RESEARCH PAPER

Medicinal and pharmacological activities of traditionally important plant garlic - *Allium sativum*

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ABSTRACT

Garlic is one of eldest recognized medicinal plants, and it's used for centuries around the world. As a key food spice plant, it has a vital role in illness prevention and control, and many diseases can be cured with garlic. Natural preparations have been used for centuries to treat ailments and are now a valuable resource in drug research; garlic (illicit) has multiple medicinal properties, variety of pharmacological properties, including anticarcinogenic, antiseptic, antibacterial, antifungal, antioxidant, analgesic, hypolipidemic actions and antihypertensive effects. *Allium sativa* contains sulfur contains phytoconstituents such as allin, ajoenes, allicin, vinyldithiinis, and quarantine. Garlic contains bioactive chemicals with anticancer effects, including allyl mercaptan, diallyl trisulfide, allicin, diallyl disulfide, and diallyl sulfide. Prostaglandins, adenosine, pectin, fructan, vitamins (B1, B2, B6, C, E), glycolipids, biotin, fatty acids, phospholipids, nicotinic acid and important amino acids, garlic extracts, derived compounds been studied for their effectiveness against malignancies such as skin, prostate, ovarian, gastric, lung, colorectal, breast, oral, liver and pancreatic. The application of bioactive compounds, extracts prevent breast cancer at all stages (commencement, advancement, and development), its bioactive substances impact cell gesticulating for cell cycle apprehension, lipid peroxidation, existence, nitric oxide synthase movement, and epidermal development factor receptor. Garlic is being used in a variety of ways. Research indicates a strong link between garlic consumption and disease risk, as evidenced by epidemiological, clinical, and preclinical investigations. Furthermore, garlic has been thoroughly explored for its health advantages.

Keywords: Allicin, Antioxidant, Anticarcinogenic, Insecticidal, Headache, Tumors

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INTRODUCTION

Allium sativum Linn. regularly recognized as garlic, camphor of the poor, nectar of the gods, rustic treacle, lehsan/lasun - □□□□□, Poondu – □□□□□□ (Tamil), Vellaipoondu- □□□□□□□□□□□□□□□ (Tamil) belongs to the Amaryllidaceae plant family and is an underground bulb. Garlic varieties include white garlic (*A. sativum*), wild garlic (*A. ursinus*), elephant garlic (*A. ampeloprasum*), alpine leek (*A. victorialis*), and garlic (*A. vineale*). It instigated in Central Asia, Mediterranean and in the 9th century its spread to South Asia and Japan. Now, it is widely cultivated internationally. Garlic is a well-known herbal with both cookery and therapeutic applications (Nagini, 2008), it has been used for centuries to treat and prevent headaches, tumors, and diarrhea. Garlic includes over 33 organic sulfur compounds that contribute to its dissimilar pharmacological and flavor properties (De Greef et al., 2020). Research indicates that fresh garlic 100 g includes; protein 4.4 g, 0.2 g fat, 23 g carbohydrate, crude fiber 0.7 g and 1.3 g ash (Zhang et al., 2020). Garlic has an extended history of use in both food and medicine. Garlic, a common food, is generally

considered safe for human use (Brodribb, 2018; Nazari et al., 2019).

Essential oil from garlic comprises an assortment of components, including important amino acids, steroidal saponins, saponin ligands, phenolic compounds, and non-sulfur chemicals. Allicin is a thiosulfinate whose arrangement was identified through Stoll and Seebeck. Allicin is naturally formed as a result of enzymatic damage to plant tissue. Allicin's precursor is the S-allyl-L-cysteine sulfoxide (non-proteinogenic amino acid alliin) (Fufa, 2019; Sowmya et al., 2025). Alliin and other S-alkyl-L-cysteine sulfoxides are hydrolyzed through enzyme alliinase, which produces dehydroalanine and allyl sulfenic acid. The allyl sulfenic acid 2 molecules of extemporaneously contract into allicin one molecule, alliin are identified in garlic (*A. sativum*) and ramsons (*A. ursinum*). Stimulatingly, onions (*A. cepa*) don't manufacture alliin. Garlic essential oil has several beneficial components (Amagase, 2006).

