International Journal of Research in Medical Sciences
*Banerjee SB. Int J Res Med Sci. 2021 Jun;9(6):1840-1845*
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012
DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20212262

**Review Article**

# Garlic: a potential spice with multifunctional pharmacological properties can prevent COVID-19 disease

**Subha Bose Banerjee***

Department of Physiology, Hooghly Mohsin College, Hooghly, West Bengal, India

**Received:** 22 April 2021
**Revised:** 18 May 2021
**Accepted:** 19 May 2021

***Correspondence:**
Dr. Subha Bose Banerjee,
E-mail: banerjee.subha@gmail.com



## ABSTRACT

Novel coronavirus disease (COVID-19) is the major health crisis in the world. World Health Organisation has declared COVID-19 as a global pandemic. There are no effective drugs to treat COVID-19 infection. Till date include remdesivir, umifenovir, favipiravir, lopinavir/ritonavir, ribavirin, hydroxychloroquine, etc. are used to treat this disease. There is an urgent need for public health measures, not only to limit the spread of the virus, but also to implement preventive approaches to control severe COVID-19 disease. Most drugs on the market have shown unwanted symptoms and toxic effects related to these drugs. In this situation people are searching for safe herbal extracts and pharmacologically active molecules having numerous therapeutic properties. Garlic (*Allium sativum* L.; Family: Amaryllidaceae) is an aromatic herbaceous annual spice with numerous therapeutic properties. Garlic is one of the most efficient natural antibiotics against the wide spectrum of viruses and bacteria. Organosulfur (e.g. allicin and alliin) and flavonoid (e.g. quercetin) compounds are responsible for immunomodulatory effects of this healthy spice. The viral replication process is accelerated with the main structural protease of severe acute respiratory syndrome corona virus-2 (SARS-CoV-2). The formation of hydrogen bonds between this serine-type protease and garlic bioactives in the active site regions inhibits the COVID-19 outbreak. Intake of garlic and its derived-products in regular diet as an adjuvant therapy may minimise side effects and toxicity of the main therapeutic drugs of COVID-19 infection.

**Keywords:** COVID-19, SARS-CoV-2, Garlic, Allicin, Quercetin, Antiviral

## INTRODUCTION

The coronavirus disease 2019 (COVID-19) epidemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) primarily induces pro-inflammatory cytokines e.g. interleukins (IL-1 and IL-6) and lung inflammation. This virus can also damage vital organs of the host body through the expression of the angiotensin-converting enzyme 2 (ACE2) receptor. Besides, the imbalance between the renin-angiotensin system and ACE2/angiotensin-(1–7)/MAS axis after the SARS-CoV-2 infection enhances comorbidities and multi-organ injuries.[1] There is no effective drugs to treat COVID-19 disease have been reported so far. Till date the drug treatments of COVID-19 include remdesivir, umifenovir, favipiravir, lopinavir/ritonavir, ribavirin, hydroxychloroquine, etc. In this situation dietary therapy and herbal medicine as an adjuvant therapy may be one of the efficient strategies to fight against COVID-19. Bioactive compounds involved in immunomodulatory, antioxidant, and antimicrobial activities in certain foods and herbs may be able to increase the activity and number of cytokine suppressors, lymphocytes, natural killer cells, and macrophages. So herbal products decrease the adverse impacts of antivirals by reducing the used dose and synergically improves the remedy and outcomes by decreasing the inflammation and respiratory symptoms.[2]

