakrapuspa[12,13].

Geographical Distribution: SG is native to Java, Malaya, New Guinea, and the Philippines. This species is widely found in tropical and subtropical areas of Asia, Africa, Oceania, and the Americas. In India, SG is cultivated and naturalized in Assam, the Andaman and Nicobar Islands, and the Himalayan regions. Because of its nutritional and medicinal uses, this species grows extensively in tropical climates around the world[14].

Taxonomic classification[15]
Kingdom: Plantae
Phylum: Streptophyta
Class: Equisetopsida
Subclass: Magnoliidae
Order: Fabales
Family: Fabaceae
Genus: *Sesbania*
Species: *Sesbania grandiflora* (L.) Pers.

Morphology
SG is a fast-growing, short-lived, slender small tree that generally attains a height of 6–9 m. It possesses a soft-wooded stem measuring approximately 0.6 m in girth, with numerous spreading branches that contribute to its open canopy. The leaves are abruptly pinnate, measuring 15–30 cm in length and bearing 16–30 pairs of linear-oblong to oblong-elliptic leaflets. The upper surface of the leaflets is glabrous, while the lower surface is sparsely pubescent. The leaves are deciduous in nature and are shed seasonally. The flowers are large, fleshy, and attractive, measuring approximately 6–10 cm in length. They are borne in loose axillary racemes containing 2–4 flowers and occur in different colors, including white, pink, and crimson red. The fruit is a pendulous, flattened pod measuring 30–50 cm in length. The pods are slightly four-angled, constricted between the seeds by partitions, and possess swollen margins. Each pod contains approximately 15–50 light-colored seeds. Flowering generally occurs during October–November, followed by fruiting in December–January[16]. According to the Raja Nighantu, SG is classified into four varieties based on the colour of the flowers, namely Blue (Neela), white (Sita), yellow (Peeta), and Red (Lohita). This classification highlights of the species described in the classical Ayurvedic literature.[12]

Rasapanchaka (Ayurvedic pharmacodynamic principles)
Cold and dry qualities (Sheeta-ruksha-guna), bitter and astringent taste (tikta-kashaya rasa), cooling potency (sheeta virya), pungent post-digestive effect (katu vipaka) and relieves pitta and kapha diseases.[16]

Action and Indications: Classical lexicons including Bhavaprakasha, Raj Nighantu, Kaiyadeva Nighantu, Nighantu Adarsha, and Harita Samhita have articulated the properties and therapeutic uses of Agastya (*Sesbania grandiflora*). The plant is recommended for the management of Quartan fever (Chaturthaka Jwara), Night blindness (Naktandhya), gout (Vatarakta), cough (Kasa), wasting disorder/tuberculosis (Kshaya), epilepsy (Apasmara), rhinitis/common cold (Pratishyaya), pain/colic (Shoola), anaemia (Pandu roga), abdominal mass (Gulma), pruritus/itching (Kandu), and bleeding disorders (Raktapitta). It is also described as possessing Krimighna and Vishghna. [11-13,17-19]

Trade importance: SG is a commercially valuable multipurpose tree species with significant applications in the food, fodder, agricultural, pharmaceutical, and industrial sectors. Its leaves, flowers, tender pods and seeds are consumed as nutritious food and are sold in markets of several Asian countries. The protein-rich foliage is an excellent livestock feed, and its rapid growth and nitrogen-fixing ability make it an important agroforestry species for soil fertility improvement and green manuring. The wood is also used for fuel and as a source of pulp. Exudates from the bark are used in gums and adhesives. The rich nutritional profile and diverse therapeutic properties of *S. grandiflora* have led to increased interest from nutraceutical and phytopharmaceutical industries, thus increasing its commercial and economic value.[2]

Agro-technique: The nitrogen-fixing tree species SG grows quickly and is well suited to tropical and subtropical climates. It can withstand a variety of soil conditions, including saline, alkaline, wet, and low-fertility soils, and it grows best in areas with 800–4000 mm of annual rainfall and temperatures between 22 and 30°C. The main method of plant propagation is by seeds, which sprout quickly and don't go dormant. Under warm conditions, seedlings establish quickly and are typically transplanted at a spacing of 1.5 × 2.0 m. The species is commonly grown in home gardens, field borders, agroforestry systems, and green manure plantations because of its rapid growth. SG is a crucial plant for sustainable agricultural systems due to its low nutrient requirements, quick biomass production, and capacity to increase soil fertility.[21]

