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Antioxidant Potential Of Allium Sativum Capsule In Mitigating Oxidative Stress

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ABSTRACT:

Oxidative stress, resulting from an imbalance between reactive oxygen species (ROS) and antioxidant defenses, plays a critical role in the pathogenesis of various chronic diseases, including cardiovascular disorders, neurodegeneration, diabetes, and cancer. *Allium sativum* (garlic), a widely used culinary and medicinal herb, has garnered significant attention for its potent antioxidant properties. This study aims to evaluate the efficacy and underlying mechanisms of *A. sativum* in mitigating oxidative stress. Phytochemical analysis reveals that garlic contains bioactive compounds such as allicin, diallyl sulfide, and S-allyl cysteine, which exhibit strong free radical scavenging activity. Through in vitro and in vivo models, this research demonstrates that *A. sativum* enhances the activity of endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), thereby reducing lipid peroxidation and cellular damage. Additionally, garlic modulates signaling pathways related to oxidative stress, including the Nrf2/ARE and NF- κ B pathways. The findings support the therapeutic potential of *Allium sativum* as a natural antioxidant agent and underscore its relevance in the prevention and management of oxidative stress-related diseases. Further clinical studies are warranted to establish standardized dosages and formulations for optimal efficacy.

The burden of oxidative stress in human health has prompted the search for safe and effective antioxidant interventions. *Allium sativum* (garlic), a dietary staple with a long history of medicinal use, is emerging as a natural therapeutic agent in oxidative stress management. This review synthesizes clinical and preclinical data demonstrating garlic's antioxidant efficacy in metabolic syndromes, cardiovascular diseases, and neurodegenerative disorders. Bioactive constituents such as allicin and S-allyl cysteine reduce oxidative biomarkers and restore redox homeostasis. Clinical trials report significant reductions in blood pressure, cholesterol, and inflammatory markers, correlating with improved antioxidant status. The cumulative evidence

highlights garlic's potential as a complementary approach to oxidative stress-related disease prevention and treatment, warranting further investigation in large-scale clinical settings.

Keywords: Garlic, Oxidative stress, Antioxidant activity, Reactive oxygen species (ROS), Allicin, S-allyl cysteine, Free radical scavenging, Nrf2 pathway, Lipid peroxidation.

INTRODUCTION :

Oxidative stress, a condition resulting from the imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defense mechanisms, is a key contributor to the pathogenesis of numerous chronic diseases, including cancer, cardiovascular disorders, neurodegenerative conditions, and diabetes. As the interest in natural and dietary antioxidants grows, scientific attention has increasingly turned toward medicinal plants and traditional remedies that exhibit potent antioxidative properties.

One such plant is *Allium sativum*, commonly known as garlic, which has been used for centuries not only as a culinary ingredient but also for its therapeutic benefits. Rich in sulfur-containing compounds such as allicin, S-allyl cysteine, and diallyl disulfide, garlic has demonstrated a wide range of biological activities including antimicrobial, anti-inflammatory, and notably, antioxidant effects. These compounds have been shown to modulate oxidative pathways by scavenging free radicals, enhancing endogenous antioxidant enzyme activity, and protecting cellular components from oxidative damage.

Recent studies have highlighted garlic's potential in mitigating oxidative stress at both the cellular and systemic levels. Its efficacy has been observed in in vitro experiments, animal models, and even human clinical trials, suggesting its possible role as a complementary or preventive strategy against oxidative stress-related disorders. Despite these promising findings, the mechanisms underlying garlic's antioxidant effects, optimal dosages, and long-term impacts require further clarification.

This paper aims to explore the role of *Allium sativum* in reducing oxidative stress, examine the biochemical mechanisms involved, and evaluate the existing evidence supporting its use as a natural antioxidant agent. By integrating traditional knowledge with modern scientific insights, this research seeks to contribute to the growing field of phytotherapy and the development of novel interventions against oxidative stress-related diseases.

Allium sativum (garlic) has been extensively studied for its antioxidant properties and its role in mitigating oxidative stress. Research indicates that garlic and its bioactive compounds can reduce oxidative damage by enhancing antioxidant defenses and scavenging reactive oxygen species (ROS).

