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Review Article

Medicinal Properties, Applications of *Hibiscus sabdariffa* and the Requirement for Further Exploration

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Abstract: In our fast paced environment, modern technology and chemical based medicine dominates the scene of medical world. Medical breakthrough happens every second as we speak and cure for previously untreatable conditions become feasible. However, consumption of chemical based medicines comes with a number of side effects. As a result, many have moved back to using plant based preparations and concoctions which come with little or no side effects. *Hibiscus sabdariffa* is one such plant that has been increasingly becoming popular due to its wide range of applications. *Hibiscus sabdariffa* is known by different names all over the world like roselle, red sorelle, Jamaican sorelle, sorelle, Indian sorelle etc. It is mostly found in Asia, Australia and Africa and consumed in different forms. It has been used traditionally as beverage served hot and cold, as flavouring and colouring agent in the food industry, and as herbal tonics. *Hibiscus sabdariffa* extracts showed antiseptic, aphrodisiac, astringent, cholagogue, demulcent, digestive, diuretic, emollient, purgative, refrigerant, resolvent, sedative, stomachic, tonic, antibacterial, emollient, sedative, anti-oxidant, anti-inflammatory, renal/diuretic effect, anti-cancer, anti-diabetic and anti-hypertensive effects among others. Because of its extensive range of traditional applications and effects on all the above medical conditions there is an enormous need for further investigation on this species.

Keywords: Anticholesterol, Antihypertensive, Antioxidant, Antitumor, Traditional medicine.

Introduction

Hibiscus which is also widely known as the queen of the tropics is grown in many tropical, subtropical and warm temperate regions around the world. It is an erect, annual or perennial bushy or herbaceous woody-based subshrub, growing to 2-2.5 m (7-8 ft) tall. Leaves are dark green to red, alternate, glabrous, long petiolate, palmately divided into 3-7 lobes, with serrate margins and 8-15 cm long, arranged alternately on the stems. Flowers colours are usually red, white, pink, yellow or maroon with a dark centre containing short-peduncles and have a stout fleshy calyx at the base, 1-2 cm wide, enlarging to 3-3.5 cm fleshy and bright red as the fruit matures. The flowers have both male and female parts and take about six months to mature. There are about 30-35 seeds which are covered by a kidney shaped capsule, 2.5cm and are pale green when young, turns into brown colour when it reaches maturity.

Hibiscus sabdariffa is also known as Roselle or Red Sorelle and belongs to the Malvaceae family. The flowers have both male and female organs and take about six months to mature. Roselle tolerates a warm, humid, tropical and subtropical climate, and is frost tender. It is widely cultivated in both tropical and subtropical regions (Morton, 1987; USDA,

2007) including India, Saudi Arabia, China, Malaysia, Indonesia, The Philippines, Vietnam, Sudan, Egypt, Nigeria and México (Chewonarin *et al*., 1999; Dung *et al*., 1999; Eslaminejad & Zakaria, 2011; Ismail, Ikram, &Nazri, 2008; Mahran *et al.,* 1979; Rao, 1996; Sharaf, 1962; YagoubbAel *et al*., 2004). It is used in various parts of India and are known to have different names in each state and region for example, Tengamorain Assam, Jingtahjajewsaw in Meghalaya, Gakroghapha in Nagaland, Silo Sougri in Manipur, Chukar in West Bengal, Pulachakiri in Karnataka etc. The most sought-after produce is from Thailand and Sudan; however, the major world suppliers are China and Thailand, while USA and Germany being the prime markets.

The common pests of the plant are root-knot nematode like *Heterodera radicicola* and beetles such as *Nisotra breweri*, *Lagris cyanea*, and Rhyparidadiscopunctulata. The white roselle is usually prominently infested with the cocoa beetle, *Steirastomabreve* in Trinidad. *Coccus hesperidum* and *Hemichionaspis aspidistrae* mildly attack stems and branches; yellow aphid, *Aphis gossypii,* on leaves and flower buds; and the cotton stainer, *Dysdercus suturellus,* on ripening calyces.