Sulfur-containing phytochemicals present in garlic (*Allium sativum* L.) provides substantial immunomodulatory, anti-

inflammatory, anticancer, antitumor, antidiabetic, anti-atherosclerotic, and cardioprotective properties. Important sulfur containing phytochemicals (~ 82%) of garlic are thiosulfinates (allicin), S-allyl cysteine sulfoxide (alliin), ajoenes (E- and Z-ajoene), vinyldithiins (2-vinyl-(4H) - 1,3-dithiin, 3-vinyl-(4H)-1,2-dithiin), and diallyl (di and tri) sulfide. In garlic there are some alliin-derived organosulfur compounds (OSCs) such as S-allyl-cysteine, S-ally-mercapto cysteine, and N-acetylcysteine.[3] The antiviral effect of garlic against a number of viruses like influenza B, human-immunodeficiency virus (HIV) (type 1), vesicular stomatitis virus, herpes simplex virus (types 1 and 2), coxsackievirus species, and gamma retrovirus has been reported.[4] Recently, researchers have realized the structure of the main protease of SARS-CoV-2, a serine-type $M^{pro}$ (chymotrypsin-like protease ($3CL^{pro}$)) protease with the kind of amino acids (such as Thr24, Thr26, and Asn119) present in the active site regions (e.g. 6 LU7 and 2GTB). $M^{pro}$ has a considerable structural similarity (~ 96.0%) between types 1 and 2 of SARS-CoV. As this protease is responsible for the viral replication and the production of functional protein as a result of the proteolytic maturation of SARS-CoV-2, the rate of infection may be substantially reduced by hindering the cleavage of the viral polyprotein.[5] In an in silico approach on the inhibitory effect of garlic against SARS-CoV-2, seven OSCs of alliin, S-(allyl/methyl/ethyl/propyl)-cysteine, S-propyl L-cysteine, and S-ally-mercapto-cysteine were considered as possible constitutes to inhibit the $M^{pro}$ of SARS-CoV-2 through H-bonds with this protease. Molecular docking analysis showed that alliin among other OSCs has higher anti-viral potential to prevent COVID-19. This bioactive component alone or in combination with the main therapeutic drug would be an efficient therapy to eradicate SARS-CoV-2 with the lowest side effects and toxicity.[6] The quercetin could also inhibit protease present in SARS-CoV-1 during the multiplication in host cells via blocking the viral attachment stage.[7]

Organosulfur (e.g. allicin) and flavonoid (e.g. quercetin) compounds in aqueous extracts and essential oils of garlic and their interaction with the $M^{pro}$ protease decrease the rate of COVID 19 infection. The encapsulation of these bioactive substances at the micro- and nano-size drug particles maintains their oxidative stability and bio-functionality and provides their controlled release and delivery to the targeted sites. Finally, the consumption of functional foods prepared by encapsulated/free bioactive compounds of garlic may have a key role in the incidence reduction of COVID-19 in different communities.

## PHARMACOLOGICAL PROPERTIES OF GARLIC

Garlic is a spice with multifunctional pharmacological properties. Garlic is very much used in our daily diet as an aromatic spice. It is rich in bioactive components. Organosulfur (e.g. allicin and alliin) and flavonoid (e.g. quercetin) compounds are responsible for immunomodulatory effects of this potent spice. Important sulfur containing phytochemicals (~ 82%) of garlic are thiosulfinates (allicin), S-allyl cysteine sulfoxide (alliin), ajoenes (E- and Z-ajoene), vinyldithiins (2-vinyl-(4H) - 1,3-dithiin, 3-vinyl-(4H)-1,2-dithiin), and diallyl (di and tri) sulfide.

### *Anti-cardiovascular disease activity*

Garlic and its phytochemicals are well known for prevention and treatment of cardiovascular diseases (CVD). Garlic intake has significant effects on lowering blood pressure, prevention of atherosclerosis, reduction of serum cholesterol and triglyceride, inhibition of platelet aggregation, and increasing fibrinolytic activity.[8] Both experimental and clinical studies on different garlic preparations demonstrate these favourable cardiovascular effects. Garlic shows antihypertensive activity by decreasing peripheral vascular resistance.[9] It has been reported that garlic significantly reduced serum cholesterol, triglyceride, and low-density lipoproteins (LDL), but there was very little effect on serum high density lipoproteins (HDL).[10] Allicin and S-allyl cysteine, two phytochemicals present in garlic extract and diallyl di-sulfide, present in garlic oil have been found to show anti-atherosclerotic effect.[11] Furthermore garlic can prevent thrombosis by inhibiting platelet aggregation.[12]

