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REVIEW ARTICLE

Garlic (*Allium sativum* L.): An overview of its biochemical composition, functional properties, ayurvedic, therapeutic and ethnoveterinary uses

CHANDA S[1] • DIKSHIT N[2*]

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ABSTRACT

Garlic is a bulbous herb and one of the oldest cultivated plants. It is used as a food item for culinary purposes and spice and is also regarded as traditional medicine in different parts of the world. Garlic not only adds taste to foods but also helps to make them digestible. It has high nutritional values and possesses different valuable minerals, vitamins and many other substances that contribute health benefits to human beings. It contains sugar, protein, fat, calcium, potassium, phosphorous, sulphur, iodine, fibre, silicon, and vitamins. Furthermore, garlic has many functional benefits like antimicrobial, anticancer, antioxidant and anti-diabetic activity. As a result, researchers worldwide are interested in ascertaining garlic's medicinal properties due to its broad-spectrum therapeutic uses in human health. This review explores all aspects of phytochemical, pharmacological and medicinal uses of garlic.

INTRODUCTION

Garlic (*Allium sativum* L.) is considered one of the twenty most important vegetables, with various uses worldwide, either as a raw vegetable for culinary purposes or as a component in traditional and modern medicine (Martins *et al*., 2016). Garlic is a common spice with many health benefits and bioactive compounds (Diretto G *et al*., 2017; Szychowski KA., 2018; Lanzotti V., 2014). It has been used for medical treatment of everything from ancient civilization to date (Petrovaska and Cekovska, 2010). Garlic products are prepared in tablets, capsules, syrup, tinctures and oil. It is consumed as raw vegetables (fresh leaves or dried cloves) or after processing in oil, extracts, and powder, showing differences in chemical composition and bioactive compound content between the various forms (Singh and Kumar, 2017). It is grown by and large throughout India, with an annual production of 3164.63 tonnes from 2021 to 22 (http://apeda.in/agriexchange/). Garlic was used in folk medicine for millennia and was included in the list of medicinal herbs in the Vedas, the Indian holy book of India. Hippocrates (460–370 BC), the father of modern medicine, prescribed garlic to treat ulcers, aid in the evacuation of the placenta, alleviate respiratory conditions, act as a purgative or cleanser, and treat growths in the abdomen, particularly uterine ones. Theophrastus (371-287 BC), a Greek alchemist, wrote that workers collecting hellebore roots used garlic to counteract the poisonous plant's harmful effects (Rivlin, 2001; Kahn, 1996; Moyers, 1996). Garlic is advised for 23 different ailments by the Greek physician Pliny the Elder (23–79 AD), who wrote the medical classic Historica Naturalis. Toothache, haemorrhoids, animal bites (shrew, scorpion), bruises, ear pains, tapeworms, epilepsy, insomnia, sore throat, poor circulation, lack of desire, and counteracting the effects of the toxic plant's aconite and henbane were among the ailments that

[1]ICAR- National Institute of Plant Biotechnology, LBS Building, Pusa Campus, New Delhi-110012, India.
[2]ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003, India.
*Corresponding author; E-mail: dikshitn@gmail.com
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Table 1: Description of Ayurvedic properties in Hindi/Sanskrit and English

Hindi/Sankrit	Properties	English	Properties
Rasa	Lavana, Madhura, Tikta, Katu, Kashya	Taste	Salt, Sweet, Bitter, Pungent, A stringent
Vipaka	Katu	Metabolic property (After digestion)	Pungent
Veerya	Ushna	Potency	Hot
Guna	Teekshana, Snigdha,Guru,	Physical Property	Heavy, Oily, Piercing and Strong

Source[https://www.planetayurveda.com/library/garlic-allium-sativum

garlic was used to treat (Rivlin., 2001, Kahn., 1996. Garlic was suggested by John Gunn (1795–1863) in the Home Book of Health as a diuretic, an antiseptic, and a general tonic for the treatment of infections and respiratory conditions like asthma. Garlic was suggested by Health Remedies, a Complete Medical Work and Family Guide, as a treatment for pneumonia and John King, American Dispensatory (1877) as a stomach tonic, for children's illnesses, for worms, coughs, hoarseness, whooping cough, and catarrhs (inflammation of the mucous membranes, especially sinuses). Many researchers have worked on garlic's insecticidal, antimicrobial, antiprotozoal and antitumor activities (Makheja and Bailey, 1990). In the Ayurvedic system of medicine, traditional Chinese medicine, Islamic medicine, and folklore medicine, garlic's therapeutic medicinal effects have been attributed mainly to anti-thrombotic, hypolipidemic and antihypertensive (Moyers, 1996). Research is currently being done to see how it may be utilized to support health and aid in modern medicine. Garlic has several health benefits, including the ability to alter your DNA, prevent wrinkles, lower blood pressure, drop fasting blood glucose, lessen cardiovascular risk, relieve arthritis, and reduce inflammation.

Additionally, garlic enhances nutrients. It controls iron metabolism and improves food-based absorption of zinc and iron. Garlic may prevent tuberculosis, eliminate food poisoning bacteria, and safeguard infant formula (Rivlin, 2001; Kahn, 1996; Moyers, 1996). Within his esteemed medical text, Materia Medica, Dioscorides suggested garlic as a means of thinning mucus and relieving coughing, eliminating worms, guarding against dog and viper bites, promoting menstrual flow, and curing ulcers, leprosy, and toothaches. This review will provide detailed insights that can aid researchers in the development of drugs, ultimately leading to benefits for pharmaceutical companies. Within this review, we aim to explore various aspects, including the origin and distribution, taxonomy, morphology chemical constituents, nutritional value, pharmacological activities, health benefits as well as side effects, offering an in-depth examination of these factors.

In the present review, published papers on garlic were collected from the library and retrieved from different search engines like Consortium for e-resources in Agriculture, PubMed, Web of Science, Science Direct (Scopus) and Google Scholar using specific keywords like chemical constituents, nutritional value, traditional, ethnoveterinary and health benefits of garlic etc. Some papers that were not related and complete texts that were not available or where only abstracts were available were excluded.

Origin and Distribution

Garlic is the most ancient cultivated vegetable with a history of several thousand years of human consumption. It is native to Central Asia, South Asia, northeastern Iran, and Southern Europe, mainly the Mediterranean region. Some authorities consider *Allium longicuspis* Regel, endemic to Central Asia, the wild ancestor and spread in ancient times to the Mediterranean region. It is known in Egypt in Pre-dynastic times, before 3000 BC, and to ancient Greeks and Romans. The secondary centres of diversity are India and China. Garlic was carried to the Western hemisphere by the Spanish, Portuguese and French. Garlic was used medicinally in ancient Egyptian, Greek, Roman, Chinese, and Indian medical texts.

Table 2: Health benefits of garlic

Health benefits	Preparation	References
Antifungal, antimicrobial and antibacterial	Garlic oil has antibacterial properties and inhibit the development *of Bacillus subtilis, Escherichia coli,* and *Staphylococcus aureus*	Ankri and Mirelman, 1999, Lemar *et al*., 2007; Guo, 2014
Common colds, hay fever and asthma	Garlic is commonly used in India and Europe for Common colds, hay fever and asthma. It is known as Russian penicillin due to its wide range of potent medicinal values and extensive use as a topical and systemic antimicrobial agent and also possess the properties of healing power	Bolton *et al*., 1982
Treatment of ring worm; rheumatism, vermifuge	Intake of decoction of garlic with vinegar and sugar helps to relief from asthma; to cure epilepsy garlic taken as infusion, powder of garlic mixed with honey	Singh and Singh, 2019, Gebreyohannes and Gebreyohannes, 2013
Anti-Cancer	Bulb of garlic has a major potential cancer-preventive properties	Nicastro HL (2015)
Chest diseases	A liter of water, 250 ml of milk, and one gram of garlic are all boiled together until they reduce to one-fourth of the decoction. It ought to be taken three times daily. When taken in large quantity doses, it is an amazing treatment for pneumonia.	Sampath Kumar *et al*., 2010.
Curing pimples	Rubbing raw garlic on pimples several times a day causes them to go away scar-free. Garlic has been shown to help some individuals with acne, including those with severe cases.	Sampath Kumar *et al*., 2010.
To clear sinuses	Toast should be covered with melted butter and minced garlic cloves before consumption.	Sampath Kumar *et al*., 2010.
Curing for herpes	Cut a clove of garlic in half. Consume half of it, then take the remaining half and apply it on the afflicted areas. Applying raw garlic juice to bug bites and rashes will instantly stop the itching. A persistent cough can be treated with 8 to 10 ounces of garlic juice mixed with 2 TBLS of honey, four times a day.	Sampath Kumar *et al*., 2010.
Curing for tonsillitis	Cut a garlic clove in half lengthwise after peeling it. After a few minutes of boiling in around 1.5 cups of water, season with nutmeg, a touch of salt, a teaspoon of butter, and a pinch of pepper.Slice a clove of garlic thinly. To treat constipation, cramping in the stomach, and bloating, swallow them all at once together with a little water.Asthma can be cured with 10 drops of garlic juice and 2 teaspoons of honey.	Sampath Kumar *et al*., 2010.

Taxonomy and Vernacular Names

Garlic (*Allium sativum* L.) belongs to the *Allium* genus, which includes more than 750 species and is divided into more than 60 taxonomic groups. It belongs to the family Amaryllidaceae, order Asparagales and class Liliopsida. Garlic is generally classified into two subspecies: hardneck garlic (ophioscorodon) and softneck garlic (sativum). Hardneck garlic is generally grown in cooler climates and produces relatively large cloves, whereas softneck garlic is generally grown closer to the equator and produces small, tightly packed cloves. Hardneck and softneck have their respective varieties or cultivars. Hardneck type includes garlic-like Glazed purple strip, Asiatic, Marbled purple strip, Creole, Porcelain, Middle Eastern, Rocambole, Purple strip and Turban. Softneck type comprises Silverskin cultivars and Artichokes (Bradley *et al.*, 2016). The common names in Indian languages of garlic are Lahsun in Hindi, Rohsun in Bengali, Rasuna in Odia, Lasan in Punjabi, Poondu in Tamil, Lahsun in Urdu and Lasan in Gujarati.

