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Review Paper

Hibiscus sabdariffa Linn.–An overview

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Abstract

***Hibiscus sabdariffa* Linn.** is an annual herbaceous shrub, cultivated for its flowers although leaves and seeds have also been used in traditional medicine. The calyces of the plant are used as a refrigerant in the form of tea, to make jellies and jams. The plant is reported to contain proteins, fats, carbohydrates, flavonoids, acids, minerals and vitamins. The plant has been reported to have antihypertensive, hepatoprotective, antihyperlipidemic, anticancer and antioxidant properties. The present paper is an overview on its phytochemical and pharmacological properties reported in the literature.

Keywords: *Hibiscus sabdariffa, Lal-ambari, Patwa*, Red sorrel, Herbal tea, Herbal medicine.

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Introduction

***Hibiscus sabdariffa* Linn.** is a shrub belonging to the family—Malvaceae. It is thought of native to Asia (India to Malaysia) or Tropical Africa. The plant is widely grown in tropics like Caribbean, Central America, India, Africa, Brazil, Australia, Hawaii, Florida and Philippines as a home garden crop. In Sudan, it is a major crop of export especially in western part where it occupies second place area wise after pearl millet followed by Sesamum[1-2].

In addition to Roselle, in English-speaking regions it is called as Rozelle, Sorrel, Red sorrel, Jamaica sorrel, Indian sorrel, Guinea sorrel, Sour-sour, Queensland jelly plant, Jelly okra, Lemon bush and Florida cranberry. In North Africa and the Near East, Roselle is called *karkade* or *carcadé* and it is known by these names in the pharmaceutical and food-flavoring trades in Europe[3]. In Indian languages it is called as *Gongura, Lal-ambari, Patwa* (Hindi), *Lal-mista, Chukar* (Bengali), *Lal-ambadi* (Marathi), *Yerra gogu* (Telugu), *Pulichchai kerai* (Tamil), *Pulachakiri, Pundibija* (Kannada), *Polechi, Pulichchai* (Malayalam) and *Chukiar* (Assam)[1].

The plant is about 3.5m tall and has a deep penetrating taproot. It has a smooth or nearly smooth, cylindrical, typically dark green to red stems. Leaves are alternate, 7.5-12.5cm long, green with reddish veins and long or short petioles. Leaves of young seedlings and upper leaves of older plants are simple; lower leaves are deeply 3 to 5 or even 7-lobed and the margins are toothed. Flowers, borne singly in the leaf axils are up to 12.5cm wide, yellow or buff with a rose or maroon eye and turn pink as they wither at the end of the day. The typically red calyx, consist of 5 large sepals with a collar (epicalyx) of 8-12 slim, pointed bracts (or bracteole) around the base, they begins to enlarge at the end of the day, 3.2-5.7cm long and fully enclose the fruit. The fruit is a velvety capsule, 1.25-2cm long, which is green when immature, 5-valved, with each valve containing 3-4 seeds. The capsule turns brown and splits open when mature and dry. Seeds are kidney-shaped, light-brown, 3-5mm long and covered with minute, stout and stellate hairs[3].

The species ***H. sabdariffa*** comprises a large number of cultivated types which, on the basis of their growth habit or end use, are classified broadly under two varieties, ***H. sabdariffa*** var. ***sabdariffa*** and ***H. sabdariffa*** var. ***altissima* Wester**. Former is generally bushy and pigmented and cultivated for the edible calyces; the latter includes tall-growing, unbranched types bearing inedible calyces and mainly cultivated for the stem fibre, roselle[1]. Sorrel is cultivated in various parts of Punjab, Uttar Pradesh, Andhra Pradesh, Assam, Bihar, Madhya Pradesh, Maharashtra, Orissa and West Bengal during April to November. The propagation is done by seeds or by rooting shoot cuttings. The edible fleshy calyces are collected after 15-20 days of flowering. Rest of the crop is left in the field until seeds are ready for threshing. The calyces can be dried and stored in air-tight containers[1].

H. sabdariffa is a hardy herbaceous shrub, grows well in most soils that are well drained. The flowers are hermaphrodite and are pollinated by insects[4]. It requires a monthly rainfall ranging from 130 to 260 mm in the first 3 to 4 months of growth. Rain and high humidity during harvest and drying can downgrade the quality of calyces and reduce the yield[5]. Roselle is usually propagated by seed but grows readily from cuttings. The latter method results in shorter plants preferred in India for interplanting with tree crops but the yield of calyces is relatively low[3]. The plants may be cut off 6 weeks after transplanting, leaving only 7.5-10cm of stem in the field. A second cutting is made 4 weeks later and a third after another 4 weeks. Then plants are thinned out and the remaining plants left to grow and develop fruit as a second product. The fruits are harvested when full-grown. The fruits of roselle ripen progressively from the lowest to the highest. Harvesting of seeds takes place when the lower and middle tiers of the last of the fruits are allowed to mature, at this time the plants are cut down, stacked for a few days, then threshed between canvas sheets. The common pests of the plant are root-knot nematode and beetles such as *Nisotra breweri, Lagris cyanea* and *Rhyparida discopunctulata*[3].