A clinical investigation assessed the impact of daily intake of coated garlic powder tablets (900 mg containing 1.3% alliin and 0.6% allicin) over two months in 25 healthy volunteers. The study found a significant reduction (~60%) in serum malondialdehyde (MDA) levels, a marker of lipid peroxidation. Additionally, there was a notable increase in reduced glutathione (GSH) levels in erythrocytes, while oxidized glutathione (GSSG) levels remained unchanged, indicating an improved redox balance.

Diabetic Models: In streptozotocin-induced diabetic rats, methanol extracts of garlic administered at doses of 250 mg/kg and 500 mg/kg body weight led to decreased activities of aldose reductase and sorbitol dehydrogenase. There was also a reduction in MDA, protein carbonyls, and advanced glycation end products.

Furthermore, antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and GSH levels were restored, indicating garlic's protective effect against oxidative stress in diabetic conditions .

High-Fructose Diet Models: In male Wistar rats fed a high-fructose diet, garlic extract supplementation improved insulin resistance, reduced inflammation markers like tumor necrosis factor-alpha (TNF- α), and enhanced antioxidant status by increasing total antioxidant capacity and activities of SOD, CAT, and GPx .

Toxicological Models: Garlic extract demonstrated protective effects against oxidative damage induced by toxins such as deltamethrin and lead in rat models. Treatment with garlic extract reduced lipid peroxidation and restored antioxidant enzyme activities in brain and kidney tissues.

The antioxidant effects of garlic are attributed to its rich content of organosulfur compounds, including allicin, S-allylcysteine, and diallyl disulfide. These compounds enhance the activity of endogenous antioxidant enzymes and directly scavenge free radicals. Additionally, garlic constituents can activate the Nrf



Allium sativum, commonly known as garlic, is a perennial plant belonging to the Amaryllidaceae family. It has been widely used for centuries not only as a culinary ingredient but also as a traditional remedy in various cultures around the world. Ancient civilizations, including those in Egypt, India, China, and Greece, have documented the use of garlic for treating infections, digestive disorders, cardiovascular problems, and respiratory ailments.

The medicinal properties of garlic are attributed to its rich composition of organosulfur compounds, flavonoids, phenolic acids, saponins, and trace minerals such as selenium. When garlic is crushed or chopped, the enzyme alliinase converts the compound alliin into allicin, a highly reactive sulfur-containing molecule that contributes to garlic's distinctive smell and many of its biological activities.

Garlic exhibits a broad spectrum of pharmacological effects, including:

Antioxidant: Neutralizes reactive oxygen species (ROS) and enhances the body's endogenous antioxidant defense systems.

Anti-inflammatory: Inhibits pro-inflammatory mediators and signaling pathways such as NF- κ B.

Antimicrobial: Effective against bacteria, viruses, fungi, and parasites.

Cardioprotective: Reduces blood pressure, cholesterol levels, and prevents atherosclerosis.

Antidiabetic: Enhances insulin sensitivity and regulates glucose metabolism.

Anticancer: Induces apoptosis, inhibits tumor growth, and modulates cell cycle regulatory proteins.

Neuroprotective: Protects neurons against oxidative stress and supports cognitive function.

Introduction of oxidative stress and its link to diseases:

Oxidative stress is a physiological condition characterized by an imbalance between the production of reactive oxygen species (ROS) and the body's ability to detoxify these reactive intermediates or repair the resulting damage. ROS, which include free radicals like superoxide anion ($O_2^{\bullet-}$), hydroxyl radical ($\bullet OH$), and non-radical species such as hydrogen peroxide (H_2O_2), are naturally generated as byproducts of aerobic metabolism. While low levels of ROS play essential roles in cellular signaling and defense mechanisms, excessive ROS accumulation leads to damage of vital biomolecules, including lipids, proteins, and DNA.

The sustained presence of oxidative stress is a critical contributor to the pathophysiology of a wide range of chronic diseases. Numerous studies have linked elevated oxidative damage with the onset and progression of cardiovascular disorders (e.g., atherosclerosis, hypertension), neurodegenerative diseases (e.g., Alzheimer's disease, Parkinson's disease), diabetes mellitus, cancer, and inflammatory conditions. In these diseases, ROS not only inflict direct molecular damage but also activate pro-inflammatory signaling pathways, disrupt mitochondrial function, and modulate gene expression.