Fig. 1. *Hibiscus sabdariffa* leaves

Traditional uses of hibiscus sabdariffa

There are two main varieties of *Hibiscus sabdariffa*, the first being *altissima*, (Eltayeib and Hamade, 2014) cultivated for its jute-like fibre and the second is *sabdariffa*. Fresh or dried calyces of *H. Sabdariffa* are used in the makingof herbal drinks, hot and cold beverages, fermented drinks, wine, jam, jellied confectionaries, ice cream, chocolates, flavouring agents, puddings and cakes. The seeds are eaten roasted or ground in meals, while the leaves and shoots are eaten raw or cooked, or as a sour-flavoured vegetable or condiment (Wilson &Menzel, 1964). In Sudan, the leaves are eaten green or dried, cooked with onions and groundnuts, Malaysians cookthe leaves and are eaten as vegetables (Ismail, Ikram, & Nazri, 2008). In India it is used to make chutney, pickles and the leaves are boiled to make tea and also boiled with other vegetables to make soup. In Africa, the seeds are roasted or ground into

Fig. 2. *Hibiscus sabdariffa* flower and fruit

Fig. 3. *Hibiscus sabdariffa* plant

Table 1. Names of H.sabdariffa according to different regions and languages.

Language	Common name
English	Roselle
Portuguese	*vinagreira, azeda de Guiné, cururúazédo* and *quiabeiroazédo*
Dutch	*Zuring*
France	*oseille rouge,* or *oseille de Guinée*
Senegal	Bissap
Nigeria	Zobo
Egypt	Karkade
Gambia	Wonjo
Hindi	Gongura, Lal-ambari, Patwa
Assam	Tengamora
Manipur	Sillo Sougri
Meghalaya	Jingtahjajewsaw
Maharashtra	Lal-ambadi
Nagaland	Gakroghapha
Andhra Pradesh	Yerragogu
Tamil Nadu	Pulichchaikerai
Karnataka	Pulachakiri, pundi palle, pundi soppu
Kerala	Pulichchai, mathippuli, pulivenda

powder and used in meals, such as oily soups and sauces. In China and West Africa, the seeds are also used for their oil (Atta & Imaizumi, 2002) and a substitute for coffee (Morton, 1987). Leaves of *Hibiscus sabdariffa* shows larvicidal activities on mosquito larva as per research (Alarcón-Alonso *et. al.,* 2012).

In West Indies, calyces are used to color and give flavour to rum, and the stalks and leaves are added in salad and for seasoning curries. The red pigment from hibiscus is used in meat and poultry, even in cheese, bakery products and beverages as a natural coloring agent. There has been an increase in demand for natural alternatives to artificial food colorants and research has been undertaken to examine the feasibility of these compounds in industrial food use. In Malaysia the oil is used to produce scrubs and soaps (Ismail, Ikram, & Nazri, 2008).

Pharmacology

The flower has been reported to be antiseptic, aphrodisiac, astringent, cholagogue, demulcent, digestive, diuretic, emollient, purgative, refrigerant, resolvent, sedative, stomachic, and tonic (Duke, 1983). Hibiscus, also known as Roselle, has been offered as treatment for abscesses, bilious conditions, cancer, cough, debility, dyspepsia, dysuria, fever, hangover, heart ailments, hypertension, neurosis, scurvy and strangury (vesical tenesmus : describes a symptom of unintentional agonising micturition of small volumes of urine or marked desire to do so, often without any urine passed) (Duke, 1983 and Ross, 2003).

