

## Review article

# AN UPDATED REVIEW ON PHYTOCHEMISTRY AND THERAPEUTIC USES OF *Hibiscus sabdariffa* L.

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## Abstract

*Hibiscus sabdariffa* Linn., commonly known as Roselle, is a very popular medicinal plant throughout the world. Besides its use in the preparation of various kinds of delicacies such as jams, puddings, cakes, the plant is widely used in various traditional systems of medicine. This article aims to provide a comprehensive review on the traditional use, pharmacognostical characterization, nutritional and phytochemical composition, and pharmacological properties of Roselle plant. A search for publications made in last ten years was retrieved from the following specialized electronic databases: Elsevier Science Direct, Springer Link, and NCBI. The results of different articles available suggest that the plant is rich in potent bioactive constituents having a range of pharmacological activity supporting its traditional claims. Although marketed formulations/infusions of Roselle are available but further studies should be carried out to evaluate the toxicological profile and therapeutic efficacy of *H. sabdariffa* on humans.

**Keywords:** *H. sabdariffa*; Roselle; pharmacognostical characterization; phytochemical; pharmacology

## Introduction

Medicinal plants are rich in bioactive compounds and are used in various traditional systems of medicine to treat different kinds of ailments. Due to the technological development, these medicinal plants are being studied using modern scientific approaches [1, 2]. The therapeutic potential of a medicinal plant can be evaluated accurately by adopting such modern scientific approaches.

*H. sabdariffa* L., a member of the Malvaceae family is listed as a medicinal plant and is used in Ayurveda, Siddha and Unani systems of medicine [3]. The plant is native to India and is cultivated worldwide for its fibers and calyces. The vernacular names

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of the plant are listed in the Table 1. In India, it is widely grown by the tribal community in the villages of Madhya Pradesh, Maharashtra, Orissa, West Bengal, Assam, Meghalaya and Andhra Pradesh [4]. The annual herb grows to 180 cm or more with glabrous stems, ovate lower leaves, palmately lobed upper leaves. The flowers are auxiliary with white petals and reddish center at the base of the staminal column. The fruits are fleshy when matured and are bright red in color. Roselle is cultivated at the beginning of the rainy season during mid-April and harvested for the calyces of fruits, about 3 weeks till the onset of flowering [5].

Commercially, the calyces of the plant are used for the production of beverages and food stuffs such as tea, juices, jams, jellies and syrup [6]. Hibiscus is used as a sole ingredient in some herbal infusions. In many countries, the leaves are also consumed as vegetable [7]. The dried or fresh calyces, seeds and leaves of *H. sabdariffa* are either eaten raw or in the form of herbal medicines, beverages and fermented drinks [8]. *H. sabdariffa* is traded worldwide for industrial production of teas and beverages. The United States and Germany are the prime markets for dried Roselle. The most desirable product is from Thailand and Sudan; however, the main world suppliers are China and Thailand.

Table 1: List of some vernacular names of *Hibiscus sabdariffa* [9]

Language	Common name
English	Roselle
Assamese	Tengamora, Chukiar
Hindi	Gongura, Lal-ambari, Patwa
Bengali	Lal-mista, Chukar
Marathi	Lal-ambadi
Telugu	Yerragogu
Tamil	Pulichchaikerai
Kannada	Pulachakiri
Malayalam	Pulichchai
Senegal	Bissap
Mexico and Spain	Jamaica
France	Congo
Nigeria	Zobo
Egypt	Karkade
Gambia	Wonjo

### **Culinary use**

Fresh or dried calyces of *H. sabdariffa* are used worldwide in the preparation of herbal drinks, hot and cold beverages, fermented drinks, wine, jam, jellied confectionaries, ice cream, chocolates, flavouring agents, puddings and cakes [10,11,15,16,17]. In Egypt, “cacody tea” is made from the fleshy calyces of Roselle plant. In Sudan and Nigeria, the calyces are boiled with sugar to produce a drink known as “Karkade” or “Zoborodo” while in Mexico this drink is known as Jamaica or “*agua de Jamaica*” or “*té de Jamaica*”. In the West Indies, the calyces are used as colouring and flavouring ingredient of alcoholic beverages. In Africa, the seeds are roasted or powdered and used in meals. In Sudan and Malaysia, the leaves are eaten green or dried, cooked with onions and groundnuts. In China, the seeds are also used for their oil. Another use for the seed is as a substitute for coffee [8].

