

Garlic: an overview of its properties, sources, health benefits, and immunity

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Abstract— Prebiotics are indigestible food ingredients, mostly dietary fibers, that specifically promote the development and activity of good bacteria like *Bifidobacterium* and *Lactobacillus* in the stomach. Prebiotics support a healthy gut microbiota by acting as a food supply for these advantageous bacteria, in contrast to probiotics, which are living microorganisms. Since 70–80% of immune cells are found in the gut-associated lymphoid tissue (GALT), the gut microbiome is essential for immune system regulation. Prebiotics improve the body's capacity to combat infections, lower inflammation, and preserve immunological homeostasis by indirectly influencing immune responses through gut microbiota modulation. The fructooligosaccharides (FOS) in garlic (*Allium sativum*), a popular prebiotic, are resistant to digestion and act as substrates for good gut flora. Short-chain fatty acids (SCFAs), including butyrate, propionate, and acetate, are produced when these bacteria ferment FOS. These SCFAs improve the integrity of the intestinal barrier, lower inflammation, and control immunological responses. As a nutritional element garlic possesses distinct properties to boost immune function because its active compounds including allicin demonstrate anti-bacterial and immunostimulatory action.

Keywords — prebiotic, garlic, *allium sativum*, immunity, healthy

INTRODUCTION

Multiple approaches exist for prebiotics to affect immune system response. The bacterial fermentation process leads to short-chain fatty acid (SCFA) synthesis in which butyrate and propionate and acetate are key products. The intestinal barrier receives its strength from SCFAs along with protective effects against bloodstream penetration of infections. The immunoregulatory actions of SCFAs are achieved through their dual capacity to reduce pro-inflammatory cytokines and improve immune response pathways which control various immune cell activities such as those of T-cells and dendritic

cells and macrophages. The utilization and competition for nutrients and adherence sites change the bacterial composition as prebiotics enhance beneficial bacterial numbers that protect against harmful bacteria. The competitive exclusion pattern allows the immune system to become stronger and infections to be prevented. Prebiotics establish contact with intestinal immune cells to activate pathways which enhance immune response alongside surveillance mechanisms.

Throughout many centuries humans have benefited from using garlic (*Allium sativum*) in their food preparation as well as therapeutic applications. Multiple studies offer proof about immunological health advantages and prebiotic properties of this substance. The prebiotic compound FOS that exists within garlic becomes resistant to upper intestine digestive processes leading to its arrival in the colon without alteration thus serving as nutritional support for beneficial gut bacteria. The two probiotic organisms *Lactobacillus* and *Bifidobacterium* along with short-chain fatty acids acetate and propionate and butyrate create through fermentation of FOS. The preservation of gut health depends on short-chain fatty acids because they enhance intestinal barrier strength alongside reducing inflammation while regulating immune response functions. Research shows that butyrate specifically regulates immune cell functions especially dendritic cells and macrophages and T-cells to generate anti-inflammatory responses while improving immune monitoring functions. (1).

The compounds present in garlic include prebiotics together with bioactive substances that generate allicin particularly after cutting or breaking garlic. Its potent antibacterial properties make allicin an effective substance which halts the growth of dangerous microorganisms and viruses and fungus. The nature of garlic provides people with a holistic treatment approach for illness prevention and treatment. Scientific assessments confirm that allicin successfully inhibits the growth of three food-related pathogens known as *Salmonella*, *Staphylococcus aureus*, and *Escherichia coli*. Studies have proven that garlic stimulates natural killer (NK) cells to greater activity and these

cells defend the body against cancer development along with viral infections. (2).

The immune system enhancing properties of garlic extend past its ability to kill bacteria. Studies have shown that people who consume garlic regularly experience reduced occurrences of infections by the flu and common cold together with decreased disease intensity . A daily garlic supplement intake for 12 weeks produced decreased cold incidence rates and shorter recovery periods when compared to placebo treatment. The study evaluated these outcomes through its randomized double-blind placebo-controlled setup as reported by Josling (2001). Garlic promotes better infection healing capabilities in addition to its protective functions for the body. Garlic serves as an immune system regulator and inflammation controller which enables its use in managing rheumatoid arthritis alongside inflammatory bowel disease (IBD) conditions. (3).

