



Bioactive compounds and nutraceutical properties of *Allium* species: A review

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Abstract

Allium is one of the largest genera under the family *Alliaceae* encompassing over 750 species, which is considered as important species in Indian traditional medicinal plants. Besides commonly known garlic and onion, there are many others like leek, scallion, shallot, wild garlic etc. which are widely grown for their culinary use and folklore medicine. Many of the biological effects of *Allium* species are related to thiosulfinate and volatile sulfur compounds, major active compounds includes, diallyl disulfide, diallyl trisulfide, diallyl sulfide, dipropyl disulfide, dipropyl trisulfide, 1-propenylpropyl disulfide, allyl methyl disulfide and dimethyl disulfide. Apart from its volatile compounds phytonutrients like flavonoids, saponins and saponins, phenolic compounds, nitrogen oxides and amides, vitamins, mineral exhibits medicinal and therapeutic properties such as anti-diabetic, anti-inflammatory, anti-carcinogenic, hypocholesterolemic and antimicrobial properties. The present reviews article provides light to the nutraceutical properties of different *Allium* species regards to metabolic syndrome.

Keywords: *Allium*, nutraceutical, thiosulfinate, phytonutrients, volatile compound

Introduction

Bioactive compounds present in plants act as health promoting agents in protecting human health. These compounds also referred as nutraceutical or phytonutrients. They have certain therapeutic value and the advent of which has opened doors to the use of alternative strategies in the protection against the pathologies of numerous age-related or chronic diseases due to the facts that they have lesser side effects [1]. Thereby, nutraceutical are gaining interest in various scientific communities such as pharmaceuticals, food industries, food researchers for introducing various drugs, herbal dietary supplements and herbal medicines [2].

The genus *Allium* is economically important containing several medicinal and edible species used as food and medicine and numerous studies have been carried out due to its rich source of phytonutrients, and recognized to have significant and wide biological activities. *Allium* species serve the purpose of as a culinary ingredient, ornamental, or as a traditional therapeutic agent, commonly used in traditional herbal drug preparations [3]. Among the different *Allium* species found in India, onion and garlic are widely used as vegetable and medicine. They are perennial plants with underground storage organs consisting of bulbs or rhizomes. Besides commonly known garlic and onion, there are numerous other species are extensively grown for cooking purposes and medicinal plants such as leek (*Allium porrum* L.), scallion (*Allium fistulosum* L.), shallot (*Allium ascalonicum* Hort.), elephant garlic (*Allium ampeloprasum* L. var. *ampeloprasum*), chive (*Allium schoenoprasum* L.) and chinese leek (*Allium tuberosum* L.) [4].

In traditional medicines, majority of the *Allium* sp. have been used to treat or prevent common flu, cold, cough, asthma, headache, stomachache, and arthritis. The phytochemical profile of *Allium* species has revealed a great distribution of secondary metabolites and bioactive compounds, mainly due to rich content of thiosulphites and other organosulfur compounds. Besides others bioactive

phytochemicals such as polyphenols, quercetin, tannins, flavonoids, gallic acid, ferulic acids, cinnamic acid, N-caffeoyltyramine, carotenoids, anthocyanins, polysulfanes, alkaloids, saponins, vitamins (B1, B2, C, and E), selenium, organoselenium, fructo-oligosaccharides, and chlorophyll are present [5]. Consumption of *Allium* vegetables is associated with health benefits like antiviral, antibacterial, antifungal, antidiabetic, anti-carcinogenic, anti-platelet, antispasmodic, antiseptic, anti-helminthic, anti-thrombotic, anti-asthmatic, anti-carminative, anti-oxidant, anti-inflammatory, antihypertensive, hypoglycemic, hypotensive, lithontripic and hypo-cholesterolemic properties [6].

