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REVIEW

Bioactive Compounds and Biological Activities of Garlic

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Abstract

Purpose of Review Garlic the famous bulb plant, is acknowledged by many as an important culinary spice and easily recognized by its pungent smell. This review seeks to establish an insight into the plant garlic, its history, bioactive compounds, and biological properties.

Recent Findings Due to various extensive clinical and experimental researches, it has been proven that garlic is not just a culinary spice but also a plant found to possess great health benefits for the treatment of various diseases. These great health benefits are attributed to the organosulfur compounds, saponins, phenolics polysaccharides, and amino acids present in it which elicit anti-inflammatory, antioxidant, anticancer, antimicrobial, antidiabetic, cardio-protective, neuro-protective, immuno-modulatory, anti-inflammatory, and antihypertensive properties. Garlic is considered generally safe for humans even by the Food and Drug Administration (FDA); the bulb can however induce gastric agitation especially when ingested in high doses. Randomized controlled studies that assessed the safety of garlic reported vomiting, insomnia, dizziness, heartburn, headache, hypotension, bloating, tachycardia, and offensive body odor. Moreover, ingesting high doses of raw garlic on an empty stomach can change in the intestinal flora and can also cause gastrointestinal disturbances.

Summary Various studies have reported the organosulfur compounds as the major bioactive compounds present in garlic. Inadvertently, the compounds have numerous advantageous effects both in checking and in managing different diseases

Keywords Garlic · Organosulfur · Compounds · Prophylactic

Introduction

Allium sativum is a well-known herb having numerous pharmacological properties that has been used in health-related purposes for more than 2000 years; its health potency is mainly due to the presence of various bioactive constituents of varying concentrations [1]. *A. sativum*'s major bioactive compounds include polysaccharides, saponins, phenolic compounds, and sulfur containing compounds like vinyldithins, ajoenes, allicin, diallyl disulfide, and diallyl trisulfide (Table 1). The "pliant spice" commonly known as garlic is the second most utilized bulb plant from the *Alliaceae* family [2]. It is harvested from its lean, elongated, and fragile roots measuring on average 12 to 14 cm in length which extends from the base of the underlying bulb [3]. The appellation garlic may have stemmed from the Celtic word 'all' translated as pungent [4]. It is extensively cultivated nearly worldwide with its genesis traceable to central Asia, from where it stretched to China, the Near East, Mediterranean areas, and eventually, its dissemination towards the west to areas in central and southern Europe and Mexico [5]. The bulb has been ingested vastly in different forms: fresh, dried, as additives in unprocessed foods and in ready-to-consume foods [6]. Garlic has a pungent smell which is more dominant in its raw form than when cooked [7]. It can be preserved up to 6 months when stored in favorable environmental conditions and tends to have a longer lifespan when preserved as bulbs than as individual cloves [8].

A. sativum has often been utilized in traditional medicine for its prophylactic and therapeutic efficacy in the treatment of

