Review: Garlic: (*Allium sativum* L.) classification and botanical description, chemical composition, nutritional value and biological functions

Nour Sabah Naji

Diyala Education Directorate, Ministry of Education, Iraq

Abstract:

Since ancient times, medicinal plants were utilized in human healthcare. The aromatic herb garlic (*Allium sativum* L.) is a lily family member. It is eaten all around the world as a food and as a traditional treatment for a number of illnesses. With its volatile oils, such as alliin, which is transformed to allicin, an antibacterial substance, by the enzyme allinase, garlic is a rich source of medicinal benefits. Additionally, it includes saponins that reduce blood sugar and flavonoids that lower blood pressure. Many biological properties, like anti-cancer, anti-inflammatory, cardio-vascular protective, antimicrobial, and antioxidant properties, were reported. Phytochemicals, like ajoene, phenyldithione, alliin, and allicin are abundant in garlic. Numerous conditions, such as parasites, arthritis, persistent coughs, and insect and snake bites, have been treated with garlic.

1- Introduction:

The Liliaceae family includes the multipurpose crop garlic, which is highly valuable both medicinally and nutritionally. It is a bulbous, aromatic flowering plant consisting of a bulb composed of several cloves with a high nutritional value, containing 29% carbohydrates, 6.3% proteins, 13 mg/100 g of vitamin C, 0.03% calcium, 0.31% phosphorus, 0.0031% iron, and 62.8% moisture (El-Faqer et al., 2024). Garlic is widely cultivated throughout the world, and 7 species out of 750 garlic genera are cultivated in different regions of the Earth's soil (Ammarellou et al., 2022). Garlic cultivation has expanded due to its medicinal properties. Approximately 81% of the world's dried garlic bulbs, or approximately 21 metric tons per year, are produced in China, making it the world's greatest garlic producer (So et al., 2021). Iran produces 58,278 tons of dry garlic bulbs annually, ranking 27th in global production (Akbarpour et al., 2021). Garlic can grow in a variety of climatic conditions, but prefers cool weather at

elevations between 900 and 1,200 feet, temperatures between 12 and 24 degrees Celsius, and a soil pH of 5.8 (Alsup-Egbers et al., 2020). Garlic has health benefits. Garlic is a popular food for humans due to its spicy, pungent aroma and flavor, including those related to medicine, nutrition and physiology (Dardona et al., 2024). Garlic stores biologically active and health-promoting compounds in various parts of it, such as the bulb and cloves. Garlic contains at least 33 organic compounds and antioxidants with more than 200 chemicals and 7 amino acids (Ezeorba et al., 2022). Its products, including essential oil, aged black garlic, aged garlic extract, and garlic powder, are potential stores of organosulfur compounds, saponins, and flavonoids with diverse biological properties, which include antioxidant, anti-inflammatory, antimicrobial, cardioprotective, antihypertensive, anticholinergic, anticancer, hepatoprotective, anthelmintic, wound healing, asthma, arthritis, sciatica, lower back pain, and inflammation. Garlic is used for bronchitis, chronic fever, rhinitis, tuberculosis, malaria, intractable skin diseases, including leprosy, vitiligo, skin discoloration and itching, indigestion, splenomegaly, hemorrhoids, colic pain, bone fractures, urinary tract diseases, diabetes, kidney stones, anemia, epilepsy, jaundice, gout, cataracts, and night blindness (Alam et al., 2016). Calcium, germanium, sulfur compounds, potassium, vitamins A, B, and C, many enzymes, water, fiber, and calcium are among the minerals found in garlic. Lysine, aspartic acid, histidine, and arginine are the most crucial of the seventeen amino acids found in garlic (Amino et al., 2018).