The nutritional component garlic stands out in supporting immune wellness between its ability to modify immune responses directly alongside its friendly bacteria promoting effects. Natural use of garlic provides effective immune support because it protects both gut microbiota health and intestinal barriers and fights infections directly. The bioactive compounds within garlic including allicin become vulnerable to processing together with exposure to heat. Fresh garlic consumption provides the best health effects when it is not overheated during processing. (4). A study reviews the impact of prebiotic substances especially garlic-derived prebiotics regarding immune system functionality and their contribution to overall wellness.

Garlic derivatives and their roles in health

The compounds that are separated or produced from garlic while maintaining its bioactive properties are known as garlic derivatives. Due to their powerful health effects, these compounds are often used in functional foods, supplements and drug applications. S-all cystin (sac), old garlic extract (age), allicin and allicin ritual chemicals (such as dilly disulfide and deellil tricelfide) are the most famous garlic derivatives. Garlic provides many health benefits, including immunological regulation, antibacterial activity and antioxidant effects, all of which are responsible for different properties for each of these compounds. Extraction and stability of these chemicals enable more regulated and efficient use in medical applications. (5)

Allicin: The Key Bioactive Compound

Many health benefits of garlic are attributed to allicin, one of the most examined components of garlic. It is made when raw garlic gets a plate or crushed, because the component containing sulfur is converted to Alicin by Enzyme Alinez. Alicin is very bio -active, although it is unstable and quickly dissolve in other molecules that include sulfur. It works well against bacteria, viruses, fungi and even parasites, thanks to the strong antibacterial properties. For example, it has been shown that Alicin Helicobacter prevents the development of pylori, bacteria associated with gastric cancer and ulcers. Alicin also has antioxidants and anti -inflammatory properties, making it useful to reduce inflammation and oxidative stress in chronic diseases. (6)

Allicin-Derived Compounds: Diallyl Sulfides

Allicin is decomposed to produce diallyl disulfide (Dads) and Dial Trisulfide (DAT), which are chemicals containing stable sulfur. These substances are known for their cancer properties as they prevent tumor growth and cancer cells causing apoptosis, or programmed cell death. For example, DATS is displayed to prevent the growth of cancer cells in the breast and prostate. The effect of garlic heart is also attributed to sulphides, which reduces cholesterol, prevents platelet aggregation and increases the blood vessel. Garlic oil often contains these chemicals, which are used in supplements due to their powerful health benefits. (2).

S-Allyl Cysteine (SAC): A Stable and Bioavailable Derivative

Aged garlic extract (AGE) includes a water-soluble substance called S-allyl cysteine (SAC). SAC is a properly-liked derivative for medicinal usage in view that, in contrast to allicin, it's far strong and pretty bioavailable. Because it could penetrate the blood-brain barrier and lessen oxidative stress within the mind, SAC is widely known for its neuroprotective residences. Research has indicated that by protective neurons from harm, SAC can also help save you neurodegenerative ailments like Parkinson's and Alzheimer's. SAC also possesses anti-inflammatory and antioxidant traits, which assist to improve immunological and cardiovascular health (7).

Aged Garlic Extract (AGE): A Unique Derivative

Raw garlic ages to produce age garlic extracts (age) for months, converting volatile substances such as allicin into stable and bio -triable derivatives such as SAC and S -All Mercaptosistine (SAMC). Because it increases the activity of natural killers (NK) cells and macrophages, which are essential to immunologists, age is especially known for its immunomodulatory functions. In addition, age improves lipid profiles, reduces blood pressure and prevents atherosclerosis between other cardiovascular benefits. Due to the antioxidant properties, which reduce oxidative stress, it can help to handle long -term conditions including diabetes and high blood pressure. (8).