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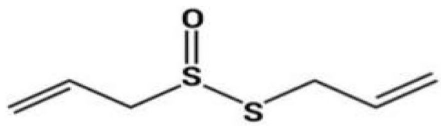
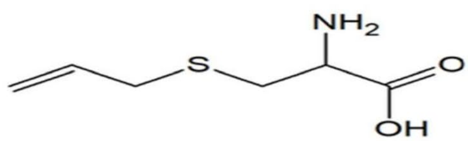
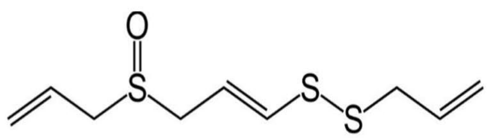
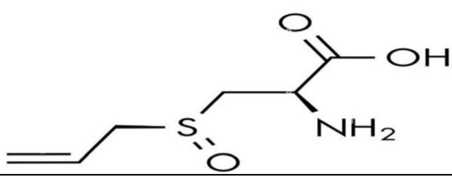
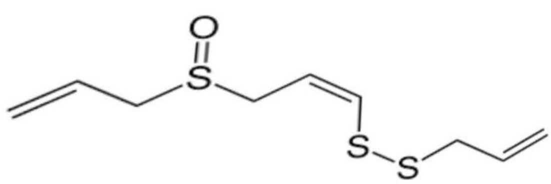
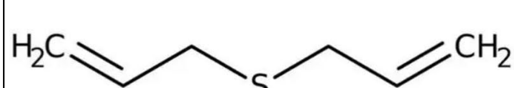
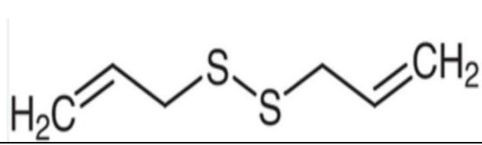
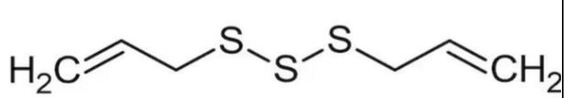
infectious diseases affecting the integumentary, gastrointestinal, and cardiopulmonary systems caused by various microorganisms [9]. In China, for example, garlic has a long history of being utilized in folk medicine as Sanskrit documentation traced its employment as a medicinal remedy to 5000 back [10]. Moreover, Pasteur took note of the antibacterial capabilities of this bulb in the year 1858 which led to its being employed for antiseptic use in gangrene infections while the World wars lasted [11•].

Table 1 Organosulfur compounds in garlic

Sulfides	Molecular formula	Chemical structure	References
Allicin	C6H10OS2		[29]
S-allyl cysteine	C6H11NO2		[30]
E-ajoene	C9H14OS3		[31]
Alliin	C6H11NO3S		[32]
Z-ajoene	C9H14OS3		[33]
Diallyl sulfide	C6H10S		[34]
Diallyl disulfide	C6H10S2		[35]
Diallyl trisulfide	C6H10S3		[36]

A. sativum has been found to contain several biologically active constituents such as flavonoids, amino acids, saponins, sugars, vitamins, essential oils, organosulfur compounds, mineral salts, and microelements (K, P, Zn, Fe, etc.) [12]. These constituents are found to have both prophylactic and therapeutic actions and serves as antidiabetic, anti-coagulant, antimicrobial, anti-aggregation, antioxidant, anti-inflammatory, cardio-protective, immune-boosting, and fibrinolytic agents [13••]. A well-established prophylactic and therapeutic efficacy of garlic is its action on the cardiovascular system where its anti-oxidative property helps: (1) to decrease the body's low-density lipoprotein, triglycerides, and total cholesterol values and thereby enhancing the lipid profile of the blood plasma and (2) to rummage and disrupt free radical reactions and thus improve the body's spontaneous anti-oxidative enzymes to provide protection against various cardiovascular diseases like arterial hypertension, heart attacks, atherosclerosis, ischemic strokes, and coronary artery diseases [14]. Although garlic has been considered to be generally safe for human consumption even by the US Food and Drug Administration, the safety profile of the bulb shows that it can trigger gastric agitation in sensitive people especially when taken in high doses. Furthermore, vomiting, insomnia, tachycardia, nausea, heartburn, and dizziness were observed with garlic administration in a randomized controlled study. Surgeons thus recommend that garlic administration be stopped 7 to 10 days before operation due to its prolonged bleeding effects [15]. This review seeks to establish an insight into the plant garlic, its history, bioactive compounds, and biological properties.

Methodology

Scientific papers used for this review were sourced from Google Scholar (https://scholar.google.com/), PubMed (https://pubmed.ncbi.nlm.nih.gov/), Science direct (https://www.sciencedirect.com), and Cambridge University Press & assessment (https://www.cambridge.org/) databases. The free text key words used were "bioactive compounds of garlic," "biological properties of garlic," "sulphur compounds in garlic," "antioxidant properties of garlic," "garlic's safety profile," "neuroprotective properties of garlic," "antidiabetic properties garlic," and "antimicrobial activity of garlic" among others. A total of 60 articles were identified during the initial search. Information was however only retrieved from 40 of the papers based on the exclusion criteria of publication years. All publications before 2013 were excluded and only those whose publication dates were from 2013 to 2023 were included.

