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Impact of Hibiscus sabdariffa supplementation on human health: a narrative review

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Abstract

Background. *Hibiscus sabdariffa* has been used for millennia in various medical traditions worldwide to treat a variety of illnesses. Due to this fact, scientists have analysed its potential medical properties, especially in most common diseases globally, such as hypertension, diabetes, or cancer, looking for a medicine that is effective, widely available, and inexpensive.

Aim. The aim of this review is to summarize the current knowledge about *Hibiscus sabdariffa* supplementation on human health, with emphasis on the most common civilization diseases.

Materials and methods. A narrative review of available literature in English language was conducted using PubMed, Scopus, and Google Scholar databases. Emphasis was placed on experimental studies, with clinical, placebo-controlled experiments prioritized.

Conclusions. *Hibiscus sabdariffa* was found to have a positive impact on hypertension, hypercholesterolemia, obesity, renal and hepatic diseases. Moreover, the active compounds have anti-cancer properties, that could potentially help in developing new anti-cancer drugs in the future.

Key words

Hibiscus sabdariffa, supplementation, natural product, phytopharmacology, herbal medicine, antioxidant, anticancer

Introduction

According to the World Health Organisation's (WHO's) Strategy for Global Traditional Medicine, traditional medicine refers to codified or non-codified systems and practices, that are distinct from biomedicine, and are based mostly on experience gathered by past generations [1]. Thanks to the WHO's recognition of nutraceuticals as natural remedies or complementary medicine, more and more studies are conducted to examine potential health benefits, assess risk factors, and establish guidelines for the use of natural compounds used for millennia across the globe. One of those compounds is *Hibiscus sabdariffa* (HS), or Roselle. It is commonly consumed as a beverage served hot, or cold, also known as sour tea. In some parts of the African continent, leaves and seeds are added to the food, while in China the plant has been used for centuries as a medicine [2], [3]. Therefore, many researchers have studied the substances in the hibiscus plant, looking for potential active molecules that could be beneficial for overall health, as well as improve the outcome of classical treatment of many diseases or comorbidities. It was found that HS contains many molecules with potentially pleiotropic effects, including antioxidant, anticancer, anti-inflammatory, antipyretic, antihypertensive, as well as hepatoprotective properties [4], [5]. Furthermore, due to the potentially high cost of treatment with traditional medicine, as well as potential cross-reaction between drugs, scientists are looking for potential lower-risk and lower-cost supportive treatments. The aim of this narrative review is to provide an overview of the active substances in this plant and discuss the possible applications of the HS.

Overview of the plant and its uses

Hibiscus sabdariffa is a species belonging to the Hibiscus genus, which is part of Malvaceae family, belonging to the order Malvales. There are around 300 described species of Hibiscus. Apart from HS, other species important for their practical use among humans include *Hibiscus rosa-sinensis*, *Hibiscus mutabilis*, and *Hibiscus acetosella* [6], [7]. Some researchers theorise, that HS derives from the Indian subcontinent or Malaysia, while others trace the domestication of this plant to ancient Sudan. Nevertheless, this plant is one of the most abundantly cultivated plants in tropical regions, with its distribution spanning from the Caribbean islands, Brazil, and Central America to Sudan, Egypt, India, China, Malaysia, and Indonesia [8], [9]. HS can be divided into two types, the first one being *Hibiscus sabdariffa* var. *Altissima* Wester, cultivated mainly for fiber resembling jute, with inedible calyces and flowers, while the other called *Hibiscus sabdariffa* var. *sabdariffa*, is grown for edible calyces and fiber, while also being a source of a natural dyes, used especially in food products [10]. The calyces (either fresh or dried) are widely used in culinary applications. First and foremost, they are used for a wide array of beverages, either as a hot equivalent of tea, or boiled with sugar and consumed as a cold drink called Karkade in Egypt and Sudan or Agua de Jamaica in Mexico. Other uses for the flowers include the production of jams, marmalades, cakes, and fermented drinks. Moreover, the seeds and leaves of HS are used as ingredients in various dishes or as side dishes in various countries, while also being a source of vegetable oils [9], [10], [11].