### **Traditional claims and uses**

In India, Africa and Mexico, infusions of the leaves or calyces are traditionally used for their diuretic, cholerectic, febrifugal and antihypertensive effects, for decreasing the viscosity of the blood and stimulating intestinal peristalsis. In Egypt, calyces preparations are used to treat cardiac and nerve diseases and also to increase urination. In Egypt and Sudan, infusion of calyces is used as a cooling agent [18]. In Guatemala it is used for treating drunkenness. In North Africa, calyces preparations are used to treat respiratory, as well as genital problems, while the leaf pulp is used for treating external wounds and abscesses [19]. In Brazil, the roots are used as stomachic and emollient. In Chinese folk medicine, it is used to treat liver disorders and high blood pressure. In Iran, sour hibiscus tea is reportedly a traditional treatment for hypertension [20], while in Nigeria, the decoction of the seeds is traditionally used to enhance lactation in cases of poor milk production, poor letdown and maternal mortality [21].

The local communities of north east India use Roselle for preparation of various kinds of dishes and also for healing of various diseases. In Mizoram, the sun-dried/smoked Roselle is locally known as “anthur rep” and is used for seasoning vegetables and meat such as fish, chicken, beef, pork etc. Leaves, calyces, petals or whole flowers are traditionally used for their therapeutic potentials. It has been used in folk medicine as a diuretic, mild laxative and for the treatment of kidney, cardiac and liver diseases, hypertension, pyrexia and skin inflammations. In Nagaland, the leaves, petals, fleshy calyces are used for making pickles and sour recipes. Fruits and calyces are traditionally used by Zeliang tribe of Nagaland to treat stomach disorders, as blood purifying agent and as hair tonic. In Assam, the plant is used for the treatment of cardiac and nerve diseases. The leaves along with ginger is used to treat hypertension. Calyx decoction is used as a general antidote for food and chemical poisoning by the ‘Karbi’ tribe of Assam. Also, dried calyces are used to

treat gynecological disorders. In Manipur, the tribals use a decoction of leaves to treat urinary troubles, especially kidney stones.

#### **Nutritional claims and uses**

Many parts of Roselle including seeds, leaves, fruits and roots are used in various foods (Fig. 1A & 1B). The fresh calyx is eaten raw in salads, or cooked and used as a flavoring agent in cakes. The calyx is rich in citric acid and pectin and so is useful for making jams, jellies, soups, sauces, pickles, puddings etc. The juice is widely used in drinks and confectionaries as it imparts a bright red color. Roselle is also rich in minerals, amino acids, organic acids, carotene, vitamin C and total sugar in its calyx, seeds and leaves at different levels depending on the variety and geographical area. A refreshing and very popular beverage can be made by boiling the calyx, sweetening it with sugar and adding ginger. The fruit drinks contain appreciable quantity of carbohydrate, iron, ascorbate and  $\beta$  carotene. It is also rich in bioactive compounds such as anthocyanins and other flavonoids, organic acid, polysaccharides, triterpenoids, steroids and alkaloids which are responsible for its antioxidant, antibacterial, anti-inflammatory, hepatoprotective and anticholesterol activities [8,22,23]. Delphinidin 3-Sambubioside and Cyanidin 3-Sambubioside are the major anthocyanin present in *H. sabdariffa*. Nutritional value per 100 g of Roselle fruits are given in the Table 2. It is reported that the Roselle juice consumption significantly decreases the serum level of iron, total cholesterol and high density lipoprotein, and increases significantly triglycerides and haemoglobin levels. The pharmacological actions of the calyx extracts include strong *in vitro* and *in vivo* antioxidant activity. The seed powder when incorporated in preparation of cookies exhibited improved antioxidant properties as well as high fiber content [24]. The oven dried seeds have been used as a coffee substitute for its aphrodisiac properties. The fermented food prepared from cooked seeds significantly increases the levels of Mg, Na, Al, Fe, Mn and Zn content. The seeds, are high in protein, can be roasted, powdered and used in soups and sauces. The young leaves and tender stems of Roselle can be eaten raw in salads or cooked as greens alone or in combination with other vegetables and/or with meat. They are also added to curries as seasoning because they are rich in organic acids and have rhubarb-like flavor. In view of its reported nutritional and functional properties, *H. sabdariffa* can be a source of active dietary constituents in the prevention of chronic and degenerative diseases as well as to challenge the micro nutrient deficiency [24]. Nutrient contents of different part of *H. sabdariffa* per 100g are presented in the Table 3.

