

Pharmacological Properties of a Magical Shrub of *Allium Sativum*

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ABSTRACT

Pakistan is rich in medicinal plants used for medicine for over a thousand years. Garlic is an essential vegetable, most consumed as spice and flavor during cooking food, which makes the food more digestible all over the world. Garlic has a tremendous pharmacological and therapeutic effect due to its biologically active compounds. The chemical composition of the plant are allicin, diallyl trisulfide, diallyl disulphide and S-allylcysteine contribute an important role in its nutraceutical/therapeutic applications. Garlic is a good source of several vitamins, minerals, and other nutrients that are useful for human health. It possesses high macro and micro nutritive molecules such as carbohydrates, protein, fat, calcium, sulfur potassium, iodine, phosphorous, fiber and silicon in addition to vitamins. Furthermore, garlic has pharmacological effects and is used to cure enormous conditions including, Antibacterial, antiviral, antifungal, antiparasitic, anthelmintic antiatherosclerotic, anti-inflammatory, antihyperlipidemic, immunomodulatory, anti-tumor, antidiabetic, diuretic, hepatoprotective, digestive effect and toxicological effects were observed *in vivo* and *in vitro*.

Keywords: *Allium Sativum*; Pharmacological; Properties; Therapeutic; Shrub

Introduction

Pakistan is rich in medicinal plants used of plants for medicine for over a thousand years. Scientists have been gaining attention to medicinal plants for therapeutic purposes (Iqbal, et al. [1]). Among the different medicinal herbs garlic has played an important role as a medicinal herb for thousands of years. Garlic is a significant food and medicinal herb commonly found in Central Asia and widely grown all over Pakistan. As an irrigated crop, it is grown in the southeast and on the Indus River. It is cultivated in Sindh and Panjab on a large scale (Varshney, et al. [2]). It is a 60 cm height perennial herb. The white

sheath or skin that covers each individual clove makes up the garlic bulb. The garlic bulb is used as a spice or medicinal herb, whether it is fresh or dried. The lower half of the stem is sheathed by long, flat, sharp leaves; the scape is thin, smooth, and glossy; the long, beaked spathes enclose the heads bearing solid bulbils. White, small blossoms with leafy edges protruded from the plant (Tsai, et al. [3]). Garlic (*Allium sativum*) a natural plant, is a member of Lilliceae (onion family) that has multipurpose medicinal applications (Labu, et al. [4]). Garlic is used as a flavoring agent in cooking and utilized as medicine since ancient times to treat and prevent a variety of conditions (Sharifi-rad, et al. [5]). Garlic can be prepared in various forms i.e., powder,

oil, extracts, and raw juice. It has been described that the oil- and water-soluble organo-sulfur components of garlic are widely known for antimicrobial therapeutic properties (Bisen, et al. [6]). Garlic contains the typical odor and flavor (Saif, et al. [7]). Garlic bulbs can be eaten alone or combined with food to produce desirable therapeutic effects (Londhe, et al. [8-10]). It is currently used in 22 forms of folk medicine to treat a wide range of infections. Many clinicians have used garlic for ages to fight infectious diseases all over the world (Londhe, et al. [8]). Garlic can be given as dietary supplements in the form of capsules and powders, making it different from traditional foods (Dureja, et al. [11]). The word garlic originated from Celtic means pungent. Indian literature reported that garlic plays a valuable role in the nutritional and therapeutic activities in the medicinal history (Singh, et al. [12]). Clinical uses of garlic include cough, abdominal pain, loss of appetite, hemorrhoids, dermatitis, rheumatism, and loss of weight (Harris, et al. [13,14]). The Father of Medicine Hippocrates noticed that garlic is an effective diuretic and was excellent for curing tumors (Rivlin, et al. [15]). Aristotle attributed garlic as effective for the treatment of rabies, and it was recommended by Prophet Mohammad for the treatment of scorpion stings (Palani, et al. [16,17]). It has been reported that treated dog and snake bites garlic was recommended (Sharifi-Rad, et al. [5]).

History of Garlic

Garlic is cultivated practically all over the world, mostly in central Asia, China, Mediterranean region, Southern, West to Central Europe, Northern Africa and Mexico (Londhe, et al. [8]). Garlic is mentioned as being helpful in treating several diseases, an ancient Egyptian medicine from 1550 BC. The Bible mentioned the cultivation of garlic one of the earliest plants in literature of Ancient Israel, India and Egypt. Asian people have been using this plant for at least 3,000 years, and some of the latest references were found approximately 5,000 years ago. Chinese strongly have faith that the garlic crop is an extended longevity crop (Papu, et al. [18,19]) (Table 1).