IUCN Status: According to the IUCN Red List (2023), *Sesbania grandiflora* (SG) is classified as Data Deficient (DD)**.** Its natural distribution and the status of wild populations remain poorly documented, preventing an accurate assessment of its conservation status. Although the species is widely cultivated throughout tropical regions for its nutritional, medicinal, fodder, fuel, and ornamental value, insufficient information on its wild occurrence limits formal conservation evaluation.[22]

Ethnomedicinal uses of SG in different parts of India: SG has been widely utilized ethnomedicinally in India for its diverse applications in traditional healthcare practices. Table 1 summarizes the common folk and traditional medicinal uses of SG based on published literature and previous ethnobotanical studies.

Nutritional value of SG *Sesbania grandiflora* is a nutritionally rich edible plant, with each part contributing unique health-promoting properties. The leaves are an excellent source of proteins, dietary fiber, carbohydrates, calcium, potassium, magnesium, iron, zinc, and selenium, supporting growth, hemoglobin synthesis, bone health, energy metabolism, digestive function, electrolyte balance, and immune function. Their abundant nutrients and antioxidant constituents also make them a valuable functional food for improving overall nutritional status. The flowers provide carbohydrates, calcium, phosphorus, potassium, iron, and natural antioxidants, contributing to energy metabolism, maintenance of healthy bones and teeth, normal hemoglobin formation, and protection against oxidative stress.[27] The edible pods (fruits) contain carbohydrates, proteins, dietary fiber, and minerals, along with bioactive phytochemicals such as phenolic compounds, flavonoids, tannins, saponins, alkaloids, glycosides, and steroids. These constituents impart significant antioxidant potential and enhance the nutritional and functional value of the pods.[28]The seeds are rich in proteins, carbohydrates, lipids, essential minerals, and antioxidant phytochemicals, including flavonoids, phenolics, saponins, and tannins. Besides their nutritional importance, seed extracts have demonstrated antioxidant and antimicrobial activities, highlighting their potential as functional food ingredients and natural therapeutic agents.[29]

Phytochemical constituents of SG: SG contains a diverse array of bioactive phytochemicals distributed across its roots, bark, leaves, flowers, and seeds. These plant parts contain flavonoids, phenolic acids and other secondary metabolites that contribute to the plant's pharmacological activities. Table 2 summarizes the major phytochemical constituents identified in different parts of SG.

Synergistic effects of phytochemical interactions of SG: SG contains multiple bioactive phytochemicals that may interact synergistically to enhance its therapeutic potential. Experimental studies suggest that combinations of flavonoids, triterpenoids and other phytoconstituents contribute to improved anti-inflammatory, hepatoprotective. Table 3 summarizes the reported or potential synergistic interactions among major phytochemicals of SG and their therapeutic relevance.

Pharmacological activities of SG: SG exhibits a broad spectrum of pharmacological activities, which have been demonstrated through *in vitro, in vivo*, and molecular studies. Different extracts and phytochemical fractions obtained from its various plant parts have shown significant hepatoprotective, antidiabetic and other therapeutic effects. Table 4 summarizes the major pharmacological activities of SG, along with the study models, extract types, and key findings reported in the literature.

Toxicity studies: Acute and sub-acute toxicological investigations of SG have consistently demonstrated a favorable safety profile for extracts prepared from different plant parts. Acute oral administration of the hydroalcoholic leaf extract at a dose of 2000 mg/kg produced neither mortality nor treatment-related behavioral abnormalities in experimental animals. Furthermore, repeated oral administration of the leaf extract at doses up to 5000 mg/kg for 28 days did not induce significant alterations in body weight, hematological indices, serum biochemical parameters, or histopathological architecture of major organs, indicating good systemic tolerability.[49] Likewise, sub-acute administration of the ethanolic flower extract for 28 days showed no evidence of toxicity or adverse histopathological changes, supporting its safety at the tested doses.[50] Similarly, the methanolic root extract was found to be safe following acute oral administration up to 2000 mg/kg in accordance with OECD guidelines, with no mortality or observable toxic manifestations.[51] However, despite these favorable toxicological findings, an *in vivo* micronucleus assay demonstrated that the methanolic flower extract induced micronucleus formation in murine bone marrow cells, suggesting a potential genotoxic effect under specific experimental conditions.[52]

