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Various Method for Extraction of Allicin-A Review

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ABSTRACT
Allicin, a bioactive organosulfur compound predominantly found in garlic (Allium sativum) and other Allium species like onions (Allium cepa), exhibits a broad spectrum of pharmacological activities. This study explores allicin's therapeutic potential, emphasizing its neuroprotective, antioxidant, anti-inflammatory, antimicrobial, cardioprotective, antidiabetic, hepatoprotective, anti-protozoal, and anti-obesity effects. Allicin exerts neuroprotective effects by reducing oxidative stress, inhibiting apoptosis, and modulating key signalling pathways. Its antioxidant properties play a crucial role in mitigating oxidative damage and preventing lipid peroxidation. Anti-inflammatory benefits arise from allicin's ability to downregulate pro-inflammatory cytokines such as TNF-α and IL-6. The compound also demonstrates potent antimicrobial activity against a variety of bacterial, fungal, viral, and protozoal pathogens. Cardiovascular benefits include lowering blood pressure, improving lipid profiles, and enhancing endothelial nitric oxide bioavailability. Additionally, allicin exhibits hypoglycaemic effects by modulating insulin secretion and glucose metabolism. Hepatoprotective properties are attributed to its ability to mitigate oxidative stress and inhibit inflammatory pathways. Studies have further highlighted allicin's potential role in preventing obesity through the regulation of adipogenesis and lipid metabolism.
Various extraction methods have been developed to optimize allicin yield and stability. These include decoction, ultrasonic-assisted extraction (UAE), microwave-assisted extraction (MAE), enzyme-assisted extraction (EAE), salting-out extraction (SOE), steam hydro distillation, and pressurized liquid extraction (PLE). High-performance liquid chromatography (HPLC) and gas chromatography (GC) are commonly employed for quantification. The choice of extraction method significantly influences allicin's bioavailability and pharmacological efficacy. Future research should focus on refining extraction techniques, enhancing allicin stability, and conducting clinical trials to establish its efficacy and safety in human health applications.

Keyword :-Allicin, Extraction, Methods, Onion ,(Allium cepa), Pharmacological Organosulfur Compounds, Bioavailability

I. INTRODUCTION

Since ancient times, onions (Allium cepa L.) have been prized as both a food and a medicinal plant. It is a vegetable bulb crop that is consumed globally and is widely grown, ranking second only to tomatoes (FAO, 2012). It is a low-latitude, short-duration horticulture crop (Brewster, 1990). Because of its highly prized flavour, scent, and distinct taste as well as the therapeutic qualities of its flavour components, it is frequently referred to as the "Queen of the kitchen." Throughout the year, onions are used in a variety of dishes, including curries, salads, as a condiment, and in baked or boiled vegetables. It is also utilized in a variety of processed foods, such as pickles, paste, flakes, and powder, and is well-known for its therapeutic properties.(Pareek et al., 2017). In many cultures' folklore, members of the genus Allium have developed a reputation as powerful preventative and curative medicines over the ages(Kendler, 1987).Organosulfur compounds, flavonoids (including quercetin), vitamins B2, B6, C, folic acid, and minerals like calcium, potassium, phosphorus, and magnesium are among the many bioactive substances found in onions. These components support several health advantages, including anti-inflammatory, anti-cancer, anti-microbial, antioxidant, and antidiabetic properties(A. J. Chakraborty et al., 2022). The risk of colon, lung, liver, brain, stomach, ovarian, prostate, and breast cancer is reduced by regular consumption of onions(Marefati et al., 2021). Climate, vegetable storage duration, and genotype

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all have a major impact on antiplatelet function. The high concentrations of naturally occurring antioxidants called flavonoids, polyphenols, and organosulfur compounds in A. cepa (onions) provide them antioxidant potential. Extract from garlic and onions efficiently eliminates all parasites and inhibits irreversible reductase. Trypanothione from Trypanosoma brucei. Onions have also been shown in studies to have antidepressant properties. For the treatment of immunological dysregulation illnesses, A. cepa and its constituents—quercetin in particular—may be immunomodulatory therapeutic possibilities. A. cepa may be utilized to treat airway problems like asthma because of its anti-inflammatory and protective effects on tracheal tolerance and lung inflammation in animals with asthma(A. Chakraborty et al., 2021).Aillium cepa extracts were discovered to exhibit hepatoprotective properties when exposed to ethanol that damages or harms the liver. A. cepa bulb aqueous extract exhibits vital hepatoprotective and antioxidant properties against ethanol-induced hepatotoxicity(Amado et al., 2009). Onion, or Allium cepa, is a perennial herb whose stem is located in the subterranean bulb. Some authors refer to onions as Alliaceae, but they are members of the Liliaceae family. One or two leafless flower stalks, which range in height from 75 to 180 cm (2.5 to 6 ft), constitute a common onion. The plant's thin, black seeds are used to grow most onions grown for commercial purposes. Onion is prized for its flavor and nutritional qualities and is often preserved as pickles. Onions are cultivated in more than 175 nations now, with its origins believed to be in Afghanistan, Iran, and the USSR(Suleria et al., 2015). The sugar content of onions is around 90% water, and they have a considerable amount of dietary fiber. The sugar content of onions is around 90% water, and they have a considerable amount of dietary fiber. Vegetable-rich diets have been linked to several health advantages, including the prevention of two of the more common and pertinent diseases in today's world(Teshika et al., 2019).

