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Characterizations and Applications of Roselle (Hibiscus Sabdariffa L): A Review

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Abstract: *Roselle (Hibiscus sabdariffa L), which is one of the most significant and popular medicinal plants, is an annual herb that grows up to 1.5 meter and belongs to the Malvaceae family. In addition to being intensively applied in many medicinal applications, it has been used in jams, jellies and fruit juices. This paper reviews the latest developments in Roselle and its potential applications in various fields. Its versatility and unique characters, such as anti-hypertension, anti-obesity and antioxidant abilities, have contributed to the successful development for medical, pharmacological and industrial applications.*

Keywords: Roselle extracts, methods, characterizations, applications

1. INTYRODUCTION

Roselle, which also called hibiscus sabdariffa L or karkade, is a tropical and subtropical plant that produces red or white edible calyces. These calyces are used as hot or cold drink. Although other parts can be used in the preparation for different applications, calyces are the most exploited part of this plant. Roselle has been used in jams, jellies and sauces and many of its medicinal and industrial applications have been developed worldwide. For instance, it has been used for hypertension and liver damage treatments, cancer prevention, and kidney stones treatment [37,45,53].

Recently, a handful of roselle reviews have been published in literture [7,25,46,54]. Nevertheless, the majority of them are narrowly focused and do not contain in-depth reviews. Another issue to bring up is that some authors did not report the part of roselle that had been utilized in their studies, while others did not provide adequate details about the preparation process. This article reviews the latest progress in the development of roselle and its various issues including characterization methods. In addition, the applications of roselle in various fields ranging from industrial to medicinal applications are also presented with some focus on applications of growing interest.

2. LITERATURE REVIEW

By using mathematical modeling, Hassan and Hobani[23] investigated the flow characteristics of Roselle extract, i.e., the impact of concentration and temperature on the flow behavior of Roselle extraction. When applying the power law model, the values of the flow behavior index (*n*) were found to be below unity suggesting shear thinning behavior. It was also found that some mathematical models can be applied to predict apparent viscosity as a function of concentration, temperature, and shear rate.

Chewonarin et al[12] reported the testing of 80% ethanol extract of roselle (Hibiscus sabdarffa Linn) for antimutagenic and chemopreventive activity in a colon carcinogenesis model. Results showed inhabitation in the mutagenicity of heterocyclic amines and MAM acetate, but a slight inhabitation in azoxymethane (AOM) and 2-amino-1-methyl-6-phenylimidazo[4,5-b] pyridine (PhIP) induced aberrant crypt focus (foci) ACF in the initiation stage and AOM-induced O^6-methylguanin (O^6- meG) formation. In addition, in the post-initiation stage, enhancement in AOM-induced ACF was observed.

According to Tsai et al[50], roselle extract was prepared from roselle petals using boiling water in order to ascertain the correlation between anthocyanin and antioxidant activity. It was found that the antioxidant capacity of roselle extract increased with increasing extraction time or weight of petals. Anthocyanin was found to be the main source of antioxidant capacity in roselle extract. Studying the storage time effect at different temperatures showed a relatively slight reduction in total phenolic compounds and antioxidant activity.

Tsai and Huang[49] reported a study on roselle anthocyanin model system for testing of the distribution of anthocyanins and antioxidant capacity by applying three assay systems, i.e., 1,1-dipheny l-2-picrylhydrazyl radical (DPPH) scavenging, ferric reducing ability of plasma (FRAP) and trolox equivalent antioxidant capacity (TEAC). Gel filtration was used to separate the anthocyanins with different degrees of polymerization following heating. The findings showed that heating resulted in a significant rise in the degradation index DI, polymeric anthocyanins, and DPPH scavenging impact but a significant loss in color density, FRAP activity, and monomeric and co-pigmented anthocyanins. Using statistical analysis, it was also found that the monomeric anthocyanins had a negative relationship with the DPPH scavenging effect and a positive relationship with FRAP activity.

The impact of an aqueous extract of petals of Hibiscus Sabdariffa (HS) on the established stages of 2-Kidney, 1-Clip renovascular hypertension in Sprague–Dawley rats was studied by Odigie et al[42]. The main finding of this study was that the HS can lower blood pressure and attenuate cardiac hypertrophy in 2K-1C hypertension supporting the belief that HS can reduce blood pressure by acting as an antihypertensive agent.