HS has been used as a natural remedy in various traditional medical systems. In Ayurvedic tradition, parts of HS were used as a remedy for hypertension, liver diseases, pyrexia, dyspepsia, and dysuria [8]. Moreover, in various regions HS is regarded as a potent diuretic agent, as well as a remedy for cough and sore throat. Additionally, HS is used in various cardiological and neurological problems. Interestingly, an ointment made from HS leaves is widely used in Africa for abscess and wound care. In Chinese traditional medicine, HS is used for the treatment of liver problems, and for lowering blood pressure [9], [10].

Phytochemistry

Due to various variables, such as the analysed parts of the plant, the region of their harvest, environmental conditions, as well as the variety of HS, or the analytical method, the exact nutritional composition and concentration of bioactive compounds may differ between studies. The nutritional value of the calyces and flowers is relatively poor, with

1,145 - 1,9 g / 100 g of protein and 12,3 g / 100 g of carbohydrates. They contain moderate levels of vitamin C, with 6,7 - 14 mg / 100 g, which is 7,4% - 15,6% of the Recommended Dietary Allowances (RDAs). Moreover, it is a poor source of other vitamins, such as thiamine (0,1 mg / 100 g), carotene (30 – 300 µg / 100 g), riboflavin (0,27 mg / 100 g), and niacin (3,8 mg / 100 g). Conversely, it is very rich in iron, with its content being within the range of 8,98 mg – 57 mg / 100 g [8], [9], [12]. Interestingly, the leaves were found to be more than 10 times richer in carotene, and 5 times richer in ascorbic acid, while having a lower iron content. The seeds of HS are a good source of protein (18,8 - 22,3 %) and fats (19,1 – 22,8 %), most of them being unsaturated fatty acids (70%) like linoleic or oleic acids [9], [13]. The organic compounds with the potential to be used as a phytopharmaceuticals comprise flavonoids, which include anthocyanins, as well as other active compounds such as organic acids, polyphenols, polysaccharides or phytoestrogens [9], [14], [15], [16].

Flavonoids are a large family of organic, polycyclic compounds mostly synthesized in plants. They can be found in most parts of plants, being used for growth, defense against pathogens, as well as contributing to the colors of the flowers, being produced as pigments [17]. The most important compounds found in the calyces and flowers of the HS include gossypitrin, gossytrin, hibiscetin-3-glucoside, kaempferol 3-O-rutinoside, luteolin, sabdaritin, quercetin, quercetin-3-sambubioside, and quercetin-3-glucoside [18], [19]. Other compounds from the flavonoid group include anthocyanins, which are mostly abundant in flowers. They comprise mostly delphinidin 3-sambubioside, and cyanidin 3-sambubioside, with small amounts of delphinidin 3-glucoside, cyanidin 3-glucoside, malvidin, peonidin, and pelargonidin [14], [20]. These compounds account for most of the medicinal uses of HS, possessing anti-cholinesterase activity, as well as anti-inflammatory, antihypertensive, antibacterial, and anticarcinogenic activities. Moreover, they are able to scavenge free radicals, helping to overcome the oxidative stress [17], [21].

The organic acids in HS include mostly citric acid, hydroxycitric acid, hibiscus acid and its derivatives, malic acid, and tartaric acid. Other compounds include protocatechuic acid, pelargonidic acid, chlorogenic acid, 3-caffeoylquinic acid, 4-caffeoylquinic acid, and 5-caffeoylquinic acid [9], [14], [16].

HS is also rich in phytoestrogens, such as daidzein, and quercetin, with smaller amounts of β -sitosterol, ergosterol, stigmasterol, campesterol, and α -spinasterol, which could be beneficial in reduction of incidents of breast cancer. Conversely, the effects of these substances should be taken into consideration, when prescribing HS to pregnant or lactating women [16].

