

HIBISCUS SABDARIFFA L. (ROSELLE): A COMPREHENSIVE REVIEW OF BOTANICAL, PHYTO-CHEMICAL, PHARMACOLOGICAL, AND THERAPEUTIC PERSPECTIVES

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ABSTRACT

Hibiscus sabdariffa L. (Malvaceae), commonly known as Roselle, is a medicinally and nutritionally important plant widely cultivated in tropical and subtropical regions. The present review compiles and critically evaluates information on its botanical characteristics, phytochemistry, pharmacological activities, traditional uses, and industrial applications. Botanically, *H. sabdariffa* is an erect, annual to short-lived perennial shrub characterized by reddish stems, palmately lobed leaves, pale yellow flowers with a dark red centre, and fleshy red calyces, which represent the most economically valuable part. The review summarizes taxonomic classification, geographical distribution, vernacular names, and Ayurvedic properties (Guna–Karma), highlighting its significance in traditional medicine systems. Microscopic and powder analysis of the calyx and leaf are discussed as essential tools for identification, authentication, and quality control. Phyto-chemical studies reveal the presence of diverse bio-active constituents, including anthocyanins, flavonoids, phenolic acids, organic acids, polysaccharides, pectin, vitamins, minerals, fatty acids, and phytosterols. The calyces are particularly rich in anthocyanins such as cyanidin and delphinidin derivatives, which contribute to strong antioxidant activity. Pharmacological investigations demonstrate antihypertensive, antihyperlipidemic, antioxidant, hepatoprotective, anticancer, antifungal, diuretic, and anti-anaemic activities. Overall, *Hibiscus sabdariffa* exhibits significant therapeutic potential and economic importance, warranting further research and standardization.

KEYWORDS: *Hibiscus sabdariffa* L., Roselle, Anthocyanins, Pharmacological activities, Phytochemistry, Medicinal plant.

INTRODUCTION

Hibiscus sabdariffa is an annual herbaceous plant that grows upright and reaches about 2m in height. It has reddish-green branches and simple, palm-shaped leaves with serrated margins. The plant produces fleshy, dark red to purple flowers arising from the leaf axils, which later develop into capsule-shaped fruits containing brown, wrinkled seeds. The flowers and leaves are the main parts used. *Hibiscus sabdariffa* is known by several common names and is widely cultivated for its medicinal and nutritional value.^[1]

Hibiscus sabdariffa is an economically important plant in the food and pharmaceutical industries. It is commonly used as a refreshing beverage, especially when

sweetened with sugar. Concentrated extracts of the plant are also used as natural colorants and enriched ingredients due to their distinctive properties.^[2,3,4]

Varieties of *Hibiscus sabdariffa*: Among the numerous species of *Hibiscus*, *Hibiscus sabdariffa* and *Hibiscus altissima* are the most common and well-established. *H. altissima* bears green-colored calyces and, although not used as food, is economically important due to its high fiber content. In contrast, *H. sabdariffa*, commonly known as **Roselle**, is a bushy, highly branched plant cultivated mainly for its edible red calyces. The flowers of Roselle are axillary or terminal in position.^[5,6]

Roselle (*Hibiscus sabdariffa*) is a flowering plant species belonging to the genus *Hibiscus*, originally native to Africa, particularly West Africa. During the 16th and early 17th centuries, the plant was introduced to Asia and the West Indies, where it subsequently became naturalized in several regions.^[7] The stems of the plant are utilized for bast fiber production, while the dried calyces, characterized by a cranberry-like flavor, are widely used to prepare a popular herbal infusion known by various names, including *carcade*.

Synonyms

Sabdariffa digitata (Cav.) Kostel.
 Sabdariffa rubra Kostel.
 Furcaria sabdariffa Ulbr.
 Hibiscus cruentus Bertol.
 Hibiscus digitatus Cav.
 Hibiscus digitatus var. kerrianus DC.
 Hibiscus gossypifolius Mill.