Health benefits of garlic

1. Immune System Support

The ability of the garlic to strengthen the immune system is widely documented. It contains substances that strengthen the immune system, such as S-All cystin (SAC), Alicin and sulfur compounds, produced from Alicin. These substances increase the activity of immune cells that are important for struggling with infections including lymphocytes, natural killers (NK) cells and macrophages. Regular garlic food has been shown to reduce the intensity and length of common diseases including flu and colds. Garlic is a natural protection against pathogens because of its antibacterial qualities, which also aid in the fight against bacterial, viral, and fungal illnesses (9).

2. Cardiovascular Health

Garlic has many heart-healthy benefits. By encouraging the synthesis of nitric oxide, which relaxes blood vessels and enhances blood flow, it lowers blood pressure. Garlic supplements significantly lower systolic and diastolic blood

pressure in people with hypertension, it's also increasing the excretion of cholesterol and preventing its synthesis in the liver, that lead to reduces cholesterol levels. Additionally, it lessens LDL cholesterol oxidation, a major contributing element to atherosclerosis formation. Together, these effects lower the risk of stroke and heart disease (10).

3. Antioxidant and Anti-Inflammatory Effects

Antioxidants found in garlic, such as sulfur compounds like SAC and allicin, can scavenge free radicals and lessen oxidative stress. Chronic conditions like diabetes, cancer, and neurological diseases are all associated with oxidative stress. Since persistent inflammation is a contributing factor to many diseases, garlic's anti-inflammatory qualities are especially important. For instance, clinical research has demonstrated that aged garlic extract (AGE) lowers inflammatory indicators like C-reactive protein (CRP) (3).

4. Antimicrobial and Antifungal Properties

Garlic has long been used to cure diseases, and recent studies have confirmed that garlic has antibacterial and fungicide properties. Garlic, the most important bioactive component of Alicin, works well against a variety of bacteria, including Salmonella, Staphylococcus Aurian, Candida Albicans and Escherichia coli. Because of these properties, garlic is a natural choice for antibiotics, especially in light of the increasing spread of antibiotic resistance (11).

5. Cancer Prevention

Garlic and its derivatives have been studied for their possible role in cancer prevention. Connections such as dialdisulfide (dads) and diallyl trisulfide (DATS) have been shown to induce apoptosis (programmed cell death) in cancer cells and disrupt tumor development. Studies of epidemiology suggest that high consumption of garlic is associated with low risk of some cancers, especially digestive systems, such as stomach and colon cancer, antioxidants and anti-inflammatory properties of garlic, also contribute to its anticancer effects. (12).

6. Neuroprotective Effects

Garlic derivatives, especially S-all cystin (sac) are found in old garlic extracts, have neuroprotective properties. SAC can overcome blood-brain obstacle and protect neurons from oxidative damage, which is an important factor in neurodegenerative diseases such as Alzheimer's and Parkinson's. Studies have shown that garlic supplements improve memory and cognitive function in animal models and may have similar benefits in humans. (7).

7. Improved Digestive Health

Garlic acts as a prebiotic, which promotes the growth of favorable gut bacteria such as lactobacillus and bifidobacterium. A healthy intestinal microbiome is important for digestion, nutritional absorption and immune function. Garlic also helps to reduce intestinal inflammation, which makes it beneficial for conditions such as inflammatory bowel disease (IBD). In addition, its antimicrobial properties can help handle harmful bacteria in the digestive system, such as Helicobacter pylori, which is associated with gastric ulcer and gastric cancer. (13)

8. Detoxification and Liver Health

Garlic supports liver function by increasing the body's detoxification processes. It increases the production of

glutathione, an important antioxidant that helps to detect harmful substances in the liver. Studies have shown that garlic can protect the liver from damage caused by toxins, alcohol and some medications, making garlic a valuable diet component to maintain liver health. (10).

9. Blood Sugar Regulation

The insulin sensitivity enhancing effects of garlic together with its capacity to control blood sugar make this ingredient advantageous to type 2 diabetes patients. The compounds allicin and SAC help improve insulin production by the body while simultaneously reducing insulin resistance levels. Research conducted by clinical practitioners shows that garlic supplements decrease fasting blood sugar while maintaining stable glycemic control. (14).

