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Garlic as food, spice and medicine: A perspective

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ABSTRACT

From ancient time garlic has been used as food, spice and household medicine for several common problems such as high cholesterol, high blood pressure, skin problems and fungal infections while its biological function is to repel herbi-voruous animals. The word garlic derived from the Germanic word being composed of two elements. One is *gar* means spear and refers to the pointed leaves and second element *lic* which generally mean either leek or onion. The therapeutic effect of garlic is due to organic sulfur compound such as alliin which metabolize to other sulphur compounds such as allicin, ajoene, allyl sulfides and vinylidithiines. This review covers the study of pharmacognosy, phytochemistry, pharmacology, its valuable effects, different herbal formulas for various diseases, garlic preparations, marketed formulations along with its major side effects and contraindication.

Key words: Garlic, Allin, allicin, Pharmacognosy, Phytochemistry, Pharmacology

INTRODUCTION

Garlic, probably nature's most potent food, is a vegetable belongs to the *Allium* (*Allium sativum*), a class of bulb-shaped plants belongs to the family Liliaceae.^[1] It is an important condiment crop in the country. It is not only a herb used as spice and food but also possess medicinal properties.

PHARMACOGNOSY

Vernacular names^[2] :

Sansk. : Rasona, Yavanesta

Assam : Maharu

Beng. : Lasuna

Eng. : Garlic

Guj. : Lasan, Lassun

Hindi. : Lahasun

Kan. : Billuci

Mal. : Vellulli, Nelluthulli

Mar. : Lasun

Tam. : Vellaipoondu

Tel. : Vellulli, Tellapya, Tellagadda

Urdu. : Lahsan, Seer

Description^[2]

a) Macroscopic character:

Drug occurs as entire bulb or isolated cloves (bulblets); bulb sub-globular, 4-6 cm in diameter, consisting of 8-20 cloves, surrounded by 3-5 whitish papery membranous scales attached to a short, disc-like woody stem having numerous, wiry rootlets on the under side; each clove is irregularly ovoid, tapering at upper end with dorsal convex surface, 2-3 cm long, 0.5 - 0.8 cm wide, each surrounded by two very thin papery whitish and brittle scales having 2-3 yellowish green folded leaves contained within two white fleshy, modified leaf bases or scales; odour is pungent and disagreeable. Taste is acrid.

b) Microscopic character:

A clove of bulb shows tri to tetragonal appearance in outline; outer scale consists of an outer epidermis, followed by hypodermal crystal layer, mesophyll made of parenchyma cells and an inner epidermis; both outer and inner epidermis consists of sub rectangular cells; hypodermis consists of compressed, irregular, tangentially elongated cells, each cell having large prismatic crystals of calcium oxalate, while many cells contain small prismatic crystals also, mesophyll several layers of parenchymatous cells having a few vascular tissues with spiral vessels; inner epidermis similar to outer one; inner scale similar to outer scale but outer epidermis composed of sclerenchymatous cells; prismatic crystals in

hypodermis slightly smaller. In surface view cells of outer epidermis elongated, narrow with thin porous wall while those of inner epidermis similar to outer one but non-porous; cells of hypodermal crystals of calcium oxalate, many cells also contain small prismatic crystals in addition to bigger ones; inner scale shows markedly sclerenchymatous cells with greatly thickened walls and very narrow lumen; cells of hypodermal crystal layer somewhat smaller with walls more frequently pitted, size of crystals also smaller.

Identity, Purity and Strength

Foreign matter	: not more than 2 Percent
Total ash	: not more than 4 Percent
Acid-insoluble ash	: not more than 1 Percent
Alcohol-soluble extractive	: not less than 2.5 Percent
Loss on drying	: not less than 60 Percent
Volatile Oil Not	: less than 0.1 Percent

Dose as per WHO

For adults daily dose is 2 to 5 g of fresh garlic (approximately one clove), 0.4 to 1.2 g of dried garlic powder, 2 to 5 mg of garlic oil, 300 to 1,000 mg of garlic extract, or other formulations that are equal to 2 to 5 mg of allicin.

PHYTOCHEMISTRY

Garlic contains a number of organic sulfur compounds e.g. alliin, allicin (allyl 2-propenethiosulfinate or diallyl thiosulfinate), ajoene, diallyl trisulfide, S-allylcysteine, vinylidithiines, S-allylmercaptocystein, and others which are responsible both for garlic's pungent odor and its therapeutic effects.

Garlic smell may be present in sweat and breathe following heavy consumption because of garlic's strong-smelling sulfur compounds are metabolized, forming allyl methyl sulfide which cannot be digested so passed into the blood and excreted from lungs and the skin.^[3,4] Alliin, present in the undamaged cloves of garlic is odorless sulphur containing amino acid derivative (+) - S- allyl- L- cysteine sulfoxide constitutes 1.2% fresh weight of garlic.^[5] Enzymes present in garlic like allinase, peroxidases, myrosinase, vitamins such as vitamin A, vitamin B1 (thiamine), vitamin B2 (riboflavin), vitamin B6 and vitamin C, proteins, minerals like calcium, copper, iron, manganese, phosphorus, potassium and selenium, saponins, flavonoids, and maillard reaction products, which are non-sulfur containing compounds. One more non-sulfur compound, phytoalexin called allixin (3-hydroxy-5-methoxy-6-methyl-2-pentyl-4H-pyran-4-one) was found to be present with a γ -pyrone skeleton structure. Mechanical injury due to crushing of garlic activates the enzyme allinase which metabolizes alliin to allicin which is the key originator of garlic's bioactive compounds. Allicin is further metabolized to other sulfur compounds, including ajoene, allyl sulfides, and vinylidithiines.^[6-12] Allicin, di-allyl thiosulfinate or diallyl disulfide is an oily, yellow liquid with a characteristic odour slightly soluble in water and soluble in alcohol and decomposes on heating.^[13,14] In the body, it oxidizes the haemoglobin in the blood to methemoglobin. Thus decreases the ability of haemoglobin to carry oxygen. Allicin is a highly unstable compound but now it is possible to produce stable allicin using advanced technologies and stability of allicin can be evaluated by using different modern analytical techniques like gas chromatography, non healing HPLC.^[15] T.L.C. of the alcoholic extract on Silica gel 'G' plate using n-Butanol : Isopropanol : Acetic acid: Water (3: 1: 1: 1) as a solvent system shows presence of a variety of compounds^[2] shown in following table 1