The thermal stability of anthocyanins extracted from the dry calyces of Hibiscus Sabdariffa L. was documented in both dry state and aqueous solutions during storage at various relative humidity levels, both with and without the addition of chlorogenic acid as a copigment (Gradinaru et al[20]). In solution, there was hardly any improvement in the stability of anthocyanin copigmentation in the presence of chlorogenic acid. However, in the dry condition, there was a noticeable increase in the degradation rate constants with water activity. The co-lyophilized pullulan-anthocyanins showed some improvement in stability at all relative humidity environments when compared with the free anthocyanin extract. In all freeze-dried materials, the temperature-dependence of the anthocyanin degradation rates was found to follow the Williams–Landel–Ferry (WLF) kinetic model. A significant reactant mobility in the glassy state was also observed due to the degradation of anthocyanins that occurred even at sub-Tg temperatures for all samples.

The influence of Hibiscus sabdariffa extract (HSE) on the carbon tetrachloride (CCl_4)- caused by chronic fibrosis in rats was investigated by Liu et al[32]. A significant reduction in liver damage including steatosis and fibrosis, as well as, an elevation in plasma aspartate aminotransferase (AST) and alanine aminotransferase (ALT) was observed after HSE had been administered. During CCl_4 treatment, it was also found that HSE restored the decrease in glutathione content and inhibited the formation of lipid peroxidative products. Furthermore, HSE greatly inhibited the activation of the hepatic stellate cells in the primary culture. The antioxidant properties of HSE are responsible for these encouraging results.

Alarcon-Aguilar et al[6] investigated the influence of a standardized *Hibiscus sabdariffa* aqueous extract on body weight gain in obesity models (MSG-obese mice). The findings indicated that in both healthy and obese mice, there was a significant decrease in body weight gain and an increase in liquid intake. On the 15th and 45th days, there was a significant rise in alanine aminotransferase (ALT) levels in obese mice. However, significant changes in aspartate aminotransferase (AST) levels were remarkable. In addition, *Hibiscus sabdariffa* treatment did not show any significant reduction in triglycerides and cholesterol levels, and there was no mortality observed in the treated groups.

Ajay et al[3] examined the the mechanisms of the anti-hypertensive effect of the HS by an analysis of the effects of crude methanolic extract of calyces of HS (HSE) on vasomotor responses of aortic rings isolated from spontaneously hypertensive rats (SHR). The obtained data supported the traditional usage of the plant as an antihypertensive medication by demonstrating that HSE has a vasodilator effect in the isolated aortic rings of hypertensive rats.

The impact of HSE on a panel of established gastric cancer cells was demonstrated by Lin et al[30]. Based on the findings, AGS apoptosis was mediated by HSE through the JNK/p38 signaling cascade. Thus, HSE, a naturally occurring agent, may be developed as an anticancer drug.

Human studies on the cholesterol-lowering effects of HSE were conducted by Lin et al[31]. HSE capsules prepared for oral use were used in the clinical research. 42 volunteers with ages ranging from 18 to 75 years old and cholesterol levels between 175 and 327 mg/dL were included in the study. According to the results, taking two capsules of HSE for a month can dramatically lower a person's serum cholesterol level, demonstrating the efficacy of HSE in treating hypercholesterolemia.

Yin and Cheo[59] conducted an experiment on the inhibitory effects of protocatechuic acid and roselle calyx extract on susceptible and antibiotic-resistant Campylobacter species in ground beef, as well as on cooking loss and sensory qualities in beef samples. The survival and growth of susceptible and antibiotic resistant C. jejuni, C. coli and C. fetus in agar plate and ground beef was found to be greatly inhibited by roselle calyx and protocatechuic acid. In addition, cooking loss, pH value, sensory attributes and content of fat, protein and moisture of beef samples were not affected by the addition of roselle calyx extract or protocatechuic acid during storage for 15 days at 4 °C. It was concluded that the obtained results support the potential use of protocatechuic acid and roselle calyx extract in food to delay lipid oxidation and avoid Campylobacter and aerobe infection.

Duangmala et al[17] reported the preparation of roselle extract in acidified water–95% ethanol (1:1). The stability of total anthocyanins in freeze-dried roselle with either trehalose or maltodextrin was the subject of the investigation. The aim of the study was also to establish the relationship between total anthocyanin content and colour changes of freezedried roselle during storage. Additionally, this investigation evaluated the color of a drink in a model system that had both synthetic carmoesin and anthocyanins. The results were compared to drinks that contained commercial colorants, such as SAN RED RCs and synthetic carmoesin. According to the results, the addition of trehalose and maltodextrin delayed the degradation of total anthocyanin. It was proven that the freeze-dried

roselle powder with maltodextrin at 3 g/100 ml has superior colour stability. Even though the drink with roselle anthocyanin powder had the least stable color over the course of 56 days, its overall appearance was evaluated as being almost 'like slightly'.

