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AMBASTHAKI (HIBISCUS SABDARIFFA LINN.): AN INTEGRATED NARRATIVE REVIEW OF ETHNOMEDICINAL KNOWLEDGE, NUTRITIONAL SIGNIFICANCE AND PHYTO-PHARMACOLOGICAL EVIDENCES

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ABSTRACT

Introduction: "*Ambasthaki*" botanically identified as *Hibiscus sabdariffa* Linn. (HS), is a medicinally and economically important shrub belonging to Malvaceae family. It has been extensively utilized in traditional medicine, functional foods, and nutraceutical formulations. Owing to its rich phytochemical profile comprising anthocyanins, flavonoids, phenolic acids, organic acids, and other bioactive metabolites, the plant has gained considerable scientific attention for its diverse pharmacological activities, including antioxidant, antihypertensive, antidiabetic, anti-inflammatory, hepatoprotective, cardioprotective, antimicrobial, and hypolipidemic effects. Although substantial evidence has been generated, the available information remains scattered across pharmacognostic, phytochemical, pharmacological, toxicological, clinical, agronomic, and commercial domains, warranting a comprehensive evidence-based synthesis. **Aims and Objectives:** To critically compile and comprehensively evaluate the available literature on the botanical profile, taxonomy, ayurvedic perspective, ethnomedicinal significance, nutritional composition, phytochemical constituents, pharmacological activities, toxicological profile, agro-technology, trade importance,

marketed formulations, and future therapeutic prospects of HS. **Materials and Methods:** A comprehensive literature survey was performed using classical Ayurvedic texts, electronic databases such as PubMed, Scopus, ScienceDirect, Cochrane Library, Ayush Research Portal and Google Scholar. Relevant publications were critically reviewed and systematically synthesized to provide an updated multidisciplinary overview of HS. **Discussion:** The diverse phytoconstituents and broad therapeutic potential of HS highlight its importance as a medicinal and functional plant. This review provides an updated evidence-based resource, identifies existing knowledge gaps, and emphasizes the need for standardized quality assessment, mechanistic investigations, and well-designed clinical studies to facilitate the development and rational utilization of HS-based phyto-pharmaceuticals and functional products.

KEYWORDS: Ayurveda, Medicinal Plants, Malvaceae, Roselle, Red sorrel, Jamaica sorrel.

1. INTRODUCTION

Medicinal plants constitute one of the most important source in healthcare and continue to play a significant role in the discovery of novel therapeutic agents owing to their rich diversity of bioactive phytochemicals. Among these medicinal plants, *Hibiscus sabdariffa* Linn., commonly known as Roselle or *Ambasthaki*, has emerged as a promising species because of its nutritional value, ethnomedicinal importance, and wide spectrum of biological activities. HS is an annual plant that belongs to the Malvaceae family [1]. This species is native to India, tropical Africa, and countries such as Brazil, Australia, Hawaii, Florida, the Philippines, Vietnam, and Central America [2]. It is typically cultivated for its fibers and calyces, with three main genotypes: green, red (most common), and dark red [3]. The calyx is commercially valuable in the food industry for producing beverages and foods like tea, juices, jams, jellies, and syrup. In many countries, the leaves are also consumed as a leafy green vegetable [4,5]. Overall, there are several reports available on the consumption of the dried or fresh calyces, seeds and leaves of HS used in the preparation of herbal medicines, beverages and fermented drinks or even cooked raw. [6]