Morphological Description

- ***Aerial Stem:*** Tall (up to one metre), simple, erect, herbaceous, green, round, glabrous and mostly hollow.
- ***A bulb*** consists of many bulblets with fibrous roots and a papery coating.
- ***Leaves:*** Slightly folded or flat, up to 7-10mm broad, 30 cm long, smooth, often glaucous, with a prominent midrib.
- ***Flower:*** Replaced by bulbils and sometimes a few flowers.
- ***Pedicels:*** Slender, more extended than perianth; bracteoles ovate, rather large, membranous, apex acute.
- ***Perianth:*** Pale red; outer segments ovate-lanceolate.
- ***Filament:*** Shorter than perianth segments, connate at base and adnate to perianth segments)

Cultivation of Garlic

Garlic can be grown under a wide range of climatic conditions. It prefers chilly conditions, but temperatures as high as 30 degrees Celsius are needed for optimal bulb development. It can also thrive at higher elevations, from 900 to 1200 meters above sea level. Garlic grows well in well-drained soils with a sandy loam or loam texture with lots of organic matter. Compost or well-rotted manure can be added to heavy soils to make the soil more friable and productive. Garlic is susceptible to waterlogging situations and highly acidic, alkaline, and saline soils, just like onions. Choosing the suitable cloves (>1.5g) is crucial when planting garlic. Extracting the individual cloves from seed garlic bulbs before planting is best. The cloves should be dipped in a carbendazim solution (0.1%) right before planting. For one hectare area, 400–500 kg of seeds is needed. Planting cloves vertically 2.0 cm below the soil's surface is recommended, with a plant-to-plant spacing of 10 cm and a row-to-row spacing of 15 cm. Recommended doses of fertiliser should be applied based on soil test. Before the final ploughing, it is recommended to apply organic manures and thoroughly mix them into the soil.

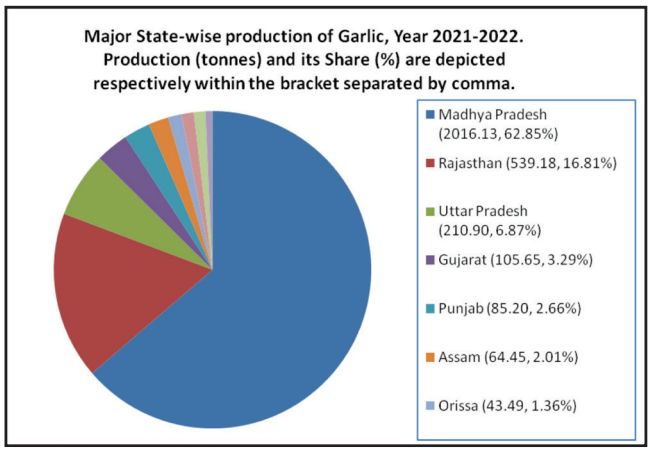

Figure 1: Major State-wise production of garlic

Indian garlic varieties recommended for various season and regions are - Bhima Omkar, Bhima Purple, Yamuna Safed (G-1), Yamuna Safed-2 (G-50), Yamuna Safed-4 (G-323), Yamuna Safed-5 (G-189), Ooty-1, VL Garlic-1, Godawari, Shweta, Phule Baswant, GG-4, VL Lahsun-2, Agrifound white (G-41), Agrifound Parvati and Agrifound Parvati-2.

For the states of Bihar, Chhattisgarh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, and Tamil Nadu, the application of 75:40:40:40 kg NPKS/ha in conjunction with a combination of two or three organic manures (FYM, poultry manure, and vermicompost) is advised. For Uttar Pradesh, Uttarakhand, and Haryana,

Figure 2: Arrangement of cloves shown inside the Garlic bulbs

100:50:50:50 kg NPKS + 20 t FYM/ha is suggested. When planting, a third of the nitrogen and the recommended potassium, sulphur, and phosphorus dose should be applied as basal. At thirty- and forty-five-days following planting, apply the remaining two-thirds of the nitrogen in two equal portions. For effective weed management, apply oxyfluorfen 23.5% EC @ 1.5–2.0 ml/L or pendimethalin 30% EC @ 3.5–4 ml/L before or at the time of planting, and then one hand weeding 40–60 days after transplanting.

Garlic is sensitive to dry soil conditions and has a relatively shallow root system. Sufficient irrigation is necessary to ensure the water holding capacity remains above 50%. When bulbs are budding, irrigation is essential from mid-May until late June or July. Bulbs that receive less water or precipitation during this phase will mature earlier and be smaller. To prevent disease and discoloured bulb wrappers, irrigation should be turned off two weeks before harvest. Garlic takes 4 ½ to 5 months to mature and is harvested when the leaves turn yellow or brown. Using a country plough, the plants are taken out or uprooted and gathered into little bundles stored in the field or shade for two to three days to cure and dry, hardening the bulbs and extending their shelf life. The bulbs should be dug when the roots and shoots are attached to be harvested (Khade *et al*., 2019; Muluneh Bekele Etana, 2018). The bulbs can be kept in a well-ventilated room on a dry sand floor or hung on bamboo poles (Shanmugavelv *et al*., 2010; Muluneh Bekele Etana, 2018).

Nutritional Value of Garlic

Garlic is nutritionally rich and contains more than 200 chemical components with various characteristics. It comprises 1.5% fibre, 65% water, 28% carbs, 2.3% organosulfur compounds, 2% proteins, and 1.2% free amino acids. It also includes minerals (Ca, Fe, Mg, P, K, Na, and Zn), water-soluble vitamins (vitamin C, B-complex vitamins: B1, B2, B3, B6, and B8), and fat-soluble vitamins (vitamins A, K, and E). Garlic's unique flavour, aroma, and medicinal characteristics are attributed to organosulfur compounds (Melguizo-Rodríguez *et al*., 2022).

Bioactive Compounds in Garlic

Zhang *et al*., (2020) illustrated a typical classification of phytoconstituents in garlic. Garlic has more than 20 distinct types of organosulfur compounds, each serving a distinctive function. These materials fall into the soluble sulfur compounds in water and oil (Fig. 4).

i. **Alliin**

Two different biosynthetic pathways lead to the production of alliin (alk(en)ylcysteine sulfoxide). The first pathway involves the alkylation of glutathione through γ-glutamyl peptides, resulting in S-alkyl cysteine sulfoxide. The second pathway involves the direct thioalkylation of serine, which is then oxidized to produce sulfoxides (Jones *et al*., 2007). Alliinase is an enzyme that breaks down alliin further into allicin. Alliin is a primary water-soluble sulphate component found in garlic. Allicin synthesis must occur. Allicin is created when alliin and alliinase combine. Allicin is the main bioactive ingredient in garlic (Subramanian *et al*., 2020; Zhang *et al*., 2020). Antibacterial solid and cancer-prevention properties of alliin have been demonstrated (Zhang *et al*., 2020). Furthermore, it has been shown that allicin and alliin exhibit blood sugar-lowering properties similar to those of glibenclamide and streptozotocin (Dubey, 2012; Lee *et al*., 2015).

ii. **S-Allylcysteine (SAC)**

The giant organosulfur molecule found in garlic is called SAC, which is created when the enzyme γ-glutamyl transpeptidase (γGTP) hydrolyzes γ-glutamyl-S-allyl-cysteine (GSAC). It is a medicinally beneficial active component of aqueous garlic extract. It has also shown promise

against inflammatory disorders and inducible diseases by inhibiting the expression of inducible nitric oxide (NO) synthase and maintaining the NO generated by endothelial NO synthase (Nwachukwu *et al*., 2012). One of the studies on SAC that affected the pancreatic antioxidant defence system in rats with streptozotocin-induced diabetes showed that SAC treatment lowers oxidative stress, a diabetes treatment (Bayan *et al* ., 2014).

iii. **S-Allyl Mercapto Cysteine (SAMC)**

In the early phase of garlic's ageing process, the endogenous enzyme γ-glutamyl transpeptidase (γGTP) biosynthesizes SAMC from γ-glutamyl-S-allyl-mercaptocysteine (GSAMC). It is an organosulfur chemical that is stable and physiologically active. Research conducted on human colon cancer cell lines has indicated their influence on the development and proliferation of the cell cycle. SAMC also induces apoptosis, which is connected to increased caspase 3-like activity. According to several studies, it is beneficial in preventing colon cancer (Batiha, 2020; Aslani *et al*., 2016). It has also been shown to provide a strong protection against hepatotoxicity.

iv. **Allicin**

Crushed garlic releases a beneficial chemical called allicin. The pharmacological impact of allicin, also known as allyl thiosulfinate, a sulfenic acid thioester, is explained by both its interaction with thiol-containing proteins and its antioxidant activity. Cysteine is converted to alliin during the allicin biosynthesis process, which is then catalyzed by the enzyme allinase (Rivlin *et al*., 1998). This enzyme, made up of pyridoxal phosphate (PLP), splits alliin to produce highly reactive and unstable products at room temperature, such as ammonium, pyruvate, and allyl sulfenic acid. These products were united to make allicin (Pârvu *et al*., 2011; Koca and Tasci, 2016). Alliinase, an enzyme present in garlic, converts alliin (l-(+)-S-allylcysteinsulfoxide) into allicin (2-propene-1-sulfinothioic acid S-2-propenyl ester) during the production of allicin. Allicin, easily identified by its odour, is found in around 45 mL of garlic cloves (Zhang *et al*., 2020). It has cardioprotective effects by inducing vasorelaxation and lowering pathological characteristics linked to cardiovascular diseases, such as angiogenesis, platelet aggregation, cardiac hypertrophy, angiogenesis, hyperlipidemia, and hyperglycemia.