Therapeutic Potential of Allium cepa

Allium cepa has been found to be an effective antibacterial agent for the treatment of infectious illnesses. Numerous bacteria, viruses, and fungi have been shown to be susceptible to different solvent extracts from Allium cepa(Teshika et al., 2019). A study by Liguori et al. has reexamine the impact of compound organosulfur on microbial development(Liguori et al., 2017). While kaempferol was more effective than quercetin at preventing the development of M. luteus and S. aureus, it was less effective at preventing the growth of L. monocytogenes, B. cereus, and P. aeruginosa(Santas et al., 2010). Another study found that the essential oil of three different kinds of onions—yellow, green, and red—showed strong antibiotic activity against some infections, such as Aspergillus nigger, Salmonella enteritidis, Fusarium oxysporum, Penicillium cyclopium, and Staphylococcus aureus(Benkeblia, 2004). It has been demonstrated that the red A. cepa extract has more antibacterial qualities than the yellow and white types(Sharma et al., 2018).

Taxonomical Classification of Allium cepa(Sampath Kumar et al., 2010)
(1) **Kingdom**: Plantae
(2) **Division:**Magnoliophyta
(3) **Class:**Liliopsida
(4) **Order:**Asparagales
(5) **Family:** Alliaceae
(6) **Genus:** Allium
(7) **Species:** A. cepa

Allicin is a bioactive compound predominantly found in garlic (Allium sativum), but it is also present in other Allium species, including onions (Allium cepa). Extracting allicin effectively requires careful selection of methods to preserve its stability and maximize yield. Below are some extraction techniques documented in scientific literature(Zaini et al., 2022).

VARIOUS METHOD FOR EXTRACTION OF ALLICIN

Decoction: A study focusing on Welsh onion (Allium fistulous L.) roots optimized allicin extraction using 70% ethanol at 70°C for 2 hours. This method yielded 1.371 mg of allicin under these conditions(Gorecka, 2014).

Two-Step Extraction Process: Research on Allium fistulous stalks optimized allicin extraction through a two-step process:

- **Incubation**: Chopped stalks were incubated in water at 26°C for 20 minutes to facilitate the enzymatic conversion of alliin to allicin(Y. Li et al., 2024).
- **Ethanol Extraction**: Post-incubation, allicin was extracted using 75% ethanol, which proved to be the most effective concentration for maximizing yield(Y. Li et al., 2024).

Ultrasonic-Assisted Extraction (UAE): While primarily studied in garlic, UAE has potential applications for onions. This method uses

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ultrasonic waves to enhance solvent penetration, thereby increasing extraction efficiency. In garlic, ultrasonic aqueous extraction resulted in the highest allicin content (0.086%), suggesting its potential effectiveness for onions as well(Loghmanifar et al., 2020).

Physical and Chemical Treatments: To reduce allicin content in Allium fistulous stalks, various treatments were evaluated:

- **Blanching at High Temperatures**: Blanching at 100°C achieved a maximal allicin clearance rate of 73.3%.
- **Freezing**: Chilling chopped stalks at -20°C for 1.5 hours resulted in a 43% reduction in allicin content(Y. Li et al., 2024).
- **Tea Polyphenols and Citric Acid Treatments**: Chemical treatments with tea polyphenols and citric acid achieved maximal allicin clearance rates of 51.4% and 54%, respectively.
- **Salting-Out Extraction (SOE)**: This technique utilizes a combination of a lower molecular weight organic solvent and an inorganic salt to partition allicin into a specific phase, facilitating its extraction and preliminary purification. In a study focusing on garlic, an ethanol/ammonium sulfate system was optimized for allicin extraction. The optimal conditions achieved a maximum extraction efficiency of 94.17% at 25°C without pH adjustment. While this study was conducted on garlic, the SOE method's principles could be adapted for extracting allicin from onions, considering the structural similarities among Allium species(F. Li et al., 2017).

Microwave-Assisted Extraction (MAE): This method utilizes microwave energy to heat the solvent and plant material, enhancing the extraction efficiency of bioactive compounds. MAE offers advantages such as reduced extraction time and solvent usage. While specific studies on allicin extraction from onions using MAE are limited, this technique has been successfully applied to extract other bioactive compounds from Allium species. For instance, a review on extraction methods for onion and garlic polysaccharides highlights the potential of MAE in efficiently extracting polysaccharides, suggesting its applicability for allicin extraction as well(Bar et al., 2022).

Steam Hydro distillation: This traditional method involves passing steam through plant material to volatilize essential oils, which are then condensed and collected. Factors such as water temperature, distillation time, and particle size influence the efficiency of this extraction method. While commonly used for garlic oil extraction, steam hydrodistillation can be adapted for onions to obtain allicin-rich extracts(Bar et al., 2022).

