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REVIEW ARTICLE

A Review on Extraction, Pharmacological Potential and Therapeutic Applications of *Hibiscus rosa-sinensis*

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Abstract: *Hibiscus rosa-sinensis*, a prominent member of the Malvaceae family, serves as a significant reservoir of bioactive metabolites with diverse therapeutic applications. Phytochemical screenings reveal the presence of alkaloids, tannins, saponins, triterpenoids, and flavonoids, which contribute to its extensive pharmacological profile. Traditional extraction methods, including maceration and Soxhlet extraction, are frequently utilized alongside modern techniques such as microwave-assisted and ultrasound-assisted extraction to isolate these valuable compounds. The plant exhibits substantial anti-diabetic activity, primarily through the modulation of glucose levels and insulin sensitivity. Apart from its metabolic effects, crude extracts and isolated fractions indicate potent antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. Morphological characteristics, ranging from ovate leaves with serrated margins to large, showy bisexual flowers, provide essential diagnostic features for botanical identification. Systematic documentation of its taxonomic hierarchy and geographical distribution highlights its prevalence in tropical and subtropical regions. Current pharmacological investigations validate the traditional use of various plant parts, including roots, leaves, and petals, in treating respiratory ailments, hair disorders, and inflammatory conditions. The integration of high-yielding extraction protocols ensures the preservation of thermolabile constituents, enhancing the efficacy of derived formulations. The literature establishes a foundation for the development of natural therapeutic agents and functional food additives, bridging the gap between traditional ethnomedicine and modern pharmaceutical applications.

Keywords: *Hibiscus rosa-sinensis*; Antidiabetic efficacy; Phytochemical screening; Extraction methods; Pharmacological activity.

1. Introduction

Herbal therapeutics offer a broad spectrum of pharmacological properties, serving as viable alternatives to synthetic agents in the management of numerous infectious and systemic pathologies. These botanical entities possess inherent antibacterial, antioxidant, anti-inflammatory, and cytotoxic potentials that remain central to modern drug discovery [1]. *Hibiscus rosa-sinensis*, popularly recognized as the "China Rose" or the "Queen of the Tropics," occupies a significant position in traditional medicine across Southeast China and the Pacific and Indian Ocean islands. In regions like Hawaii, the plant is regarded as a national symbol, integrated into both ceremonial traditions and local ethnomedical practices [1, 2].

Figure 1. Flowers and Leaves of *Hibiscus rosa-sinensis*

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Historically, various parts of the hibiscus plant have been employed to alleviate febrile conditions, asthma, and systemic inflammation. Scientific validation of these traditional claims has identified potent antioxidant, antifungal, and antibacterial attributes within the flowers [2].

It is a tropical evergreen shrub which belongs to the Malvaceae family and is frequently utilized in folk medicine for treating gastrointestinal distress, including dysentery and diarrhea, as well as respiratory complications like influenza. Its application extends to the regulation of menstrual flow and the enhancement of blood circulation [3]. The plant is known by various synonyms in different regions, including Chinese Hibiscus, Shoeblack, and Blacking Plant, reflecting its versatile historical utility [4].

2. Plant Description and Taxonomy

The systematic identification and classification of *Hibiscus rosa-sinensis* are essential for ensuring the consistency of phytochemical research and therapeutic application.

2.1. Taxonomic Classification

The biological classification of *H. rosa-sinensis* places it within the Kingdom Plantae and the Subkingdom Tracheobionta. As a member of the Super Division Spermatophyta and Division Magnoliophyta, it is categorized under the Class Magnoliopsida and Subclass Dilleniidae. Within the Order Malvales, it belongs to the Family Malvaceae and the Genus *Hibiscus* [5].

Table 1. Taxonomic Classification of *Hibiscus rosa-sinensis*

Taxonomic Rank	Classification
Kingdom	Plantae
Subkingdom	Tracheobionta (Vascular plants)
Superdivision	Spermatophyta (Seed plants)
Division	Magnoliophyta (Flowering plants)
Class	Magnoliopsida (Dicotyledons)
Subclass	Dilleniidae
Order	Malvales
Family	Malvaceae
Genus	*Hibiscus*
Species	*Hibiscus rosa-sinensis* L.