Sanchez-Mendoza et al[47] studied a number of physical characteristics that are dependent on moisture, including morphology, sphericity, bulk and true densities, porosity, thousand seed mass, and static coefficient of friction of three cultivars of Roselle seeds (Mexico, China, and Sudan). An increase in the dimensions, estimated porosity, thousand seed mass and static coefficient of friction of Roselle seed was observed with increasing moisture content. Nonetheless, it was found that when moisture content increased, the bulk actual densities for various moisture levels decreased. It was also observed that the sphericity changed as the moisture content increased, approaching a spherical form in the case of cultivar Sudan.

The study reported by Emmy Hainida et al[19] aimed at studying the nutritional composition of Roselle seeds cultivated in Malaysia as well as the impact of sun- and boiling-drying techniques on the seeds' nutritional composition. The procedure included raw freeze-dried, sun dried and boiled sun-dried Roselle seeds. Results revealed that Roselle seeds may be considered as a potential source of functional ingredients since they are rich in proteins, dietary fibre, essential amino acids and lipids.

Prasongwatana et al[45] reported on uricosuric effect of Roselle in normal and renal-stone former subjects. Data obtained on the urinary compositions from both groups of subjects did not show any increase in the level of urinary stone inhibitors and as a result, no proof for antilithiasic effect of Roselle tea was found.

Karabacak and Bozkurt[27] studied the effect of Urtica dioica, Hibiscus sabdariffa butylatedhydroxytoluene (BHT) and nitrite/nitrate on the quality (pH, Hunter L-, a- and b-value and sensory attributes) and safety [2-thiobarbituric acid reactive substances (TBARS) value and biogenic amine] during the ripening periods of sucuk (Turkish dry-fermented sausage). The natural antioxidant extracts were found to be more effective than nitrite/nitrate and BHT, and therefore they could be utilized instead of synthetic ones.

The effect of thermo-mechanical Instant Controlled Pressure Drop (DIC) treatment on the extraction of Roselle anthocyanins by comparing kinetics and yield for treated and untreated Roselle calyces was investigated by Ben Amor and Allaf[9]. Data collected after DIC treatment and optimizing DIC operative parameters revealed improvements in the kinetics and the extraction yield of anthocyanins from the dried calyces of Roselle.

Three different varieties of Hibiscus sabdariffa were studied for their calyces, which varied in color and maturity season (Christian and Jackson[13]). The purpose of the study was to examine the changes in total phenolic, monomeric anthocyanins, and antioxidant. Samples were taken of the three types, which were known as traditional red (TRED), early bearing red (ERED), and white (WHTE), both before and after flowering (after 3 days, 7 days, 21 days, and 35 days). The outcomes demonstrated that antioxidant activity was present all varieties. However, the values for phenolic and anthocyanin content were highest for ERED, and therefore, harvesting 35 days after blooming would produce a greater yield, suggesting the optimum variety and harvest time.

Using KOH as a catalyst, Nakpong and Wootthikanokkhan[39] reported the production of biodiesel from crude roselle oil by alkali-catalyzed trans esterification with methanol. According to the results, the optimum conditions for the production process were a molar ratio of 8:1 (methanol: oil), a catalyst concentration of 1.5% w/w of oil, and 60^{o}C and 60 min for a reaction temperature and a reaction time respectively.

Mohd-Esa et al[35] investigated the antioxidant activity, free radical-scavenging and total phenolic of extracts from calyxes, leaves, seeds and stems of the Roselle plant. Among all parts of the Roselle plant examined, Roselle seed extracts had the highest antioxidant activity and strongest radical-scavenging activity. In order to assess the antioxidant activity of Roselle seeds throughout a full food system, this study also looked at the impact of Roselle on lipid oxidation in cooked beef stored at 4^{o}C for up to 14 days. Findings indicated that roselle seed treatment decreased lipid oxidation in patties more than commercial synthetic antioxidant treatment with butylated hydroxytoulene (BHT). Lastly, this study raised the prospect of using Roselle seeds as food antioxidants for human consumption.

