

Hibiscus sabdariffa (Roselle): Unveiling its Nutritional Profile and uses

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ABSTRACT

Hibiscus sabdariffa known as roselle, is a tropical plant that people grow because its red calyces offer numerous health and nutritional benefits. People grow roselle extensively in Africa, Asia and the Caribbean because this Malvaceae species thrives in warm temperatures. People appreciate the plant because it serves many food and drink purposes while providing healing benefits and essential nutrients. The red color and powerful antioxidant power of hibiscus come from the many bioactive substances in its calyces, including anthocyanins, flavonoids, and phenolic acids. The plant contains essential vitamin B along with vitamins C and A plus nutritional fiber and mineral nutrients. The plant provides great value for health because its small caloric value and fat level make it ideal for nutritional supplements. People use it to create herbal tea blends and drinks, plus multiple other products like jam and syrup. People pick hibiscus tea because it provides refreshing drinks with a cranberry taste. Medical science recognizes H. sabdariffa because it helps the liver while reducing blood pressure and improving cholesterol levels. Traditional medical treatments, such as diabetes, hypertension which depend on hibiscus because it shows properties that

reduce bacteria and inflammation. Roselle easily fits into culinary uses because people make savory dishes, sauces, and desserts with it. From health benefits to culinary use hibiscus stands out as an important plant for society and food science. The future investigation needs to perform clinical trials while establishing standardized extraction techniques for developing functional food items and nutraceuticals. Further evaluation of *H. sabdariffa* in sustainable agriculture practices as well as cosmetic applications, has the potential to boost its commercial possibilities. This review confirms how *H. sabdariffa* represents a plant with multiple uses that shows potential across health domains and nutritional sections and industrial applications.

Keywords: Anthocyanins, Antioxidant, Traditional medicine, Nutritional supplement

Introduction

The plant family Malvaceae member *H. sabdariffa*, known as roselle suits poor countries since it grows well easily and helps multiple crops plus nations use it for food and fabric production most everywhere. *H. sabdariffa* maintains worldwide popularity as a tropical and subtropical farming staple. After the last frost is over plant *H. sabdariffa* seeds directly into warm soil The plant needs consistent water until seed emergence while needing direct sunlight to grow well. Regular light watering develops robust health in the plant most during dry seasons after its roots settle. People harvest the calyces at their deep red peak when they are ready for use. The plant starts producing calyces 90 to 120 days following its planting. Once the calyces dry you can either start using them or set them aside for future use. Spider mites, aphids, and whiteflies create problems for *H. sabdariffa* plants. Successful plant development depends on continuing checks and proper management practices.

Table 1: Taxonomical classification of *H. sabdariffa* (Sim and Nyam, 2021)

Kingdom	Plantae
Subkingdom	Tracheobionta
Division	Magnoliophyta
Class	Magnoliopsida
Order	Malvales
Family	Malvaceae
Genus	Hibiscus
Species	Rosa-sinensis

The annual or perennial herb *H. sabdariffa* can reach a height of 2 to 2.5 meters (7-8 feet). The deeply lobed leaves are placed alternately on the stalks and range in length from 8 to 15 cm (3-6 inches). The flowers have a dark red base and white to pale yellow petals, and they are 8–10 cm (3–4 inches) in diameter. As they grow, the calyces which is the plant's primary edible portion become meaty and scarlet red (Sanou et al., 2020). West Africa uses the leaves and powdered seeds in food, whereas China uses the seeds for their oil and the plant for its therapeutic qualities. Furthermore, the food and pharmaceutical industries employ it (Rocha et al., 2014).

The calyces are the most important component of the plant, however practically every part is utilized to prepare meals. Roselle plant has been used to make tea or beverages, serve as a colouring ingredient, and make traditional remedies. In Florida, calyces are used to make "cranberry," while in Europe, they are used to prepare liqueurs for the creation of soft drinks in Nigeria. The use of calyces extracts in the production of alcoholic beverages is permitted under US regulations. The drink's nutrient and therapeutic qualities, as well as its affordable, easily accessible, and simple preparation, as well as its pleasing flavour, colour, and aroma, are the reasons for its rising consumption rate. Millions of people from all socioeconomic backgrounds in West Africa currently drink it, and it has gained popularity as a refreshing beverage throughout the world. Due to the drink's widespread usage, many women in West Africa now make a living from selling it (Salami et al., 2023).

Table 2: Nutrient composition per 100g of calyx (Swati et al., 2023)	
Water	84.5%
Protein	1.99g
Fat	0.1g
Ash	1.2g
Total carbohydrate	12.3g

The red calyces are used to make drinks, jams, and other culinary goods, but many other parts of the roselle, including the leaves, seeds, flowers, and roots, are eaten. As with spinach you cook and eat the leaves as a vegetable. Farmers in Niger include *H. sabdariffa* leaves in millet or sorghum diets as a nutritious sauce component. Laboratory tests showed that *H. sabdariffa* leaves deliver useful amounts of micronutrients, including iron, manganese, copper, and zinc. The low level of natural sugar in Roselle calyx makes it a nutritious choice because it contains high amounts of iron and potassium, along with vitamin C and malic acid. The roselle plant seeds deliver vital minerals plus protein alongside a significant amount of dietary fiber, according to Omabuwajo et al. (2000).

People grow Roselle plants to harvest their flower pods leaves and seeds. The seeds provide oil while we cook both leaves and stalks as vegetables or salad items. People value calyces most because they use them to make drinks such as sorrel in Caribbean regions and karkadeh in Arab communities. According to Bouker and colleagues from 2024 traditional medicine utilizes this plant to treat diabetes liver issues and high blood pressure. Fresh calyx material deteriorates soon while holding high water content. The dried calyces retain their functional properties while becoming ready to apply in various industries. Various present-day and traditional procedures exist to dry hibiscus calyces including vacuum drying and roasting alongside natural sun drying. The highest retention of ascorbic acid, phenolic compounds, and flavonoids in hibiscus calyces happens when researchers bake at 135°C for 9 minutes under -0.6 bar vacuum pressure at 35°C and boil at 115°C for 30 seconds. To keep dried calyces at their best you need to store them properly. Placing dried goods in a dark safe place with little moisture and temperature helps prevent product damage. When placed in airtight containers the calyx nutrients together with its taste and color values remain stable (Nguyen 2020).

Nutritional Profile of *H. sabdariffa*

The plant *H. sabdariffa* inspires widespread cultivation because the tea maker extracts its fruit's edible tissue for quality beverages with their distinctive color and therapeutic properties. Different plant compounds including anthocyanins, phenolic acids, flavonoids, and tannins thrive in *H. sabdariffa*. The plant's chemical components help reduce inflammation and lower high blood pressure while providing strong antioxidant protection. This review examines the nutritional elements of *H. sabdariffa* including its bioactive substances, main nutrients and trace nutrients (Joven et al., 2014).

Macronutrients in *H. sabdariffa*

Proteins

Plant-based diets benefit from *H. sabdariffa* seeds because these seeds deliver 19.18% protein from natural sources. Proteins help build tissue, heal damage and support body processes including hormone production while handling protein-based functions (Hounkpè et al., 2019). Food scientists study that roselle seeds due to their harmonious amino acid profile with legumes making them a protein alternative for plant-based diets. For generations people have known that legumes provide high protein but roselle shows a similar protein capability. Human health needs essential amino acids which are found in the proteins of roselle seed. Due to its incapability to create them the body requires obtaining essential amino acids through dietary sources (Singh et al., 2017).

The amino acids found in *H. sabdariffa* matter because human bodies cannot create these specific protein building blocks. Roselle seeds deliver eight key amino acids including lysine, methionine, valine, leucine, isoleucine, phenylalanine, threonine and tryptophan. For instance, lysine is required for enzyme synthesis, hormone synthesis and antibodies, immune system and calcium absorption. Muscle build-up and tissue remodeling are controlled by Leucine, while mood and cognitive function are controlled by Phenylalanine. Facilitating tissue repair and muscle metabolism is the function of valine. *H. sabdariffa* contains some non-essential amino acids that can be produced by the body apart from the essential amino acids. Some of these are arginine, proline, serine and alanine, glutamic acid and aspartic acid. Additionally, aspartic acid and glutamic acid are both categorized as being involved in metabolic and neurotransmission. Arginine play a crucial role in immunological defense and angiogenesis that aids in healing of the human body. Proline is helpful for skin health and it also promotes collagen synthesis. Serine is used in the manufacturing of nucleotides and proteins (Ogo et al., 2021).

Carbohydrates

Carbohydrate constituents formed about 56.16% of dry weight of roselle seeds. From *H. sabdariffa*, the main power necessary for all the activities and functions throughout life is obtained. These carbohydrates include; dietary fibers, complex carbohydrates, and simple carbohydrates. Carbohydrates also have an energy reservoir that is longer lasting compared to fat in form of starch and other complex polysaccharides but if you want energy now then fructose and glucose will do the honors. Compounds that help promote gut health and ease digestion are also factored in roselle's carbohydrate list

which belongs to dietary fibers.