2.2. Geographical Distribution and Habitat

Initially described by Carl Linnaeus in 1753, the specific epithet *rosa-sinensis* denotes its association with China, although it lacks a direct botanical relationship with the true roses of the Rosaceae family. While the plant is cultivated extensively across the globe, botanists note an absence of confirmed wild populations, leading to continued debate regarding its precise native origin [6]. It thrives in tropical and subtropical climates, where it is utilized both as an ornamental shrub and a medicinal resource.

2.3. Morphological and Microscopic Characteristics

Hibiscus rosa-sinensis is a perennial evergreen shrub characterized by a robust taproot system and a light-grey bark. In its natural habitat, the plant can reach heights of 10 meters, although cultivated varieties typically range from 2.5 to 5 meters with a spread of 1.5 to 3 meters [7, 8].

2.3.1. Leaf and Stem

The leaves are ovate and simple, measuring approximately 8 to 10.5 cm in length. They exhibit an alternate phyllotaxy along the cylindrical, branched, and upright stems. The leaf margins are typically serrated with an acute apex, and the venation is described as unicostate reticulate. A notable feature of the foliage is the presence of free lateral stipules and a high mucilage content within the tissues [8, 9].

2.3.2. Flowers and Fruits

The flowers are large, bisexual, and solitary, arising from the upper leaf axils. They can reach a diameter of 25 cm and feature five free petals that are often joined at the base. While the classic variety displays deep red petals, cultivars exist in shades of white, yellow, orange, and purple [10-12]. The calyx consists of five sepals joined in a cup-like structure, often accompanied by an epicalyx. The reproductive apparatus includes a superior ovary with five stigmas and a characteristic long style that facilitates pollen transport. The stamens are numerous and often form a prominent column around the style [13, 14]. The resulting ovoid fruit contains up to 20 seeds and is characterized by a beaked structure that splits into five distinct parts upon maturity.

3. Methods of Extraction

The isolation of medicinally active compounds from *Hibiscus rosa-sinensis* necessitates the use of specific solvents, referred to as the menstruum, to separate bioactive solutes from the insoluble cellular matrix, known as the marc. The efficiency of this process determines the concentration and purity of the resulting phytochemicals.

3.1. Conventional Extraction Techniques

Traditional methods rely on the solubility of plant constituents at varying temperatures and durations, often involving basic equipment.

3.1.1. Maceration

Maceration is a fundamental technique involving the immersion of coarsely powdered hibiscus leaves in a sealed vessel with a suitable solvent, such as ethanol or water, for a period of three to five days. This process occurs at room temperature, making it ideal for isolating thermolabile compounds that might degrade under heat. Periodic agitation increases the concentration gradient, facilitating the diffusion of alkaloids and flavonoids into the menstruum. Following the extraction period, the mixture is filtered through muslin cloth or specialized filter paper to obtain the filtrate, which may then be concentrated via rotary evaporation [15-17].

Table 2. Comparison of Extraction Methods

Method	Temperature	Duration	Efficiency	Best For
Maceration	Room Temp	3–5 Days	Moderate	Thermolabile compounds [17]
Decoction	Boiling (100°C)	15–30 Mins	High	Water-soluble heat-stable compounds [23]
Soxhlet	Solvent Boiling Pt	4–8 Hours	Exhaustive	Non-volatile lipids and steroids [25]
MAE	50°C – 80°C	2–10 Mins	Very High	Rapid isolation of flavonoids [27]
UAE	25°C – 50°C	10–30 Mins	Very High	Sensitive antioxidants and pigments [30]

3.1.2. Infusion and Decoction

Infusions are prepared by steeping plant material in either hot or cold water for brief intervals. Hot infusions are suitable for rapidly extracting water-soluble polyphenols, whereas cold infusions, often requiring 8 to 12 hours, are preferred for preserving delicate antioxidant profiles [18-21]. In contrast, decoction involves boiling the plant material in water for approximately 15 to 30 minutes. This method is particularly effective for extracting heat-stable components and hard plant tissues, ensuring the release of anthocyanins and organic acids into the aqueous medium [22-24].