Chemical constituent of *Allium* vegetables

The biological activities of *Allium* plants are primarily attributed to thiosulfates and volatile sulfur compounds which are responsible for the pungency of *Allium* vegetables. Garlic and other *Allium* plants contain the highest amount of organosulfur compounds (ORCs) compared to common vegetables [7]. The composition of organosulphur compounds (OCSs) differs depending on the *Allium* species, plant cultivation or storage conditions and processing methods [8]. The main chemical constituent of intact garlic is the amino acid "alliin". It is an alkyl derivative of cysteine alkyl sulfoxide, responsible for the typical odors, which may vary from 0.2 – 2 percent fresh weight basis. Crushing, chewing and cutting of garlic cloves releases the enzyme alliinase that acts upon the cytosolic cysteine sulfoxide to form sulfenic acid (R-SOH) which rapidly condenses to form allicin [9]. Thirty three organosulphur compounds are reported after crushing and sixteen OSCs before crushing. The conversion of alliin to allicin is particularly rapid because enzyme and substrate appear in equal high amounts within the cell [8]. Due to their high instability, the volatile thiosulfates are degraded within 24 hours into "second generation products" like oil-soluble mono-, di- and triallylsulfides (DAS, DADS,

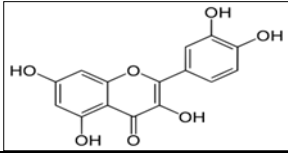
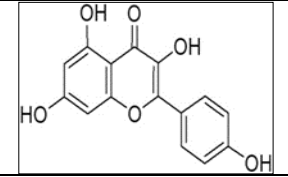
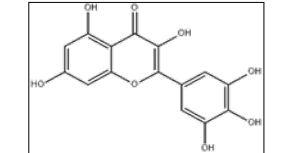
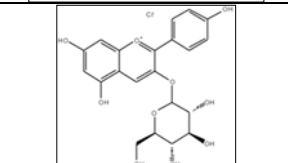
DATS) as well as vinylthiins, thioacroleins and ajoene^[10], which still possess considerable biological activities to prevent against cancer, diabetes, and cardiovascular problems^[11]. The total thiosulfide contents in green onion leaves, chive, and onion bulb were 0.2, 0.72, and 1.02 g/kg fresh weight, respectively. Depending on different types of *Allium* vegetables, the concentration and type of thiosulphides is also variable. For example onion bulbs contained 34% methiin, 5% ethiin, 6% propiin, 5% alliin, and 49% isoalliin while garlic cloves contained about 92% alliin, 8% methiin, and trace amounts of ethiin, propiin, and isoalliin^[12]. The different types of organosulfur compounds and bioactive compounds present in *Allium* species is elaborate in table 1.

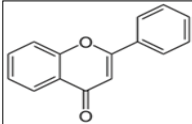
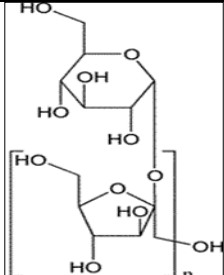
Flavonoids and their derivatives is one the second most important bioactive compounds present in *Allium* vegetables such as *Allium sativum*, *Allium cepa*, *Allium schoenoprasum* and also from wild species like *Allium filidens*, *Allium griffithianum*, *Allium rosenbachianum*. They have

antioxidant, antitumor, antiinflammatory and antimutagenic activities^[11]. Two types of flavonoids are found in onion bulbs, anthocyanins in red onions and flavonols like quercetin and kaempferol in most yellow fresh cultivars. The total flavonoid content in onion leaves and garlic were about 2.7 and 1.0 g/kg dry weight, respectively^[17]. Nearly 55% of total flavonoids are quercetin, 31% kaempferol, and 14% luteolin in onion leaves^[18] and in garlic cloves, 72% of the total flavonoids are myricetin, 23% apigenin, and 5% quercetin^[17].

A broad range of other compounds has also been isolated from the different genus of *Allium* such as *Allium cepa* contain carotene, vitamin B, calcium and traces of vitamin C, *Allium sativum* (phenol, vitamin C, carotenoid), and *Allium tuberosum* (terpenes, oxygenated compounds). Other compounds reported from this genus include saponins, cartechol, terpenes, seleno amino acids, potassium, sodium, magnesium, ascorbic acid^[6].