Table 1: Nutritive valves of Garlic

S. No.	One clove of garlic (3 grams)	Quantity
1	Water	58.68%
2	Energy	623 kJ (150 kcal)
3	Carbohydrates	1 gram
4	Protein	6.39g
5	Fat	0.5g
6	Dietary fiber	2.1 g
7	Potassium	12 mgs
8	Calcium	5 mgs
9	Sodium	1 mg
10	Calories	4

Physical Characters of Allium sativum

Allium sativum is characterized by its distinct macroscopic features, which are easily recognized. The plant can be found as a whole bulb with isolated cloves (bulblets); a diameter 4-6 cm of the sub-globular, and each bulb contains 8-20 cloves (Chanda, et al. [20]). It is attached to 3-5 papery whitish membranous scales and a short woody disc stem attached to a bulb with numerous, wiry rootlets on the underside (Kadam, et al. [21]). Each clove is tapering, ovoid and irregularly upper end 2-3 cm long, 0.5-0.9 cm wide of dorsal convex surface, with yellowish-green folded leaves wrapped within two white fleshy, modified leaf bases or scales, each is covered by two very thin papery, white, and brittle scales. The odor is strong, unpleasant and the taste is bitter (Jayapraash, et al. [22]).

Microscopic Characters of Allium Sativum

Parenchyma tissue, is composed of large, polygonal, thin-walled cells that contain intercellular spaces. These parenchyma cells primarily function in nutrient storage, housing starch granules that are abundant in garlic tissue. Additionally, secretory cells within the parenchyma are rich in volatile sulfur-containing compounds such as allicin, which contribute to garlic’s characteristic odor (Kopec, et al. [23]). Garlic cloves possess a poorly developed vascular system, with small vascular bundles comprising xylem and phloem located within the parenchyma. The xylem features narrow, lignified vessels, while the phloem is composed of sieve tubes and companion cells. Calcium oxalate crystals, which can appear as small prism-shaped structures, are scattered throughout the parenchyma, serving a protective function. Starch grains found within the parenchyma cells are typically oval or rounded and stain blue when treated with iodine, confirming their presence (Yoneska, et al. [24]). Furthermore, unicellular, conical trichomes, although sparse, can occasionally be observed on the surface of the outer scales, aiding in moisture retention and protection of the bulb. Together, these microscopic characteristics contribute to garlic’s functional properties, including its nutrient storage capacity and its renowned medicinal qualities attributed to its sulfur compounds. The epidermis of garlic cloves consists of rectangular cells with straight walls, forming a single layer of compactly arranged cells covered by a thin cuticle. Beneath this epidermis lies a predominance (Mohammed, et al. [25]).

Garlic Oil

Garlic oil has been proven to have antibacterial characteristics and to inhibit the growth of different microbes, including *Penicillium funiculosum*, *S. aureus*, *E. coli*, and *B. subtilism* (Bhatwalkar, et al. [26]). Most likely through invading cells and organelles, disrupting cell structure, cytoplasm, and macromolecules of the microorganisms. Additionally, garlic oil has also been found to be effective against bacterial cell metabolism, which is linked to the expression of gene mutations that are involved in the cell cycle, oxidative phosphorylation,

and protein synthesis in the endoplasmic reticulum. Furthermore, raw garlic treatment reduced *Helicobacter pylori* in the stomach of patients with *H. pylori* infection. The antibacterial activity of garlic oil is dependent on the variety of processing methods utilized (Zardast, et al. [27]). Garlic oil extracted through steam distillation showed antimicrobial properties. Garlic oil is composed of diallylsulphides (57%), allyl methyl sulfides (37%), and dimethyl mono to hexasulfides after steam distillation of garlic bulbs (6%) (Sendl, et al. [28]). Fresh garlic bulbs have an essential oil concentration of 0.09 to 0.35%. The chemical structures of garlic's key phytoconstituents (Ezeorba, et al. [29]).

Chemical Composition of Garlic

Garlic is found to include at least 33 sulphur compounds, many micro and macro minerals like zinc, copper, potassium, iron, germanium, magnesium, selenium, calcium, water-soluble and fat-soluble vitamins such as A, B1, B2 and E, C, fibers, and water (Casado, et al. [30]). Amino acids such as arginine, threonine, lysine, histidine, as-

partic acid, proline, cysteine, swine, glutamine, alanine, methionine, and valine are among seventeen most effective amino acids contained in garlic (Rauf, et al. [31]). Allicin is one of the most physiologically active substances in garlic, along with phenylalanine (diallyl thiosulfinate or diallyldisulfide), leucine, tryptophan (serotonin), methionine, and isoleucine. Allicin (S-allylcysteine sulfoxide) is the most prevalent sulphur component in garlic, with 12 and 32 mg/gm in fresh and dry garlic, respectively. During food preparation garlic used by different methods such as crushing, chopping and mincing, disrupt S-allyl cysteine sulfoxide, exposing it to allinase enzymes, which swiftly convert it to diallyl thiosulfinate, which gives garlic its distinctive scent (Kopce, et al. [23]). The enzyme allinase, which converts diallyl thiosulfinate, is rendered inactive below a pH of 3.5 or under heat. Molecular pharmacological, such as polar compounds of phenolic and steroidal origin, without odor and are also heat stable, allicin plays a significant role as an antioxidant and scavenging compound (Mohammed, et al. [25,32]) (Figure 1).