Bioactive Components of Garlic

Garlic is reported to contain several hundreds of bioactive compounds including nine essential amino acids (histidine, lysine, leucine, methionine, tryptophan, thronine, isoleucine, valine, and phenylalanine) [16]; eight non-essential amino acids (glycine, cysteine, serine, aspartic acid, arginine, glutamine, proline, and methionine) and their gycosides [17]; and organosulfur compounds like diallyl sulfide (DAS), E/Z-ajoene, diallyl trisulfide (DATS), allicin, diallyl disulfide (DADS), S-allylmercaptocysteine (SAC), and vinyldithiins (2-vinyl-(4H)-1,3-dithiin, 3-vinyl-(4H)-1,2-dithiin) which are the most abundant compounds in garlic accounting for about 82% of the total garlic's sulfur content [18]. Garlic is thus known to contain a higher percentage of sulfur compounds than all other *Allium* species. Ailliin which is the major cysteine sulfoxide is usually converted to allicin by the allinase enzyme upon the maceration of garlic parenchyma [19]. The sulfenic acid thioester, allicin, otherwise known as allyl thiosulfinate is thought to elicit pharmacological effects by its interaction with thiol-containing proteins. The compound can be further metabolized within hours into vinyldithiines (during cooking this takes only minutes) [20]. Ajoene which is another organosulfur compound of garlic is also produced by several enzymes from pure allicin [21]. Aged garlic, garlic oil, and steam-distilled garlic do not contain noteworthy amounts of aliin or allicin, but rather contain various products of allicin transformation although none of them appear to have pharmacological activity that compares to fresh garlic or garlic powder [22]. More than that, garlic also contains saponins, polysaccharides, and phenolic compounds [23]. The saponin content of garlic is characteristically more stable when cooked and is found to be higher in the purple garlic than in the white in a comparable ratio of 1:40 [24]; some saponin compounds however are contained exclusively in the purple garlic (rhamnose, sativoside R1 desgalactotigonin-rhamnose, sativoside B1-rhamnose, proto-desgalactotigonin, and voghieroside D1) [25]. The polysaccharide contents of garlic have remarkable molecular masses and relatively minute toxicity levels. They include fructose, glucose, and galactose in the ratios 85:14:1, respectively, and constitute approximately 1/3 of the total weight of fresh garlic. Garlic likewise contains oligosaccharides, flavonoids, and phenolic compounds and enzymes like peroxidase, allinase, and myrosinase [26]. More than 20 phenol-contained compounds are present in garlic in concentrations that are way more than in most common vegetables with β-resorcylic acid being the major phenolic compound [27]. Minerals like selenium, tellurium, germanium, and other trace elements are also found in garlic [28]. Besides these, garlic also contains an essential oil which contributes to its pharmacological properties. Table 1 contains some organosulfur compounds contained in garlic.

Biological Properties and Activities of Garlic

Anti-Oxidative Property

The organosulfur compounds (S-allyl cysteine (SAC) and *S*-allyl mercapto cysteine) contained in garlic in high amounts help in activating antioxidant enzymes in the liver: heme oxygenase-1 (HO-1) and glutamate-cysteine ligase modifier (GCLM) [13]. The by-product of aged garlic extract (AGE) has also been found to contain a higher concentration of anti-oxidative property than that of fresh garlic [37]. Allicin the major compound extracted from AGE exhibits a wide range of anti-oxidative activities as shown by its actions on cellular reactive oxygen species (ROS), and its inhibition of mitogen-activated protein kinase [38]. The ethanolic extract and *N*-fructosyl glutamate of garlic sprout also shows potent anti-oxidative property. Certain compounds, i.e., glutathione peroxidise, *N*-fructosyl arginine, and *N*-fructosyl lysine, identified recently to be contained in the extracts of aged garlic are believed to work interdependently exerting their antioxidizing activities by increasing the rummaging of reactive oxygen species (ROS) as well as promoting the activity of the cellular antioxidant enzymes catalase and superoxide dismutase and increasing cellular levels of glutathione [39]. The anti-oxidative effects of garlic are however dependent on its form. The antioxidant efficacy of some forms of garlic are as follows: raw garlic > cooked garlic, fermented garlic > crude garlic.