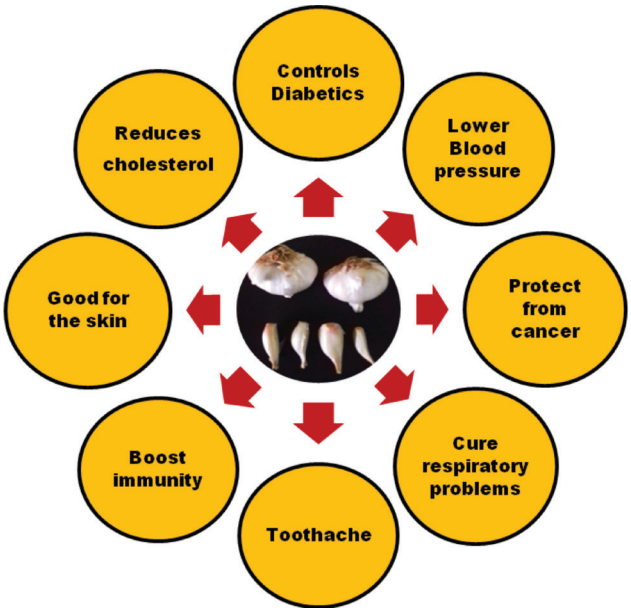

Figure 3: Health benefits of garlic (*Allium sativum* L.)

v. **Diallyl sulfides (DAS)**

The three additional compounds, diallyl monosulfide, diallyl disulfide, and diallyl trisulfide, occur from the reaction of alliin with the enzyme alliinase in an aqueous media, which leads to the biosynthesis of DAS (Dethier *et al*., 2013). Garlic's flavour and aroma are attributed to organosulfur compounds known as DAS. Lipophilic thioethers are produced when oxidized allicin is produced from crushed garlic. The compounds are oxidized at three locations: the terminal double bonds, the allylic carbon, and the sulfur atom. These compounds possess antimutagenic and anticarcinogenic qualities. The content and effect of DAS on a limited number of foodborne pathogenic bacteria have proven its enormous potential in controlling pathogenic bacteria (Shang *et al*., 2019; Arreola *et al*., 2015). Studies have shown that DAS can reduce various chemically created cancers by guarding against chemically generated hepatoxicity. DAS also has antimicrobial, hypoglycemic, antiatherosclerotic, and hypolipidemic qualities (Batiha *et al*., 2020; Bhandari *et al*., 2012).

vi. **Diallyl Disulfides (DADS)**

Garlic cloves and garlic oil contain 140 mM of DADS, an essential class of organosulfur compounds that can mainly induce redox stress in cancer cells, leading to apoptotic cell death (Subramanian *et al*., 2020). Its potential as an antioxidant agent has been

demonstrated by its ability to activate antioxidant enzymes, which catalyze oxidant reduction and inhibit free radical production (Charu *et al*., 2014; Shang *et al*., 2019). The antitumor activities of DADS have been documented in several investigations, including both humans and animals (Yi *et al*., 2019). In the murine model, topically applying DADS to the skin has demonstrated promising results in effectively inhibiting the production of skin papillomas and increasing survival rates (Li *et al*., 2018).

Pharmacological Activities

Allium sativum has several therapeutic and pharmacological activities. The following is most crucial phytopharmacology and therapeutic properties of garlic, which are amalgamated from standard published literature, are as follows:

(i) Antimicrobial Activity

Allicin was said to exhibit antibacterial action and was shown to be the most effective spice in preventing the growth of certain bacteria. It significantly lowers the microbiota in animals fed synthetic and stock diets, as evidenced by its effect on the caecal microbiome of rats (Subrahmanyan *et al*., 1958). For five days, rats given a substandard rice diet supplemented with buttermilk or red gram dhal combined with garlic showed a significant drop in their caecal flora. Rats were given 5 millilitres of raw garlic extract per kilogram of body weight, and they experienced mortality and stunted growth (Nakagawa *et al*., 1980). The total number of streptococci, coliforms, lactobacilli, aerobes, and anaerobes decreased in albino rats fed raw garlic extract for four weeks. Both aerobes and anaerobes showed a similar degree of effect. Boiling garlic extract was fed, but instead of causing any of the above mentioned alterations, it encouraged the growth of specific gut bacteria like Streptococci and Coliforms (Shashikanth *et al*., 1986). Following an intragastrical administration of garlic extract containing eight µM of allicin to albino rats, a maximum of 0.4 µM was found in the gut and 2.4 µM in the caecum after 4 and 6 hours, respectively. After 4 hours of dosing, there was a 50–60% drop in microflora in the intestine, but no such change was seen in the caecum, not even after 6 hours. However, only after eight hours did the microflora in the caecum show a five-fold drop. According to Shashikanth *et al*., (1986), reducing agents in the gut, allicin's inherent instability, dietary ingredients' antagonistic effects, and absorption in the intestine may cause a progressive drop in allicin content throughout transit through the gut. In general, the aerobes were more susceptible than the anaerobes to the concentration of allicin in the stomach (Shashikanth *et al*., 1985).

(ii) Antifungal Activity

Garlic has an active compound, Ajoene, vital as a topical antifungal agent (Ankri and Mirelman, 1999; Lemar *et al*., 2007). A comparison was made regarding garlic's effectiveness with standard medical treatment procedure treatment, which exhibits the involvement of a very toxic antibiotic called Amphotericin-B. The study also demonstrated that the administration of intravenous garlic was remarkably effective than the drug and did not show toxicity regardless of its dosages (Bolton *et al*., 1982; Ankri and Mirelman, 1999; Sabitha *et al*., 2005). A study revealed that treating with liquid garlic extract significantly reduced Candida colonies in mice. It was also found that garlic stimulated phagocytic activity, which involves infections like Candida, which stimulates the body's defences. Diseases such as ringworm, skin parasites, and warts can be treated externally using garlic oil. Garlic extract can be used externally for the treatment of lesions caused by the fungi in the skin of rabbits and guinea pigs and initiates its healing process after seven days (Bolton *et al*., 1982; Ankri and Mirelman, 1999; Appel *et al*., 2010). Garlic enzyme alliinase derived from the harmless substrate alliin produces Allicin (diallyl-dithiosulfinate), which shows a broad range of antifungal specificity. For the treatment of candidiasis, an in vitro study showed twofold activities of allicin, such as antifungal activity and its synergistic effect with the azoles. Studies also demonstrated the effect of Amphotericin B (AmB) against *C. albicans*, which showed the significant enhancement of allicin (Ogita, 2007). Another study revealed that when polymyxin B (PMB) was combined with allicin, it showed its effectiveness against various yeasts and filamentous fungi and increased the permeability of the plasma membrane in *Saccharomyces cerevisiae*. The synergistic activity between PMB and allicin combination causes structural alterations of its vacuole, which is responsible for the disappearance of the swollen spherical structure of the yeast (Mikaili, 2017; Yousuf *et al*., 2010).

A study demonstrated the effectiveness of diallyl disulphide (DADS), a significant component of garlic, regarding antioxidant systems in *Candida* species. It was observed that in the presence of DADS, significant changes occurred in antioxidant metabolites and antioxidant activity in *Candida* species and also showed a decreasing trend in the activity of all antioxidant enzymes except catalase (Yousuf *et al*., 2010; Avato *et al*., 2000). A study illustrated the efficacy of garlic distilled oil in six different mixtures containing diallyl disulfide (DDS) and diallyl trisulfide (DTS). It showed its activeness against several yeasts like *C. tropicalis*, *C. albicans*, and *Blastoschizomyces capitatus* (Yousuf *et al*., 2010; Borek, 2001). Saponins, a significant compound in garlic, were effective against *Trichoderma harzianum* and *Botrytis cinerea* (Yousuf *et al*., 2010). Cu^{2+} exhibited a fungicidal action against *Saccharomyces cerevisiae* cells that was dosage dependent, and the addition of allicin significantly increased the deadly effect of the compound. Allicin affected AHP1's mechanism of cell surface localization or associated function as a protective mechanism against phospholipid peroxidation caused by external Cu^{2+} activity. Lipid production is one of the physiological processes in microorganisms that allicin impacts RNA production, causes platelet aggregation, and lowers lipid levels in mammals. Allicin has been demonstrated to inhibit the acetyl-CoA synthetases of yeast, animals, and plants. Acetate kinase and phosphotransacetylase were blocked, the two enzymes comprising the bacterial acetyl-CoA-forming machinery. It was discovered exclusive to the fatty acid synthesis sequence's enzymes. Since allicin reacts quickly with free thiol groups through the thiol-disulphide exchange process, its primary mode of antimicrobial action is assumed to be through contact with thiol-containing enzymes, such as alcohol dehydrogenases and cysteine (Rahman *et al*., 2017).

(iii) Antibacterial Activity

The antibacterial properties of two unique garlic cultivars from Italy's Campania region, "Rosato" and "Caposele", were examined. *Aspergillus versicolor* and *Penicillium citrinum* were shown to be highly inhibited by the Caposele variety, although *Penicillium expansum* was more strongly inhibited by the Rosato variety (Fratianni *et al*., 2016). Additionally, AGE effectively inhibited Burkholderia cepacian (Wallock-Richards *et al*., 2014). Additionally, garlic oil had antibacterial properties and inhibited the development of *Bacillus subtilis*, *Escherichia coli*, and *Staphylococcus aureus* (Guo, 2014). Garlic oil was discovered to suppress *Penicillium funiculosum*, most likely by entering cells and organelles, breaking down cell walls, and inducing the leakage of cytoplasm and macromolecules.

(iv) Anti-Inflammatory Activity

The body uses inflammation as a defence mechanism in reaction to damaging stimuli. The bioactive chemical alliin is the source of several main classes of compounds, including organic sulfurs like N-acetylcysteine, SAMC, and SAC. While SAMC has anti-cancerous activity, SAC has anti-inflammatory, anti-apoptotic, and antioxidant qualities (El-Saber Batiha *et al*., 2020). Organic sulfur compounds, including thiacremonone isolated from garlic, reduce inflammation by blocking nuclear factor-kB (NF-κB). One of the critical target molecules of the organosulfur compounds found in garlic is NF-κB, which is also known to function as a transcription factor that controls the genes that cause inflammatory reactions (Ban *et al*., 2009). In one study, garlic extract dramatically reduced liver inflammation and damage from *Eimeria papillate* infections (Ahmad *et al*., 2016). Due to their significant prevalence around the world, oral disorders such as gingivitis, periodontitis, oral cancer, receding gums, and plaque margin accumulation brought on by gram-positive and gram-negative bacterial infections are serious health problems—poor oral health impacts systemic health, economic productivity, and quality of life. In developed nations, treating oral diseases accounts for over 10% of expenditure (Bin *et al*., 2020). In lipopolysaccharide-stimulated J774A.1 macrophages, another study found that the 14-kDa protein from garlic suppressed the inflammatory mediators, such as NO, TNF-α, and interleukin (IL)-1β, by blocking the transcription factor nuclear factor-kappa B (NF-κB) signalling pathway (Rabe *et al*., 2015). Furthermore, in animals lacking apolipoprotein E, AGE reduced inflammation. Tumour necrosis factor-α (TNF-α) and IL-1 receptor-associated kinase four levels were decreased, and adenosine monophosphate-activated protein kinase (AMPK) activity was increased in the liver after AGE therapy (Morihara *et al*., 2017). Furthermore, allicin may be utilized as a supplemental therapy to mitigate the inflammatory response that schistosome

infection causes in BALB/c mice (Metwally *et al*., 2018). Additionally, by lowering resistin, garlic supplements helped patients who were overweight or obese with osteoarthritis (Dehghani *et al*., 2018).