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Table 1 : R_f values of some suspected compounds with their sensitivity

S.N.	R _f value of suspected compounds	Sensitivity
1.	0.58, 0.72 (both light blue)	UV (366 nm)
2.	0.18, 0.26, 0.34, 0.38, 0.46, 0.58, 0.72, 0.77 and 0.93 (all yellow)	Iodine vapour
3.	0.26, 0.38, 0.46, 0.58, 0.67, 0.72 and 0.93 (all pink)	Ninhydrin reagent
4.	0.26, 0.38, 0.46, 0.58, 0.67, 0.72 and 0.93 (all grey)	Vanillin-Sulphuric acid reagent

Nutritional Constituents [16]

Garlic holds all the best properties for which it is consider as a food. It has been used as a food for many of years. Traditionally it is used to add flavour to food. The nutritional value of garlic is described in the following table 2

Table 2 : Nutritional value of garlic

Nutritional value per 100 g (3.5 oz)			Energy 623kJ (149kcal)		
S.N.	Constituents	Quantity	S.N.	Constituents	Quantity
1.	Carbohydrate	33.06 g	12.	Folate (Vit. B ₉)	3 µg (1%)
2.	Sugar	1.0 g	13.	Vitamin C	31.2 mg (52%)
3.	Dietary fiber	2.1 g	14.	Calcium	181 mg (18%)
4.	Fat	0.5 g	15.	Iron	1.7 mg (14%)
5.	Protein	6.39 g	16.	Magnesium	25 mg (7%)
6.	Beta carotene	5 µg (0%)	17.	Phosphorus	153 mg (22%)
7.	Thiamine (Vit. B ₁)	0.2 mg (15%)	18.	Potassium	401 mg (9%)
8.	Riboflavin (Vit. B ₂)	0.11 mg (7%)	19.	Sodium	17 mg (1%)
9.	Niacin (Vit. B ₃)	0.7 mg (5%)	20.	Zinc	1.16 mg (12%)
10.	Pantothenic acid (B ₅)	0.596 mg (12%)	21.	Manganese	1.672 mg
11.	Vitamin B ₆	1.235 mg (95%)	22.	Selenium	14.2 µg

USES [17]

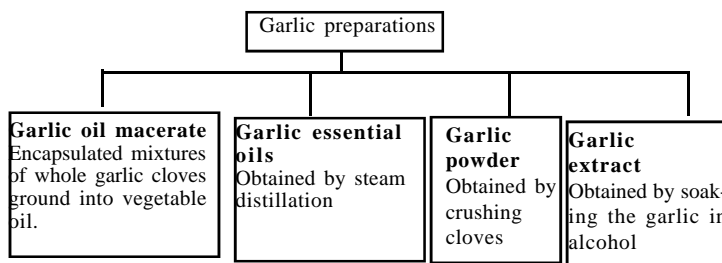
Antibacterial/Antifungal, Antimycotic/Antiviral, Hypoglycemic, Anticoagulant (antiplatelet aggregating), Fibrinolytic activity enhancement, Lipid lowering, Antioxidant /Anticancer, Hypotensive, Hepatoprotective, Immunomodulatory, Aphrodisiac, Expectorant, Stimulant, Diuretic, carminative etc.

Uses according to ancient medical text

- For the treatment of heart disease and arthritis (*Charaka-Samhita*).
- For the treatment of fatigue, parasitic disease, digestive disorder and leprosy *Bower Manuscript* (~300 AD).^[18]
- For the treatment of toothache, constipation, dropsy and plague.^[18]
- For the treatment of digestive disorders, infestation with worms and renal disorders, as well as to help mother during difficult childbirth.^[19]
- To aid respiration.^[20]

GARLIC PREPARATION

There are different formulations and herbal formulas^[21] of garlic are described in the following table no 3 and 4 respectively.



Some marketed formulations and herbal formulas^[21] of garlic are described in the following table no 3 and 4 respectively.

Table 3 : Marketed formulation of garlic

Brand name	Amount of allicin produced by the product
Allimax®	180 milligrams of allicin powder
Kwai™*	1.8 milligrams*
Garlique™*	5.0 milligrams*
Pure Gar™*	10.0 milligrams *
Garlimax™*	5.5 milligrams*
Garlic Powder™*	3.0 milligrams*

Table 4 : Some herbal formulas involving garlic

Formula	Consists of
Anticancer formula anti-plague formula	Broccoli, garlic juice, onions and ginger and few drops of graviola tincture Garlic, vinegar, comfrey root, wormwood, lobelia, marshmallow, white oak, black walnut, mullein, skullcap, uva-ursi
Asthma formula Respiratory Relief Syrup Cold sore relief formula Breathing Aid Formula	Extracts of Comfrey leaf, Mullein, Garlic and glycerin Onion Juice, Garlic Juice, Fennel, Nettle, Mullein and Chickweed Golden Seal Root, Garlic and Skullcap Brigham Tea, Horseradish, Marshmallow, Cayenne, Garlic, Rosehips, Watercress, and Feverfew.
Bowel Formula	Aloe, Senna, Cascara Sagrada, Gentian Root, Ginger Root, Garlic, Cayenne, Turkey Rhubarb, and Flax Seed also with X-Ceptic, Oak Bark, Golden Seal Root, Myrrh, Garlic and Capsicum