Enzyme-Assisted Extraction (EAE): This method employs specific enzymes to break down cell walls, enhancing the release of bioactive compounds like allicin. While direct studies on allicin extraction from onions using EAE are limited, the technique has been applied to extract polysaccharides and other compounds from Allium species. For instance, a review on extraction methods for onion and garlic polysaccharides highlights the potential of EAE in efficiently extracting these compounds, suggesting its applicability for allicin extraction as well(H. J. Lee et al., 2013).

Optimized Ethanol Extraction:

- Peel and crush the onion using a mortar and pestle (or blender). This helps release allicin.
- Mix the crushed material with ethanol or water (enough to cover it).
- Let it sit for 15–30 minutes at room temperature.
- Filter the mixture using a cloth or filter paper to remove solid pieces.
- Store the liquid extract in a dark glass bottle and keep it in the fridge(Y. Li et al., 2024).

Pressurized Liquid Extraction (PLE): Also known as accelerated solvent extraction, PLE utilizes high pressure and temperature to enhance the extraction efficiency of bioactive compounds like allicin. This method reduces extraction time and solvent usage while maintaining the integrity of heat-sensitive compounds. While specific studies isPLE for allicin extraction from onions are limited, this technique has been successfully applied to extract similar compounds from Allium species, suggesting its potential applicability(Bar et al., 2022).

High-Performance Liquid Chromatography (HPLC), the extracted sample is filtered and injected into HPLC vials for quantification.

1. Different mobile phases used for elution:

- Methanol to water (50:50).
- 0.1% acetic acid and methanol (50:50).

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- Methanol: water (0.1% formic acid) at (6:4).
- Acetonitrile: water: methanol (50:41:9).
- Methanol: water: ethyl acetate (6:3:1).

2. A C18 column is used for separation.
3. Flow rate, run time, and temperature are set prior to operation.
4. UV detection is performed at 254 nm and 240 nm.
5.The quantification of allicin in garlic is performed by comparing the sample peak area with the calibration curve of standard allicin of known concentrations.
6.The ratio of peak height of the sample and internal standard is plotted against concentration.
7.Linearity is evaluated using an ANOVA table.
8.Precision is determined through repeatability("a review on different extraction and quantification methods of allicin from garlic," 2021).

GAS CHROMATOGRAPHY

1. It is a time-consuming method as Thio sulfinates are unstable and must be converted to a stable form to withstand the high temperatures inside the gas chromatography unit.
2. Thiols react with the disulfide bonds of Thio sulfinates, and the resulting thiol concentration is observed.
3. An alternative conversion method involves the reaction of excess thiol with a disulfide acid compound, 5,5'-dithiobis-2-nitrobenzoic acid (DTNB).
4. This reaction produces a yellow-coloured compound, which is detected under the ultraviolet range.
5. The instability of allicin leads to its decomposition at acidic pH due to the presence of nucleophiles and at higher temperatures.
6. Another method involves gas chromatography combined with mass spectroscopy, where the sample is coated with polydimethylsiloxane.
7. The garlic bulbs are crushed, and the volatiles are trapped and transferred to the injector in the column("A review on different extraction and quantification methods of allicin from garlic," 2021).

PHARMACOLOGICAL ACTIVITIES OF ALLICIN

Neuroprotective Effect

Garlic's possible neuroprotective advantages have been the subject of numerous investigations(Song et al., 2019). highlighting its active ingredients, such allicin(Borlinghaus et al., 2014). Allicin's capacity to lessen glutamate-induced neurotoxicity in primary cultured spinal cord neurons is one way it exhibits neuroprotective properties. According to Liu et al., allicin therapy preserved cell viability, decreased apoptosis, and significantly decreased the release of lactate dehydrogenase (LDH) in neurons exposed to glutamate. Allicin's ability to reduce lipid peroxidation, reduce reactive oxygen species (ROS) generation, and sustain the activity of antioxidant enzymes is responsible for this protective action(Liu et al., 2015). It has also been demonstrated that allicin inhibits glutamate release and lessens calcium-dependent glutamate release brought on by 4-aminopyridine(Lu et al., 2019).

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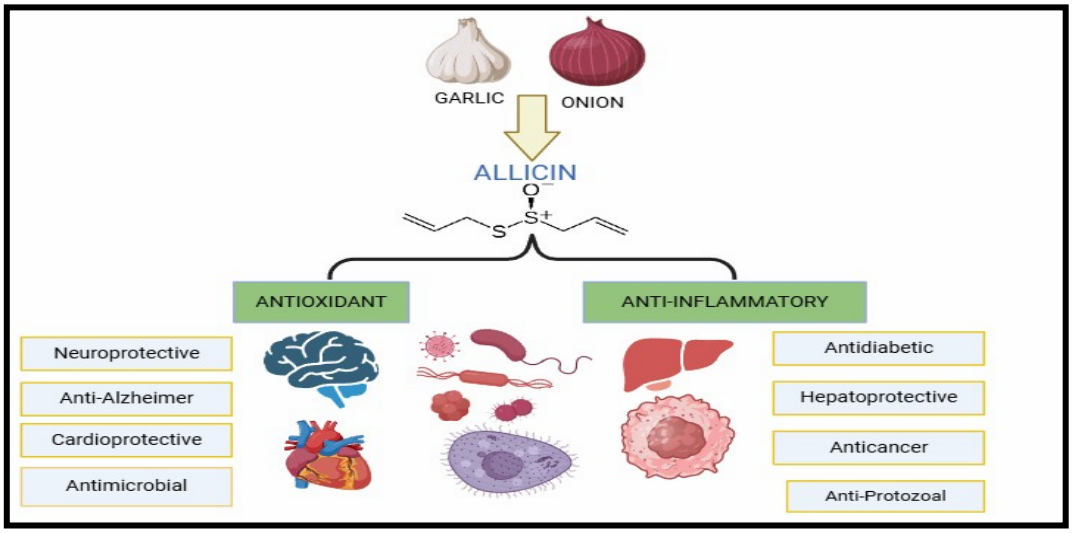