### *Anti hyperglycemic effect*

Garlic and its phytochemical derivatives have anti hyperglycemic effect. Various studies showed that garlic can reduce blood glucose level in diabetic animals. It has been found that garlic can reduce blood glucose level in streptozotocin- and alloxan-induced diabetes mellitus in rats and mice.[13] The beneficial effect of garlic on diabetes mellitus is mainly attributed to the presence of volatile sulfur compounds, such as alliin, allicin, diallyl disulfide, diallyl trisulfide, diallyl sulfide, S-allyl cysteine, ajoene, and allyl mercaptan. Garlic extracts have been reported to be effective in reducing insulin resistance.[14]

### *Antioxidant activity*

Frequent garlic intake promotes antioxidant activities and reduces oxidative adverse effects either by increasing the endogenous antioxidant synthesis or reducing the production of oxidizers such as oxygen-free radical species (ORS).[15] Alliin isolated from garlic, showing wide-spectrum antioxidant activities by controlling ROS generation and preventing mitogen-activated protein kinase (MAPK). Moreover, it was reported to prevent ROS production by inhibiting NADPH oxidase 1, and thus, inhibiting the osteoclast fusion caused by receptor activator of nuclear factor-kappa B ligand (RANKL).[16] Allicin also isolated from garlic showed an antioxidant effect in lower doses at the physiological level.

### *Anti-inflammatory activity*

Garlic its bioactive phytochemicals have been reported to possess anti-inflammatory activity. It has been observed

that the anti-inflammatory activity of garlic is caused by inhibiting the emigration of neutrophilic granulocytes into epithelia.[17] It has been investigated that the anti-inflammatory effect of garlic may be due to the direct suppression of toll-like receptor 4 (TLR4) signalling cascade activation in macrophages, reducing nuclear NF-κB level and improving the NF-κB and IκB cytosolic levels in LPS-activated RAW264.7 cells.[18] Furthermore it has been observed that garlic extract may act by inhibiting the iNOS and COX-2 expression, and so, prevented the NO, interleukin-6 (IL-6) and TNF-α formation of in LPS-activated RAW264.7 cells and TPA-mediated dermatitis in mice. Allicin showed a defensive mechanism against pathogens by enhancing the activity of immune cells and influence signalling pathways associated with these immune cells. Moreover, allicin works on T-cell lymphocytes by inhibiting the SDF1α chemokine which is related with the weakness of the dynamic structure of the actin cytoskeleton and it leads to inhibit the transendothelial migration of neutrophils.[19]

### *Anti-cancer effect*

Numerous studies have shown cancer-preventive effects of garlic. Garlic has been found to contain various potent bioactive compounds with anticancer properties, mainly allylsulfide derivatives. Various garlic derivatives have been shown to modulate an increasing number of molecular mechanisms in carcinogenesis, such as deoxyribonucleic acid (DNA) adduct formation, mutagenesis, scavenging of free radicals, cell proliferation and differentiation as well as angiogenesis. The growth rate of cancer cells is reduced by garlic, with cell cycle blockade that occurs in the G2/M phase.[20] Garlic has a variety of anti-tumor effects, including tumor cell growth inhibition and chemopreventive effects. Diallyl trisulfide (DATS), an organosulfur compound isolated from garlic, has potent anticancer activity. It has potent anti-cancer activity against PC-3 cancer cells.[21] Furthermore it has also been found to reduce tumor mass and number of mitotic cells within tumors. DATS reduced mitosis in tumors by decreasing histone deacetylase activity and increasing acetylation of H3 and H4. It has also been found to inhibit cell cycle progression and decrease pro-tumor markers (survivin, Bcl-2, c-Myc, mTOR, EGFR, VEGF).[22]