Essential oils

Garlic essential oil contains volatiles such as allyl sulfides (DATS and DADS), currently, around is limited research on the essential oil of garlic's bioactivities, this page discusses the components, qualities, and presentations of essential oil of garlic.

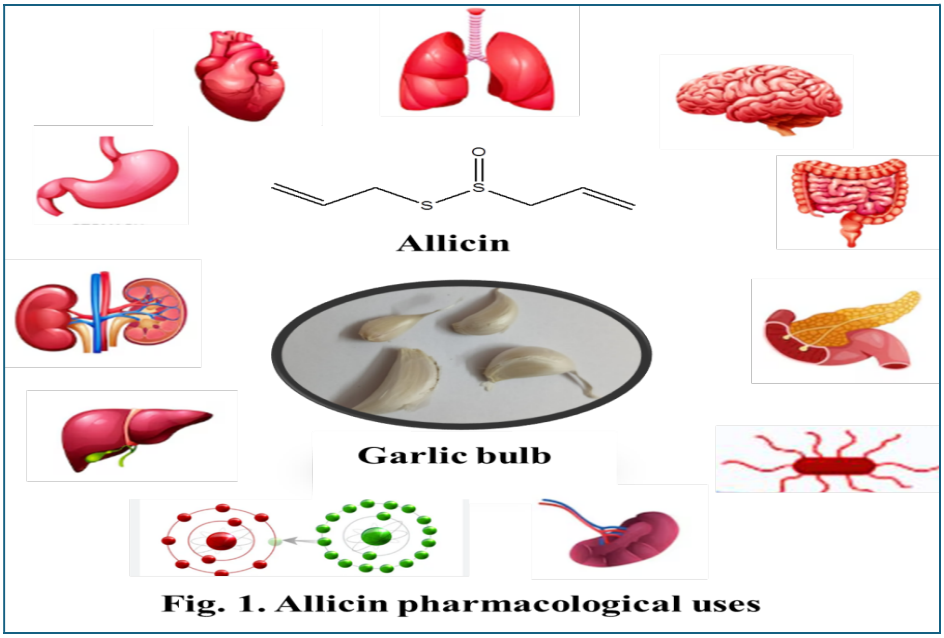

Fig. 1. Allicin pharmacological uses

This article addressed garlic essential oil's biological activity, including antibacterial, insecticidal, antioxidant, and anti-tumor properties, as well as its possessions on human health, such as hypoglycemia and inflammation (Satyal et al., 2017). Garlic bulbs contain a significant amount of γ-glutamylcysteine, which is dissolved to an deskbound derivate-alliin by alliinase during crushing. This derivate-alliin is then metabolized to a extremely active thiosulfite diallyl ester, eventually forming allicin. Allicin quickly breaks down into sulfur enclosing compounds, such as DATS and DADS (Alinezhad et al., 2013; Sivasuriyan et al., 2025) (Fig. 1).

Pharmacological properties of garlic

Antioxidant activity

Endogenous and exogenous antioxidants can effectively cure cellular destruction caused by NO, synthetic antioxidants like butylhydroxytoluene and butylhydroxyanisole are obtainable, but they come with various negative effects. Natural chemicals, rather than synthetic ones, are increasingly being used to combat free radicals in illness treatment. Garlic essential oil contains allyl sulfide, acts as antioxidant through searching reactive oxygen species (ROS) (Borek, 2001). Kim et al. (2011) found that it can protect DNA from permitted essential encouraged injury and mutations by reducing ischemic, constraining lipid peroxidation, reperfusion impairment, and reducing oxidative stress. Essential oil of garlic is typically acquired through distillation of chopped garlic. Chopped garlic exhibits stronger antioxidant movement than fresh garlic and other garlic derivatives. The extraction procedure may enhance stable and bioactive water solvable sulfur compounds, including S-allyl mercapto cysteine, and S-allyl cysteine which have considerable antioxidant potential (Santhosha et al., 2013; Vedhamani et al., 2025).