Carbohydrate is the befitting and primary energy provider of the body. The carbohydrates that are ingested with *H. sabdariffa* are metabolized into glucose for use as fuel by the cells of the body. The above is very important and should be encouraged prominently for physical activity and body functions. It has both the, simple and complex carbohydrates therein to ensure that energy is gradually released to leave out the sugar rush and dump effect. Other external factors that influences the carbohydrate composition of *H. sabdariffa* includes harvesting period, post-harvest processing and ambient conditions. For example, it has been proved that controlled sieving and drying procedures can affect the content of sugars and fiber and the extent of the processing loss (Singh et al., 2017).

Fats

Hibiscus seed contain 13.6% total fatty acids where six essential fatty acids are found in hibiscus seeds oil. At the same time, the fat level of *H. sabdariffa* fresh calyces is 2.61 % which makes it a low-fat food. This fat is good for the heart, and it is made up of unsaturated fatty acids that make up majority of this fatty substance. The fact that monounsaturated and polyunsaturated fats can in fact reduce the levels of bad cholesterol and the likelihood of getting sick from heart disease is a fact well understood all over the world. There are good reasons for ingesting fats which includes protecting our vital organs, energy reserve, and thermal protection. Another factor known as linoleic acid as part of the lipid profile was determined in *H. sabdariffa* (Hounkpè et al., 2019)

Fiber

Another benefit that results comes from the dietary fibre that is contained in *H. sabdariffa* which aids in digestion as well as promoting the feeling of being fuller, in addition to maintaining a healthy track for the digestive system. Essential for the prevention of digestive diseases and controlling constipation is the use of dietary fibers. *H. sabdariffa* contains soluble and insoluble fibers to mention but a few. Fiber is part of the carbohydrate content of *H. sabdariffa*. Proper digestion entails dietary fiber that is found in the seeds and calyces of the plant. Discrimination between constipation and loose motion is made; normal passage is eased and the composition of the gut microbiome is promoted. It has been revealed that insoluble fiber assists waste move through the colon, on the other hand, soluble fiber assist in regulating the blood glucose levels and cholesterol level (Montalvo-González et al., 2022).

Fiber in *H. sabdariffa* also has confirmed feeding, applying and stimulating large intestine bacteria, prebiotic, and overall digestive health. In order to lower the risk of digestive diseases and avoid constipation, dietary fibers are essential. There are both soluble and insoluble fibers in *H. sabdariffa*. Dietary fiber is one of the important parts of *H. sabdariffa* 's carbs. Maintaining digestive health requires dietary fiber, which is present in the plant's seeds and calyces. Constipation is avoided, regular bowel movements are facilitated, and a healthy gut micro biota is encouraged. While insoluble fiber helps waste pass through the digestive system, soluble fiber can help keep blood sugar and cholesterol levels under control (Montalvo-González et al., 2022).

H. sabdariffa 's fiber content acts as a feeding good gut flora, prebiotic, and promoting general digestive health. This in turn helps to build up the body's immune system, improve the body ability to absorb nutrients and also helps in digestion. Consuming foods containing fiber regularly can reduce the likelihood of developing digestive tract diseases like diverticulitis and IBS, and H. sabdariffa is one of those foods (Hainida et al., 2008).

Table 3: Hibiscus flower macronutrient nutritional content based on fresh weight (Yashaswini et al., 2011).

Water	89.8%
Protein	0.06g
Fat	0.4g
Fiber	1.56g
Carbohydrates	6.5g

Micronutrients in H. sabdariffa

Several researches have been carried out to determine the micronutrient content from H. sabdariffa. This plant has numerous uses as a source of needed minerals such as calcium, zinc, and iron for the improvement of human health. Three elements, potassium (K), magnesium (Mg), and phosphorus (P), which directly regulate the body's electrolyte balance and bone mass are also most concentrated in the calyces (Anel et al., 2016).

Vitamins and minerals

Roselle contains Vitamin C or another antioxidant and minerals. The body needs vitamin C for several reasons such as wound healing, skin health and immune health, and H. sabdariffa is loaded with this vitamin. Furthermore, Vitamin C is an antioxidant that protects cells from any loss caused by free radicals. Other vitamins found in the plant are niacin also known as vitamin B3 and riboflavin also known as vitamin B₂ which are important in the metabolism of energy and general body wellbeing. Nutrient salts including calcium, iron, magnesium, potassium and sodium can be obtained from good proportions from roselle plant. Iron is important for blood oxygen transportation while calcium is fundamental in muscular and skeletal system. Just over 300 activities including the synthesis of protein, muscle contraction and nerve transmission require this mineral. Sodium is required to maintain the electrolyte stability while potassium helps in governing fluids balance and muscular contractions (Singh et al., 2017).

Bamishaiye et al. (2011) examined the effect of heat treatment on the quality of vitamin C and minerals (Ca, K, Na, Fe, Zn, Mg, and Pb) of soft drinks prepared from aqueous extract of three ROS kinds (dark red, red and burgundy). To coffee and tea, strawberry flavour and 13% sugar solution were added to all the remaining drink items. Concentration of vitamin C was significantly higher in beverages prepared from cooked extracts at 10 minutes (30.5 ± 5.2 mg/100 g), while the least concentration of vitamin C was detected in beverages prepared from extract heated for 15 minutes (26.5 ± 6.5 mg/100 g). The beverage made from extract of dark red Roselle

Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

calyces which was produced by steeping the calyces for 10 minutes contained the highest vitamin C content (36.24 ± 1.76 mg/100 g). Compared to the beverages produced from the red and burgundy roselle calyces (14.3% and 14.7%, respectively) the darker colored calyces contained a higher mineral ash content (16.7%).

Table 4: Hibiscus flower micronutrient nutritional content based on fresh weight of 100g (Park et al., 2022)

Calcium	4mg
Phosphorus	27mg
Iron	1.7
Thiamine(B ₁)	0.03mg
Riboflavin(B ₂)	0.05mg
Niacin	0.6mg
Vitamin A	300g
Ascorbic acid	14mg

Bioactive compounds found in *H. sabdariffa*

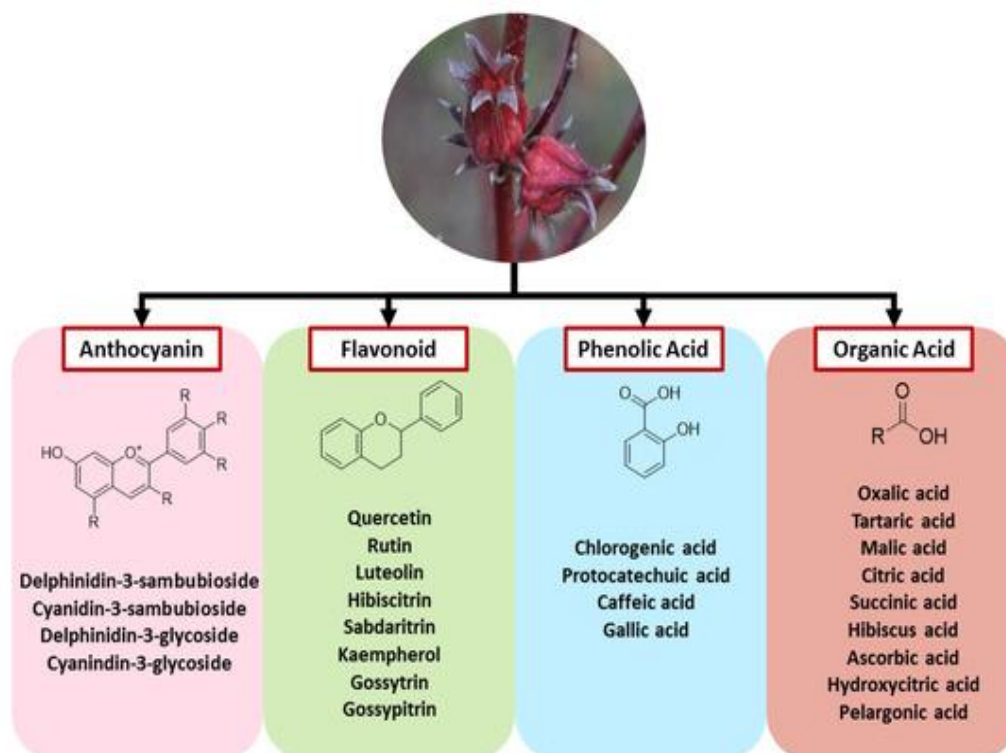


Figure 1: Bioactive compounds in *H. sabdariffa*

There is likely variation in the content of the bioactive compounds, mainly phenols and anthocyanins of roselle calyces depending on the cultivar, extraction technique, solvent type and particle size of the material used. The effectiveness of extraction of bioactive chemicals is higher in binary solvent systems than in monosolvent

extraction systems since the former have a higher polarity than the latter. This is the right moment to discuss the bioactive compounds more thoroughly. The pigments which give the *H. sabdariffa* calyces their bright red color include water soluble pigments known as anthocyanins which are also potent antioxidants. They reduce inflammation and decrease oxidation stress due to the free radicals by anthocyanins. Recent investigations for *H. sabdariffa* have report that anthocyanins are capable of combating free radicals and prevent cellular contents from oxidative metabolism of reactive oxygen species (ROS) (Zaman et al., 2017).