### *Anti-hepatotoxic activity*

Several studies showed that garlic can protect the liver cells from some toxic agents. Acetaminophen is a leading analgesic and antipyretic drug used in many countries.[23] It is demonstrated that garlic protects against acetaminophen-induced hepatotoxicity. Gentamycin also induces hepatic damage as revealed by elevation of liver damage marker enzymes (aspartate transaminase and alanine aminotransferase) and reduction in plasma albumin level. Dietary inclusion of garlic powder protects rats against gentamycin-induced hepatotoxicity, improves antioxidant status, and modulates oxidative stress.[24] Garlic extract may reduce lipid peroxidation and enhance antioxidant defence system.[25]

### *Anti-Alzheimer's disease activity*

Alzheimer's disease (AD) is the main cause of dementia in the elderly with neurodegenerative and cerebrovascular disorders. Acetylcholinesterase (AChE) is the main enzyme that break down the acetylcholine (ACh) in the nervous system into acetate and choline.[26] Acetylcholine depletion in the central nervous system is the important pathophysiology found in AD.[27] For this reason donepezil (AChE inhibitor) was effectively used in the management and prevention of AD. It has been observed that oil from garlic bulbs suppressed AChE activity of cerebral cortex synaptosome. Garlic oil exhibits antioxidant properties and due to this anti-oxidant property it inhibits AChE activity in vitro[28]. Thus garlic can be used to prevent AD.

### *Anti-obesity activity*

Obesity is the severe lifestyle disorder in recent times. It can cause diseases like hypertension, dyslipidemia, cardiovascular disorders. Garlic extracts have been shown to reduce body weight, adipose tissue mass.[29] Furthermore garlic extracts have also been shown to improve plasma lipid profiles in mice with high-fat diet-induced obesity. These effects might be attributed due to the downregulation of multiple gene expression that is included in adipogenesis along with upregulation of the mitochondrial inner membrane proteins expression.[29]

### *Antimicrobial activity*

The antimicrobial activity of garlic is due to allicin. Allicin present in garlic acts toward a wide variety of microorganisms including antibiotic-resistant, gram-positive and gram-negative bacteria such as *Shigella, Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Streptococcus mutans*, *S. faecalis*, *S. pyogenes*, *Salmonella enterica, Klebsiella aerogenes*, *Vibrio*, *Mycobacteria*, *Proteus vulgaris,* and *Enterococcus faecalis*.[30-33] Furthermore garlic has also been found as a treatment for multi-drug resistant tuberculosis.[34]

### *Anti-protozoal activity*

Numerous studies reported the anti-protozoal activity of garlic extracts. Allicin has been found to prevent the parasite's RNA, DNA and protein synthesis. Moreover allicin and DATS showed antiparasitic activity against *Entamoeba histolytica*, *Plasmodium falciparum, Babesia, Theleria, Trypanosoma brucei,* and *Giardia lamblia*.[35] Ajoene, another phytochemical isolated from garlic, has also been found to exhibit antiparasitic activity by inhibiting the human glutathione reductase and *T. cruzi* trypanothione reductase.[36] Furthermore, garlic oil has been reported to show its activity against broad-spectrum microorganisms such are *Cochlospermum*

*planchonii*, *Plasmodium*, *Giardia*, *Leishmania*, and *Trypanosoma*.[36]

### *Antifungal activity*

Garlic extracts showed a broad-spectrum fungicidal effect against a wide range of fungi including *Candida*, *Torulopsis*, *Trichophyton*, *Cryptococcus*, *Aspergillus*, *Trichosporon*, and *Rhodotorula* species.
Allicin and garlic oil have been found to show potent antifungal effects against *Candida albicans*, *Ascosphaera apisin*, and *A. niger*.[37] These two phytochemicals act by penetrating the cellular membrane as well as organelles membranes like the mitochondria and leading to organelles destruction and cell death. Furthermore, DADS and DATS isolated from garlic essential oil have been found to show antifungal activity against a number of fungi (*C. albicans*, *C. tropicalis*, and *Blastoschizomyces capitatus*).[37] It has also been found that garlic exhibited antifungal effects on two species, the air-borne pathogen Botrytis cinerea and Trichoderma harzianum.[38] Moreover, it has also been found that garlic is more effective than nystatin in patients with denture stomatitis.[39]