Table 1: Elaborates on the different types of organosulfur compounds and bioactive compounds present in *Allium* species^[13, 14, 15, 16]

	Compounds	Chemical Structures
Organosulfur Compounds	S-allylcysteine sulfoxide (SACS)	CH ₂ =CH-CH ₂ -S(O)-CH ₂ -CH(NH ₂)-COOH
	S-Propenylcysteine sulfoxide (SPCS) (Lacrimatory precursor)	CH ₃ -CH=CH-S(O)-CH ₂ -CH(NH ₂)-COOH
	S-Propylcysteine sulfoxide	CH ₃ -CH ₂ -CH ₂ -S(O)-CH ₂ -CH(NH ₂)-COOH
	S-methylcysteine sulfoxide (SMCS)	CH ₃ -S(O)-CH ₂ -CH(NH ₂)-COOH
	Allicin	CH ₂ =CH-CH ₂ -S(O)-S-CH ₂ -CH=CH ₂
	Ajoene	CH ₂ =CH-CH ₂ -S(O)-CH ₂ -CH=CH-S-S-CH ₂ -CH=CH ₂
	Propanethial S-oxide	CH ₃ -CH ₂ -CH=SO
	Diallyl sulphide	CH ₂ =CH-CH ₂ -S-CH ₂ -CH=CH ₂
	Diallyl disulfide (DADS)	CH ₂ =CH-CH ₂ -S-S-CH ₂ -CH=CH ₂
	Diallyl trisulfide (DATS)	CH ₂ =CH-CH ₂ -S-S-S-CH ₂ -CH=CH ₂
	Allylmethyl sulfide (AMS)	CH ₂ =CH-CH ₂ -S-CH ₃
	Allylmethyl disulfide (AMDS)	CH ₂ =CH-CH ₂ -S-S-CH ₃
	Allylmethyl trisulfide (AMTS)	CH ₂ =CH-CH ₂ -S-S-S-CH ₃
	Dipropyl sulfide (DPS)	CH ₃ -CH ₂ -CH ₂ -S-CH ₂ -CH ₂ -CH ₃
	Dipropyl disulfide (DPDS)	CH ₃ -CH ₂ -CH ₂ -S-S-CH ₂ -CH ₂ -CH ₃
	Dipropyl trisulfide (DPTS)	CH ₃ -CH ₂ -CH ₂ -S-S-S-CH ₂ -CH ₂ -CH ₃
	Propylmethyl sulfide (PMS)	CH ₃ -CH ₂ -CH ₂ -S-CH ₃
	Propylmethyl disulfide (PMDs)	CH ₃ -CH ₂ -CH ₂ -S-S-CH ₃
	Propylmethyl trisulfide	CH ₃ -CH ₂ -CH ₂ -S-S-S-CH ₃
	S-Allylcysteine (SAC)	CH ₂ =CH-CH ₂ -S-CH ₂ -CH(NH ₂)-COOH
S-Allylmercaptocysteine (SAMC)	CH ₂ =CH-CH ₂ -S-S-CH ₂ -CH(NH ₂)-COOH	
Bioactive Compounds	Quercetin	
	Kaempferol	
	Myricetin	
	Anthocyanin	

	Flavanoid	
	Inulin	

Biological activities of *Allium* species

The genus *Allium* possesses wide range of biological activities due to its bioactive phytochemical constituents include organosulfur compounds, thiosulfonates, polysulfanes, polyphenols, tannins, flavonoids, alkaloids, saponins, fructans, fructo-oligosaccharides, essential oils, amino acids, vitamins, pigments, and much more; which

have broad range of applications in health field such as anti-inflammatory, anti-spasmodic, anti-carcinogenic, anti-septic, lithontripic and hypocholesterolemic properties [3, 5]. This review will overview of current pharmacological applications of different *Allium* species. Summary of the biological activities of the *Allium* species is displayed in table 2.

