Phytochemical Potential of Hibiscus Sabdariffa: A Systematic Review

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Abstract: The calyx of Hibiscus sabdariffa Linn, commonly known as Rosella or Sorrel, is a rich source of bioactive compounds with applications in food, medicine, and cosmetics. A member of the Malvaceae family, this plant is cultivated in tropical and subtropical regions including India, Africa, Brazil, Australia, and Southeast Asia. The calyx, noted for its vibrant red color, is abundant in phytochemicals. Studies on H. sabdariffa calyx have revealed the presence of secondary metabolites such as anthocyanins, flavonoids, phenolic acids, and organic acids like hibiscus acid, citric acid, and malic acid. It also contains polysaccharides, pectins, tannins, and vital nutrients like vitamin C and β-carotene. These constituents contribute to its strong antioxidant activity and support its use in functional foods and traditional remedies. Hibiscus sabdariffa exhibits a broad range of medicinal properties. Research supports its role in managing diabetes, cancer, hypertension, and dyslipidemia. The calyx also provides essential minerals and amino acids, enhancing its nutritional value. With its diverse phytochemical composition, the calyx of H. sabdariffa is extensively studied for its therapeutic and nutritional potential. Its bioactive compounds make it a valuable natural resource for the development of nutraceuticals, herbal formulations, and dietary supplements.

Keywords: Anthocyanins, Antioxidant, Flavonoids, Hibiscus acid, *Hibiscus sabdariffa Linn*.

INTRODUCTION [1-4]

Hibiscus sabdariffa Linn, commonly called Roselle, belongs to the Malvaceae family and is also known by various names such as Sorrel, Indian Sorrel, and Karkade (in North Africa and the Middle East). In India, it has numerous regional names including Gonguru, Lal Ambari, and Pulichchai Kerai. Native to either the India-Malaysia region or tropical Africa, Roselle is widely cultivated in countries like India, Egypt, Sudan, Thailand, and Mexico, both for consumption and traditional medicine. It's also commonly grown in tropical areas such as the Caribbean, Central America, Brazil, and Southeast Asia.

This shrub can reach up to 3.5 meters, with reddish stems and green leaves marked by red veins. Its red calyx includes five sepals and a ring of pointed bracts, while its fruit is a small capsule containing several seeds. There are two main types: H. sabdariffa var. sabdariffa and var. altissima. The plant is rich in beneficial compounds such as flavonoids, anthocyanins, citric acid, vitamins, and specific phytochemicals like hibiscetin and sabdaretin.

Fig 1. Hibiscus sabdariffa plant

Botanical classification

Kingdom: Plantae
Division: Tracheophyta
Class: Magnoliopsida
Order: Malvales
Family: Malvaceae

Genus: Hibiscus L
Species: Hibiscus sabdariffa L

ORIGIN [5-6]

The origin of Hibiscus sabdariffa (Roselle) remains a topic of debate among scholars. Some believe it is native to West Africa and later spread to other regions, including the Americas. Others suggest its origin lies in India and Saudi Arabia. Historical records indicate that Roselle was domesticated in western Sudan as early as 4000 BC. It was first documented in Europe in 1576 AD. In India, the Mesta variety is commonly cultivated and harvested in Maharashtra.

CULTIVATION [7-8]

Hibiscus sabdariffa (Roselle) is cultivated in India over approximately 1.5 lakh hectares, with an average yield of around 11 quintals per hectare. It is also grown in countries such as Sudan, the United States, and South Africa for various purposes, including medicinal use, nutrition, fiber extraction, and food consumption. Roselle is an annual shrub that requires about five months from planting to harvest, though it is sometimes considered a perennial plant.

PLANTING [9-10]

Roselle (Hibiscus sabdariffa) growth is strongly influenced by daylight duration, making planting time critical. Although rainfall supports development, photoperiod is more decisive. The plant benefits from deep plowing due to its extensive root system. Around 6–8 kg of seed per hectare is used, sown 2.5 cm deep at the beginning of the rainy season. Recommended spacing is 60–100 cm between rows and 45–60 cm between plants, as wider gaps promote larger calyx formation. Sowing may be done by hand or using appropriate machinery, followed by manual thinning. Numerous cultivars exist, with key ones grown in regions like China, Mexico, Thailand, and Africa.