Table 1: Ethnomedicinal uses of SG in different parts of India

Plant part	Ethnomedicinal use	Mode of uses/route of administration	Region/community
Leaves	Cold, nasal congestion, headache	Fresh leaf juice instilled intranasally	Odisha [23]
	Night blindness	Fried leaves consumed as vegetable	Odisha [23]
	Indigestion, constipation, intestinal worms	Leaf juice taken orally	Odisha [23]
	Wound healing, cuts and skin infections	Leaf paste applied externally	Odisha [23], kerala[24] Maharashtra[25],
	Eye irritation	Leaf juice applied locally	Kerala[24]
	Pulmonary disorders	Leaf preparations taken orally	India [26]
Leaves +flowers	Indigestion, constipation and helminthiasis	Combined juice taken orally	Odisha [23]
Flowers	Hypertension	Flower decoction taken orally	Odisha [23]
	Cough and bronchitis	Decoction/juice	Kerala[24], Gujarat [26]
	Edible flower with nutraceutical value	Cooked as vegetable	India [26]
Bark	Abdominal colic	Bark extract with honey	Odisha [23]
	Diarrhea and dysentery	Bark extract taken orally	Odisha[23], Maharastra[25]
	Cough	Bark preparation with honey	Odisha [23]
	Wound healing and inflammation	Bark paste applied externally	Maharashtra[25]
	Gastrointestinal disorders	Bark decoction	Gujarat [26]
Roots	Arthritis, gout and rheumatic pain	Root paste applied externally	Odisha [23]
	Swelling and inflammation	Root paste applied externally	Odisha [23]
Pods	Edible vegetable with nutritional and health-promoting value	Cooked and consumed as vegetable	India and Southeast Asia[24,26]

Table 2: Phytochemical Constituents of SG

Plants part	Class of compounds	Phytoconstituents
Root	Isoflavonoids, Triterpenoids	Medicarpin, Isovestitol, Betulinic acid [30,31]
Stem Bark/Bark	Flavonoids, Phenolic acids, Tannins	Quercetin, Gallic acid, Tannic acid, Sesbagrandiflorains A andB [30,31,32]
Leaves	Flavonoids, Triterpenoids, Norisoprenoids, Phenolic acids, Carbohydrates	Kaempferol, Oleanolic acid, Vomifoliol, Loliolide, Gallic acid [30,31,32]
Flower	Flavonoids, Triterpenoids, Aliphatic compounds	Kaempferol, Oleanolic acid, Nonacosan-6-one [30,31,32]
Seeds	Flavonoids, Anthocyanins, Alkaloids, Polysaccharides, Fatty acids	Nicotiflorin, Cyanidin-3-glucoside, Sesbanimide, Galactomannan, Oleic acid[30,31,32]
Twigs	Norisoprenoids, Monoterpene lactones	Vomifoliol, Loliolide [30,31]
Whole plant	Fatty acids, Flavonoid glycosides, Anthocyanins, Carbohydrates	Linoleic acid, Linolenic acid, Kaempferol-3,7-diglucoside, Cyanidin-3-glucoside[30,31,32]

Table 3: Synergistic Effects of Phytochemical Interactions in SG [30]

Phytochemical Combination	Observed/Potential Synergistic Effect	Therapeutic Relevance
Tannins + Polysaccharides	Enhanced gut protective and antidiarrheal effect	Gastrointestinal disorders
Medicarpin + Betulinic acid	Enhanced anti-inflammatory and antioxidant activity	Neuroprotection, inflammation
Sesbanimide + Saponins	Increased immunomodulatory and cytotoxic activity	Cancer and immune regulation
Kaempferol + Oleanolic acid	Enhanced hepatoprotective and antioxidant effect	Liver disorders
Quercetin + Oleanolic acid	Improved anticancer and antiproliferative activity	Cancer therapy