Wahabi et al. (2010) have also opined that but for the bioactive substances in the anthocyanins and proanthocyanidins of Roselle calyces, blood pressure lowering effect cannot be obtained. Total anthocyanins content was $2,520 \pm 50$ mg/100 g of finely powdered Roselle as stated by Peng-Kong et al. (2002). They also stated, based on high-performance liquid chromatography (HPLC) examination, that the two principal anthocyanins found in Roselle calyces were delphinidin-3-sambubioside (71.4%) and cyanidin-3-sambubioside (26.6%). Total anthocyanin content was reported by the authors as ranging between 172.58-296.99 mg 100 g-1 dry calyces and between 364.98-606.67 mg 100 g-1 dry ground sample in the extract made using methanol containing 1% trifluoroacetic acid. In the same investigation, the authors established 92% inhibition of antioxidant activity using the DPPH (2,2-Diphenyl-1-picrylhydrazyl).

Contrarily, total anthocyanins content (measured in absorbance at 510 nm) was 179 µg cyaniding-3-glucoside/25 g dry weight of the present Roselle; total phenols content was $0.41 (\pm 0.02)$ mg gallic acid equivalents/100g dry weight Roselle through Folin Ciocalteu method and antioxidant capacity detected by DPPH was of Chumsri et al. (2008) obtained similar results after doing the extraction at 50°C for 30 minutes with a 1:10 Roselle:water ratio. They deducted that in 100g of dried calyces they found 502.33 ± 0.52 mg of AN and 4300 ± 97 mg GAE respectively. The antioxidant capacity, or EC50, quantified by the DPPH technique was found to be 44.78 ± 0.49 mg/mL. Cid-Ortega and Guerrero-Beltrán (2014) indicated that anthocyanins (differential pH method) and total phenols (Folin-Ciocalteu method) as contents of Roselle calyces extract from powder (average particle size of 0.55 ± 0.016 mm) were 451.4 ± 28.1 mg/100 g, and 2016.2 ± 159 .

The extraction was done on 50% ethanol for forty-five minutes at a temperature of 50°C. Mohd-Esa et al. (2010) also analyzed the phenolic content of Roselle seed, calyces, leaf and stem. They analyzed that total phenol content in aqueous extracts was 1.85 ± 0.1 mg gallic acid / g calyces and in 80% methanol (v/v) extracts was 2.91 ± 0.07 mg gallic acid / g calyces. The extracts used in this investigation were made by stirring at room temperature for two hours while maintaining a 1:1000 Roselle:solvent ratio. Kumar et al (2012) works focused on the effects well concentrated Roselle extracts, where he got EC50 of 94.16 ± 1.52 µg/mL for aqueous extract and 46.13 ± 3.37 µg/mL for ethanolic extracts of 96 %v/v

H. sabdariffa contains four major flavonoids, quercetin and kaempferol among of them. These substances have great antioxidant activity due to the fact that they prevent the continuing of the lipid oxidation and formation of free radicals. Kumar et al. (2017) pointed out that flavonoids are also anti-inflammatory which boosted overall health. Gallic, hibiscus and chromogenic acids are some of the phenolic acids

that are in plenty in *H. sabdariffa*. These substances have been proven to possess rich antioxidant property and they curb chronic ailments and protect cells from harm due to oxidation. Phenolic acids have been associated with lowered risks of cardiovascular disease and several forms of cancer through suppression of inflammation (Montalvo-González et al., 2022).

Table 5: Effect of *H. sabdariffa* on hypertension

Plant name	Form used	Citation	Mode of action
H. sabdariffa	Extract used in tea and capsules	Wahabi et al., 2010	H. sabdariffa lowers the blood pressure level by vasodilation and ACE inhibition mechanism.
H. sabdariffa	Hibiscus extract in tea	Hopkins et al., 2013	Phytochemicals such as anthocyanins, antioxidants present in hibiscus has antihypertensive effect and responsible for lowering the systolic and diastolic BP by ACE inhibition and by diuretics because hibiscus are generally considered to have lower toxicity levels.
H. sabdariffa	Methanol extract of hibiscus use in vitro study	Ajay et al., 2007	Antihypertensive effects in rats mediated through examining the effect of crude methanolic extract of hibiscus on vasoculor reactivity in isolated aortas.
H. sabdariffa	Calyx extract use in hot herbal tea	Serban et al., 2015	Suppresses the antihypertensive activity by confirming the major pathways which are involved in ACE inhibition, diuretic activity and changes to endothelial NO concentrations.
H. sabdariffa	Hibiscus calyx tea	Mozaffari Khosravi et al., 2009	Hibiscus extract enhances the NO availability in diabetes by improving the endothelial modulation and by showing the inhibitory angiotensin-converting enzyme as lisinopril.
H. sabdariffa	Use extract in capsules	Herrera Arellano et al., 2004	Hibiscus extract improves the endothelial function which dilate the blood vessels easily and suppress the blood pressure levels
H. sabdariffa	Hibiscus tea	Jalalyazdi et al., 2019	In stage I hypertension, H. sabdariffa improves vascular

			endothelial responses due to the nitric oxide release which reduce oxidative damage and stabilize blood vessel tone.
H. sabdariffa	Use in powdered form in food and as supplements	Zhang et al., 2019	H. sabdariffa supplements lowers the antihypertensive effects due to polyphenol induced vasodilation which inhibit the lipid oxidation and anti- inhibitory action.
H. sabdariffa	Hibiscus juice and tea (Extract)	Amos and Khaita., 2020	H. sabdariffa shows a broad mechanism in multidisciplinary system modulation by lowering the blood sugar , BP levels and reduce the oxidative stress to emphasize its systematic action
H. sabdariffa	Used as hibiscus tea and an aqueous extract of hibiscus consumed as a capsule	Ellis et al., 2022	H. sabdariffa recovered the endothelial and regulates the lipid profile by dose dependent BP reduction
H. sabdariffa	Hot and cold aqueous extract	Salam et al., 2022	Hibiscus extract helps in vasorelaxation, metabolic reprogramming and on the evaluation of angiotensin converting enzyme (ACE) inhibition activities.
H. sabdariffa	As an polyphenol rich extract	Joven et al., 2014	Suppress the oxidative stress and enhance the endothelial nitric oxide
H. sabdariffa	Hibiscus polyphenol extract	Abdelmonem et al., 2022	Polyphenol extract reduce the arterial stiffness and enhance the vasodilation which lowers BP levels.
H. sabdariffa	Hibiscus extract capsule	Bule et al., 2020	Activates AMPK pathway and regulates eNOS (endothelial nitric oxide synthease) which increases NO production and insulin sensitivity.
H. sabdariffa	Hibiscus juice	Ali et al., 2019	Blocks ACE enzyme activity and improves vasodilation capacity
H. sabdariffa	Hibiscus aqueous extract	Olatunji et al., 2017	Strengthen vascular endothelium and promotes NO mediated dilation.
H. sabdariffa	Hibiscus sour tea	Faraji & Tarakhani., 1999	Hibiscus sour tea reduces BP levels in patients

H. sabdariffa	Aqueous extract of hibiscus calyx	Mojiminiyi et al., 2007	HS reduces antihypertensive, hypotensive and chronotropic effects by salt induction and L-arginine methyl ester induction.
H. sabdariffa	Aqueous extract of hibiscus	Walton et al., 2016	Anthocyanins enhance nitric oxide availability by vasodilation of blood vessels and effective in ACE inhibition.
H. sabdariffa	Hibiscus extract	Nwachukwu et al., 2015	HS act as an effective natural antihypertensive by reducing sodium serum levels and by sustained vascular modulation.
H. sabdariffa	Hibiscus sour tea	Shafiee et al., 2021	Hibiscus exerts antihypertensive effects by ACE inhibition and improves endothelial dependent vasodilation by increasing NO availability
H. sabdariffa	Hibiscus calyx extract	Ali et al., 2005	Hibiscus extract lowers blood pressure level by smooth muscle relaxation, antioxidant protection of blood vessels and by lowering lipid profile.

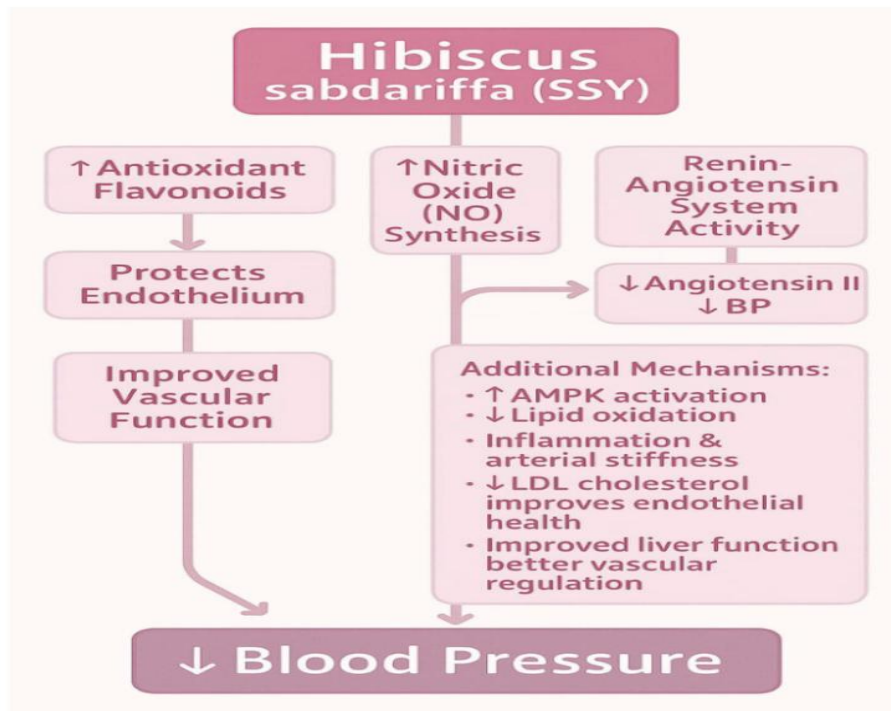


Figure 2: Mechanism of H. sabdariffa in hypertension

Benefits of *H. sabdariffa*

Roselle, also known as *H. sabdariffa*, has attracted a lot of interest due to its many health advantages.