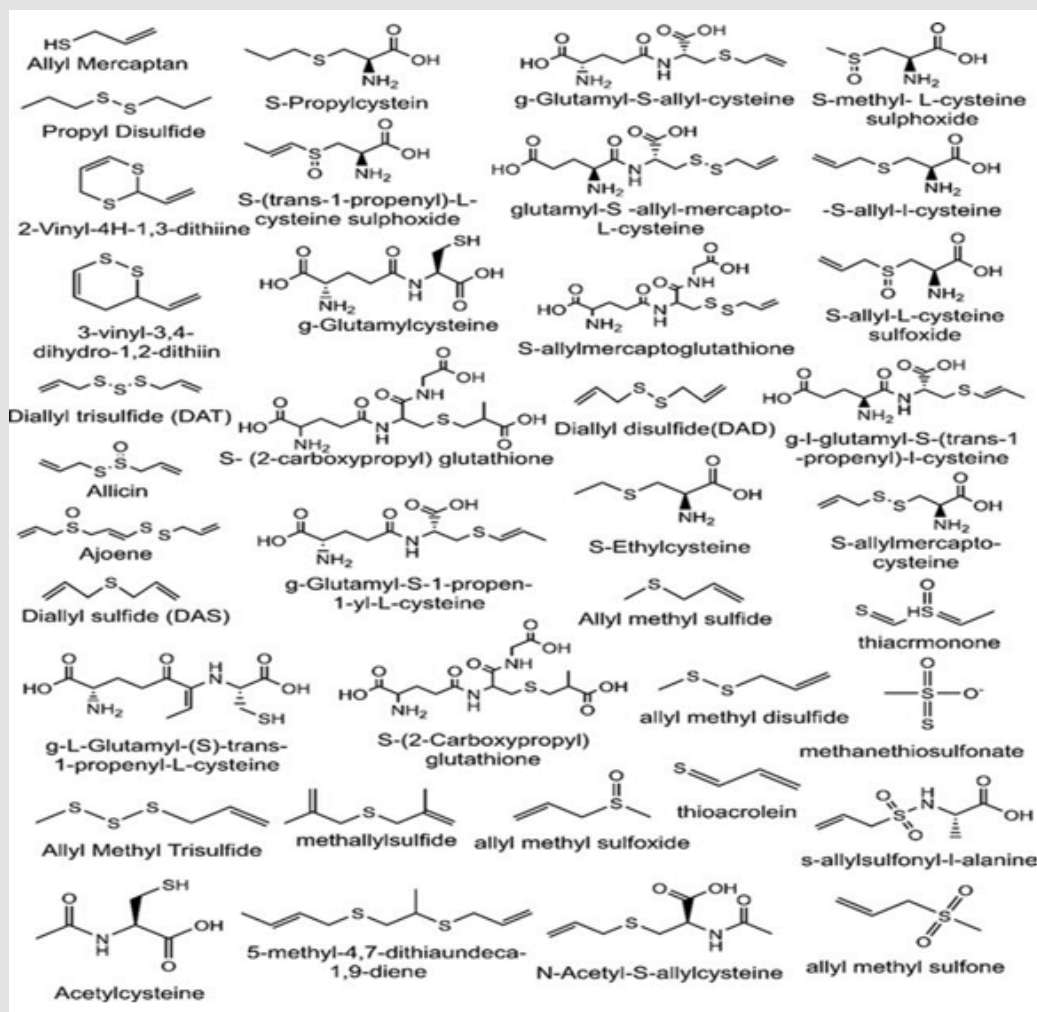


Figure 1: Chemical structure of garlic oil compounds (Shang, et al. [20]).

Pharmacological Activities of Garlic

Garlic contains biologically active compounds, including allicin and its derivatives, that have been historically recognized for their medicinal properties. It has been traditionally used to manage various cardiovascular conditions such as high cholesterol, heart attack, coronary heart disease and thickening of the arteries (atherosclerosis), antilipemic, anti-hypertensive, and anti-atherosclerotic [Mikaili, et al. [33]]. Garlic extracts are also known to provide protective benefits against certain types of cancer, such as lung, breast, prostate, stomach, colon, and rectum. Garlic has demonstrated efficacy in treating allergic rhinitis, osteoarthritis, diabetes, traveler's diarrhea, as well as conditions common in late pregnancy. It has been also recognized for its immune-boosting properties and effectiveness against bacterial and fungal infections [Corz-Martinez, et al. [34]]. Tesfaye, et al. [35]