Fig No 01: Pharmacological Activities of Allicin

Anti-Alzheimer Activity

The most common neurodegenerative disease linked to dementia is Alzheimer's disease (AD). Its clinical manifestations include gradual cognitive deterioration, neurofibrillary tangles, amyloid-beta (Aβ) plaques, and neuronal atrophy. In AD, mitochondrial bioenergetic failure is frequently seen, which adds to the pathophysiology(Onyango, 2018). In APP/PS1 double-transgenic mice, allicin has been shown to improve cognitive function. By lowering Aβ expression levels, reducing oxidative stress, and enhancing mitochondrial function, it accomplishes this. These positive effects are mediated in large part by the inhibition of the p-JNK/p-c-Jun signalling pathway.Additionally, the enzymes acetylcholinesterase and butyrylcholinesterase, which break down acetylcholine, a neurotransmitter implicated in cognition, are inhibited by allicin(Kumar, 2015).Additionally, it was discovered that administering 180 mg/kg of allicin improved cognition in a mouse model of AD. The decrease in reactive oxygen species (ROS) levels and the enhanced activity of superoxide dismutase (SOD) are probably responsible for this impact(Savairam et al., 2023).

Antioxidant Effect

Because of its exceptional antioxidant action in preventing oxidative stress, allicin has attracted a lot of interest. The development of many diseases is significantly influenced by oxidative stress, which is brought on by an imbalance between the body's antioxidant defines systems and the generation of reactive oxygen species (ROS). Allicin has become a popular choice for managing oxidative stress because it is a powerful natural therapy with few side effects(Koca et al., 2020). One study demonstrated how allicin and alliin, its precursor, work as antioxidants in the Fenton oxygen-radical producing system by interacting with enzymes that contain thiols(Rabinkov et al., 1998). This relationship implies that allicin can shield cells from oxidative damage and efficiently eliminate dangerous oxygen radicals. The capacity of allicin to inhibit the activity of hydroxyl and superoxide radicals—two extremely reactive species implicated in oxidative stress—is thought to be the source of its antioxidant qualities(Chung, 2006; SCHWARTZ et al., 2002).

Anti-inflammatory

Pro-inflammatory chemicals, such as cytokines like TNF-α, IL-1β, and others, are released by several cell types during inflammation(LANG, 2004; Wright, 1997). Garlic and its related extracts have been shown in studies to have anti-inflammatory properties, including lowering inflammatory cytokines including TNF-α, IL-1α, IL-6, and interferon-c in leukocytes(D. Y. Lee et al., 2012). Allicin can lower IL-8 and TNF-α while also regulating the immune system. According to a study, allicin can help mice with ankylosing spondylitis with their spinal impairment, reduce the production of IL-6, IL-8, and TNF-α, and suppress the expression of the HLA-B2704 protein. It has been discovered that allicin lowers TNF-α and IL-8 levels and controls the immune system. Allicin has been demonstrated to alleviate spinal dysfunction in ankylosing spondylitis, reduce IL-6, IL-8, and TNF-α release, and suppress HLA-B2704 protein expression in rats(Gu et al., 2013).

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Cardioprotective activity

Garlic consumption has been shown to have positive benefits on a number of cardiovascular risk factors in numerous studies. It has been demonstrated to dramatically lower blood pressure, stop atherosclerosis from developing, lower serum triglyceride and cholesterol levels, stop platelet aggregation, and increase fibrinolytic activity("Onion," n.d.). Additionally, eating garlic has been linked to better serum lipid profiles, which include higher levels of HDL cholesterol and lower levels of triglycerides and total LDL cholesterol(Orekhov &Tertov, 1997). Numerous pathways are thought to be involved in the cardioprotective effects of allicin. The ability of allicin to contribute hydrogen sulphide, which has been demonstrated to encourage phosphorylation at the endothelial nitric oxide synthase (eNOS) active site, is one such method. This then triggers cardioprotective processes by increasing endothelial nitric oxide (NO) production and/or release, which causes vasorelaxation and increases NO's bioavailability(Ku et al., 2002).

Anti-diabetic activity

Strong evidence for the possible antidiabetic effects of garlic and its active ingredient, allicin, can be found in the large body of research on the subject. Allicin has been shown in numerous research to have hypoglycaemic effects, especially in animal models. Allicin plus tolbutamide dramatically reduced blood sugar levels in alloxan-induced diabetic rabbits, suggesting that it may be used as a hypoglycaemic drug(Augusti, 1975). It has also been demonstrated that allicin lowers blood pressure, insulin, and cholesterol. One possible mechanism of action for the SUR 2's anti-diabetic properties is its selective opening. Allicin has also demonstrated potential in preventing insulin-dependent diabetic mellitus (IDDM). It has been shown to influence blood sugar and insulin levels and shield pancreatic tissue. Allicin may also stop the development of substrata that lead to advanced glycation end products by regulating blood lipids(Elkayam, 2003).