Garlic may reduce inflammation overall in both in vitro and in vivo studies primarily by inhibiting inflammatory mediators like NO, TNF-α, and IL-1. Due to its low or absent toxicity, garlic has considerable potential to treat inflammatory illnesses in humans, including arthritis.

(v) Antidiabetic Activity

The effects of garlic extract (GE) on average and streptozotocin-induced diabetic rats were conducted. GE was administrated orally (0.1, 0.25, and 0.50 g/ kg body weight) for 14 days to normal and diabetic rats, making several groups. This experiment was done on serum glucose, triglycerides, total cholesterol, uric acid, urea, creatinine, alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in normal and streptozotocin-induced diabetic rats. The results showed appreciably decreased serum glucose, triglycerides, total cholesterol, uric acid, urea, creatinine, (ALT) and (AST). The result also exhibited an increment of serum insulin in diabetic rats, but nothing happened in the case of normal rats. A comparative study was made between GE and Glibenclamide (600 micro gm/kg), a well-known anti-diabetic drug. GE showed more efficacies than Glibenclamide (Petrovic *et al*., 2018).

Furthermore, in diabetic rats, garlic exhibited a protective effect against diabetic retinopathy; after seven weeks of gastric gavage of raw garlic extract in rats, the weight, blood glucose, and morphological changes of retinal tissue improved in the garlic-treated group. If diabetes is not controlled, it can lead to cardiovascular disease, kidney illness, and memory problems (Okoro *et al*.,2023). Fresh garlic oil inhibited weight gain and the development of white adipose tissue (WAT) in high-fat-fed rats by upregulating uncoupling protein-1 and increasing energy expenditure.

(vi) Antioxidant Activity

Antioxidant enzymes were activated in the presence of diallyl sulfide (DAS), diallyl disulfide (DADS), s-acetylcysteine (SEC), and n-acetylcysteine (NAC) to protect against lipid-related oxidation. When examined by HPLC, diallyl disulfide was shown to be the most stable of the two sulphur compounds—diallyl trisulfide and disulfide. It was discovered that adding α-tocopherol and L-ascorbyl palmitate to a lard system might boost the potency and efficacy of diallyl disulfide as an antioxidant. Antioxidants in garlic help eliminate free radical particles that deteriorate DNA and cell membranes and speed up ageing. Antioxidants, including those found in garlic, help combat free radicals, which can harm DNA and cell membranes and speed ageing (Capasso, 2013; Ajayi *et al*., 2009).

The antioxidant activity of garlic homogenates mixed with various concentrations of oil and distilled water was investigated by Kim *et al*.,1997. The concentration of garlic aroma in the oil layer was discovered to have considerable antioxidant activity.

Allicin is an effective antioxidant in vitro by interacting with enzymes containing free thiols and trapping free radicals. It has been discovered that allicin scavenges hydroxyl radicals and prevents human granulocytes stimulated by phorbol ester from producing superoxide. Allicin demonstrated an additional therapeutic effect, inhibition of NO production, and modulation of SH-dependent activities. Ajoene also demonstrated the NO production inhibitory effect (Dirsch *et al*., 1998).

According to Asdaq and Inamdar, 2011, frequent intake of garlic increases endogenous antioxidant synthesis or lowers the generation of oxidizers such as oxygen-free radical species (ORS), which boosts internal antioxidant activities and mitigates oxidative unfavourable effects. The antibiotic gentamycin has been used to treat a variety of bacterial infections. It has been shown to decrease plasma albumin levels and increase the enzymes aspartate transaminase and alanine aminotransferase, both known to cause liver damage. Garlic has been shown to mitigate hepatotoxicity caused by acetaminophen and gentamycin by enhancing antioxidant status and controlling oxidative stress.

Garlic's antioxidant effect may be its ability to modulate reactive oxygen species (ROS), increasing glutathione and cellular antioxidant enzymes. This is reasonable, given that ROS appears at the root of many diseases (Shokrzadeh and Ebadi, 2006). Furthermore, in rat liver tissues, garlic extract was shown to lower glutathione peroxidase (GSH-Px) and boost the activity of several antioxidant enzymes, such as superoxide dismutase (SOD). Several studies have shown that AGE is rich in phenol, flavonoids,

and other sulfur compounds. For example, SAC has strong radical scavenging potential (Jang *et al*., 2017). Furthermore, through the nuclear factor erythrobia-2 related factor 2 (Nrf2)-antioxidant response element (ARE) pathway, which is responsible for human endothelial cells' protection against oxidative stress, AGE acted by inducing the expression of several antioxidant enzymes, including glutamate-cysteine ligase modifier (GCLM) and heme oxygenase-1 (HO-1) subunit. The main AGE component, alliin, has been shown to have broad-spectrum antioxidant properties by inhibiting the production of reactive oxygen species (ROS) and mitogen-activated protein kinase (MAPK). The primary antioxidants demonstrating an antioxidant action at the physiological level at lower concentrations include allicin, DADS, and DATS (Gruhlke *et al*., 2010). Garlic saponins have been shown to scavenge intracellular ROS and protect mouse-derived C2C12 myoblasts from H2O2-induced DNA damage and growth inhibition.

(vii) Anti-cancer Activity

It is admitted that cancer is becoming the primary issue causing the death of many people in the modern world. Recent research has shown that many readily available foods, such as garlic and onions, comprise a healthy diet significantly impact cancer prevention. The protective effect of garlic is greater than onions, and these cancer-fighting foods can interfere with the development of cancerous tumours. American National Cancer Institute considered bulbs of garlic as a significant potential cancer-preventive food.

In epidemiological studies, the role of garlic and its extract has been established to decrease cancer. Experiments being performed on the molecular and cellular activities of a simple homemade ethanol-based garlic extract (GE) showed that GE slows down the growth of various cancer cells in vitro, in addition to that decrement of growth of cancer in a synergetic orthotopic breast cancer model in vivo. Multiple studies have been conducted that paved the way towards facilitating a mechanism demonstrated that via endoplasmic reticulum (ER) stress, Organic Sulphur Compounds (OSCs) in GE trigger apoptosis and exhibit the effects on cellular redox regulation. The molecular mechanisms associated with anti-cancer effects intervened by garlic are very complex and vary from cancer cell to cell (Steinmetz *et al*., 1994). It is reported that aged garlic extract prevents a decline of NK cell number and activity in patients with advanced cancer (Ishikavaka *et al*., 2006)

Another significant epidemiological study has been published regarding Americans, and the most notable outcome demonstrated in a report titled "Iowa Women's Health Study" was that garlic was the lone food and found to be the statistically most crucial association towards decreasing colon cancer risk. The study was conducted on 41 387 women of different age groups (ages 55 to 69), and they were given 127 different foods, including vegetables and fruits and monitored for five years to find the incidence of colon cancer (Waris and Ashfaq ., 2013).

(viii) Cardiovascular Activity

Hypertension is considered a significant risk factor towards leading cardiovascular disease. It has been found that the consumption of garlic has some involvement in the controlling of blood pressure. The blood pressure-controlling properties of garlic are associated with the production of hydrogen sulphide and the presence of allicin released from alliin and the enzyme alliinase; the compound contains angiotensin II, which has vasodilating properties.

Additionally, garlic lowers hypertension by decreasing oxidative stress, producing more NO and hydrogen sulfide (H2S), and inhibiting the angiotensin-converting enzyme (Cruz *et al*., 2007; Fasolino *et al*., 2015; Takashima *et al*., 2017; Asdaq and Inamdar, 2010; Sausbier *et al*., 2000; Kim *et al*., 2010; Ushijima *et al*., 2018; Park *et al*., 2016; Park *et al*., 2017). According to a study, AGE could increase NO production in the isolated rat aortic rings, which would cause endothelial-dependent vasodilation. Furthermore, l-arginine in AGE played a critical role in the NOS-mediated synthesis of NO (Takashima *et al*., 2017). Furthermore, it was demonstrated that the primary antihypertensive substance in the AGE was S-1-propylenecysteine. Without altering the systolic blood pressure of control rats, it was demonstrated that S-1-propylene cysteine enhanced peripheral blood circulation and decreased systolic blood pressure in rats with spontaneous hypertension. In another investigation, *Bacillus subtilis* was shown to convert the nitrites in the fermented garlic extract (FGE) into NO in vivo.

Furthermore, by activating the soluble guanylyl cyclase (sGC)-cyclic guanosine monophosphate (cGMP)-protein kinases G (PKG) pathway, NO

decreased the systolic blood pressure in rats with spontaneous hypertension (Park *et al*., 2016).

Additionally, in rats with monocrotaline-induced pulmonary hypertension, FGE was demonstrated to reduce vascular endothelial cell adhesion molecule-1 and matrix metalloproteinase-9 (MMP-9) while increasing the expression of PKG and endothelial nitric oxide synthase (eNOS) (Park *et al*., 2017). Also, when combined with captopril, garlic's bioactive component alliin enhanced captopril's ability to inhibit the angiotensin-converting enzyme (ACE) and hypertension in rats (Asdaq and Inamdar, 2010). When 44 hypertensive patients provided processed garlic with enzyme browning in a placebo-controlled experiment, their diastolic and systolic blood pressures considerably decreased. Garlic extracts and their bioactive compounds have been shown to have an antihypertensive effect in several human and experimental studies. When Sobenin *et al*. 2012 examined the plasma fibrinolytic activity of garlic extracts, they discovered that both healthy and participants experiencing an acute myocardial infarction had higher fibrinolytic activity.