HS has many traditional and medicinal uses around the world. In Chinese traditional medicine, it is used in the management of hypertension, as well as pyrexia and liver diseases [7-8]. Its sepal extract has been used as a valuable treatment option against leukemia [9]. Decoction of calyces and leaves are used as diuretic, febrifugal, choleretic and hypotensive by decreasing the viscosity of the blood and stimulating intestinal peristalsis. The extracts of

the HS have antioxidant, anticholesterol, and antidiabetic effects due to their high levels of bioactive compounds such as organic acid (hydroxycitric acid and hibiscus acid), anthocyanins (delphinidin-3-sambubioside and cyanidine-3-sambubioside) [11], phenolic acids (protocaticoic acid and caffeic acid, flavonoids (epigallocatechin gallate and catechin [12], and volatile compounds (3-methylbutan-1-ol, phenylacetaldehyde, and acetic acid [13]. It has antispasmodic, antihelmintic and antibacterial activities as well. The extract of HS is claimed to decrease the rate of absorption of alcohol and so lessen its effect on the system [14]. In classical Ayurveda texts, HS is described as a medicinal plant with significant therapeutic potential, particularly in *kapha-pitta pradhana vikaras* such as *shotha* (inflammation), *kantha roga* (throat disorders), and *medoroga* (metabolic disorders), *raktapitta* (bleeding disorders) and *vatabalasa* (gout) [15,16,17]

Although numerous reviews on HS have been published, most focus on specific areas such as phytochemistry, nutrition, or pharmacological activities. This review provides a broader and more integrated perspective by combining classical Ayurvedic knowledge with contemporary scientific evidence. In addition to botanical, pharmacognostic, phytochemical, pharmacological, toxicological, and clinical aspects, it uniquely highlights along with agrotechnology, commercial importance, marketed formulations, and future research opportunities. By bringing together these diverse yet interconnected domains, this review offers a comprehensive and updated resource that extends beyond the scope of previous reviews.

2. MATERIALS AND METHODOLOGY

A detailed literature search was conducted to compile and evaluate the available data on HS from classical Ayurvedic texts and scientific literature. Classical texts such as *Charaka Samhita, Sushruta Samhita, Ashtanga Hridaya*, and available *Nighantus* were reviewed to collect information regarding its nomenclature, Ayurvedic properties, therapeutic indications, and traditional uses. Standard reference books including The Wealth of India, Compendium of Indian Medicinal Plants, Review on Indian Medicinal Plants and other published literature on medicinal plants were also consulted.

Electronic databases such as ScienceDirect, Scopus, Google Scholar, ResearchGate, Ayush Research Portal, PubMed, and Cochrane Library were searched to retrieve scientific information related to the nutritional, phytochemical, pharmacological, analytical, and therapeutic aspects of HS .

Keywords used for the database search included "*Hibiscus sabdariffa*", "*Ambasthaki*", "Ambadi", "Roselle", "Malvaceae", "nutritional composition", "phytochemical constituents", "pharmacological activities", "antioxidant", "anti-inflammatory", "antihypertensive", "hepatoprotective", "antimicrobial", "ethnomedicinal use", "traditional medicine", and "Ayurveda".

A manual search of classical literature, reference lists of published articles, and ethnomedicinal records was also performed to ensure comprehensiveness and to capture relevant information not identified through electronic database searches. The collected data were critically analyzed and systematically organized under various headings, including botanical description, vernacular names, geographical distribution, Ayurvedic review, nutritional composition, phytochemical profile, analytical studies, pharmacological activities, therapeutic applications, and safety aspects of HS.

3. DESCRIPTION

Taxonomic description:

- Kingdom – Plantae
- Phylum – Streptophyta
- Class – Euisetopsida
- Subclass – Magnoliidae
- Order – Malvales
- Family – Malvaceae
- Genus – *Hibiscus*
- Species – *Hibiscus sabdariffa* Linn.
- Synonyms – *Sabdariffa gossypiifolius* Mill.