Conversely, outstanding to it's off mark numerous structure poisonousness, experimental use often results in adverse consequence such testicular damage (Mohammadi et al., 2013), the impact of essential oil of garlic on CYP encouraged oxidative pressure and hormone insufficiency in the male rats. The studies used

DPPH and FRAP methods to regulate the total flavonoid and phenolic content, as well as determining the antioxidant capability (Ekeleme-Egedigwe et al., 2020). Garlic essential oil significantly reduced CYP-induced reductions in testicular SOD, CAT, and GPx activity. Histopathology confirms that CYP reduces glutathione, increases malondialdehyde (MDA), and decreases luteinizing hormone, serum testosterone and follicle-stimulating hormone levels (Nafees et al., 2011) (Table 1).

Table 1. Different types of pharmacological aspects of garlic extracts and compounds

S. No.	Extract/compounds	Bioactivities	Bioactivities (*In vivo, In vitro* studies)	Doses administration
1	Garlic powder extract	Hypolipidemic	Human aortic subendothelial and intimal smoother strength cells since men who expired from a myocardial infarction.	Allicin (3.58 mmol/L), with ajoene (0.184 mmol per liter
2	Allicin	Hypolipidemic	A extraordinary fat nutrition resulted in Apo E−/− mice (6 weeks) and peritoneal macrophage	10, 20 mg/kg/d
3	Fresh garlic extract	Hypolipidemic	Caco-2, HepG2 cells, male SD rats	3, 6, 5 grams/kg body weight
4	Allicin	Hypolipidemic	Ox-LDL stimulates THP-1 macrophages generated from cells	2.5, 5, 10, 20, 40 grams per liter
5	Allicin	Antioxidant	H_2O_2 triggered HUVECs	5 Nano gram/ml
6	Diallyl disulfide	Antioxidant	Great overweight nourishment caused Wistar rats (200 ± 20 g)	15, 30, and 60 mg/kg bw
7	Allicin	Antioxidant	Male New Zealand rabbits with a highest cholesterol nutrition	10 mg/kg/d
8	Fermented garlic	Antithrombotic	The hypercholesterolemic diet caused SD rats	300 mg/kg/d
9	Garlic powder	Antithrombotic	SD rats were stimulated with saline, collagen, and adrenaline	500 mg/kg/d
10	Aged garlic extract	Antiinflammatory	CE-2 dietary caused ApoE-KO mice	The solid component of AGE was increased to 3% by combining liquid AGE with CE-2
11	Single garlic oil	Antiinflammatory	High in fat dietary stimulated Balb/C mice	12.5, 25, 50 mg/kg·bw/d
12	Allicin	Antiapoptotic	Ox LDL induces Human umbilical vein endothelial cells	10–100 μM
13	Garlic oil	Antiapoptotic	Diet induced high cholesterol in Golden Syrian hamsters	Cholesterol 2%, garlic oil 1%
14	Allicin capsule	Endothelium Protection	Elderly patients with myocardial infarction	120 mg/d
15	Allicin	Endothelium Protection	People with chest pain called angina pectoris	60 mg/d

Anticancer and antitumor activity

In garlic essential oil the anticancer mechanism of DATS is unclear, but it has been linked to changes in cell cycle arrest, carcinogenic metabolic enzymes and orientation of apoptotic cell decease, embarrassment of carcinogenic indication transduction pathways, and neoangiogenesis embarrassment (Antony and Singh, 2011). Dietary bioactive substances are thought to decrease cytochrome P450-dependent monooxygenases, which is a key strategy for cancer prevention. Discovered that garlic essential oil contains DATS, which inhibits cancer cell development (Ha et al., 2005). DATS inhibits cell proliferation in various cancer cells, including human hepatoma cells, gastric cancer cells, colon cancer

(Hosono et al., 2005), prostate cancer (Zeng, & Hahm, et al., 2009), and lung cancer cells (Wu et al., 2009).

Antitumor action cancer often acknowledged as a malevolent tumor, kills active to seven million people each year. Currently, cancer treatments such as radiation, surgery, and chemotherapy have significant side effects. Exploring natural alternative remedies is crucial for cancer prevention and therapy. Natural plant products have conventional a proportion of attentiveness in contemporary years outstanding to their remarkable anticancer efficacy and lack of side effects (De Greef et al., 2021) (Table 1).