Potential uses in medicine

1. Hypertension

One of the most analysed properties of the HS extract is its antihypertensive effect. Several *in vitro* studies showed, that HS extracts had smooth muscle relaxing properties in the isolated rat aorta, both endothelial-dependent and endothelial-independent. Interestingly, it seems that endothelial-dependent relaxation plays a more crucial role, with activation of the Nitric Oxide Synthase being a part of the process [22], [23]. Moreover, anthocyanins extracted from HS, namely the most abundant delphinidin- and cyanidin-3-O-sambubiosides, showed an inhibitory effect on the Angiotensin Converting Enzyme [24]. Other *in vitro* studies showed acetylcholine-like and histamine-like hypotensive mechanisms of HS extract, as well as natriuretic and diuretic properties, suggesting aldosterone-modulating properties of HS [25], [26]. There have been many *in vivo* studies, exploring the hypotensive potential of HS in patients. In the first study, a hypotensive effect was compared between a 250 mg/dose of anthocyanin extract from HS and 10 mg of lisinopril among hypertensive, otherwise healthy adults. It was found that while showing moderate effectiveness in lowering blood pressure (17,14/11,97 mmHg or 11,58/12,21%), it was found to be well tolerated among the patients (100%). Nevertheless, the blood pressure reduction was significantly better in the control group receiving lisinopril [27]. Another study compared the otherwise healthy hypertensive patients from Nigeria, who were given 150 mg/kg of body weight of HS extract, 25 mg of hydrochlorothiazide, or placebo daily. Interestingly, after 4 weeks HS was found to be significantly more effective, than the standard medication in lowering blood pressure [28]. Conversely, it was found to be not superior to 12,5 mg of captopril taken twice a day, but overall HS showed some hypotensive properties [29]. Moreover, another study where it was compared to 25 mg of captopril twice a day showed, that both HS extract and captopril significantly lowered blood pressure. In addition, no statistically significant difference between the average reduction rates was shown [30]. Two studies comparing standardized HS tea to placebo showed a significant improvement in blood pressure after the supplementation periods. It is worth noting, that one study showed a better response to treatment among patients with the higher baseline systolic blood pressure values [31], [32]. A study by Bourqui et al. compared the effects of HS and *Combretum micranthum* as either a standardized decoction or a tablet to 50 mg of captopril twice a day. It is worth noting, that this study had the longest 6 months follow-up period. It was found, that the brews were superior to the standardized tablets, while being as effective as captopril in lowering blood pressure.

Nevertheless, the authors of this study acknowledged some limitations, like a high rate of attrition, and simple testing methods [33]. In a study comprising patients with uncontrolled hypertension, HS also showed positive results. It is worth noting that this study included Internally Displaced Persons and Refugees in Iraq, who couldn't treat their hypertension on a regular basis, showing that HS can be a safe and readily available alternative to standard treatment in times of crisis and drug shortages [34]. Another study observed the effects of 3 doses of HS tea among patients with normal blood pressure and mild hypertension and uncomplicated diabetes mellitus. It was found that among these patients a significant lowering of blood pressure was achieved [35]. Overall, studies have shown, that HS exhibits a hypotensive effect *in vivo*, and *in vitro*, suggesting that it could be a safe and effective natural remedy for hypertension, optimally used with classical medicine.

2. Hyperlipidemia, obesity

Other cardiovascular risk factors that could be managed by HS supplementations are hyperlipidemia, obesity, and metabolic syndrome. In a study conducted by Chen et al., rabbits were fed with a diet containing extra cholesterol, as well as an extract from HS. In the study group serum triglyceride, cholesterol and LDL levels were significantly lower after 10 weeks than in the control group. Moreover, atherosclerosis in the thoracic aorta walls was significantly more prominent in the control group than in the study group [36]. Another study conducted by da Costa et al. examined the effects of supplementation with HS water extract on obese and eutrophic rats consuming a high-fat diet, or a normal diet. It was found that in the study group, LDL cholesterol levels were significantly lower, in addition to decreased AST and bilirubin levels, which could indicate hepatoprotective properties of HS. Moreover, a reduction of body fat gain and total adipose tissue weight was observed in the study group [37]. Similar results were observed in other studies performed on rats, with one study proving a dose-dependent efficiency of the extract, although the highest concentration (300 mg/kg) was still less effective than atorvastatin, while another study proved that no significant difference between HDL levels was observed in both groups [38], [39]. In a study performed on healthy adult men, a comparison of the effects of green tea and sour tea (HS beverage) was examined. A significant improvement in total, LDL and HDL cholesterol, as well as systolic blood pressure was obtained after 6 weeks of sour tea consumption. Conversely, green tea consumption improved significantly only HDL levels in the second study group. Nevertheless, when comparing between the groups, a significant difference was observed only in systolic blood pressure in favor of the sour tea [40]. A randomized, crossover study was performed on 42 patients with elevated cholesterol levels. After 4 weeks, serum cholesterol levels decreased