BOTANICAL DESCRIPTION [11-13]

The Hibiscus genus, belonging to the Malvaceae family, consists of over 300 species of annual and perennial herbs, shrubs, and trees. Hibiscus sabdariffa has several synonyms, including Abelmoschus crientus (Bertol) Walp, Furcaria sabdariffa Ulber, Hibiscus crentus Bertol, Hibiscus fraternus L., Hibiscus palmatilobus Baill, and Sabdariffa rubrakostel.
While some sources suggest that H. sabdariffa originated in India or Saudi Arabia, other research, including that of Murdock, indicates that it was first domesticated by the Black population in western Sudan. Today, it is cultivated in tropical and subtropical regions, including India, Saudi Arabia, China, Malaysia, Indonesia, the Philippines, Vietnam, Sudan, Egypt, Nigeria, and Mexico. There are two primary varieties of H. sabdariffa. The first, H. sabdariffa var. altissima Wester, is grown for its jute-like fiber and has inedible green calyces with red streaks. The second, H. sabdariffa var. sabdariffa, produces yellow-green edible calyces and also yields fiber.

GEOGRAPHICAL PREVALENCE [14-16]

The true origin of Hibiscus sabdariffa L. is unknown, though some link it to Africa, India, or the Americas. It was likely grown in Sudan thousands of years ago and later spread through trade routes. By the 17th century, it appeared in Asia and the Caribbean, eventually reaching parts of North America. Today, it thrives in tropical climates. Countries like Sudan, Thailand, and China lead its production, with Sudan focusing on traditional farming and Thailand on quality cultivation. Several other regions grow it for local use.

IMPORTANCE [17]

Beyond its traditional use as food and medicine in its native regions, Hibiscus sabdariffa has gained global significance, particularly in the beverage industry. Today, hibiscus flowers are widely traded and used as key ingredients in industrially produced teas and drinks. The United States and Germany are among the largest markets for dried hibiscus. In England, much of the herbal tea supply comes from imports via Germany. While specific statistics on the volume and value of hibiscus imports are limited, major consumers of imported hibiscus include herbal tea manufacturers. The plant is a common base ingredient in many herbal and fruit teas, often blended with apple peel, orange peel, and lemon zest.

NUTRITIONAL VALUE [18]

The nutrient content of Hibiscus sabdariffa differs depending on its genetic makeup, environmental conditions, and harvesting methods. Its fresh flower parts (calyces) offer a blend of carbohydrates, small amounts of protein and fat, and are notable for containing vitamin C, β-carotene, iron, and calcium. The leaves serve as a good plant-based protein source and also contribute essential vitamins and minerals, including thiamine, riboflavin, phosphorus, and vitamin C. The seeds stand out for their dense nutritional value, comprising substantial protein, natural oils, dietary fiber, and key minerals like potassium, calcium, magnesium, and phosphorus. Oils extracted from the seeds primarily contain healthy fats, with unsaturated fatty acids like linoleic and oleic dominating, complemented by smaller amounts of saturated fats such as palmitic and stearic acids.

PHYTOCHEMICALS [19-20]

Roselle (Hibiscus sabdariffa) is widely cultivated for its calyces, which are typically green, red, or dark red. The red variety is most commonly used due to its high content of natural pigments, particularly anthocyanins like delphinidin-3-sambubioside and cyanidin-3-sambubioside. These calyces also offer organic acids, vitamins (such as vitamin C), carotene, minerals, amino acids, and sugars. In addition, the plant's seeds and leaves contain beneficial phytochemicals, although their composition may vary with variety and growing conditions. Research has highlighted the presence of several active compounds, including flavonoids, triterpenoids, alkaloids, steroids, and anthocyanidins.

BIOACTIVE COMPONENTS OF HIBISCUS SABDARIFFA [21-26]

Hibiscus sabdariffa contains several bioactive compounds that contribute to its pharmacological properties, including organic acids, anthocyanins, polysaccharides, and flavonoids.

1. Organic Acids

Hibiscus sabdariffa is known for its abundance of organic acids, with tartaric and citric acids being the most prevalent. Water extracts usually feature citric and malic acids, while oxalic and vitamin C appear in smaller amounts. Past research has identified these acids in the flower components, including studies from the 1930s and later, like Linn's work in 1975.

The acid profile of the calyces varies widely, with hibiscus acid comprising up to 14%, citric acid ranging significantly, and tartaric sometimes reaching 80%. Malic, oxalic, succinic, and ascorbic acids are also present, with vitamin C levels in fresh or dried calyces reported as high as 280 mg per 100 grams—more than earlier findings.

