



REVIEW ARTICLE

Antidiabetic potential of *Allium sativum*: A mini review

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Abstract

Diabetes is the most common metabolic disorder worldwide. This can occur due to defect in insulin secretion, insulin action, or both. Despite the availability of treatment regimen for the control of this disorder, the search for novel herbal therapeutic remedies is still widely investigated. Garlic (*Allium sativum*) has been used by folklore medicine as an alternative treatment for its antidiabetic potential. This review validates some the research done in animal models and its effect. Research done on the potentials of garlic as antidiabetic agent on animal models is promising but warrants more intensive research in diabetic patients to prove its effectiveness.

Keywords

Allium sativum; diabetes; herbal medicine

Introduction

Diabetes mellitus (DM) is one of the most common metabolic disorders worldwide. The global estimate of the disorder in year 2017 was 451 million people and is expected to be around 635 million by year 2045 (1). This can occur due to defect in insulin secretion, insulin action, or both. Insulin deficiency in turn leads to chronic hyperglycemia with disturbances of carbohydrate, fat, and protein metabolism (2). Diabetes is also a known risk factor for blindness (3), vascular brain diseases, renal failure, and limb amputations (4). To prevent micro- and macrovascular complications of DM, hyperglycemia has been suggested as the major target of treatment (5-7). It is, however, not always easy to closely control blood glucose concentrations, partly because the pathophysiology of hyperglycemia is complicated by various degrees of insulin resistance and by the failure of islet b-cells, especially in type 2 DM-the most rapidly increasing type of DM. Management of DM and most especially the complications it brings led researchers to look for novel therapies for the treatment. Additional therapeutic options are needed to overcome this disease.

Garlic (*Allium sativum*) is a common and popular herb used worldwide. It is commonly used in food for flavor and spice. For centuries, it has been associated with folklore medicine to relieve various ailments such as headaches, bites, worms and tumors. Modern research has provided scientific evidences for the practice (8-10). It is widely used for the prevention and treatment of cardiovascular and metabolic diseases such atherosclerosis, hyperlipidemia, thrombosis, hypertension and diabetes (11,2).

Research have been done to know the antidiabetic activity, property and efficacy of garlic as hypoglycemic agent. In this review, we will discuss several research that can be used as preliminary data in the conduct of more intensive research on the efficacy of garlic as an antidiabetic agent on humans as well as to animals. It is interesting to note, that garlic has long been believed to possess hypoglycemic effect in many parts of the world (12-14) and despite the fact that no well controlled clinical trials have been report in DM patients, it is still one of the most popular plant preparations prescribed by Italian herbalist for better glycemic control in hyperglycemic subjects

(15). The objective of this review is to lay down research conducted in the antidiabetic potential of garlic as tested in animal models.

Overview of Garlic

Garlic (*Allium sativum*) has been utilized as aromatic agent and as a traditional medicine for over 5000 years (16, 17). Garlic is also known as Rocambole, ajo, Allium, stinking rose, rustic treacle, nectar of the gods, camphor of the poor, poor man's treacle, and clove garlic. It is easy to grow and requires very little space in the garden. Garlic grows from individual cloves broken off from a whole bulb. Each clove will multiply in the ground, forming a new bulb that consists of 5-10 cloves (18).

Components of Garlic

Garlic contains approximately 65% water, 28% carbohydrate (fructans), 2.3% organosulfur compounds, 2% proteins (allinase), 1.2% free amino acid (arginine) and 1.5% fiber (17, 18). The major active substance, known as allicin (diallyl thiosulfate), is responsible for the typical pungent smell and for its therapeutic properties (19-21). This compound is the main bioactive compound found in raw garlic homogenate or aqueous garlic extract. Allinase enzyme, present in garlic, is activated when garlic is chopped or crushed (22). Enzyme allinase is responsible in converting Allin which is present in garlic bulb to allicin (23).

Hypoglycemic effect of Garlic

The action of garlic as a hypoglycemic agent, as tested in experimental animals, can be attributed to two mechanisms: insulin secretagogue and insulin-sensitizing effects (24).