significantly by 11-14%, indicating that HS was not superior to etofibrate in lowering cholesterol levels [41]. Another study enrolled 90 essentially hypertensive participants. After 15 days of ingestion of HS beverage or black tea as placebo, blood samples were taken and analysed. No statistically significant differences were noted between the groups when comparing the fasting blood sugar levels, total, LDL, and HDL cholesterol, as well as total triglycerides. Creatinine and blood urea nitrogen (BUN) were measured as well, but showed no improvement between the groups. Nevertheless, the observation period was very short in this study, moreover, no blood pressure measurements were taken during it [42]. In a study performed by Hajifaraji et al., 43 adults with polygenic hyperlipidemia were treated with 2 cups of HS beverage daily or received no beverage for 12 weeks. Both groups were trained in lifestyle modification. After the intervention, total cholesterol, as well as HDL and LDL levels were significantly reduced in the study group. On the contrary, HS seemed not to have any significant influence on triglyceride serum levels [43]. Several studies have evaluated HS supplementation in the treatment of the metabolic syndrome. In one study, participants were divided into 3 groups- one receiving only 100 mg of HS extract daily, the second receiving only a diet, and the third receiving both the capsule and the diet. After one month of treatment, blood glucose, HDL, LDL and total cholesterol levels improved significantly in the group receiving only HS extract. Additionally, a significant improvement in blood pressure (both systolic and diastolic), blood glucose, HDL, and VLDL cholesterol, as well as triglyceride levels was observed in the group receiving both HS and diet. No such changes were noted in the diet-only group, with the exception of an improvement in HDL cholesterol levels [44]. In another study comprising patients with metabolic syndrome, the participants were given 500 mg of calyx powder or placebo for 4 weeks. A significant improvement in systolic blood pressure and triglyceride serum levels was noted compared to placebo. A statistically significant lowering of BMI was noted in the study group, with no statistical difference between it and the control group [45]. Another study compared the impact of HS on blood cholesterol levels among patients with type 2 diabetes. Although statistically significant results were obtained in the study group, the only statistical difference between the groups was obtained in the LDL cholesterol level improvement [46]. Another study examined the impact of daily supplementation with 450 mg of HS on NAFLD, as well as on lipid profiles and blood pressure. After 8 weeks, a significant improvement of alanine aminotransferase and aspartate aminotransferase was noted, as well as a significant decrease in total triglyceride levels and blood pressure. No significant changes in total cholesterol, LDL cholesterol and HDL cholesterol were noted [47]. In summary, studies have shown different, sometimes

contraindicatory results. Nevertheless, the above evidence suggests at least some positive impact of HS supplementation on the cholesterol profile, as well as on triglyceride levels.

3. Antibacterial properties

In times of growing microbial resistance to classical antibiotics, researchers often turn to natural remedies, seeking new compounds that could be effective against various microbes. Venkatesan et al. studied the effects of HS flower methanol extract on the growth of pathogenic bacteria and fungi, namely *Staphylococcus aureus*, *Enterococcus faecalis*, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Candida albicans*. It was found that the extracts inhibited the growth of *S. aureus* and *E. coli* at a minimal inhibitory concentration (MIC) of 128 and 512 mg/l respectively of crude extract [48]. Another study looked at the effectiveness of HS aqueous extract against enteropathogenic *E. coli*. The MIC was determined to be 6,5 mg/l, and interestingly, the extract at the concentration of 25 mg/l reached the bactericidal endpoint after 24 hours. Moreover, the extract impaired the formation of pathogenic cellular pedestals by the bacteria, suggesting lower adhesion of the bacteria to the cells [49]. In another study, antibacterial properties of HS were studied in *E. coli* O157:H7 isolates. It was proven to have inhibitory properties not only in the clinical isolates, but in food and veterinary as well, suggesting potential activity against this type of bacteria [50]. Similar results were obtained in another experiment, where HS extract was able to inhibit the growth of *Staphylococcus aureus*, *Klebsiella pneumoniae*, and, interestingly, streptomycin-resistant *Escherichia coli*, suggesting a potential in managing antibiotic-resistant strains of bacteria [51]. Abbas et al. compared the antimicrobial effect of HS aqueous extract and classical antimicrobial substances including chlorhexidine, amoxicillin with clavulanic acid, metronidazole and tetracycline against *Streptococcus mutans*, *Staphylococcus aureus*, and *Enterococcus faecalis*. It was found that the extract of 50 mg/l was as effective as 0,2% chlorhexidine, and 100 mg/l as 2% chlorhexidine. Moreover, it showed the greatest activity against *S. mutans*, then against *E. faecalis* with the least activity against *S. aureus*, proving that it could be used as a good alternative to conventional mouthwash [52]. A similar study including different strains of oral pathogenic bacteria, namely *Streptococcus mutans*, *Streptococcus sobrinus*, *Porphyromonas gingivalis*, *Prevotella intermedia* and *Aggregatibacter actinomycetemcomitans* showed a bactericidal potential of HS [53]. Several studies have shown, that HS extract has an antimicrobial effect against *Helicobacter pylori*. *In vitro*, it had an inhibitory effect on strains resistant to clarithromycin and metronidazole. Additionally, in another study HS extracts showed synergistic effects against *H. pylori* with metronidazole, amoxicillin, and clarithromycin [54], [55]. Another study showed that HS