### *Antiviral activity*

There are very few information regarding the antiviral activity of garlic. Antiviral activity of garlic extracts has been shown against influenza A and B, rhinovirus, HIV, herpes simplex virus 1, human cytomegalovirus (HCMV), herpes simplex type 1 and 2 herpes simplex virus 2, parainfluenza virus type 3, viral pneumonia, rotavirus, vaccinia virus, and vesicular stomatitis virus.[40-46] The antiviral activity of garlic is mainly due to allicin, organosulfur compound present in garlic. Allicin shows antiviral activity by preventing several thiol enzymes. Diallyl trisulfide and ajoene have also been shown to be active. Ajoene acts by inhibiting the integrin dependent processes in HIV infection.[47] Allyl alcohol and diallyl disulfide have also been shown to be effective against HIV-infection.[48] In the context of recent COVID-19 pandemic scientists over the globe is searching for safe antiviral drug which might prevent us from this fatal disease. A very recent study attempted to explore the potential of effective natural compounds from garlic against the main protease of COVID-19 in comparison to proposed drug hydroxychloroquine.[49] In another study garlic clove extract showed a potent in vivo inhibitory effect against SARS-CoV-1 multiplication, probably due to the formation blocking of structural proteins and genetic materials.[50] Recently, researchers have realized the structure of the main protease of SARS-CoV-2, a serine-type $M^{pro}$ (chymotrypsin-like protease ($3CL^{pro}$)) protease with the kind of amino acids (such as Thr24, Thr26, and Asn119) present in the active site regions (e.g. 6 LU7 and 2GTB). $M^{pro}$ has a considerable structural similarity (~ 96.0%) between types 1 and 2 of SARS-CoV. Since this protease is responsible for the viral replication and the production of functional protein as a result of the proteolytic maturation of SARS-CoV-2, the infection rate may be substantially reduced by hindering the cleavage of the viral polyprotein.[51] It has been observed that alliin showed the best binding efficacy against COVID-19 main proteases.[49] Further study is needed to examine its potential in pre-clinical and clinical studies.

## CONCLUSION

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infects pulmonary epithelial cells. In severe cases, COVID-19 is accompanied by excessive activation of the innate immune system with progressive inflammation and a cytokine storm from activated cells, particularly in the airways, leading to the acute respiratory distress syndrome (ARDS). WHO has declared COVID-19 as a global pandemic.

Older peoples are more prone to have COVID 19 disease than younger people. The reason for this might be due to their less immune power and age related co morbidity like cardiovascular disease and diabetes mellitus. Modification of nutritional pattern can control COVID-19 disease. Till date there is no effective drug to control COVID-19 infection. Garlic is a spice with numerous therapeutic properties. Sulfur-containing phytochemicals present in garlic provides substantial immunomodulatory, anti-inflammatory, antidiabetic, anti-atherosclerotic, and cardioprotective properties. Furthermore garlic is one of the most efficient natural antibiotics against the wide spectrum of viruses and bacteria. Organosulfur (e.g. allicin and alliin) and flavonoid (e.g. quercetin) compounds are responsible for immunomodulatory effects of this healthy spice. Allin present in garlic showed anti COVID-19 activity. Further study is needed to examine its potential in pre-clinical and clinical studies. Intake of garlic and its derived-products in regular diet as an adjuvant therapy may minimise side effects and toxicity of the main therapeutic drugs of COVID-19 infection.