Table 2: Nutritional value of Roselle calyces

Nutritional value per 100 g of Roselle (Raw)	
Energy	205 kJ (49 cal)
Carbohydrates	11.31 g
Fat	0.64 g
Protein	0.96 g
<b>Vitamins</b>	
Vitamin A equiv.	14µg (2%)
Thiamine (B1)	0.011 mg (1%)
Riboflavin(B2)	0.028 mg (2%)
Niacin(B3)	0.31 mg (2%)
Vitamin C	12 mg (14%)
<b>Trace metals</b>	
Calcium	215 mg (22%)
Iron	1.48 mg (11%)
Magnesium	51 mg (14%)
Phosphorus	37 mg (5%)
Potassium	208 mg (4%)
Sodium	6 mg (0%)

Units: µg:Micrograms; mg:Miligrams; g: Grams; cal:Calories

Table 3: Nutritional values of different parts of roselle plant [25]

Nutrients	Calyxes	Seeds	Leaves
Protein(g)	2	28.9	3.5
Carbohydrates[g]	10.2	25.5	8.7
Fats[g]	0.1	21.4	0.
Vitamin A[IE]	-	-	1000
Thiamines[mg]	0.05	0.1	0.2
Riboflabins[mg]	0.07	0.15	0.4
Niacin[mg]	0,06	1.5	1,4
Vitamin C[mg]	17	9	2.3
Calcium[mg]	150	350	240
Iron[mg]	3	9	5



(A)

(B)

Figure 1: (A) *Hibiscus sabdariffa* aerial part and (B) Fresh Roselle calyxes

### Pharmacognostical evaluation

**Macroscopic evaluation:** The macroscopic characteristics of the calyxes and leaves, as determined by Emelia *et al.*, (2020) are depicted in Table 4.

Table 4: Macroscopical parameters of *Hibiscus sabdariffa* calyxes and leaves

Morphology	Description (calyxes)	Description (leaves)
Nature	Fresh	Fresh
Color	Red	Green
Shape	Conical	Palmately lobed
Texture	Acute	Leathery
Odour	Odourless	Odourless
Surface	Pubescent	Glabrous
Arrangement(aestivation)	Valvate	Alternate
Venation	-	Reticulate
Base	-	Symmetrical
Apex	-	Acute
Margin	-	Serrate

**Microscopic evaluation:** Quantitative characteristics such as vein islet number, veinlet termination numbers, stomata number, and stomatal index of *H. sabdariffa* leaves as determined by Emelia *et al.* (2020) is given in Table 5

Table 5: Leaf constants *Hibiscus sabdariffa*

Parameter	<i>Hibiscus sabdariffa</i>
Stomatal number	8.1
Epidermal cell number	31.6
Veinlet number	12.7
Veinlet termination number	17.7
The stomatal index[stomatal per square mm of epidermis]	20.40

**Physico-chemical analysis:** The physico-chemical analysis was done on the extract of the sepals by estimating the extractive values, ash values, swelling index, foaming index, moisture content, and foreign organic matter content. The results of physico-chemical analysis are given in the Table 6 and 7 [26].

Table 6: Physico-chemical parameters of *Hibiscus sabdariffa*

Parameters	<i>Hibiscus sabdariffa</i>
Total ash	6.71±0.56
Acid insoluble ash	4.47 ± 0.25
Water insoluble ash	5.72 ± 0.77
Moisture content	13.50 ±0.50
Foreign organic matter	0.0
Foaming index	111.11 ±3.5
Swelling index	0.0

Table 7: Extractive values of *Hibiscus sabdariffa*

Solvents	Extractive value(%w/w)
Petroleum ether	13.00 ±1.4
50% ethanol	45.00 ±1.9
Water	32.00 ±1.6

**Fluorescent studies:** Fluorescence analysis of the powdered sepals was performed and the results are given in the Table 8[26]

Table 8: Fluorescent studies of *Hibiscus sabdariffa* sepals

Powdered plant sample and reagent	Daylight	Short wavelength(254nm)	Long wavelength(365nm)
Distilled water	Crimson	Brown	Ash
1 NHCl	Crimson	Black	As

1N NaOH	Orange	Green	Ash
10N Sulphuric acid	Crimson	Pink	Brown
Methanol	Crimson	Ash	Ash
Glacial acetic acid	Crimson	Pink	Ash
Nitric acid	Orange	Green	Ash
Chloroform	Colourless	Pink	Ash
50% Ferric chloride	Brown	Black	Ash
50% Ethanol	Crimson	Pink	Ash

### Phytochemicals

The main constituents of *H. sabdariffa* are organic acids, anthocyanins, polysaccharides and flavonoids [27]. The dried calyces contain the flavonoids such as gossypetin, hibiscetin and sabdaretin. The major pigment, formerly reported as hibiscin has been identified as daphniphyllin. Small amounts of myrtillin (delphinidin 3-monoglucoside), chrysanthenin (cyanidin 3-monoglucoside) and delphinidin are also present. Roselle seeds are a good source of lipidsoluble antioxidants, particularly tocopherol [28]. The calyces are rich in organic acids, namely citric acid, malic acid, tartaric acid and hibiscus protocatechuic acid [29,30]. The acid content of the calyces gradually decreases as the fruits start to mature. The presence of anthocyanins in *H. sabdariffa* calyces imparts a very rich red pigmentation to it [31,32,33]. The calyces also contain a high amount of iron (164.78 mg/kg) [34]. The plant is also found to be rich in minerals especially potassium and magnesium. Vitamins (ascorbic acid, niacin and pyridoxine) are present in appreciable amounts [35]. The different phytoconstituents isolated/present in different parts of Roselle extract along with their reported pharmacological activity are shown below in Table 9, and Fig 2 represents the structures of the isolated compounds from Roselle plant.