Common Names

Roselle

Red sorrel
 Florida cranberry
 Indian sorrel
 Sour tea plant

Vernacular Names

Hindi: Ambadi, Lal Ambadi
 Kannada: Pundi soppu
 Tamil: Pulichai keerai
 Telugu: Gongura
 Malayalam: Pulichakka, Pulichakeerai

Taxonomic classification

Kingdom: Plantae
Division: Tracheophyta
Class: Magnoliopsida
Clade: Angiosperms
Order: Malvales
Family: *Malvaceae*
Genus: *Hibiscus* L
Species: *Hibiscus sabdariffa*
Binomial name: *Hibiscus sabdariffa* L.^[8]



Fig. 1: *Hibiscus sabdariffa* Plant.

Botanical description

Habit: *Hibiscus sabdariffa* is an erect, fast-growing, annual to short-lived perennial shrub, usually attaining a height of 1.5–3.5 m. The plant is profusely branched, forming a bushy appearance.

Stem: The stem is cylindrical, smooth to slightly pubescent, and green to deep red or purplish in color. Young stems are tender, becoming woody at the base with maturity.

Leaves: They are **alternate**, **simple**, and **glabrous**, borne on long petioles (8–15 cm). The leaf blade is **ovate to lanceolate**, palmately divided into **3–7 lobes**, with **serrated or dentate margins**. Leaf color varies from dark green to reddish-green depending on cultivar and environmental conditions. Stipules are linear to filiform and deciduous.

Flowers: They are **solitary**, **axillary**, and **bisexual**, borne on short peduncles. The epicalyx consists of 8–12 narrow bracteoles. The calyx is campanulate, initially

green and later becoming thick, fleshy, and bright red after flowering.

The corolla comprises five large, overlapping petals, pale yellow to creamy white with a distinctive dark red or maroon center. Stamens are numerous, united into a staminal column surrounding the style. The ovary is superior, five-lobed, with axile placentation.

Fruit: The fruit is an **ovoid, loculicidal capsule**, enclosed by the persistent, enlarged, fleshy calyx. The capsule contains numerous seeds and dehisces at maturity.

Seeds: Seeds are **reniform (kidney-shaped)**, smooth to slightly rough, brown to dark brown in color, and rich in oil and proteins.

Calyx: The calyx is the most economically important part of the plant. It is thick, succulent, bright red, and rich in organic acids, anthocyanins, pectin, mucilage,

minerals, and vitamin C. Dried calyces are widely used in food, beverages, herbal teas, and natural dyes.

Root System: The plant possesses a well-developed **taproot system** with several lateral roots, enabling efficient uptake of nutrients and water.^[6,9,10,11]



Fig. 2: Hibiscus sabdariffa Flowers.



Fig. 3: Hibiscus sabdariffa Fruits.



Fig. 4: Hibiscus sabdariffa Seeds.



Fig. 5: Freshly Harvested Calyces



Fig. 6: Dried Calyces of Hibiscus sabdariffa

Geographical distribution

Hibiscus sabdariffa is native to tropical Africa, particularly West Tropical Africa, including countries such as Central African Republic, Chad, Congo, DR Congo, Gabon, Ghana, Nigeria, and Sudan–South Sudan. It grows primarily in seasonally dry tropical biomes and savanna habitats in these regions.

Asia: India, China, Thailand, Malaysia, Indonesia, Sri Lanka, Bangladesh.

Americas and Caribbean: Mexico, Jamaica, Haiti, Colombia, and other West Indies islands

Climatic and Ecological Range

Warm temperatures with well-distributed rainfall

Low altitude areas (sea level up to ~600 m)

Annual rainfall ~800–1600 mm

Soils ranging from sandy loams to more retentive loams

Ayurvedic(Guna–Karma)

Taste (Rasa): Astringent (Kashaya), Bitter (Tikta).

Qualities (Guna): Light (Laghu), Dry (Rooksha).

Potency (Veerya): Cold (Sheet).

Post-digestive effect (Vipaka): Pungent (Katu).

Action (Karma): Balances Kapha & Pitta doshas (Kaphapitta shamaka).