Antioxidant Properties

Flavonoids, anthocyanins and phenolic acids are present as antioxidants in *H. sabdariffa*. These substances help to remove the radical species and in decrease of oxidative stress that are involved in chronic diseases like cancer, heart ailments and neurological diseases (Singh et al., 2021). *H. sabdariffa* calyces bear more antioxidant activity than quite a number of fruits and vegetables as explained in a study by Montalvo-González et al. (2022). Hibiscus tea can improve the body antioxidant status and reduce the probability of chronic diseases, it has been shown. Antioxidative activity refers to the measures of a chemical's ability to neutralize reactive oxygen and free radicals and prevent further development of oxidative routes. It delays the aging process as well as mask lower organelle lining, early cell damage. Recent in vitro and in vivo studies have revealed the high level of antioxidant activity in extracts of roselle calyxes.

Augustine (2011) posited that both the total aqueous and anthocyanin contents of roselle possess antioxidant properties. *H. sabdariffa* contains antioxidants that help the body combat what are known as free radicals, which are associated with the ageing process and a host of diseases including diabetes and cancer. The polyphenolic contents in the hibiscus flowers especially anthocyanin possesses significant antioxidants property for reducing inflammation as well as oxidative stress, according to the works of Mounika et al. (2021). Such qualities make *H. sabdariffa* useful especially in arthritis and cardiovascular diseases. The ROS also being free radicals the human body is guarded by antioxidants against them.

ROS are produced along the metabolism; all living cells possess them, such as the respiratory chain in mitochondria. The main reasons for extracellular ROS production are UV light, toxins, radiation, xenobiotics, and insects. Some of other types of ROS include, hydrogen peroxide, superoxide anion radicals, OH radicals, singlet oxygen, hypochlorite radicals, NO radicals, and lipid oxide radicals. ROS are not bad if taken in moderation, but when the body produces more ROS than the endogenous antioxidants it leads to oxidative stress which can result into DNA damage, destruction of proteins and fats and carbohydrates metabolism. Increased oxidant production is implicated in many diseases such as diabetes, cancer, arthritis, and cardiovascular diseases.

Therefore, it is important to maintain optimum levels of antioxidant and ROS. They include; free radical scavengers, inhibitors of lipid peroxidation, inhibitors of malondialdehyde production, inhibitors of f₂-BHP, inhibitors of thiobarbituric acid formation and antioxidants that decrease glutathione depletion. Through sequestering of metals, stimulating antioxidant enzymes, and delivering a hydrogen ion which negates the enzymes that generate free radicals, flavonoids interfere with ROS and minimize free radicals. Antioxidants fall into two categories: synthetic and natural. Although synthetic antioxidants generate new chemicals that are carcinogenic, natural antioxidants are preferred (Fitrotunnisa et al., 2019).

Potential Applications due to antioxidant properties

Dietary Supplements:

H. sabdariffa is often included in dietary supplements thanks to its high antioxidant activity. These supplements are marketed for their ability to slow aging.

Cosmetic goods:

H. sabdariffa is utilized in various cosmetic products because of its antioxidant properties. It is used in serums, lotions and creams for skin beautification and as an antioxidant against skin damaging effects of oxidation.

Functional Foods:

It has therefore been incorporated into functional foods such as teas, juices and snacks so as to enhance their antioxidant value and provide consumers health benefits.

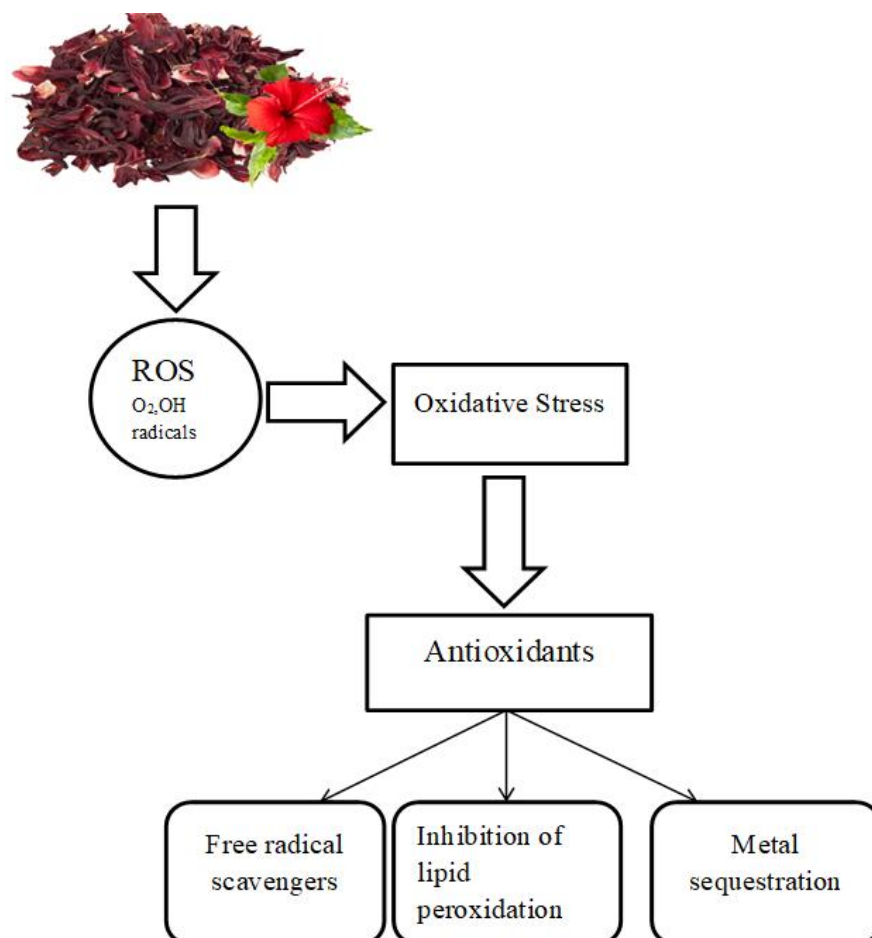


Figure 2: Mechanism of antioxidants in hibiscus

Hypoglycemic properties

There is also evidence that roselle extract possess hypoglycemic activity. Wen-Chin et al. (2009) studied the impact of roselle extract to glucosamine-nitrosourea that is toxic to the beta cells that produce insulin. They found that density influenced the

glucosamine-nitrosourea in a positive way. As a control, Sini et al. (2011) administered oral glibenclamide (0.08 mg/mL), ascorbic acid (0.2 mg/mL), and roselle calyces extract (0.5 mg/mL) harmful to the beta cells that make insulin. They discovered a favourable impact on the glucosamine-nitrosourea. As a control, Sini et al. (2011) gave male albino rats an oral dose of glibenclamide (0.08 mg/mL), ascorbic acid (0.2 mg/mL), and Roselle calyces extract (0.5 mg/mL). They saw similar outcomes. For five weeks the researchers gave rats an oral dose of extract and chemical compounds. Roselle calyces extract lowered blood glucose levels by 42.6 ± 18.6 while the control conditions showed stronger effects in ascorbic acid at $74.2 \pm 1.5\%$ and glibenclamide at $61.6 \pm 11.0\%$. Their research showed that glucosamine-nitrosourea treatment produced good results.

To test control conditions Sini et al. (2011) gave male albino rats an oral dose of glibenclamide (0.08 mg/mL), ascorbic acid (0.2 mg/mL), and Roselle calyces extract (0.5 mg/mL). They saw similar outcomes. Researchers gave rats their daily treatment of extract and chemical elements by mouth for 35 days. Our results reveal that Roselle calyces extract reduced blood sugar by 42.6 percent followed by glibenclamide at 61.6 percent and ascorbic acid provided 74.2 percent reduction based on experimental data and glibenclamide by $61.6 \pm 11.0\%$ as per the findings. They discovered a favourable impact on the glucosamine-nitrosourea.

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Anti-inflammatory Effects

The plant *H. sabdariffa* shows anti-inflammatory action through a wide range of phytochemical substances including flavonoids, polyphenols, and anthocyanins. These bioactive compounds stop the formation of inflammatory chemicals TNF-alpha and IL-1 beta which change how inflammation works. In male Wistar overtrained rats *H. sabdariffa* normalized the IL-1 β /IL-1 α balance both in their blood and hippocampus leading to reduced brain inflammation and preserved cognitive functions (Bayani et al., 2018).