An experimental study which involved Wistar rats and investigated the anti-oxidative effects of garlic in protecting tissues against oxidative damage and improving organ functions found that the administration of garlic aqueous extract to the rats for 21 days after their previously being administrated against nicotine hydrogen bitartrate sped up glutathione levels and reduced malondialdehyde levels in the heart, aorta, kidney, and bladder tissues of the rats [40]. It was thus concluded that aqueous garlic extracts, when administered, served as a protection to tissues against nicotine-induced oxidative damage and subsequently improved kidney functions [41]. In another study in which carcinogenesis was induced in rats using *N*-methyl-*N*′-nitro-*N*-nitrosoguanidine, the pre and post initiation data showed that aqueous garlic extract administered alongside neem leaf can decrease micronuclei and chromosomal aberrations induced by *N*-methyl-*N*′-nitro-*N*-nitrosoguanidine [42]. Following that observation, the researchers concluded that aqueous garlic extracts possess antioxidant potential.

Anti-Inflammatory Property

Garlic extracts express anti-inflammatory properties and proves its potency in the management of some inflammatory diseases in humans like osteoarthritis, Crohn's disease, ulcerative colitis, etc. The main anti-inflammatory property of garlic is expressed by its inhibitory action on the body's inflammatory intermediaries like nitric oxide (NO), TNF-α, and interleukin (IL-1). The initiation of these inflammatory mediators is achieved through the nuclear factor-kappa B (NF-κB) signaling pathway in J774A.1 macrophages stimulated by lipopolysaccharide [43]. Through inhibition of neutrophil granulocytes from entering into epithelial cells also, garlic exhibits anti-inflammatory effects [44]. Furthermore, various compounds in garlic also catalyze the production of pro-inflammatory catalysts such as cyclooxygenase-II and NOS [45]. observed that DAS exhibited anti-inflammatory activity by decreasing the expressions of the inflammatory cytokines (e.g., NF- κB, IL-1β, and TNF-α), and the generation of ROS by suppressing CYP-2E1 hepatic enzyme. Another investigation showed that thiacremonone (a sulfur compound isolated from garlic) by blocking the NF-κB activity prevents neuroinflammation and amyloidogenesis and can therefore be used to treat inflammation-related neurodegenerative disorders like Alzheimer's disease [46].

Antimicrobial Property

Garlic has shown a wide spectrum of antimicrobial potential, the aqueous, methanolic, ethanol, and chloroform extracts in garlic all showed inhibitory effects on the growth of various bacteria with alternating levels of susceptibility [47]. Allicin compound found in garlic has evidently expressed itself as the main antimicrobial component in garlic and acts as an antimicrobial agent against a large variety of microorganisms including methicillin-resistant *Staphylococcus areus* (MRSA), and gram-negative and gram-positive bacteria such as *Klebsiella aerogenes*, *Escherichia coli*, *Staphylococcus aureus*, *Shigella*, *Pseudomonas aeruginosa*, *Salmonella enterica*, *S. faecalis*, *Mycobacteria*, *S. pyroxenes*, *Enterococcus faecalis*, *Vibrio*, *Proteus vulgaris*, and *Streptococcus mutans* [31]. In a clinical study, it was discovered that the use of unprocessed garlic repressed *H. pylori* activity in the abdomen *H. pylori*–infected patients [9]. The potent antimicrobial activity of allicin arises from its chemical interactions between the compound and thiol which exhibits biocidal effects by oxidation of the protein cysteine proteinase and results in the killing of microbe. Allicin, a constituent of garlic, is thus a dose-related biocide that is capable of causing the metabolism of cysteine proteinase and thereby resulting in the killing of eukaryotic cells because of the presence of thiol groups in all living cells [48].