Figure (1) Garlic plant

2- Scientific classification:

Table (1) shows the scientific classification of garlic as mentioned by (Dardona et al., 2024)

Rank	Scientific Name
Kingdom	Plantae
Sub kingdom	Tracheobionta
Super division	Spermatophyta
Division	Magnoliophyta
Class	Liliopsida
Subclass	Liliidae
Order	Liliales
Family	Liliaceae Juss
Genus	Allium L.
Species	*Allium sativum* L

3- Appearance:

According to Espinoza et al. (2020), garlic is characterized through a stem that contains the active ingredient and is separated into six to twelve small bulbs known as cloves, which are connected by a thin pericarp to create the head. Up to 80 cm below the plant's base, garlic roots develop from the disc's basal part. There are eight chromosomes in garlic (2n=2x=16). A variety of techniques, such as diversity matrix (Egea et al., 2017), amplified fragment length polymorphism (AFP) (Garcia-Lampasona *etal*., 2012), and simple sequence repeats (SSR) (Barboza *etal*., 2020; Li *etal*., 2022), could be utilized for quantifying genetic diversity of garlic. Leeks, onions, shallots, and chives are all closely related to it. The head, often called cloves, is the underground part that is thought to be edible. The garlic plant's reproductive organs are cloves. Garlic differs from other vegetables in that it reproduces by cloves instead of seeds (Tavares et al., 2019). These cloves germinate upon planting and grow into new garlic plants.

Garlic is characterized by its long, narrow, flat leaves, but with a cylindrical and pointed tip, measuring 1.25–2.5cm in width and 60cm in length. These leaves are arranged in a rosette (Kirac et al., 2022). The flowering stem of the garlic plant stands tall and straight, reaching a height of 1

m. Its flowers are small, hermaphrodite, whitish-purple flowers clustered in a spherical head (Ozma et al., 2021). These flowers, during the early growth stages, encourage the growth of a larger bulb, so new garlic plants can be obtained as the flowers mature and produce small bulbs. Environmental conditions and the variety greatly influence the size of garlic, which ranges from 2 cm to 10 cm (Tavares *etal*., 2019; Ozma *etal*., 2021). Genetic influence plays a role in the variation of varieties in terms of shape and stem arrangement (Maccelli et al., 2020). The root has a thick, sparsely branched lateral root system with a multicellular epidermis, cortex, and endodermis surrounding the central stem (Ozma et al., 2023). The bulb can have oval, round, or circular shapes, as well as wide oval and narrow wide shapes, and it could be brown, light brown, purple, white, light purple, or dark purple (Balqis et al., 2018).

4- Chemical components:

The plant's aroma, flavor, and health benefits are all a result of its chemical composition, which offers a number of advantages. Numerous essential compounds that include allicin, diallyl disulfide, diallyl tri-sulfide, and S-allyl cysteine, are among its most significant constituents. Because of its potent antioxidant and antimicrobial properties, allicin is an essential part of medicinal treatments (El-Saber Batiha *etal*., 2020). Garlic's main components are sulfur compounds, which are also found in amino acids, minerals like selenium, and enzymes. Sulfur and its compounds are responsible for the aromatic scent as well as many of its advantages. Allin includes salylcysteine sulfoxide and makes up 1% of dried, ground garlic. One of the most biologically active compounds that are found in garlic is allicin, also known as diallyl thiosulfinate or diallyl disulfide. The enzyme alliinase, which changes alliin into allicin, activates it. With antiviral, antimicrobial, antifungal, antibacterial, and antiparasitic properties, allicin was initially discovered in the 1940s. Allicin metabolites, which lack the physiological activity regarding fresh garlic or garlic powder, are present in garlic oil products and steam-cooked garlic, yet contain no large levels of allicin or alliin (Kemper KJ et al., 2000). Allicin's chemical formula is CH2=CHCH2SSCH2CH=CH2. According to Seebeck and Stoll (1984), the odorless molecule (+) S-allyl-L-cysteine sulfoxide (CH2=CHCH2S(O)CH2-CH(NH2) COOH) is the precursor to allicin. This molecule, known as alliin, makes up 0.24% of a typical garlic bulb's weight. It is created when the sulfur atom regarding the amino acid cysteine forms a link with an oxygen atom as well as an allyl group. Alliin is an amino acid that is odorless, colorless, and

soluble in water. The enzyme alliinase, which is present in the vacuoles of healthy garlic cells, is activated when garlic is crushed or chopped. Alliinase breaks down alliin to allicin, a sulfur-containing substance, in healthy garlic cells (Borlinghaus *etal*., 2014).