In India, Africa and Mexico, infusions of the leaves or calyces are traditionally used for their diuretic, cholerectic, febrifugal and hypotensive effects, decreasing the viscosity of the blood and stimulating intestinal peristalsis. It is also recommended as a hypotensive in Senegal (Morton, 1987). In Egypt, preparations from the calyces have been used to treat cardiac and nerve diseases and also to increase the production of urine (diuresis). In Egypt and Sudan, an infusion of Karkade calyces is also used to help lower body temperature (Leung, 1996). In Guatemala it is used for treating intoxication (Morton, 1987). In North Africa, calyces preparations are used to treat sore throats and coughs, as well as genital problems, while the emollient leaf pulp is used for treating external wounds and swellings (Neuwinger, 2000). In India, a decoction from the seeds is used to relieve pain in urination and indigestion. In Brazil, the roots are believed to have stomachic and emollient properties. In Chinese folk medicine, it is used to treat liver disorders and high blood pressure (Morton, 1987). In Iran, sour hibiscus tea is reportedly a traditional treatment for hypertension (Burnham, Wickersham, & Novak, 2002), while in Nigeria the decoction of the seeds is traditionally used to enhance or induce lactation in cases of poor milk production and maternal mortality (Gaya, Mohammad, Suleiman, Maje, & Adekunle, 2009).

Antihypertensive:

Tea of calyces showed 11.2% reduction in the systolic blood pressure and 10.7 % decrease in diastolic pressure (Faraji *et al.*, 1999). Effectiveness and tolerability of a standardized extract was studied in patient with mild and moderate hypertension which revealed a reduction in systolic and diastolic blood pressure by more than 10% (Herrera Arellano *et al.*, 2004). Regular intake 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 (Diane L McKay *et al.*, 2008). A recent double blind, reference controlled trial demonstrated significant reduction in blood pressure in the hibiscus group when compared with lisinopril (it is a medicine typically used for high blood pressure, congestive heart failure, and also given after heart attacks) (Ezugwu *et al.*, 2002). Aqueous extract of petals exhibited antihypertensive and cardioprotective effects in rats (Arellano *et al.*, 2004). Infusion is also found to lower both systolic and diastolic pressure significantly in spontaneously hypertensive and normotensive rats (Odigie *et al.*, 1999).

Antioxidant:

A large number of in vitro and in vivo studies have shown that Roselle calyxes contain potent antioxidants. Studies have highlighted that poly-phenolic acid; flavonoids and anthocyanins found in Roselle are potent antioxidants (D Costa Rocha *et al.*, 2014). The antioxidant and free radical scavenging effects of the two fractions of the ethanol extract (chloroform soluble fraction and ethyl acetate soluble fraction) obtained from its dried flowers were investigated and found that both the fractions scavenge hydrogen peroxide (79-94%) at the doze of 500 µg (Faromi *et al.*, 2005).

Presenti *et al.*, 2007 found the total antioxidant power of hibiscus decoction were high and proposed that hibiscus beverages act as a protection against free-radical damage. Due to the high content of tocopherols, roselle seed oils also possess strong antioxidant capacity with highly lipid-soluble extracts (Mohamed R 2007).

Several biological studies have shown *H. sabdariffa* extract to protect liver cells against toxic damage from a variety of causes. Numerous *in vivo* studies have shown a protective effect of hibiscus derived protocatechuic acid (Liu *et al.*, 2002), hibiscus derived anthocyanins (Wang C, 2000) and raw *H. sabdariffa* extract (Tseng *et al.*, 1997) against oxidativestress on the hepatocytes of rats. Hibiscus protocatechuic acid has also beenshown to protect hepatocytes against lipopolysaccharide induced nitric oxide synthetase in rats. Treatment with protocatechuic acid significantly reduced serum concentrations of hepatic enzyme markers associated with hepatotoxicity (Lin WL *et al.*, 2003). Hibiscus extract was shown to weaken acetaminophen-induced toxicity to hepatocytes. High doses were able to restore levels of serum markers indicative of liver damage (Ali *et al.*, 3002). Another study has shown that HSE administered by intraperitoneal injection demonstrates the ability to protect rat liver cells against CCl4 induced fibrosis, significantly reducing serum concentration of marker enzymes associated with hepatocyte toxicity (Liu *et al.*, 2005). Other researchers have demonstrated the ability of HSE to prevent lipid peroxidation in the brain induced by Fe SO4, sodium nitro prusside, and quinolinic acid. This has been demonstrated in vivo to exhibit neuro protective properties in rats (Oboh G *et al.*, 2008).