Persistent inflammation worsens medical conditions like diabetes heart disease and arthritis. Multiple scientific studies prove that *H. sabdariffa* has powerful anti-inflammatory properties which help fight long-term inflammation and its linked dangers. Sanou et al. (2022) show that *H. sabdariffa* extract controls inflammation through its ability to shut down inflammatory protein production. The research demonstrated *H. sabdariffa* could serve as a natural anti-inflammatory medicine for treating inflammatory health problems. organism interacting with both the hardware and soft wares environment and the arrival of photo marketers or what is more familiar to the auto industry first-tier suppliers, Through the stimulation of insulin or plank of the pancreatic beta cells, an endocrine gland that is purely responsible for the

production of glucagon as well as insulin, roselle extract may produce hypoglycemic effect.

Antimicrobial Activity

Preliminary study suggests that *H. sabdariffa* has the potential in anticancer activity. Hibiscus extract is also cytotoxic to various cancer cell lines, particularly linked to hepatocellular carcinoma and breast cancer based on Ahmad et al. (2024). These effects have been attributed to the levels of anthocyanins and flavonoids which have been shown cause apoptosis and slow the growth of cancer cells. For the remainder of this paper, details will be elaborated concerning the effect of *H. sabdariffa* calyces extracts on specific cancers. Akim and colleagues have evaluated the ability of the two-week, two month and two-year-old commercial juice of roselle calyces to inhibit the growth of breast (MCF-7 and MDA-MB-231), ovarian (Caov-3), and cervical (HeLa) cancer cells as well as quantity antioxidants. Roselle juices derived from the calyces corresponding to all the tested duration showed significantly high antioxidant activity. In the present study, no changes ($P > 0.05$) were noticed over the storage period. Moreover, they pointed out that all the juices possess the ability to inhibit cell proliferation in MDA-MB-231, HeLa, Caov-3 and MCF-7 cell lines. Due to the content of flavonoids and saponins in the juices, the scientists proved that the juices from Roselle calyces have antioxidant and anti-neoplastic effect in references, meaning that they affect negatively, cancer cells.

Table 6: Specific parts of the roselle against certain type of cancer (Ahmad et al., 2024)

Roselle parts	Type of cancer
Calyxes	Breast cancer, lung cancer, breast cancer, leukemia
Roots	Ehrlich ascites carcinoma
Leaves	Prostate cancer, leukemia, Liver cancer
Callus	Colon cancer, cervical cancer
Stems	Melanoma cells cancer
Seeds	Melanoma cells cancer

Weight Management

Contained in *H. sabdariffa*, the bioactive compounds support people to reduce weight through influencing fat consumption and the deposit of cholesterol. Perhaps weight control strategies can benefit from the plant's ability to improve lipid profile and diabetes. Montalvo-González et al., (2022) looked into the performance of *H. sabdariffa* in obesity and metabolic syndrome. In the participants who were either overweight or obese, daily intake of hibiscus tea helped reducing body weight, waist circumference, and body fat percentage. These outcomes were attributed to the ability of the plant to enhance the insularity of insulin response and lipid utilization. It possesses ant- obesity activity through the increase in metabolism rate and decreased

absorption of fats by the extracts from hibiscus. Its polyphenolic content which can reduce fat accumulation and enhance lipid metabolism seems to be utilizing this effect (Aziz et al., 2007).

Besides, such cardiovascular benefits, *H. sabdariffa* has been associated with the fat metabolism and therefore can play a role in the weight loss. In the clinical study of Kamkaew et al. (2023), it was claimed that increased hibiscus extract consumption reduced weight and fat gain in obese individuals sharply. The extract is very beneficial as a supplement to weight loss strategies because it has been established to influence lipid profile, decrease fat absorption and regulate fat deposition.

Liver Health

H. sabdariffa is useful in hepatotherapeutic activity which implies that it assists in boosting of liver functions and protection of the liver from damage. To warrant the liver intact the Roselle plant contains antioxidants that help to detoxify the liver and decrease oxidative stress. A work done by Boukar et al in 2024 examines the effect of *H. sabdariffa* for the treatment of hepatoprotective in rats subjected to liver damage. Consequently, as measures of liver health, liver enzymes were significantly reduced, indicating better liver health by the extract derived from the plant, the study revealed.

Skin Health

The plant *H. sabdariffa* has those antioxidant compounds that would prevent the skin from getting damaged through oxidation, which if it happens leads to early aging. Some parts of the plant show that they shield the skin against UV harm, firm and reduce skin wrinkling. Sanou et al. (2022) explained when they looked at the impact of *H. sabdariffa* extract, it had positive effects on the skin health, namely, moisture, the skin's ability to stretch or return to normal size, and tumor. Based on the study, the plant has the potential to enhance the synthesis of collagen and protecting the skin against any destruction caused by the free radicals.

Immune Support

H. sabdariffa contains vitamin C and polyphenolic antioxidant chemicals. Indirectly, these substances decrease oxidative stress by mopping free radicals and enhance the health of immune cells. Flavonoids protective role in infections occurs through improvement of both, natural and acquired immunity. Roselle is also an effective antimicrobial because it is capable of halting bacterial and fungal biofilm formation, which contributes to bacterial and fungal infections. Both avoiding infections and modeling immunological moderate is crudely mitigated by this action. As shown by some findings, polyphenols within it may change composition of gut microbiota which can enhance immunity (Amer et al., 2022).

This could decrease the body's ability to fight off diseases due to compromise of the immune system caused by chronic inflammation. Roselle reduces anti-inflammatory biomarkers and guards valuable immune action due to the phytochemicals present as organic acids and anthocyanins. As stated by Singh et al. (2021) another element of *H. sabdariffa* is vitamin C which helps the immune system. The study found that consumption of hibiscus tea is beneficial for the immune system and helps to prevent easy sicknesses.

Digestive Health

They also observed that *H. sabdariffa* has prebiotic effect that is it promotes growth of good bacteria in the stomach. Increasing gut microbiota density is crucial for immune and Digestive health stability. Research suggests that active extra cellular Roselle calyx can support beneficial lactic acid microorganisms including *Bifidobacterium* and *Lactobacillus*. The dietary fiber in *H. sabdariffa* can help digestion health since it helps to maintain a good gut micro biota as well as regulate bowel movements. Apart from contributing to a reduction in risks related to digestive diseases, fiber prevents constipation, as indicated by Montalvo-González et al. (2022).

Uses of *H. sabdariffa*

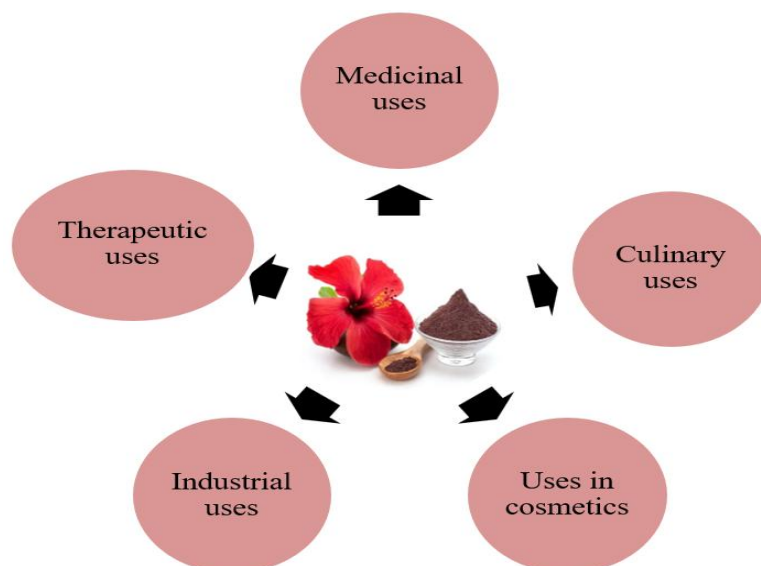


Figure 3: Uses of *H. sabdariffa*

Medicinal and Therapeutic Applications

Several pharmacological effects of *H. sabdariffa* have been established especially concerning the management of many diseases. It contains many vitamins, antioxidants and polyphenol to give it credits as being capable of treating and also preventing chronic diseases.

The effects of lowering blood pressure are one of the most documented uses of *H. sabdariffa*. Normal to moderate hypertensive patients can take hibiscus tea because it has been shown to lower high blood pressure due to its calyx content. Lucy et al. (2022), in their systematic review, found that *H. sabdariffa* has a major capacity of reducing both systolic and diastolic blood pressure of hypertensive patients mainly because of its flavonoids and anthocyanins that are known to have vasodilatory effects. The uses of the Roselle flowers include the preparation of the widely known Arabic drink Karkade treating colds, heart and upper respiratory tract ache, nerve disorders, lack of appetite, inflammation, stomach and intestinal upset, water retention, circulation and phlegm related disorders.

From the findings of Odigie et al., it also possesses antihypertensive, antibacterial,

sedative, diuretic, digestive, purging, emollient, demulcent and astringent qualities. The calyces are used in treating leukaemia, hypertension and heart diseases. Others are stomachic, antitussive, expectorant, emetic, refrigerant, diuretic, aphrodisiac, antiseptic, antibacterial, cholagogue, and sedative and laxative. They also have an application in treatment of abscess and pyrexia. Cough and bronchitis diseases are treated with fruits and flowers (Maregesi et al., 2013). Roselle contains depthinidin 3-sambubioside, cyanidin 3-sambubioside, delphinidin 3-glucoside, and cyanidin 3-glucoside as anthocyanin compound. They are good for health since, they are a natural food colourant and are rich in antioxidants. It is anticipated that incorporation of the Roselle juice with the tropical fruit liquids will lead to the development of products with high nutritional quality and functional activity (Kilima et al., 2014).