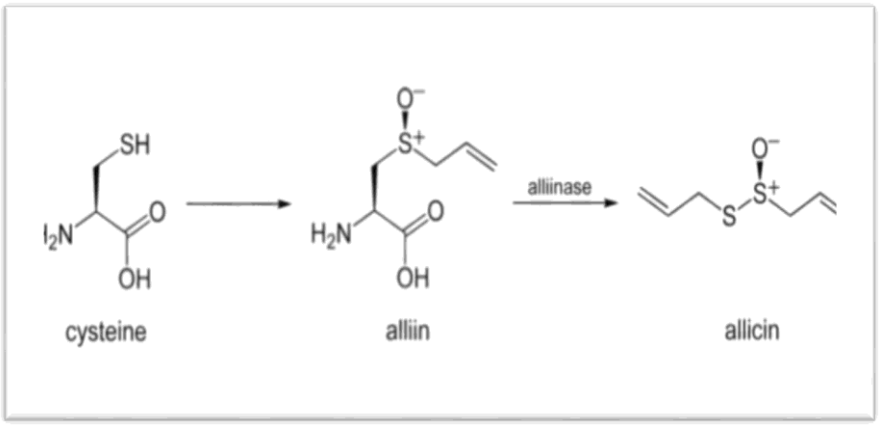

Figure (2) Chemical components of garlic plant

Garlic also contains a group of other beneficial plant secondary metabolites such as phenols and flavonoids. The most prominent of these compounds are quercetin, valerian acid, and beta-resorcinol, all of which are known for their antioxidant properties. In addition, garlic contains large amounts of saponins and polysaccharides (Shang *etal*., 2019). The chemical nature of garlic varies depending upon several factors, including environment, variety, and processing method. Studies indicate differences in the levels of active ingredients before and after harvest, which impacts the effectiveness and benefits of these compounds (Bazzraliyeva et al., 2022).

Table (2) shows garlic's main chemical components (Dardona et al., 2024)

Component	Comments
Allicin	The most important compounds found in garlic that contain organic sulfur
, Diallyl disulfide, Diallyl sulfide, Diallyl trisulfide, S-allyl-cysteine	Compounds with therapeutic effects due to their sulfur content
Alliin and Alliinase	Alliin is an allicin Alliinase precursor is an enzyme converting Alliin to allicin when garlic is crushed
Flavonoids (e.g., quercetin):	Anti-oxidant activity Significant in the inhibition of oxidative stress Mitigate chronic disease risk
Saponins	Group of naturally occurring glycosides aglycone part Anti-oxidant Properties, Anti-microbial Activity, Immune

	Modulation, and Cardiovascular Benefits.
Phenolic compounds	Biological activities and health benefits. Anti-oxidant properties β-Resorcylic Acid: This is a predominant phenolic compound that is found in garlic Quercetin: This flavonoid is a well-known anti-oxidant
Polysaccharides	Characterized by inulin-type structure that is Soluble in water and easily digestible. Health benefits include immune-modulating, promoting gut health and hypolipidemic effects.
Vitamins, minerals, proteins, and enzymes	smaller amounts Significant for nutritional

5- Nutritional value of garlic:

Garlic is widely used in food. People mostly use it for seasoning, as it adds a distinctive flavor to foods and makes them more delicious and easier to digest, which varies depending on the cultivation areas and genotypes (Spyridon *etal*., 2018). According to Melguizo-Rodríguez *etal*. (2022), garlic has the following nutrients: 65% water, 2% proteins, 28% carbs, 1-4% sulfur compounds, free amino acids (1-1.5%), 1.5% fiber, several vitamins (B and C), and minerals (Mn, Zn, Cu, Fe, Se). Additionally, garlic is one of the rich sources of vitamins and minerals. It is abundant in potassium, calcium, iron, manganese to support nutrient processing and bone growth, and vitamins B6 and C, which are critical for brain health and metabolism. Selenium, an antioxidant, is abundant in it. Garlic contains trace amounts of other vital minerals like zinc, magnesium, potassium, and phosphorus (Gambelli et al., 2021), which are known to boost the immune system's effectiveness, improve bone health, and aid in the production regarding red blood cells (Hussein et al., 2017). Garlic is vital for overall health (Rais et al., 2023).