One study demonstrated that S-allyl cysteine sulfoxide (SAC) isolated from garlic ameliorated the diabetic condition almost to the same extent as glibenclamide and insulin in alloxan diabetic rat. SACS significantly stimulated in vitro insulin secretion from B cells isolated from normal rats (25). Chang and Johnson (26) further demonstrated an increase in random peripheral insulin concentrations in normal rats fed steamed garlic preparation. Increase in peripheral insulin-like activity as possibly resulting from the direct stimulation of residue pancreatic b-cells or from the indirect production of gastrointestinal hormones associated with the pancreatic secretion of insulin. These authors also suggested that the most probable mechanism of action for allicin's effects is its action against insulin-inactivating-sulphydryl group compounds, which spares insulin from inactivation (27-29). This suggestion is based on well-established knowledge that allicin interacts with thiol groups, which is thought to be a mechanism for the many therapeutic effects of allicin (30).

The potential of garlic as hypoglycemic agent has been investigated in various animal models. The result of the studies is summarized in Table 1. The use of alloxan-induced animal models (31, 32) has been found to be selectively toxic to pancreatic beta cells as it preferentially accumulates in the beta cells as glucose analogues. In addition, the cytotoxic action of alloxan is mediated mainly by the generation of reactive oxygen species (ROS). Alloxan and the product of its reduction, dialuric acid, has been noted to establish a redox cycle with the formation of superoxide radicals, which undergo dismutation to hydrogen peroxide (H₂O₂) and more

highly reactive hydroxyl radicals are formed by the Fenton reaction (33-35). The hypoglycemic effect of garlic in alloxan induced rats' possible mechanism of action may be due to an increase in either the release of bound insulin from beta cells or an increase in pancreatic production of insulin. (36). The hypoglycemic effect can also be attributed to the presence S-allyl cysteine sulfoxide (37). It is suspected that due to spare insulin from sulphydryl group, allicin, a bioactive component of garlic can effectively combine with compounds like cysteine and thus enhances serum insulin. For this mechanism, there has been a significant decrease of plasma glucose and lipid profile in experimental rats as compared to the control. Also, the decrease in blood glucose and lipid profile is dose dependent (31, 32). Streptozocin induced rats are also used in the hypoglycemic effect of garlic. Streptozotocin causes pathological effects in the beta cells of the pancreas which causes induction of diabetes (38). Garlic significantly reduced serum glucose (39-41, 27) and histological evaluation showed improved islet architecture and B-cell function (42). In addition, fructose rich diet in animal models such as rats and mice is also used for the induction of diabetes. Induction is characterized by insulin resistance like type 2 DM (43-45). Animal models with fructose rich diet and were fed with raw garlic significantly showed a reduction in blood serum glucose level, insulin and triglycerides. Administration of raw garlic to fructose fed rats (Dia+Garl group) significantly ($p < 0.05$) reduced serum glucose, insulin, triglyceride and uric acid levels, as well as insulin resistance when compared with fructose fed rats (46).

Diabetic induced animal models demonstrated a decrease in blood glucose concentration administered with raw garlic (41), ethanolic extract of bulb (39, 40), aqueous extract (31,32), age garlic extract (42). Moreover, several studies have identified bioactive compounds in garlic to relate in its hypoglycemic potential. Among these studies, S-allylcysteine (SAC) in induced diabetic rats normalized blood glucose and glycoprotein components such as hexose hexosamine, fructose and sialic acid in plasma, liver and kidneys (31), alliin extracted from garlic leaves of plant grown in situ showed significant reduction of Serum glucose, triglycerides, total lipids, total cholesterol, low-density lipoprotein (LDL)-, and very low-density lipoprotein (VLDL) in comparison with those administered with distilled water (47). Enzyme and High hydrostatic -assisted extraction on the content of the bioactive compounds, including SAC reduced hyperglycemia and improved islet architecture and β -cell function in STZ-induced rats as compared to conventional aging process (48).