Antifungal Property

Garlic extracts also remarkably exhibit a broad spectrum of antifungal property against a variety of fungi microbes too acting as excellent fungicides against several funguses namely *Candida*, *Cryptococcus*, *Torulopsis*, *Aspergillus*, *Rhodotorula*, *Trichosporon*, and *Trichophyton species* [49]. The potent components of garlic which show the antifungal property are diallyl sulfide (DAS) and diallyl disulfide (DADS) [50••]. They act by disrupting the fungal cell wall leading to permanent ultrastructural changes in the fungal cells and resulting in structural compromise and inhibition of growth. These disruptions ultimately give rise to damaged nucleus and cell organelles and eventually lead to death of the organism. An experimental study to evaluate the antifungal action of garlic against some selected fungi samples revealed that garlic extracts inhibited the growth of species *Fusarium* and *Rhizopus* [51]. DADS and DATS extracted from garlic aromatic oil also exhibited antifungal activity against some fungi (*C. albicans*, *Blastoschizomyces capitatus*, and *C. tropicalis*). Additionally also, saponins extracted from garlic showed antifungal activity against *Trichoderma harzianum* and *Botrytis cinerea*, thus confirming the antifungal properties of garlic phytochemicals [52].

Antiviral Property

The phytochemical compounds ajoene, allyl, methyl thiosulfinate, methyl allyl thiosulfinate, and allicin found in garlic have been shown to inhibit cellular proliferation of viral cells [27]. These compounds showed effectiveness against several viral infections such as herpes simplex type 1 and 2, parainfluenza virus type 3, vesicular stomatitis virus, influenza B, human cytomegalovirus (HCMV), vaccinia virus, and human rhinovirus type 2 [53]. In an in vivo study involving mice, it was shown that diallyl trisulfide (DATS) enhanced immune response to the viral infection caused by murine cytomegalovirus (MCMV) through enhancing regulatory T (Treg) cells in chronic murine cytomegalovirus infection [53]. Allicin elicits its antiviral activity by repressing thiol enzymes, while ajoene carries out antiviral activity by preventing the adhesive interaction and fusion of leukocytes. DATS can otherwise act by enhancing the activity of natural killer-cell (NK-cell) to destroy virus-infected cells. The actions of these compounds attest to the antiviral capacity of garlic [54].

Anti-Protozoal Property

The aqueous, dichloromethane, and ethanol extracts of garlic show remarkable anti-protozoal actions by inhibitory actions on the cell's protein synthesis process as well as their disruption of RNA and DNA [55]. They have been found to effectively act as antifungal agents in a broad spectrum of protozoan diseases such as *giardia*, *leishmaniasis*, and *trypanosomiasis*. A study that determined the anti-protozoal actions of garlic using garlic oil on different groups of mouse infected with *Cryptosporidium parvum* observed that the group of mice treated with garlic oil had a significant lower oocysts count than those of the mice that served as control group [56]. Additionally, the phytochemicals DATS and allicin and DATS, extracted from garlic, exhibited antiparasitic activity against *Plasmodium falciparum*, *Giardia lamblia*, *Babesia*, *Entamoeba histolytica*, *Theleria*, and *Trypanosoma brucei* [57]. Ajoene was also seen to exhibit antiparasitic activity through the inhibition of the human glutathione reductase and *T. cruzi* trypanothione reductase [58]. The results of these investigations showcase the efficacy of garlic against protozoan infections [56].

Anticancer Property

Cancer cells are characterized by uncontrollable multiplication and proliferation. Garlic has anti-proliferation properties thanks to its organo-sulfur compounds [29]. The extracts of raw garlic were found to be a more efficient and more specific anticancer drug against different cancer cells in comparison to 33 other raw vegetables [59]. These garlic-containing compounds are effective against several types of cancer such as breast cancer, colon cancer, prostate cancer, liver, pancreatic, and gastric cancers. They act by inhibiting the growth and proliferation of the cancerous cells. Their action can be summarized as follows: inhibition of cell growth and proliferation, regulation of carcinogen metabolism, activation of apoptosis, disruption of angiogenesis, invasion and migration, and minimizing anticancer agent's negative effects [60]. They also reduce the risk of cancer by the action against carcinogens and disruption of DNA alkylation. In a clinical study, it was found that the ajoene constituent of garlic inhibited the growth of cancer cells in breast cancer and cancer stem cells in glioblastoma multiforme [51]. Another study involving rats revealed that AGE showed effects against tumors when colon cancer was induced by 1,2-dimethylhydrazine in the rats. The cell growth at G2/M phase was also restrained through deactivating the NF-κB communication pathway [61]. Z ajoene also stimulated apoptosis in human leukemic cells through the promotion of caspase-3-like and caspase-8 activities as well as the promotion of peroxide production. Interestingly also, tumor cells were reported to be killed after incubation in an allicin solution back in 1960 [62], with these and more experimental results proving the potency of garlic as an anticarcinogen.