Additionally, an in vivo study demonstrated the antihypertensive impact of aqueous garlic extract in the "2 kidney 1-clip" model of rat hypertension by lowering the levels of prostaglandin E2 and thromboxane B2, which in turn lowered the test rats' blood pressure. A two-month trial was conducted among hypertensive patients using garlic pearls containing 250 gm of garlic. This trial showed a remarkable decrement in blood pressure level as well as a diminishing of biomarkers that are responsible for oxidative stress occurring in the blood (plasma, plasma-oxidized LDL, and urinary concentration of 8-iso-Prostaglandin F2alpha) and eventually lowering the risk of cardiovascular disease. Garlic inhibits platelet aggregation or adhesion, a significant risk factor for cardiovascular disease. Allicin and ajeones undergo a self-condensation process, and hence, the end product shows antithrombotic action (Rahman and Lowe, 2006). In isolated rat pulmonary arteries, garlic administration at 100 mg/kg for five days completely prevented acute hypoxic pulmonary vasoconstriction caused by endothelin-1. They also discovered that garlic functions by lowering the production of endothelin I and angiotensin II (Drobiova *et al*., 2011).

Mode of Action and Therapeutic Uses

(i) Infectious Processes

It has been demonstrated that giving allicin and garlic oil can help prevent respiratory tract infections. Treatment with oral allicin supplements may shield against common cold virus infection. When children between 10 and 12 were given 300 mg extended-release garlic capsules daily for 20 weeks, acute respiratory infection morbidity decreased. In a model of sepsis in mice, garlic extract effectively inhibited the infectious process (Yarnell, 2018; Ko *et al*., 2018; Josling 2001; Andrianova *et al*., 2003; Lee, 2015).

(ii) Tumoral Processes

Garlic has been shown to have anti-tumour capabilities, primarily in specific components like DADS, DATS, SAC, and SAMC (Miraghajani *et al*., 2018; Liu *et al*., 2019 and Zhang *et al*., 2020). Rat sarcoma and breast tumour cells showed less tumour activity after being treated with garlic extract and garlic protein fractions. It has been demonstrated that the protein portion of garlic and AGE can alter natural killer cell function in healthy individuals and those with advanced cancer diseases. Zhou *et al*., (2020) reduced the tumour activity of rat sarcoma cells and breast tumour cells in 68 treatments with garlic extract and garlic protein fractions. Hu *et al*., 2002, Moutia, Habti and Badou, 2018 and Rodrigues and Percival., 2019). Garlic and its constituents have demonstrated advantageous effects in tumour treatment through modulation of cytokine novelties, including TNF-α, IFN-γ, and IL-2, as well as T-cell function (Suddek, 2014; Hodge *et al*., 2008). Garlic and vitamin supplementation together for 7.3 years lowered the chance of precancerous stomach lesions. After a follow-up of more than 22 years, it was discovered that an oral vitamin and garlic supplementation treatment delivered for 7.3 years reduced the incidence of stomach cancer mortality. Patients with advanced digestive system cancers (pancreatic, colon, and liver cancer) who received daily supplementation with AGE (500 mg) for six months had an improvement in NK cell function. A high-dose AGE (2.4 mL day−1) supplementation for 12 months reduced the quantity and dimensions of colorectal adenomas (You *et al*., 2006; Li *et al*., 2019).

(iii) Prebiotic Agent

Garlic's fructose content may stimulate the formation of Bifidobacteria. After three months of AGE supplementation, *lactobacillus* and *Clostridium* in the gut microbiota significantly increased (Zhang *et al*., 2013; Ried, 2020).

(iv) Therapeutic Endocrine and Metabolic Effect

Garlic extract treatments have improved glucose, fructosamine, and glycosylated haemoglobin levels and weight loss in diabetic rats. Garlic has been shown to benefit several aspects of the metabolic syndrome in people, including reducing waist circumference and increasing high-density cholesterol, insulin resistance, weight and arterial blood pressure.(Askari *et al*., 2021; Kaur *et al*., 2016; Thomson *et al*., 2016; Wang *et al*., 2017; Sangouni *et al*., 2021 and Yang *et al*., 2016).

Uses of Garlic as Mentioned in the Classical Ayurvedic Texts

Garlic is considered a safe food and has been used for culinary and traditional medicine for centuries. The classical Ayurvedic texts describe various uses of garlic alone or with different ingredients. Description of Ayurvedic properties in Hindi/Sanskrit and its translation in English are mentioned for better understanding. Several health benefits of garlic are discussed below and depicted in Fig.2. Some important uses of garlic, as mentioned in the classical Ayurvedic texts, are

Garlic preparation with alcohol is suggested in Rheumatoid conditions (Amavata).

- Garlic paste kills organisms by applying it externally.
- Paste of garlic promotes lactation.
- Ghee and honey mixed with garlic paste, taken for one year, act as a rejuvenator (*Rasayana*) and help support good health and longevity.
- Garlic juice helps treat disorders of the female genital tract and should be taken in the morning.

Milk processed with garlic cloves is recommended in cases of gout (cataract), fever, cardiac disorders, abscesses and oedema.

Garlic is a valuable tonic in ancient Indian medicine, used as roborants to treat a variety of ailments, including rheumatism, haemorrhoids, joint weakness, cough, and lack of appetite. Asthma, hoarseness, coughing, breathing difficulties, and most other lung illnesses can all be effectively treated with garlic. Because of its ability to promote expectoration, garlic is very beneficial in treating chronic bronchitis. An ancient and once-popular treatment for asthma was a syrup created from cooking garlic bulbs until they were soft. After that, they were sugared and cooked to syrup by adding an equivalent amount of vinegar to the boiling water. After the garlic bulbs have been boiled and allowed to dry, the syrup is poured over them and stored in a jar. Take one or two bulbs each morning, together with a teaspoon of syrup. Place a tiny slice of garlic inside the ear after wrapping it in tissue to treat ear infections. Leave it there overnight. Pain is relieved nearly instantly, and the infection usually disappears overnight. A small piece of garlic is kept inside the mouth and held there for ten to fifteen minutes to cure scratchy throats. To help release the juice from the garlic slice, place it between your teeth and cheek and lightly scrape it with your teeth. This juice relieves the pain as it slides down your throat. The pain from insect bites, such as those from centipedes and scorpions, can be relieved using garlic. Use fresh garlic juice and salt for ringworm, sprains, and bruises. Chop four fresh garlic cloves, consume them raw or use them as a garnish on soups and other dishes during the first cold symptoms. To relieve toothache, chop raw garlic and apply the cut edge to the tooth and gums many times daily. Crush some fresh garlic cloves and apply the mixture to warts until they disappear. Using a dessert spoon, crush one or two cloves, then add with olive oil and down the hatch. The advantages of raw garlic are yours without the bad breath.

Side Effects

Garlic is known to induce ghastly inhaling (halitosis), and it can also generate a pungent "garlicky" odour that should be avoided when it comes to good health (Borrelli *et al*., 2007). This smell is caused by ally methyl sulfide (AMS). Ally methyl sulfide is an unstable fluid that enters the bloodstream during the metabolic process of garlic and produces sulfur compounds. From there, it travels to the lungs, the oral cavity, which causes bad breath (garlic breath), and finally to the skin's surface, where it is expelled through pores. For the most part, the surface properties of the long-

standing garlic addition are unknown, and no Food and Drug Administration-approved research has been conducted. While the US Food and Drug Administration (FDA) considers garlic safe for human consumption, sensitive individuals may experience stomach irritation if they consume large amounts of garlic. Randomized controlled trials were conducted to evaluate the safety of garlic. The following adverse effects were noted: Menstrual abnormalities, digestive pain, sweating, lightheadedness, allergic responses, and bleeding (Rana *et al*., 2011). When older than necessary, dosages of garlic are taken with anticoagulant medicine; this can indicate a greater risk of bleeding (Brown *et al*., 2015). Garlic may interact with anticoagulants, antiplatelets, saquinavir, antihypertensives, calcium channel blockers, antibiotics with quinolone relations of antibiotics, such as ciprofloxacin, hypoglycaemic medications, and other prescription medications. Garlic overdosages can be harmful and result in gastrointestinal issues and anaemia. Garlic in excess can be harmful and lead to gastrointestinal issues and anaemia. In rat liver, high doses of garlic powder (200 mg/kg) significantly damaged cells in a way that was not seen at lower concentrations (Didry *et al*., 1992). Garlic's harmful effects could be noticeably lessened in lower quantities. Adults should take 4 g (1-2 cloves) of raw garlic daily and 300 mg of dried garlic tablets (standardized to 1-3% alliin or 0.6% allicin) to promote their health (Tattelman, 2005). Many surgeons advised against administering high doses of garlic up to seven or ten days before surgery because it tended to extend bleeding times, as seen in a patient who experienced an epidural spontaneous hematoma. Previous in vivo studies showed that while administering 5 mL/kg of raw garlic juice caused stomach damage that ultimately ended in death, continuous feeding of raw garlic in high dosages caused weight loss and anaemia due to red blood cells (RBCs) lysis (Mathew and Biju, 2008).

Ethnoveterinary Uses of Garlic

Garlic is also used as ethnoveterinary medicine, either in combination with other herbs or some herbal mixture preparation for a few animal diseases like a tympany, ectoparasites (Lice, Ticks and Mites), Foot and Mouth disease, herbal masala bolus for all digestive problems, and in curing poultry diseases. Ingredients, procedures and preparation are mentioned.

(i) Tympany (Bulged Stomach and Difficulties Breathing)

10-gram garlic (Lashun), 50 gm rock salt, ten numbers of betel leaves (*Paan*), 10 grams of pepper (*Kallimirch*) and 20-gram ginger (Adrak) crushed and mixed in lukewarm water and administered orally at 6 hours intervals for curing tympany in large animals.

(ii) Ectoparasites (Lice, Ticks and Mites)

Due to the infestation of ectoparasites (Lice, Ticks and Mites), the animal becomes thin, weak, and dull, leading to death in severe cases. A paste is prepared with 10-20 gm each of Tulsi, garlic, neem leaves, turmeric and seeds of Sitaphal and boiled in 250 ml of neem oil. The surface of the body of large animals is treated with this preparation to get rid of these ectoparasites.

(iii) Foot and Mouth Disease

A mixture is prepared through a grinder by mixing water from coconut kernel extract (one coconut), turmeric 200 gm (freshly harvested rhizome preferred), garlic 100 gm, *Aloe vera* 200 gm, palm jaggery 200 gm, common salt 100 gm, pepper 50 gm, cumin 50 gm, fenugreek 50 gm. Then, the powder of pepper, cumin, fenugreek, and all the ingredients were thoroughly mixed and added, and the amount of water to make was added to 1 litre. Filter it. Adult animals are given 100 ml at a time. Young ones or goats and sheep 50 ml at a time. Before applying the treatment, the animal should be fed about two bananas with sesame oil (50ml).