Iyare et al[26] explored the potential mechanisms behind the decrease in food and fluid consumption as well as the weight gain that occurred in rats after HS consumption during pregnancy. After (HS) consumption, rats showed a decrease in food and fluid intake, a reduction in weight gain, and a rise in sodium ion concentration in their plasma. The possible mechanisms imply that Na+ has a role in the content of HS.

The influences of a Hibiscus Sabdariffa extract powder (HSEP) and a recognized preventive treatment (diet) on the lipid profiles of individuals with and without metabolic syndrome (MeSy) were demonstrated by Gurrola-Dıaz et al[21]. The study was conducted according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III)) guidelines. A significant

reduction in glucose and total cholesterol levels, a rise in HDL-c levels, and improvement in TAG/HDL-c ratio and a marker of insulin resistance were observed for the MeSy patients treated with HSEP. Results indicated a triglyceride-lowering impact for MeSy patients treated with HSEP plus diet, as well as for those without MeSy treated with HSEP. In light of these and the well documented hypotensive effects of Hibiscus Sabdariffa, the authors suggested the use of HSEP in individuals with dyslipidemia associated with MeSy.

Woottisin et al[57] studied the antilithic impact of Hibiscus Sabdariffa extract on known risk factors for calcium oxalate stones in rats. The Hibiscus Sabdariffa group showed a considerable decrease in serum oxalate and glycolate levels as well as a greater oxalate urine excretion in comparison to the untreated group. Compared to the untreated group, the Hibiscus Sabdariffa group exhibited significantly lower serum levels of oxalate and glycolate as well as a higher oxalate urinary excretion. Hibiscus Sabdariffa and Phyllanthus amarus reduced calcium crystal deposition in the kidneys. The antilithic effect of Hibiscus sabdariffa may be related to decreased oxalate retention in the kidney and more excretion into urine.

The flow properties of roselle i.e. the effect of temperature (20-60^{o}C), shear rate (5-200 s^{-1}), shearing time (15, 30 and 45 seconds) and time (storing at 4^{o}C), on the apparent viscosity and shear stress were investigated by Elhefian[18]. The viscosity and shear stress both reduced as the temperature rose. However, the impact of temperature was more noticeable at higher shear rates. Studying the impact of shearing time revealed that for all applied shearing times, viscosity and shear stress hardly changed. When the effect of time was studied (storing at 4^{o}C), no change in viscosity and shear stress was observed until week 25 wherein a sudden increase in both was noticed. The author came to the conclusion that the sudden increase in viscosity could be due to the growth of some organs and that keeping roselle solutions at 4^{o}C could greatly extend its shelf life.

A systematic investigation of Hibiscus sabdariffa extracts was carried out by Sindi et al[48] using a variety of solvents (water, methanol, ethyl acetate, and hexane) in the presence or absence of formic acid at various extraction temperatures and periods. The goal of this study was to determine the optimal extraction conditions for various chemical and biochemical analyses. The obtained data showed that the extraction using water, with or without formic acid, for 10 min and at 100^{o}C recorded the highest antioxidant capacities and concentrations of cyanidin 3-sambubioside and delphinidin 3-sambubioside.

Borrás-Linaresa et al[10] investigated the ethanolic extracts of 25 varieties of Mexican Roselle, differing in the intensity of calyx color and grown under identical conditions, for anthocyanidin, antioxidant, and antimicrobial activities as well as for phenolic compounds. Results showed that seven new compounds were found in the Roselle extracts such as; 3-deoxy-D-lyxo-heptulosaric acid, syringetin-3-O-glucoside, kinsenoside, luteolin-7-O- -D-glucuronide methyl ester, and 4-O-acetylquercitrin. In addition, some of the tested extracts showed antioxidant, antimicrobial and antibacterial properties.

The effect of fermentation on the chemical composition of Roselle (calyces and leaves) was investigated by Mohmed et al[36]. It was found that while moisture and carbohydrate contents decreased during fermentation, the fiber, protein, and ash contents of calyces increased. As for karkade leaves, results indicated that moisture and protein contents dropped with fermentation. However, the oil and carbohydrate contents were found to increase. Additionally, as the fermentation time increased, a general decrease in the mineral contents of the karkade calyces and leaves was noted. Among the fermentation treatment periods examined (3, 5 and 7 days), the 5 day fermentation was found to give the best results.

The determination of some properties and chemical composition of Roselle seeds was demonstrated by Nasrabadi et al[40]. Results indicated that Roselle seeds are a good source of nutrients since they are rich in protein, fiber and oil with unsaturated fatty acids. Furthermore, linoleic acid was found to be the major fatty acid in Roselle seeds, and among the other extracts (methanol and water extracts), the acetone extract had the highest total phenol content and antioxidant activity.