Hepatoprotective activity

Significant hepatoprotective effects of allicin have been reported in the literature. Allicin's strong SH-modifying and antioxidant qualities have been linked to its capacity to shield the liver from several hepatic conditions marked by lipid peroxidation and oxidative stress.(Ipsen et al., 2018a). Oral administration of allicin was found to enhance levels of Bcl-2 (an anti-apoptotic protein) and Ki-67 (a measure of cell proliferation) in an acetaminophen-induced liver injury model, suggesting that it has a protective impact on the liver. Allicin's capacity to lower oxidative stress and block the liver's inflammasome pathway was thought to be the cause of this action(Ipsen et al., 2018b).In a related in vivo investigation, allicin treatment improved hepatocellular pathological deficits and normalized blood levels of liver enzymes (ALT and AST) and inflammatory markers (TNF-α and IL-6). It was discovered that allicin inhibited inflammatory stress linked to the intrahepatic TLR4/NF-κB pathway.(47) Protecting the liver from severe lipid peroxidation requires the antioxidant properties of allicin. Allicin decreased oxidative stress by decreasing the levels of liver enzymes (sGOT and sGPT) and increasing the levels of antioxidative enzymes in hepatic damage brought on by d-galactosamine/lipopolysaccharide(Vimal & Devaki, 2004). Additionally, in a model of thioacetamide-induced acute hepatic encephalopathy, oral administration of allicin decreased oxidative stress biomarkers, inflammatory mediators, and liver serum function(Saleh et al., 2021).

Antimicrobial Properties:

Allicin has demonstrated significant antimicrobial effects against a wide range of microorganisms, including antibiotic-resistant strains of both Gram-positive and Gram-negative bacteria(El-Saber Batiha et al., 2020).

Anti-Protozoal Activity

Garlic extracts and phytochemicals have been shown in numerous studies to have anti-protozoal efficacy against a variety of protozoan parasites. For example, an in vitro investigation found that the aqueous, ethanolic, and dichloromethane extracts of A. sativum demonstrated anthelmintic activity against Haemanthus contorts, with the ethanolic extract being the most effective. Additionally, the aqueous garlic extract demonstrated strong activity against Angiostrongyliasis cantonises and Trichuris Muris(Zhen et al., 2006).

Effect on Obesity

One of the most prevalent health issues, obesity can result in several conditions, including metabolic syndrome, hypertension, dyslipidaemia, and cardiovascular diseases. In mice with high-fat diet-induced obesity, garlic extracts have been shown to be effective in lowering body weight, adipose tissue mass, and improving plasma lipid profiles. These effects are mediated by the upregulation of the expression of mitochondrial inner membrane proteins and the downregulation of several genes involved in adipogenesis(M.-S. Lee et al., 2011). Additionally, Lee et al. found that the anti-obesity effect of garlic extracts was ascribed to the activation of AMP-activated protein kinase (AMPK), which in turn boosted thermogenesis and reduced the expression of several genes involved in adipogenesis. Without affecting the quantity of food consumed, ajoene, which is extracted from garlic extracts, was shown to promote apoptosis, reduce fat accumulation in 3T3-L1 adipocytes, and significantly reduce mice's body weight increase(Han et al., 2011). By lowering C/EBP, PPAR 2, and LPL expression as well as the PPAR effect in human adipocytes, 1,2-vinyldithiin has also been shown to block the differentiation of human preadipocytes and reduce lipid accumulation(Keophiphath et al., 2009).

II. CONCLUSION

Allicin, a key bioactive compound in Allium sativum (garlic) and other Allium species, possesses significant pharmacological properties, including antimicrobial, antioxidant, anti-inflammatory, anticancer, and cardioprotective effects. It also shows potential in neuroprotection, diabetes management, and liver health. However, due to its instability and rapid degradation, optimized extraction methods like ethanol extraction, ultrasonic-assisted extraction (UAE), microwave-assisted extraction (MAE), and enzyme-assisted extraction (EAE) are essential for maintaining its bioactivity. Future research should focus on enhancing its stability, bioavailability, and clinical applications to fully harness its therapeutic potential.