*Funding: No funding sources*
*Conflict of interest: None declared*
*Ethical approval: Not required*

## REFERENCES

1. Hashemifesharaki R, Gharibzahedi SM. Future nutrient-dense diets rich in vitamin D: a new insight toward the reduction of adverse impacts of viral infections similar to COVID-19. Nutrire. 2020;45(2):19.
2. Panyod S, Ho CT, Sheen LY. Dietary therapy and herbal medicine for COVID-19 prevention: a review and perspective. J Tradit Complement Med. 2020;10(4):420-7.
3. El-Saber Batiha G, Magdy Beshbishy A, Wasef LG, Elewa YH, Al-Sagan AA, El-Hack A, et al. Chemical constituents and pharmacological activities of garlic (Allium sativum L.): A review. Nutrients. 2020;12(3):872.

4. Chakraborty D, Majumder A. Garlic (Lahsun)–an immunity booster against SARS-CoV-2. Biotica Res Today. 2020;2(8):755-7.
5. Liu X, Wang XJ. Potential inhibitors against 2019-nCoV coronavirus M protease from clinically approved medicines. J Genet Genomics. 2020;47(2):119-21.
6. Rajagopal K, Byran G, Jupudi S, Vadivelan R. Activity of phytochemical constituents of black pepper, ginger, and garlic against coronavirus (COVID-19): an in silico approach. Int J Health Allied Sci. 2020;9(5):43-50.
7. Chen L, Li J, Luo C, Liu H, Xu W, Chen G, et al. Binding interaction of quercetin-3-β-galactoside and its synthetic derivatives with SARS-CoV 3CLpro: structure–activity relationship studies reveal salient pharmacophore features. Bioorg Med Chem. 2006;14(24):8295-306.
8. Chan JY, Yuen AC, Chan RY, Chan SW. A review of the cardiovascular benefits and antioxidant properties of allicin. Phytother Res. 2013;27:637-46.
9. Rashid A, Khan HH. The mechanism of hypotensive effect of garlic extract. J Pak Med Assoc. 1985;35:357-62.
10. Kamanna VS, Chandrasekhara N. Effect of garlic on serum lipoproteins cholesterol levels in albino rats rendered hypercholesteremic by feeding cholesterol. Lipids. 1982;17:483-8.
11. Yu-Yan Y, Liu L. Cholesterol lowering effect of garlic extracts and organosulfur compounds: Human and animal studies. J Nutr. 2001;131:989-93.
12. Allison GL, Lowe GM, Rahman K. Aged garlic extract inhibits platelet activation by increasing intracellular cAMP and reducing the interaction of GPIIb/IIIa receptor with fibrinogen. Life Sci. 2012;91:1275-80.
13. Ohaeri OC. Effect of garlic oil on the levels of various enzyme in the serum and tissue of streptozotocin diabtic rats. Biosci Rep. 2001;21:19-24.
14. Padiya R, Banerjee SK. Garlic as an anti-diabetic agent: recent progress and patent reviews. Recent Pat Food Nutr Agric. 2013;5:105-27.
15. Asdaq SMB, Inamdar MN. Pharmacodynamic and pharmacokinetic interactions of propranolol with garlic (Allium sativum) in rats. Evid. Based Complement. Altern Med. 2011;824042.
16. Chen Y, Sun J, Dou C, Li N, Kang F, Wang Y, et al. Alliin attenuated RANKL-induced osteoclastogenesis by scavenging reactive oxygen species through inhibiting Nox1. Int J Mol Sci. 2016;17:1516.