Anti-tumor:

Anthocyanins and their corresponding aglycones have been screened against a number of common carcinomas, including stomach, colon, breast and CNS cancer cell lines. The sugar substituted anthocyanins exhibited no significant inhibitory effect. However, the anthocyanin aglycones of cyaniding, delphindin, malvidin and pelargonidin exhibited marked inhibition of tumor growth (Zhang Y *et al.*, 2008). The anthocyanins derived from *H. sabdariffa* have been screened against certain human cancer cell lines. The study showed that hibiscus anthocyanin extract prompt apoptosis in human promyelocytic leukemia cells, thought to be mediated by the p38-FasL and Bid pathway (Chang Y *et al.*, 2005). Chewonarin *et al.*, 1999 have demonstrated the ability of ethanol hibiscus extract to prevent mutagenicity of various hetrerocyclic amines, known to be colon carcinogen in rats. It was found that HSE induced apoptosis in AGS cancer cell line in a concentration dependent manner, proposed to be mediated by the JNK/ p38 signaling cascade (Lin H. *et al.*, 2007). Wang C.J. filed for a patent issued in 2011 for the use of anthocyanins derived from H. sabdariffa for the inhibition of tumor growth.

Anthocyanins can cause cancer cell apoptosis, especially in HL-60 cells (Chang *et al.*, 2005). Antioxidative

activity of anthocyanins was evaluated by their effects on LDL oxidation in cell free system and anti-apoptotic abilities in RAW 264.7 cells. The study showed that anthocyanins of this plant may be used to inhibit LDL oxidation and ox LDL-mediated macrophage apoptosis, serving as chemo-preventive agent. Inhibitory effect of proto-catechuic acid on tumor promotion in mouse skin demonstrated that proto-catechuic acid possesses potential as a cancer chemo-preventive agent against tumor promotion (Hsu *et al.* 1998).

Anti-cholesterol/ anti-obesity:

Hibiscus also has a history of use in traditional-medicine relative to weight-loss and reducing cholesterol. Hibiscus tea has been recommended as a safe and natural alternative to many weight loss supplements (Brudnak, 2002). Ethanolic extracts of hibiscus have been shown to reduce the serum lipid profile of rats fed in high lipid content diet (Lin *et al.,* 2011). Aqueous hibiscus extract has also been shown to reduce the levels of LDL and the ratio of LDL to HDL in rats (Lin *et al.*, 2007). There was decrease in weight gain by rats fed with a high fat diet simultaneously with hibiscus extract. This study also demonstrates the ability of hibiscus extract to inhibit LDL oxidation, which is linked to the development of artherosclerosis (Gurrola-Diaz *et al.*, 2010). Studies have also shown the ability of *H. sabdariffa* extract to effect human lipid serum levels. A clinical trial of 42 patients aged 18-75 with a serum cholesterol level of 175-327 mg/dL were observed. After 4 weeks, serum cholesterol levels had been reduced by 8.3-14.4%, showing the potential for *H.sabdariffa* extract to be used as a treatment for patients with hypercholesterolemia (Carvajal-Zarrabal *et al.*, 2009). Treatment of patients diagnosed with metabolic syndrome with powdered hibiscus extract has been shown to lower serum lipid profiles and decrease insulin resistance (Herranz-Lopez *et al.*, 2017) this effect is augmented by exercise. *Hibiscus sabdariffa* extract has been indicated for the use in individuals with metabolic syndrome to control lipid levels.

The potential inhibitory activity against pancreatic lipase was also reported by examining the effect of HSE on fat absorption-excretion and body weight in rats (Peng *et al.*, 2011). Thus, continuous administration of *H. sabdariffa* polyphenols might improve obesity-related metabolic disorders in a similar manner to Orlistat which is lipase inhibitor medicine to treat obesity (Yamada *et al.*, 2007). While this action may be viewed as a potential approach in obesity management, its mechanism in obesity therapy is yet to be explored.