Omar et al[43] reported the potential weight-loss effects of roselle calyces aqueous extract on obese rats at different doses. Results showed that the roselle extract at the greatest dose used (300 mg/kg) is recommended for weight management and blood cholesterol reduction with no health risks.

During the process of roselle extract degradation, Wu et al[58] measured the total anthocyanin content, antioxidant potential, and color changes of the roselle extract. First-order reaction kinetics were utilized during the anthocyanin degradation. At higher temperatures, low-acid conditions exhibited a greater rate of deterioration. However, temperature and pH both had an impact on the anthocyanin content. It was suggested that roselle anthocyanins could be used in acidic beverages due to the exhibition of some heat tolerance in acidic settings.

Ahmed et al[2] reported a comparative study on the primary contents of the two types of Sudanese roselle calyces (the red and white types) for nutritional value evaluation. Similar results were obtained for both types of roselle with respect to calcium, anthocyanin and vitamin C levels. On the other hand, iron level was higher in red calyces while hibiscus acid level was higher in the white variety.

The application of Roselle calyces (Hibiscus sabdariffa L.) as an antidiabetic was studied by Mohanty and Bhadra[34]. The study involved the in silico docking of chemical compounds from Roselle calyces with the protein enzyme Phosphoenolpyruvatee Carboxykinase (PEPCK). Using the in silico docking method, the goal of the research was to ascertain the activity of the active chemicals from Roselle calyces as a possible inhibitor for the protein enzyme phosphoenolpyruvatee carboxykinase (PEPCK). The protein enzyme phosphoenolpyruvate carboxykinase (PEPCK), which was downloaded via the Protein Data Bank (PDB) with code 1KHB, and chemical compounds Roselle calyces were used in the study. The docking process was then carried out using the PLANTS program, and the docking score was evaluated as the docking process results. Docking scores were found to be 89.2883, 85.6101, 83.7724, 70.9521, and 64.9661 for quercetin, hibiscetin, gossypetin, protocatechuic acid, and metformin, respectively. The findings showed that compared to metformin, the four chemical compounds present in Roselle calyces have a lower docking score and more potential to be inhibitors of the protein enzyme phosphoenolpyruvate carboxykinase (PEPCK).

Wang et al[56] conducted an investigation to determine the biological activities of the extracts, chromatographic fractions, and hibiscus acid derived from roselle calyces for their potential bioactivities. Utilizing enzyme-linked immunosorbent assays, their capacity to stimulate extracellular matrix synthesis in skin fibroblasts was assessed. In addition, a nitric oxide (NO)–Griess inflammatory experiment was used to assess their anti-inflammatory activity. Furthermore, by creating a model of oxidative stress brought on by hydrogen peroxide, hibiscus acid was shown to have a potent anti-oxidative stress impact. Results showed that the HS crude extract appears to be more active than hibiscus acid by itself. This finding suggests that the activity of HS is probably the consequence of many compounds working in concert. It was concluded that the findings of this study offer a fresh perspective and a new scientific evidence supporting the development of HS and its application in postponing skin aging.

Cho et al[15] looked into the possible uses of callus cells and Roselle leaves water extracts for pharmaceutical and cosmetic applications. They used Roselle leaves to create calluses, and then they used heat extraction to create two distinct water extracts that were called Hibiscus sabdariffa plant extract (HSPE) and Hibiscus sabdariffa callus extract (HSCE). The components of the two extracts were found to differ by HPLC analysis, with nucleic acids and metabolites like tryptophan and phenylalanine being the most prevalent elements in both extracts. According to in vitro tests, HSCE supports the skin barrier and exhibits potent anti-melanogenic properties. Significant variations in the transcriptome profiles of human skin cells treated with HSPE and HSCE were found, with HSPE having a greater impact. Genes up-regulated by HSPE are involved in angiogenesis, the oxidation-reduction process, and glycolysis; on the other hand, genes up-regulated by HSCE encode IFI6 and ribosomal proteins, which are involved in the repair of skin cells damaged by radiation. As a result, they recommend using the two Roselle extracts for cosmetic and pharmacutical objectives in various ways. The research showed that roselle extracts have potential as a natural ingredient in skincare products.