6- Biological functions of garlic:

6-1 antioxidant properties:

Garlic's capacity to scavenge oxidative free radicals gives it anti-inflammatory properties. Raw garlic has strong antioxidant properties because of its capacity to remove hydroxyl radicals. High-pressure liquid chromatography (HPLC) has been used to investigate allicin's capacity to scavenge free radicals. Through decreasing lipid peroxidation, it showed great effectiveness in lowering hydroxyl radicals. According to Becerril-Chavez et al. (2017), such antioxidant activity

aids in prevention of chronic diseases, like cardiovascular disease, cancer, neurodegenerative diseases, and vascular disease. Allicin and water-soluble, highly bioavailable organosulfur-containing compounds like SAMC and SAC are examples of unstable molecules that were stabilized through extended extraction and have antioxidant properties (Hiramatsu et al., 2016). Along with conventional antioxidants like butylhydroxytoluene, butylhydroxyanisole, and ascorbyl palmitate, bioactive compounds like polyphenols also offer protection against oxidative stress-related diseases. Garlic extracts' potent antioxidant properties are a result of their high phenolic content in methanol and ethanol. Antioxidant qualities are present in both aqueous solutions and extracts prepared with organic solvents. The extracts' antioxidant efficiency in removing free radicals like DPPH is influenced by the quantity of tocopherols and phenols they contain (Bar et al., 2022). Additionally, compared to fresh garlic, the sulfur compounds found in garlic extract have an antioxidant potency that is about 1,000 times lower. It has been discovered that fermented garlic, like black garlic, was more effective compared to raw garlic, but raw garlic showed greater activity than boiled garlic (Gambelli et al., 2021). Garlic has been found to lower systolic blood pressure and serum glucose levels in rats with diabetes and hypertension, respectively (Jayasekara and Amarakoon, 2017).

6-2 antimicrobial characteristics:

Garlic has a broad range of antifungal, antibacterial, anti-viral, and antiparasitic properties. Steam distillation regarding garlic bulbs yields an essential oil extract that is rich in diallyl tetrasulfide, diallyl disulfide, and diallyl trisulfide. This extract has been shown to have strong anti-microbial activity against both Gram-negative and -positive bacteria, including Staphylococcus, Salmonella, Micrococcus, Streptococcus, and Enterobacter (Abidullah *etal*., 2021; Ismail *etal*., 2020). Garlic oil is a potent antifungal agent that could penetrate the cell membranes of Candida albicans, mitochondria, and other organelles, causing organelle destruction and ultimately cell death, according to a fungal study (Li et al., 2016). Garlic works just as well as ketoconazole to cure a variety of significant pathogenic species, including dermatophytes as well as Candida (Khounganian et al., 2023). It is beneficial for treating parasites, and this is because garlic is rich in allicin, which is the active ingredient released when garlic is crushed and which disrupts the parasites' critical functions (Suroshe et al., 2018).

6-3 Maintaining the heart and blood vessels:

Natural plant products for cardiovascular protection are becoming more popular due to the recent rise in cardiovascular disease-related fatalities (Benjamin et al., 2018). One of the most promising choices is garlic (Bayan et al., 2014). The primary component in garlic, lysine, has positive cardiovascular health effects. Lysine's hydrophobic properties allow it to readily cross cell membranes without jeopardizing the phospholipid bilayer. Allicin has vital pharmacological effects for the circulatory system, including enhancing microcirculation, and is easily absorbed because of its hydrophobic properties. Additionally, garlic lowers blood pressure's diastolic and systolic levels (Tsui et al., 2018). It has been shown that allicin treatment inhibited apoptosis brought on by a reduction in myocardial perfusion, which in turn affected the heart's ability to receive oxygen. Apoptosis-related proteins have been elevated, cytochrome C expression was downregulated, pro-inflammatory cytokines, like interleukin-6 were downregulated, and intracellular reactive oxygen species (ROS) were reduced (Deng *etal*., 2021). Because it dramatically decreases blood pressure, lowers triglycerides and cholesterol, prevents atherosclerosis, and stimulates fibrinolysis, garlic was utilized for treating cardiovascular problems since ancient times. Through promoting the formation of nitric oxide and hydrogen sulfide, lowering oxidative stress, and blocking the angiotensin-converting enzyme (ACE), garlic reduces blood pressure (Ried, 2016).