Conclusion

Garlic (*Allium sativum*) has been widely studied for its antidiabetic activity in different animal models. The mechanism of action can be associated to the different bioactive compounds, allicin and allin, for its therapeutic activity. Several studies on animal models also confirmed the efficacy of garlic as an antidiabetic agent. More clinical trials are warranted in the efficacy of garlic and its level of toxicity to be able to confirm its usefulness.

Table 1. Summary of the studies on antidiabetic activity of Garlic in animal models

Year	Aim of the study	Result	Reference
2019	evaluated the antihyperglycemic and antioxidant effect against alloxan-induced diabetic male albino rats of <i>Allium sativum</i> using the biochemical parameters such as blood glucose, insulin, and lipid profile (cholesterol, triglycerides, high-density lipoprotein, low-density lipoprotein (LDL) and very LDL, urea, uric acid, and creatinine)	In the aqueous bulb extract of <i>A. sativum</i> administrated animals, the increased levels of plasma glucose and lipid profile were decreased significantly when compared to the levels in control animals. The decrement of the blood glucose and lipid profile was dose dependent. The serum insulin levels showed a significant depletion in diabetic animals when compared to that of normal animals. On administration of the aqueous extract of the bulb of <i>A. sativum</i> , a significant augmentation of the serum insulin was recorded and was dose dependent. The aqueous extract shows very good antidiabetic activity confirmed by biochemical parameters	(31)
2016	investigated the effects of enzyme- and high hydrostatic pressure (HHP)-assisted extraction on the content of the bioactive compounds, including SAC, in black garlic juice (BGJ) and evaluated the antidiabetic effects of SAC enriched BGJ in streptozotocin (STZ)-treated mice	The aging process increased the contents of SAC, total polyphenols, and flavonoids in garlic juice. More importantly, pretreatment of pectinase cocktail with HHP resulted in a greater increase in those compounds during aging. Enzyme-treated BGJ reduced hyperglycemia and improved islet architecture and β -cell function in STZ-treated mice. Moreover, these effects were more potent than those of BGJ prepared by the conventional aging process	(48)
2013	Investigate the renoprotective effect of AGE in streptozotocin-induced diabetic rats	The diabetic rats showed a significant change in the urine ($P < 0.001$) and serum ($P < 0.01$) constituents such as albumin, creatinine, urea nitrogen and glycated hemoglobin. In addition, the serum lipid profile of the diabetic rats were altered significantly ($P < 0.05$) compared to that of the control rats. However, the diabetic rats supplemented with aged garlic extract restored all these biochemical changes. The efficacy of the extract was substantiated by the histopathological changes in the kidney.	(42)
2011	To compare the production and therapeutic efficiency of alliin extracted from garlic leaves of plants grown under ex situ and in situ conditions.	Alliin production noted ~50% enhancement in leaves from plants grown under in situ conditions. Serum glucose, triglycerides, total lipids, total cholesterol, low-density lipoprotein (LDL)-, and very low-density lipoprotein (VLDL)-cholesterol in diabetic rats treated with alliin produced from in situ grown plants noted significant reduction of ~54%, 15%, 14%, 20%, 24%, and 15%, while 35%, 14%, 10%, 12%, 17% and 11% reduction was noted in diabetic rats treated with alliin produced from ex situ grown plants in comparison with those administered with distilled water. High-density lipoprotein (HDL)-cholesterol did not show any significant change. Leaf extract of plants lowered serum enzyme levels (alkaline phosphatase, aspartate aminotransferase, and alanine aminotransferase) toward the norm better than glibenclamide. The histopathological alteration in pancreas caused by alloxan was also reduced by leaf extract.	(47)