17. Gu X, Wu H, Fu P. Allicin attenuates inflammation and suppresses HLA-B27 protein expression in ankylosing spondylitis mice. BioMed Res Int. 2013;171573.
18. You BR, Yoo JM, Baek SY, Kim MR. Anti-inflammatory effect of aged black garlic on 12-O-tetradecanoylphorbol-13-acetate-induced dermatitis in mice. Nutr Res Pract. 2019;13:189-95.
19. Sela UR, Ganor S, Hecht I, Brill A, Miron T, Rabinkov A, et al. Allicin inhibits SDF-1α-induced T cell interactions with fibronectin and endothelial cells by down-regulating cytoskeleton rearrangement, Pyk-2 phosphorylation and VLA-4 expression. Immunology. 2004;111:391-9.
20. Capasso A. Antioxidant action and therapeutic efficacy of Allium sativum L. Molecules. 2013;18:690-700.
21. Borkowska A, Knap N, Antosiewicz J. Diallyl Trisulfide Is More Cytotoxic to Prostate Cancer Cells PC-3 than to Noncancerous Epithelial Cell Line PNT1A: A Possible Role of p66Shc signaling Axis. Nutr Cancer. 2013;65:711-7.
22. Wallace IV GC, Haar CP, Vandergrift WA 3rd, Giglio P, Dixon-Mah YN, Varma AK et al. Multi-targeted DATS prevents tumor progression and promotes apoptosis in ectopic glioblastoma xenografts in SCID mice via HDAC inhibition. J Neurooncol. 2013;114:43-50.
23. Bayan L, Koulivand PH, Gorji A. Garlic: a review of potential therapeutic effects. Avicenna J Phytomed. 2014;4(1):1-14.
24. Ademiluyi AO, Oboh G, Owoloye TR, Agbebi OJ. Modulatory effects of dietary inclusion of garlic (Allium sativum) on gentamycin–induced hepatotoxicity and oxidative stress in rats. Asian Pac J Trop Biomed. 2013;3:470-5.
25. El-Kott AF. Amelioration of Nitrate-induced Hepatotoxicity. J Med Sci. 2012;12:85-91.
26. Dall'Acqua S, Maggi F, Minesso P, Salvagno M, Papa F, Vittori S, et al. Identification of non-alkaloid acetylcholinesterase inhibitors from Ferulago campestris (Besser) Grecescu (Apiaceae). Fitoterapia. 2010;81:1208-12.
27. Lu SH, Wu JW, Liu HL, Zhao JH, Liu KT, Chuang CK et al. The discovery of potential acetylcholinesterase inhibitors: A combination of pharmacophore modeling, virtual screening, and molecular docking studies. J Biomed Sci. 2011;18:8.
28. Akinyemi AJ, Lekan Faboya AP, Awonegan IO, Anadozie S, Oluwasola TA. Antioxidant and anti-Acetylcholinesterase activities of essential oils from garlic (Allium sativum) Bulbs. Int J Plant Res. 2018;31.
29. Lee MS, Kim IH, Kim CT, Kim Y. 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. J Nutr. 2011;141:1947-53.
30. Ross ZM, O'Gara EA, Hill DJ, Sleightholme HV, Maslin DJ. Antimicrobial properties of garlic oil against human enteric bacteria: Evaluation of methodologies and comparisons with garlic oil sulfides and garlic powder. Appl Environ Microbiol. 2001;67:475-80.
31. Kuda T, Iwai A, Yano T. Effect of red pepper Capsicum annuum var. conoides and garlic Allium sativum on plasma lipid levels and cecal microflora