Anti-diabetic:

Extracted polyphenolic components of Roselle were studied for their effect in a type II diabetic rat model (high fat diet model) (Adisakwattana *et al.*, 2012). Studies 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 Advanced glycation end products (AGEs) formation and lipid per oxidation. Intestinal á-glycosidase and pancreatic á-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 (Mojiminiyi *et al.*, 2000). Hibiscus acid (hibiscus- type (2S,3R)- hydroxycitric acid lactone) have been shown as a potent inhibitor of pancreatic áamylase and intestinal á-glucosidase and pancreatic á-amylase activity (Christian *et al.*, 2006). In an *in vitro* study Roselle extracts was found as an effective inhibitor of pancreatic áamylase.

Anti-Inflammatory

Mojiminiyi *et al.*, 2000, confirmed the anti-inflammatory effect. Anti-inflammatory activity has been shown in HSE, mediated by inhibition of cyclooxygenase enzymes 1 and 2. The extracts showed higher inhibition of COX-1 than COx-2, indicating its potential for use as a blood thinner as well. A patent issued in 2004 listed extracts of *H. sabdariffa* as ingredient in a dietary food supplement meant to treat inflammation by inhibition of COX-2 (Nair, 2004).

Renal/ diuretic effect

The renal effect of Roselle has been characterized pharmacologically both in clinical trials (Prasongwatana *et al*., 2008) and in pre-clinical experiments in rats (Laikangbam *et al*., 2012).The cHs WE (250, 500 and 750 mg/kg body weight) also effectively prevented the development of urolithiasis (stone-disorder) in male albino rats (Laikangbam & Damayanti Devi, 2012).

In another pre-clinical study in rats, cHs WE produced diuretic and natriuretic effects at the dose range of 500 to 2500 mg/kg b.w. with a potassium-sparing effect (Alarcon-Alonso *et al*., 2012). This diuretic effect is in accordance with previous studies in experimental animals (Aguwa *et al*., 2004; Caceres *et al*., 1987; Onyenekwe *et al*., 1999; Ribeiro Rde *et al*., 1988) and one clinical trial (Herrera-Arellano *et al*., 2004). In this single clinical trial, assessing a chemically characterised extract of Hs (9.6 mg of total anthocyanins) in patients with mild to moderate hypertension, the treatment demonstrated a natriuretic effect with no effects on chloride, potassium and pH (Herrera-Arellano *et al*., 2004.

Antiparasitic activities

Human lymphatic filariasis, a vector-borne disease, is distributed in tropical, subtropical regions, causing a public health problem. Saxena *et al*., 2011, determined antifilarial activity of ethanolic extract of *H. sabdariffa* leaves by in vitro motility and MTT methods. The results showed that the extract affected both the adult worms and microfilariae of Brugiamalayi. The butanol fraction exhibited remarkable inhibitory effect, which was related to anthocyanin-glycosides. Animal trypanosomosis, a parasitic disease is still the main factor of decreasing the growth of livestock in Africa. (Umar and colleagues, 2009) investigated in vivo the effect of aqueous extracts of *H. sabdariffa* calyces on the heamatological profile and organ pathological changes in *Trypanasomacongolense* infected rats. The results showed that consumption of the extract (9.94 mg/100g/day) enhanced the pathological changes in blood and organs of *T. congolense*-infected rats.

Nutritional values and phytochemistry

Early studies reported that *Hibiscus sabdariffa* contains protein (1.9 g/100 g), fat (0.1 g/100 g), carbohydrates (12.3 g/100 g)

Table 2. List of the constituents isolated/present in different parts of Roselle (Hibiscus sabdariffa) extract along with their property.