REFERENCES

[1]. A REVIEW ON DIFFERENT EXTRACTION AND QUANTIFICATION METHODS OF ALLICIN FROM GARLIC. (2021). Journal of Xidian University, 15(6). https://doi.org/10.37896/jxu15.6/020
[2]. Amado, L. L., Garcia, M. L., Ramos, P. B., Freitas, R. F., Zafalon, B., Ferreira, J. L. R., Yunes, J. S., & Monserrat, J. M. (2009). A method to measure total antioxidant capacity against peroxyl radicals in aquatic organisms: Application to evaluate microcystins toxicity. Science of The Total Environment, 407(6), 2115–2123. https://doi.org/10.1016/j.scitotenv.2008.11.038
[3]. Augusti, K. T. (1975). Studies on the effect of allicin (diallyl disulphide-oxide) on alloxan diabetes. Experientia, 31(11), 1263–1265. https://doi.org/10.1007/BF01945769
[4]. Bar, M., Binduga, U. E., & Szychowski, K. A. (2022). Methods of Isolation of Active Substances from Garlic (Allium sativum L.) and Its Impact on the Composition and Biological Properties of Garlic Extracts. Antioxidants, 11(7), 1345. https://doi.org/10.3390/antiox11071345
[5]. Benkeblia, N. (2004). Antimicrobial activity of essential oil extracts of various onions (Allium cepa) and garlic (Allium sativum). LWT - Food Science and Technology, 37(2), 263–268. https://doi.org/10.1016/j.lwt.2003.09.001
[6]. Borlinghaus, J., Albrecht, F., Gruhlke, M., Nwachukwu, I., &Slusarenko, A. (2014). Allicin: Chemistry and Biological Properties. Molecules, 19(8), 12591–12618. https://doi.org/10.3390/molecules190812591
[7]. Chakraborty, A. J., Uddin, T. M., Matin Zidan, B. M. R., Mitra, S., Das, R., Nainu, F., Dhama, K., Roy, A., Hossain, Md. J., Khusro, A., & Emran, T. Bin. (2022). Allium cepa: A Treasure of Bioactive Phytochemicals with Prospective Health Benefits. Evidence-Based Complementary and Alternative Medicine, 2022, 1–27. https://doi.org/10.1155/2022/4586318
[8]. Chakraborty, A., Mitra, S., Tallei, T., Tareq, A., Nainu, F., Cicia, D., Dhama, K., Emran, T., Simal-Gandara, J., & Capasso, R. (2021). Bromelain a Potential Bioactive Compound: A Comprehensive Overview from a Pharmacological Perspective. Life, 11(4), 317. https://doi.org/10.3390/life11040317
[9]. Chung, L. Y. (2006). The Antioxidant Properties of Garlic Compounds: Allyl Cysteine, Alliin, Allicin, and Allyl Disulfide. Journal of Medicinal Food, 9(2), 205–213. https://doi.org/10.1089/jmf.2006.9.205
[10]. Elkayam, A. (2003). The effects of allicin on weight in fructose-induced hyperinsulinemic, hyperlipidemic, hypertensive rats. American Journal of Hypertension, 16(12), 1053–1056. https://doi.org/10.1016/j.amjhyper.2003.07.011
[11]. El-Saber Batiha, G., Magdy Beshbishy, A., G. Wasef, L., Elewa, Y. H. A., A. Al-Sagan, A., Abd El-Hack, M. E., Taha, A. E., M. Abd-Elhakim, Y., & Prasad Devkota, H. (2020). Chemical

Constituents and Pharmacological Activities of Garlic (Allium sativum L.): A Review. Nutrients, 12(3), 872. https://doi.org/10.3390/nu12030872

[12]. Gorecka, D. (2014). Evaluation of cytotoxicity of buckwheat grains and buckwheat products to HT29 cells in an in vitro environment. Journal of Food Processing & Technology, s1(01). https://doi.org/10.4172/2157-7110.S1.006

[13]. Gu, X., Wu, H., & Fu, P. (2013). Allicin Attenuates Inflammation and Suppresses HLA-B27 Protein Expression in Ankylosing Spondylitis Mice. BioMed Research International, 2013, 1–6. https://doi.org/10.1155/2013/171573

[14]. Han, C. Y., Ki, S. H., Kim, Y. W., Noh, K., Lee, D. Y., Kang, B., Ryu, J.-H., Jeon, R., Kim, E. H., Hwang, S. J., & Kim, S. G. (2011). Ajoene, A Stable Garlic By-Product, Inhibits High Fat Diet-Induced Hepatic Steatosis and Oxidative Injury Through LKB1-Dependent AMPK Activation. Antioxidants & Redox Signaling, 14(2), 187–202. https://doi.org/10.1089/ars.2010.3190

[15]. Ipsen, D. H., Lykkesfeldt, J., & Tveden-Nyborg, P. (2018a). Molecular mechanisms of hepatic lipid accumulation in non-alcoholic fatty liver disease. Cellular and Molecular Life Sciences, 75(18), 3313–3327. https://doi.org/10.1007/s00018-018-2860-6

[16]. Ipsen, D. H., Lykkesfeldt, J., & Tveden-Nyborg, P. (2018b). Molecular mechanisms of hepatic lipid accumulation in non-alcoholic fatty liver disease. Cellular and Molecular Life Sciences, 75(18), 3313–3327. https://doi.org/10.1007/s00018-018-2860-6

[17]. Kendler, B. S. (1987). Garlic (Allium sativum) and onion (Allium cepa): A review of their relationship to cardiovascular disease. Preventive Medicine, 16(5), 670–685. https://doi.org/10.1016/0091-7435(87)90050-8

[18]. Keophiphath, M., Priem, F., Jacquemond-Collet, I., Clément, K., & Lacasa, D. (2009). 1,2-Vinyldithiin from Garlic Inhibits Differentiation and Inflammation of Human Preadipocytes. The Journal of Nutrition, 139(11), 2055–2060. https://doi.org/10.3945/jn.109.105452