Vernacular names: Angami: Gakhro; Hindi: Lal Ambari, Patwa; Manipuri: Silo-sougree; Marathi: Ambadi, Tambdi-ambadi; Maring: Khimphong; Tamil: simaikkasuru, sivappukkasuru, shimai-kashuruk-kirai; Malayalam: polechi, puli-cheera; Telugu: erragomgura, erragonkaya, ettagomgura; Kannada: Kempupundrike, Pulichakire, Pundibija; Bengali: chukar; Mizo: Lekhar-anthur; Assamese: Chukiar, Tengamora; Sanskrit: Ambasthaki

Geographical Distribution: HS are grown over the world. Tropical Africa is widely recognized as the primary centre of origin of this species. Due to its adaptability in warm

climatic conditions, it is extensively cultivated across tropical and subtropical regions, including Philippines, Malaysia, Indonesia, India, Cuba, Central America, California, Florida, Egypt, Sudan, Nigeria, the West Indies, and Sri Lanka. In India, its cultivation is widespread in several states such as Bihar, Punjab, Uttar Pradesh, West Bengal, Assam, Odisha, Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu. [18]

Morphology: HS is an annual, erect, glabrous, and unarmed herb with purple stems and branches. The leaves are 5–7.5 cm long, cuneate at the base, usually 3–5 lobed, although the lower leaves may sometimes be entire. The lobes are lanceolate or oblong, with the middle lobe being the longest, and have serrate margins. The leaves are often blotched with purple and possess glandular structures on the underside of the midrib. Petioles are reddish-purple and measure 4–6.3 cm in length, while stipules are linear, acute, and about 12 mm long. The flowers are borne on very short, stout, axillary pedicels that are jointed near the base and purple in colour. The involucel consists of 10 lanceolate bracts, shorter than the calyx and adnate to its base. The calyx is fleshy, purple, and divided into lanceolate, three-nerved lobes; it enlarges and persists around the fruit. The corolla is purple with a darker centre. The fruit is an ovoid, beaked, hairy capsule. The seeds are large, blackish-brown, and densely covered with minute, stout, stellate hairs.[19]

Synonyms: *Suchimukha, Ambastha, Ambalika, Bahumula, sahastra, Amavikashi, Madhukaparna, Ekaishika, Mayurvidala* [15], *Dantasatha, Balika, Shathi, Saakanthmukhi* [16], *Shathamba, Machika, Dridhavalka, Mayurika, Gandhpatri, Chitrapushpi, Shreyasi, Mukhvachika, Chinnapatra, Bhurimalli* [17],

Review in Ayurveda: HS is a controversial and debated drug in Ayurvedic literature due to differences in its botanical identification. *Ambasthaki* is mentioned in *Charaka Samhita* [20], *Sushruta Samhi*ta [21] and *Ashtanga Hridaya* [22]. Various commentators of these classical literatures have associated HS with different plants, including *Patha* (*Cissampelos pareira*)**,** *Patasana***,** *Kakamachi* (*Solanum nigrum*)**,** the fruits/galls of Tamarix spp., and notably *Hibiscus cannabinus* Linn. The texts further refer to an *Ambasthadi Gana*, indicating its therapeutic significance in classical Ayurveda. In the Ayurvedic *Nighantus*, HS has been categorized under *Abhyadi Varga* in *Madanapala Nighantu* [16], *Aushadhi Varga* in *Kaiyadeva Nighantu* [15], and *Chandanadi Varga* in *Dhanvantari Nighantu* [17], reflecting its recognized medicinal significance in classical Ayurvedic literature.

***Rasapanchaka* (Ayurvedic pharmacodynamic principles):** *Rasa* (taste) - *Kasaya* (astringent)*, Amla* (sour)*, Tikta* (bitter), *Madhura* (sweet); *Vipaka* (post-digestive metabolic

effect) - *Amla*; *Virya* (potency)- *Sita* (cold); *Guna* (property) - *Laghu* (light); *Doshakarma* (actions on *doshas*) - *Kaphapittahar* (pacifiy both *kapha* and *pitta* dosha)

Actions and Indications: Classical lexicons including *Bhavprakasha Nighantu, Raj Nighantu, Kaiyedev Nighantu* have articulated the properties and uses of *Ambasthaki*. It's actions include *Grahi* (enhance digestion), *Dipana* (carminative), *Kanthya* (throat beneficial). The plant is recommended to be prescribed for *Pakva atisara* (chronic diarrhea), *Raktapitta* (bleeding disorders), *Kapha* and *kantha roga* (throat disorders), *Vatabalasa* (a metabolic joint and blood disorder).