Table 9: List of the phytoconstituents isolated/present in different parts of Roselle (*Hibiscus sabdariffa*) extract along with their reported medicinal property.

Sl no.	Phytoconstituents	Plant part	Solvent used for extraction	Medicinal property	Reference
1	Flavanoids, tanins, saponins, steroids	Leaves	Methanol	Antibacterial activity	[36]
2	Dephinidinsambubioside, cyanidin	Calyxes	Methanol	Obesity/hyper	[37]



	n, 3sambubioside,delphinidin 3-glucoside,cyanidin 3-glucoside			glycemic activity	
3	Carbohydrates,protein, alkaloids,phytosterol,flavanoids, diterpenes	Leaves and stem	Methanol	Antibacterial activity	[38]
4	Saponin ,phenols, tannins	Leaf	Methanol	Antibacterial activity	[38]
5	Alkaloids ,tannins, saponins,glycosides,phenols , flavonoids	Calyxes	Methanol, ethanol, ethyl acetate and pet ether	Antihypertensive activity	[39]
6	Cyaniding 3-sambubioside and delpindhin 3-sambubioside	Flowers	Methanol, ethanol and hexane	Antioxidant activity	[40]
7	Neochlorogenic acid, chlorogenic acid, cryptochlorogenic acid, quercetin, kaempferol and 5-(hydroxymethyl)furfural	Leaves	Methanol/water with 0.1% acetic acid solution	Antioxidant, anti-inflammatory activity	[41]
8	Gallic acid, gentisic acid, caffeic acid, chlorogenic acid, ellagic acid, ferulic acid, p-coumaric acid, salicylicacid, sinapic acid, veratric acids, catechin, epicatechin, genistein, gossypin, naringenin, quercetin, isoquercetin,rutin, vanillin, cyanidin, delphinidin, malvidin, peonidin, petunidin, cyanidin 3-O-glucoside, delphinidin 3-O-	Flower petals	Methanol	Antioxidant activity	[42]

glucoside, malvidin3-O-glucoside, peonidin 3-Oglucoside and petunidin 3-O-glucoside

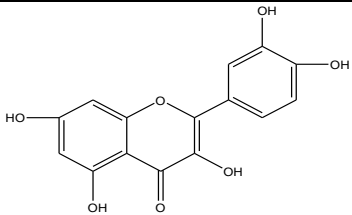
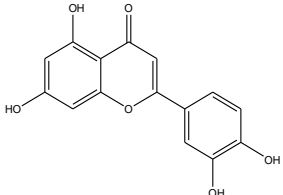
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|----|---|---------|------------------------------------|---------------------------|------|
| 9  | Hydroxycitric acid, hibiscus acid, quercetin, hibiscetin, gossypetin and hibiscin   | Calyxes | Methanol, ethyl acetate and hexane | Vasorelaxant activity     | [43] |
| 10 | Hexadecanoic acid, methyl ester , 9,12- Octadecadienoic acid (Z,Z), methyl ester , 9, - octadecadienoic acid, methyl ester , cyclopropaneoctanoic acid ,dotriacontane, 1,3 benzodioxole, 4methoxy-6-(2-propenyl) and apiol , 17-androstannone, 3-(3, 4-dimethylphenyl) and Sstigmasta-4,7,22-trien-3.beta.-ol, $\alpha$ amyrrin | Seed    | n-hexane                           | Antibacterial activity    | [44] |
| 11 | Phytol , $\alpha$ -tocopherol, methyl linolenate, ethyl palmitate , ethyl linolenate $\alpha$ -terpinyl acetate, anisaldehyde, $\beta$ -carotene, $\beta$ -sitosterol.  | Leaf    | Ethanol                            | Antioxidant activity      | [45] |
| 12 | Delphinidin, cyanidin, kaempferol, quercetin, myricetin, hibiscus lactone, hibiscus acid, caffeoylquinic acids  | Calyxes | 10l of 0.1% TFA aqueous solution   | Hepatoprotective activity | [46] |