Key Bioactive Constituents

The five primary bioactive compounds detected in H. sabdariffa include:

1. Delphinidin-3-sambubioside
2. Cyanidin-3-sambubioside
3. Hibiscus protocatechuic acid
4. Hibiscetin
5. Gossypectin

Organic Acids and Anthocyanins in Hibiscus sabdariffa

2. Hydroxycitric Acid

Hibiscus sabdariffa contains (2S, 3R)-Hydroxycitric acid, a stereoisomer with an additional hydroxyl group at the second carbon of citric acid. This compound differs from the commonly known (2S, 3S)-Hydroxycitric acid (HCA) found in Garcinia species, raising questions about potential differences in their pharmacological effects.

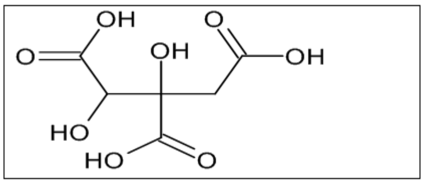

Fig 2. Hydroxycitric acid

3. Hibiscus Acid

Hibiscus acid is the lactone form of (+)-allo-hydroxycitric acid, derived from citric acid with an extra hydroxyl group at the second carbon. It exists in two diastereomeric forms due to the presence of two chiral centers. This organic acid is one of the major components found in the calyces of H. sabdariffa.

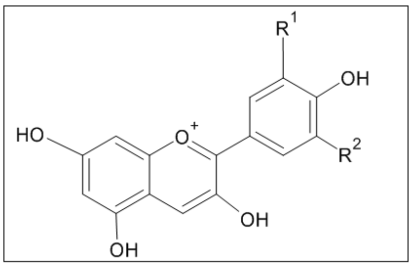

Fig 3. Hibiscus acid

4. Anthocyanins

Hibiscus sabdariffa flowers are rich in anthocyanins, natural pigments that shift color depending on pH levels. These pigments, especially delphinidin-3-sambubioside and cyanidin-3-sambubioside, have been the main focus of scientific studies. Early research in the 1930s first identified these compounds and their structures were later revised through continued analysis. In the 1970s, additional types such as delphinidin-3-glucoside and cyanidin-3-glucoside were isolated from different geographic samples. Some studies also found minor pigments like cyanidin-3,5-diglucoside in specific plant varieties. The levels and types of anthocyanins can vary based on the plant strain and growing region. In general, the dried calyces contain about 1.7% to 2.5% anthocyanins by weight, with delphinidin-3-sambubioside being the most abundant.

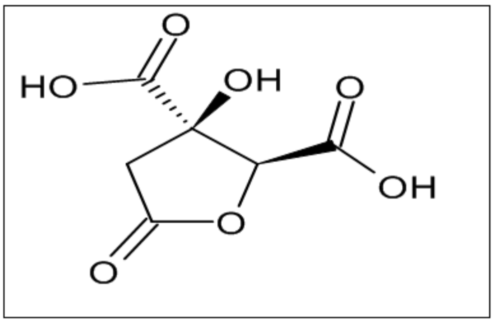

Fig 4. Structure of Anthocyanin

5. Flavonoids

Hibiscus sabdariffa contains a wide range of naturally occurring compounds known for their antioxidant and therapeutic effects. These include a variety of flavonoids such as quercetin, luteolin, and hibiscetin, as well as several glycosides. Among the most prominent are hibiscitrin, gossypitrin, and sabdaritrin. The plant also offers important phenolic acids, including protocatechuic and chlorogenic acid. Quantitative studies have shown around 2.7 mg/g of chlorogenic acid in some samples. Other compounds found in the calyces and leaves include rutin, catechin, ellagic acid, and gallocatechin gallate. Additionally, sterols like β-sitosterol in the leaves and ergosterol in the seeds contribute to its bioactivity. The concentration and presence of these constituents may vary with plant variety and extraction method, making this species useful for both nutritional and pharmaceutical research.

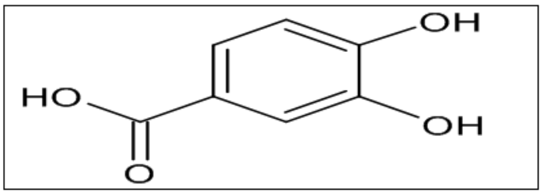

Fig 5. Protocatechuic acid

6. Mucilage content Pectin, and Polysaccharides

Hibiscus sabdariffa petals are rich in mucilage, forming a significant part of their dry mass. This mucilage, when chemically broken down, releases specific sugars such as galactose, rhamnose, and galacturonic acid. The plant's calyces also yield water-soluble polysaccharides in notable quantities. Some studies have shown that alcohol-assisted extraction methods isolate reddish polysaccharide compounds, which include sugar units like arabinose, glucose, and galactose, along with smaller traces of other sugars such as mannose and xylose. Variations among plant strains affect the mucilage levels, which tend to rise in later stages of development, especially in varieties cultivated in Thailand and Senegal. In these strains, mucilage content in calyces can reach over 25%, whereas pectin content typically stays below 5%. These components are largely composed of anhydrouronic acid, contributing to their structure. Compared to the petals, the leaves contain less mucilage—about 10%—highlighting the flower parts as the main source of these bioactive polysaccharides.