Insecticidal activity

Natural extracts have demonstrated insecticidal properties and resistance to various pests and diseases, the effectiveness of 97 essential oils, includes black pepper and garlic oil, in preventing and treating Duncan Babesia disease. Essential oil of garlic inhibits *Eimeria* growth in bovine kidney cells by *in vitro*. *In vivo* research indicates that garlic essential oil reduces gut bacteria and oocyst discharge. According to Sidiropoulou et al. (2020), garlic essential oil effectively inhibits Eimeria development and reproduction. A comparable investigation was conducted through Asghar et al. (2020). The investigation compared the anticoccidial properties of garlic and essential oil of ginger, the standard anticoccidial medication Amprolium *in vivo*. According to Sidiropoulou et al. (2020), Amprolium and garlic essential oils effectively control coccidiosis, while essential oil of ginger has no experimental consequence on tremble coccidiosis (Zhang et al., 2020).

Garlic essential oil contains allyl disulfide, which not only inhibits pests but also prevents insect eggs from developing, the essential oil of garlic of toxicity and essential oil of Ferula - Asafoetida on *Culex pipiens* and its caterpillars, whether used unaccompanied or together. Muturi et al. (2018) found that allyl disulfide in 2 essential oils had significant egg assassination and larvicidal properties, contributing to their overall toxicity (Fig. 1).

Antimicrobial activities

Garlic methanol, ethanol, ethyl acetate extracts, essential oil's antibacterial activity is mostly attributed to its copious allyl sulfide and its products, through quantity of atoms of sulfur responsible its intensity (Casella et al., 2012). Garlic essential oil contains allyl sulfide, which modulates genes associated to membrane transport, bacterial metabolism, and secretion, contributing to its antibacterial effect (Yin and Cheng, 2003). Garlic crushed and it's known for its antibacterial activities. formulations of garlic exhibits a comprehensive range for antibacterial activity against gram-negative and gram +ve bacteria are including *Salmonella, Escherichia, Bacillus, Streptococcus, Campylobacter jejuni, E. coli, S. typhimurium, Staphyllococcus aureus, L. monocytogenes, Staphylococcus, Klebsiella, Clostridium* and *Proteus*. Even acid dissolute bacteria like *Mycobacterium* TB are vulnerable to garlic (Benkeblia, 2004), plant essential oils contain extensive antibacterial, antifungal, and antiviral properties (Tsao and Yin, 2001).

Table 2. Different biological activities of garlic extracts and compounds

S. No.	Extract/compounds	Bioactivities	Bioactivities
1	Ethanolic, aqueous, chloroform	Antibacterial	*Escherichia coli, Staphylococcus aureus, Salmonella typhi*
2	Methanolic, ethanolic, aqueous	Antibacterial	*Kelebsiella pneumonia, Bacillus subtilis*
3	Extract	Antibacterial	*Proteus mirabilis, Helicobacter pylori*
4	Extract	Antibacterial	*Salmonella enteritidis, Actinobacillus pleuro pneumonia*
5	Extract	Antifungal	*Candidia albicans, Blastoschizomyces capitatus, C. tropicalis, Aspergillus niger*
6	Essential oil vapors	Antifungal	*Ascosphaera apis, Trichoderma harzianum*
7	Alcoholic	Antifungal	*Saprophytes, Dermatophytes, Cryptococcal*

8	Extract	Antiparasitic	*Entamoeba hirtolytica, Trypanosoma sp, Giardia spp, Plasmodium spp, Giardia lamblia*
9	Aqueous, dichloro methane, Ethanol	Antiparasitic	*Haemonchus contortus, Leishmania spp, Hymenolepiasis, Giardiasis, Cochlospermum planchomi*
10	Extract	Antiviral	*Influenza B, Vesicular stomatitis virus, Human cytomegalo virus, Human rhino virus*