2011	investigate the effect of raw garlic on fructose induced insulin resistance, associated metabolic syndrome and oxidative stress in diabetic rats.	Administration of raw garlic to fructose fed rats (Dia+Garl group) significantly ($p < 0.05$) reduced serum glucose, insulin, triglyceride and uric acid levels, as well as insulin resistance when compared with fructose fed rats. Garlic also normalised the increased serum levels of nitric oxide (NO) and decreased levels of hydrogen sulphide (H ₂ S) after fructose feeding. Although body weight gain and serum glycated haemoglobin levels of fructose fed rats (Diabetic group) were not significantly different from control rats, significant ($p < 0.05$) reduction of these parameters was observed in fructose fed rats after garlic administration (Dia+Garl group). Significant ($p < 0.05$) increase in TBARS and decrease in GSH was observed in diabetic liver. Catalase was not significantly affected in any of the groups. Administration of raw garlic homogenate normalised both hepatic TBARS and GSH levels.	(46)
2010	Investigate the effect of Increasing dosage of <i>A. sativum</i> aqueous extracts on alloxan induced diabetic <i>Rattus norvegicus</i> for possible use in the management of diabetes mellitus	Increasing dosages of <i>A. sativum</i> aqueous extracts produced a dose dependent significant ($P < 0.05$) reductions in the blood glucose levels, total serum lipid and total serum cholesterol when compared with that of the control rats. The most effective percentage reduction in blood glucose level, total serum lipids and cholesterol were observed at 300mg/kg.	(32)
2010	investigate the effect of S-allylcysteine (SAC) on dearrangement in glycoprotein levels in the streptozotocin induced diabetic model	STZ-induced diabetic rats showed significant increase in blood glucose and glycoprotein components such as hexose, hexosamine, fucose and sialic acid in plasma, liver and kidneys of diabetic rats. Oral administration of SAC to diabetic rats for a period of 45 days normalized all the above-mentioned biochemical parameters	(49)
2010	The hypoglycemic properties of the ethanolic extract of the bulbs of <i>Allium sativum</i> were evaluated in normoglycemic rats in order to scientific validate its traditional therapeutic use with the doses of 500 mg/kg body weight	The ethanolic extract of <i>A. sativum</i> bulbs reduced the blood glucose level by 49 % after two weeks treatment of albino rats respectively. Oral administration of the ethanolic extract of <i>A. sativum</i> bulbs at dosed equivalent to 100, 250 and 500 mg/kg body weight produced significant ($P < 0.10$) hypoglycemic effects in normal fasted animals after 7 days and 14 days respectively. The dose of extract reduced the blood concentration of the fasted normal rats from an initial mean value of 288.24 ± 7.48 at 0 day reduced blood glucose level 141.32 ± 10.61 at the end of 14 days.	(39)
2007	hypoglycaemic, hypocholesterolaemic and hypotriglyceridaemic effects of garlic were studied in streptozotocin (STZ)-induced diabetic rats.	Daily treatment of STZ-induced diabetic rats with an extract of raw garlic (500mg/kg intraperitoneally) for seven weeks significantly lowered serum glucose, cholesterol and triglyceride levels. Compared to control diabetic rats, garlic-treated rats had 57% less serum glucose, 40% lower serum cholesterol levels and 35% lower triglyceride.	(41)
2006	The antidiabetic effect of garlic ethanolic extract (<i>Allium sativum</i> L.) was investigated in normal and streptozotocin-induced diabetic rats.	Oral administrations of the garlic extract significantly decreased serum glucose, total cholesterol, triglycerides, urea, uric acid, creatinine, AST and ALT levels, while increased serum insulin in diabetic rats but not in normal rats. A comparison was made between the action of garlic extract and glibenclamide (600 mg/kg), the known antidiabetic drug. The antidiabetic effect of the extract was more effective than that observed with glibenclamide.	(40)
2005	Investigated the effects of garlic oil and diallyl trisulfide on glycemic control in rats with streptozotocin-induced diabetes	The insulin resistance index as assessed by homeostasis model assessment and the first-order rate constant for glucose disappearance were significantly improved by both garlic compounds ($P < 0.05$).	(27)

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Compliance with ethical standards

Conflict of interest: Author does not have any conflict of interests to declare.