In Egypt and Sudan, the deep red tea from the calyces, called *Karkade*, is popular as a refrigerant[2]. It is commonly used to make jellies, jams and beverages. In Ayurvedic literature of India, different parts of this plant have been recommended for various ailments like hypertension, pyrexia and liver disorders. It is traditionally used as antiseptic, aphrodisiac, astringent, cholagogue, demulcent, digestive, diuretic, emollient, purgative, refrigerant, sedative, stomachic and tonic[6-9]. On the basis of traditional uses several phytochemical and pharmacological studies on the whole plant, calyces and seeds have been conducted by researchers. An overview of these reports are presented here to facilitate further investigations and preparation of useful herbal drugs.

Dried calyces

Freshly harvested calyces

Phytochemistry

The leaf is reported to contain protein, fat, carbohydrate, fibre, ash, calcium, phosphorus, iron, thiamine, β-carotene, riboflavin, niacin and ascorbic acid[10-16]. The flower yields a yellow dye; the major pigment identified is daphniphylline. The plant contains flavonoids such as hibiscitrin and hibiscetin[1] and dried calyces contain the flavonoids gossypetine, hibiscetine and sabdaretine. It also contains alkaloids, β-sitosterol, anthocyanin, citric acid, cyanidin-3-rutinose, delphinidin, galactose, pectin, protocatechuic acid, quercetin, stearic acid and wax[17]. Small amounts of delphinidin 3-monoglucoside, cyanidin 3-monoglucoside (chrysanthenin) and delphinidin are also present[3]. Three water soluble polysaccharides have been isolated from flower buds; neutral polysaccarides composed of arabinans and arabinogalactans[18].

The calyces are rich in acid and pectin. Analysis of calyces has shown the presence of crude protein and minerals such as iron, phosphorus, calcium, manganese, aluminium, magnesium, sodium and potassium. Mucilage, calcium citrate, ascorbic acid, gossypetin and hibiscin chlorideare also present in calyces[1].

The seeds contain protein (18.8-22.3%), fat (19.1-22.8%) and dietary fibre (39.5-42.6%) content were found to be high. The seeds were found to be a good source of minerals like phosphorus, magnesium, calcium, lysine and tryptophan contents. Seed oil is rich in unsaturated fatty acids (70%), of which linoleic acid constituted 44%. Seeds contain nitrogen, fatty oil, cellulose, pentosans and starch[19]. Steroids and tocopherols have been reported in the seed oil[19-21]. Kaempferol-3-O-rutinoside, kaempferol-3-O-glucopyranoside, quercetin, 3-O-rutinoside, citrusin C, 2,3-dihydro-2-(4'-hydroxy-3'-methoxyphenyl)-

Table 1: Physicochemical constituents of the fresh calyces and leaves of *H. sabdariffa*

Constituents	Calyces (fresh)	Leaves (fresh)
Moisture	9.2g	86.2 %
Protein	1.145g	1.7-3.2 %
Fat	2.61g	1.1 %
Fibre	12.0g	10 %
Ash	6.90g	1 %
Calcium	12.63mg	0.18 %
Phosphorus	273.2mg	0.04 %
Iron	8.98mg	0.0054 %
Carotene	0.029mg	—
Thiamine	0.117mg	—
Riboflavin	0.277mg	—
Niacin	3.765mg	—
Ascorbic Acid	6.7mg	—