Garlic extracts demonstrated comprehensive spectrum fungicidal action in contradiction of *Torulopsis, Candida, Cryptococcus, Trichophyton, Rhodotorula, Aspergillus* and *Trichosporon* species. Plant essential oil effectively inhibited drug unaffected bacteria that were difficult to treat with standard antibiotics. Plant essential oils kill fungal infections by destroying ATP association and causing cell wall destruction through membrane potential. Garlic essential oils can act as antifungals by damaging mitochondrial membranes and disrupting electron transport. Plant essential oil damages the cell membrane of bacterial pathogens, leading to component leakage and ion loss, as well as disrupting vitality construction and membrane transportation, ultimately culminating in cell expiry (Burt, 2004). The antifungal action of numerous garlic extracts, specifically ethanolic, aqueous, petroleum ether, and methanolic in contradiction of human pathogenic fungi such as *T. rubrum, T. mentagrophytes, T. verrucosum, Candida* species*, Aspergillus niger, Botrytis cinerea, E. floccosum, Rhizopus stolonifera, A. flavus, M. audouinii, M. gypseum, Neofabraea alba, Penicillium expansum* and *Alternaria alternate* (de Turina et al., 2006; Parvu et al., 2019) (Table 2).

Antiinflammatory activity

Inflammation is the body's protective response to stimuli, resulting in redness, heat, swelling, dysfunction and pain. Inflammation is a natural protection reaction in the organization, but it can also be damaging in some situations, occurrences on human materials or swelling of translucent tissues, chronic inflammation can cause diseases such as asthma, conjunctivitis, and arthritis. Garlic essential oil can reduce inflammation in inflammatory bowel illnesses by regulating IL-10 (Interleukin 10) and reducing IL-12. This prevents IL-12 since attaching to NK and T cell receptors (Hodge et al., 2002), decreasing IFN-γ construction. Garlic essential oil contains sulfides that can reduce inflammation by inhibiting the construction of NO, pro-inflammatory cytokines and prostaglandin E2 in lipopolysaccharide triggered macrophages ((Lee et al., 2012) (Fig. 2).

Essential oil of garlic has remained examined for its anti-inflammatory effects and putative molecular mechanism on serious pancreatitis and lung damage in rats (Mathan Kumar and Tamizhselvi, 2020). Garlic essential oil's antioxidant characteristics variety it current for handling peptic ulcers. Previous research indicates that intracellular glutathione can safeguard intestinal mucosal cells from ethanol persuaded impairment in both *in vitro* and *in vivo*, discovered that terpenes and their derivatives can safeguard the stomach and boost glutathione levels in adenocarcinoma cells ((Mutoh et al., 1990; Rodrigues and Percival, 2019) (Table 1).

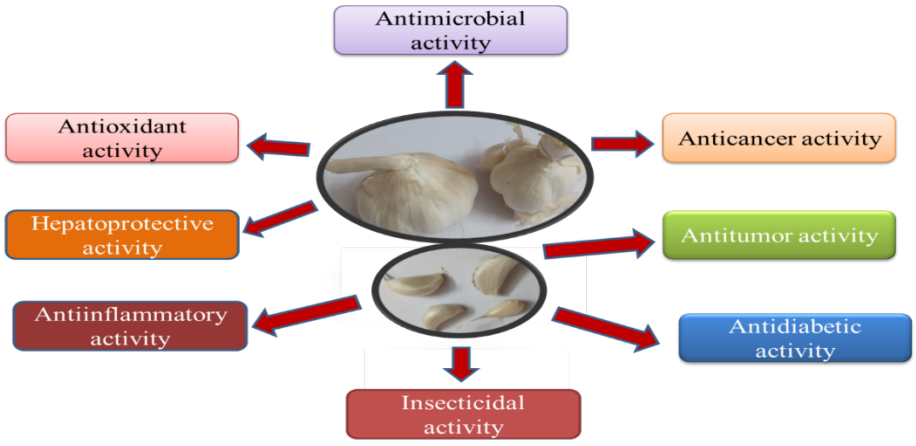

Fig. 2. Pharmacological effects of Garlic bulb

Antidiabetic activity

Diabetes mellitus is a metabolic condition caused through inadequate insulin production and insulin antagonism, subsequent in persistent hyperglycemia and associated

consequences, found that one-third of diabetics take alternative treatments that they believe are successful, with garlic being the most widely utilized option (Ryan et al. 2001). Streptozotocin-induced diabetes rats' skeletal muscle cells had lower levels of glucose transport rate, glucose transporter-4, and glycogen synthase activity. This reduced glucose utilization and lactate production (Oku et al., 2000), essential oil of garlic contains DATS, which progresses glycemic regulator in diabetic rats through accumulative sensitivity and secretion of insulin (Liu et al., 2005) (Table 1).