Ethical issues: None

References

1. Cho NH, Sahaw JE, Karuranga S, Huang Y, Fernandez JD, Ohlrogge AW, et al. IDF Diabetes Atlas: Global estimates of diabetes. *Diabetes Res Clin Pract.* 2018;138:271–81. <https://doi.org/10.1016/j.diabres.2018.02.023>
2. Lebovitz H. Diagnosis, classification and pathogenesis of diabetes mellitus. *J Clin Psychiatry.* 2000;61(Suppl 27):5–9.
3. Pascolini SM. Global estimates of visual impairment. *J Ophthalmol.* 2011;2011:250–60. <https://doi.org/10.1155/2011/250790>
4. Chobanian AV, Bakris GL, Black HR. The seventh report of the joint committee on prevention, detection, evaluation and treatment of high blood pressure. *JAMA.* 2003;289(19):2560–72. <https://doi.org/10.1001/jama.289.19.2560>
5. Shamooh H, Duffy H, Fleischer N, Engel S, Saenger P, Strelzyn M, et al. The effect of intensive treatment of diabetes on the development and progression of long term complications in insulin dependent diabetes mellitus. *N Engl J Med.* 1993;329(14):977–87. <https://doi.org/10.1056/NEJM199309303291402>
6. UK Prospective Diabetes Study. Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes. *Lancet.* 1998;352(9131):837–53. [https://doi.org/10.1016/S0140-6736\(98\)07019-6](https://doi.org/10.1016/S0140-6736(98)07019-6)
7. Kirkman MS, Shah J, McCarren M. The association between metabolic control and prevalent macrovascular disease in type 2 diabetes. *J Diabetes Complications.* 2006;20(2):75–80. <https://doi.org/10.1016/j.jdiacomp.2005.05.004>
8. Harris JC, Cottrell S, Plummer S, Lloyd D. Antimicrobial properties of *Allium sativum* (garlic). *Appl Microbiol Biotechnol.* 2001;57(3):282–6. <https://doi.org/10.1007/s002530100722>
9. Borlinghaus J, Albrecht F, Gruhlke MC, Nwachukwu ID, Slusarenko AJ. Allicin: chemistry and biological properties. *Molecules.* 2014;19(8):12591–618. <https://doi.org/10.3390/molecules190812591>
10. Block E. Garlic and other alliums. Cambridge: RSC Publishing; 2010.
11. Craig J. Health-promoting properties of common herbs. *Am J Clin Nutr.* 1999;70(3 Suppl):491S–5S. <https://doi.org/10.1093/ajcn/70.3.491s>
12. Matthew PT, Augusti KT. Studies on the effect of allicin (diallyl disulphide-oxide) on alloxan diabetes: Part I - hypoglycemic action and enhancement of serum insulin effect and glycogen synthesis. *Indian J Biochem Biophys.* 1973;10(3):209–12.
13. Grover JK, Yadav S, Vats V. Medicinal plants of India with antidiabetic potential. *J Ethnopharmacol.* 2002;81(1):81–100. [https://doi.org/10.1016/S0378-8741\(02\)00059-4](https://doi.org/10.1016/S0378-8741(02)00059-4)
14. Bailey CJ, Day C. Traditional treatments of diabetes. *Diabetes Care.* 1989;12(8):553–64. <https://doi.org/10.2337/diacare.12.8.553>
15. Cicero A, Derosa G, Gaddi A. What do herbalists suggest to diabetic patients in order to improve glycemic control? Evaluation of scientific evidence and potential risks. *Acta Diabetol.* 2004;41(3):91–8. <https://doi.org/10.1007/s00592-004-0109-0>
16. Adaki S, Adaki R, Shah K, Karagir A. Garlic: review of literature. *Indian J Cancer.* 2014;51(4):577–81. <https://doi.org/10.4103/0019-509X.150899>
17. Morales-Gonzalez J, Madrigal-Bujaidar E, Sanchez-Gutierrez M, Izquierdo-Vega JA, Valdez-Vega M, Alvarez-Gonzalez I, et al. Garlic (*Allium sativum* L.): a brief review of its antigenotoxic effects. *Foods.* 2019;8(8):343. <https://doi.org/10.3390/foods8080343>