Medicinal Properties

- a. Cardiovascular benefits: Exhibits antihypertensive and hypolipidemic effects, helping to lower blood pressure and cholesterol levels; commonly consumed as *Karkade* tea to support heart health.
- b. Antioxidant activity: Rich in phenolic compounds, flavonoids, and anthocyanins (e.g., cyanidin-3-sambubioside), which neutralize free radicals and reduce oxidative stress.
- c. Anti-inflammatory effects: Bioactive constituents such as caffeic acid and anthocyanins contribute to significant anti-inflammatory activity.
- d. Metabolic regulation: Demonstrates hypoglycemic and anti-obesity potential, aiding in the management of blood glucose, lipid metabolism, and body weight.
- e. Hepato-renal protection: Shows hepatoprotective and renoprotective properties, supporting liver detoxification and kidney function, including uric acid reduction.
- f. Digestive support: Acts as a digestive aid and mild laxative, helping alleviate gastrointestinal disorders.
- g. Diuretic activity: Enhances urine output, assisting in fluid balance and renal health.
- h. Antimicrobial properties: Possesses antibacterial and antifungal activities that may help in managing infections.
- i. Febrifuge action: Traditionally used to reduce fever.
- j. Skin and hair benefits: Promotes skin elasticity and hair growth, attributed to its antioxidant and anti-aging effects.

Microscopy, powder Analysis and Standardization parameters**Microscopic Characters****A. Transverse Section (T.S.) of Calyx.**

The transverse section of the calyx shows the following anatomical features

- **Epidermis:** The outer epidermis consists of a **single layer of polygonal to rectangular cells**, covered with a thin cuticle. The cells contain abundant **anthocyanin pigments**, imparting the characteristic red color to the calyx.
- **Hypodermis:** Below the epidermis, a few layers of **thin-walled parenchymatous cells** are present, providing flexibility and storage.
- **Ground Tissue:** The bulk of the calyx is composed of **loosely arranged parenchymatous cells rich in mucilage, organic acids, and pigments**. These cells are thin-walled and isodiametric.
- **Vascular System:** Vascular bundles are **collateral and scattered within the ground tissue**. Each bundle consists of xylem elements (vessels and tracheids) towards the inner side and phloem elements towards the outer side. Fibers are few or absent.
- **Crystals:** Calcium oxalate crystals are generally **absent**, which serves as an identifying character.^[9,10]

B. Transverse Section (T.S.) of Leaf

- **Epidermis:** The leaf shows a **dorsiventral structure**. Both upper and lower epidermis are **single-layered and covered with a thin cuticle**. Stomata are mainly of the **anomocytic type, more numerous on the lower epidermis**.
- **Mesophyll:** The mesophyll is differentiated into:
 - i. Palisade parenchyma: One to two layers of elongated, chlorophyll-containing cells beneath the upper epidermis.
 - ii. Spongy parenchyma: Loosely arranged cells with intercellular spaces towards the lower epidermis.
- **Vascular Bundles:** Vascular bundles are collateral, surrounded by a parenchymatous bundle sheath. Xylem faces the upper side, while phloem is oriented towards the lower side.
- **Trichomes:** Trichomes are generally absent or very sparse, which differentiates *H. sabdariffa* from other Malvaceae members.

C. Powder Microscopy (Calyx Powder)

The powdered calyx is deep red to maroon in color and exhibits the following diagnostic features under the microscope:

- Epidermal cell fragments containing red anthocyanin pigments
- Thin-walled parenchymatous cells filled with mucilage
- Spiral and reticulate xylem vessels
- Fibers with tapering ends
- Occasional pollen grains.^[12,13,14]