13	Vitamin C, anthocyanins, $\beta$ -carotene, lycopene, polyphenols.	Whole plant	Methanol	Antioxidant activity	[47]
14	Delfinidin-3-sambubioside, cyanidin-3-sambubioside, flavonoids, phenols	Calyxes	Aqueous extract	Antioxidant, antiproliferative activity	[48]
15	Hexadecanoic acid ethyl ester	Leaf	Methanol	Antioxidant activity	[49]
16	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	Leaf	Aqueous extract	Anti-microbial, Antioxidant, Antityrosinase, Antinociceptive, Anti-inflammatory activity	[50,51,52,53]
17	$\alpha$ -tocopherol	Leaf	Methanol	Antioxidant Activity	[54]
18	9,15-octadecadienoic acid, methyl ester, 9,12,15-octadecatrienoic acid, ethyl ester.	Leaf	Methanol, ethanol	Antioxidant activity	[55]

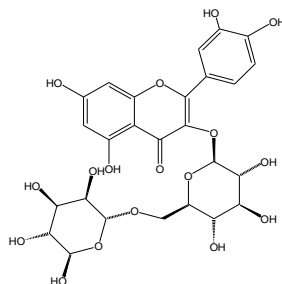
29	Quercetin, luteolin, hibiscitrin, phenolic: chlorogenic, hibiscus acid	protocatechuic, hydroxycitric,	Calyxes	Methanol and aqueous	Obesity/hepatic steatosis.	[56]
20	Protocatechuic anthocyanins	acid,	Calyxes	Methanol, ethanol, hexane, acetone, water, chloroform	Antibacterial activity	[57]
21	Delphinidin-3-glucoside, sambubioside; hibiscetin, eugenol, ergosterol	cyanidin-3-gossypetin, protocatechuic acid, $\beta$ -sitoesterol and	Calyxes	Aqueous and alcohol	Antioxidant and antibacterial activity.	[58]
22	Tannins, carotenoids, alkaloids, glycosides, triterpenoids, anthraquinones	saponins, steroids,	Calyxes	Hydro-ethanol	Antioxidant, antimicrobial activity	[59]
23	Carbohydrate, protein, phytosterols, flavonoids, diterpenes	alkaloids,	Stems and leaves	Methanol	Antimicrobial activity	[60]
24	Saponins, phenol, tannins		Leaves	Methanol	Antimicrobial activity	[61]

25	Anthocyanins, protocatechuic acid, gossypetin, hibiscetin and sabdaretine, Hibiscin (daphniphylline), myrtillin (delphinidin 3-monoglucoside), chrysanthenin (cyaniding 3-monoglucoside), delphinidin.	Flower	Methanolic	Anti-inflammatory activity	[62]
26	Organic acids, polysaccharides, volatile compounds, flavonoids, phenolic acids, anthocyanins.	Calyxes	Aqueous	Renoprotective activity	[63]
27	Saponins, tannins, flavonoids, phenols, triterpenoids, steroids, and fixed oils	Leaves	Methanol	Anti-hypertensive activity	[64]

Fig 2: Some structural representation of important phytochemicals present in Roselle plant [65]

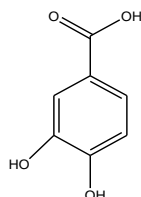
Organic compound	Molecular structure	Origin
Quercetin		Calyx
Luteolin		Calyx

Rutin



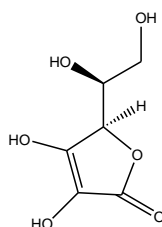
Calyx

Protocatechuic acid



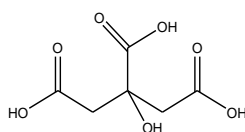
Calyx

Ascorbic acid



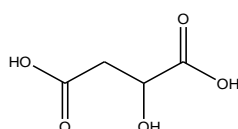
Calyx

Citric acid



Calyx

Malic acid



Calyx

### Medicinal applications

Apart from its traditional uses, *H. sabdariffa* is reported to exhibit various pharmacological activities some of them are discussed below.

**Antioxidant activity:** The calyces of *H. sabdariffa* have repeatedly been studied and shown to have positive health effects. Protective property of a compound to inhibit the oxidative mechanisms by scavenging reactive oxygen and free radicals is known as antioxidant activity. It protects lining organelles from premature cell damage and reduces ageing. A large number of *in vitro* and *in vivo* studies have shown that Roselle calyces contain potent antioxidants. Studies have highlighted that poly-phenolic acid, flavonoids and anthocyanins found in Roselle are potent antioxidants[8]. The antioxidant bioactivity in rat primary hepatocytes and hepatotoxicity was studied by Wang *et al.* It was reported that Hibiscus