The present study reveals roselle aqueous methanolic extract have antibacterial action against several bacterial species. In roselle, hibiscus anthocyanins (HAs), a class of naturally occurring pigments located in the dried calyx, yielded liver protective and antioxidant activity within Puro et al. (2014). One colorful natural source fits perfectly for natural food dye is the red color of rosella petals: almost entirely anthocyanic compounds. The protective action of anthocyanins includes high thermo stability, antioxidative activities, anti-inflammatory, cardio and hepatoprotective effects (Azevedo et al., 2010). Most authors say that anthocyanins inhibit low density lipoprotein LDL oxidation and the growth of human cancer cells. Therefore, use of natural anthocyanins in the food colouration would further enrich the nutrition value of the food in question apart from enhancing its outlook (Abeda et al., 2014).

Culinary Uses

Within the cookery context, hibiscus flower pod and fresh or dried calyx include making tea, fermented beverages, ice cream, chocolates, jams and jellies, warm and cold drinks, cakes and flavoring agents. A lot of civilizations have in the past consumed hibiscus-based concoctions. For example, in Sudan and Nigeria, calyces are boiled with sugar to produce a drink, Karkade or Zoborodo respectively, however in Egypt, the calyces are used in preparation of fermented drinks and cacody tea. The calyces are also employed for as a natural aroma and pigment for rum in region of west India.

In Mexican cooking, the flower is incorporated in some meals and can be seen in the making of the popular drink commonly referred to as Jamaica water, or Jamaica tea. In Sudan, Malaysia, China, and Africa there source show that the leaves of the plant are eaten raw or cooked, as green vegetables and seeds are pounded or roasted and used to make oil or used to make a coffee substitute. Even though there are many ways to use the plant, hibiscus tea is the most popular drink In this case, it has a bright red color and a rather sour taste. Most civilizations of the world including those in Africa, Middle East and Caribbean regions consume it hot or cold. According to Reddy et al. (2015), it is used in India as a vegetable and its tea has been used to cure hypertension.

Abd El-Ghany et al. (2019) pointed out that hibiscus tea is accepted as a good coffee substitute for its refreshing antidepressant effects because it contains vitamin C and polyphenolic compounds. Due to its rich red color, *H. sabdariffa* is the best natural food dye. It's commonly used in items such as ice cream, soft drinks, beers, wines and

spirits. Equally, it is used to enhance natural flavor in cakes, jams and sauces among other food products. Kumar et al. (2022) demonstrated through research how hibiscus extract could compete with synthetic food dyes due to health concerns about their chemical nature.

Baking and confectionery food production benefits from using Roselle in culinary everyday cooking. Roselle seeds provide fiber through fine flour products used to improve bakery items. Aside from that, this application helps to improve fluffiness of foods such as cakes and biscuits while also adding a subtle taste. Besides that, this plant also provides edible pigments which can substitute synthetic colors in sauces, jams, and jellies. Also, *H. sabdariffa* is incorporated in smoothies, soups, and salad bowls for the edible leaves and flowers. These plant portions are rich sources of calcium, iron and vitamins A and C and E making the plant portions to have a nutritional advantage.

Singh et al., (2021), explaining that the hibiscus leaves are another great source of dietary fiber and this aids digestion and the health of the lining of the stomach. Besides tea, the calyces make other edible products such as jams, jellies, sauces, and syrups to mention but a few. They can also be candied and used as decoration of sweets and cakes. Some of the uses of this plant are in cultures where the leaves are eaten like any vegetable in salads or for making soups.

Cosmetic and Skincare Applications

The cosmetic industry also benefits from *H. sabdariffa*, as skincare products use its anti-inflammatory and antioxidant qualities. The abundance of anthocyanins in hibiscus draw attention as an important part of skincare products because they fight skin aging. Research by Wang and colleagues shows hibiscus extract stimulates collagen production in the skin to help fade the appearance of wrinkles and lines. People use antioxidant rich hibiscus extract specifically for skincare products that help reduce aging effects and make skin more flexible. People integrate *H. sabdariffa* into hair care products so their hair stays healthier and their scalp function improves better. Users claim the plant helps create keratin proteins because it contains amino acids. In 2021 Singh et al found that hibiscus extract produced better hair growth and reduced dandruff through its moisturizing and anti-inflammatory effects when users applied the scalp massager. People in Malaysia use hibiscus seed oil mainly to create exfoliating scrubs and skincare products.

Industrial Uses

Besides food and medicinal purposes, *H. sabdariffa* has lots of uses in industries as discussed below. The fibers of the *H. sabdariffa* are strong and therefore the plant's fabric can be used in the making of clothes, ropes among others. These fibers are used for processing of cloth, sacks and other fibrous materials in several industries (Sanou et al., 2022). Fractional extracts of *H. sabdariffa* can be utilized for fabric dyeing, the dyes obtained from *H. sabdariffa* are natural and can replace the chemical dyes, *H. sabdariffa* waste products can be similarly processed into biofertilizers that boost agricultural productivity and the quality of the soil, Studies have shown that the use of residues of *H. sabdariffa* as organic matter improves roselle is utilized increasingly in the synthesis of polymeric natural colorants which has a great importance in the

preparation of green plastic products and coatings (Luvonga et al., 2012).

Other Uses and Traditional Applications of *H. sabdariffa*

H. sabdariffa contains several compounds that have other uses and the tree has other traditional application.

Traditional Medicine

H. sabdariffa is used by many indigenous cultures in medicine for infections, fever and a host of ailments associated with the gastrointestinal tract. It is thought that hibiscus plant has a mild laxative effect and is able to cure constipation. In addition, *H. sabdariffa* is used in folk medicine on the basis of vitamin C to alleviate instances of flu and common cold. In the Middle East the leaves of the plant and particularly the tea are used to normalized blood pressure and extending a cup of tea every day can help in controlling blood pressure. *H. sabdariffa* is consumed in Ayurveda as it provides a cooling effect on the “pitta” dosha which has added diuretic and anti-inflammatory properties. In the Caribbean, roselle has been used as restorative tonic and is considered to possess some sexually related qualities (Mohammad et al., 2012).

Biodiesel Production

Knowledge on biodiesel production using *H. sabdariffa* is valuable because of the innovations proposed for the plant. It has been discovered that the seeds of the plant contain oil that may be extracted and refined into biodiesel, a non-hazardous alternative to fossil fuels. As discovered by Akpinar et al. (2022), due to advantageous fatty acid content, *H. sabdariffa* oil holds the potential to act as biodiesel raw feedstock.

Conclusion

Roselle or scientifically known as *H. sabdariffa* is one of the most powerful natural plants that definitely have beneficial impact on the health of human beings. The particular fusion of features such as nutritional value, therapeutic properties and versatility for cooking and baking make its importance well underpinned in the traditional as well as the modern world. Being loaded with phenolic acids, flavonoids, and anthocyanins, *H. sabdariffa* 's calyces are an oracle of nutrient value added. These substances improve cellular viability as well as combating oxidative damage in-particular because of its potent antioxidant action and responsible for its bright red hue. Vitamin C, vitamin A and the B vitamins are some of the vitamins that help in meet the body's immunological support and metabolism needs. Continuing from the point, the mineral aspect, which consist of calcium, magnesium and potassium lends its function in the aspect of electrolyte balance, muscles and bones. Its calorie and fat percentage values are low and could serve most diets while the dietary fiber is beneficial to digestive health. There is an identified place for this *H. sabdariffa* in the area of functional foods. This herb is commonly used as a cooling and astringent herb the pleasantly sharp taste of the fresh leaves has made lemon balm an important herb in herbal teas and drinks. Three, it is also tasty; finally, research has proven that it can lower blood pressure, lower cholesterol, detoxify the liver, and therefore, for these reasons alone, it has a place in prevention of diseases. According to the traditional

medicine, it is used to treat infections, and inflammation in the gut, and the antibacterial and anti-inflammatory properties taken from the plant gives it this ability. Roselle is very versatile and can therefore be used as an ingredient in savoury dishes and sauces, jam, syrup or even in desert. As natural food color, it fits the current and future needs of the food industry for clean-label ingredients. Used to enhance flavors and provide health benefits this makes it an invaluable asset in the art of cooking. Due to their nutrient value and therapeutic properties *H. sabdariffa* has an enormous opportunity to meet the current health challenges. It is one of the most important crops that are cultivated today at the international level because of its suitability in various dietary plans and ethnic group cooking habits. To optimize its future use whether to developing new food products, exploring the use of ganoderma in medicine or guaranteeing its organic cultivation to address future demand further research and development will be crucial. Integrating *H. sabdariffa* into usual meals enriches the pallet and helps to embrace multiple-aspect approach for healthier living and life. In conclusion, *H. sabdariffa* proves that if people have a good imagination and possibility of combining these, it is a plant of great importance in culinary, medicinal, and nutritional characteristic. If people learn more of its uses, new creative ways of cooking and preparing food may be developed, ensuring that this wonder herb will remain useful in people's everyday creation and traditions.

Declarations:

Ethics Approval and Consent to Participate

This article is a review based on previously published literature and does not involve any studies with human participants or animals performed by any of the authors. Therefore, ethical approval and consent to participate are not applicable

Availability of Data and Materials

The data supporting the findings of this review are derived from published literature, which has been appropriately cited throughout the manuscript. No new data were generated or analyzed in this study.