The effectiveness of roselle (Hibiscus sabdariffa L.) calyces water-extract as a hepatoprotective material against liver damage produced by N-diethylnitrosamine (DEN) in rats was investigated by Abaker et al[1]. When comparing the DEN group to the control group, the results showed a significant rise in superoxide dismutase (SOD) and catalase (CAT), two antioxidant indicators, and a drop in malondialdehyde (MAD) level. In addition, compared to the normal control group, the DEN-group showed a considerable drop in tumor necrosis factor-alph (TNF-α) and a high increase in the apoptotic marker caspase-3. Roselle extract administration resulted in a marked rise in MDA and a fall in SOD and CAT values. Furthermore, a significant rise in TNF-α and a decrease in caspase-3 were observed. The histopathology results confirmed these findings. It was concluded that the roselle extract has the ability to enhance the architecture of the liver and may have hepatoprotective effects against DEN exposure.

The impact of roselle flower petal extract on the elimination of the smear layer on crown dentin was examined by Khoswanto et al[28]. As samples, eight human maxillary first premolars from patients undergoing orthodontic extractions were utilized. In this pre-experimental investigation, a test group of 2,5%, 5%, and 10% roselle flower petal extract were administered, while the control group was conditioned with sterile distilled water. The research data was acquired by examining the scanning electron microscope (SEM) results. It was found that the smear layer could be cleaned more effectively by roselle flower petal extracts at 5% and 10% concentration than by extracts at 2.5% concentration and the control group. This could be as a result of the solution's acidic pH and the demineralization process due to the presence of some organic acids including citric acid in roselle flower petal extract.

3. SOME APPLICATIONS OF ROSELLE

Most of the applications of this plant have been developed globally based on its used parts. According to the literature, the majority of roselle uses are in food and medicine. Table 1 summarizes the applications of roselle using different materials.

Table 1: Some applications of roselle

Material	Application	Ref.
Seeds	Food antioxidants	35
Seeds	Potential source of functional ingredients	19
Calyces	As a natural colorant in food or beverages	17
Calyces	Foods to prevent contamination from campylobacter and aerobes, also as delay lipid oxidation	59
Powder	Antimutagenic activity in a colon carcinogenesis model	12
Crude roselle oil	As a supplementary oil feedstock for biodiesel production	39
Seeds	Recovery of phytosterol from roselle seeds	41
Calyces	Antihypertensive agent.	3
Calyces	Anti-obesity	6
calyces	Decreasing food consumption and weight gain during pregnancy	26
Powder	Metabolic syndrome treatment	21
Petals	Antihypertensive agent.	42
Flower	Chemopreventive agent (prevention of cancer)	30
/	Antihypertension	22
Calyces	Antihypertension	44
/	Anti-inflammation	16
/	Antimutagenicity	12
/	Against liver disorders	5,8,32
/	Against immunemodulating	38
Hibiscus protocatechuic acid	Antioxidant	52,55
Hibiscus protocatechuic acid	as a cancer chemopreventive agent against tumor promotion.	51,53
Flower	Enhancing of Sucuk (Turkish dry-fermented sausage) quality and offering safer products.	27
Flower	As antioxidant for protecting the liver against CCl_4-induced fibrosis	32
Capsule	Reducing serum cholesterol in humans	31
Calyces	Promoting cardiovascular health and preventing hypertension.	14
Calyces	Anticancer, antihypertensive and improving the digestive system in humans	37
Calyces	Kidney stones treatment	45
Calyces	Against low density lipoprotein (LDL)-oxidation, in addition to its hypolipidemic effects in vivo	24
Tablets	Decreasing Ca crystal deposition in the kidneys.	57
Flower	Inhibition of adipogenesis	29
Flower	Developing chemotherapeutic agent for tumor cells (as chemopreventive agents)	11
Calyces	Inhibition of body weight increase and reduction of glycemia in an obese model	6
Calyces and leaves		36

Seeds	Nutritional source, and blood cholestrol and blood pressure reduction	[40]
Calyces	for weight management and blood cholesterol reduction	[43]
Calyces	In acidic beverages	[58]
Calyces	Antidiabetic	[34]
Calyces	Delaying skin aging	[56]
Leaves	In skincare products	[15]
Calyces	Hepatoprotective agent against DEN exposure	[1]
Petals	Removal of the smear layer in crown dentin	[28]

4. CONCLUSION

Roselle is a natural product that has proposed for a wide variety of applications ranging from food industry to medicinal products. In this review, an attempt has been made for better understanding of roselle in various aspects. This includes its properties, the preparation and characterization of its calyx, oil and seeds as well as its applications.

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