Table 2: Summary of the biological activities of the *Allium* species

Therapeutic activity	Compound/ Extract	Mode of effect	References
Antioxidant activity	<ul style="list-style-type: none"> ▪ DAS, DADS and garlic oil ▪ SAMC and SAC from aged garlic ▪ Superoxide dismutase (SOD) and catalase (CAT), enzymatic antioxidants like glutathione (GSH) and flavonoids 	<p>Enhancing SOD activity, stimulate the activity of glutathione reductase.</p> <p>Reduces radical scavenging properties</p> <p>High antioxidant activity is found due to Antioxidant enzyme activities</p>	19 20 5
Anti-diabetic activity	<ul style="list-style-type: none"> ▪ <i>Allium sativum</i> extracts is presence of volatile sulfur compounds, such as alliin, allicin, diallyl disulfide, diallyl trisulfide, diallyl sulphide. ▪ S-methyl cysteine sulfoxide (SMCS) <i>Allium cepa</i> ▪ <i>Allium cepa</i> is a good source of chromium 	<p>Effective in reducing insulin resistance.</p> <p>Stimulation of insulin secretion, effective in reduction of blood glucose level.</p> <p>Decrease fasting glucose levels, Improve glucose tolerance, lower insulin levels and decrease total cholesterol and triglyceride levels</p>	21 22 23
Anti-cancer activity	<ul style="list-style-type: none"> ▪ Allicin from garlic ▪ DADS from <i>Allium</i> species ▪ Quercetin 	<p>Interference with tumor angiogenesis, induction of apoptosis by activation of proapoptotic "Bax molecule" in ovarian cancer cell lines.</p> <p>Synergizes the effect of eicosapentaenoic acid, a breast cancer suppressor, and antagonizes the effect of linoleic acid, a breast cancer enhancer.</p> <p>Inhibits migration and invasion of SAS human oral cancer cells through inhibition of NF-κB and MMP-2/-9 signaling pathways.</p>	24, 25 26 27
Anti-inflammatory activity	<ul style="list-style-type: none"> ▪ S-allyl-cysteine and allicin ▪ Effect of allicin <i>in vitro</i> studies ▪ S-methyl cysteine sulfoxide (SMCS) 	<p>Expression of nuclear factor-κB, oxidative stress, renin-angiotensin-aldosterone system and reduction in the bioavailability of nitric oxide</p> <p>Inhibition of ADP-induced Platelet aggregation and increased its fibrinolytic activity</p> <p>Reduce the level of cholesterol, triglyceride and phospholipids</p>	28 29 22
Antimicrobial activity	<ul style="list-style-type: none"> ▪ Allicin (diallylthiosulfinate) ▪ Saponins and sapogenins from <i>A. porrum</i> ▪ Antiviral activities of shallots, garlic, onions, leeks, and green onions extract 	<p>Reduces the proliferation of bacteria and inhibit the methicillin-resistant <i>Staphylococcus aureus</i> (MRSA).</p> <p>Cure fungal diseases such as <i>Fusarium oxysporum</i>, <i>Fusarium solani</i>, <i>Rhizoctonia solani</i>, air-borne pathogens <i>Botrytis cinerea</i>, <i>Alternaria alternate</i>. Showed highest antiviral activity against ADV41 and ADV3, followed by garlic and onions.</p>	11 30 31

Antioxidant activity

Bioactive compounds from plants origin behave as antioxidant because they can act as free radicals scavengers, singlet oxygen quenches or metal chelators. Chronic and

degenerative diseases include cardiovascular, neurodegenerative; inflammatory diseases and cancer are caused due to the oxidative modification of DNA, proteins and lipids by reactive oxygen species (ROS). Consumption

of plants processing antioxidant potentials protects from oxidative damage from ROS. Medicinal plants rich in polyphenols can retard the oxidative degradation of lipids and improve the quality and nutritional value of food [32].

Allium species prevent tumour promotion and process be involved with free radicals, like cardiovascular diseases and aging. In many *Allium* species (both wild and cultivated) the superoxide dismutase (SOD) and catalase (CAT) activities were detected in bulbs. High antioxidant activity is mainly due to antioxidant enzyme activities like SOD, CAT and non-enzymatic antioxidants like glutathione (GSH) and flavonoids [5]. There are countless researches that have presented the antioxidant properties of different kinds of *Allium* species. Garlic (*Allium sativum*) contains stable organosulphur compounds, flavonoids, and polyphenols, which had potent antioxidant properties [33]. Studies have shown that DAS, DADS and garlic oil are capable of enhancing SOD activity, stimulate the activity of glutathione reductase [19]. Another study showed that SAMC and SAC from aged garlic showed radical scavenging properties [20].