3.1.3. Percolation and Soxhlet Extraction

Percolation utilizes a cone-shaped apparatus where the solvent slowly passes through a packed column of pre-moistened plant material. This ensures continuous contact with fresh solvent, leading to a highly saturated extract [21, 22]. Soxhlet extraction, or hot continuous extraction, is employed when the target compounds have limited solubility. The solvent is evaporated and condensed repeatedly, passing through a thimble containing the hibiscus powder. This cycle continues until the siphon liquid becomes clear, ensuring exhaustive extraction of non-volatile and heat-stable constituents [25, 26].

3.2. Non-Conventional Advanced Methods

Modern techniques enhance yield and reduce processing time by utilizing physical forces to disrupt plant cell walls.

3.2.1. Microwave-Assisted Extraction (MAE)

MAE utilizes microwave energy to cause dipolar rotation and ionic conduction within the solvent and plant matrix. This generates rapid internal heating, leading to the expansion and eventual rupture of the cell walls, which accelerates the release of intracellular phytochemicals. The efficiency of MAE is heavily dependent on the dielectric constant of the solvent, with ethanol-water mixtures often providing optimal results for extracting flavonoids and phenolic acids within a few minutes [27, 28].

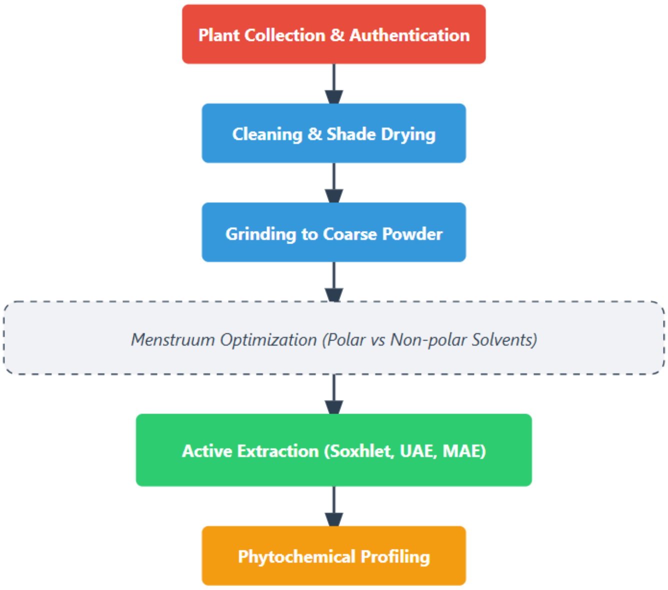

Figure 2. Process for Standardized Extraction and Phytochemical Screening

3.2.2. Ultrasound-Assisted Extraction (UAE)

UAE relies on the phenomenon of acoustic cavitation. High-frequency ultrasonic waves create micro-bubbles in the solvent that collapse violently near the plant tissue. This mechanical action breaks the cell barriers and improves solvent penetration without requiring high temperatures. UAE is highly efficient for the recovery of heat-sensitive antioxidants and anthocyanins from hibiscus petals and leaves, often completing the extraction in under 30 minutes while consuming minimal solvent [29, 30].

4. Phytochemical Composition

The therapeutic efficacy of *Hibiscus rosa-sinensis* is attributed to a diverse array of secondary metabolites identified through qualitative and quantitative screenings.

4.1. Major Phytoconstituents

Phytochemical investigations have confirmed the presence of tannins, anthraquinones, phenols, and flavonoids across different plant parts. The leaves and flowers are particularly rich in alkaloids, saponins, and cardiac glycosides. The plant contains essential amino acids, carbohydrates, and mucilage, alongside specialized cyclopropanoid compounds such as methyl sterculate and malvalate. Steroidal components, notably beta-sitosterol, contribute to the anti-inflammatory and lipid-lowering properties of the extracts [31].