IUCN Status: According to the IUCN Red List, HS has not been evaluated (NE) for its global conservation status. The species is widely cultivated and naturalized across tropical and subtropical regions, and no official assessment of its extinction risk has yet been published.

Agro-technique: HS is an annual crop well adapted to tropical and subtropical climates. It grows best at temperatures above 21°C in fertile, well-drained loamy soils rich in organic matter. Seeds are usually directly sown at the onset of the rainy season at a depth of about 2.5 cm, using a seed rate of 6–8 kg/ha and spacing of 60–100 × 45–60 cm. The crop requires approximately 45–50 cm of well-distributed rainfall and generally matures within 4–6 months. Since flowering is induced by short-day conditions, planting time should be adjusted according to photoperiod. Appropriate weed management, soil fertility, and timely harvesting are important for achieving higher calyx yield and enhancing the accumulation of bioactive compounds, particularly anthocyanins and organic acids. [23]

Trade importance: HS is an economically important multipurpose crop valued for its calyces, leaves, seeds, and fiber. The calyces are widely traded for the production of beverages, jams, jellies, syrups, teas, and nutraceutical products, while the bast fiber is used in sacks, ropes, carpets, paper pulp, and biocomposite materials. Roselle is a significant export commodity in countries such as Sudan, Thailand, China, Egypt, and India, with major markets in the United States and Germany. In addition to generating foreign exchange, it provides income and employment to millions of farmers, industrial workers, and traders. Its diverse industrial, nutritional, and medicinal applications make Roselle an important crop in global trade. [23]

Ethnomedicinal uses of HS: HS has a long history of ethnomedicinal use in traditional healthcare systems, where its leaves, calyces, seeds, and roots are utilized for both nutritional and therapeutic purposes. Traditionally, HS has been used to manage digestive disorders, liver ailments, anemia, skin diseases, hypertension, fever, and inflammatory conditions, with

the mode of preparation varying across different cultures and communities. The documented ethnomedicinal uses of various plant parts, their modes of use, and the corresponding regions or communities are summarized in Table 1.

Phytoconstituents of HS: Different parts of possess distinct phytochemical profiles that contribute to their diverse therapeutic applications. The major phytoconstituents identified in different parts of plants and their reported therapeutic uses are summarized in Table 2.

Nutritional value: HS has been noted to have a high nutritional potential, particularly in the leaves, calyces, and seeds. The HS calyx, which is used to make a variety of beverages, has been said to contain a significant amount of vitamins, minerals, protein, carbs, lipids, flavonoids and other nutrients. [30] The red calyxes are the mostly characterized by their concentration of anthocyanin. Delphinidin 3-Sambubioside and Cyanidin3- Sambubioside are the major component of anthocyanin. Overall, the plant is rich in organic acids, minerals, amino acids, carotene, vitamin C and total sugar in its calyx, leaves and seeds at various levels depending on the variety and geographical condition. For various nutrients in HS, refer Table-3

Pharmacological activity of HS: Numerous in vitro, in vivo, and clinical studies have demonstrated a wide range of pharmacological activities, which are largely attributed to its rich content of anthocyanins, flavonoids, phenolic compounds, and organic acids. The reported pharmacological activities of HS, along with the study design, extract type, experimental model, and key findings, are summarized in Table 4.