Cardio-Protective and Antihypertensive Property

Garlic has cardio-protective properties which are seen in its ability to decrease isoproterenol-induced cardiac hypertrophy and increase Na^+/K^+-ATPase protein levels. In an investigation that involved rats, it was discovered that the sirtuin 3-manganese superoxide dismutase process was activated by garlic extracts thereby providing protection for the hearth [63]. The inhibition of platelet aggregation by polyphenolic compounds contained in garlic also helps to improve myocardial contractility. In addition, AGE was found to inhibit lipid deposition and vascular inflammation at the preliminary stage of atherosclerosis in a mice study [64]. The accumulation of calcium salts in human arteries was also seen to be inhibited by AGE. The cardio-protective properties of garlic can be chiefly attributed to it oxidative stress inhibition, decrease in lipid peroxidation, inhibition of angiotensin-converting enzymes, and increase of H_2S and NO production [65]. Hydrogen sulfide and allicin in garlic are also chiefly accountable for its blood pressure–regulating property. They act as vasodilators by inhibiting the action of angiotensin-converting enzymes. Garlic by the aid of its many sulfur compounds stimulates the factors that are responsible for constricting and relaxing the endothelium thus lowering blood pressure levels [66]. Garlic has also been shown to cause vasodilatation by the activation of hydrogen sulfide and nitric oxide production hence its use as a medicinal plant for blood pressure management worldwide [13]. In a certain study where rats were given the aqueous extracts of garlic ("2 kidney 1-clip" model) in order to ascertain its antihypertensive actions, the reports were that the extracts exhibited an antihypertensive property by decreasing thromboxane and prostaglandin E-2 in the rats [67]. In another 5-day study that yet involved rats, it was observed that the administration of 100 mg/kg/day of garlic completely averted the development of acute hypoxic pulmonary vasoconstriction in the endothelin-1-induced hypoxic pulmonary vasoconstriction rats [68], these all attesting to the cardioprotective and antihypertensive effects of garlic compounds.

Antidiabetic Property

Allicin and SACS compounds in garlic chiefly elicit antidiabetic activity [69]. While allicin increases the amount of glutathione peroxidise and catalase, Sacs stimulates insulin production and restricts absorption of dietary glucose [70]. Furthermore, garlic is seen to exercise its glucose-lowering action by two major mechanisms: increasing the secretion of insulin from the pancreas and improving receptor cells sensitivity to insulin [71]. In a study in rabbits to which diabetes mellitus was induced by alloxan, it was observed that different garlic extracts exerted hypoglycemic properties by improving O-GlcNAc transferase (OGT) in the rabbits. The study also revealed a decrease in the fasting blood sugar of the diabetic rabbits confirming the antidiabetic properties of garlic [72].

Neuroprotection and Anti-Alzheimer Property

The organosulfur compounds present in garlic play a significant role in neuroprotection, acting mainly on the hippocampus [73]. In a study which assessed murine BV-2 microglial cells in which oxidative stress was induced using lipopolysaccharide, it was observed that in AGE together with N-α-(1-deoxy-D-fructos-1-yl)-L-arginine, its carbohydrate derivative prevented neuro-inflammation by inhibiting nitric oxide from been produced as well as modulating the expression of multiple protein targets [42]. Speaking of its anti-Alzheimer's disease potential, a disease characterized by the depletion of acetylcholine (Ach), acetylcholinesterase an enzyme mostly involved in the degradation of acetylcholine into acetate and choline within the nervous system, had its actions in the cerebral cortex synaptosome inhibited by garlic oil showing antioxidant activity. Moreover, the consumption of garlic is seen to improve memory capacity as free radicals that result in oxidative damage are eliminated [74]. With allicin, also the brain's acetylcholine concentration is seen to increase and cognitive decline is delayed through its inhibition of acetylcholinesterase and butyrylcholinesterase (BuChE) enzymes. Table 2 indicates some bioactive properties of garlic compounds.