Competing Interests

The authors declare that they have no competing interests.

References

- Abeda, H. Z., M. K. Kouassi, K. D. Yapo, E. Koffi, R. S. Sie, M. Kone and H. T. Kouakou (2014). Production and enhancement of anthocyanin in callus line of Roselle (*H. sabdariffa* L.). *Int. J. Rec. Biotechnol.*, 2(1) : 45- 56.
- Abou-Arab AA, Abu-Salem FM, Abou-Arab EA (2011) Physicochemical properties of natural pigments (anthocyanin) extracted from Roselle calyces (*H. sabdariffa*). *J Am Sci* 7(7):445–456
- Ahmed, A. M. A., & Khalid, K. A. (2024). Anticancer properties of Roselle (*H. sabdariffa* L), review article. *Vegetos*, 10(3), 47-56.
- Ahmed, A.M.A., Khalid, K.A. Anticancer properties of Roselle (*H. sabdariffa* L), review article. *Vegetos* (2024).
- Akim, A. M., Ling, L. C., Rahmat, A., & Zakaria, Z. A. (2011). Antioxidant and anti-proliferative activities of roselle juice on caov-3, mcf-7, mda-mb-231 and hela

- cancer cell lines. *African Journal of Pharmacy and Pharmacology*, 5(7), 957-965.
- Amer, S.A., et al. (2022). [Rich Roselle \(H. sabdariffa L.\) Extract on Immune Status of Broiler Chickens](#). *Antioxidants*.
- Anel, T. C., Thokchom, R., & Subapriya, M. S. (2016). *H. sabdariffa* —A natural micro nutrient source.
- Augustine O Olusola (2011) Evaluation of the Antioxidant Effects of *H. sabdariffa* calyx extracts on 2,4-dinitrophenylhydrazineinduced oxidative damage in rabbits. *Webmed Central* 2(10): WMC002283
- Azevedo, J., I. Fernandes, A. Faria, J. Oliveira, A. Fernandes, V. Freitas and N. Mateus (2010). Antioxidant properties of anthocyanidins, anthocyanidin-3-glucosides and respective portisins. *Food Chem.*, 119(2) : 518-523.
- Aziz, E. E., Gad, N., & Badran, N. M. (2007). Effect of cobalt and nickel on plant growth, yield, and flavonoids content of *H. sabdariffa* L.
- Ajay, M., Chai, H. J., Mustafa, A. M., Gilani, A. H., & Mustafa, M. R. (2007). Mechanisms of the anti-hypertensive effect of *H. sabdariffa* L. calyces. *Journal of ethnopharmacology*, 109(3), 388-393.
- Ali, B. H., Wabel, N. A., & Blunden, G. (2005). Phytochemical, pharmacological and toxicological aspects of *H. sabdariffa* L.: a review. *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, 19(5), 369-375.
- Bamishaiye EI, Olayemi FF, Bamishaiye OM (2011) Effects of boiling time on mineral and vitamin C content of three varieties of *H. sabdariffa* drink in Nigeria. *World J Agric Sci* 7(1):62–67
- Bayani GFE, Marpaung NLE, Simorangkir DAS, Sianipar IR, Ibrahim N, Kartinah NT, Mansur IG, Purba JS, Ilyas EII. Anti-inflammatory Effects of *H. sabdariffa* Linn. on the IL-1 β /IL-1ra Ratio in Plasma and Hippocampus of Overtrained Rats and Correlation with Spatial Memory. *Kobe J Med Sci*. 2018 Oct 15;64(2):E73-E83. PMID: 30381729; PMCID: PMC6347049.
- Boukar, K. K., Abdourazak, M. A., Maina, M. C., Saley, M. D., & Yacoubou, B. (2024). *Roselle (H. sabdariffa L.): Overview of its biology, ecology, socio-economic importance, and cultivation constraints in West Africa*. *World Journal of Pharmaceutical and Life Sciences*, 10(3), 47-56.
- Bule, M., Albelbeisi, A. H., Nikfar, S., Amini, M., & Abdollahi, M. (2020). The antidiabetic and antilipidemic effects of *H. sabdariffa* : A systematic review and meta-analysis of randomized clinical trials. *Food Research International*, 130, 108980.
- Chao C, Yin M (2008). Antibacterial Effects of Roselle Calyx Extracts and protocatechuic Acid in Ground Beef and Apple Juice. *Foodborne Pathogen Dis* 6(2): 201-206
- Chumsri P, Sirichote A, Itharat A (2008) Studies on the optimum conditions for the extraction and concentration of Roselle (*H. sabdariffa* Linn.) extract. *Songklanakarin J Sci Technol* 30(1): 133–139
- Da-Costa-Rocha, I., Bonnlaender, B., Sievers, H., Pischel, I., and Heinrich, M. (2014). *H. sabdariffa* L.—A phytochemical and pharmacological review. *Food chemistry*, 165, 424-443.

- D'Andrea, G., et al. (2020). "The antihypertensive effect of *H. sabdariffa* extract: A systematic review." *Journal of Clinical Hypertension*, 22(7), 1159-1166.
- Emmy Hainida, Amin Ismail, Normah Hashim, Norhaizan Mohd.-Esa and Ainul Zakiah. 2008. Effects of defatted dried roselle (*H. sabdariffa* L.) seed powder on lipid profiles of hypercholesterolemia rats. *Journal of the Science of Food and Agriculture*. 88:1043–1050.
- Fitrotunnisa, Q., Arsianti, A., Tejaputri, N. A., & Qorina, F. O. N. A. (2019). Antioxidative activity and phytochemistry profile of *H. sabdariffa* herb extracts. *International Journal of Applied Pharmaceutics*, 11(6), 29-32.
- Fullerton M, Khatiwada J, Johnson JU, David S, William LL (2011). Determination of antimicrobial activity of sorrel (*H. sabdariffa*) on *E.coli* O157:H7 isolated from food, veterinary and clinical samples. *J Med Food* 14(9): 950-956
- Faraji, M. H., & Tarkhani, A. H. (1999). The effect of sour tea (*H. sabdariffa*) on essential hypertension. *Journal of Ethnopharmacology*, 65(3), 231-236.
- Galicia-Flores LA, Salinas-Moreno Y, Espinoza-García BM, SánchezFeria C (2008) Caracterización fisicoquímica y actividad antioxidante de extractos de Jamaica (*H. sabdariffa* L.) nacional e importada. *Revista Chapingo Serie Horticultura (Mexico)* 14(2):121–129
- Houknpè, L. H., Adovélandé, J., Bossou, A. F. A. D., Konfo, C. T. R., Koudoro, Y. A., Bogninou, G. S. R., Bothon, F. T. D., Dossa, C. P. A., Avlessi, F., & Sohounhloué, D. C. K. (2019). Nutritional Valorization and Chemical Composition of Seeds of *H. sabdariffa* from Benin. *American Journal of Food Science and Technology*, 7(5), 146-151.
- Herrera-Arellano, A., Flores-Romero, S., Chavez-Soto, M. A., & Tortoriello, J. (2004). Effectiveness and tolerability of a standardized extract from *H. sabdariffa* in patients with mild to moderate hypertension: a controlled and randomized clinical trial. *Phytomedicine*, 11(5), 375-382.
- Hopkins, A. L., Lamm, M. G., Funk, J. L., & Ritenbaugh, C. (2013). *H. sabdariffa* L. in the treatment of hypertension and hyperlipidemia: a comprehensive review of animal and human studies. *Fitoterapia*, 85, 84-94.
- Joven, J., March, I., Espinel, E., Fernández-Arroyo, S., Rodríguez-Gallego, E., Aragonès, G., ... & Camps, J. (2014). *H. sabdariffa* extract lowers blood pressure and improves endothelial function. *Molecular nutrition & food research*, 58(6), 1374-1378.
- Jalalyazdi, M., Ramezani, J., Izadi-Moud, A., Madani-Sani, F., Shahlaei, S., & Ghiasi, S. S. (2019). Effect of *H. sabdariffa* on blood pressure in patients with stage 1 hypertension. *Journal of advanced pharmaceutical technology & research*, 10(3), 107-111.
- Kamkaew, J., et al. (2023). "Effect of *H. sabdariffa* extract on weight loss and fat metabolism in obese individuals." *Obesity Research & Clinical Practice*, 17(2), 123-130.
- Kilima, B. M., S. F. Remberg, B. E. Chove and T. Wicklund (2014). Physio-chemical, mineral composition and antioxidant properties of Roselle (*H. sabdariffa* L.) extract blended with tropical fruit juices. *Afr. J. Food Agr. Nutr. Dev.*, 14(3) : 8963-8978.

