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Garlic (Allium sativum L.): A review of varied health benefits

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ABSTRACT

Introduction:

Garlic (Allium sativum L.), has been cultivated in various countries and is valued for its medicinal and culinary properties. It contains bioactive compounds such as phenolic compounds, organic sulfides, polysaccharides, and saponins, with allicin being a particularly studied compound. These compounds have been shown to possess antioxidant, antimicrobial, antiviral, anticancer, anti-inflammatory, anti-hyperlipidemic and antihypertensive effects. Garlic has been used for over 5000 years as a curative plant and has potential applications in food science, medicine, and nutraceuticals.

Aim of the Study:

The aim of the study is to provide a comprehensive review of the overall impact of Allium sativum L. on human health and in order to draw attention to the benefits of regular consumption.

Materials and methods:

A comprehensive review of scientific and medical literature was conducted utilizing PubMed and Google Scholar databases. Searching terms were: garlic, Allium sativum L., garlic anti-inflammatory, garlic anticancer, garlic health effects.

Conclusion:

Allium sativum L. is associated with a comprehensive range of beneficial effects on the human body. These include anti-inflammatory and antioxidant properties, positive influence on lipid profile, cardiovascular system, and the anticancer activity among others by stimulation of tumor apoptosis. As a result, garlic and its bioactive compounds hold promise as functional foods or nutraceuticals for the prevention and treatment of various diseases.

Keywords: garlic; Allium sativum L.; allicin; anti-inflammatory; antioxidant; anticancer

INTRODUCTION

Allium sativum L., commonly known as garlic, is a member of the Amaryllidaceae family and is believed to have originated in Asia. Garlic is extensively cultivated in various countries such as Egypt, Mexico, China, and Europe. Garlic has been used for its medicinal and culinary properties for centuries and is known for its pungent flavor and aroma. Its various medicinal properties have made it a subject of interest for researchers in the medical and pharmaceutical fields. Its popularity has also led to the creation of various garlic-based products, including supplements and extracts, which are widely available in the market today [i,ii]. Garlic has been used as a curative plant for the treatment of many diseases for the past 5000 years [iii]. Its therapeutic effects can be attributed to its bioactive compounds, such as phenolic compounds, organic sulfides, polysaccharides and saponins [iv,v,vi]. Garlic constitutes a rich source of organosulfur compounds, with diallyl thiosulfonate (allicin), diallyl sulfide (DAS), diallyl disulfide (DADS), diallyl trisulfide (DATS), E/Z-ajoene, S-allyl-cysteine (SAC), and S-allyl-cysteine sulfoxide (alliin) being the major active components [vii,viii,ix]. These compounds have been shown to possess a range of beneficial properties, including antioxidant, antimicrobial, antiviral, anticancer, anti-inflammatory, immunomodulatory, anti-diabetic, anti-obesity and cardioprotective effects [x,xi,xii,xiii,xiv,xv]. Of particular interest is the compound allicin, which has been extensively studied for its pharmacological and therapeutic potential. The presence of these biologically active compounds in garlic makes it a valuable medicinal and culinary herb, with potential applications in various fields, including food science, medicine, and nutraceuticals.

AIM OF THE STUDY

The objective of this study is to conduct a comprehensive investigation into the varied health impacts of garlic and its constituent substances on human health, considering both biochemical and physiological aspects. The review undertaken includes an analysis of the substances present in garlic, their beneficial effects on different systems of the human body, and the mechanisms of their action. The aim of this work is also to emphasize the antioxidant, anti-inflammatory, anti-obesity, anti-diabetes, anti-cancer, immunomodulatory, and cardiovascular effects of garlic, and to bring attention to the advantages of its frequent consumption.