Chemical composition of garlic

The plant species Allium sativum contains bioactive substances which create its distinctive sensory characteristics together with its therapeutic properties. The diverse substance makeup of garlic incorporates sulfur compounds that work alongside antioxidants and vitamins as well as essential minerals. Bioactive compounds in garlic become active after the garlic clove undergoes crushing or chopping because such actions initiate enzymatic transformations. The chemical compounds which form in garlic after chopping release properties that provide antimicrobial and antioxidant effects as well as anti-inflammatory benefits and immunomodulatory actions. (15).

Sulfur-Containing Compounds

Sulfur-containing molecules serve as the most crucial bioactive components in garlic because they generate its distinctive odor and its various health advantages. The key sulfur compounds include:

The enzyme alliinase transfers alliin through chemical breakdown which creates allicin. Allicin maintains its high bioactivity yet proves unstable because its decomposition results in diallyl disulfide (DADS) together with diallyl trisulfide (DATS). Studies have proven that the health compound allicin performs dual roles as a strong antimicrobial and antioxidant agent.

The stable compounds Diallyl Sulfides consist of two elements: DADS and DATS as derivatives from the breakdown of allicin. Research demonstrates that these substances display anticancer capabilities together with anti-inflammatory properties as well as benefits for cardiovascular health (2). S-Allyl Cysteine (SAC) remains as a stable and water-soluble compound which can be detected in aged garlic extract (AGE). Clinical research demonstrates that SAC possesses antioxidant strength as well as neuroprotective activity and cardioprotective advantages (7).

Antioxidants

Several antioxidants present in garlic act to both destroy free radicals and minimize stress associated with oxidation. Key antioxidants in garlic include:

The anti-inflammatory and anticancer properties of quercetin and kaempferol along with other flavonoids exist in garlic. The antioxidant properties of garlic emerge from phenolic

compounds which defend cells against reactive oxygen species (ROS) according to (16). Garlic has minimal amounts of vitamin C and vitamin B6 together with antioxidants that support its protective effects.

Other Bioactive Compounds

- In addition to sulfur compounds and antioxidants, garlic contains other bioactive molecules that contribute to health benefits:
- Saponins: These compounds have shown cholesterol reduction and immune -growing effects.
- Ajoene: a sulfur -containing compound, formed from Alicin, known for its antithrombotic (anti -clockwise) and cancer properties.
- Fructooligosaccharides (FOS): prebiotic fibers that promote beneficial intestinal bacteria, support digestion and immune health (1).

Nutritional Composition

Supplementing the diet with garlic provides beneficial nutrients that include essential dietary components. Selenium along with manganese and calcium appear in garlic as minerals that support enzyme functions while preserving bone health. Arginine amino acid serves two functions by providing the precursor for nitric oxide production while supporting cardiovascular health. Eating dietary fiber has two major benefits for digestive health and intestine wellness. (17).

CONCLUSION

Prebiotics found in garlic play an important role in supporting immune health by changing microbiota and increasing the immune responses. Through the production of short-chain fatty acids (SCFA), prebiotics strengthen intestinal obstruction, reduces inflammation and regulates the activity of immune cells such as macrophages, dendritic cells and T cells. Garlic stands in particular as a powerful prebiotic due to high content of fruit osaccharides (FOS) and bioactive compounds such as alicin, providing additional antimicrobial and immune -busted advantages. Regular consumption of garlic has been shown to reduce the incidence and severity of infection, improve intestinal health and support the general immune function. In addition, garlic derivatives, such as the age of garlic extracts (age) and S-all sytil (sac), offer stable and bio-for forms of their beneficial compounds, making them effective for medical use. Despite the promising benefits of prebiotics and garlic, further research is needed to adapt their use and understand their effects in the diverse population. Including prebiotic rich foods such as garlic in the diet can provide a natural and effective strategy to increase immune health and prevent disease.

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