Phytochemistry

Leaf

The leaf is reported to contain a wide spectrum of nutritional and phytochemical constituents, including proteins, fats, carbohydrates, dietary fibre, and ash, along with essential minerals such as calcium, phosphorus, and iron. It is also a rich source of vitamins, notably thiamine, riboflavin, niacin, ascorbic acid, and β -carotene. In addition to these nutritional components, the leaves possess several bioactive compounds, including α -terpinyl acetate, anisaldehyde, β -sitosterol, β -D-galactoside, β -sitosteryl benzoate, and malic acid. Various volatile and aliphatic alcohols such as isoamyl alcohol (3-methyl-1-butanol), isopropyl alcohol, methanol, benzyl alcohol, and ethanol have also been identified, contributing to the overall chemical profile and potential biological activities of the leaf.^[15,16]

Flowers

The flowers of *Hibiscus sabdariffa* contain carbohydrates, proteins, fats, dietary fibre, minerals, and ash, along with polysaccharides such as arabinans, arabinogalactans, mucilage, pectin, sucrose, mannose, and xylose. They are a source of vitamins including thiamin, riboflavin, niacin, β -carotene, and ascorbic acid, as well as phytosterols. The flowers yield a yellow dye, with daphniphylline identified as the major pigment, and contain flavonoids such as hibiscitrin and hibiscetin. In addition, alkaloids, β -sitosterol, quercetin, galactose, organic acids, and water-soluble neutral polysaccharides mainly composed of arabinans and arabinogalactans have been reported.^[17]

Calyces

The calyces of *Hibiscus sabdariffa* are rich in acids and pectin and contain carbohydrates, crude protein, and dietary fibre, resin, minerals, and ash. Mineral analysis has revealed the presence of iron, phosphorus, calcium, manganese, aluminium, magnesium, sodium, and potassium, along with mucilage, calcium citrate, and ascorbic acid. The dried calyces are particularly abundant in anthocyanins and flavonoids, including cyanidin-3-glucoside, cyanidin-3-sambubioside, cyanidin-3-xyloglucoside, delphinidin and its glycosides, gossypetin, gossypetin-3-glucoside, hibiscetin, hibiscin, hibiscitrin, sabdaretin, and sabdaritrin, which are responsible for their characteristic red colour and strong antioxidant activity. A wide range of organic and fruit acids, such as citric, malic, maleic, tartaric, oxalic, hibiscic, glycolic, utalonic, protocatechuic acids, along with derivatives including (+)-allooxycitric acid lactone and alhydroxycitric acid, has also been reported. Minor quantities of delphinidin-3-monoglucoside and cyanidin-3-monoglucoside (chrysanthenin) are additionally present.^[18]

Seeds

The seeds of *Hibiscus sabdariffa* are nutritionally rich, containing high levels of protein (18.8–22.3%), fat

(19.1–22.8%), and dietary fibre (39.5–42.6%), along with carbohydrates, starch, cellulose, pentosans, nitrogen, and various minerals such as phosphorus, magnesium, calcium, as well as essential amino acids including lysine and tryptophan.^[19] The seed oil is rich in unsaturated fatty acids (\approx 70%), with linoleic acid (\approx 44%) as the major component, and also contains palmitic, oleic, myristic, stearic, palmitoleic, malvalic, sterculic, caprylic, and pelargonic acids, along with cis-12,13-epoxy-cis-9-octadecenoic acid. Phytosterols such as β -sitosterol, campesterol, ergosterol, together with cholesterol, steroids, and tocopherols, have been reported in the seed oil.^[20,21] In addition, the seeds contain propionic and formic acids, various alcohols (methanol, ethanol, isopropyl alcohol, isoamyl alcohol, and 3-methyl-1-butanol), and minerals. Furthermore, flavonoids and related compounds including kaempferol-3-O-rutinoside, kaempferol-3-O-glucopyranoside, quercetin-3-O-rutinoside, citrusin C, corchoionoside C, trans-carveol-6-O- β -D-glucopyranoside, and 2,3-dihydro-2-(4'-hydroxy-3'-methoxyphenyl)-3- β -D-glucopyranosylmethyl-7-hydroxy-5-benzofuranpropanol have been isolated, mainly from 70% aqueous ethanol extracts.^[22]

Fruit

The fruit of *Hibiscus sabdariffa* contains α -terpinyl acetate, anisaldehyde, and benzaldehyde, along with pectin, ascorbic acid, and calcium oxalate. A variety of organic acids such as citric, acetic, formic, propionic, caprylic, and pelargonic acids have been reported, together with volatile alcohols including ethanol, methanol, isopropyl alcohol, benzyl alcohol, and 3-methyl-1-butanol. In addition, the fruit contains minerals, which contribute to its nutritional and functional properties.