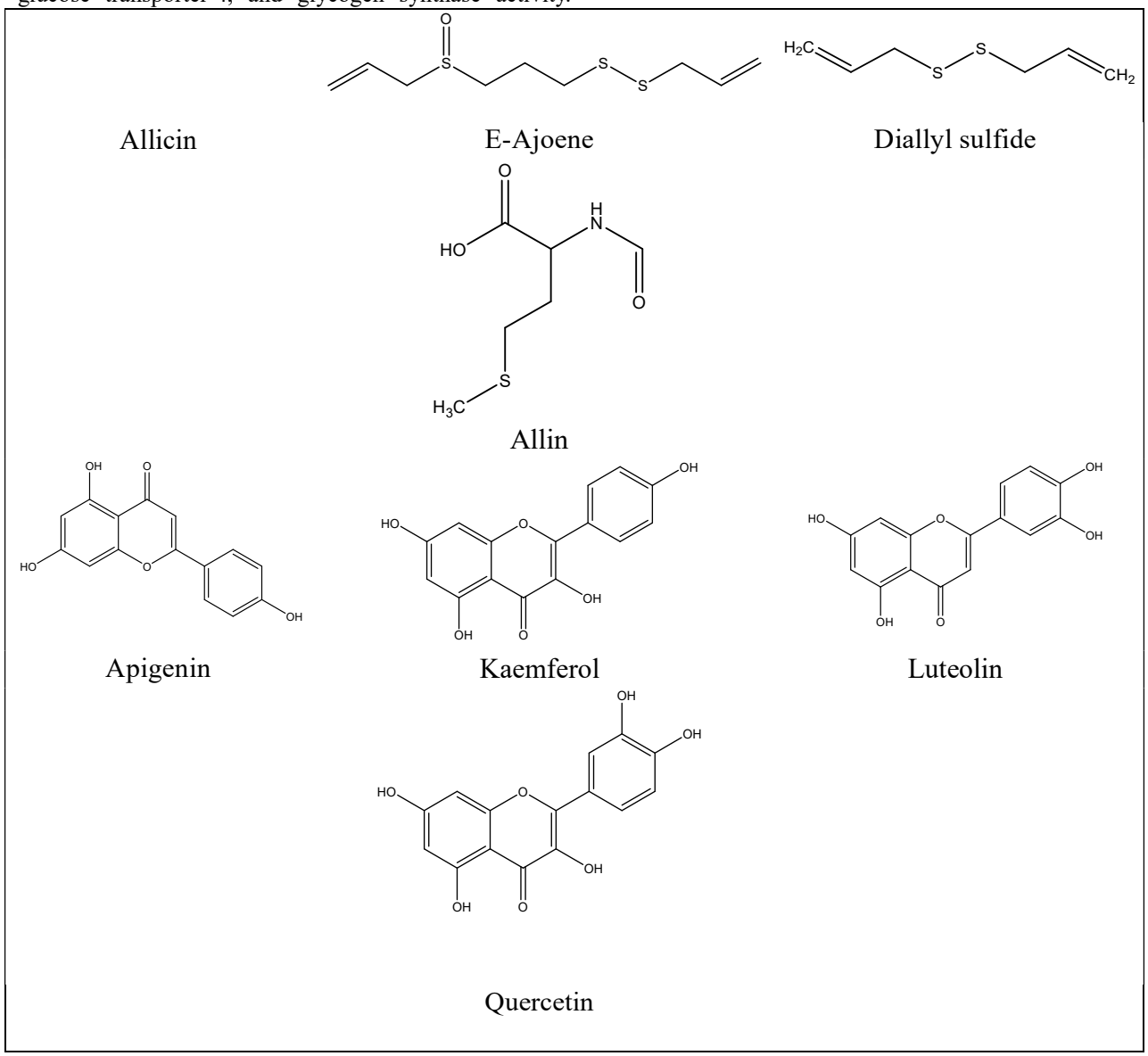

Figure 3. List compounds isolated from garlic plant

Hepatoprotective effects

The chemical processes of diallyl sulfide and DADS encouraged hepatocyte noxiousness were examined. In comparison to allyl sulfide, NaHS utmost cytotoxicity on hepatocytes, followed through DADS and DATS smallest impact. Truong et al. (2009) discovered that all three medications reduce hepatocyte membrane probable in mitochondrial while increasing the production of TBARS and ROS. AAP-induced ROS production harms mitochondria and activates mitogen triggered protein kinases, counting c-Jun N-terminal protein kinase. Pretreatment through DADS in essential oil of garlic significantly reduced critical liver damage and oxidative pressure produced by AAP. DADS pretreatment reserved cytochrome P450 2E1 (CYP2E1) heights and reduced AAP-induced CYP2E1 activity. Research suggests that DADS can protect against acute hepatotoxicity caused by AAP (Ko, Shin, et al., 2017), the garlic essential oil can rescue experimental animals from injury in liver (Zakaria et al., 2010) (Fig. 3).

Anti-protozoal Activity

Several investigations found that garlic extracts and phytochemicals had anti-protozoal efficacy against a variety of parasites are protozoan. The *in vitro* research found that dichloromethane, ethanolic and aqueous, garlic extracts all had anthelmintic movement alongside *H. contortus*, with the ethanol extract being greatest operational, whereas garlic aqueous extract had effective movement contrary to *Angiostrongylus cantonensis* and *T. muris* (Abdel-Hafeez et al., 2015). Garlic was tested both *in vitro* and *in vivo* alongside *Hymenolepis microstoma, H. diminuta*, *T. taeniaeformis, Fasciola hepatica* and *E. caproni*. The garlic extract inhibits the *Blastocystis* spp. growth in *in vivo* and activity was accredited to the fact that *A. sativum* extracts contain numerous secondary metabolies, such as thiosulfinates, which are bioactive compounds that retain antibacterial action connected to the inhibition of thiol enzymes, which is present in numerous microorganisms (Hazaa et al., 2016) (Table 2).

Antiviral activity