- Kumar, M., Garg, R., & Garg, R. (2017). Phytochemical Properties and Antioxidant Activity of *H. sabdariffa* Linn. International Journal of Pharmaceutical and Chemical Sciences, 45(187), 1-10.
- Kumar, P., et al. (2022). "Natural food colorants: *H. sabdariffa* as a safe alternative to synthetic dyes." Food Chemistry, 383, 132530.
- Lucy R Ellis, Sadia Zulfiqar, Mel Holmes, Lisa Marshall, Louise Dye, Christine Boesch, A systematic review and meta-analysis of the effects of *H. sabdariffa* on blood pressure and cardiometabolic markers, Nutrition Reviews, Volume 80, Issue 6, June 2022, Pages 1723–1737
- Luvonga, W.A., Njoroge, M.S., & Makokha, A. (2012). [Chemical characterisation of *H. sabdariffa* \(Roselle\) calyces and evaluation of its functional potential in the food industry](#). Journal of Stored Products and Postharvest Research.
- Mojiminiyi, F. B. O., Dikko, M., Muhammad, B. Y., Ojobor, P. D., Ajagbonna, O. P., Okolo, R. U., ... & Anga, T. J. (2007). Antihypertensive effect of an aqueous extract of the calyx of *H. sabdariffa*. Fitoterapia, 78(4), 292-297.
- Margesi, S., G. Kagashe and D. Dhokia (2013). Determination of iron contents in *Hibiscus sabdariffa* calyces and *Kigelia Africana* fruit. Scholars Acad. J. Biosci. (SAJB), 1(4) : 108-111.
- Mohamed, R., Fernández, J., Pineda, M., & Aguilar, M.** (2012). "Roselle (*H. sabdariffa* L.) seed oil is a rich source of γ -tocopherol." Journal of Food Science, 72(3), S207-S211.
- Mozaffari-Khosravi, H., Jalali-Khanabadi, B. A., Afkhami-Ardekani, M., Fatehi, F., & Noori-Shadkam, M. (2009). The effects of sour tea (*H. sabdariffa*) on hypertension in patients with type II diabetes. Journal of human hypertension, 23(1), 48-54.
- Montalvo-González, E., Villagrán, Z., & González-Torres, S. (2022). Physiological Effects and Human Health Benefits of *H. sabdariffa* : A Review of Clinical Trials. Pharmaceuticals (Basel), 15(4), 464-476.
- Mounika, K., et al. (2021). "Antioxidant properties of *H. sabdariffa* extracts." Antioxidants, 10(7), 1085.
- Nwachukwu, D. C., Aneke, E., Nwachukwu, N. Z., Obika, L. F. O., Nwagha, U. I., & Eze, A. A. (2015). Effect of *H. sabdariffa* on blood pressure and electrolyte profile of mild to moderate hypertensive Nigerians: A comparative study with hydrochlorothiazide. Nigerian Journal of Clinical Practice, 18(6), 762-770.
- Odigie, I. P., R. R. Ettarh and S. A. Adigun (2003). Chronic administration of aqueous extract of *H. sabdariffa* attenuates hypertension and reverses cardiac hypertrophy in 2K-1 C hypertensive rats. J. Ethnopharmacol., 86 : 181- 185.
- Ogo OA, Gloria O, Bawa I, Emmanuel EU (2021) Nutraceutical Properties of *H. sabdariffa* Stem and Leaf Extract as a Potential Alternative to Management of Clinical Manifestations Associated with Diabetes Mellitus. J Nutraceuticals Food Sci Vol.6 No.3:11.
- Olaleye MT (2007). Cytotoxicity and antibacterial activity of methanolic extract of *H. sabdariffa*. J Med Plant Res 1: 9-13
- Omabuwajo TO., LA. Sanni, and YA. Balami. 2000. Physical properties of Roselle (*H. sabdariffa*) seeds. J. Food. Eng. 45:37-41

- Olatunji, O. A., & Ademoyegun, O. T. EVALUATION OF SYNERGISTIC EFFECT OF ROSELLE (*H. sabdariffa*) HERBAL TEA INFUSED WITH GINGER (*Zingiber officinale*) AND SCENT LEAVES (*Ocimum gratissimum*). USING *Citrullus colocynthis*, *Ricinus communis* and *Parkia biglobosa* SEEDS, 2017.
- Park, Y., Kwon, S. H., Jang, Y. L., Lee, D. H., Yang, S. O., Eo, H. J., ... & Kwon, H. Y. (2022). Nutritional composition and phytochemical screening in different parts of *Hibiscus syriacus* L. *Food Science & Nutrition*, 10(9), 3034-3042.
- Park, Y., Kwon, S. H., Jang, Y. L., Lee, D. H., Yang, S. O., Eo, H. J., ... & Kwon, H. Y. (2022). Nutritional composition and phytochemical screening in different parts of *Hibiscus syriacus* L. *Food Science & Nutrition*, 10(9), 3034-3042.
- Peng-Kong W, Yusof S, Ghazali HM, Che-Man YB (2002) Physico chemical characteristics of Roselle (*H. sabdariffa* L.). *Nutr Food Sci* 32(2):68–73
- Puro, K., R. Sunjukta, S. Samir, S. Ghatak, I. Shakuntala and A. Sen (2014). Medicinal uses of Roselle plant (*H. sabdariffa* L.) : a mini review. *Indian J. Hill Farming*, 27(1) : 81-9
- Salami, S. O., & Afolayan, A. J. (2020). Suitability of Roselle-*H. sabdariffa* L. as Raw Material for Soft Drink Production. *Journal of Food Quality*, 2020(1), 8864142.
- Salem, M. A., Zayed, A., Beshay, M. E., Mesih, M. M., Ben Khayal, R. F., George, F. A., & Ezzat, S. M. (2021). *H. sabdariffa* L.: phytoconstituents, nutritive, and pharmacological applications. *Advances in Traditional Medicine*, 22, 497-507.
- Salem, M. A., Ezzat, S. M., Ahmed, K. A., Alseekh, S., Fernie, A. R., & Essam, R. M. (2022). A comparative study of the antihypertensive and cardioprotective potentials of hot and cold aqueous extracts of *H. sabdariffa* L. in relation to their metabolic profiles. *Frontiers in Pharmacology*, 13, 840478.
- Serban, C., Sahebkar, A., Ursoniu, S., Andrica, F., & Banach, M. (2015). Effect of sour tea (*H. sabdariffa* L.) on arterial hypertension: a systematic review and meta-analysis of randomized controlled trials. *Journal of hypertension*, 33(6), 1119-1127.
- Sanou, A., Konate, K., Dakuyo, R., Kabore, K., Sama, H., & Dicko, M. H. (2022). *H. sabdariffa* : Genetic variability, seasonality and their impact on nutritional and antioxidant properties. *PLOS ONE*, 17(3), e0261924.
- Sim, Y. Y., & Nyam, K. L. (2021). *Hibiscus cannabinus* L.(kenaf) studies: Nutritional composition, phytochemistry, pharmacology, and potential applications. *Food chemistry*, 344, 128582.
- Sim, Y. Y., & Nyam, K. L. (2021). *Hibiscus cannabinus* L.(kenaf) studies: Nutritional composition, phytochemistry, pharmacology, and potential applications. *Food chemistry*, 344, 128582.
- Singh, P., Khan, M., & Hailemariam, H. (2017). Nutritional and health importance of *H. sabdariffa* : a review and indication for research needs. *Journal of Nutritional Health & Food Engineering*, 6(5), 125-128.
- Sini JM, Umar IA, Inuwa HM (2011) The beneficial effect of extract of *H. sabdariffa* calyces in alloxan-diabetic rats: hypoglycaemic and hypolipidaemic activities. *J Med Plants Res* 5(11):2182–2186

- Swati N, Burle, S. S., Kosalge, S. B., & Bansode, M. N. (2023). Antimicrobial and Antioxidant activity of *H. sabdariffa* Linn (Roselle). *International Journal of Pharmacy Research & Technology (IJPRT)*, 12(1), 22–27.
- Shafiee, M., Mohammadi, V., Kazemi, A., Davarpanah, H., Tabibzadeh, S. M., Babajafari, S., ... & Mazloomi, S. M. (2021). The effect of *H. sabdariffa* (sour tea) compared to other herbal teas and antihypertension drugs on cardiometabolic risk factors: Result from a systematic review and meta-analysis. *Journal of Herbal Medicine*, 29, 100471.
- Wang, D., Nagata, M., Matsumoto, M., Amen, Y., Wang, D., & Shimizu, K. (2022). Potential of *H. sabdariffa* L. and Hibiscus Acid to Reverse Skin Aging. *Molecules*, 27(18), 6076.
- Wen-Chin L, Chau-Jong W, Yu-Hsin C, Jen-Dong H, Su-Ya C, Hong-Chen C, Huei-Jane L (2009) Polyphenol extracts from *H. sabdariffa* Linnaeus attenuate nephropathy in experimental type 1 diabetes. *J Agric Food Chem* 57(6):2206–2210
- Wahabi, H. A., Alansary, L. A., Al-Sabban, A. H., & Glasziou, P. (2010). The effectiveness of *H. sabdariffa* in the treatment of hypertension: a systematic review. *Phytomedicine*, 17(2), 83-86.
- Yashaswini, S., Hegde, R. V., & Venugopal, C. K. (2011). Health and nutrition from ornamentals. *International Journal of Research in Ayurveda & Pharmacy*, 2(2), 375-382.
- Yashaswini, S., Hegde, R. V., & Venugopal, C. K. (2011). Health and nutrition from ornamentals. *International Journal of Research in Ayurveda & Pharmacy*, 2(2), 375-382.
- Zaman, H.U., Das, P., Das, P., & Sahu, N.K. (2017). Analysis of Physicochemical, Nutritional and Antioxidant Properties of Fresh and Dried Roselle (*H. sabdariffa* Linn.) Calyces. *International Journal of Pure and Applied Bioscience*, 5(1), 261-267.