Root: The roots of *Hibiscus sabdariffa* contain tartaric acid and saponins, which may contribute to their traditional medicinal properties.

PHARMACOLOGICAL EFFECTS

Antihypertensive activity

Aqueous extracts of *Hibiscus sabdariffa* petals and calyces have demonstrated antihypertensive and cardioprotective effects in both experimental animals and humans.^[23] Petal extracts and infusions significantly reduced systolic and diastolic blood pressure in normotensive and spontaneously hypertensive rats.^[24] Tea prepared from calyces lowered systolic pressure by 11.2% and diastolic pressure by 10.7%.^[25] Clinical studies with standardized extracts in patients with mild to moderate hypertension showed reductions in blood pressure by more than 10%,^[26] comparable to the effects of lisinopril in controlled trials. The aqueous calyx extracts also exert a dose-dependent decrease in mean arterial pressure^[27] and a vasodilatory effect on isolated aortic rings, likely mediated through the endothelium-derived nitric oxide-cGMP pathway and inhibition of calcium influx into vascular smooth muscle.^[28] Daily

consumption of hibiscus tea may therefore serve as an effective dietary intervention for pre-hypertensive and mildly hypertensive individuals.^[29]

Antihyperlipidemic activity

The inhibitory effects of the plant extract on low-density lipoprotein (LDL) oxidation and its antihyperlipidemic potential in fructose- and cholesterol-fed rats have been demonstrated.^[30] The study revealed a significant reduction in LDL levels and a decreased LDL-cholesterol to HDL-cholesterol ratio. Consumption of dried calyx ethanolic extract was shown to improve the lipid profile in rats.^[31] Furthermore, hypocholesterolemic and antioxidant effects of aqueous extracts in hypercholesterolemic rats have also been reported.^[32] Antioxidant activity of aqueous extracts of dried calyx against rat LDL oxidation was investigated, demonstrating a protective effect of *Hibiscus sabdariffa* on LDL oxidation.^[33] Additionally, aqueous extracts of the petals of red and green varieties significantly decreased total plasma lipid concentrations in rats, suggesting notable cardiovascular protective effects.^[34]

Antioxidant activity

The antioxidant and free radical scavenging activities of two fractions of the ethanolic extract, namely the chloroform-soluble and ethyl acetate-soluble fractions, obtained from dried flowers were evaluated.^[35] Both fractions exhibited strong hydrogen peroxide scavenging activity (79–94%) at a concentration of 500 µg. In addition, the extracts showed significant inhibitory effects (70–80%) against superoxide anion radicals (O₂⁻) at a concentration of 1000 µg. Furthermore, antioxidant activities of three varieties assessed using a liposome system have also been reported. Methanolic and ethyl acetate extracts demonstrated higher cyclooxygenase-1 (COX-1) enzyme inhibition compared to cyclooxygenase-2 (COX-2) inhibition.^[36]

Hepatoprotective activity

Protective effects of dried flower extracts against oxidative stress in rat primary hepatocytes have been demonstrated.^[37] Protocatechuic acid, a simple phenolic compound isolated from *Hibiscus sabdariffa*, exhibited significant protective effects against tert-butyl hydroperoxide (t-BHP)-induced cytotoxicity and genotoxicity in hepatocytes, possibly due to its free radical scavenging properties.^[38]

Petal extracts have been shown to protect rats against cadmium-induced lipid peroxidation in the liver, prostate, and testis.^[39] Additionally, the extract exerted hepatoprotective effects by modulating lipid peroxidation products and liver marker enzymes in experimental hyperammonemia, an effect attributed to the antioxidant activity of natural compounds present in the plant.^[40]