7. Lipid content

In 1979, researchers Salama and Ibrahim analyzed the oil extracted from Hibiscus sabdariffa seeds and identified several plant-based sterols, such as β-sitosterol, campesterol, stigmasterol, ergosterol, α-spinasterol, and small amounts of cholesterol. The oil also demonstrated antioxidant properties due to its tocopherol content, primarily β-tocopherol (74.5%), followed by α-tocopherol (25%) and a minor level of γ-tocopherol (0.5%). The fatty acid profile revealed both common and rare compounds, including palmitic (35.2%), oleic (34%), linoleic (14.4%), stearic (3.4%), and myristic acid (2.1%). Notably, unusual fatty acids such as 12,13-epoxoleic acid (4–5%), sterculic acid (2.9%), and malvalic acid (1.3%) were also present.

8. Volatile compounds

The distinctive scent of Hibiscus sabdariffa is linked to its volatile compounds. A 1992 study identified more than 25 volatile substances in the seeds, comprising less than 8% of the total seed content. These compounds included unsaturated hydrocarbons, alcohols, and aldehydes, with carbon chains ranging from C8 to C13. Additional research on water extracts from the plant's calyces identified 37 volatile compounds, categorized into five groups: fatty acid derivatives (such as hexanal), sugar-related compounds (e.g., furfural), phenolics (like eugenol), terpenes (including limonene), and acetic acid.

In another study, volatile compounds were analyzed in aqueous extracts from both fresh and dried calyces using GC-MS. A total of 32 volatiles were detected, with the majority being aldehydes, followed by terpenes and an acidic compound. Common compounds across all samples included hexanal, octanal, nonanal, and geranylacetone. Polyphenols—such as anthocyanins, phenolic acids, flavonoids, and organic acids—play a significant role in the biological properties of H. sabdariffa, contributing to its therapeutic effects.

USES [27-31]

Household and Culinary Uses

Hibiscus sabdariffa, also known as Roselle, is widely appreciated for its versatility in both the kitchen and traditional health practices. Nearly every part of the plant—including its leaves, seeds, roots, and fruits—is utilized in various global cuisines. The bright red, fleshy calyces are especially popular and are processed into a range of food and drink products. These include non-alcoholic beverages such as herbal teas and tonics, as well as syrups, jams, jellies, juices, and dried spice blends. These calyces are known for their high nutritional content, providing essential nutrients like vitamin C, iron, calcium, carotenoids, riboflavin, anthocyanins, niacin, and ascorbic acid.

Young leaves and tender stems are commonly eaten as green vegetables, either raw or cooked. In numerous African regions, the seeds serve as a dietary staple, valued for their richness in proteins, essential fats, and sugars.

Medicinal and Industrial Uses

Hibiscus sabdariffa (Roselle) has a long history of use in traditional medicine across various cultures. In Chinese medicine, it is commonly used to treat conditions like high blood pressure, fever, and liver ailments. Similarly, it is incorporated into Ayurvedic treatments for similar health concerns. Modern research suggests that compounds in the sepals of Roselle, particularly polyphenols like protocatechuic acid, may offer potential benefits in treating leukemia.

While Roselle seeds are not yet widely commercially exploited, they are a rich source of vegetable oil. This oil is low in cholesterol and contains high levels of plant sterols and vitamin E, including β-sitosterol and γ-tocopherol, making it valuable for industrial uses and increasing the economic value of Roselle cultivation.

Roselle tea is a popular herbal remedy known for its health benefits. It is traditionally consumed to ease symptoms like congestion, fever, and indigestion, and is believed to support kidney health, reduce fluid retention, and act as a mild laxative. Some also claim that it may help in cancer prevention. When prepared correctly, these beverages are typically free from microbial contamination.

Phytochemicals such as flavonoids, organic acids, and polysaccharides are believed to contribute to these effects. Additionally, extracts have shown pain-relieving and anti-inflammatory activity, possibly by enhancing IL-10 and reducing COX-2 expression through MAPK pathway modulation.

CONCLUSION

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