A. sativum extracts are showed antiviral activity, has tested in contradiction of parainfluenza virus type 3, human rhinovirus type 2, influenza B, human cytomegalovirus (HCMV), herpes simplex type 1,2 and vesicular stomatitis virus, vaccinia virus (Sawai et al., 2008). Interestingly, an *in vivo* experimentation demonstrated the antiviral movement of *A. sativum* extracts, and its described that *A. sativum* presented defensive action alongside viruses of influenza through increasing manufacture of counteracting antibodies when prearranged to mice, and its based on the presence of several phytochemicals, including allicin, ajoene, methyl allyl thiosulfinate and allyl methyl thiosulfinate,. Allicin inhibits thiol enzymes, whereas ajoene prevents leukocyte adhesion and fusion, contributing to its antiviral effect (Gruhlke et al., 2016) (Table 2).

Anti-apoptotic

Apoptosis and cell proliferation rates underwrite to development and instability of atherosclerotic plaques (Chen et al., 2016) found that allicin boosted cell viability, reduced apoptosis, and protected HUVECs alongside ox-LDL-induced impairment via decreasing caspase-3 and NADPH oxidase-related apoptotic pathways. H_2O_2 is a well-known model of oxidative damage, causing death in vascular endothelial cells via many routes. Allicin inhibited H_2O_2-induced apoptosis in HUVECs through stabilizing the expression of pro-Caspase-3 and decreasing the expression of PARP and Bax proteins. Allicin can reduce oxidative stress and protect HUVECs from apoptosis by increasing SOD, NO, and eNOS while decreasing MDA (Chen et al., 2014).

CONCLUSION

Garlic contains bioactive compounds that inhibit carcinogenesis through many routes, such as cell cycle arrest, death, and angiogenic stimulation. Garlic is widely recognized for its nutritional and medicinal properties. Garlic contains phytoconstituents such as allicin, SAC, SAMC, DAS, DADS and DATS, which must resilient anticancer movement. *A. sativum* essential oil is a popular natural product with numerous health advantages. Pharmacological research can benefit the development of functional food ingredients and innovative medicine formulations. Forthcoming investigation must investigate the toxicity, beneficial efficacy, and lateral properties of garlic extracts and bioactive components, as well as their active mechanisms in cellular, molecular and depth gene level.

Declaration

Conflict of interest

Authors don't have any conflict of interest among authors

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Ethical approval

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