Sl.No.	Compound	Plant part	Medicinal property	Reference
1	Flavanoids, tanins, saponins, steroids	leaves	antibacterial	Adamu H and Ngwu RO. 2015
2	Dephinidinsambubioside, cyanidin, 3 sambubioside, delphinidin 3-glucoside, cyanidin 3-glucoside	calyxes	Obesity/hyperglycemic activity	Francisco et al., 2007
3	Carbohydrates, protein, alkaloids, phytosterol, flavanoids, diterpenes	Leaves and stem	Antibacterial activity	Abdallah, 2016
4	Saponin, phenols, tannins	leaves	Antivacterial activity	Abdallah, 2016
5	Alkaloids, tannins, saponins, glycosides, phenols, flavonoids	calyxes	Antihypertensive activity	Okereke et al., 2015
6	Cyaniding 3-sambubioside and delpindhin 3-sambubioside	flowers	Antioxidant activity	Sindi et al
7	Neochlorogenic acid, chlorogenic acid, cryptochlorogenic acid, quercetin, kaempferol and 5- (hydroxymethyl) furfural	leaves	antioxidant, antiinflammatory activity	Zhen et al., 2016
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 glucoside, malvidin3-Oglucoside, peonidin 3- Oglucoside and petunidin 3-Oglucoside	Flower petals	Antioxidant activity	Pacôeme et al 2014

9	Hydroxycitric acid, hibiscus acid, quercetin, hibiscetin, gossypetin and hibiscin	calyxes	Vasorelaxant activity	Zheoa et al., 2019
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, á amyrin	Seed	Antibacterial activity	Hagr TE and Adam IA. 2020
11	Phytol , á-tocopherol, methyllinolenate, ethyl palmitate , ethyl linolenate á-terpinyl acetate, anisaldehyde, âcarotene,â-sitosterol.	Leaf	Antioxidant activity	Subhaswaraj et al., 2017
12	Delphinidin, cyanidin, kaempferol, quercetin, myricetin, hibiscus lactone, hibiscus acid, caffeoylquinic acids	calyxes	Hepatoprotecti ve activity	Ezzat et al., 2016
13	Vitamin C, anthocyanins, âcarotene , lycopene , polyphenols.	Whole plant	Antioxidant activity	Mohd-Esa et al., 2010
14	Delfinidin3-sambubioside, cyanidin-3- sambubioside, flavonoids,phenols	calyxes	Antioxidant, antiproliferative activity	Maciel et al., 2008
15	Hexadecanoic acid ethyl ester	Leaf	Antioxidant activity	Sudha et al., 2018
16	3,7,11,15-Tetramethyl-2- hexadecen-1-o	leaf	Antimicrobial, Antioxidant, Antityrosinase, Antinociceptive, Anti inflammatory activity	Santos et al., 2013; Silva et al., 2013; Pejin et al., 2014; Zhang et al., 2016
17	á-tocopherol	leaf	Antioxidant Activity	Vargas et al., 2014
18	9,15-octadecadienoic acid, methyl ester, 9,12,15-octadecatrienoic acid, ethyl ester.	leaf	Antioxidant Activity	Sharma et al., 2015
19	Quercetin, luteolin, hibiscitrin, phenolic: protocatechuic, chlorogenic, hydroxycitric, hibiscus acid	calyxes	Obesity/hepati c steatosis.	Elizabetha et al., 2018
20	Protocatechuic acid, anthocyanins	calyxes	Antibacterial activity	Cabrera et al., 2013
21	Delphinidin-3-glucoside, sambubioside, cyanidin-3-sambubioside; gossypetin, hibiscetin, protocatechuic acid, eugenol, â-sitoesterol and ergoesterol	calyxes	Antioxidant and antibacterial activity	Hashimi. 2012
22	Tannins,carotenoids, saponins, alkaloids, flavonoids, glycosides, steroids, triterpenoids,anthraquinones	calyxes	Antioxidant, antimicrobial activity	Mensah an Golomeke, 2015
23	Carbohydrate, protein, alkaloids, phytosterols, flavonoids,diterpenes	stems and leaves	Antimicrobial activity	Kumar and Sheba. 2019
24	Saponins, phenol, tannins	leaves	Antimicrobial activity	Garbi et al., 2017
25	Anthocyanins, protocatechuic acid,gossypetin, hibiscetine and sabdaretine,Hibisin(daphniphylli ne), myrtillin (delphinidin 3- monoglucoside), chrysanthenin(cyaniding 3- monoglucoside),delphinidin	flower	Antiinflammatory activity	Ali et al., 2007
26	Organic acids, polysaccharides, volatile compounds, flavonoids, phenolic acids, anthocyanins.	calyxes	Renoprotective activity	Balogun et al., 2016
27	Saponins, tannins, flavonoids, phenols, triterpenoids, steroids, and fixed oils	leaves	Antihypertensive activity	Mojica et al., 2012

and fibre (2.3 g/100 g). They are rich in vitamin C(14 mg/100 g), b-carotene (300 lg/100 g), calcium (1.72 mg/100 g) and iron (57 mg/100 g) (Ismail *et al.*, 2008)