anthocyanins, at the concentrations of 0.10 and 0.20mg/ml, significantly decreased the leakage of lactate dehydrogenase and the formation of malondialdehyde and significantly lowered the serum levels of hepatic enzyme markers (alanine and aspartate aminotransferase) and reduced oxidative liver damage. The histopathological evaluation of the liver revealed that Roselle pigments reduced the incidence of liver lesions including inflammatory leucocyte infiltration, and necrosis induced by tert-butyl hydroperoxide (t-BHP) in rats [66]. In animal models, extracts of its calyces have demonstrated hypocholesterolemic and antihypertensive properties irrespective of age, gender or dietary supplement used. The antioxidant potential of three fractions of the ethanol crude extract (HS-C: chloroform soluble fraction; HS-E: ethyl acetate soluble fraction; HS-R: residual fraction) from the dried flowers were evaluated for their capacity to quench free radicals and inhibiting xanthine oxidase (XO) activity. HS-E showed the greatest capacity of scavenging free radical, and HS-C showed the strongest inhibitory effect on xanthine oxidase activity. Furthermore, antioxidant bioactivities of these crude extracts were investigated on rat primary hepatocytes [67]. All fractions were found to inhibit significantly the Unscheduled DNA Synthesis (UDS). These results revealed that the dried flower extracts (HS-C and HS-E) protect rat hepatocytes from tert-butyl hydroperoxide induced cytotoxicity and genotoxicity.

**Hypo-lipidemic activity:** Several studies have showed that extracts of Roselle have a lipid lowering activity, which could prevent diseases like hyperlipidemia and cardiovascular diseases (atherosclerosis and coronary heart disease) [68]. The hypolipidemic effect of ethanolic extract of the leaves of *H. sabdariffa* (HSEE) (100, 200, and 300 mg/kg) was investigated in hyperlipidemic rats. Administration of HSEE (200 mg/kg and 300 mg/kg) together with continuous cholesterol feeding for four weeks caused significant reduction in serum cholesterol level by 18.5% and 22%, respectively ( $P < 0.05$ ) as compared to cholesterol group. However, no significant change in HDL level was observed [69]. The effects of *H. sabdariffa* calyx aqueous extract on the serum cholesterol, body weight and liver marker enzymes activities were studied in normal albino rats. The aqueous extract was orally administered (100 – 800 mg/kg bw for 28 days) to normal male albino rats. *Hibiscus sabdariffa* administration significantly resulted in reduction of serum cholesterol and body weight in a dose and duration dependent pattern [70]. Dietary supplementation with *Hibiscus sabdariffa* was effective in lowering serum concentrations of triglycerides, total cholesterol and LDL-cholesterol in hypercholesterolemic rabbits and hypercholesterolemic rats [71] worked with an atherogenic rabbit model to assess the antiatherosclerotic and lipid-lowering effect of *H. sabdariffa* extracts. Histologically, it was reported that exposure for 10 weeks to doses of a 0.5-1% w/w diet of *H. sabdariffa* aqueous extract resulted in decreased fat cell formation and the inhibition of blood vessel calcification, as well as serum

total cholesterol, LDL, and triglyceride levels. According to a study conducted among hyper-cholesterolemic patients, two capsules of Roselle extract (1g), given three times a day (for a total of 3g/day), could significantly lower serum cholesterol [72]. While another study confirmed that the ethanolic extract from the leaves of Roselle exhibit hypo-lipidemic effect [73]. Subjects with metabolic syndrome that received the ethanolic extract of Roselle had significantly reduced glucose, total cholesterol and low density lipoprotein, while increasing high density lipoprotein [74]. Studies have shown that Roselle tea contains an enzyme inhibitor which blocks production of amylase, and it is possible that drinking a cup of hibiscus tea after meals can reduce the absorption of dietary carbohydrates and assist in weight loss [75].

**Blood pressure lowering activity:** The effectiveness of an aqueous extract of Roselle on mild to moderate hypertension was investigated in many researches. Aqueous extract of Roselle was as effective as captopril in treating mild to moderate hypertension and there is no adverse effect with the treatment, confirming the effectiveness and safety of the extract [76]. Even though the possible mechanism(s) of action of Roselle extract is not investigated, daily consumption of an aqueous Roselle extract resulted in decrease in systolic and diastolic blood pressure [77].