reported that a broad spectrum of therapeutic uses in treating routine infections, including sinus congestion, fever, cough, and headache. It is also applied to managing, rheumatism, gout, bronchitis, asthma, and snakebites. Additionally, garlic has been used to promote liver health, reduce stress and fatigue, and regulate blood sugar and blood pressure. Further studies have reported promising effects in addressing various other health issues such as sciatica, arthritis, skin diseases (e.g., leprosy and leukoderma), anemia, tuberculosis, malaria, and chronic fever [Sanie-Jahromi, et al. [36]]. It has even been suggested for treating conditions like piles, colic pain, spleen enlargement, kidney stones, epilepsy, cataracts, and night blindness [Yoneska, et al. [24]]. The extensive pharmacological potential of garlic continues to make it a valuable herb in modern and traditional medicine, as defined below: (Figure 2).

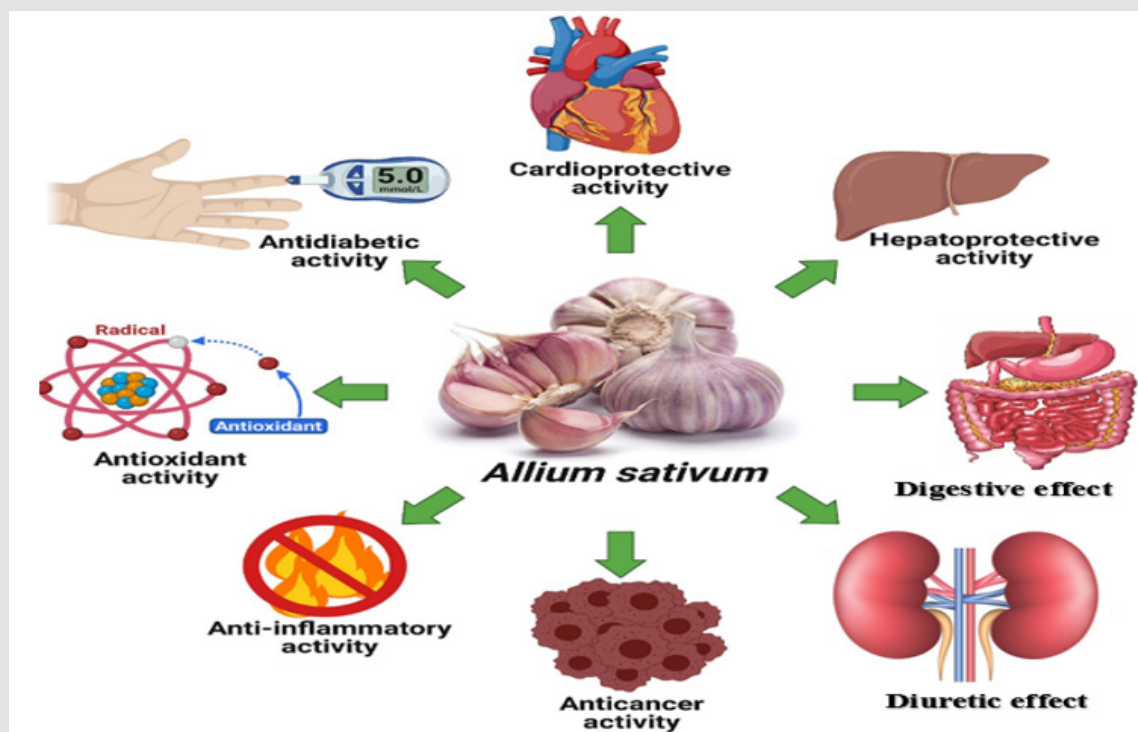


Figure 2: The pharmacological features of Garlic (*Allium sativum*).

Antibacterial Activity of Garlic

The Sulphur components present in garlic are responsible for both its strong aroma and its medicinal properties. One such compound, alliin (S-allyl-L-cysteine sulfoxide) is found throughout the garlic plant. When garlic cloves are damaged the enzyme alliinase breaks down alliin into lactic acid and 2-propenyl-sulfonic acid, which is rapidly from allicin-diallyl sulphate or diallyl disulfide [Strika, et al. [37]]. Allicin is a soluble and aromatic crystalline compound, pos-

sesses potential antibacterial properties and acts as a cysteine analog. Its formation and transformation are shown in Figure 3. Allicin is a highly reactive molecule that can easily convert into stable lipid-soluble allylsulfides, such as ajoene (4,5,9-trithiadodeca-1,6,11-triene-9-oxide), which is an important natural compound formed through the alliinase-induced cleavage of alliin. The pharmacological activity of garlic is attributed to its oil and water-soluble organosulfur compound. The antibacterial efficacy of garlic may diminish when action

of garlic. Additionally, the antibacterial activity of allicin may diminish when thiosulfates (allicin) and diallyl disulfide are removed from the extract. Moreover, allicin's antimicrobial activity is reduced when it is converted into diallyl disulfide. Allicin antibacterial action mainly involves the rapid inhibition of RNA synthesis with a lesser extent of

suppression in DNA and protein synthesis. This suggests that RNA is the primary different bacterial stain that may influence their susceptibility to garlic metabolites. Due to allicin short half-life, its defense mechanism is swift and localized, ensuring that the remaining allicin in the clove is preserved for future threats (Kamal [38]) (Figure 3).