Toxicological study: Acute toxicity studies have shown that the oral LD_{50} of the calyx extract in rats exceeds 5000 mg/kg, indicating very low toxicity. Subchronic administration in hypertensive rats did not produce significant adverse effects and was associated with reductions in serum creatinine, cholesterol, and glucose levels. However, prolonged administration of high doses (2.3–4.6 g/kg/day) has been reported to induce testicular alterations and reduced sperm counts in male rats, suggesting a potential reproductive risk at excessive doses. Moderate doses (150–180 mg/kg/day) appear safe without histopathological damage to major organs, although higher doses may elevate hepatic enzyme levels. Overall, HS is considered relatively safe when consumed within recommended therapeutic limits, but long-term use of very high doses warrants caution. [58]

Products of HS available in market: Owing to its rich phytochemical composition and health benefits, HS is increasingly marketed as herbal teas, jams, bars and other nutraceuticals aimed at promoting general health and wellness. Representative marketed formulations of HS and their applications are summarized in Table 5.

4. DISCUSSION

HS is a valuable medicinal plant with a long history of use in traditional systems of medicine and as a functional food. Different parts of the plant, particularly the calyces, leaves, seeds, and flowers, possess a wide range of phytochemicals that contribute to its diverse pharmacological properties. Findings from both preclinical and clinical studies suggest that HS play a beneficial role in the prevention and management of chronic disorders such as hypertension, dyslipidemia, cardiovascular diseases, obesity, type 2 diabetes mellitus, non-alcoholic fatty liver disease (NAFLD), chronic liver disease, chronic kidney disease, inflammatory disorders, and other oxidative stress-related conditions. Its dual role as a medicinal plant and functional food further enhances its relevance in preventive healthcare and the development of nutraceuticals. Nevertheless, differences in plant varieties, extraction techniques, phytochemical composition, formulations, dosage regimens, and study methodologies continue to limit the consistency and clinical translation of available evidence. Therefore, future research should focus on standardized phytochemical profiling, well-designed multicenter randomized clinical trials, mechanistic investigations, and long-term safety evaluations to establish optimal therapeutic protocols. Addressing these knowledge gaps will provide stronger evidence for the rational integration of HS into evidence-based healthcare and facilitate the development of safe, standardized, and effective plant-derived interventions for chronic disease management.

Table- 1: Ethnomedicinal Uses of HS in India.

S. N.	Plant Part	Ethnomedicinal Use	Mode of Use	Region/Community
1.	Leaves [24,25,26]	Indigestion, dyspepsia, constipation, loss of appetite, anemia, liver disorders, skin diseases and	Fresh leaves consumed as vegetable or chutney	Maharashtra (Ambadi users)
		Constipation	Cooked leaves consumed as food	Maharashtra, Andhra Pradesh
		Loss of appetite	Sour leaf preparations (curry/chutney)	Andhra Pradesh (Gongura tradition)
		Anemia and nutritional deficiencies	Leafy vegetable rich in iron and vitamin C	Rural Maharashtra, Karnataka
		Liver disorders	Decoction and dietary consumption	Tribal communities of Central India
		Skin diseases and wounds	Leaf paste applied	Tribal communities of

			externally	Maharashtra
		Fever	Leaf decoction taken orally	Tribal communities of Madhya Pradesh
2.	Calyx [6,27,28]	Hypertension	Hot/cold infusion (Roselle tea)	Various regions of India
		Heart ailments	Herbal tea consumed regularly	North and South India
		Hyperlipidemia	Aqueous infusion	Traditional household remedy
		Liver disorders	Decoction and infusion	Traditional medicine practitioners
		Urinary disorders and diuresis	Sour herbal drink	Rural communities of India
		Fever and body heat	Cooling beverage (Sharbat)	Rajasthan, Gujarat
		Digestive disorders	Infusion consumed after meals	Various Indian communities
3.	Seeds [24]	General debility and malnutrition	Roasted seeds or seed flour	South India
		Nutritional supplementation	Seeds incorporated into food preparations	Karnataka, Tamil Nadu
4.	Roots [24,25,26]	Cough and respiratory ailments	Root decoction	Tribal communities of Central India
		Inflammatory conditions	Root paste applied externally	Folk medicine practices
		Dysentery and gastrointestinal disorders	Decoction	Tribal communities of India
		Rheumatism and inflammatory disorders	Folk medicinal preparations	Central and Southern India
		General health tonic	Food and medicinal beverage	Across India