4.2. Quantitative Analysis

Quantitative assessments indicate that the dry weight of the plant contains significant concentrations of bioactive markers. Flavonoids are present at approximately 0.171 mg/100 g, while carbohydrates and proteins constitute 0.356 mg/100 g and 0.247 mg/100 g, respectively. Phenolic compounds (0.092 mg/100 g) and tannins (0.073 mg/100 g) further augment the antioxidant capacity [16].

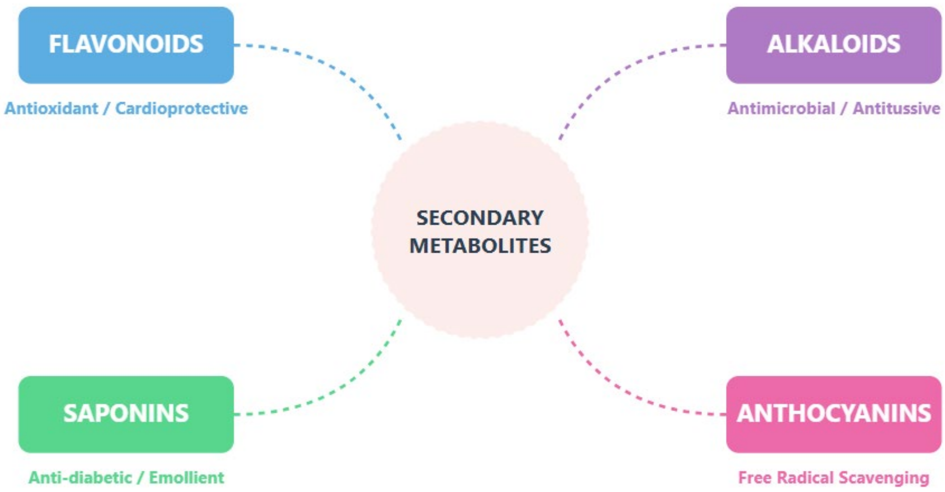

Figure 3. Phytochemical-Bioactivity Mapping of *H. rosa-sinensis*

5. Pharmacological Activities

The biological potential of *H. rosa-sinensis* has been validated through various *in vitro* and *in vivo* models, highlighting its role in managing metabolic and infectious diseases.

5.1. Antidiabetic and Hypolipidemic Efficacy

Ethanolic extracts of the leaves have shown significant blood glucose-lowering effects in diabetic rat models. Doses of 350 and 700 mg/kg body weight resulted in improved insulin sensitivity and a reduction in hyperlipidemia [32, 33]. Similarly, root extracts have shown the ability to restore antioxidant enzyme levels while inhibiting hepatic steatosis, suggesting a protective role against metabolic syndrome [34, 35].

Table 3. Major Pharmacological Investigations

Activity	Plant Part	Model/Subject	Dosage	Primary Outcome	Ref
Antioxidant	Flowers	*In-vitro* DPPH	Variable	Scavenging of free radicals	[28]
Anti-diabetic	Leaves	Wistar Rats	350-700 mg/kg	Significant glucose reduction	[34]
Anti-inflammatory	Leaves	Male Rats	100 mg/kg (i.p)	Reduction in paw edema	[46]
Anti-cancer	Petals	KB Cell Line	75–125 μg	DNA fragmentation/Apoptosis	[50]
Hypolipidemic	Roots	Alloxan Rats	500 mg/kg	Restoration of lipid profile	[33]
Antitussive	Flowers	Citric acid model	Methanolic ext.	Reduction in cough frequency	[50]

5.2. Antioxidant and Anti-inflammatory Properties

The presence of polyphenols and flavonoids facilitates the scavenging of free radicals, thereby reducing oxidative stress linked to chronic disorders [36, 37]. Intraperitoneal administration of leaf extracts has shown effectiveness in reducing carrageenan-induced edema, validating its traditional use in treating bronchitis and oral mucosa inflammation [38].