Toxicity Reports of Garlic

The US Food and Drug Administration names garlic as being safe for human consumption although the bulb can trigger gastric disturbances when taken in high doses (above 4 g of raw garlic or 7.2 of AGE). Clinical studies report that low doses (4 g) of garlic are safe, therapeutic doses might cause mild gastrointestinal disorders, and high doses can cause liver damage. Additionally, other reports reveal the adverse effects of garlic on the cardiovascular system including its potentially irreversible anticoagulant activity, antiplatelet activity, and fibrinolytic activity, as well as notable reduction in platelet accumulation and mixed activity on fibrinolytic effectiveness [65]. A separate report also revealed that dehydrated raw garlic powder when given orally resulted in acute injury to the gastric mucosa as observed by [80]. Furthermore, ingesting raw garlic in high doses on an empty stomach can also induce changes in

Table 2 Bioactive properties of garlic compounds

Garlic compound	Type of activity	Description	Reference
Z ajoene Allicin, alliin, DADS, and DAS	Anticancer	Stimulates apoptosis in human leukemic cells, promoting the peroxide production, caspase-3-like, and caspase-8 activities Enhancing p38 expression and cleaved caspase 3	[75]
DATS, allicin Ajoene	Antiprotozoal	Preventing the parasite's RNA, DNA, and protein synthesis Inhibiting the human glutathione reductase and *T. cruzi* trypanothione reductase	[76]
DAS Alliin	Antioxidant	Suppressing the enzymatic activity of cytochrome P450-2E1, reducing the generation of reactive oxygen and nitrogen species Controlling ROS generation and preventing mitogen-activated protein kinase (MAPK)	[77]
Allicin, cysteine sulfoxide, and S-allyl cysteine sulfoxide, alliin	Antidiabetic	Decreasing the insulin secretion from pancreatic cells, increasing liver metabolism, and thus enhancing the short-acting insulin production	[78]
Gamma-glutamylcysteine	Antihypertensive	Inhibiting the angiotensin-converting enzyme	[79]
DATS Allicin	Antiviral	Enhancing natural killer-cell (NK-cell) activity that destroys virus-infected cells Chemical interaction with enzymes containing thiol	

the intestinal flora and flatulence and cause gastrointestinal distress. Another investigation showed that garlic powder or allicin at high concentrations of 200 mg/ml showed cell damages in rat liver in vitro.

Conclusion

Various studies have reported the organosulfur compounds as the major bioactive compounds present in garlic. Inadvertently, the compounds have numerous advantageous effects both in checking and in managing different diseases. The antidiabetic, neuro-protective, antioxidant, cardio-protective, anticancer properties have been attributed to its organosulfur compounds. The bioavailability of these compounds however varies with different forms of garlic, and these compounds metamorphose into different compounds when they undergo thermal reactions, good to know that these drawbacks have been overcome with extensive research on how to improve their bioavailability. Our review has focused on the plant, its history, and its bioactive compounds and their corresponding biological properties. In our opinion, garlic is more than just a common herb used in the culinary world. More clinical research should be conducted to establish the effectiveness of garlic, its best form, safe dosage, and best route of administration as an unorthodox medicine for immunocompromised patients.

Author Contribution RM, GE, AJ, and JA were responsible for the conception and design of the study; RM, GE, and AJ performed data collection. RM, GE, and AJ performed data analysis and drafted the article. GE supervised the study and contributed to data analysis, interpretation, and critical revisions. All authors approved the final manuscript.

Data Availability All data will be made available upon reasonable request.

Declarations

Ethics approval and consent to Participate Not applicable.

Consent for Publication Not applicable.

Competing Interests The authors declare no competing interests.

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Particullary interesting articles published recently have been highlighted as:
• Of importance
•• Of major importance

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