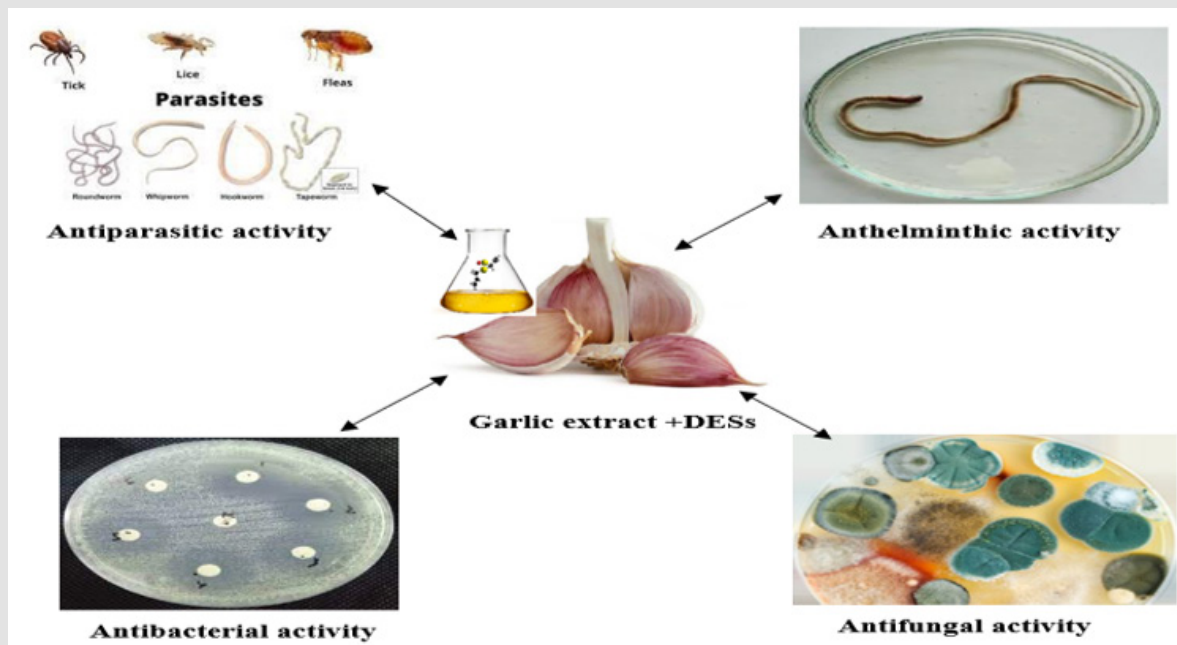


Figure 3: Chemotherapeutic properties of *Allium sativum*.

Antiviral Activity of Garlic

Garlic has demonstrated *in vivo* antiviral efficacy, particularly in mouse models infected with the influenza virus through intranasal administration. The effect is linked to garlic's ability to enhance the production of neutralizing antibodies, particularly when combined with the influenza vaccine (Mehrbood, et al. [39]). Furthermore, the antiviral properties of garlic are attributed to its bioactive compounds such as ajoene, allicin, allyl methyl thiosulfinate, and methyl allyl thiosulfinate. Research has shown these constituents to be potent virucidal agents, effective against ranges of virus types 1 and 2, parainfluenza virus type 3, vaccinia virus, and human rhinovirus type 2. In a clinical study involving 146 volunteers, supplementation with allicin-containing garlic was found to reduce the incidence of the common cold, suggesting its potential to prevent viral spread. Additionally, garlic contains Diallyl trisulfide, which has shown antihuman cytomegalovirus (anti-HCMV) activity. These antiviral actions are believed to be related to the inhibition of viral gene transcription, providing insight into garlic's broad-spectrum antiviral effect (Guo, et al. [40]).

Antifungal Activity of Garlic

Studies conducted both *in vitro* and *in vivo* have highlighted the significant antifungal properties of garlic. Garlic extract has demonstrated potential antifungal effects against 40 species of zoo pathogenic fungi, with growth inhibition observed in 8 out of the 16 tested genera. Its broad-spectrum antifungal action has been confirmed against 17 different fungal species, including *Penicillium*, dermatophytes, *Aspergillus* and various yeast. When compared to common antifungal agents like nystatin, griseofulvin, and amphotericin, garlic outperformed nystatin in reducing fungal growth. Research has identified allicin as the key antifungal component particularly inhibiting *Candida* species. Furthermore, garlic aqueous extract has been shown to suppress the growth of multiple stains of *Cryptococcus neoformans* (Singh, et al. [41]).