g and mg/100g

Table 2: Phytochemicals of *H. sabdariffa*

Part of the plant	Chemical constituents
Flower	Carbohydrates, arabinans, mannose, sucrose, thiamin, xylose, mucilage, niacin, pectin, proteins, fat, arabinogalactans, rhamnogalacturans, riboflavin, β-carotene, phytosterols, citric acid, ascorbic acid, fruit acids, maleic acid, malic acid, hibiscic acid, oxalic acid, tartaric acid, (+)-allooxycitronic acid-lactone, allohydroxycitric-acid, glycolic acid, utalonic acid, protocatechuic acid, cyanidin-3-glucoside, cyanidin-3-sambubioside, cyanidin-3-xyloglucoside, delphinidin, delphinidin-3-glucoside, delphinidin-3-sambubioside, delphinidin-3-xyloglucoside, delphinin, gossypetin, gossypetin-3-glucoside, hibiscetin, hibiscin, hibiscitrin, sabdaretin, sabdaritrin, fibre (crude), resin, fibre (dietery), minerals and ash.
Seed	Starch, cholesterol, cellulose, carbohydrates, campesterol, β-sitosterol, ergosterol, propionic acid, pentosans, pelargonic acid, palmitoleic acid, palmitic acid, oleic acid, myristic acid, methanol, malvalic acid, linoleic acid, sterculic acid, caprylic acid, formic acid, stearic acid, cis-12,13-epoxy-cis-9-octadecenoic acid, isopropyl alcohol, isoamyl alcohol, ethanol, 3-methyl-1-butanol, fibre and minerals.
Leaf	α-Terpinyl acetate, anisaldehyde, β-carotene, β-sitosterol, β-D-galactoside, β-sitosteryl benzoate, niacin, fat, isoamyl alcohol, iso-propyl alcohol, methanol, 3-methyl-1-butanol, benzyl alcohol, ethanol, malic acid, fibre and ash.
Fruit	α-Terpinyl acetate, pectin, anisaldehyde, ascorbic acid, calcium oxalate, caprylic acid, citric acid, acetic acid, ethanol, formic acid, pelargonic acid, propionic acid, isopropyl alcohol, methanol, benzyl alcohol, 3-methyl-1-butanol, benzaldehyde and minerals.
Root	Tartaric acid and saponin.

3-β-D-glucopyranosylmethyl-7-hydroxy-5-benzofuranpropanol, corchoionoside C and trans-carveol-6-O-β-glucopyranoside were isolated from 70% aqueous ethanol extract of leaves[22]. The physicochemical analysis of the fresh calyces and leaves are given in Table 1 and phytochemicals present in the various parts of the plant are presented in Table 2.

Pharmacology

Antihypertensive

Aqueous extract of petals exhibited antihypertensive and cardioprotective effects in rats[23]. Infusion is also found to lower both systolic and diastolic pressure significantly in spontaneously hypertensive and normotensive rats[24].

Tea of calyces showed 11.2% reduction in the systolic blood pressure and 10.7% decrease in diastolic pressure[25]. Effectiveness and tolerability of a standardized extract was studied in patients with mild to moderate hypertension which revealed a reduction in systolic and diastolic blood pressure by more than 10 per cent[26].

The aqueous extracts of the calyx showed a dose-dependent decrease in mean arterial pressure of the rats[27]. The extract has a vasodilator effect in the isolated aortic rings of hypertensive rats. These effects are probably mediated through the endothelium-derived nitric oxide-cGMP-relaxant pathway and inhibition of calcium influx into vascular smooth muscle cells[28]. Daily consumption of tea lowers blood pressure in pre and mildly hypertensive adults and may prove an effective component of the dietary changes recommended for people at risk of developing hypertension[29]. A

standardized extract has shown effective blood pressure lowering activity in hypertensive humans. A recent double blind, reference-controlled trial demonstrated significant reduction in blood pressure in the hibiscus group when compared with lisinopril[30].

Hepatoprotective

Protective effects of dried flower extracts against oxidative stress in rat primary hepatocytes were demonstrated[31]. Protocatechuic acid, a simple phenolic compound isolated from ***H. sabdariffa*** showed protective effects against cytotoxicity and genotoxicity of hepatocytes induced by t-BHP. One of mechanisms may be associated with its property of scavenging free radicals[32].

The extract of its petals protected rats against cadmium induced liver, prostate and testis lipoperoxidation[33]. The extract offers hepatoprotection by influencing the levels of lipid peroxidation products and liver marker enzymes in experimental hyperammonemia and this could be due to the free radical scavenging property of natural antioxidants present in the plant[34].

The protective effect of aqueous extract and anthocyanins on paracetamol-induced hepatoxicity in rats has also been reported[35]. Aqueous-ethanol (1:1) extract of the calyx showed a significant decrease in the level of lipid peroxidation in carbon tetrachloride induced liver damage[36]. However, a study showed that prolonged usage of aqueous-methanol extract of the calyces could cause liver injury[37].

Antihyperlipidemic

Inhibitory effects of the plant extract on low-density lipoprotein oxidation and anti-hyperlipidemia in fructose and cholesterol-fed rats was demonstrated[38]. It revealed that the extract reduced the level of LDL and the ratio of LDL-cholesterol to HDL-cholesterol. Consumption of dried calyx ethanol extract reduces lipid profile in rats[39]. Hypocholesterolemic and antioxidant effects of aqueous extracts in hypercholesterolemic rats is also reported[40]. Antioxidant effects of the aqueous extracts of dried calyx using rat low density lipoprotein was investigated and the study demonstrated protective effect of roselle on LDL oxidation[41]. Biochemical dynamics and hypocholesterolemic action of the plant demonstrated that its administration induces significant decrease in the activity of serum GOT, GPT, alkaline and acid phosphatase as well as total serum protein. These values nearly returned to the initial levels after 9 weeks of administration[42].