PHARMACOLOGICAL STUDY

Alliin exhibits antibacterial and anti-fungal properties.^[22] Wills E. D. reported that specific interference with the sulfhydryl enzymes may be the cause of alliin's antimicrobial properties.^[23]

Literature survey reveals that alliin may reduce chances of atherosclerosis and fat deposition maintain the lipoprotein level, decrease blood pressure, have anti-thrombotic and anti-inflammatory activities, and function as an antioxidant to some extent.^[24-32]

Alliin disables dysentery-causing amoebas by blocking two groups of enzymes, cysteine proteinases and alcohol dehydrogenases by reacting with one of their important components known as sulfhydryl (SH) groups, or thiols. Cysteine proteinases, a significant contributor to amebic virulence, as well as alcohol dehydrogenase, are strongly inhibited by alliin.^[33] Alliin inhibits the platelets aggregation in vitro without affecting cycloxygenase or thromboxane synthase activity c-AMP levels or altering the vascular prostaglandin synthase activity.^[34] Ajoene, chemically more stable than alliin, have anti-thrombosis, anti-microbial and cholesterol lowering activities. Ajoene strongly inhibits the metabolism of arachidonic acid by both cyclooxygenase and lipoxygenase pathways thus inhibiting the synthesis of thromboxane A2 and 12-HETE.^[35, 36] Antiaggregatory effect of ajoene may also be due to its direct interaction with the putative fibrinogen receptor (GPIIb/IIIa).^[37] It inhibits proliferation and induces apoptosis of several human leukaemia CD34-negative cells including HL-60, U937, HEL and OCIM-1.^[38] Topical application of ajoene may be useful in patients with skin basal cell carcinoma.^[39] It also shows activity against *Aspergillus niger*, *Candida albicans*, *Paracoccidioides-Brasiliensis*, and *Fusarium* species and act as antioxidants by inhibiting the interactions of leukocytes which mediate release of superoxide anion.^[21]

The two major compounds in aged garlic, S-allylcysteine and S-allylmercaptol-cysteine, were found to have highest scavenging activity. Allixin (3-hydroxy-5-methoxy-6-methyl-2-pentyl-4H-pyran-4-one), a non sulfur compound in garlic have anti-oxidative effects, anti-microbial effects, anti-tumor effects, inhibition of aflatoxin B2 DNA binding, and neurotrophic effects.^[40, 41]

Beneficial effects of garlic

Garlic as antioxidant

Rabinkov A. et al investigated the antioxidant properties of alliin and its precursor alliin in the Fenton oxygen-radical generating system [H₂O₂-Fe (II)] using the spin trapping technique and ESR. Alliin irreversibly inhibited SH-protease papain, NADP (+)-dependent alcohol dehydrogenase from *Thermoanaerobium brockii* (TBAD), and the NAD (+)-dependent alcohol dehydrogenase from horse liver.^[42] Aged garlic extract (AGE) is obtained by storing sliced raw garlic in 15-20 % ethanol for 20 months. Long-term extraction of garlic results in the conversion of unstable molecules into stable and highly bioavailable water-soluble organosulfur compounds, such as S-allylcysteine and S-allylmercaptocystein with significance antioxidant activity. AGE mainly contains S-allyl cysteine (SAC), S-allyl mercaptocystein, allixin, N-alpha-(1-deoxy-D-fructos-1-yl)-L-arginine (Fru-Arg) and selenium.^[43, 44] AGE exerts its antioxidant action by scavenging reactive oxygen species and enhancing the cellular antioxidants, like reduced glutathione superoxide dismutase, catalase and glutathione peroxidase of vascular endothelial cells.^[45]

Garlic as antidiabetic

Garlic acts as an insulin secretagogue in diabetic rats. Garlic is able to reduce blood glucose level in diabetic mice, rats, and rabbit.^[46-52] Blood glucose reducing property of alliin (200 mg/kg) in a diabetic rat is almost same as glibenclamide and insulin.^[49, 50, 53] There is a significant decrease in blood glucose level on chronic feeding of garlic oil and garlic powder however some other studies showed negative result.^[54-58] Antioxidant effect of alliin may also be responsible for its beneficial effect in diabetes.^[53]

Garlic as blood pressure lowering agent

Hypotensive properties of garlic may be due to its prostaglandin like effect and breakdown of garlic's polysulfides to hydrogen sulphide(an endogenous cardio protective vascular cell signaling molecule) in RBC and alliin content which has angiotensin II inhibiting and vasodilating effects.^[59-69] Modulation of both endothelium derived relaxing and constricting factors by garlic may contribute to its protective effect in hypoxic pulmonary vasoconstriction.^[70] One additional mechanism may be initiation of nitric-oxide-dependent relaxation in pulmonary arteries but pulmonary vasodilatory effect of alliin are independent of the synthesis of NO, ATP-sensitive (K⁺) channel, activation of cyclo-oxygenase enzyme.^[70-72]

Primary studies in humans and reviews of garlic preparations and blood pressure were indecisive. A meta-analysis done by Silagy and Neil (1994) reported promising results in subjects with mild hypertension but insufficient evidence to recommend garlic for clinical therapy.^[73]

Garlic as Antihyperlipidemic

Protective effects of garlic in atherosclerosis may be due to its ability to reduce deposition of fat on artery wall by depressing the hepatic activities of lipogenic and cholesterologenic enzymes such as malic enzyme, fatty acid synthase, glucose-6 phosphate dehydrogenase and 3-hydroxy-3-methylglutaryl-CoA (HMG CoA) reductase increasing the excretion of cholesterol.^[74-76] Water-soluble organosulfur compounds, especially S-allyl cysteine of aged garlic extract and diallyl-di-sulfide of garlic oil are also potent inhibitors of cholesterol synthesis.^[77,78] Administration of garlic (1–4% in diet) and garlic protein in hypercholesterolemic rats significantly reduced serum cholesterol, triglyceride and LDL cholesterol but not serum HDL.^[79, 80 - 85] Silagy and Neil analyzed sixteen trials showed that Garlic, in powder and non-powder form, significantly lowered serum lipid levels over a 1–3 month period. Serum cholesterol fell by 8% with dried powder preparations and 15% with non-powder preparations. Serum triglyceride level also dropped significantly, while HDL-cholesterol was essentially unchanged.^[86] However a more recent meta-analysis of thirteen trials, revealed a no significant difference between garlic and placebo groups.^[87]