extract had an inhibitory effect on fluconazole- resistant *Candida albicans* strains, as well as prevented the formation of biofilm, suggesting future research in this field [56]. In conclusion, traditional uses of HS in bacterial infections might have a grain of truth, with many *in vitro* studies suggesting a potential for antimicrobial activity against many types and strains of bacteria and fungi.

4. Anticancer properties

HS, being a plant rich in flavonoids and anthocyanins, has been thoroughly studied for its potential anticancer use. A study by Chang et al. used methanol extract from the flowers of HS on human promyelocytic leukemia cells from multiple lines. This extract was found to be a potent cytotoxic agent for those cells by stimulation of p38 mitogen-activated protein kinase, which phosphorylates the c-jun protein, activating the FAS-dependent apoptotic cascade. It is worth noting, that p53-null lines of those cells, namely HL-60 and Hep3B, were the most sensitive to the cytotoxic effect of HS [57]. Another study including human oral squamous cell carcinoma cells SCC-25 and multiple myeloma RPMI 8226 cells were treated with an extract obtained from HS flowers. Interestingly, it was found to be effective in both tumors, with a cytostatic effect induced by phosphorylation of the p38 protein. Moreover, HS extract suppressed the phosphorylation of the ERK1/2 protein, further inhibiting the proliferation of the cells [58]. A study on melanoma cells suggested, that HS leaf extract not only induces apoptosis via the aforementioned FAS/FASL cascade, but also stimulates autophagy via inhibition of Akt/mTOR and stimulation of PI3K class III and Beclin-1 [59]. Lin et al. found that HS aqueous flower extract had an apoptotic effect on human gastric carcinoma cells via the p38/JNK pathway. On the other hand, an earlier study on the same type of cancer had shown, that stimulation of the p53-dependent pathway also plays a role in apoptotic characteristics of HS extract [60], [61]. Similar results were found in a study conducted on Ehrlich ascites carcinoma cells, suggesting a p53-activated apoptotic pathway [62]. The previous mechanisms are shown in fig. 1.