THE STATE OF KNOWLEDGE:

Garlic and its bioactive compounds

Alium Sativum L. has wide range of bioactive components such as saponins, phenolic compounds, polysaccharoides and approximately 65% of the garlic consists of water, with around 28% being carbohydrate, 2% protein, 1.2% amino acids, and 1.5% fiber. Additionally, it contains fatty acids, and trace elements [xvi,xvii,xviii,xix]. It also constitutes a rich source of organosulfur compounds, with diallyl thiosulfonate (allicin), diallyl sulfide (DAS), diallyl disulfide (DADS), diallyl trisulfide (DATS), E/Z-ajoene, S-allyl-cysteine (SAC), and S-allyl-cysteine sulfoxide (alliin) [xxxxixxii]. Garlic is known for its various functional compounds, among which alliin is the most prevalent organosulfur compound found in the whole garlic. Alliin is a derivative of cysteine, an amino acid. The primary cysteine sulfoxide, alliin, undergoes a transformation into allicin through the action of the allinase enzyme subsequent to the cutting of garlic and the subsequent breakdown of the parenchyma [xxiii,xxiv].

Allicin is a bright yellow, highly unstable, oily liquid with a distinct garlic odor. It readily decomposes, even at room temperature. Previous research indicates that allicin degrades when exposed to heat, forming ajoenes ((E)- and (Z)-4,5,9-trithiadodeca-1,6,11-triene-9-oxides) and vinyldithiins. These degradation products, which are more stable than allicin, are commonly found in oil, aqueous, and chloroform garlic extracts as (E) and (Z) isomers. Typically, (E)-ajoene is present in double the quantity of (Z)-ajoene [xxv,xxvi,xxvii].

The chemical composition of preparations derived from garlic fractions is known to be influenced by a range of extraction conditions, including temperature, time, and solvent polarity. The content of organosulfur compounds within garlic bulbs is known to vary throughout the cultivation and storage process. The biological activity of garlic is subject to a variety of factors, including the country of origin and the diverse processing methods applied to isolate novel organosulfur compounds or decompose existing ones [xxviii]. It has been observed that raw garlic contains organosulfur compounds that are more easily digestible compared to those present in cooked garlic. Furthermore, saponins have been found to be more resistant to degradation during the cooking process. Interestingly, the overall quantity of saponin found in purple garlic was nearly 40 times greater than that observed in white garlic [xxix,xxx]. In addition, garlic is found to contain more than twenty phenolic compounds, which exhibit higher levels than many commonly consumed vegetables [xxxi].

Positive biological functions of Garlic and its mechanism

Antioxidant function

As per the findings reported by Asdaq and Inamdar, regular consumption of garlic has been linked to the enhancement of internal antioxidant activities and the mitigation of oxidative adverse effects. This can be attributed to the potential increase in endogenous antioxidant synthesis or the reduction of oxidizing agents such as oxygen-free radical species (ORS) [xxxii]. The potential role of reactive oxygen species (ROS) in various pathological conditions warrants consideration of garlic's antioxidant properties, which may involve the modulation of ROS levels, enhancement of glutathione, and upregulation of cellular antioxidant enzymes [xxxiii]. Numerous scientific studies have demonstrated that garlic exhibits a potent antioxidant effect. A study was conducted to compare the antioxidant activity of raw and cooked garlic, which revealed that raw garlic possesses a greater antioxidant activity by 1,1-diphenyl-2-picrilhydrazyl (DPPH) radical scavenging assay, 2,2'-Azino-bis(3-ethyl- benzothiazoline-6-sulfonic acid) (ABTS) radical scavenging assay, and ferric ion reducing antioxidant power (FRAP) assay) [xxxiv]. Studies show that stir-fried garlic has stronger antioxidant activity and in the context of stir-fried samples, it was determined that the primary mode of action involved a predominantly inhibitory effect on the pro-oxidant enzyme, along with the capacity to disrupt radical chain propagation reactions [xxxv]. The primary antioxidative compounds that exhibit antioxidant effects at lower doses include allicin, DADS, and DATS [xxxvi]. Saponins derived from garlic have been documented to effectively eliminate intracellular reactive oxygen species (ROS) and safeguard mouse-derived C2C12 myoblasts against growth inhibition and H2O2-induced DNA damage [xxxvii].