[19]. Koca, F. D., Demirezen Yilmaz, D., ErtasOnmaz, N., Yilmaz, E., &Ocsoy, I. (2020). Green synthesis of allicin based hybrid nanoflowers with evaluation of their catalytic and antimicrobial activities. Biotechnology Letters, 42(9), 1683–1690. https://doi.org/10.1007/s10529-020-02877-2

[20]. Ku, D. D., Abdel-Razek, T. T., Dai, J., Kim-Park, S., Fallon, M. B., & Abrams, G. A. (2002). Garlic And Its Active Metabolite Allicin Produce Endothelium- And Nitric Oxide-Dependent Relaxation In Rat Pulmonary Arteries. Clinical and Experimental Pharmacology and Physiology, 29(1–2), 84–91. https://doi.org/10.1046/j.1440-1681.2002.03596.x

[21]. Kumar, S. (2015). Dual inhibition of acetylcholinesterase and butyrylcholinesterase enzymes by allicin. Indian Journal of Pharmacology, 47(4), 444. https://doi.org/10.4103/0253-7613.161274

[22]. LANG, A. (2004). Allicin inhibits spontaneous and TNF-? induced secretion of proinflammatory cytokines and chemokines from intestinal epithelial cells. Clinical Nutrition, 23(5), 1199–1208. https://doi.org/10.1016/j.clnu.2004.03.011

[23]. Lee, D. Y., Li, H., Lim, H. J., Lee, H. J., Jeon, R., & Ryu, J.-H. (2012). Anti-Inflammatory Activity of Sulfur-Containing Compounds from Garlic. Journal of Medicinal Food, 15(11), 992–999. https://doi.org/10.1089/jmf.2012.2275

[24]. Lee, H. J., Suh, H. J., & Park, Y. (2013). Utilization of hydrolytic enzymes for the extraction of cycloalliin from garlic (Allium sativum L.). Process Biochemistry, 48(7), 1111–1117. https://doi.org/10.1016/j.procbio.2013.05.008

[25]. Lee, M.-S., Kim, I.-H., Kim, C.-T., & Kim, Y. (2011). Reduction of Body Weight by Dietary Garlic Is Associated with an Increase in Uncoupling Protein mRNA Expression and Activation of AMP-Activated Protein Kinase in Diet-Induced Obese Mice. The Journal of Nutrition, 141(11), 1947–1953. https://doi.org/10.3945/jn.111.146050

[26]. Li, F., Li, Q., Wu, S., & Tan, Z. (2017). Salting-out extraction of allicin from garlic (Allium sativum L.) based on ethanol/ammonium sulfate in laboratory and pilot scale. Food Chemistry, 217, 91–97. https://doi.org/10.1016/j.foodchem.2016.08.092

[27]. Li, Y., Ma, J., Cao, Y., & Yang, D. (2024). Efficient removal of allicin from the stalk of Allium fistulosum for dietary fiber production. Npj Science of Food, 8(1), 32. https://doi.org/10.1038/s41538-024-00275-w

[28]. Liguori, L., Califano, R., Albanese, D., Raimo, F., Crescitelli, A., & Di Matteo, M. (2017). Chemical Composition and Antioxidant Properties of Five White Onion (Allium cepa L.) Landraces. Journal of Food Quality, 2017, 1–9. https://doi.org/10.1155/2017/6873651

[29]. Liu, S.-G., Ren, P.-Y., Wang, G.-Y., Yao, S.-X., & He, X.-J. (2015). Allicin protects spinal cord neurons from glutamate-induced oxidative stress through regulating the heat shock protein 70/inducible nitric oxide synthase pathway. Food & Function, 6(1), 320–329. https://doi.org/10.1039/C4FO00761A

[30]. Loghmanifar, S., Nasiraie, L. R., Nouri, H., & Jafarian, S. (2020). Effects of Different Extraction Methods on Antioxidant Properties and Allicin Content of Garlic. Journal of Food Science and Hygiene, 1(1), 16–25. https://doi.org/10.14302/issn.2835-2165.jfsh-20-3487

[31]. Lu, C.-W., Hung, C.-F., Lin, T.-Y., Hsieh, T. Y., & Wang, S. J. (2019). Allicin Inhibits Glutamate Release from Rat Cerebral Cortex Nerve Terminals Through Suppressing Ca^{2+} Influx and Protein Kinase C Activity. Journal of Medicinal Food, 22(7), 696–702. https://doi.org/10.1089/jmf.2018.4337

[32]. Marefati, N., Ghorani, V., Shakeri, F., Boskabady, M., Kianian, F., Rezaee, R., &Boskabady, M. H. (2021). A review of anti-inflammatory, antioxidant, and immunomodulatory effects of Allium cepa and its main constituents. Pharmaceutical Biology, 59(1), 285–300. https://doi.org/10.1080/13880209.2021.1874028

[33]. onion. (n.d.). INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH, 11(9).