(iv) Treatment of Wounds in the Foot Region

Grind the herbal items like sesame oil 1 litre, Haldi (freshly harvested preferred or turmeric powder 50 g) 100 g, garlic 50 g; neem leaves 10 g, Mehandi (*Lawsonia inermis*) leaves Kuppi (*Acalypa India*) 10 g mix with the oil and boil the oil well, filter it and store in a bottle. Thailam can be applied over the affected foot region of animals for three days continuously or till the wound is cured.

(v) Herbal Masala Bolus for all Digestive Problems

Three different types of mixtures (Mixtures 1,2 and 3) are mixed thoroughly, and a bolus of 100 gm each (lemon fruit size) is prepared, and orally, it is to be administered. It can be administered preferably

on an empty stomach once a month. Young animals like calves, sheep, or goats can be treated with half the quantity or the estimated quantity according to the body weight of the animals. This preparation gives good results in digestive problems, viz. indigestion, impaction and anorexia. It also fulfils the function of preventive medicine for foot and mouth disease: fever, hemorrhagic, mastitis, blue tongue and septicaemia.

Ingredients

Mixture 1(dry): Black pepper, jeera, coriander seeds, fenugreek, ajwains, red chillies.

Mixture 2 (fresh herb): *Aloe vera*, curry leaf, garlic, tulsi, ginger, turmeric, coconut (grated), galo and tarwar

Mixture 3: Jaggery (after making into small pieces) and Rock salt (Sodium bicarbonate),

(vi) Poultry Disease

a) Ranikhet disease

In the case of Ranikhet disease, chop together leaves of return (*Pergularia daemia*) 20 gm, fresh haldi (turmeric: *Curcuma longa*) 20 gm., leaves of kirayat (*Andrographis paniculata*) 20 gm, garlic 20 gm and onion 20 gm. Feed with other poultry feed occasionally as preventive or curative treatment.

b) Lice infestation of poultry

Symptoms. Small, white lice lay eggs on the feathers; lice move on skin and feathers; slower weight gain; reduced egg production; birds constantly peck at themselves or scratch themselves with their beak. Ground together and boiled in 250 ml of neem oil garlic, neem leaves, tulsi,custa seeds, and haldi (turmeric), each of 10-20 gm is applied over the body's surface of 10-15 birds.

CONCLUSION

Garlic (*Allium sativum* L), from crushed to capsules, has been reported to various biological activities and consumed from ancient times as a spice or medicine worldwide. Crushed garlic produces the active compound allicin, allowing the enzyme alliinase to act on the stable precursor allicin. Many researchers have tried to find garlic and its bioactive compounds, successfully treating various life-threatening diseases and disorders. The concept of this review paper demonstrated the broad spectrum of garlic for its potential bioactive compound and therapeutic uses. This paper attempted to provide the gateway for the other researchers to gather the essential ideas and information for further study towards the clinical trials to be carried out to confirm the health benefits and efficacy of this important medicinal plant, and special attention should be paid to the side effects of garlic if any.

AUTHOR CONTRIBUTIONS

Both authors played a significant role regarding the conceptual framework towards reviewing the literature, collecting essential ideas and information, analysing and interpreting, and finally preparing the manuscript.

CONFLICT OF INTEREST

The authors have no conflict of interest.

REFERENCES

Ahmad TA, El-Sayed BA, El-Sayed LH. 2016. Development of immunization trials against Eimeria spp. *Trials in Vaccinol* **5**: 38-47.

Ajayi GO, Adeniyi TT, Babayemi DO. 2009. Hepatoprotective and some haematological effects of *Allium sativum* and vitamin C in lead-exposed Wistar rats. *Int J Med Med Sci* **1**: 064-7.

Andrianova IV, Sobenin IA, Sereda EV, Borodina LI, Studenikin MI. 2003. Effects of the long-acting garlic tablets "Allicor" on the incidence of acute respiratory viral infections in children. *Ter Arkh* **78**: 53-6.

Ankri S, Mirelman D. 1999. Antimicrobial properties of allicin from garlic. *Microbes Infect* **2**: 125-129.

Appel E, Vallon-Eberhard A, Rabinkov A, Brenner O, Shin I, Sasson K, Shadkchan Y, Osherov N, Jung S, Mirelman D. 2010. Therapy of murine pulmonary aspergillosis with antibody-alliinase conjugates and alliin. *Antimic Agents Chemoth* **54**: 898-906.

Arreola R, Quintero-Fabián S, López-Roa RI, Flores-Gutiérrez EO, Reyes-Grajeda JP, Carrera-Quintanar L, Ortuño-Sahagún D. 2015. Immunomodulation and anti-inflammatory effects of garlic compounds. *J Immunol Res* **2015**: 401630. doi: 10.1155/2015/401630

Asdaq SM, Inamdar MN. 2010. The potential of garlic and its active constituent, S-allyl cysteine, as antihypertensive and cardioprotective in the

presence of captopril. *Phytomed* **17**: 1016–1026. doi: 10.1016/j.phymed.2010.07.012.

Asdaq SMB, Inamdar MN. 2011. Pharmacodynamic and pharmacokinetic interactions of propranolol with garlic (*Allium sativum*) in rats. *Evid Based Complement Altern Med* 824042. DOI: 10.1093/ecam/neq076

Askari M, Mozaffari H, Darooghegi Mofrad M, Jafari A, Surkan PJ, Amini MR, Azadbakht L. 2021. Effects of garlic supplementation on oxidative stress and antioxidative capacity biomarkers: a systematic review and meta-analysis of randomized controlled trials. *Phytother Res* **35**: 3032-45.

Aslani N, Entezari MH, Askari G, Maghsoudi Z, Maracy MR. 2016. Effect of garlic and lemon juice mixture on lipid profile and some cardiovascular risk factors in people 30-60 years old with moderate hyperlipidaemia: a randomized clinical trial. *Int J Prev Med* **7**.

Avato P, Tursil E, Vitali C, Miccolis V, Candido V. 2000. Allylsulfide constituents of garlic volatile oil as antimicrobial agents. *Phytomed* **7**: 239–243. 10.1016/s0944-7113(00)80010-0

Ban JO, Oh JH, Kim TM, Kim DJ, Jeong HS, Han SB, Hong JT. 2009. Anti-inflammatory and arthritic effects of thiacremonone, a novel sulfur compound isolated from garlic via inhibition of NF-κB. *Arthritis Res Ther* **11**: 1-3.

Bayan L, Koulivand PH, Gorji A. 2014. Garlic: a review of potential therapeutic effects. *Avicenna J Phytomed* **4**: 1.

Bhandari PR. 2012. Garlic (*Allium sativum* L.): a review of potential therapeutic applications. *Int J Green Pharm* Article 102826, doi: 10.4103/0973-8258.

Bin C, Al-Dhabi NA, Esmail GA, Arokiyaraj S, Arasu MV. 2020. Potential effect of *Allium sativum* bulb for the treatment of biofilm-forming clinical pathogens recovered from periodontal and dental caries. *Saudi J Biol Sci* **27**: 1428-34.

Bolton S, Null G, Troetel WH. 1982. The medicinal uses of garlic-fact or fiction. *Am Pharm* **22**: 448-451.

Borek C. 2001. Antioxidant Health Effects of Aged Garlic Extract. *The J Nutrition* **131**: 1010S–1015S.

Borrelli F, Capasso R, Izzo AA. 2007. Garlic (*Allium sativum* L.): adverse effects and drug interactions in humans. *Mol Nutr Food Res* **51**: 1386-97.

Bradley JM, Organ CL, Lefer DJ. 2016. Garlic-derived organic polysulfides and myocardial protection. *J Nutr* **146**: 403S-9S.

Brown DG, Wilkerson EC, Love WE. 2015. A review of traditional and novel oral anticoagulant and antiplatelet therapy for dermatologists and dermatologic surgeons. *J Am Acad Dermatol* **72**: 524-34.

Capasso, A. 2013. Antioxidant action and therapeutic efficacy of *Allium sativum* L. *Molecules* **18**: 690–700.

Charu K, Yogita S, Sonali S. 2014. Neutraceutical potential of organosulfur compounds in fresh garlic and garlic preparations. *Int J Pharm Bio Sci* **5**: 112-26.

Cruz C, Correa-Rotter R, Sánchez-González DJ, Hernández-Pando R, Maldonado PD, Martínez-Martínez CM, Medina-Campos ON, Tapia E, Aguilar D, Chirino YI, Pedraza-Chaverri J. 2017. Renoprotective and antihypertensive effects of S-allylcysteine in 5/6 nephrectomized rats. *Am J Physiol-Ren Physiol* **293**: F1691-8.

Dehghani S, Alipoor E, Salimzadeh A, Yaseri M, Hosseini M, Feinle-Bisset C, Hosseinzadeh-Attar MJ. 2018. The effect of a garlic supplement on the pro-inflammatory adipocytokines, resistin and tumor necrosis factor-alpha, and on pain severity, in overweight or obese women with knee osteoarthritis. *Phytomed* **48**: 70-5.

Dethier B, Nott K, Fauconnier ML. 2013. (Bio) synthesis, extraction and purification of garlic derivatives showing therapeutic properties. In: National Symposium on Applied Biological Sciences. Faculty of Bioscience Engineering, Ghent, Belgium.

Didry N, Dubreuil L, Pinkas M. 1992. Antimicrobial activity of naphthaquinones and *Allium* extracts combined with antibiotics. *Pharmacol Acta Helv* **67**: 148-151.

Diretto G, Rubio-Moraga A, Argandoña J, Castillo P, Gómez-Gómez L, Ahrazem O. 2017. Tissue-specific accumulation of sulfur compounds and saponins in different parts of garlic cloves from purple and white ecotypes. *Molecules* **22**: 1359.

Dirsch VM, Kiemer AK, Wagner H, Vollmar AM. 1998. Effect of allicin and ajoene, two compounds of garlic, on inducible nitric oxide synthase. *Atherosclerosis* **139**: 333-9.

Drobiova H, Thomson M, Al-Qattan K, Peltonen-Shalaby R, Al-Amin Z, Ali M. 2011. Garlic increases antioxidant levels in diabetic and hypertensive rats, determined by a modified peroxidase method. *Evid Based Complement Alternat Med* **2011**: 703049. doi: 10.1093/ecam/nep011.