The protective effects of aqueous extracts and anthocyanins against paracetamol-induced hepatotoxicity in rats have also been reported.^[41] Furthermore,

aqueous-ethanol (1:1) extracts of the calyx significantly reduced lipid peroxidation in carbon tetrachloride-induced liver damage.^[42] However, prolonged administration of aqueous-methanol extracts of the calyces has been reported to induce liver injury, indicating potential dose- and duration-dependent hepatotoxicity.^[43]

Anticancer activity

Anthocyanins have been shown to induce apoptosis in cancer cells, particularly in HL-60 human leukemia cells.^[44] The antioxidant activity of anthocyanins was further evaluated through their inhibitory effects on low-density lipoprotein (LDL) oxidation in a cell-free system and their anti-apoptotic effects in RAW 264.7 macrophage cells.^[45] These findings suggest that anthocyanins derived from *Hibiscus sabdariffa* may inhibit LDL oxidation and oxidized LDL (oxLDL)-mediated macrophage apoptosis, thereby functioning as potential chemopreventive agents.

Additionally, protocatechuic acid exhibited significant inhibitory effects on tumor promotion in mouse skin models, indicating its potential role as a cancer chemopreventive agent against tumor promotion.^[46]

Antifungal Activity

Several studies have evaluated the antifungal potential of *Hibiscus sabdariffa* extracts, reporting variable outcomes depending on the plant part, extraction solvent, and fungal strain tested. An aqueous-methanolic extract of dried calyces showed no inhibitory effect against *Candida albicans* in vitro, indicating limited antifungal efficacy against yeast-like fungi in this extract system.^[47]

Conversely, ethanolic and methanolic extracts of *H. sabdariffa* calyces demonstrated moderate antifungal activity against filamentous fungi, including *Aspergillus niger*, *Aspergillus flavus*, *Penicillium* spp., and *Fusarium* spp., which are commonly associated with food spoilage and mycotoxin contamination.^[48,49] The antifungal activity was concentration-dependent and generally less potent than standard antifungal agents. The observed antifungal effects have been attributed to phenolic compounds, flavonoids, anthocyanins, and organic acids, which may disrupt fungal cell membrane integrity, interfere with enzyme activity, and alter intracellular metabolic processes.^[50] Acidic constituents of *H. sabdariffa* are also believed to contribute to antifungal action by reducing environmental pH and inhibiting fungal growth. Overall, the antifungal activity of *Hibiscus sabdariffa* appears to be extract- and strain-specific, with greater efficacy against filamentous fungi than against yeasts such as *Candida albicans*, warranting further investigation using standardized extracts and in vivo models.

Diuretic Effects

The renal effects of *Hibiscus sabdariffa* have been demonstrated in both clinical and preclinical studies. A

two-phase clinical study in Thailand involving healthy male volunteers showed that consumption of *H. sabdariffa* juice (16–24 g/day) significantly reduced urinary excretion of creatinine, uric acid, calcium, sodium, potassium, and phosphate, without affecting oxalate levels, indicating a protective role against urolithiasis.

Preclinical studies revealed that aqueous calyx extracts (250–750 mg/kg) effectively prevented urolithiasis in rats, improved renal function by reducing serum urea and creatinine levels, and decreased renal $\text{Ca}^{2+}/\text{Mg}^{2+}$ -ATPase activity without altering calcium handling. Additionally, higher doses (500–2500 mg/kg) produced marked diuretic and natriuretic effects with potassium-sparing action, supporting the traditional use of *H. sabdariffa* as a diuretic agent.^[51]

Anti-Anaemic Effect

A preliminary study investigated the use of *Hibiscus sabdariffa* decoctions as an alternative source of iron for treating anaemia and other mineral deficiency disorders. The study demonstrated that dry fermented calyces of *H. sabdariffa* have a very low pH, which enhances mineral availability. Additionally, the high concentration of ascorbic acid in the decoctions further improves the bioavailability of essential minerals such as iron, zinc, calcium, and magnesium.