in mice fed beef tallow. Food Chem Toxicol. 2004;42:1695-700.
32. Cutler R, Wilson P. Antibacterial activity of a new, stable, aqueous extract of allicin against methicillin-resistant Staphylococcus aureus. Br J Biomed Sci 2004;61:71-4.
33. Wallock-Richards D, Doherty CJ, Doherty L, Clarke DJ, Place M, Govan JR, et al. Garlic revisited: Antimicrobial activity of allicin-containing garlic extracts against Burkholderia cepacia complex. PLoS One. 2014;9(12):112726.
34. Dini C, Fabbri A, Geraci A. The potential role of garlic (Allium sativum) against the multi-drug resistant tuberculosis pandemic: a review. Ann Ist Super Sanita. 2011;47:465-73.
35. Gallwitz H, Bonse S, Martinez-Cruz A, Schlichting I, Schumacher K, Krauth-Siegel RL. Ajoene is an inhibitor and subversive substrate of human glutathione reductase and Trypanosoma cruzi trypanothione reductase: Crystallographic, kinetic, and spectroscopic studies. J Med Chem. 1999;42:364-72.
36. Hazaa IKK, Al-Taai NA, Khalil NK, Zakri AMM. Efficacy of garlic and onion oils on murin experimental Cryptosporidium parvum infection. Al-Anbar J Vet Sci. 2016;9:69-74.
37. Pai ST, Platt MW. Antifungal effects of Allium sativum (garlic) extract against the Aspergillus species involved in otomycosis. Lett Appl Microbiol. 1995;20:14-8.
38. Lanzotti V. The analysis of onion and garlic. J Chromatogr A. 2006;1112:3-22.
39. Bakhshi M, Taheri JB, Shabestari SB, Tanik A, Pahlevan R. Comparison of therapeutic effect of aqueous extract of garlic and nystatin mouthwash in denture stomatitis. Gerodontology. 2012;29:680-4.
40. Fenwick GR, Hanley AB. Allium species poisoning. Vet Rec. 1985;116:28.
41. Tsai Y, Cole LL, Davis LE, Lockwood SJ, Simmons V, Wild GC. Antiviral properties of garlic: in vitro effects on influenza B, herpes simplex and coxsackie viruses. Planta Med. 1985;5:460-1.
42. Meng Y, Lu D, Guo N, Zhang L, Zhou G. Anti-HCMV effect of garlic components. Virol Sin. 1993;8:14-50.
43. Nai-Lan G, Cao-Pei L, Woods GL, Reed E, Gui-Zhen Z, Li-Bi Z et al. Demonstration of antiviral activity of garlic extract against human cytomegalovirus in vitro. Chin Med J. 1993;106:93-6.
44. Zhen H, Fang F, Ye DY, Shu SN, Zhou YF, Dong YS, et al. Experimental study on the action of allitridin against human cytomegalovirus in vitro: Inhibitory effects on immediate-early genes. Antiviral Res. 2006;72:68-74.
45. Weber ND, Andersen DO, North JA, Murray BK, Lawson LD, Hughes BG. In vitro virucidal effects of Allium sativum (garlic) extract and compounds. Planta Med. 1992;58:417-23.
46. Hughes BG, Murray BK, North JA, Lawson LD. Antiviral constituents from Allium sativum Pl. Med. 1989:55.
47. Tatarintsev AV, Vrzhets PV, Ershov DE, Shchegolev AA, Turgiev AS, Karamov EV, Kornilaeva GV, Makarova TV, Fedorov NA, Varfolomeev SD. The ajoene blockade of integrin-dependent processes in an HIV-infected cell system. Vestn Ross Akad Med Nauk. 1992;12:6-10.
48. Shoji S, Furuishi K, Yanase R, Miyazaka T, Kino M. Ally1 compounds selectively killed human immunodeficiency virus (type 1)-infected cells. Biochem Biophys Res Commun. 1993;194:610-21.
49. Pandey P, Khan F, Kumar A, Srivastava A, Jha NK. Screening of potent inhibitors against 2019 novel coronavirus (Covid-19) from Allium sativum and Allium cepa: An in silico approach. Biointerface Res Appl Chem. 2021;11(1):7981-93.
50. Shojai TM, Langeroudi AG, Karimi V, Barin A, Sadri N. The effect of Allium sativum (garlic) extract on infectious bronchitis virus in specific pathogen free embryonic egg. Avicenna J Phytomed. 2016;6(4):458-67.
51. Khubber S, Hashemifesharaki R, Mohammadi M, Gharibzahedi SMT. Garlic (Allium sativum L.): a potential unique therapeutic food rich in organosulfur and flavonoid compounds to fight with COVID-19. Nutr J. 2020;19(1):124.

**Cite this article as:** Banerjee SB. Garlic: a potential spice with multifunctional pharmacological properties can prevent COVID-19 disease. Int J Res Med Sci 2021;9:1840-5.