Table 4: Pharmacological activity of SG

Pharmacological activity	Study design and model used	Form \ type of drug used	Result
Hepatoprotective [33]	*In vitro* (ethanol-induced HepG2 cells), *in vivo* (anti TB-drug induced hepatotoxicity in wistar rats) and molecular docing	Flavonoid-rich fraction of ethanolic whole plant extract	Significantly reduced SGOT, SGPT, bilirubin and triglycerides, increased CAT, SOD and GSH levels, restored hepatic histoarchitecture and exhibited cytoprotective activity in HepG2 cells.
Anti diabetic[34,35]	*In vitro*: α-amylase inhibitory assay (Bernfeld method). *In vivo*: HFD + low-dose STZ-induced Type 2 diabetic rats treated with methanolic extract (200 and 400 mg/kg, p.o.) for 28 days; metformin/acarbose used as standards.	Commercial *Sesbania grandiflora* extract (plant part not specified) and methanolic leaf extract (MESG).	Exhibited significant dose-dependent antidiabetic activity. Showed 81% α-amylase inhibition (IC_{50} 50.95 µg/mL) and significantly reduced blood glucose, improved insulin sensitivity, lipid profile, hepatic glycogen, antioxidant status, and liver/kidney biomarkers in diabetic rats.
Anti cancer[36,37]	*In vitro*: HEp-2 (human laryngeal carcinoma) cell line by MTT assay; *In vivo*: Ehrlich Ascites Carcinoma (EAC)-bearing Swiss albino mice	Aqueous, ethanol and acetone leaf extracts (*in vitro*); ethanolic leaf and flower extracts (100 and 200 mg/kg, i.p.) (*in vivo*)	Demonstrated dose-dependent cytotoxicity against HEp-2 cells ($IC_{50} \approx 200$ µg/mL, ethanol extract most active). In EAC-bearing mice, significantly reduced tumor volume, tumor weight and viable tumor cell count, prolonged survival, restored hematological parameters (RBC, Hb, lymphocytes), decreased lipid peroxidation (LPO) and increased GSH, SOD and CAT, indicating potent antioxidant-mediated anticancer activity comparable to 5-fluorouracil.
Anti helmintic[38]	*In vitro*: Egg hatch assay, larval migration inhibition assay, larval development assay against mixed ovine gastrointestinal nematodes; *In vivo*: Faecal egg count reduction test (FECRT) in naturally infected sheep	Aqueous and ethanolic leaf extracts; aqueous extract orally at 125, 250 and 500 mg/kg	Aqueous extract showed potent dose-dependent anthelmintic activity with significant egg hatch inhibition (ED_{50} = 1.489 mg/mL), larval migration inhibition (LM_{50} = 0.683 mg/mL) and 98.1% faecal egg count reduction at 500 mg/kg, exceeding albendazole (93.25%). Haematological and serum biochemical parameters remained largely within normal limits, indicating good safety.
Anti ulcer[39]	*In vitro*: Broth microdilution assay against Gram-positive and Gram-negative bacteria, including drug-resistant strains (MRSA, VRE, E. coli, P. aeruginosa). *In vivo*: Therapeutic efficacy and toxicity evaluated in Staphylococcus aureus-infected silkworm (Bombyx mori) model. Qualitative and preparative HPLC analysis performed.	Sequential bark extracts: Hexane (HXF), Chloroform (CFF), and Ethyl acetate fraction (EAF)	Ethyl acetate fraction (EAF) exhibited the strongest antibacterial activity with MIC values of 1.6 mg/mL (MRSA), 0.4 mg/mL (VRE), 6.2 mg/mL (E. coli), and 3.1 mg/mL (P. aeruginosa). EAF was non-toxic to silkworms (LC_{50} >400 mg/mL) and demonstrated significant therapeutic efficacy against S. aureus-infected silkworms (EC_{50} = 1.9 mg/mL). HPLC identified gallic acid as one major constituent, while fractionation suggested synergistic antibacterial activity among multiple phytoconstituents.
Anti-bacterial [40]	*In vitro*: MIC and MBC against Gram-positive, Gram-negative, MRSA and VRE. *In vivo*: Immunosuppressed MRSA pneumonia mouse model; short-term safety evaluation in mice; skin irritation test in rats.	Dermaseptin-AC (novel antimicrobial peptide)	Exhibited broad-spectrum antibacterial activity with MIC 2–8 µM against seven bacterial strains. Demonstrated potent activity against MRSA with efficacy comparable to vancomycin (10 mg/kg) in mice. Showed relatively low hemolytic activity (HC_{50} 76.55 µM), acceptable short-term safety with no significant toxicity to liver, heart, spleen, kidney or blood, except mild pulmonary congestion, and no skin irritation on wound application.