Table- 2: Part-wise Phytoconstituents and Therapeutic Uses of HS based on IMPPAT Database [29]

Plant Part	**Major Phytoconstituents**	**Reported Therapeutic Uses**
Flowers	Hibiscetin, Flavylium, Citric acid, 2-Hydroxycinnamic acid, d-Tartaric acid, Kaempferol, Gossypetin, Quercetin, Myricetin, , Cyanin, Ergosterol, Delphinidin 3-sambubioside, 5,7,8-trihydroxy-3-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxy-2-(3,4,5-trihydroxyphenyl)chromen-4-one	Anthelmintics, Anti-bacterial agents, Antihypertensive agents, Antioxidants, Foodborne diseases, Hyperlipidemias, Hypertension, Hypolipidemic agents, Immunomodulation, Insecticides, Labor pain, Mitogens, Scurvy, Vomiting.
Fruit	Flavylium, Gossypetin, Ascorbic acid, 5,7,8-trihydroxy-3-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxy-	Anti-infective agent (local), Cholagogues & choleretics, Colic, Coronary artery disease,

	2-(3,4,5-trihydroxyphenyl)chromen-4-one	Diarrhea, Diuretics, Dysentery, Heart diseases, Hypertension, Laxatives, Nervous system diseases, Scurvy, Wounds & injuries, Cooling effect on body.
Seeds	Myristic acid, Malvalic acid, Dihydrosterculic acid, d-Tartaric acid, Stearic acid, Cholesterol, Sterculic acid, trans-2-Icosenoic acid, Palmitic acid, alpha-Spinasterol, Palmitoleic acid, (-)-Vernolic acid, Oleic acid, 2,2-Dimethyl-3-propyloxirane, Epoxyoleic acid, Ergosterol, 2,4-Dimethylheptan-1-ol, Linolenic acid, β-Sitosterol, Stigmasterol, Campesterol, Lenoleic acid	Anti-infective agents, Asthenia, Constipation, Dyspepsia, Dysuria, Scurvy, Urination disorders
Leaves	Quercetin, Kaempferol, Gossypetin, Luteolin, β-Sitosterol, Chlorogenic acid	Antineoplastic agents, Antioxidants, Colic, Diuretics, Dysentery, Emollients, Hyperlipidemias, Hypnotics & sedatives, Hypolipidemic agents, Lipid peroxidation, Lithiasis, Liver diseases, Scurvy, Wounds & injuries, Cooling effect on body.
Roots	Tannins Saponins Phenolic compounds	Diarrhea, Fever, Fractures, Genital diseases (female), Pharyngitis, Ulcer.
Whole Plant	Myrtillin, Cyanidin 3-O-beta-D-sambubioside, Hibiscetin 3-glucoside, Cyanidin 3-glucoside	Insecticides, Anti-bacterial agents, Labor pain, General tonic for rejuvenation.

Table- 3: Various nutrients in HS. [31]

Nutrients	Calyces	Seeds	Leaves
Protein (g)	2	28.9	3.5
Carbohydrate (g)	10.2	25.5	8.7
Fat (g)	0.1	21.4	0.3
Thiamine (g)	0.05	0.1	0.2
Riboflavin (g)	0.07	0.15	0.4
Niacin (g)	0.06	1.5	1.4
Vitamin C (g)	17	9	2.3
Calcium (g)	150	350	240
Iron (g)	3	9	5

Table- 4: Pharmacological activities of HS by in vitro, in vivo and clinical trials.