[34]. Onyango, I. (2018). Modulation of mitochondrial bioenergetics as a therapeutic strategy in Alzheimer's disease. Neural Regeneration Research, 13(1), 19. https://doi.org/10.4103/1673-5374.224362

[35]. Orekhov, A. N., &Tertov, V. V. (1997). In vitro effect of garlic powder extract on lipid content in normal and atherosclerotic human aortic cells. Lipids, 32(10), 1055–1060. https://doi.org/10.1007/s11745-997-0136-7

[36]. Pareek, S., Sagar, N. A., Sharma, S., & Kumar, V. (2017). Onion (Allium cepa<scp>L</scp> .). In Fruit and Vegetable Phytochemicals (pp. 1145–1162). Wiley. https://doi.org/10.1002/9781119158042.ch58

[37]. Rabinkov, A., Miron, T., Konstantinovski, L., Wilchek, M., Mirelman, D., & Weiner, L. (1998). The mode of action of allicin: trapping of radicals and interaction with thiol containing proteins. Biochimica et Biophysica Acta (BBA) - General Subjects, 1379(2), 233–244. https://doi.org/10.1016/S0304-4165(97)00104-9

[38]. Saleh, D. O., Mansour, D. F., & Fayez, A. M. (2021). Thioacetamide-induced acute hepatic encephalopathy: central vs peripheral effect of Allicin. Metabolic Brain Disease, 36(6), 1331–1340. https://doi.org/10.1007/s11011-021-00695-7

[39]. Sampath Kumar, K. P., Bhowmik, D., & Tiwari, P. (2010). Allium cepa: A traditional medicinal herb and its health benefits. J. Chem. Pharm. Res, 2(1), 283–291.

[40]. Santas, J., Almajano, M. P., & Carbó, R. (2010). Antimicrobial and antioxidant activity of crude onion (Allium cepa , L.) extracts. International Journal of Food Science & Technology, 45(2), 403–409. https://doi.org/10.1111/j.1365-2621.2009.02169.x

[41]. Savairam, V. D., Patil, N. A., Borate, S. R., Ghaisas, M. M., & Shete, R. V. (2023). Allicin: A review of its important pharmacological activities. Pharmacological Research - Modern Chinese Medicine, 8, 100283. https://doi.org/10.1016/j.prmcm.2023.100283

[42]. SCHWARTZ, I. F., HERSHKOVITZ, R., IAINA, A., GNESSIN, E., WOLLMAN, Y., CHERNICHOWSKI, T., BLUM, M., LEVO, Y., & SCHWARTZ, D. (2002). Garlic attenuates nitric oxide production in rat cardiac myocytes through inhibition of inducible nitric oxide synthase and the arginine transporter CAT-2 (cationic amino acid transporter-2). Clinical Science, 102(5), 487. https://doi.org/10.1042/CS20010221

[43]. Sharma, K., Mahato, N., & Lee, Y. R. (2018). Systematic study on active compounds as antibacterial and antibiofilm agent in aging onions. Journal of Food and Drug Analysis, 26(2), 518–528. https://doi.org/10.1016/j.jfda.2017.06.009

[44]. Song, H., Cui, J., Mossine, V., Greenlief, C., Fritsche, K., Sun, G., & Gu, Z. (2019). Bioactive components from garlic on brain resiliency against neuroinflammation and neurodegeneration (Review). Experimental and Therapeutic Medicine. https://doi.org/10.3892/etm.2019.8389

[45]. Suleria, H. A. R., Butt, M. S., Anjum, F. M., Saeed, F., & Khalid, N. (2015). Onion: Nature Protection Against Physiological Threats. Critical Reviews in Food Science and Nutrition, 55(1), 50–66. https://doi.org/10.1080/10408398.2011.646364

[46]. Teshika, J. D., Zakariyyah, A. M., Zaynab, T., Zengin, G., Rengasamy, K. R., Pandian, S. K., & Fawzi, M. M. (2019). Traditional and modern uses of onion bulb (Allium cepa L.): a systematic review. Critical Reviews in Food Science and Nutrition, 59(sup1), S39–S70. https://doi.org/10.1080/10408398.2018.1499074

[47]. Vimal, V., & Devaki, T. (2004). Hepatoprotective effect of allicin on tissue defense system in galactosamine/endotoxin challenged rats. Journal of Ethnopharmacology, 90(1), 151–154. https://doi.org/10.1016/j.jep.2003.09.027

[48]. Wright, T. M. (1997). Cytokines in acute and chronic inflammation. Frontiers in Bioscience, 2(4), A171. https://doi.org/10.2741/A171

[49]. Zaini, A. S., Putra, N. R., Idham, Z., Mohd Faizal, A. N., Che Yunus, M. A., Mamat, H., & Abdul Aziz, A. H. (2022). Comparison of Alliin Recovery from Allium sativum L. Using Soxhlet Extraction and Subcritical Water Extraction. ChemEngineering, 6(5), 73. https://doi.org/10.3390/chemengineering6050073

[50]. Zhen, H., Fang, F., Ye, D., Shu, S., Zhou, Y., Dong, Y., Nie, X., & Li, G. (2006). Experimental study on the action of allitridin against human cytomegalovirus in vitro: Inhibitory effects on immediate-early genes. Antiviral Research, 72(1), 68–74. https://doi.org/10.1016/j.antiviral.2006.03.017