Hypolipidemic activity [41]	*In vivo*; Triton WR-1339-induced hyperlipidemia in Wistar albino rats	Aqueous leaf extract (200 mg/kg, p.o., 7 days)	Significantly reduced serum total cholesterol (195.22→69.70 mg/dL), triglycerides (115.1→76.53 mg/dL), phospholipids (207.27→177.70 mg/dL), LDL (154.52→30.33 mg/dL), VLDL (23.1→15.32 mg/dL), and increased HDL (17.70→24.10 mg/dL). Also reduced hepatic cholesterol, triglycerides and phospholipids, demonstrating marked hypolipidemic activity comparable to fenofibrate.
Anti tuberculosis[42]	*In vitro* Tetrazolium Microplate Assay against Mycobacterium tuberculosis H37Rv (ATCC 27294); isolation and characterization of active phytoconstituents using chromatographic and spectroscopic techniques	Methanolic root extract; isolated compounds: isovestitol, medicarpin, sativan and betulinic acid	Methanolic root extract exhibited moderate antitubercular activity (MIC 625 µg/mL). Isovestitol, medicarpin and sativan demonstrated stronger activity with MIC 50 µg/mL, while betulinic acid showed MIC 100 µg/mL. The study identified isoflavonoids as major contributors to the antitubercular activity of *Sesbania grandiflora* roots.
Cardioprotective [43]	*In vivo* study in adult male Wistar–Kyoto rats exposed to cigarette smoke for 90 days; treatment with aqueous suspension of *Sesbania grandiflora* leaves (1000 mg/kg, p.o.) for 3 weeks	Aqueous suspension of leaves	Significantly reduced serum LDH and cardiac lipid peroxidation (TBARS); restored antioxidant enzymes (SOD, CAT, GPx, GR, GST, G6PDH), increased GSH, vitamin C and vitamin E levels, normalized cardiac micronutrients (Zn, Mn, Se), reduced Cu accumulation, and protected against cigarette smoke-induced oxidative myocardial injury through antioxidant and cytoprotective mechanisms.
Anti-arthritic Activity [44,45]	*In vitro*: BSA protein denaturation assay; *In vivo*: CFA-induced arthritis in Sprague–Dawley rats	Ethyl acetate extract; Ethanol seed extract (800 mg/kg, p.o.)	Demonstrated significant anti-arthritic activity by inhibiting protein denaturation and attenuating CFA-induced arthritis. The extract reduced paw edema, improved body weight, normalized AST, ALT, total protein, Hb, RBC, WBC and ESR. The effects were attributed to flavonoids (quercetin), phenolics and antioxidant constituents, with enhanced efficacy when combined with the MMP-3 inhibitor UK-356618.
Anti Inflammentory[46]	*In vitro*: HRBC membrane stabilization assay, protein denaturation assay, COX/LOX inhibition, cytokine inhibition (TNF-α, IL-6). *In vivo*: Carrageenan-induced and formalin-induced paw edema in rats/mice.	Methanolic, ethanolic and aqueous leaf/flower extracts	Demonstrated significant membrane stabilization, inhibition of protein denaturation and pro-inflammatory cytokines (TNF-α, IL-6), reduced paw edema and inflammation, with activity attributed mainly to flavonoids and phenolic compounds.
Analgesic [47]	*In vivo*: Acetic acid-induced writhing test and tail immersion test in Swiss albino mice	Methanolic leaf extract (250 and 500 mg/kg, p.o.)	Produced significant dose-dependent peripheral and central analgesic activity. At 500 mg/kg, writhing inhibition was 85.56%, exceeding diclofenac sodium (78.09%), and significantly increased tail-withdrawal latency.
Wound healing activity [48]	*In vivo*: Excision wound model in Wistar albino rats	Methanolic bark extract formulated as 2.5%, 5% and 10% (w/w) topical ointment	The methanolic bark extract significantly enhanced wound healing in a dose-dependent manner. 10% ointment produced 100% wound contraction by day 18, comparable to 1% framycetin sulphate. The extract also reduced the epithelialization period and accelerated wound closure compared with the control group.