Dubey H. 2012. Allicin, a SUR2 opener: possible mechanism for the treatment of diabetic hypertension in rats. *Rev Bras Farmacogn* **22**: 1053-1059.

El-Saber Batiha G, Magdy Beshbishy A, G. Wasef L, Elewa YH, A. Al-Sagan A, Abd El-Hack ME, Taha AE, M. Abd-Elhakim Y, Prasad Devkota H. 2020. Chemical constituents and pharmacological activities of garlic (*Allium sativum* L.): A review. *Nutrients* **12**: 872.

Fasolino I, Izzo AA, Clavel T, Romano B, Haller D, Borrelli F. 2015. Orally administered allyl sulfides from garlic ameliorate murine colitis. *Mol Nutr Food Res* **59**: 434–442. doi: 10.1002/mnfr.201400347.

Fratianni F, Riccardi R, Spigno P, Ombra MN, Cozzolino A, Tremonte P, Coppola R, Nazzaro F. 2016. Biochemical characterization and antimicrobial and antifungal activity of two endemic varieties of garlic (*Allium sativum* L.) of the Campania region, southern Italy. *J Med Food* **19**: 686-91.

Gebreyohannes G, Gebreyohannes M. 2013. Medicinal values of garlic: A review. *Int J Medicine and Medical Sci* **5**: 401-408.

Gruhlke MC, Nwachwukwu I, Arbach M, Anwar A, Noll U, Slusarenko AJ. 2010. Allicin from garlic, effective in controlling several plant diseases, is a reactive sulfur species (RSS) that pushes cells into apoptosis. In: Modern fungicides and antifungal compounds VI. 16th International Reinhardsbrunn Symposium, Friedrichroda, Germany, Deutsche Phytomedizinische Gesellschaft eV Selbstverlag, pp. 325-330.

Guo YJ. 2014. Experimental study on the optimization of extraction process of garlic oil and its antibacterial effects. *Afr J Tradit Complement Altern Med* **11**: 411–414.

Hodge G, Davis S, Rice M, Tapp H, Saxon B, Revesz T. 2008. Garlic compounds selectively kill childhood pre-B acute lymphoblastic leukemia cells in vitro without reducing T-cell function: Potential therapeutic use in the treatment of ALL. *Biologics: Targets Therapy* **2**: 143-9.

Hu X, Cao BN, Hu G, He J, Yang DQ, Wan YS. 2002. Attenuation of cell migration and induction of cell death by aged garlic extract in rat sarcoma cells. *Int J Mol Med* **9**: 641-3.

Ishikawa H, Saeki T, Otani T, Suzuki T, Shimozuma K, Nishino H, Fukuda S, Morimoto K. 2006. Aged garlic extract prevents a decline of NK cell number and activity in patients with advanced cancer. *J Nutr* **136**: 816S-82OS.

Jang HJ, Lee HJ, Yoon DK, Ji DS, Kim JH, Lee CH. 2018. Antioxidant and antimicrobial activities of fresh garlic and aged garlic by-products extracted with different solvents. *Food Sci Biotechnol* **27**: 219-25.

Jones MG, Collin HA, Tregova A, Trueman L, Brown L, Cosstick R, Hughes J, Milne J, Wilkinson MC, Tomsett AB, Thomas B. 2007. The biochemical and physiological genesis of alliin in garlic. *Med Arom Pl Sci Biotech* **1**: 21-4.

Josling P. 2001. Preventing the common cold with a garlic supplement: A double-blind, placebo-controlled survey. *Adv Ther* **18**: 189–193.

Kahn G. 1996. History of garlic. In Koch HP, Lawson LD, eds. Garlic: The Science and Therapeutic Application of *Allium sativum* L. and Related Species. Williams and Wilkins, New York, NY. pp. 25-36.

Kaur G, Padiya R, Adela R, Putcha UK, Reddy GS, Reddy BR, Kumar KP, Chakravarty S, Banerjee SK. 2016. Garlic and resveratrol attenuate diabetic complications, loss of β-cells, pancreatic and hepatic oxidative stress in streptozotocin-induced diabetic rats. *Front Pharmacol* **7**: 360.

Khade YP, Thangasamy A, Gorrepati K. 2017. Garlic production technology. *Indian Horticulture* **62**: 57-59. https://epubs.icar.org.in/index.php/IndHort/article/view/87715

Kim SM, Kubota K, Kobayashi A. 1997. Antioxidative activity of sulfur-containing flavor compounds in garlic. *Biosci Biotechnol Biochem* **61**: 1482-5.

Ko JW, Jeong SH, Kwon HJ, Shin NR, Seo YS, Kim JC, Shin IS, Kim JS. 2018. Preventive effect of garlic oil and its organosulfur component diallyl-disulfide on cigarette smoke-induced airway inflammation in mice. *Nutrients* **10**: 1659.

Koca BT, Tasci B. 2016. Garlic as a functional food. *Acta Hortic* **1143**: 139-146. DOI: 10.17660/ActaHortic.2016.1143.20.

Lanzotti V, Scala F, Bonanomi G. 2014. Compounds from Allium species with cytotoxic and antimicrobial activity. *Phytochem Rev* **13**: 769-791.

Lee HS. 2016. Antiobesity effect of garlic extract fermented by Lactobacillus plantarum BL2 in diet-induced obese mice. *J Med Food* **19**: 823-829.

Lee SK, Park YJ, Ko MJ, Wang Z, Lee HY, Choi YW, Bae YS. 2015. A novel natural compound from garlic (*Allium sativum* L.) with therapeutic effects against experimental polymicrobial sepsis. *Biochem Biophy Res Commun* **464**: 774-9.

Lemar KM, Miguel AA, Sonia C, Brian O, Carsten TM, David L. 2007. Diallyl disulphide depletes glutathione in Candida albicans: oxidative stress mediated cell death studied by two-photon microscopy. *Yeast* **24**: 695-706.

Li WQ, Zhang JY, Ma JL, Li ZX, Zhang L, Zhang Y, Guo Y, Zhou T, Li JY, Shen L, Liu WD. 2019. Effects of Helicobacter pylori treatment and vitamin and garlic supplementation on gastric cancer incidence and mortality: follow-up of a randomized intervention trial. *BMJ* **366**: l5016. doi: 10.1136/bmj.l5016.

Li X, Kim HY, Cui HZ, Cho KW, Kang DG, Lee HS. 2010. Water extract of Zanthoxylum piperitum induces vascular relaxation via endothelium-dependent NO-cGMP signaling. *J Ethnopharmacol* **129**: 197–202. doi: 10.1016/j.jep.2010.03.003.

Li Z, Le W, Cui Z. 2018. A novel therapeutic anticancer property of raw garlic extract via injection but not ingestion. *Cell Death Discov* **4**:108.

Liu X, Baecker A, Wu M, Zhou JY, Yang J, Han RQ, Wang PH, Liu AM, Gu X, Zhang XF, Wang XS. 2019. Raw garlic consumption and risk of liver cancer: A population-based case-control study in Eastern China. *Nutrients* **11**: 2038.

Makheja AN, Bailey JM. 1990. Antiplatelet constituents of garlic and onion. *Agents Actions* **29**: 360-3. doi: 10.1007/BF01966468.

Martins N, Petropoulos S, Ferreira IC. 2016. Chemical composition and bioactive compounds of garlic (Allium sativum L.) as affected by pre- and post-harvest conditions: A review. *Food Chem* **211**: 41-50.

Mathew B, Biju R. 2008. Neuroprotective effects of garlic: a review. *Libyan J Med* **3**: 23–33.

Melguizo-Rodríguez L, García-Recio E, Ruiz C, De Luna-Bertos E, Illescas-Montes R, Costela-Ruiz VJ. 2022. Biological properties and therapeutic applications of garlic and its components. *Food Funct* **13**: 2415-2426. doi: 10.1039/d1fo03180e.

Metwally DM, Al-Olayan EM, Alanazi M, Alzahrany SB, Semlali A. 2018. Antischistosomal and anti-inflammatory activity of garlic and allicin compared with that of praziquantel *in vivo*. *BMC Compl Altern Med* **18**: 1-1.

Miraghajani M, Rafie N, Hajianfar H, Larijani B, Azadbakht L. 2018. Aged garlic and cancer: A systematic review. *Int J Prev Med* **9**: 84.

Morihara N, Hino A, Miki S, Takashima M, Suzuki JI. 2017. Aged garlic extract suppresses inflammation in apolipoprotein E-knockout mice. *Mol Nutr Food Res* **61**: 1700308.

Moutia M, Habti N, Badou A. 2018. *In vitro* and *in vivo* immunomodulator activities of *Allium sativum* L. *Evid Based Compl Alternat Med* **2018**: 4984659. doi: 10.1155/2018/4984659.

Moyers S. 1996. History of garlic. In: Garlic in Health, History and World Cuisine. Suncoast Press, St. Petersburg, FL.

Muluneh Bekele Etana. 2018. Review on the Agronomic Management Practices of Garlic (*Allium sativum* L.). *J Biol Agric Healthcare* **8**.

Nakagawa S, Masamoto K, Sumiyoshi H, Kunihiro K, FUWA T. 1980. Effect of raw and extracted-aged garlic juice on growth of young rats and their organs after peroral administration. *J Toxicol Sci* **5**: 91-112.

Nicastro HL, Ross SA, Milner JA. 2015. Garlic and onions: their cancer prevention properties. *Cancer Prev Res (Phila)* **8**: 181-9. doi: 10.1158/1940-6207.CAPR-14-0172.

Nwachukwu ID, Slusarenko AJ, Gruhlke MC. 2012. Sulfur and sulfur compounds in plant defence. *Nat Prod Commun* **7**: 1934578X1200700323.

Ogita A, Nagao Y, Fujita KI, Tanaka T. 2007. Amplification of vacuole-targeting fungicidal activity of antibacterial antibiotic polymyxin B by allicin, an allyl sulfur compound from garlic. *The J Antibiot* **60**: 511-518.

Okoro BC, Dokunmu TM, Okafor E, Sokoya IA, Israel EN, Olusegun DO, Bella-Omunagbe M, Ebubechi UM, Ugbogu EE. 2023. The Ethnobotanical, Bioactive Compounds, Pharmacological Activities and Toxicological Evaluation of Garlic (*Allium sativum*): A Review. *Pharmacol Res-Mod Chin Med* **100273**.