S.N.	Pharmacological Activity	Study design	Type of Extract	Model Assay	Results/ finding of the study	Ref.
1.	Anti-oxidant	In vitro	Water-methanol-	DPPH$^{\bullet}$ and ABTS^{+} scavenging and FRAP	Extracts exhibited	[32]

			acetone		antioxidant properties	
		In vitro	Decoction and cold infusions	Briggs–Rauscher oscillating reaction	Beverages exhibited antioxidant properties	[33]
2.	Anti-hypertensive	In vitro	Anthocyanin-rich fraction	ACE inhibitory assay	Fraction exhibited ACE inhibitory activity in a dose-dependent response	[34]
		In vivo	Aqueous	Salt hypertensive-induced rats	The extract attenuated the development of salt-induced hypertension	[35]
		Clinical trial	*H. sabdariffa* calyx extract and *Olea europaea* leaf extract (NW Roselle)	Phase-II randomized, double-blind, captopril-controlled clinical trial in 134 Egyptian patients with grade 1 essential hypertension	Significantly reduced systolic and diastolic blood pressure in patients with grade 1 essential hypertension.	[36]
3.	Vaso-relaxant	In vitro	Hexane-ethyl acetate-methanol	Rat aorta tissue	Fractions showed vasorelaxant effects by inhibition of Ca^{+} influx	[37]
4.	Anti-diabetic	In vitro	Aqueous	α-amylase and α-glucosidase inhibition assay	The extract exhibited higher α-amylase inhibitory activity than α-glucosidase	[38]
		In vivo	Aqueous	Alloxan-induced diabetic rat	The extract showed hypoglycemic and antioxidant effects	[39]
5.	Cardio-protective	In vitro	Aqueous	Doxorubicin-induced cytotoxicity in rat heart-derived myoblast H9c2 cardiac myocyte cells	The extract exhibited a protective effect on cardiomyocytes, increasing cell viability and decreasing cell	[40]

					apoptosis	
		In vivo	Polyphenol-rich extract	Hyperglycemia-induced cardiac oxidative stress rats	The extract ameliorated oxidative stress damage in diabetic heart	[41]
6.	Anti-bacterial	In vitro	Aqueous-methanolic	*Staphylococcus aureus*, *Escherichia coli*, *Klebsiellapneumoniae*, and *Bacillus cereus*	The extract exhibited potent antimicrobial activity against Gram-negative bacteria	[42]
7.	Anti-viral	In vitro	Aqueous decoction	Feline calicivirus, murine norovirus, and hepatitis A virus	Extracts showed antiviral activity to undetectable levels	[43]
8.	Anti-proliferative	In vitro	Methanolic	Murine melanoma cell line (B16-F1) and human umbilical vein endothelial cells	Extract inhibits melanoma cell growth, migration, and tube formation in a dose-dependent response	[44]
9.	Cytotoxic	In vitro	Aqueous	Human breast cancer (MCF-7) cell line	The extract showed selective cytotoxic activity in a dose-dependent manner	[45]
10.	Neuro-protective	In vivo	Aqueous decoction	Ischemic brain injury-induced adult male Wistar rats	The extract showed protective effects against neuronal damage induced by BCCAO	[46]
		In vivo	Ethanolic	Cypermethrin-induced oxidative stress in mice *Mus musculus*	The extract showed protective effects against toxicity induced by cypermethrin	[47]
11.	Sedative	In vivo	Maceration in hot water	Apomorphine-induced stereotypic behavior test using Swiss albino mice	HSE significantly reduced the exploratory behavior in mice, similar to	[48]

					diazepam	
12.	Anti-anxiety	In vivo	Ethyl acetate fractions	Elevated plus-maze rat model	HS fraction reduced anxiety at low concentrations	[49]
13.	Anti-depressant	In vivo	Ethyl acetate fractions	Porsolt's forced swim test in rats	HS fraction exhibited antidepressant properties at doses of 20 mg/kg	[49]
14.	Hepato-protective	In vivo	Aqueous extract	Wistar rats injected with 2,4-dinitrophenylhydrazine (DNPH)	The extract inhibited the toxicity of DNPH in a dose-dependent response similar to the control drug	[50]
15.	Anti-hyperinsulinemic	In vivo	Aqueous	High fructose diet-induced insulin resistance rats	The extract showed a similar effect to metformin, an oral antidiabetic drug	[51]
16.	Anti-obesity	In vivo	HS by-products	HF/HFr-induced rats	HS by-products reduced adipocyte hypertrophy, insulin resistance, and hepatic steatosis	[52]
17.	Anti-inflammatory	In vivo	Methanolic	Paw edema-induced rat	The extract significantly reduced the paw size edema in a dose-dependent manner in less time than aspirin	[53]
18.	Hypolipidemic	In vivo	Aqueous	Hypercholesterolemic rats	The extract exhibited hypolipidemic effects in a dose-dependent response	[54]
19.	Renal function improvement	In vivo	Aqueous	Metabolic syndrome-induced rats	The extract decreased oxidative stress and promoted	[55]