Garlic showing antibiotic activity and antifungal activity

Garlic, a natural antibiotic is active against a number of bacteria, viruses, fungi, and many other parasites.^[88-90] It inhibits the growth of Staphylococcus, Streptococcus, Bacillus, Brucella, Vibrio and Candida species^[91, 92] and shows antimycotic activity stronger than that of nistatin and other antimycotics.^[93-98] It shows a virucidal activity against Herpes simplex type 1 and 2, Parainfluenza virus type 3, Vaccinia virus, Vesicular stomatitis virus, and Human rhinovirus type 2.^[99] Garlic has only 1% of the impact of synthetic penicillin but it is more effective with gram negative bacteria than penicillin.

Aqueous extracts of bulbs of garlic (*Allium sativum* L.) were fungicidal for 39 of 41 recent clinical isolates of *Candida albicans* at 68 µg total dry weight of crude extract per ml of 2% (w/v) malt extract broth in standing culture and in shake culture the crude extract was fungistatic between 50 and 300 µg/ml and fungicidal above 400 µg/ml.^[100]

Garlic showing as an anticancer agent

Garlic have the ability to accumulate the selenium (a cancer fighting mineral from soil) which is essential for the production of glutathione peroxidase which is the body's primary antioxidant.^[101] Protective effects of garlic may be due its antibacterial properties or ability to block the formation of cancer-causing substances, ability to halt the activation of cancer-causing substances, ability to enhance DNA repair, ability to reduce cell proliferation, or ability to induce cell death, ability to activating the immune cells against cancerous cells.^[102-106]

The European Prospective Investigation into Cancer and Nutrition (EPIC) study showed higher intakes of onion and garlic were associated with a reduced risk of intestinal cancer.^[107] Iowa Women's Health Study showed that women who regularly consumed garlic had 35% lower risk of developing colon cancer.^[108] Another study shows that greater intake of *Allium* vegetables (more than 10 g per day vs. less than 2.2 g per day), particularly garlic and scallions, was associated with an approximately 50 percent reduction in prostate cancer risk.^[106]

Three randomized clinical trials have evaluated the effect of garlic intake on gastric cancer risk. First study showed 33 percent reduction in the risk for stomach cancer.^[109] Second study showed that garlic supplementation (800 mg garlic extract plus 4 mg steam-distilled garlic oil daily) did not improve the prevalence (number of existing cases) of precancerous gastric lesions or reduce the incidence (number of new cases) of gastric cancer.^[110] Third study compared the effects of daily high-dose (2.4 mL) and low-dose (0.16 mL) intake of aged-garlic extract after 6 and 12 months of use on individuals with colorectal adenomas (non-cancerous tumors).^[111] Another study involving 21 persons with basal cell carcinoma shows that the application of ajoene (a sulfurous chemical found in garlic) to the skin for 1 month markedly decreased (69–88%) the size of 17 tumors^[112]. Increased garlic consumption may also reduce the risk of breast cancer.^[113]

Garlic showing as a beauty aid

The high sulfur content in garlic is useful in toning of the skin, conditioning of hair and preventing dandruff. Garlic also act as nail booster. In combination with B complex vitamins garlic supports body metabolism and helps in maintaining the body weight.

CONTRAINDICATIONS

Allicin is a very potent substance. Excessive use can also cause blisters on skin. Strong breath and body odors. Allergies to garlic and other plants in the allium family that can range from mild irritation to potentially life-threatening problems. Symptoms can include irritable bowel, diarrhoea, mouth and throat ulcerations, nausea, breathing difficulties, and in rare cases anaphylaxis. With patients with profuse hemorrhages, bleeding is further increased. Garlic also acts as a natural blood thinner so should be avoided by pregnant women, lactating mother and people about to undergo surgery, and with anticoagulants warfarin.^[20] Garlic should also be avoided by people who are prone to stomach conditions, such as ulcers, as it can exacerbate the condition or cause new ones.

CONCLUSION

There are many claims to the benefits of garlic and its uses; it is belonging to the family liliaceae. The garlic native to central Asia is a herb providing widest range of physiological effects however results of some studies conducted to explore the beneficial effects of garlic were positive and some were negative. Though there are several common use and benefits, the most popular frequent use is as a spice. Prolongation of garlic extract leads to the formation of antioxidant phytochemicals which include unique water soluble organosulfur compounds, lipid soluble organosulfur components and flavonoids that prevent oxidant damage and as a result plays an important role in aging and disease, including cardiovascular, neurodegenerative and inflammatory diseases even in cancer. It is contraindicated to pregnant women, lactating mother and also peoples about to undergo surgery and having ulcer to stomachs.