18. Burpee. Garlic. <https://www.burpee.com/gardenadvicecenter/vegetables/garlic/garlic/article10268.html>
19. Macpherson LJ, Geierstanger BH, Viswanath V, Bandell M, Eid SR, Hwang S, et al. The pungency of garlic: activation of TRPA1 and TRPV1 in response to allicin. *Curr Biol.* 2005;15(10):929–34. <https://doi.org/10.1016/j.cub.2005.04.018>
20. Li TC. Medicinal plants. Pennsylvania: Technomic Publ Co; 2000.
21. Song J, Milner JA. The influence of heating on the anticancer properties of garlic. *J Nutr.* 2001;131(3s):1054S–7S. <https://doi.org/10.1093/jn/131.3.1054S>
22. Lawson LD, Gardner CD. Composition, stability, and bioavailability of garlic products used in clinical trials. *J Agric Food Chem.* 2005;53(16):6254–61. <https://doi.org/10.1021/jf050736x>
23. Banerjee SK, Mukherjee PK, Maulik SK. Garlic as an antioxidant: the good, the bad and the ugly. *Phytother Res.* 2003;17(2):97–106. <https://doi.org/10.1002/ptr.1281>
24. Liu CT, Sheen LY, Lii C. Does garlic have a role as an antidiabetic agent? *Mol Nutr Food Res.* 2007;51(11):1353–64. <https://doi.org/10.1002/mnfr.200700040>
25. Augusti KT, Sheela CG. Antiperoxide effect of S-allyl cysteine sulfoxide, an insulin secretagogue, in diabetic rats. *Experientia.* 1996;52(2):115–9. <https://doi.org/10.1007/BF01923371>
26. Chang M, Johnson MA. Effect of garlic on carbohydrate metabolism and lipid synthesis in rats. *J Nutr.* 1980;110(5):931–6.
27. Liu CT, Wong P, Lii CK, Sheen H. Antidiabetic effect of garlic oil but not diallyl disulfide in rats with streptozotocin-induced diabetes. *Food Chem Toxicol.* 2006;44(8):1377–84. <https://doi.org/10.1016/j.fct.2006.03.008>
28. Khyatnouri M, Bahari K, Safamashaei S. Study of the glizalide and garlic extract on blood sugar level in STZ-induced diabetic male mice. *Adv Environ Biol.* 2011;5(9):1751–5.
29. Thomson M, Al-Amin Z, Al-Qattan KK, Shaban LH, Ali M. Antidiabetic and hypolipidaemic property of garlic in streptozotocin-induced diabetic rats. *Int J Diabetes Metab.* 2007;15:108–15.
30. Augusti KT, Matthew PT. Effect of allicin on certain enzymes of liver after a short term feeding to normal rats. *Experientia.* 1975;31(2):148–9. <https://doi.org/10.1007/BF01923092>
31. Sureshkumar S, Senthikumar B, Rajeshkumar S, Mangalingam M. Antihyperglycemic and antioxidant effect of *Allium sativum* aqueous bulb extract against alloxan-induced diabetic male albino rats. *Drug Invent Today.* 2019;11(8):1965–8.
32. Ozougwu JC, Eyo J. Studies on the antidiabetic activity of *Allium sativum* (garlic) aqueous extracts on alloxan-induced diabetic albino rat. *Pharmacologyonline.* 2010;3:1078–88.
33. Rohilla A, Al S. Alloxan-induced diabetes: mechanisms and effects. *Int J Res Pharm Biomed Sci.* 2012;3(2):819–23.
34. Zarrow MX, Yochim JM, McCarthy JL. Experimental endocrinology: a source book of basic techniques. New York: Academic Press; 1964.
35. Nafissa PC, Chakradhar VL, Vandana SP, Suresh RN. An experimental evaluation of the antidiabetic and antilipidaemic properties of a standardized *Momordica charantia* fruit extract. *BMC Complement Altern Med.* 2007;7:29–55. <https://doi.org/10.1186/1472-6882-7-29>
36. Jain RC, Vyas CR. Garlic in alloxan-induced diabetic rabbit. *Am J Clin Nutr.* 1975;28(6):684–5. <https://doi.org/10.1093/ajcn/28.6.684>