5.3. Antimicrobial and Anticancer Activity

Extracts exhibit strong inhibitory activity against both Gram-positive and Gram-negative bacteria, including *Staphylococcus aureus*. The antimicrobial action is quantified through zones of inhibition, which vary based on solvent polarity [39, 40]. Studies on oral cancer cell lines have indicated that hibiscus oil extracts induce DNA fragmentation and apoptosis, highlighting its potential in oncological research [41].

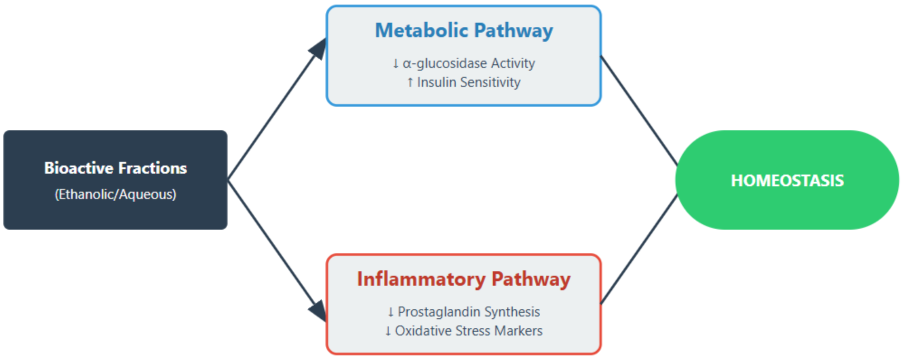

Figure 4. Multi-targeted Mechanism of Action for Therapeutic Efficacy

5.4. Additional Therapeutic Effects

H. rosa-sinensis serves as a natural antitussive agent, with methanolic extracts significantly reducing cough frequency in citric acid-induced models [42]. It also exhibits analgesic, hepatoprotective, and renal-protective effects, particularly in hypertensive and toxin-induced injury models [43-45].

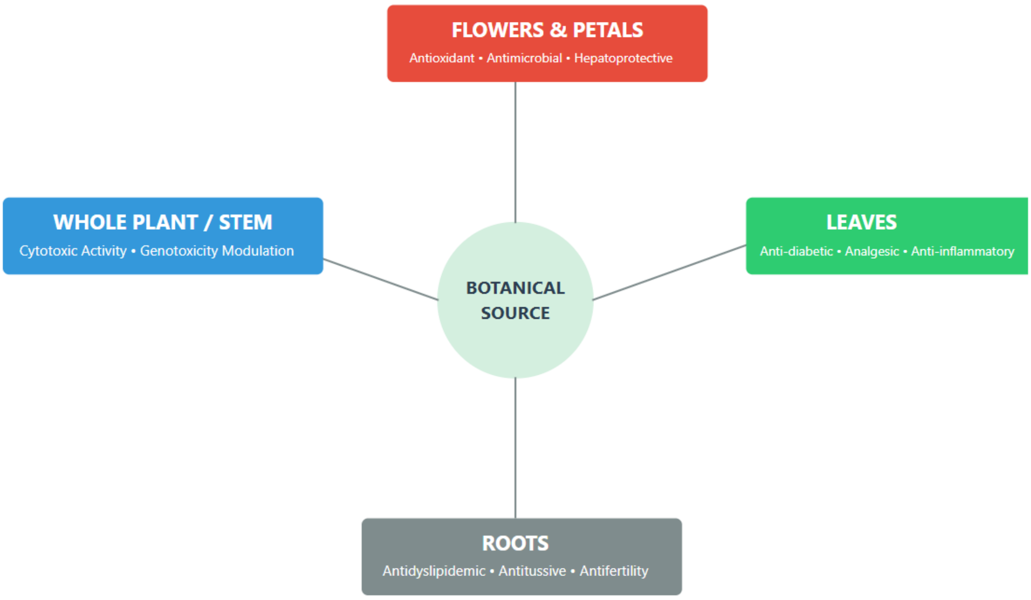

Figure 5. Organ-specific Pharmacological Effects of *H. rosa-sinensis*

6. Industrial and Traditional Applications

The versatility of the plant extends beyond medicine into various industrial sectors.