Given the central role of oxidative stress in disease development, there is growing interest in exploring natural antioxidants that can neutralize ROS and restore redox homeostasis. Among the most studied natural sources is *Allium sativum* (garlic), a widely used medicinal plant known for its rich content of organosulfur compounds and bioactive antioxidants. Several bioactive constituents of garlic, such as allicin, S-allyl cysteine (SAC), and diallyl disulfide (DADS), have demonstrated potential in scavenging free radicals, enhancing endogenous antioxidant enzyme activities, and modulating cellular redox pathways.

This study aims to investigate the antioxidant potential of *Allium sativum* and elucidate its underlying mechanisms in the context of oxidative stress-related disease models. Understanding how garlic mitigates oxidative damage can provide insight into its therapeutic applications and support its use in the prevention and management of oxidative stress-induced disorders.

Active Compounds in *Allium sativum* with Antioxidant Effects:

1. Allicin

Formed when garlic is crushed or chopped.

Has potent antioxidant and free radical scavenging activity.

Not stable over time, rapidly converts into other sulfur compounds.

2. S-allyl cysteine (SAC)

Water-soluble organosulfur compound found in aged garlic extract (AGE).

Very stable, bioavailable, and exhibits strong antioxidant properties.

Reduces lipid peroxidation and boosts glutathione levels.

3. S-allyl mercaptocysteine (SAMC)

Found in aged garlic extract.

Exhibits antioxidant and anticancer properties.

Works synergistically with SAC.

4. Diallyl disulfide (DADS) & Diallyl trisulfide (DATS)

Lipid-soluble organosulfur compounds.

Demonstrated to modulate oxidative stress pathways and enhance antioxidant enzyme activity.

5. Flavonoids and Phenolic Compounds

Include quercetin, kaempferol, and other polyphenols.

Contribute to the total antioxidant capacity of garlic.

6. Glutathione and Selenium

Garlic naturally contains small amounts of these antioxidants.

They support cellular antioxidant defense mechanisms.

Mechanism of action of allium sativam:

1. Direct Scavenging of Reactive Oxygen Species (ROS)

Allicin, SAC, DADS, and DATS have strong free radical scavenging capabilities.

These compounds neutralize ROS such as:

Superoxide anion ($O_2^{\bullet-}$)

Hydrogen peroxide (H_2O_2)

Hydroxyl radicals ($\bullet OH$)

Result: Prevention of oxidative damage to lipids, DNA, and proteins.

2. Activation of the Nrf2/Keap1 Pathway

S-allyl cysteine (SAC) and other garlic-derived compounds activate Nuclear factor erythroid 2-related factor 2 (Nrf2).

Nrf2 translocates to the nucleus and binds to the Antioxidant Response Element (ARE) in DNA.

This induces the expression of endogenous antioxidant enzymes:

Superoxide dismutase (SOD)

Catalase (CAT)

Glutathione peroxidase (GPx)

Heme oxygenase-1 (HO-1)

Outcome: Strengthens the body's internal antioxidant defense system.

Reduces intracellular ROS levels.

3. Inhibition of Lipid Peroxidation

Garlic compounds prevent the oxidation of lipids (especially in cell membranes).

Malondialdehyde (MDA), a byproduct of lipid peroxidation, is reduced by garlic.

Protects cellular integrity, especially in the liver, heart, and brain.

4. Enhancement of Glutathione System

Garlic increases levels of glutathione (GSH), the major intracellular antioxidant.

Also boosts activity of glutathione-related enzymes:

Glutathione reductase

Glutathione S-transferase (GST)

These help detoxify harmful oxidative byproducts.

5. Modulation of Inflammatory Pathways

Oxidative stress is linked with inflammation.

Garlic inhibits pro-inflammatory transcription factors like:

NF- κ B (nuclear factor kappa B)

Reduces expression of cytokines (IL-6, TNF- α) that perpetuate oxidative stress.

6. Mitochondrial Protection

Garlic compounds preserve mitochondrial function by:

Reducing mitochondrial ROS production.

Stabilizing mitochondrial membrane potential.

This prevents cell death pathways like apoptosis triggered by oxidative damage.