REFERENCES

- Block E. The chemistry of garlic and onions, *Sci Am*, 1985; 252,114–9.
- Ayurvedic Pharmacopoeia, Edn 1 Part I, Vol.III, Govt. of India, Ministry of Health and Family Welfare Dept. of Indian System of Medicine and Homoeopath, New Delhi,1989,108-109.
- Amagase H, Clarifying the real bioactive constituents of garlic, *J Nutr*,136 Suppl 3, 2006, 716–25.
- Boon H, Wong J, Botanical medicine and cancer: A review of the safety and efficacy, *Expert Opinion on Pharmacotherapy*, 5(12), 2004, 2485–2501.
- Rangari VD, Pharmacognosy and phytochemistry, 1st ed., Carrier publications; 2002, 235.
- Blania G, Spangenberg B, Formation of allicin from dried garlic (*Allium sativum*): a simple HPTLC method for simultaneous determination of allicin and ajoene in dried garlic and garlic preparations, *Planta Med*, 57(4),1991, 371-75.
- Sendl A, Wagner H, Isolation and identification of homologues of ajoene and alliin from bulb-extracts of *Allium ursinum*, *Planta Med*, 57(4), 1991, 361-62.
- Koch J, Berger L, Reiter CV, Allicin in garlic (*Allium sativum* L.) and garlic preparation: quantitative determination using headspace gas chromatograph, *Planta Med*,55,1989,327-31.
- Freeman F, Koderia Y, Garlic Chemistry: Stability of S-(2-Propenyl) 2-Propene-1-sulfinothioate (Allicin) in Blood, Solvents, and Simulated Physiological Fluids, *J Agric Food Chem*, 43(2), 1995, 2332-38.
- Calvey E, White K, Matusik J, Sha D, Block, Allium Chemistry: Identification of organosulfur compounds in ramp (*Allium tricoum*) homogenates, *Phytochemistry*,49(2),1998, 359-64.
- Ilic DP et al. Thermal degradation, antioxidant and antimicrobial activity of the synthesized allicin and allicin incorporated in gel, *Hem Ind*, 64(2), 2010, 85-91.
- Lawson LD, Ransom DK, Hughes BG Inhibition of whole blood platelet-aggregation by compounds in garlic clove extracts and commercial garlic products, *Throm Res*, 65(2), 1992, 141-56.
- Cremlyn RJ, An Introduction to Organosulfur Chemistry, 1st Ed, John Wiley and Sons, Chichester, 1996.
- Eric Block, Garlic and Other Alliums: The Lore and the Science. Cambridge: Royal Society of Chemistry, London, 2010.
- Yu, T-H, and Wu, C-M, Stability of allicin in garlic juice, *J Food Sci*, 54(4), 1989, 977-81.
- <http://en.wikipedia.org/wiki/Garlic>
- Kokate CK, Purohit AP, Gokhale SB, Pharmacogogy, 13th ed., Nirali Prakashan, Pune 1999.
- Rivlin RS, Historical perspective on the use of garlic, *Journal of Nutrition*, 131(3S), 2001, 951S-954S.
- Moyers S, Garlic in Health, History and World Cuisine, Edn1. *St. Petersburg FL: Suncoast Press*, 1996.
- Woodward PW, Garlic and Friends: The History, Growth and Use of Edible Alliums, *Melbourne Australia, Hyland House*, 1996.
- <http://www.herballegacy.com/>
- Chester j, cavallito, john hays bailey, Allicin, the antibacterial principle *allium sativum*. Isolation, Physical Properties and Antibacterial Action, *J Am Chem Soc*, 66(11), 1944, 1950 - 51.
- Wills ED, Enzyme inhibition by allicin, the active principle of garlic, *Biochem J*, 63(3), 1954, 514–20.
- Eilat S, Oestraicher Y, Rabinkov A, Ohad D, Mirelman D, Battler A, Eldar M, Vered Z, Alteration of lipid profile in hyperlipidemic rabbits by allicin, an active constituent of garlic. *Coron Artery Dis*, 6(12), 1995, 985–90.
- Abramowitz D, Gavri S, Harats D, Levkovitz H, Mirelman D, Miron T et al. Allicin-induced decrease in formation of fatty streaks (atherosclerosis) in mice fed a cholesterol-rich diet. *Coron Artery Dis*, 10(7), 1999, 515–19.
- Silagy CA, Neil HA, A meta-analysis of the effect of garlic on blood pressure, *J Hypertens*, 12(4), 1994, 463–68.
- Lawson LD, Ransom DK, Hughes BG, Inhibition of whole blood platelet-aggregation by compounds in garlic clove extracts and commercial garlic products, *Throm Res*, 65(2), 1992, 141-56.
- Srivastava KC. Evidence for the mechanism by which garlic inhibits platelet aggregation, *Prostaglandins Leukot Med*, 229(3), 1986, 313–21.
- Sela U, Ganor S, Hecht I, Brill A, Miron T, Rabinkov A et al. Allicin inhibits SDF-1alpha-induced T cell interactions with fibronectin and endothelial cells by down-regulating cytoskeleton rearrangement, Pyk-2 phosphorylation and VLA-4 expression. *Immunology* 2004; 11(4):391–99.
- Lindsey J, Macpherson, Bernhard H, Geierstanger, Veena Viswanath, Michael Bandell, Samer R. Eid, SunWook Hwang, and Ardem Patapoutian, The pungency of garlic: Activation of TRPA1 and TRPV1 in response to allicin, *Current Biology*, 15(10), 2005, 929–34.
- Bautista DM, Movahed P, Hinman A, Axelsson HE, Sterner O, Hogestatt ED et al. Pungent products from garlic activate the sensory ion channel TRPA1, *Proc Natl Acad Sci*, 102(34), 2005, 12248–52.
- Vaidya, Vijraja, Keith U. Ingold, Derek A, Pratt, Garlic: Source of the Ultimate Antioxidants - Sulfenic Acids, *Angewandte Chemie*, 121(1), 2009, 63–6.