Maintenance of Healthy Teeth and Gums

The calcium present in roselle helps maintain healthy teeth and gums by strengthening the jawbone throughout life. A strong jawbone ensures firmly fitting teeth, thereby reducing spaces where bacteria can accumulate. Adequate calcium intake is particularly important during childhood, as it supports the natural development of strong and healthy teeth.

Healthy Pregnancy

Pregnant women have an increased requirement for iron compared to the general population. Therefore, the

inclusion of iron-rich foods such as roselle is beneficial during pregnancy, as the recommended daily iron intake is approximately 27 mg, often supplemented through prenatal multivitamins. In addition, pregnant women are advised to consume adequate amounts of healthy fats and folate-rich foods to support fetal development and overall maternal health.

Treatment of the Common Cold

Roselle is rich in Vitamin C, which helps strengthen the immune system, providing protection against common colds and coughs. Vitamin C also enhances the absorption of iron, further boosting the body's resistance to infections. Additionally, Roselle exhibits antiviral properties that support overall immunity.

Prevention of Constipation

Roselle contains magnesium, which helps relieve constipation effectively. Magnesium acts as a natural laxative by relaxing intestinal muscles, promoting smoother bowel movements. It also attracts water into the intestines, softening the stool and facilitating easier passage. With 29 mg of magnesium per serving, Roselle contributes approximately 6.9% of the recommended daily intake.

Weakness

Roselle is a source of phosphorus, an essential mineral that helps address minor health issues such as muscle weakness, fatigue, and numbness. Maintaining normal phosphorus levels—about 1200 mg per day for adults—supports overall physical fitness and activity. Adequate phosphorus intake may also help improve sexual health by enhancing libido, addressing impotence, and supporting sperm motility.

Different drying methods

Sl.no	Type of Drying	Description
01	Forced air oven drying	Roselle calyces were dried at 60 °C
02	Constant temperature and humidity chamber	Roselle calyces were dried at different temperatures (35, 45, 55, and 65 °C) and relative humidity (30%, 35%, 40%, 45%, 50% RH)
03	Tunnel drier	Roselle calyces were dried at 70 °C for 4.5 h
04	Thin layer drying (Tray drier)	Drying was carried out at temperatures 40, 50, and 60 °C with air velocity of 1.5–1.6 m/s
05	Sun and oven drying	Fresh red and light red Roselle calyces were sun dried for three days, then oven dried for 24 h at 50 °C
06	Hot air drying	Roselle calyces were dried at 60 °C
07	Oven drying	Roselle calyces were dried at 105 °C for 45–60 min

Usage of *Hibiscus sabdariffa* in Daily Life

1. Food and Beverage Uses

The dried calyces of *Hibiscus sabdariffa* L. are widely used in the preparation of herbal drinks and teas such as

karkade and roselle tea, which are valued for their refreshing sour taste, deep red colour, and high content of organic acids and anthocyanins. Intake of *H. sabdariffa* (Roselle) tea has been linked to reductions in

blood pressure and lipid levels, largely attributed to its abundant polyphenols and anthocyanins. In addition, it exhibits strong antioxidant and hepatoprotective effects and may aid in body weight regulation. Beyond tea, roselle is commonly processed into juices, squashes, and syrups that are consumed as cooling beverages in many cultures. The high pectin content of the calyces supports their use in the preparation of jams, jellies, and sauces. Furthermore, *H. sabdariffa* is incorporated into traditional dishes and condiments, contributing both flavour and natural colour to regional cuisines.^[1,2]

2. Medicinal and Health Uses

From a medicinal perspective, *H. sabdariffa* is commonly consumed to help regulate blood pressure and is widely recognized for its antihypertensive activity. In traditional household remedies, it is used to alleviate fever, cold, cough, and sore throat. Roselle preparations also act as digestive aids and mild laxatives, promoting gastrointestinal health. Owing to its rich antioxidant profile, regular consumption supports immune function and metabolic health. Additionally, the plant has been traditionally used for urinary and renal health due to its mild diuretic properties.^[52]