The total phenols content and antioxidant activity of *Allium sativum* are 97.5 (mg GAE/100g) and 18.42 DPPH percent, respectively [34]. *Allium ampeloprasum* showed similar values of ascorbic acid content to those found in cultivated leek (*Allium porrum*) of nearly 5.15 mg/100g [35] as well as in garlic (*Allium sativum*) 14 mg/100g [36] which is a potent antioxidant activity. *Allium odorum* shows high total flavanoid content as 215 mg/100g, total alkaloid 11.95 mg/100g, reducing power 1.13 mg/100g, DPPH 51.72 percent, and total phenol as 88.46 mg/100g [37].

Anti-diabetic activity

Diabetes mellitus is a metabolic syndrome of hyperglycaemia and its consequences is due to relative or absolute deficiency of insulin or insulin resistance. *Allium sativum* extracts have been reported to be effective in reducing insulin resistance, and the beneficial effect is attributed to the presence of volatile sulfur compounds, such as alliin, allicin, diallyl disulfide, diallyl trisulfide, diallyl sulfide, S-allyl cysteine, ajoene, and allyl mercaptan [21]. Kumar *et al* [38] investigated that garlic and metformin treatment on diabetes patients for 12 weeks reduces fasting blood glucose (FBG), but the percentage of change in FBG was more substantial with metformin supplemented with garlic than with metformin alone. Raw garlic (3.6 grams for 30 days on fasting) was given to diabetic patients showed a significant decrease in fasting hyperglycaemia and lipid levels [39]. Raw garlic homogenate is effective in reducing cardiac hypertrophy and fructose-induced myocardial oxidative stress through the PI3K/ AKT/Nrf2-Keap1-dependent pathway [40].

S-methyl cysteine sulfoxide (SMCS) isolated from *Allium cepa* has been proved for antidiabetic effects, the mechanism of action could be partly dependent on the stimulation of insulin secretion. Aqueous extract of *A. cepa* shows effective in reduction of blood glucose level was observed at 300mg/kg [22]. Onions contain many active compounds such as APDS along with other active sulfur-containing compounds as well quercetin which is a flavonoid shows the hypoglycaemic properties [41]. The hypoglycaemic effects of garlic and onion juice on alloxan-induced diabetic rats and observed an increase in the activity

of glutathioneS-transferase in plasma, liver, testes, brain and kidneys in the diabetic rats compared with normal rats. Garlic and onion juice also exhibited antioxidant and anti-hyperglycemic effects in the treated rats and, in addition, alleviated liver and renal damage in alloxan-induced diabetic rats [42]. Clinical studies on diabetic patients have shown that chromium can decrease fasting glucose levels, improve glucose tolerance, lower insulin levels and decrease total cholesterol and triglyceride levels. Two hundred grams of onions contain up to 20% of the daily requirements in chromium [23].

Oral administration of *Allium ampeloprasum* for one month caused a significant reduction in the level of glucose, cholesterol, and triglyceride in experimental models of diabetes mellitus induced by streptozotocin in rats and the study also indicates that one-month administration of *Allium ampeloprasum* could attenuate nociceptive score in an experimental model of diabetes mellitus [43].