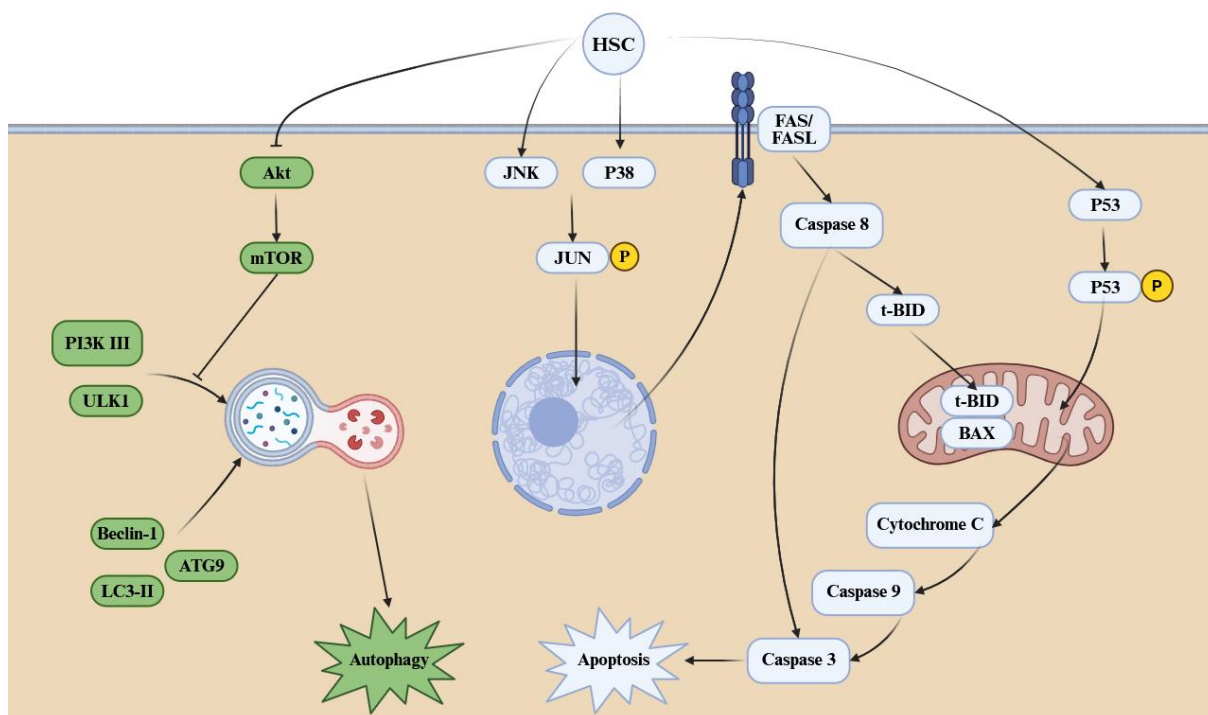


Fig. 1. Anticancer molecular properties of the Hibiscus Sabdariffa's compounds. Their activity relies mostly on inhibiting the Akt/mTOR inhibition of the autophagy pathway (on the left of the picture), and multi-way stimulation of caspase-dependent apoptosis of the cancer cells (on the right of the picture).

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The researchers have also taken a step further, and analysed the active compounds in HS that could have anticancer properties. The first one is delphinidin-3-sambubioside, whose effect was studied on human leukemia cells HL-60. The researchers found out that this molecule stimulates the generation of reactive oxygen species, which in turn stimulates either the FAS/FASL pathway, or disrupts mitochondria and releases cytochrome c, thus leading to cell death [63]. The other analysed active compound was protocatechuic acid, which was used on the same cell line. This compound caused cell death by DNA fragmentation, which resulted from lowering the level of hyperphosphorylated retinoblastoma protein, thus stimulating caspases and resulting in apoptosis [64].

Due to the fact, that HS contains phytoestrogens, it has emerged as a potential agent for the treatment of breast cancer. Malacrida et al. studied its effects on two breast cancer lines- MCF-7, which is ER α positive, and MDA-MB-231, which is triple negative. It was found, that HS extract slowed down the duplication in both cell cultures, while being more efficient in apoptosis induction in the ER α positive line. Interestingly, the ability to metastasize was

diminished more in the MDA-MB-231 line [65]. Another study performed on the MCF-7 line also proved the effectiveness of HS against breast cancer cells [66]. Additionally, a study performed on triple-negative HCC-70 breast cancer cells also showed that the cells underwent apoptosis after the exposure to HS extract, but only at the highest concentration of 1,0 mg/ml [67]. A study *in vivo* performed by Bassong et al. compared the effectiveness of HS extract on breast cancer positive rats compared with that of tamoxifen. The results showed that although less effective than tamoxifen, HS was relatively effective in reduction of tumor burden and its volume, as well as in the levels of CA 15-3. Interestingly, HS proved to be more effective at lower doses, with 125 mg/kg being more effective than 250 mg/kg and 500 mg/kg [68].

5. Impact of HS on kidneys

There are several *in vivo* studies regarding the potential nephroprotective effects of HS. The first one was conducted on albino rats, which were exposed to sub-lethal doses of malathion. The rats received either a water extract of HS or didn't receive any treatment. The scientists found that the group receiving this extract had significantly lower creatinine and urea levels compared to the untreated group, as well as lower kidney mass. Moreover, the histological exam of the kidneys of the treated rats suggested lower glomerular and tubular damage, than in the untreated group. All in all, those findings suggested nephroprotective effects of HS, by reducing oxidative stress in the cells [69]. Diabetic nephropathy was also thoroughly studied among rats with streptozotocin-induced type I diabetes. In the first study comparing the use of metformin and HS leaf extract, it was found that the active compounds in those leaves helped significantly to maintain electrolyte homeostasis, lower creatinine, urea and uric acid levels, as well as lower inflammatory markers and reduce the histological damage in the kidneys, suggesting nephroprotective activity [70]. A similar study also reported similar results, with the additional improvement of total plasma cholesterol, LDL and triglycerides after HS treatment [71]. Conversely, another study showed, that increased consumption of HS extract could potentially lead to kidney damage due to an increase in H₂S levels intracellularly, yet the findings were only histological and immunohistochemical, and no blood tests were performed on the rats [72].