Anti-inflammatory function

Garlic and its bioactive compounds have demonstrated anti-inflammatory properties in various studies. The primary sulfur compound that dissolves in water, S-allyl-l-cysteine in garlic extract, appears to directly inhibit nuclear factor-κB (NF-κB) and indirectly inhibit IL-1β and TNF-α induced by lipopolysaccharide (LPS) in human blood [xxxviii,xxxix] Allicin and diallyl disulfide also block NF-κB and lower the production of inducible nitric oxide (NO) synthase (iNOS) in macrophages stimulated with LPS [xl]. A recent study found that the 14-kDa protein derived from garlic has been shown to inhibit inflammatory mediators such as nitric oxide (NO), tumor necrosis factor-alpha (TNF-α), and interleukin-1β (IL-1β) by targeting the transcription factor nuclear factor-kappa B (NF-κB) signaling pathway. This inhibitory effect was observed in lipopolysaccharide-stimulated macrophages [xli]. Morihara et al. Conducted study to investigate the anti-atherosclerotic effect of aged garlic extract (AGE) involves the inhibition of inflammation by reducing the serum levels of C-reactive protein (CRP) and thromboxane B2 (TXB2), as well as decreasing the protein levels of tumor necrosis factor-alpha (TNF-α) and interleukin-1 receptor-associated kinase 4 (IRAK4). Additionally, it leads to an increase in adenosine monophosphate-activated protein kinase (AMPK) activity in the liver [xlii].

In both in vitro and in vivo experiments, garlic has demonstrated the potential to inhibit inflammation by primarily targeting inflammatory mediators such as NO, TNF-α, and IL-1. Due to its low or absent toxicity, garlic shows promise in the treatment of inflammatory diseases, including arthritis, in humans.

Antiviral function

Studies have shown that garlic and its organosulfur compounds (OSCs) have antiviral potential against a wide range of viruses from various families including Adenoviridae, Arteriviridae, Rhabdoviridae, Retroviridae, Coronaviridae, Flaviviridae, Picornaviridae, Paramyxoviridae, Herpesviridae, Orthomyxoviridae, Picornaviridae, Paramyxoviridae and Poxvirus. Razina et al. have reviewed the antiviral effects of garlic and its OSCs in clinical and pre-clinical studies. The major pathways for the antiviral activity of garlic and its OSCs include blocking viral entry and fusion into host cells, inhibiting viral RNA polymerase, reverse transcriptase and replication, as well as enhancing the host immune response. Garlic enhances innate and adaptive immunity through macrophage, T cells, B cells, NK cells and anti-inflammatory cytokines [xliii]. Studies have indicated that garlic may have a positive impact on the frequency of self-reported colds, while not significantly reducing the number of days required for recovery. This suggests that while garlic may not act as a cure for the common cold, it may have a prophylactic effect on symptom onset [xliv]. Faik's study showed that garlic has an inhibitory effect on human immunodeficiency virus type 1 (HIV-1) and saquinavir, which is the main defense mechanism of the HIV-1 virus. This protective effect is due to the organosulfur compounds present in garlic [xlv]. Aleks et al. conducted a study to investigate the effects of garlic's active compounds, namely diallyl disulfide (DADS), diallyl sulfide (DAS), and alliin, on inflammation during Denga virus (DENV) infection. Their findings suggest that the aforementioned compounds are capable of suppressing inflammation by modulating the body's response to oxidative stress. This discovery highlights the potential of garlic as an alternative treatment for DENV infection [xlvi].

Antihypertensive function

Allium sativum L. also can increase production of NO and hydrogen sulfide (H_2S), and inhibit the angiotensin converting enzyme, leading to lower hypertension [xlvii,xlviii,xlix]. Takashima et al. conducted study to investigate the vasorelaxant effect of AGE (aged garlic extract). The vasorelaxation induced by AGE in isolated rat aortic rings, precontracted with norepinephrine, exhibited a concentration-dependent response. Notably, this effect was significantly attenuated in aortic rings lacking endothelium. Furthermore, the vasorelaxant effect of AGE was found to be inhibited by a nitric oxide synthase (NOS) inhibitor and a nitric oxide (NO) scavenger. Additionally, AGE treatment of the aorta resulted in a significant increase in nitric oxide (NO) production. Of the various constituents of AGE tested, vasorelaxation of the aorta was observed only in the presence of L-arginine, a substrate of NOS [l]. In a separate study, it was found that the nitrites present in fermented garlic extract (FGE) could undergo conversion into nitric oxide (NO) in vivo through the action of Bacillus subtilis. Further, stimulation of NO production resulted in a reduction of the systolic blood pressure in spontaneously hypertensive rats by activating the soluble guanylyl cyclase (sGC)-cyclic guanosine monophosphate (cGMP)-protein kinases G (PKG) pathway [li].