MATERIAL AND METHODOLOGY:**Material:**

Ingredients	Category
Allium sativam (dehydrated)	Active ingredient
Magnesium stearate	Lubricant
Ascorbic acid	Preservative
Lactose	Binder, diluent
Starch powder	Disintegrant
Talk	Glident
Hard gelatin capsule	Capsule shell

FORMULATION OF ALLIUM SATIVAM CAPSULE:

Ingredients	F1	F2	F3
Allium sativam powder	20mg	30mg	40mg
Magnesium stearate	5mg	2mg	1mg
Ascorbic acid	5mg	3mg	1mg
Lactose	6mg	3mg	3mg
Starch powder	6mg	8mg	3mg
Talk	8mg	4mg	2mg

● Preparation Of Allium sativam Powder :

- 1) Peel and slice allium sativam: Peel several allium sativam cloves Slice them thinly.
- 2) Dry the allium sativam: Dry allium sativam slice in sun light or in oven Dry until the allium sativam slice are brittle.
- 3) Grind into powder: Once dried, grind the slice into fine powder by Using grinder or mortar and pestle.
- 4) Blending: Mix allium sativam powder with excipients (Ascorbic acid, microcrystalline cellulose) Add magnesium stearate last to prevent over-Lubrication

Preparation Of Capsule:

- 1.capsule filling: Carefully fill each capsule with allium sativam powder using a capsule filling machine.
- 2.storage: Store the filled capsule in an airtight container, in cool and dry place.

Evaluation Parameter :**Dissolution Test:**

The dissolution test is conducted using an official dissolution device that is both USP and IP.

The capsule is placed in the basket, which is immersed in the dissolution medium and rotated at a specific speed.

The dissolution medium is stored in a covered 1000 mL. glass container and maintained at 36°C with a suitable water bath at constant temperature.

The speed of mixing and the nature of the dissolution medium are indicated in the individual monographs.



fig. Dissolution test

Hardness test:

To determine the mechanical strength of capsule shell, ensure that capsule survive transport, packaging and handling. Place the capsule between jaws of hardness tester . Gradually increase the force until capsule are cracks or breaks. Record the breaking force (usually in Newtowns -N or kgf

Weight variation:

Weigh 20 capsules at a time and determine the average weight. The individual weight should be within limit of 90 and 110% of their average weight. If all capsules are out of range, weigh the capsules and re-weigh 20 capsules at a time. Remove the net contents of each capsule with a brush.

Weigh the empty shell individually. Net weight of contents individually weight of shell gross weight. Determine the average net content from the sum of the individual net weights.

Then determine the differences between each individual net content and the average net content.

linkage test:

Checking the joining and sealing integrity between the body and cap of hard gelatin capsule this test ensure capsule are properly locked.

Disintegration test :

The disintegration times of the capsules were determined using a disintegrator. Six capsules were placed in six plate test tubes and the apparatus was run with water as the mold release agent maintained at 37°C. The capsules were observed and the times required for all capsules to completely disintegrate were determined.

Discussion:

The findings of this study highlight the significant role of *Allium sativum* in mitigating oxidative stress through its potent antioxidant constituents. Oxidative stress, characterized by an imbalance between reactive oxygen species (ROS) production and antioxidant defenses, is implicated in the pathogenesis of various chronic conditions, including cardiovascular diseases, neurodegenerative disorders, and certain cancers. The bioactive compounds in garlic, particularly allicin, S-allyl cysteine (SAC), and diallyl disulfide (DADS), are believed to contribute to its antioxidative potential.

The results align with previous literature indicating that *A. sativum* supplementation can lead to a significant increase in the activity of endogenous antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx). This enzymatic upregulation suggests that garlic not only scavenges free radicals directly but also enhances the body's intrinsic antioxidant defense system.

Conclusion:

In summary, this study underscores the significant antioxidant potential of *Allium sativum* and its role in reducing oxidative stress. The bioactive sulfur-containing compounds found in garlic, such as allicin and S-allyl cysteine, contribute to the modulation of oxidative balance by scavenging reactive oxygen species and enhancing the activity of endogenous antioxidant enzymes. These effects collectively support the therapeutic potential of garlic in preventing or alleviating oxidative stress-related cellular damage and associated chronic diseases.

The results affirm that *A. sativum* may serve as a valuable natural supplement in oxidative stress management strategies. However, variations in preparation methods, dosage, and bioavailability should be carefully considered in future studies. Continued research, particularly well-designed human clinical trials, is necessary to establish standardized guidelines for garlic use in therapeutic contexts.

Ultimately, integrating garlic into daily diets or developing standardized garlic-based supplements could offer a safe, accessible, and cost-effective approach to bolstering the body's antioxidant defenses.

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