3. Nutritional Uses

Nutritionally, *H. sabdariffa* is a good source of vitamin C, iron, calcium, and anthocyanins, making it beneficial in daily diets. These nutrients contribute to its role in managing anaemia and mineral deficiencies, particularly in resource-limited settings. The combination of essential nutrients and bioactive compounds has led to its recognition as a functional food that promotes overall wellness.^[2,5]

4. Household and Industrial Uses

In household and industrial applications, *H. sabdariffa* is widely used as a natural food colourant due to the presence of red anthocyanin pigments. These pigments are increasingly preferred as alternatives to synthetic dyes in bakery and confectionery products (candies, gummies, toffees, fruit chews, chocolates, marshmallows, and glazed sweets). The plant is also utilized in cosmetic and herbal formulations because of its antioxidant and skin-protective properties. Moreover, the seeds are used for oil extraction and as animal feed, enhancing the economic value of the plant.^[1]

5. Cultural and Traditional Uses

Culturally, *H. sabdariffa* holds an important place in traditional medicine systems and daily diets. It is commonly consumed during festivals and social gatherings in the form of beverages and special dishes, reflecting its long-standing cultural and ethnobotanical significance.^[2]

Non-Dietary Uses of *Hibiscus sabdariffa*

1. Pharmaceutical and Medicinal Applications

The plant is incorporated into herbal formulations, capsules, syrups, and topical preparations for managing inflammation, skin infections, and wound healing.

2. Cosmetic and Personal Care Uses

Due to its rich anthocyanins, organic acids, and antioxidants, *H. sabdariffa* is used in cosmetics and personal care products such as hair oils, shampoos, conditioners, face masks, soaps, scrubs, and anti-aging creams. It promotes hair growth, scalp health, skin exfoliation, and protection against oxidative damage.

3. Natural Colorant and Dye

The deep red pigments (anthocyanins) present in the calyces are used as natural dyes in textiles, cosmetics, pharmaceuticals, and traditional crafts. Hibiscus dye serves as an eco-friendly alternative to synthetic colorants.

4. Agricultural and Horticultural Uses

Hibiscus sabdariffa is cultivated as a fiber plant, with its stems yielding bast fibers used for making ropes, twines, sacks, mats, and paper pulp. The plant residues are also applied as green manure and organic compost, improving soil fertility.

5. Environmental and Household Uses

Hibiscus extracts function as natural cleaning agents, insect repellents, and eco-friendly preservatives. The plant extracts is also used in traditional rituals, ornamental gardening, landscaping and biodegradable packaging materials,

CONCLUSION

The present review provides a consolidated account of the pharmacognostic, phytochemical, and pharmacological aspects of *Hibiscus sabdariffa* L., a plant of considerable importance in traditional and modern medicine. Detailed evaluation of its botanical features, microscopic characteristics, and powder analysis offers essential parameters for proper identification and quality control of the crude drug. Phytochemical studies reveal that the plant is a rich source of anthocyanins, flavonoids, phenolic acids, organic acids, vitamins, minerals, fatty acids, and phytosterols, which collectively contribute to its therapeutic potential.

Pharmacological investigations have demonstrated a wide range of biological activities, including antihypertensive, antihyperlipidemic, antioxidant, hepatoprotective, anticancer, antifungal, diuretic, and anti-anaemic effects. These findings support the traditional use of *H. sabdariffa* in the management of cardiovascular disorders, metabolic abnormalities, liver and kidney dysfunctions, and nutritional deficiencies. Moreover, its application as a functional food and natural

colourant enhances its relevance in pharmaceutical and nutraceutical development.

Future research should focus on standardization of extracts, elucidation of molecular mechanisms, toxicity profiling, and large-scale clinical studies to ensure safety and efficacy. The scientific evidence presented in this review highlights the potential of *Hibiscus sabdariffa* as a valuable candidate for pharmaceutical research and product development.

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