Anti-Parasitic Activity of Garlic

Ultrastructural analysis has revealed that Allicin, a key compound in garlic, can significantly alter the morphology of *Schistosoma mansoni* males. Additionally, allicin has demonstrated efficacy against

parasites such as *Trypanosoma brucei*, *Trypanosoma cruzi* and *Plasmodium falciparum*. Allicin also shows potent activity against intestinal protozoan parasites including *Entamoeba histolytica* and *Giardia lamblia*, which affect both humans and animals [Papu, et al. [18]]. The stable compound diallyl trisulfide, a final product derived from allicin, has been tested *in vitro* against various protozoan parasites, showing promise for treating parasitic disorders in humans and animals, particularly those caused by *Trypanosoma sp.*, *Ent. histolytica*, and *Giardia lamblia*. Ajoene, another compound found in garlic, inhibits human glutathione reductase and trypanothione reductase. Its ability to target key enzymes in the antioxidant thiol metabolism may partly explain its antiparasitic and cytostatic properties [Mikaili, et al. [33]].

Anthelmintic Activity of Garlic

Garlic has been recognized as a highly effective treatment for intestinal worms due to its sulphurous components. These components are particularly potent in eliminating tapeworm such as that are effective in eliminating tapeworms such as *Taenia saginata*, *Taenia solium* and *Taenia asiatica*, as well as cestodes like *Hymenolepis* and *Microstoma*. Garlic anthelmintic properties extend to trematodes, including *Echinostoma Caproni* and *Fasciola hepatica* with studies confirming its ability to kill these parasites *in vitro* [Marufatuzzahan, et al. [42]]. Specifically, garlic sulphur compounds were effective in killing intestinal fluke *Echinostoma Caproni* through less so against liver fluke. Essential oils from *Allium sativum* exhibited a paralytic effect on *Fasciola gingantica*, significantly reducing the frequency and intensity of spontaneous muscle contractions at dosages of 1 and 3 mg/ml. Furthermore, *Allium sativum* extract has demonstrated larvicidal activity against mosquito species like *Anopheles stephensi*, and *Culex quinquefasciatus*, and acaricidal effects against tick larvae such as *Rhipicephalus microplus*. The essential oils also have insecticide properties against larvae of *Aedes albopictus*, *Lycoriella ingenua*, and *Spodoptera litura* [Kavindra, et al. [43]]. Additionally, garlic oil significantly inhibited parasitic oxygen consumption and reduced their glucose and glycogen uptake, while leaving host tissue metabolism relatively unaffected, highlighting its potential mechanism of action [Iqbal, et al. [44]].

The Antiatherosclerotic Activity of Garlic

Garlic demonstrates both preventive (antiatherogenic) and therapeutic (antiatherosclerotic) effects in combating atherosclerosis. It helps inhibit the progression of atherosclerotic plaque formation and curbs the accumulation of collagen in the aorta, which is involved in the thickening of the atrial wall [Duan, et al. [45]]. Garlic's antiatherosclerotic properties are linked to its ability to reduce and normalize key symptoms of atherosclerosis reducing lipid accumulation, cellular proliferation and fibrosis. Research suggests that garlic extract inhibit the adenosine diphosphate pathway (ADP), mirroring the mechanism of clopidogrel, a commonly used anti platelet drug [Johny, et al. [46]]. The pharmacologically active components in garlic, particularly lipo-

philic substances such as allicin and thiosulfates are responsible for its in-vitro antiaggregatory activity (IVAA). Moreover, studies indicate that increasing the intake of crushed garlic can offset the diminished antithrombotic effect that sometimes occurs with reduced garlic activity [Yuristo [47]].

Anti-Inflammatory Activity of Garlic

Garlic extracts are well known for their potent anti-inflammatory properties. Research has shown that garlic significantly reduces inflammation and liver damage, particularly in cases of infectious such as *Eimeria papillate*. This effect is primarily due to garlic oil's ability to interfere with the assembly and disassembly of the cytoskeleton, which plays a crucial role in cellular inflammation processes infections [Linoj, et al. [48]]. Additionally, the sulfur-containing compound thiocresone, derived from garlic has been found to inhibit NF- κ B activity, a key regulator of inflammation. This inhibition helps prevent neuroinflammation and amyloid buildup, making garlic a potential therapeutic agent for neurodegenerative diseases like Alzheimer's disease [Monika, et al. [49]]. While garlic is effective in reducing inflammation, improper topical application, such as using it under pressure bandages or in cases of poor wound care, can lead to severe skin reaction, including deep chemical burns [Uddin, et al. [50]].