**Anti-diabetic activity:** Extracted polyphenolic components of Roselle were studied for their effect in a type II diabetic rat model (high fat diet model) [78]. Studied revealed anti-insulin resistance properties of extract at a dose level of 200mg/kg, and reduction in hyper glycaemia and hyper insulinemia. The extract was found to be effective in lowering serum cholesterol, triglycerol, the ratio of low density lipoprotein/high-density protein (LDL/HDL), and also (AGE) formation and lipid per oxidation. Intestinal  $\alpha$ -glycosidase and pancreatic  $\alpha$ -amylase help in digestion of complex carbohydrates present in the food into bioavailable monosaccharide and plays an important role in postprandial hyperglycaemia; therefore inhibition of these enzymes has been reported as an effective mechanism for the control of postprandial hyperglycaemia [79]. Hibiscus acid (hibiscus- type (2S,3R)-hydroxycitric acid lactone) have been shown as a potent inhibitor of pancreatic  $\alpha$ -amylase and intestinal  $\alpha$ -glucosidase and pancreatic  $\alpha$ -amylase activity [80]. In an *in vitro* study Roselle extracts was found as an effective inhibitor of pancreatic  $\alpha$ -amylase [81].

**Renal /Diuretic activity:** The renal effect of Roselle has been characterised pharmacologically both in clinical trials and in pre-clinical experiments in rats [82,83,84]. A two-phase study in Thailand with thirty-six healthy men was conducted to evaluate the changes in urine after consumption of Roselle juice (16 g/day and 24 g/day) to determine its effect on the treatment and prevention of renal stones. The study resulted that consumption of Roselle caused a decrease in creatinine, uric acid, citrate, tartrate, calcium, sodium, potassium and phosphate and



it did not affect the concentration of oxalate in urinary excretion. This study suggested that there was no beneficial effect in preventing renal stone formation and that long term and higher doses should be further investigated [85].

**Anti-microbial activity:** Roselle is known for its antibacterial, antifungal and anti-parasitic actions. Oil extracted from seeds of Roselle has been shown to have an inhibitory effect on *Bacillus anthracis* and *Staphylococcus albusin vitro*[86]. Aqueous and ethanol extracts were also found to be effective against *Schistosomamansoni* and other microorganisms, which demonstrated the antibacterial effect of hibiscus extract on *Streptococcus mutans*, a bacterium from oral cavity[87]. In a similar study, antibacterial potential of hibiscus was also observed on *Campylobacter* species. An ethanol extract of the dried leaves of Roselle reduce aflatoxin formation and have *in vitro* inhibitory effect against some fungi[87].

**Anticancer activity:** Various *in vitro* studies have shown that *H.sabdariffa* extracts can induce apoptosis in cancer cells. The anticancer activities of Roselle juice were evaluated by using different cell lines like ovarian (Caov-3), breast (MCF-7, MDA-MB-231) and cervical (HeLa) cancer cell lines and found that it exhibited the strongest antiproliferative potency towards the MCF-7 cancer cells[35]. Another group of compounds present in *Hibiscus sabdariffa* calyx extracts are anthocyanins such as delphinidin-3- sambubioside. They induce apoptosis in human leukaemia cells. Roselle anthocyanins (HA) showed apoptosis of human cancer cells (HL-60) in a dose and time-dependent manner [88]. *H.sabdariffa* leaf extract (HLE) dose-dependently inhibited the migration and invasion of human prostate cancer LNCaP (lymph node carcinoma of the prostate) cells under non-cytotoxic concentrations [89].

**Anti- obesity activity:** Obesity is a growing problem affecting not only adults but also children. Roselle tea is very beneficial in losing weight and preventing obesity. Research studies have suggested that Roselle extract lowers the absorption of starch and glucose and may help with weight loss [90]. A report showed that a standardised (33.64 mg of total anthocyanins per each 120 mg) water extract of calyces of Roselle was able to reduce weight gain in obese mice while at the same time it increase the liquid intake in healthy and obese mice [91]. Various *in vivo* and *in vitro* studies showed that the Roselle extract inhibited the activity of  $\alpha$ -amylase, blocking sugars and starch absorption, which may assist in weight loss [65].

**Other pharmacological activities:** Roselle has been reported to possess a lactogenic activity [92], observed enhancement in the serum prolactin level of lactating female Albino Rats on administration of seed extract of Roselle [10], studied the lactogenic effect of ethyl acetate fraction of *H. sabdariffa*, from 3-17 days of lactation. The results showed an increase in serum prolactin level and milk production in lactating female albino rats, which confirms the lactogenic

property of *H. sabdariffa*. It was also reported that Roselle is considered as a possible anti-obesity agent. Extracts from Roselle are also known to have effect on inflammatory disease and cancer [93]. In one clinical trial involving 50 patients, administration of a decoction of dried fruit (3 g/person, three times every day for 7 days to 1 year) was shown to produce antiinflammatory activity. However, more work on this aspect, using several models for the assay of antiinflammatory activity is warranted. The anthocyanins present in Roselle contribute benefit for health as a good source of antioxidants and as well as a natural food colorant [94]. According to many studies, anthocyanins inhibit the growth of human cancer cells and low density lipoprotein (LDL) oxidation. Therefore, the addition of natural Roselle - Hibiscus anthocyanins (HAs) as food colorants would not only enhance the decorative value of the food but also improve its beneficial properties [95].