6-4 Anti-inflammatory:

Inflammation can be defined as a biological response that is brought on by damaged cells, pathogens, or irritants acting as detrimental stimuli to vascular tissue (Chen et al., 2023). Swelling, redness, heat, pain and loss of function are all indicators of acute inflammation. Through eliminating damaging stimuli and starting the healing process, inflammation defends the body. With a chemical composition that varies greatly depending on genetic variety, agricultural processing, and habitat, garlic, a member of Liliaceae family, contains 1–2% dried essential oil. It has anti-inflammatory properties, was utilized for treating colds, coughs, and asthma in the past, and is useful in identifying influenza virus replication, particularly in the early stages of illness (Mehrbod et al., 2013). Both garlic and garlic oil's anti-inflammatory

properties have been characterized as plant-based. Garlic has anti-inflammatory properties comparable to those of indomethacin, according to research (Olimov et al., 2013).

6-5 Anti-cancer activity:

Due to chromosomal and genetic instability, cancer is recognized as one of the primary death causes globally (Chen et al., 2022). Numerous natural plant products were demonstrated to possess anticancer effects, including cruciferous vegetables, berries, tomatoes, and ginger (Bray et al., 2018). Additional research on the benefits of garlic as well as its active compounds has demonstrated how important they are in lowering the risk of several cancers, including lung, stomach, colon, bladder, and rectal cancer (Wu et al., 2015). L-cysteine sulfoxides as well as γ-glutamyl-L-cysteine peptides are two types of organic molecules found in garlic (Mondal *etal*., 2022). Garlic's allicin compound has been shown in numerous tests to prevent the growth regarding cancerous human colon and endometrial cells. A component of garlic improves the effect of eicosapentaenoic acid, which suppresses breast cancer, whereas decreasing the effect of linoleic acid, which is thought to raise the risk of breast cancer (Milner, 1996). Anticancer potential is linked to the existence of bioactive compounds like DATS and DADS. It was demonstrated that aqueous extracts have anticancer properties (Kallel *etal*., 2014). Garlic contains bio-active sulfur compounds, including DADS, DAS, alanine, DATS, AC, and SAC, which change mitochondrial permeability, improve antioxidant qualities, prevent angiogenesis, and control cell proliferation. Additionally, garlic oil lowers DNA content, raises the bone marrow micronucleus ratio, and prevents the loss of peripheral blood cells (Bar et al., 2022). According to one study, those who regularly ate raw or cooked garlic had a about one-third lower risk of colorectal cancer and a roughly half-risk of stomach cancer when put to comparison with those who ate little to no garlic (Gambelli et al., 2021). According to research, eating garlic increased a woman's risk of developing colon cancer (Galeone et al., 2006).

Conclusions:

Garlic's numerous compounds, especially allicin, give it strong antimicrobial, antioxidant, anticancer, anti-inflammatory, and cardiovascular protective qualities, making it a versatile crop with nutritional, economic, and medicinal significance. Garlic can be consumed dried, fresh, or extracted, and careful production and cultivation practices are necessary to satisfy the demand for garlic products around the world. Even if study shows a lot of information, more investigations and lab tests are required to ascertain garlic's effectiveness, establish the right dosages, and show its use as a complementary medicine. In the end, garlic proves to be a natural defense against viruses, bacteria, and cancer, providing promise for an easy-to-follow and thorough treatment approach.

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