- [33] Ankr S, Miron T, Rabinov A, Wilchek M, Mirelman D, Allicin from Garlic Strongly Inhibits Cysteine Proteinases and Cytotoxic Effects of Entamoeba histolytica, Antimicrobial Agents and Chemotherapy, 41(10), 1997, 2286-8.
- [34] Banerjee SK, Maulik SK, Effect of garlic on cardiovascular disorders: a review, Nutrition journal, 19(11), 2002, 1-4.
- [35] Wagner H, Wierer M, Fessler B, Effects of garlic constituents on arachidonate metabolism, *Planta Med*, 53(3), 1987, 305-6.
- [36] Srivastava KC, Tyagi OD, Effects of a garlic-derived principle (ajoene) on aggregation and arachidonic acid metabolism in human blood platelets, *Prostaglandins Leukot Essent Fatty Acids*, 49(2), 1993, 587-95.
- [37] Apitz-Castro R, Ledezma E, Escalante J, Jain MK, The molecular basis of the antiplatelet action of ajoene: direct interaction with the fibrinogen receptor, *Biochem Biophys Res Commun*, 14(1), 1986, 145-50.
- [38] Ahmed N, Laverick L, Sammons J, Zhang H, Maslin DJ, Hassan HT, Ajoene, a garlic-derived natural compound, enhances chemotherapy-induced apoptosis in human myeloid leukaemia CD34-positive resistant cells, *Anticancer Res*, 21(5), 2001, 3519-23.
- [39] Tlili CM, Stavast-Kooy AJ, Vuerstaek JD, The garlic-derived organosulfur component ajoene decreases basal cell carcinoma tumor size by inducing apoptosis, *Archives of Dermatological Research*, 295(3), 2003, 117-23.
- [40] Koderia Y, Matsuura H, Yoshida S, Sumida T, Itakura Y, Fuwa T. et al. Allixin, a stress compound from garlic, *Chem Pharm Bull*, 37(44), 1989, 1656-58.
- [41] Yamasaki T, Teel R, W, Lau BH, Effect of allixin, a phytoalexin produced by garlic, on mutagenesis, DNA-binding and metabolism of aflatoxin B1, *Cancer Letters*, 59(2), 1991, 89-94.
- [42] Rabinov A, Miron T, Konstantinovski L, Wilchek M, Mirelman D, Weiner L, The mode of action of allixin: trapping of radicals and interaction with thiol containing proteins, *Biochim Biophys Acta*, 1379(2), 1998, 233-44.
- [43] Borek C, Antioxidant health effect of aged garlic extract, *J Nutr*, 131(3S), 2001, 1010-1015.
- [44] Ichikawa M, Yoshida J, Ide N, Sasaoka T, Yamaguchi H, Ono K, Tetrahydro-beta-carbolone derivatives in aged garlic extract show antioxidant properties, *J Nutr*, 136(3S), 2006, 726-31.
- [45] Ryu K, Ide N, Matsuura H, Itakura Y: N alpha-1-(deoxy-D-fructos-1-yl)-L-arginine, an antioxidant compound identified in aged garlic extract, *J Nutr*, 131(3S), 2001, 72-76.
- [46] Kumar GR, Reddy KP, Reduced nociceptive responses in mice with alloxan induced hyperglycemia after garlic (*Allium sativum*) treatment, *Indian J Exp Biol*, 37(7), 1999, 662-66.
- [47] Kasuga S, Ushijima M, Morihara N, Itakura Y, Nakata Y, Effect of aged garlic extract (AGE) on hyperglycemia induced by immobilization stress in mice, *Nippon Yakurigaku Zassh*, 114, 1999, 191-97.
- [48] Patumraj S, Tewit S, Amatyakul S, Jariyapongskul A, Maneesri S, Kasantikul V, Shepro D, Comparative effects of garlic and aspirin on diabetic cardiovascular complications, *Drug Deliv*, 7(2), 2000, 91-96.
- [49] Sheela CG, Kumud K, Augusti KT, Anti-diabetic effect of onion and garlic sulfoxide amino acids in rats, *Planta Medica*, 61(4), 1995, 356-57.
- [50] Sheela CG, Augusti KT, Antidiabetic effects of S-allyl cysteine sulphoxide isolated from garlic *Allium sativum* Linn, *Indian J Exp Biol*, 30(6), 1992, 523-26.
- [51] Jain RC, Vyas CR, Garlic in alloxan-induced diabetic rabbits, *Am J Clin Nutr*, 28(7), 1975, 684-85.
- [52] Mathew PT, Augusti KT, Studies on the effect of allixin (diallyl disulphide-oxide) on alloxan diabetes I. Hypoglycaemic action and enhancement of serum insulin effect and glycogen synthesis, *Indian J Biochem Biophys*, 10, 1973, 209-12.
- [53] Augusti KT, Sheela CG, Antiperioxide effect of S-allyl cysteine sulfoxide, an insulin secretagogue, in diabetic rats, *Cellular and Molecular Life Sciences*, 52(2), 1996, 115-20.
- [54] Kiesewetter H, Jung F, Pindur G, Jung EM, Mrowietz C, Wenzel E, Effect of garlic on thrombocyte aggregation, microcirculation, and other risk factors, *Int J Clin Pharmacol Ther Toxicol*, 29(4), 1991, 151-55.
- [55] Zhang XH, Lowe D, Giles P, Fell S, Connock MJ, Maslin DJ, Gender may affect the action of garlic oil on plasma cholesterol and glucose levels of normal subjects, *J Nutr*, 131(5), 2001, 1471-78.
- [56] Bordia A, Verma SK, Srivastava KC, Effect of garlic (*Allium sativum*) on blood lipids, blood sugar, fibrinogen and fibrinolytic activity in patients with coronary artery disease, *Prostaglandins, Leukot Essent Fatty Acids*, 58(4), 1998, 257-63.
- [57] Jain AK, Vargas R, Gotzkowsky S, McMahon FG: Can garlic reduce levels of serum lipids? A controlled clinical study, *Am J Med* 131(5), 1993, 632-35.
- [58] Ali M, Thomson M, Consumption of garlic clove a day could be beneficial in preventing thrombosis, *Prostaglandins Leukot Essent Fatty acids*, 53, 1995, 211-12.