37. Augusti KT, Sheela CG. Antidiabetic effect of SACS isolated from garlic *Allium sativum* L. *Indian J Exp Biol*. 1992;30(6):523–6.
38. Akbarzadeh A, Norouzian D, Mehrabi MR, Jamshidi SH, Farhangi A, Verdi A, et al. Induction of diabetes by streptozotocin in rats. *Indian J Clin Biochem*. 2007;22(2):60–4. <https://doi.org/10.1007/BF02913315>
39. Shakya VK, Saxena RC, Shakya A. Effect of ethanolic extract of *Allium sativum* bulbs on streptozotocin. *J Chem Pharm Res*. 2010;2(4):171–5.
40. Eidi A, Eidi M, Esmaeili E. Antidiabetic effect of garlic (*Allium sativum* L.) in normal and streptozotocin-induced diabetic rats. *Phytomedicine*. 2006;13(9–10):624–9. <https://doi.org/10.1016/j.phymed.2005.09.010>
41. Thomson M, Al-Amin Z, Al-Qattan KK, Shaban LH, Ali M. Antidiabetic and hypolipidaemic property of garlic in streptozotocin-induced diabetic rats. *Int J Diabetes Metab*. 2007;15:108–15.
42. Shiju TM, Rajesh NG, Viswanathan P. Renoprotective effect of aged garlic extract in diabetic rats. *Indian J Pharmacol*. 2013;45(6):586–91. <https://doi.org/10.4103/0253-7613.121381>
43. Veerapur V, Prabhakar K, Thippeswamy B, Bansal P, Srinivasan K, Unnikrishnan M. Antidiabetic effect of *Dodonaea viscosa* (L.) Jacq. aerial parts in high fructose-fed insulin resistant rats: a mechanism-based study. *Indian J Exp Biol*. 2010;48(8):800–10.
44. Reungjui S, Roncal C, Mu W, Srinivas T, Sirivongs D, Johnson R, et al. Thiazide diuretics exacerbate fructose-induced metabolic syndrome. *J Am Soc Nephrol*. 2007;18(10):2724–31. <https://doi.org/10.1681/ASN.2007030300>
45. Asdaq S, Inamdar M. The potential benefit of garlic and hydrochlorothiazide combination as antihypertensive and cardioprotective in rats. *J Nat Med*. 2010;64(1):81–8. <https://doi.org/10.1007/s11418-009-0378-3>
46. Padiya R, Khatua T, Bagul PK, Kuncha M, Banerjee S. Garlic improves insulin sensitivity and associated metabolic syndromes in fructose-fed rats. *Nutr Metab*. 2011;8:53. <https://doi.org/10.1186/1743-7075-8-53>
47. Nasim SA, Bhupinder D, Kapoor R, Fatima S, Mujib A. Alliin obtained from leaf extract of garlic grown under in situ conditions. *Pharm Biol*. 2011;49(4):416–21. <https://doi.org/10.3109/13880209.2010.523289>
48. Kim JH, Yu SH, Cho YJ, Pan JH, Cho HT, Kim JH, et al. Preparation of S-allyl cysteine-enriched black garlic juice and its antidiabetic effects in type 2 diabetic mice. *J Agric Food Chem*. 2016;64(24):4769–75. <https://doi.org/10.1021/acs.jafc.6b00644>
49. Saravanan G, Ponmurugan P, Senthilkumar GP, Rajarajan T. Antidiabetic effect of S-allylcysteine: effect on plasma and tissue glycoproteins in streptozotocin-nicotinamide induced type 2 diabetic rats. *Phytomedicine*. 2010;17(14):1086–9. <https://doi.org/10.1016/j.phymed.2010.04.012>