Anti-cancer activity

Cancer is still a major cause of mortality and morbidity in developing as well as in the developed countries. The genus *Allium* consisted of many phytochemicals having cancer chemo-protective abilities, possess cancer-preventive properties. Diallyl sulfides, disulfides and trisulfides from *A. cepa*, *A. sativum*, *A. schoenoprasum* and *A. tuberosum* are cancer chemoprotective phytochemicals. They also contain flavonoids, saponins and carotenoids which are cancer chemo-protective. These substances act as antioxidant and electrophile scavengers and stimulate the immune system [6]. Various forms of *Allium sativum*, including fresh garlic extract, aged garlic, garlic oil and a number of organosulphur compounds, appear to offer protection against some cancers. Among all the biological activities, inhibition of the growth of cancer is one of the most notable one. They have several synergistic biological effects that either prevent or possibly may fight cancer. The role of allicin in interference with tumour angiogenesis and anti-apoptotic proteins is well established [24] and induction of apoptosis by activation of proapoptotic "Bax molecule" in ovarian cancer cell lines is documented for allicin [25]. The effect of DADS was investigated in terms of the proliferation of gastric adenocarcinoma cell line at various concentrations. It was observed that the percentage of live gastric adenocarcinoma cells was decreased to 23 percent of that in the control group after 400 µM DADS treatment for 48 hours [44]. DADS synergize the effect of eicosapentaenoic acid, a breast cancer suppressor, and antagonize the effect of linoleic acid, a breast cancer enhancer [26]. DADS is also involved in inhibition of BaP-induced carcinogenesis. This includes inhibition of cell proliferation, regulation of cell cycle, attenuation of ROS formation and inhibition of DNA damage. Thus, the investigators suggest that DADS could be an effective attenuator of BaP-induced breast carcinogenesis *in vitro* [45].

A. cepa contains organosulfur compounds, which suppress the proliferation of tumor cells, alteration in carcinogen-metabolizing enzymes, cell cycle arrest, induction of apoptotic cell death, suppression of oncogenic signal transduction pathways, and inhibition of neoangiogenesis [46]. Onion contains flavonoid quercetin that shows considered as a good anticancer activity. Quercetin inhibits migration and invasion of SAS human oral cancer cells through inhibition of NF-κB and MMP-2/-9 signaling

pathways [27]. It also shows antiproliferation, cell cycle arrest, and induction of apoptosis of cancer cells. It induces the apoptosis of certain malignant cells mainly on human malignant pleural mesothelioma [47]. Fisetin is highly useful natural agent present in onion shows potential inhibitory role against cancer in several *in vitro* and *in vivo* studies [48]. Researchers demonstrate that there is the potential effect of *Allium ampeloprasum* on osteosarcoma cells (U2OS). It depressed U2OS cell viability, proliferation and affected their morphology. It was also found that *Allium ampeloprasum* not only inhibited cancer cells directly via anti-proliferation but also affected the cancer cells metastasis process [49].

Anti-inflammatory activity

Cardiovascular diseases (CVD) are a disease of societal change that has led to altered lifestyles. It is the obstruction or clogging of the coronary arteries which causes more deaths than any other factors. The two greatest means of heart disease are high blood pressure and high blood serum cholesterol levels. Disorders of the heart and the circulatory system claim more lives than any other diseases. Various plants of *Allium* sp. are well established for their active role played in reducing cholesterol levels under *in vitro* and *in vivo* conditions [3]. Studies have shown that organosulfur compounds such as *s*-allyl-cysteine and allicin are effective in preventing some pathophysiological factors in hypertension such as expression of nuclear factor- κ B, oxidative stress, renin-angiotensin-aldosterone system and reduction in the bioavailability of nitric oxide [28]. *In vitro* studies, Allicin has a direct effect on platelet aggregation and plasma fibrinolytic activity. Plasma incubation with Allicin (80 μ g/ml) resulted in a significant inhibition of ADP-induced platelet aggregation by 36 percent as compared to the same plasma samples incubated without Allicin. Additionally, incubation of plasma with Allicin also increased its fibrinolytic activity by 2.8 fold (from 11.6 to 32.5 mm^2) [29]. Aged garlic extract was superior to placebo in lowering systolic blood pressure in patients suffering from uncontrolled hypertension. A dosage of 240-960 mg of aged garlic extract containing 0.6-2.4 of *S*-allyl cysteine significantly lowered blood pressure by about 12 mmHg over 12 weeks [50].