Antihyperlipidemic Activity of Garlic

Garlic has demonstrated significant potential in preventing lipid peroxidation of low-density lipoprotein (LDL) and protecting damaged erythrocytes, while also enhancing antioxidant levels. Additionally, it inhibits the angiotensin-converting enzyme (ACE), contributing to its cardiovascular benefits [Xie, et al. [51]]. Garlic extract has been shown to reduce cholesterol synthesis by up to 75%, a process believed to be linked to its inhibition of sterol 4- α -methyl oxidase all without reducing cellular toxicity. Moreover, garlic's anti-clotting properties promote the breakdown of blood clots, adding to its therapeutic advantages. Garlic powder and oil further inhibit cholesterol production by targeting enzymes such as 14- α -demethylase and HMG-CoA reductase enzymes, both key players in lipid synthesis [Varade, et al. [52]].

Immunomodulatory Activity of Garlic

Allium sativum has a wide range of biological functions, including immunomodulation. It has been shown that mature garlic extract has better immunomodulatory effects than raw garlic extract. The influenced organosulfur chemicals in garlic are responsible for this chemical reaction. Mature garlic has immunomodulatory properties *in vitro* [Song, et al. [53]]. In addition to cytokines regulation garlic extract enhances the production of nitric oxide (NO), a signaling molecule with antimicrobial properties. NO plays a significant role in the immune system by aiding macrophages in neutralizing pathogens, thus contributing to the body defense mechanism [Hamad [54]]. Moreover, allicin has been shown to prevent immune-mediated liver damage in

animal model, particularly mice. This protective effect through to be the allicin ability to modulate T cells activity, reduce the expression of adhesion molecules, and inhibit the activation nuclear factor kappa-light-chain-enhancer of activated B cells (NF- κ B) a key player in the inflammatory response (Yun, et al. [55]).

Anti-Tumor Effects of Garlic

Allium sativum is widely used for its potent ant-tumor properties, primarily attributed to its sulphurous components. These compounds, particularly allyl sulfides, exhibit the ability to inhibit cancer cell growth, prevent the development of carcinogenic cell, and suppress tumor promotion across various organs, such as the stomach, colon, liver, and breast (Huang, et al. [56]). The sulfur-rich bioactive compounds found in garlic, including allicin, diallyl sulfide (DAS), diallyl disulfide (DADS) and ajoene, have been extensively studied for their anticancer properties. These compounds exert their effects through various mechanisms, including the induction of apoptosis (programmed cell death) in cancer cell, inhibition of angiogenesis (the formation of new blood vessels that nourish tumors), and the modulations of detoxifying enzymes that deactivate carcinogens (Sahidur, et al. [57]). Both *in vitro* and *in vivo* studies have demonstrated the ability of garlic extracts to reduce tumor growth and metastasis, making it an effective natural treatment option in cancer therapy (Rani, et al. [58]). In addition to sulfur compound is also one of the richest natural sources of germanium, a trace element that has been linked to cancer prevention. Germaniums anticancer properties are believed to stem from its ability to enhance immune function, oxygenate tissue, and detoxify harmful substances, further supporting its potential role in cancer therapy (Johnny, et al. [59]). Besides that, garlic is a rich source of selenium, an essential trace mineral known for its role in cancer prevention. The primary selenium compound in garlic is semethyl selenocysteine, which has been shown to inhibit tumor development. Selenium is believed to prevent cancer by reducing oxidative stress, enhancing immune response, and inhibiting cell proliferation in cancerous tissue (Oravetz, et al. [60]).

Antidiabetic Activity of Garlic

Garlic has a strong hypoglycemic effect due to the presence of allicin, and this effect is thought to increase insulin release insulin sparing, and hepatic metabolism (Nasir, et al. [61]). Experimental studies involving rats and mice with diabetes induced by streptozotocin and alloxan have shown that garlic administration effectively lowers blood sugar levels. These animal models stimulate both type 1 and type 2 diabetes and the results suggest that garlic has the potential to regulate glucose levels in diabetic conditions (Ranjan, et al. [62]). Garlic antidiabetic effects are linked to its bioactive compound alliin, which undergoes conversion to allicin when garlic is crushed. alliin and its derivatives have been shown to exhibit not only hypoglycemia but also hypotensive and hypolipidemic properties. These attributes make garlic an effective treatment for metabolic syndrome, which en-

compasses a cluster of conditions including diabetes, hypertension and dyslipidemia. By addressing multiple aspects of metabolic dysfunction, garlic contributes to overall metabolic health improvement. Numerous *in vivo* actions of alliin include diabetes prevention. Because of its antidiabetic, hypotensive, and hypolipidemic characteristics, garlic and its components have shown potential in the treatment of metabolic syndrome. Garlic in lowering blood sugar in both human and animal models of type 1 and type 2 diabetes. These researchers hypothesized that the chemicals in garlic juice that include sulphur are principally responsible for the hypoglycemic impact of garlic. Diallyl disulfide in high doses may make the worse metabolic disturbances in diabetic patients (Saikat, et al. [63]).