In a study involving humans, patients with mild to moderate hypertension were divided into groups receiving 150 mg/kg of HS infusion, 10 mg of lisinopril, or a placebo daily for 4 weeks. Interestingly, the HS group had greater improvement in systolic, diastolic and mean arterial pressure, than the group receiving lisinopril, as well as an increase in urine volume and creatinine clearance, which was also better than in the lisinopril group [73]. Two studies performed in Thailand looked for the potential antilithiatic effect of HS, a belief widely held

among the local population. The results showed, that although these plants have some positive renal impact, they do not lower oxaluria. Moreover, in one of these studies the levels of uric acid in urine were significantly increased. In conclusion, no effect that could potentially prevent the formation of kidney stones was demonstrated [74], [75] . Concluding these findings, HS may have some nephroprotective activity, especially in hypertension and toxicological cases.

6. Impact of HS on liver

Due to the antioxidative and anti-inflammatory properties of HS, it has been examined by scientists for the potential hepatoprotective effects. Due to the fact, that the liver is the most important detoxification organ in the organism, it is under constant oxidative and toxic pressure. Several toxic compounds have been tested, the first one being acetaminophen, also known as paracetamol. The first study compared other medicinal plants, including *Kigelia africana*, *Calotropis procera*, and *Alchornea cordifolia* with HS. Serum AST and ALT were significantly lower in the HS group, than in the paracetamol-only group. Moreover, activities of superoxide dismutase, catalase, δ -aminolevulinatase and glutathione peroxidase although reduced, were significantly higher than in the paracetamol-only group, suggesting hepatoprotective properties of HS [76] . In another study, HS extract didn't significantly improve the liver function, regarding enzyme activities such as ALT, AST, and sorbitol Dehydrogenase, whereas hepatic GSH levels significantly improved after 4 weeks. An anthocyanin extract in another group improved significantly those measurements only at the highest dose of 200 mg/kg, suggesting a dose-dependent effectiveness [77]. HS extract also offered a protection against hepatotoxic agents such as cadmium, or CCl₄ [78], [79]. A study involving rats observed, whether HS supplementation could alleviate liver steatosis in high fat diet. It was found that serum AST, ALT, hepatic IL-6 and TNF- α were significantly lower in the groups receiving HS, than in the one receiving only high-fat diet. Moreover, the Lee index, which is used to measure obesity status in rats, was significantly lower in the HS group. Hepatic triglycerides and cholesterol levels were also lower in the HS group, although this effect was dose-dependent [80] . In a study involving humans, 36 obese patients with fatty liver were randomly divided into a control group, and a group receiving 450 mg of HS extract twice a day for 12 weeks. The HS group had a significantly higher BMI and body weight decrease; moreover, it had a significant decrease in ultrasonographic fatty liver score. Nevertheless, no significant differences in levels of cholesterol, glucose, and hepatic enzymes were noted after 12 weeks [81] . In conclusion, HS impact on the liver relies mostly on

scavenging free radicals and protecting it from oxidative stress, with some moderate effect on fatty liver disease associated with obesity.

Conclusions

Hibiscus sabdariffa is a cheap and widely available plant with a considerable phytopharmacological potential in many areas of medicine. It can be effectively used as an additional medicine in illnesses such as hypertension, hyperlipidemia, obesity, and various nephrotoxic and hepatotoxic states. Moreover, in most studies, it is a very safe and almost non-toxic substance, with rarely reported side effects. With anti-inflammatory and antioxidant properties, it could potentially be used in various inflammatory diseases. The anticancer properties of this plant could yield some effective drugs in the future, but further studies of the active compounds should be performed. Moreover, more studies on a larger scale and with longer follow-up periods should be performed, to assess the safety of supplementation, the dosage, as well as pharmacokinetics, and interactions with other drugs.

Disclosure

Author contribution statement

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Supplementary materials

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Conflict of interest

The authors declare no conflict of interest.

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