					normal renal function	
20.	Anti-ulcer	In vivo	Aqueous	Indomethacin-induced gastric ulcer rats	The extract exhibited a protective effect against induced gastric ulcer	[56]
21.	Anti-anemic	In vivo	Aqueous	Healthy rats	The extract improved hematological parameters	[57]

Table- 5: Marketed Products of HS in India.

S.N.	Product	Plant Part Used	Formulation	Manufacturer/Brand	Uses/Application
1.	Mystique HS Tea (Roselle herbal tea)	Dried calyces	Herbal tea	Agasthiya Organics (Mangalore, Karnataka)	Functional beverage, antioxidant supplement
2.	FEMAP HS Tea (Roselle herbal tea)	Dried calyces	Loose herbal tea	FEMAP Naturals	Herbal tea, cardiovascular wellness beverage
3.	Roselle Jam	Roselle calyces	Jam	Monks Bouffe Organic Lifestyle & Farming LLP, Mumbai	Functional spread, antioxidant-rich food product
4.	Roselle Powder	Dried calyces/petals	Powder	Monks Bouffe Organic Lifestyle & Farming LLP	Beverage ingredient, nutraceutical ingredient
5.	Roselle Syrup (Sharbat)	Roselle calyces	Syrup/Concentrate	Various SHGs and FPOs in Maharashtra (marketed regionally)	Ready-to-serve beverage, cooling drink
6.	Roselle Fruit Bar (Ambadi Bar)	Calyces	Fruit bar	Mahatma Phule Krishi Vidyapeeth (technology dissemination), SHGs in Maharashtra	Functional snack rich in anthocyanins and vitamin C
7.	Ambadi Aam Papad	Calyces	Fruit leather	SHGs and food-processing units in Maharashtra	Nutritious snack and preservation product
8.	Roselle Jelly	Calyces	Jelly	Cottage food industries and SHGs	Confectionery and functional food
9.	Hibiscus Extract	Standardized calyx extract	Capsules	Solaray and Just Jaivik	Antioxidant and cardiovascular

	Capsules				support supplement
10.	Roselle Pickle (Ambadi Pickle)	Calyces/Leaves	Pickle	Regional food processors in Maharashtra and Telangana	Traditional condiment

5. CONCLUSION

The increasing global interest in herbal medicines has reinforced the importance of medicinal plants with proven therapeutic potential. HS is one such widely used medicinal and functional plant with a rich ethnomedicinal background and diverse pharmacological properties. Traditionally, it has been employed in the management of hypertension, liver disorders, gastrointestinal ailments, fever, urinary disorders, and inflammatory conditions. Phytochemical analyses have identified anthocyanins, flavonoids, phenolic acids, organic acids, and other bioactive constituents that contribute to its antioxidant, antihypertensive, antihyperlipidemic, antidiabetic, hepatoprotective, nephroprotective, anti-inflammatory, antimicrobial, cardioprotective, and anticancer activities. Experimental and clinical studies support many of these traditional claims, although the underlying molecular mechanisms are not yet fully understood. Further studies focusing on standardization, pharmacokinetics, long-term safety, and well-designed clinical trials are essential to validate its therapeutic efficacy and facilitate its integration into evidence-based medicine, pharmaceutical formulations, and functional food products.

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