Anti-hyperlipidemic function

Studies have indicated that garlic possesses the ability to reduce blood lipids in both animals and humans. A specific study revealed that subjecting garlic to high temperature and high pressure processing can mitigate its pungent properties, resulting in the effective reduction of total cholesterol, low-density lipoprotein cholesterol, and triglyceride levels in high-cholesterol diet-fed Sprague–Dawley rats [lii]. In another study, the administration of 300 mg/day of garlic over an 8-week period demonstrated a reduction in cholesterol and low-density lipoprotein levels, as well as an increase in high-density lipoprotein levels among patients with diabetic dyslipidemia. However, the intake of garlic did not appear to affect the levels of triglycerides in this patient population [liii]. Another study exhibit that baseline serum total cholesterol (TC) level decreased from an initial value of 262 ± 34 mg/dL to 247 ± 40 mg/dL ($p < 0.01$) after 12 weeks of common garlic treatment. In comparison, the corresponding values for the placebo group were 276 ± 34 mg/dL before and 274 ± 29 mg/dL after placebo treatment. Low-density lipoprotein cholesterol (LDL-C) exhibited an 11% reduction with garlic treatment and a 3% reduction with placebo ($p < 0.05$). No significant changes were observed in high-density lipoprotein cholesterol and triglyceride levels [liv].

Anticancer activity

Garlic is known for its potent anticancer properties attributed to the presence of various organic and sulfur compounds including allicin. These compounds have a significant impact on multiple aspects of cancer cell behavior, including proliferation, development, growth, migration, invasion, and metastasis. They achieve this by disrupting cell cycle regulation, inhibiting cell signaling pathways, inducing apoptosis and autophagy, as well as displaying antioxidant capabilities [lv,lvi]. Research conducted on animals has demonstrated that specific sulfur-containing compounds have the ability to chemically inhibit the development of cancer in various organs [lvii]. Diallyl disulfide (DADS) is generated as a byproduct of allicin decomposition, and its medicinal properties have been the subject of numerous comprehensive studies [lviii]. Research has demonstrated the potent efficacy of garlic derivatives, such as diallyl disulfide, in inhibiting the proliferation of breast cancer cells [lix]. Numerous studies have demonstrated the anticancer properties of diallyl disulfide (DADS) against various types of tumor cells, including those associated with gastric cancer, breast cancer, and colon cancer [lx,lxi].

DADS has demonstrated the ability to intrinsically activate the apoptosis pathway in breast cancer cells lxii. Altonsy et al. establish that DADS has been observed to induce apoptosis in MCF-7 breast cancer cell lines by disrupting cell-cycle progression, leading to a notable increase in the sub-G0 population and a significant deceleration in DNA synthesis [lxiii]. The study delved into the role of diallyl disulfide (DADS) and its impact on breast cancer stem cells (BCSCs), examining the underlying mechanisms. The research findings demonstrated that DADS effectively decreased glucose metabolism and the stemness of BCSCs [lxiv]. DADS also has an impact on gastric cancer. The growth of AGS human gastric adenocarcinoma cells was significantly reduced by DADS through the induction of apoptosis and increased reactive oxygen species (ROS) generation. Additionally, DADS downregulated Bcl-2 expression while upregulating the expression of Bax, Fas, and caspase-3 in AGS cells [lxv].

Conclusion

Garlic is a widely utilized spice known for its distinctive aroma. It contains an array of bioactive components, including organic sulfides, saponins, phenolic compounds, and polysaccharides. Major bioactive components in garlic include organic sulfides such as allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene, and S-allyl-cysteine. Garlic and its bioactive components exhibit diverse biological functions, including antioxidant, anti-inflammatory, cardiovascular protective, anticancer, antihypertensive, anti-hyperlipidemic, antiviral activities. Generally, garlic demonstrates low toxicity or is non-toxic. As a result, garlic and its bioactive compounds hold promise as functional foods or nutraceuticals for the prevention and treatment of various diseases. Future research should focus on further evaluating the biological functions of garlic and identifying the specific compounds present in garlic.

DISCLOSURE

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