Table 5: Commercial Nutraceutical Products Based on SG

Product category	Formulation	Major application	Representive companies
Plant-based biotin supplements [53]	Capsules, powder	Hair growth, reduction of hair fall, skin and nail health	OZiva, Alpspure, Growequal
Hair multivitamin formulations[53]	Gummies, capsules	Hair nourishment and follicle strengthening	OZiva, Carbamide Forte, Infooze
Beauty nutraceuticals[53]	Powder	Skin hydration and collagen support	OZiva
Standardized botanical ingredients [54]	Leaf extract	Functional ingredient for nutraceutical/cosmeceutical formulations	Zenherb Labs, Orgenetics Inc.
Herbal dietary supplements[55]	Tablet, powder	General nutritional and wellness support	Bharat Herbal, Sidhara Betta Herbals

Commercial nutraceutical products based on SG: SG is increasingly incorporated into commercial nutraceutical and cosmeceutical products because of its nutritional and phytochemical properties. Table 5 summarizes the major SG-based commercial products, their formulations, applications, and representative manufacturers.

DISCUSSION

SG is a nutritionally valuable medicinal plant with a long history of use in traditional healthcare systems. Classical texts of Ayurveda describe its utility in various conditions, while ethnomedicinal reports document its use in the management of respiratory, gastrointestinal, inflammatory, and nutritional disorders. A notable feature of SG is its dual role as both a food and a medicine. The leaves, flowers, and tender pods are commonly consumed as vegetables, curries, soups, and fritters in

several regions of India, particularly in South India. This widespread dietary utilization highlights its nutritional importance and supports its recognition as a functional food. Nutritional studies have shown that the plant is rich in proteins, dietary fibers, iron, calcium, vitamins, and other essential micronutrients, which may contribute to its traditional use in conditions associated with malnutrition, weakness, and anemia.

Phytochemical investigations have revealed the presence of diverse bioactive constituents, including flavonoids, phenolic compounds etc. These phytoconstituents are believed to be responsible for the various pharmacological activities reported for the plant. Experimental studies have demonstrated antioxidant, anti-inflammatory, thereby providing scientific support for many of its traditional therapeutic applications. Collectively, the available evidence indicates that SG possesses a wide margin of safety in conventional acute and sub-acute toxicity studies; however, its possible genotoxicity warrants further investigation, particularly with respect to extraction solvent, dosage, and duration of exposure.

In recent years, SG has gained increasing attention from the nutraceutical industry due to its rich nutritional composition and health-promoting properties. The plant has been incorporated into a variety of commercial products, including capsules, powders, tablets, and gummies. Furthermore, SG has emerged as a natural plant-based source of biotin, leading to the development of proprietary ingredients of products for nutraceutical and cosmeceutical formulations. The growing commercialization of SG-based products highlights its industrial relevance and demonstrates its potential for the development of innovative functional foods and nutraceuticals.

SG is widely used as a medicinal plant and as a nutraceutical supplement, but the scientific validation of its therapeutic efficacy is lacking. Thus, further research with well-designed clinical trials, detailed safety assessment and mechanistic studies is warranted. Moreover, formulation of SG based formulations using novel drug delivery systems could improve its bioavailability, therapeutic efficacy and patient acceptability. Such investigations are needed to establish its evidence-based utilization in healthcare and nutraceutical applications.

CONCLUSION

SG has gained considerable attention due to its rich nutritional composition and diverse medicinal applications, making it a promising source of therapeutic and nutraceutical agents. Evidence from classical text of Ayurveda, ethnomedicinal practices, phytochemical investigations, pharmacological studies supports and toxicity studies collectively supports its diverse health-promoting properties. Its rich nutritional profile, abundance of bioactive constituents, and emerging utilization as a natural source of biotin further enhance its significance as a functional food and nutraceutical ingredient. Overall, SG represents a valuable natural resource with significant potential for future applications in functional foods, nutraceuticals, and evidence-based healthcare.

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