- [59] Leoper M, DeBray M, Hypotensive effect of tincture of garlic, *Prog Med*, 36, 1921, 391-92.
- [60] Damru F, The use of garlic concentrate in vascular hypertension, *Med Rec* 153, 1941, 249-51.
- [61] Benavides GA, Squadrito GL, Mills RW, Patel HD, Isbell TS, Patel RP, Darley-Usmar VM, Doeller JE, Kraus DW, Hydrogen sulfide mediates the vasoactivity of garlic, *Proc Natl Acad Sci*, 104(46), 2007, 977-982.
- [62] Banerjee SK, Mukherjee PK, Maulik SK, Garlic as an antioxidant: the good, the bad and the ugly, *Phytother Res*, 17(2e), 2003, 97-106.
- [63] Higdon J, Lawson L, Garlic and Organosulfur Compounds. Micronutrient Information Center, Linus Pauling Institute, Oregon State University, 2005.
- [64] Al-Qattan KK, Khan I, Alnaqeb MA, Ali M, Mechanism of garlic (*Allium sativum*) induced reduction of hypertension in 2K-1C rats: a possible mediation of Na/H exchanger isoform-1, *Prostaglandins Leukot Essent Fatty Acids*, 69(4), 2003, 217-22.
- [65] Al-Qattan KK, Thomson M, Al-Mutawa'a S, Al-Hajeri D, Drobiova H, Ali M, Nitric oxide mediates the blood-pressure lowering effect of garlic in the rat two-kidney, one-clip model of hypertension, *J Nutr*, 136(3), 2006, 774-6.
- [66] Sendl A, Elbl G, Steinke B, Redl K, Breu W, Wagner H, Comparative pharmacological investigations of *Allium ursinum* and *Allium sativum*, *Planta Medica*, 58(1), 1992, 1-7.
- [67] Mohamadi A, Jarrell ST, Shi SJ, Andrawis NS, Myers A, Clouatre D, Preuss HG, Effects of wild versus cultivated garlic on blood pressure and other parameters in hypertensive rats, *Heart Dis*, 2(1), 2000, 3-9.
- [68] Sharifi AM, Darabi R, Akbarloo N, Investigation of antihypertensive mechanism of garlic in 2K1C hypertensive rat, *J Ethnopharmacol* 86(2-3), 2003, 219-24.
- [69] Rashid A, Khan HH, The mechanism of hypotensive effect of garlic extract, *J Pak Med Assoc*, 35(12), 1985, 357-62.
- [70] Kim-Park S, Ku DD, Garlic elicits a nitric oxide-dependent relaxation and inhibits hypoxic pulmonary vasoconstriction in rats, *Clin Exp Pharmacol Physiol*, 27(10), 2000, 780-86.
- [71] Fallon MB, Abrams GA, Abdel-Razek TT, Dai J, Chen SJ, Chen YF, Luo B, Oparil S, Ku DD, Garlic prevents hypoxic pulmonary hypertension in rats, *Am J Physiol*, 275, 1998, L283-87.
- [72] Kaye AD, De Witt BJ, Anwar M, Smith DE, Feng CJ, Kadowitz PJ, Nossaman BD, Analysis of responses of garlic derivatives in the pulmonary vascular bed of the rat, *J Appl Physiol*, 89(1), 2000, 353-58.
- [73] Silagy CA, Neil HA, A meta-analysis of the effect of garlic on blood pressure, *J Hypertens*, 12, 1994, 463-68.
- [74] Orekhov AN, Grunwald J, Effects of garlic on atherosclerosis, *Nutrition*, 13, 1997, 656-63.
- [75] Yu-Yan Yeh, Liu L, Cholesterol lowering effect of garlic extracts and organosulfur compounds: Human and animal studies, *J Nutr*, 131, 2001, 989-93.
- [76] Chi MS, Koh ET, Stewart TJ, Effect of garlic on lipid metabolism in rats fed cholesterol or lard, *J Nutr*, 112(2), 1982, 241-48.
- [77] Simons LA, Balasubramanian S, Von Konigsmark M, Parfitt A, Simons J, Peters W, On the effects of garlic on plasma lipids and lipoproteins in mild hypercholesterolemia, *Atherosclerosis*, 113(2), 1995, 219-25.
- [78] Gebhardt R, Beck H, Differential inhibitory effects of garlic-derived organosulfur compounds on cholesterol biosynthesis in primary rat hepatocyte culture, *Lipids*, 31(12), 1996, 1269-76.
- [79] Chang MLW, Johnson MA, Effect of garlic on carbohydrate metabolism and lipid synthesis in rats, *J Nutr*, 110, 1980, 931-36.
- [80] Rajasree CR, Rajmohan T, Agusti KT, Biochemical effects of garlic on lipid metabolism in alcohol fed rats, *Ind J Exp Biol*, 37, 1999, 243-47.
- [81] Mathew BC, Daniel RS, Hypolipidemic effect of garlic protein substituted for casein diet of rats compared to those of garlic oil, *Ind J Exp Biol*, 34(4), 1996, 337-40.
- [82] Qureshi AA, Din ZZ, Aburaimileh N, Burger WC, Ahmed Y, Elson CE, Suppression of avian hepatic lipid metabolism by solvent extracts of garlic: impact on serum lipids, *J Nutr*, 113(9), 1983, 1746-55.
- [83] Kamanna VS, Chandrasekhara N, Effect of garlic on serum lipoproteins cholesterol levels in albino rats rendered hypercholesteremic by feeding cholesterol, *Lipids*, 17(7), 1982, 483-88.
- [84] Chi MS, Effect of garlic products on lipid metabolism in cholesterol-fed rats, *Proc Soc Exp Biol Med*, 171(2), 1982, 174-8.
- [85] Chi MS, Koh ET, Stewart TJ, Effect of garlic on lipid metabolism in rats fed cholesterol or lard, *J Nutr*, 112, 1982, 241-8.
- [86] Silagy C, Neil A, Garlic as a lipid lowering agent-a meta-analysis, *J R Coll Physician Lond*, 28, 1994, 39-45.
- [87] Neil HA, Silagy CA, Lancaster T, Hodgeman J, Vos K, Moore JW, Jones L, Cahill J, Fowler GH, Garlic powder in the treatment of moderate hyperlipidaemia: a controlled trial and meta-analysis, *J R Coll Physicians Lond*, 30(4), 1996, 329-34.