- The leaves contain protein (3.3 g/100 g), fat (0.3 g/ 100 g), carbohydrate (9.2 g/100 g), minerals (phosphorus (214 mg/100 g), iron(4.8 mg/100 g) thiamine (0.45 mg/100 g), b-

carotene (4135 lg/ 100 g), riboflavin (0.45 mg/100 g) and ascorbic acid (54 mg/100 g) (Ismail *et al.*, 2008).

- The seeds contained crude fatty oil (19-21.85%), crude protein(18-27.78%), carbohydrate (21.25%), crude fibre (16.44%) and ash(6.2%). In terms of minerals, the most prevalent is potassium (1329 ± 1.47 mg/100 g), followed by sodium (659 ± 1.58 mg/ 100 g), calcium (647 ± 1.21 mg/100 g), phosphorus (510 ± 1.58 mg/100 g) and magnesium (442.8 ± 1.80 mg/100 g). The major saturated fatty acids identified in the seed oil are palmitic (20.84%) and stearic (5.88%) acids and the main unsaturated fatty acids are linoleic (39.31%) and oleic acid (32.06%) (Nzikou *et al.*, 2011).

The seed powder when assimilated in preparation of cookies exhibited improved antioxidant properties as well as high fibre content. 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. (Puro K *et al.*, 2014)

Seeds are a good source of lipid soluble antioxidants, particularly ã-tocopherol. Its seed oil was extracted and characterized, and its physicochemical parameters were reported: acidity, 2.24%; peroxide index, 8.63 meq/ kg; extinction coefficients at 232 (k232) and 270 nm (k270), 3.19 and 1.46, respectively. Oxidative stability, 15.53 h; refractive index, 1.477; density, 0.92 kg/L; and viscosity, 15.9 cP. Roselle seed oil belongs to linoleic/oleic category, most abundant fatty acids being C18:2 (40.1%), C18:1 (28%), C16:0 (20%), C18:0 (5.3%), and C19:1 (1.7%). Sterols include â-sitosterol (71.9%), campesterol (13.6%), "-5-avenasterol (5.9%), cholesterol (1.35%), and clerosterol (0.6%). Total tocopherols were detected as an average concentration of 2000 mg/kg, including á-tocopherol (25%), ã-tocopherol (74.5%), and ä-tocopherol (0.5%). The seed powder when incorporated in preparation of cookies exhibited improved antioxidant properties as well as high fiber content (Anel TC *et al.* 2019).

- The calyces are rich in acid and pectin. Crude proteins and minerals such as iron, manganese, phosphorous, calcium, aluminium, magnesium, sodium and potassium were seen to be present. In the late 1930s, citric and malic acids were first reported in aqueous extracts of the calyx (Buogo & Picchinenna, 1937; Indovina & Capotummino, 1938; Reaubourg & Monceaux, 1940) and also in five different strains (from Egypt, Senegal, India, Thailand and Central America) of *H. sabdariffa* varieties (Khafaga *et al.*, 1980). Ascorbic acid is also present in Hs but its content varies dramatically between fresh (6.7–14 mg/100 g (Ismail *etal.*, 2008; Morton, 1987)) and dried calyces (260–280 mg/100 g (Ismail *et al.*, 2008). The amount of ascorbic acid in the latter report being much higher than the ones previously reported in the literature. The differences observed might be due to different varieties, genetics, or external factors such as environment, ecology and harvest conditions.
- The flowers contain gossypetin, anthocyanin, and the glycoside hibiscin. These may have diuretic and choleretic effects, which decreases the viscosity of the blood, reducing blood pressure and stimulating intestinal peristalsis (Onyenekwe PC, *et al.* 1999)