Pandrangi, A. 2015. Cancer Chemoprevention by Garlic – A Review, *Hereditary Genet* **4**:147.

Park BM, Cha SA, Kim HY, Kang DK, Yuan K, Chun H, Chae SW, Kim SH. 2016. Fermented garlic extract decreases blood pressure through nitrite and sGC-cGMP-PKG pathway in spontaneously hypertensive rats. *J Funct Foods* **22**: 156–165. doi: 10.1016/j.jff.2016.01.034.

Park BM, Chun H, Chae SW, Kim SH. 2017. Fermented garlic extract ameliorates monocrotaline-induced pulmonary hypertension in rats. *J Funct Foods* **30**: 247-53.

Pârvu M, Pârvu AE, Vlase L, Rosca-Casian O, Pârvu O, Puscas M. 2011. Allicin and alliin content and antifungal activity of *Allium senescens* L. ssp. montanum (FW Schmidt) Holub ethanol extract. *J Med Plants Res* **5**: 6544-9.

Petrovic V, Nepal A, Olaisen C, Bachke S, Hira J, Søgaard CK, Røst LM, Misund K, Andreassen T, Melø TM, Bartsova Z. 2018. Anti-cancer potential of homemade fresh garlic extract is related to increased endoplasmic reticulum stress. *Nutrients* **10**: 450.

Petrovska BB, Cekovska S. 2010. Extracts from the history and medical properties of garlic. *Pharmacogn Rev* **4**: 106.

Rahman K, Lowe GM. 2006. Garlic and cardiovascular disease: a critical review. *J Nutr* **136**: 736S-40S.

Rahman MS. 2007. Allicin and Other Functional Active Components in Garlic: Health Benefits and Bioavailability. *Int J Food Prop* **10**: 245–268. doi: 10.1080/10942910601113327.

Rana SV, Pal R, Vaiphei K, Sharma SK, Ola RP. 2011. Garlic in health and disease. *Nutr Res Rev* **24**: 60-71.

Ried K. 2020. Garlic lowers blood pressure in hypertensive subjects, improves arterial stiffness and gut microbiota: A review and meta-analysis. *Exp Ther Med* **19**: 1472–1478.

Rivlin RS. 1998. Patient with hyperlipidemia who received garlic supplements. *Lipid Manag.* Report from the Lipid Education Council **3**: 6-7.

Rivlin RS. 2001. Historical perspective on the use of garlic. *J Nutr* **131**: 951S-954S.

Rodrigues C, Percival SS. 2019. Immunomodulatory effects of glutathione, garlic derivatives, and hydrogen sulfide. *Nutrients* **11**: 295.

Sabitha P, Adhikari PM, Shenoy SM.2005. Efficacy of garlic paste in oral candidiasis. *Trop Doct* **35**: 99-100.

Sampath Kumar KP, Debjit Bhowmik, Chiranjib, Pankaj Tiwari, Rakesh Kharel. 2010. *Allium sativum* and its health benefits: An overview. *J Chem Pharm Res* **2**: 135-146.

Sangouni, AA. 2021. Effects of garlic powder supplementation on metabolic syndrome components, insulin resistance, fatty liver index, and appetite in subjects with metabolicsyndrome: A randomized clinical trial, *Phytother Res* **35**: 4433–4441.

Sausbier M, Schubert R, Voigt V, Hirneiss C, Pfeifer A, Korth M, Kleppisch T, Ruth P, Hofmann F. 2000. Mechanisms of NO/cGMP-dependent vasorelaxation. *Circ Res* **87**: 825–830. doi: 10.1161/01.RES.87.9.825

Shang A, Cao SY, Xu XY, Gan RY, Tang GY, Corke H, Mavumengwana V, Li HB. 2019. Bioactive compounds and biological functions of garlic (*Allium sativum* L.). *Foods* **8**: 246.

Shanmugavelv KG, Kumar N, Peter KV. 2002. Production technology of spices and plantation crops. Agrobios, Jodhpur, India.

Shashikanth KN, Basappa SC, Murthy VS. 1986. Effect of feeding raw and boiled garlic (A. *sativum* L.) extracts on the growth, caecal microflora and serum proteins of albino rats. *Nutr Rep Int* **33**: 313-9.

Shashikanth KN, Basappa SC, Sreenivasamurthy V. 1985. Allicin concentration in the gut of rats and its influence on the microflora. *J Food Sci Technol* **22**: 440-2.

Shokrzadeh M, Ebadi AG. 2006. Antibacterial effect of garlic (*Allium sativum* L.) on Staphylococcus aureus. *Pak J Biol Sci* **9**: 1577–1579.

Singh R, Singh K. 2019. Garlic: a spice with wide medicinal actions. *J Pharm and Phytochem* **8**: 1349–1355.

Singh V, Kumar R. 2017. Study of Phytochemical Analysis and Antioxidant Activity of *Allium sativum* of Bundelkhand Region. *Int J Life Sci Sci Res* **3**: 1451-1458.

Sobenin I, Andrianova I, Ionova V, Karagodin V, Orekhov. 2012. Anti-aggregatory and fibrinolytic effects of time-released garlic powder tablets. *Appl Technol Innov* **7**: 1.

Steinmetz KA, Kushi LH, Bostick RM, Folsom AR, Potter JD. 1994. Vegetables, fruit, and colon cancer in the lowa women's health study. *Am J epidemiology* **139**: 1-5.

Subrahmanyan V, Krishnamurthy K, Sreenivasamurthy V, Swaminathan M. 1958. The effect of garlic on certain intestinal bacteria. *Food Sci* **7**: 223-4.

Subramanian MS, Nandagopal MS, Amin Nordin S, Thilakavathy K, Joseph N. 2020. Prevailing knowledge on the bioavailability and biological activities of sulphur compounds from alliums: A potential drug candidate. *Molecules* **25**: 4111. https://doi.org/10.3390/molecules25184111

Suddek GM. 2014. Allicin enhances chemotherapeutic response and ameliorates tamoxifen-induced liver injury in experimental animals. *Pharm Biol* **52**: 1009–1014.

Szychowski KA, Rybczynska-Tkaczyk K, Gawel-Beben K, Swieca M, Karas M, Jakuczyk A, Matysiak M, Binduga UE, Gminski J. 2018. Characterization of active compounds of different garlic (*Allium sativum* L.) cultivars. *Pol J Food Nutr Sci* **68**: 73-81. doi: 10.1515/pjfns-2017-0005

Takashima M, Kanamori Y, Kodera Y, Morihara N, Tamura K. 2017. Aged garlic extract exerts endothelium-dependent vasorelaxant effect on rat aorta by increasing nitric oxide production. *Phytomed* **24**: 56–61. doi: 10.1016/j.phymed.2016.11.016

Tattelman E. 2005. Health effects of garlic. *Am Fam Physician* **72**: 103-106

Thomson M, Al-Qattan KK, Js D, Ali M. 2016. Anti-diabetic and antioxidant potential of aged garlic extract (AGE) in streptozotocin-induced diabetic rats. *BMC Complement Altern Med* **16**: 1-9.

Ushijima M, Takashima M, Kunimura K, Kodera Y, Morihara N, Tamura K. 2018. Effects of S-1-propenylcysteine, a sulfur compound in aged garlic extract, on blood pressure and peripheral circulation in spontaneously hypertensive rats. *J Pharm Pharmacol* **70**: 559-65.

Wallock-Richards D, Doherty CJ, Doherty L, Clarke DJ, Place M, Govan JR, Campopiano DJ. 2014. Garlic revisited: antimicrobial activity of allicin-containing garlic extracts against Burkholderia cepacia complex. *PLoS One* **9**: e112726.

Wang J, Zhang X, Lan H, Wang W. 2017. Effect of garlic supplement in the management of type 2 diabetes mellitus (T2DM): a meta-analysis of randomized controlled trials. *Food Nutr Res* **61**: 1377571.

Waris Q, Ashfaq T. 2013. Role of Garlic Usage in Cardiovascular Disease Prevention: An Evidence-Based Approach. *J Evid Based Compl Altern Med* **2**: 1-9.

Yang DJ, Moh SH, Son DH, You S, Kinyua AW, Ko CM, Song M, Yeo J, Choi YH, Kim KW. 2016. Gallic acid promotes wound healing in normal and hyperglucidic conditions. *Molecules* **21**: 899.

Yarnell E. 2018. Herbs for Viral Respiratory Infections. *Altern Complement Ther* **24**: 35–43.

Yi LV, Kwok-Fai SO, Nai-Kei WO, Jia XI. 2019. Anti-cancer activities of S-allylmercaptocysteine from aged garlic. *Chin J Nat Med* **17**: 43-9.

You WC, Brown LM, Zhang L, Li JY, Jin ML, Chang YS, Ma JL, Pan KF, Liu WD, Hu Y, Crystal-Mansour S. 2006. Randomized double-blind factorial trial of three treatments to reduce the prevalence of precancerous gastric lesions. *J Natl Cancer Inst* **98**: 974-83.

Yousuf S, Ahmad A, Khan A, Manzoor N, Khan LA. 2010. Effect of diallyldisulphide on an antioxidant enzyme system in *Candida* species. *Can J Microbiol* **56**: 816-21.

Zamani Taghizadeh Rabe S, Ghazanfari T, Siadat Z, Rastin M, Zamani Taghizadeh Rabe S, Mahmoudi M. 2015. Anti-inflammatory effect of garlic 14-kDa protein on LPS-stimulated-J774A.1 macrophages. *Immunopharmacol Immunotoxicol* **37**: 158-64.

Zhang N, Xuesong Huang, Yanhua Zeng, Xiyang Wu, Xichun Peng, 2013. Study on prebiotic effectiveness of neutral garlic fructan *in vitro*. *Food Sci Human Wellness* **2**: 119-123

Zhang N. 2013. Study on prebiotic effectiveness of neutral garlic fructan *in vitro*. *Food Sci Hum* **2**: 119–123.

Zhang Y, Liu X, Ruan J, Zhuang X, Zhang X, Li Z. 2020. Phytochemicals of garlic: Promising candidates for cancer therapy. *Biomed Pharmacother* **123**: 109730.

Zhou X, Qian H, Zhang D, Zeng L. 2020. Garlic intake and the risk of colorectal cancer: A meta-analysis. *Medicine (Baltimore)* **99**: e18575. doi: 10.1097/MD.0000000000018575.