Diuretic Effect of Garlic

Garlic is helpful for the removal of excess liquid fluid from the body so it acts as a diuretic. In the case of rheumatism, arthritis, gout, and edemas, garlic performs effective results. Its diuretic action is largely attributed to sulfur- containing compounds found in garlic, such as allicin, which help regulate kidney function and fluid balance (Sanjay, et al. [64]). The diuretic effects of *Allium sativum* on anesthetized dogs and rabbits. The natriuretic and diuretic responses were dose-dependent when garlic powder was administered to dogs under anesthesia. To induce diuretic-natriuretic responses in anesthetized rabbits, chromatographically separated fractions of garlic targeting allicin are administered intravenously. These purified components induced a biphasic diuretic effect, with an initial increase in urine output followed by a secondary inhibitory phase. The purified component had a biphasic diuretic and inhibitory impact on kidney Na, K-ATPase, an enzyme responsible for regulating sodium and potassium balance in the kidney, which further explains its ability to influence diuretic and natriuretic responses (Tiwaie, et al. [65]).

Hepatoprotective Activity of Garlic

Garlic can protect the liver cells from many toxic substances. This protective effect is largely attributed to the antioxidant properties of garlic, which help neutralize oxidative stress and prevent cellular damage in the liver (Chidinma, et al. [66]). Garlic powder in the diet of rat's boosts antioxidant status, modulates oxidative stress, and protects rats from gentamycin-induced hepatotoxicity. Mature garlic extract protects the liver. It has been proved *in vivo* study of the liver toxins bromobenzene, paracetamol (acetaminophen) and carbon tetrachloride. It has been demonstrated to inhibit the production and bioactivation of liver carcinogenic nitrosamines and prevent the mutagenic effects of aflatoxin B1 (Singh, et al. [41]). A high dose of garlic causes liver toxicity and a pro-oxidative state characterized by increased malondialdehyde and decreased antioxidant enzyme functions such as catalase, peroxidase, and superoxide dismutase (Bar, et al. [67]). Excessive doses of garlic may cause liver damage. The soft tissues (lungs and liver) of Rats are more severely damaged by intraperitoneal administration of a high dose of garlic than by oral admin-

istration. The hemostatic equilibrium may become even more impacted by the negative effects of excessive dosages of garlic oil [Lamponi, et al. [68]].

Digestive Effect of Garlic

Garlic improves digestion by stimulating enzymes from the liver, gall bladder, and pancreas, which aid in breaking down food and improving nutrient absorption. This stimulation of digestive enzymes enhances the efficiency of digestion, particularly by supporting bile acid secretion, which plays a key role in fat metabolism, but its use should be avoided when the stomach suffering from acidity and has a frail stomach, so it can be mashed or raw and combined with butter [Sarvzadeh, et al. [69]]. According to research, garlic contains allicin, which has positive effects on the microbes in the gut and can promote digestion and energy utilization. Additionally, garlic can help with bile acid secretion to control digestion, and garlic oil may help Japanese seabass digest better [Xu, et al. [70]]. The consumption of a high dose of garlic oil causes intestinal mucosal damage in addition it increases peripheral proinflammatory cytokines, which can contribute to inflammations and negatively affect gut health [Dorrigiv, et al. [71]]. This highlights the importance of moderate consumption of garlic to minimize its digestive benefits while minimizing potential adverse effects.

Clinical Trials of Garlic

Garlic has been utilized clinically to produce desired pharmacological and therapeutic activity. For instance, the pre and post-transplant period in patients with hepatopulmonary syndrome can be improved using garlic. Clinically studied for its ability to improve patient outcomes in both the pre and post-transplant periods. Garlic's antioxidant and anti-inflammatory properties are believed to play a role in reducing liver stress and enhancing recovery, contributing to better patient prognosis in transplant scenarios [Tudu, et al. [72]]. In atherosclerotic patients, daily use of allicin may reduce the risk of fatal cardiovascular problems. Although there is a potential that garlic could be used clinically to treat some diseases, care should be taken combining it with other medications because of possible drug interactions that might occur [Panyad, et al. [73]].

Conclusion

It was concluded from the present data, that this review provides proof that other researchers can use garlic, along with their active components, as a safe and effective therapeutic. A single clove of garlic can protect against several diseases by reducing the number of harmful microorganism (bacteria, viruses and fungus), parasites and helminths. Garlic prevention against atherosclerotic, inflammatory, hyperlipidemic, immunomodulatory, tumor, diabetic, diuretic, hepatoprotection and digestion. As a result, agriculturists and public health experts should give more attention to garlic. To fully explore its potential for the well-being of humanity, additional research is still

needed in the fields of experimentation, clinical practice, and epidemiology [74].

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