Protocatechuic Acid (PCA), a phenolic compound isolated from the dried flower, was found to inhibit the survival of human promyelocytic leukemia (HL-60) in a concentration and time dependent manner, and apoptosis was induced via reduction of retinoblastoma phosphorylation and down regulation of Bcl-2 protein expression (Tseng *et. al.*, 2000)

Common recipes using *Hibiscus sabdariffa*:

1. Tea: The leaves and calyces of *H.sabdariffa* can be brewed and drank as tea. Roselle tea is very popular especially in the north eastern part of India. The leaves and calyces of roselle are washed and then dried under the sun, shade or dehydrated by using dehydrator. Roselle tea can be either served as hot tea or cold beverage. Roselle tea is a popular sugary herbal tea in Africa. Roselle tea was found to be beneficial in lowering high blood pressure and cholesterol, to sooth sore throat, and also aided in weight loss. Roselle tea is also produced in Jamaica by adding additional flavour from ginger. Roselle flowers are also widely used to make herbal tea (Mohamed *et al.* 2012).

2. Soup: Roselle is also consumed as vegetable in many parts of the world. Roselle leaves are boiled with other vegetables like potato, onion, fermented fish, and dried shrimp and consumed as soup or with white rice in the north eastern part of India. In Sudan, the leaves are eaten green or dried, cooked with onions and groundnuts, while in Malaysia the cooked leaves are eaten as vegetables (Ismail *et al*., 2008)

3. Zobo drink: Zobo drink originated from the northern part of Nigeria. It is prepared by boiling the dried calyces of *Hibiscus sabdariffa* in water for about 10-15 minutes from which the pigment or flavor embedded is extracted. After extracting the filtrate, it may be taken as hot tea or allowed to cool and packed in plastic sachet or containers and consumed as a refreshing drink when chilled, the sharp taste of raw extract is usually sweetened with sugar cane or granulated sugar, pineapple, orange or other fruits depending on choice. The sweetness of 'Zobo' drink does not last long due to spoilage by microbial activities; its shelf of life is approximately 48 hours following production if not refrigerated (Okereke *et al*., 2015)

4. Chutney or pickle: Roselle is made into chutneys and pickles in the southern part of India. Leaves are boiled with onion and green chillies till the leaves become soft. The water is discarded and the boiled ingredients are ground in a blender with salt to taste. In a frying pan, various spices like mustard, cumin, garlic and red chilli are fried in oil and mixed with the previously prepared chutney. This chutney is eaten with hot white rice. (https://seasonalflavours.net/gongura-pachadi-recipe-andhra/)

5. Jam: Roselle calyces can be used to make delicious jam. First the seed is separated from the calyces and the calyces are washed thoroughly and boiled with just enough water to cover the calyces. It is boiled until the calyces go soft and sugar is added as required. The ingredients are boiled for about 5 to 10 minutes until the consistency becomes thick and jammy. This jam can be enjoyed with bread. Calyx of roselle is rich with various nutrients especially vitamins (B1, B2, B3 and C), minerals and antioxidants. Roselle jam and jelly are also manufactured in different countries of the world. (Morton 1987; Mohamed *et al*., 2012)

Conclusion:

Hibiscus sabdariffa has many therapeutic properties and there are many researches that support this. With the increasing interest in herbal medicine which has proven to have little to no side effects, plants like *Hibiscus sabdariffa* with its uncountable number of medicinal benefits is one of the front runners in the field of modern medicine. The *Hibiscus sabdariffa* plant does not require any special care and condition; it requires little or no human intervention which is also another added advantage for its use for medicinal purpose. It is cost effective, easily available and considerably simple to use. With more directed studies on the various properties of *H. sabdariffa* like antioxidant, antihypertensive, anti-obesity, anti-cancerous, anti-diabetic, anti-bacterial, anti-fungal, anti-parasitic, diuretic, anti-inflammatory, a further effectual use of the plant can be achieved.

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