S-methyl cysteine sulfoxide (SMCS) a precursor of onion oil, isolated from *Allium cepa* have been reported to reduce the level of cholesterol, triglyceride and phospholipids showing that it have hypolipidemic effects and reducing the cholesterol levels [28]. Onion (*A. cepa*) leaves showed cardioprotective and antioxidant activity in doxorubicin-induced cardiotoxicity in rats [51]. A study carried out by Movahedian *et al* [52] on rabbits fed with hypercholesterolemic diet to evaluate the antihypercholesterolemic effect of a hydroalcoholic extract of *A. porrum* L. bulbs for twelve weeks showing low plasma total cholesterol, LDL decreased significantly in all groups treated with *A. porrum* extract. *Allium ampeloprasum* has significant effects on decreasing liver triglycerides (TG), plasma Alanine aminotransferase and gene expression of tumor necrosis factor- α in hamsters fed a high-fat diet containing Persian leek as compared to high-fat diet [53]. Parmadi *et al* [54] revealed that *Allium odorum* showed positive effect on lowering blood Pressure level in test human subjects, from 122 mmHg to 105 mmHg in systolic blood pressure whereas 79 mmHg to 71 mmHg in diastolic blood pressure after consuming chives boiling water.

Antimicrobial activity

The organosulfur compounds found in *Allium* species have been shown to have antibacterial activity, these activities are related by their rich content in sulfur compounds [41]. Antimicrobial activities of *Allium sativum* have been studied extensively over the past decade and the main constituents that fight or inhibit microbes are the sulfoxides. The chief of these sulfoxides is alliin from garlic and giant garlic, isoalliin from onion and shallot and methiin from chives and Chinese chives [55]. Allicin (diallylthiosulfinate) can hinder the proliferation of bacteria and has also been reported to inhibit the methicillin-resistant *Staphylococcus aureus* (MRSA) [11]. The antimicrobial effect of garlic and Chinese chive are due to diallyl sulfide and their compositions. Garlic essential oil contains DATS and diallyl tetrasulfide, while Chinese chive contains DMDS, AMDS, DMTS and AMTS which shows the inhibition against the antimicrobial activities [56].

A. cepa and *A. sativum* show great potential in treatment of fungal diseases and have revealed to inhibit against *Malassezia furfur*, *Candida albicans*, dermatophyte species and compared with the activity of a known antifungal drug, ketoconazole (KTZ) [57]. Saponins and saponinins are secondary metabolites isolated from species of *Allium* such as from *A. porrum* has been used to cure many fungal diseases *Fusarium oxysporum*, *Fusarium solani*, *Rhizoctonia solani*, air-borne pathogens *Botrytis cinerea*, *Alternaria alternata*. It was concluded that the bulb extract showed high antifungal activity against these strains [30].

Antiviral activities of shallots, garlic, onions, leeks, and green onions extract against adenovirus results revealed that shallots showed highest antiviral activity against ADV41 and ADV3, followed by garlic and onions [31]. Onion oil (*Allium cepa*) has showed to present hexadecanoic acid which has high binding affinity for the selected proteins in dengue virus, thereby it may be recommended to use as an efficient target drug to treat dengue virus (58). Studies have showed that *Allium sativum* enhance the immune system as well as to suppress proinflammatory cytokine production which can be used as a preventive measure against COVID-19 infection [59].

Conclusion

Allium species is one of the oldest cultivated species which have a history of using as traditional medicine and culinary purposes over centuries. Onion (*Allium cepa* L.) and garlic (*Allium sativum* L.) are one of the common species used; other edible *Allium* species were also used in specific native areas. They are rich source of phytochemicals and well-known for its wide range of biological activities. Studies have proved that thiosulfinates and volatile sulfur compounds are responsible for various biological activities, other phytochemicals such as flavonoids, saponins and saponinins, phenolic compounds, nitrogen oxides and amides, vitamins, mineral exhibits medicinal and therapeutic properties such as anti-diabetic, anti-inflammatory, anti-carcinogenic, hypocholesterolemic and antimicrobial properties. With the recent increase in application and utilization of alternative medicine and natural bioactive products, *Allium* and their derivatives can be promising and potential natural remedies. However, further research is needed to fully explore the bioactive compounds in the wild *Allium* species to improve our future experimental and clinical research plans.

Conflict of Interest

The authors declare no conflict of interest.

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