6.1. Traditional and Ethnomedical Uses

In folk medicine, the roots are prepared to suppress chronic coughs, while the leaves and flowers are integrated into hair care routines to stimulate growth and prevent premature graying. Emollient preparations of the leaves assist in managing gastrointestinal distress, and root decoctions are historically cited in the treatment of venereal diseases [46].

Table 4. Commercial and Industrial Applications of Hibiscus Formulations

Product Type	Primary Function	Bioactive Components	Industry
Conditioning Gel	Hair strengthening	Mucilage and Flavonoids	Cosmetic
Nutraceutical Tea	BP & Weight Mgmt	Anthocyanins & Organic acids	Food & Beverage
Restorative Oil	Scalp health	Essential oils & Steroids	Pharmaceutical
Exfoliating Cream	Skin firming	Alpha-hydroxy acids (AHAs)	Cosmetic
Natural Pigment	Fabric dyeing	Anthocyanin fractions	Textile

6.2 Industrial Applications

In the food and beverage industry, hibiscus serves as a natural colorant and flavoring agent for herbal teas, jams, and jellies [47]. The cosmetic industry utilizes the natural alpha-hydroxy acids (AHAs) found in the plant for exfoliating skincare products and anti-aging creams [48]. Additionally, the textile industry employs hibiscus anthocyanins as biodegradable dyes for cotton and wool fabrics [49, 50].

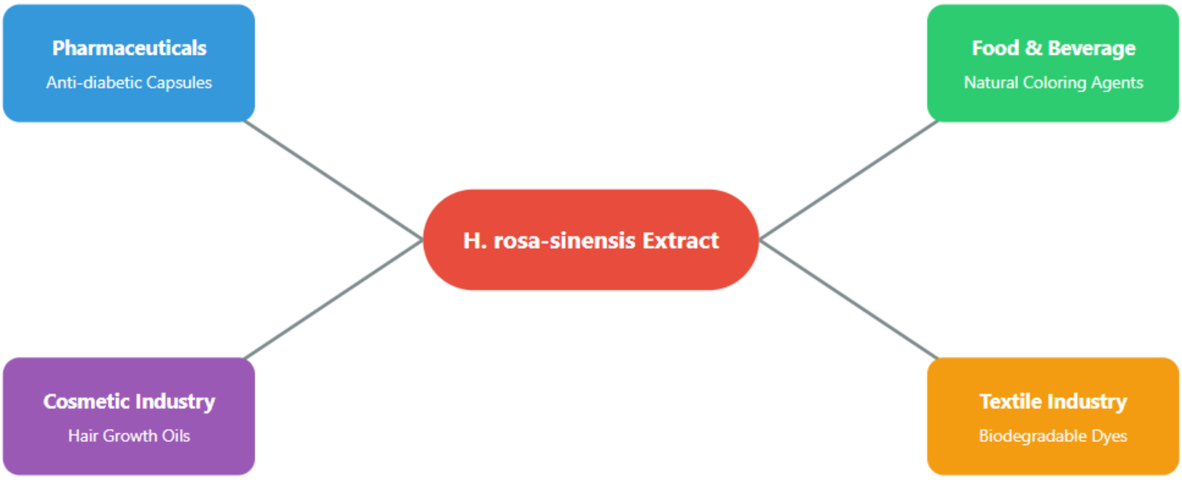

Figure 6. Industrial Applications and Value-Added Products

7. Conclusion

Hibiscus rosa-sinensis represents a multifaceted botanical resource characterized by a rich phytochemical profile and diverse pharmacological activities. The integration of modern extraction techniques has enhanced the recovery of bioactive compounds like flavonoids and anthocyanins, providing a scientific basis for its traditional use. Evidence from various studies confirms its efficacy as an anti-diabetic, antioxidant, and anti-inflammatory agent, alongside promising antimicrobial and anticancer properties. The plant's utility in the food, cosmetic, and pharmaceutical industries further highlights its economic and therapeutic value. Future research focusing on the isolation of specific molecular markers and clinical trials will be instrumental in standardizing hibiscus-based formulations for global healthcare.

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