- [88] Adetumbi MA, Lau BH, *Allium sativum* (garlic): A natural antibiotic, *Med. Hypothesis*, 12(3), 1983, 227-64.
- [89] H. P. Koch, Garlicin - Fact or fiction? The antibiotic substance from garlic (*Allium sativum* L.), *Phytother Res*, 7(4), 1993, 278-358.
- [90] B. G. Hughes, L. D. Lawson, Antimicrobial effects of *Allium sativum* L. (garlic), *Allium ampeloprasum* L. (elephant garlic) and *Allium cepa* L. (onion), garlic compounds and commercial garlic supplement products, *Phytother Res*, 5(4), 1991, 154-62.
- [91] C. J. Cavallito, J. H. Bailey, Allixin, the Antibacterial Principle of *Allium sativum*. Isolation, Physical Properties and Antibacterial Action, *J Am Chem Soc*, 66(11), 1944, 1950 -51.
- [92] Ankr S, Mirelman D, Antimicrobial properties of allixin from garlic, *Microbes and Infect*, 1(2), 1999, 125 -9.
- [93] Amer M, Taha M, Tosson Z, Effect of aqueous garlic extract on the growth of dermatophytes, *Int J Dermatol*, 19(5), 1980, 285-87.
- [94] Moore GS, Atkins RD, The fungicidal and fungistatic effects of an aqueous garlic extract on medically important yeast-like fungi, *Mycologia*, 69(2), 1977, 341-349.
- [95] Sandhu DK, Warraich MK, Singh S, Sensitivity of yeasts isolated from cases of vaginitis to aqueous extracts of garlic, *Mykosen*, 23(5), 1980, 691-8.
- [96] Prasad G, Sharma VD, Efficacy of Garlic (*Allium sativum*) treatment against experimental candidiasis in chicks, *Br Vet J*, 136(5), 1980, 448 - 99.
- [97] Fromtlng RA, Bulmer GS, In vitro effect of aqueous extract of garlic (*Allium sativum*) on the growth and viability of *Cryptococcus neoformans*, *Mycologia*, 70, 1978, 397-405.
- [98] Cutler RR, Wilson P, Antibacterial activity of a new, stable, aqueous extract of allixin against methicillin-resistant *Staphylococcus aureus*, *Br J Biomed Sci*, 6, 2004, 71-4.
- [99] Tsai J, Cole L, Davis L, Lockwood S, Simmons V, Vild G, Antiviral properties of garlic: in vitro effects on influenza B, herpes simplex and coxsackie viruses, *Planta Med*, 51(5), 1985, 460-61.
- [100] Barone FE, Tansey MR, Isolation, purification, identification, synthesis and kinetics of activity of the anticandidal component of *Allium sativum* and hypothesis for its mode of action, *Mycologia*, 69(4), 1977, 793-825.
- [101] Arnault I, Auger J, Seleno-compounds in garlic and onion, *J Chromatogr A*, 1-2, 2006, 23-30.
- [102] Ruddock PS, Liao M, Foster BC, Garlic natural health products exhibit variable constituent levels and antimicrobial activity against *Neisseria gonorrhoeae*, *Staphylococcus aureus* and *Enterococcus faecalis*, *Phytother Res*, 19, 2005, 327-34.
- [103] Shenoy NR, Choughuley AS, Inhibitory effect of diet related sulphuryl compounds on the formation of carcinogenic nitrosamines, *Cancer Lett*, 65(3), 1992, 227-232.
- [104] Milner JA, Mechanisms by which garlic and allyl sulfur compounds suppress carcinogen bioactivation, *Garlic and carcinogenesis*, *Adv Exp Med Biol*, 492, 2001, 69-81.
- [105] L'voa GN, Zasukhina GD, Modification of repair DNA synthesis in mutagen-treated human fibroblasts during adaptive response and the antimutagenic effect of garlic extract, *Genetika*, 38(3), 2002, 306-9.
- [106] Hsing AW, Chokkalingam AP, Gao YT, Allium vegetables and risk of prostate cancer: A population-based study, *J Natl Cancer Inst*, 94(21), 2002, 1648-51.
- [107] Gonzalez CA, Pera G, Agudo A, Fruit and vegetable intake and the risk of stomach and oesophagus adenocarcinoma in the European Prospective Investigation into Cancer and Nutrition, *Int. J. Cancer*, 118(10), 2006, 2559-66.
- [108] Fleischauer AT, Arab L, Garlic and cancer: A critical review of the epidemiologic literature, *J Nutr*, 131(3S), 2001, 1032-40.
- [109] Li H, Li HQ, Wang Y, et al. An intervention study to prevent gastric cancer by micro-selenium and large dose of allitridum, *Chin Med J*, 117(8), 2004, 1155-60.
- [110] You WC, Brown LM, Zhang L, et al. Randomized double-blind factorial trial of three treatments to reduce the prevalence of precancerous gastric lesions, *J Natl Cancer Inst*, 98(14), 2006, 974-83.
- [111] Tanaka S, Haruma K, Kunihiro M, et al. Effects of aged garlic extract (AGE) on colorectal adenomas: A double-blinded study, *Hiroshima J Med Sci*, 53(3-4), 2004, 39-45.
- [112] Tlili CM, Stavast-Kooy AJ, Vuerstaek JD, The garlic-derived organosulfur component ajoene decreases basal cell carcinoma tumor size by inducing apoptosis, *Arch Dermatol Res*, 295(3), 2003, 117-23.
- [113] Chailier B, Perama JM, Viel JF, Garlic, onion and cereal fibre as protective factors for breast cancer: A French case-control study, *Eur J Epidemiol*, 14(8), 1998, 737-47.

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