Aqueous extracts of the petals of red and green plant decreases total plasma concentrations in rats indicating cardiovascular protective effects[43].

Antioxidant activity

The antioxidant and free radical scavenging effects of two fractions of the ethanol extract (chloroform soluble fraction and ethyl acetate soluble fraction) obtained from its dried flowers were investigated[44] and found that both the fractions scavenge hydrogen peroxide (79-94%) at the dose of 500µg. Similarly, the extracts showed inhibitory (70-80%) effects on superoxide anions radicals (O_2^-) at a dose of 1000µg. The antioxidant activities of three varieties using liposome system have also been reported. Methanol and ethyl acetate extracts showed higher COX-1 enzyme inhibition than COX-2 inhibition[45].

Anticancer

Anthocyanins can cause cancer cell apoptosis, especially in HL-60 cells[46]. Anti-oxidative activity of anthocyanins was evaluated by their effects on LDL oxidation in cell free system and anti-apoptotic abilities in RAW264.7 cells[47]. The study showed that anthocyanins of this plant may be used to inhibit LDL oxidation and oxLDL-mediated macrophage apoptosis, serving as a chemopreventive agent. Inhibitory effect of protocatechuic acid on tumour promotion in mouse skin demonstrated that protocatechuic acid possesses potential as a cancer chemopreventive agent against tumour promotion[48].

Other activities

Delphinidin 3-sambubioside, a anthocyanin isolated from the dried calyces of ***H. sabdariffa*** can induce a dose-dependent apoptosis in human leukemia cells (HL-60) as characterized by cell morphology, DNA fragmentation, activation of caspase 3, 8 and 9, and inactivation of poly(ADP) ribose polymerase[49]. Ethanol and aqueous extracts of its calyces possess antipyretic activity in experimental animals[50].

Ethanol extract of the plant reduces the extent of cisplatin-induced sperm abnormality and enhanced sperm motility in rats[51]. Inhibition of intestinal motility by methanol extract in rats showed a significant dose dependent relaxant effect on rat ileal strip comparable to the effect shown by nifedipin and papaverine as reference compounds[52]. Investigation of the antispasmodic potential revealed that

aqueous extract of calyces inhibited the tone of various isolated muscle preparations[53].

Effect of zobo drink (***H. sabdariffa*** water extract) on the pharmacokinetics of acetaminophen in human volunteers was studied and the results showed no statistically significant changes in the absorption parameters $t_{1/2}a$, Ka, T_{max}, C_{max} and $AUC_{0\text{-alpha}}$ after the administration of zobo[54].

Investigation of the anti-inflammatory activity showed that its extract had no effect on rat paw edema but had an inhibitory effect on yeast induced pyrexia and a significant effect on the hot plate reaction time[55]. Polysaccharides from its flowers can stimulate proliferation and differentiation of Human Keratinocytes[56]. The study also showed that raw polysaccharides and all acidic fractions cause a strong induction of proliferation of human keratinocytes while the neutral polymers were ineffective. Neuropharmacological effects of the aqueous extract of calyx in rodents revealed that the extract produced a remarkable dose dependent decrease in spontaneous motor activity in mice and increased the duration of pentobarbital induced sleep in rats[57].

Anticlastogenic effects of aqueous extract of fruits in bone marrow cells of mice were studied[58]. The results showed that administration of a crude extract led to a significant reduction of micronuclei in polychromatic erythrocytes and combination of ***H. sabdariffa*** and sodium arsenite reduced significantly the frequencies of micronucleated PCEs induced by sodium arsenite. Studies on *in vitro* enzyme inhibitory and *in vivo* cardioprotective activities revealed that a crude hydroalcoholic extract showed an appreciable enzyme-inhibiting activity towards the angiotensin I converting enzyme, attributable to flavones, but weak inhibiting activities towards elastase, trypsin and alpha-chymotrypsin[59].

Antibacterial activity of gossypetin isolated from ***H. sabdariffa*** was carried out and results revealed that the activity may be due to polyphenolic nature of the flavonoid gossypetin[60]. Investigation on nootropic acitivity of its calyces in mice indicated that the extract of calyces might prove to be useful memory restorative agent in the treatment of dementia seen in elderly which may be due to its anti-acetylcholinesterase property[61]. The haemostatic effect of the leaves was evaluated to confirm its traditional use to arrest bleeding. The extract enhanced coagulation of blood, while causing precipitation of some blood material. The bleeding time was also decreased[62].

Tea made from dry roselle calyces was given to human and analysed for uric acid and other chemical composition related to urinary stone risk factors. The results suggest the urocosuric effect of the tea in human[63].

Conclusion

The reported phytochemical and pharmacological studies support its traditional uses and may prove to be useful for clinical evaluation and development of commercial drugs. Introduction and commercial cultivation of its varieties in India is also recommended.

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