#### **Marketed products containing *Hibiscus sabdariffa*.L**

*H. sabdariffa* is extensively used in herbal preparations apart from their use in food industry. This plant is rich in bioactive compounds that can combat various kinds of diseases and disorders. The traditional knowledge together with modern scientific research claims the health benefits of Roselle plant. Some Marketed Products for infusion preparation containing *Hibiscus sabdariffa*L are listed in Table 10[96].

Table 10: List of marketed formulations of *Hibiscus sabdariffa*.L

SL No	Pack names	Plant parts	Statement/claims	Beverage preparation	Doses
1	<i>HIBISCUS</i>	Flowers	“The hibiscus has stimulant and tonic properties that contribute to resistance to physical and mental fatigue. It also helps to reduce the feeling of heavy legs.”	1 bag/cup min	3–5 2–3 cups/day
2	100% Hibiscus flowers	Flowers	-	3–4 tbsp boiling	1 L of -
3	Tea antioxidant, cholesterol control, blood	acai Flowers	-	1 bag/cup Boiling water 5 min	1–1.5 4– L/day Between meals

circulation

4	Tea		Flowers			Infusion	4–5	2–3
	Echinacea, hibiscus, and rosehip			-		min		cups/day Between meals
5	Tea	Ideal	Extract	“The hibiscus combats fluid retention which facilitates weight loss.”		1 bag/cup or 2 bags/500 mL	Cold/hot water	At bed time: 1 bag During the day: 1–2 bags between meals or 1–2 bags/day
6	Eglantine fruit		Flower					2–3 cups/day
	Hibiscus flowers			-		-		
7	Red Rooibos	tea	Flower	(...) high level of antioxidants (...).”		1 bag/cup	Water, 100 °C 3 min	-
8	Detox		Flower	“The hibiscus (...) traditionally is consumed to body well-being and purification.”		1 bag/200 mL	Water, 100 °C 4–5 min	-
9	Draining activity		Flower	In addition to dietary measures for slimming purposes, this product will contribute to the success of your slimming		1 bag	Boiling water 4 min	1–4 infusions/day
10	Decaffeinated		Flower	“Antioxidant mixture (...).”				

green	tea	extract	“Vitamin C to help immune		
blueberry			system (...).”	-	-

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### Future directions and scope in food industry

The *H. sabdariffa* extract when consumed in moderate amounts induced no toxic effects and is safe, thus, it can be introduced in food processing and clinical practices. It has already begun its foray into food industry as dietary fibre, antioxidant and colorant. Fruit flavoured drinks were prepared from dried calyces of *H. sabdariffa* and fruits: apple, orange and pineapple, which showed a shelf-life of more than two weeks [97] reported that cyclodextrin improves the thermal stability of anthocyanins in *H. sabdariffa* extract, both in solution and in solid state. The complex remained intact even at 100–250°C where the free extract got oxidized[48],determined high antioxidant activity of its seeds. When incorporated in cooked beef patties stored at 4°C for 14 days, reduced lipid oxidation compared to BHT-treated patties treated came forth[98], examined the functional properties of the seeds by replacing cookie flour powder at levels of 0–30%. The substitution of 20% showed higher dietary fibre as well as antioxidant content as compared to control cookie [99], used response surface methodology (RSM) to investigate the effect and interactions of processing variables, such as *H. sabdariffa* extract (0.1–1.3%) and soybean oil (5–20%) on physicochemical, textural and sensory properties of cooked pork patties. The preference of color, tenderness, juiciness and water-holding capacity depended on both the additives. The maximum over all quality score was observed when 12.5 g of soybean oil was added to 0.7 g of *H. sabdariffa* extract.

### Conclusion

The result of this review reveals that Roselle is one of the cheap foods, capable of providing a natural micronutrient source and natural antioxidant potential, as well as enhancing mineral availability. Roselle has been reported to use as a flavouring for sauces, jellies, marmalades and soft drinks or to use as a colourant for foods in which Roselle appear to be good and promising sources of water soluble natural red colourants. There is a huge demand for quantification and purification of anthocyanins found in the calyces of Roselle *viz.*, delphinidin-3-sambubioside, cyanidin-3-sambubioside, delphinidin-3-monoglucoside and cyanidin-3-monoglucoside. This result will serve as base data for nutritionists and traditional medical practitioners who may be looking for an alternative source of micro nutrients to combat deficiency diseases. It can be concluded that the *H. sabdariffa* extracts are endowed with many beneficial activities without any significant genotoxic effects. This will further help in generating entrepreneurship opportunities and upliftment of socio economic condition of the farming community.

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