A COMPREHENSIVE REVIEW OF THE THERAPEUTIC SIGNIFICANCE OF GARLIC (*ALLIUM SATIVUM* L.) IN THE MANAGEMENT OF DIABETES

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ABSTRACT

Diabetes stands out as the most prevalent metabolic disease in the world, affecting a large percentage of the population. Scientifically classified as *Allium sativum* L., belonging to the Liliaceae family, garlic is a widely used food spice that has a long history of use in traditional medicine. Research has established its potential as an agent with anti-diabetic properties. Garlic contains natural sulfur-containing bioactive compounds that show excellent anti-diabetic properties. This study aims to demonstrate a succinct summary of the most updated and relevant research on the use of garlic to prevent and treat diabetes. It also looks into the possibility of using this organic food as an additional or substitute kind of treatment. This review analyzes the vital biological functions of the bioactive compounds in garlic, providing information on how garlic can be used to treat diabetes and addressing important pathways related to the regulation of the disease. The review also emphasizes the significance of data showing garlic's anti-diabetic effectiveness in studies using human cell lines as well as genetically or experimentally induced animal models. It explores the mode of action of garlic, emphasizing its dual function as a secretagogue and an insulin sensitizer. The medicinal properties of *Allium sativum* L. and its bioactive components emphasize the significance of this spice in traditional medicine and its ability to fight diabetes.

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INTRODUCTION

Diabetes is one of the most common and possibly most rapidly expanding metabolic diseases in the world. Chronic hyperglycemia, which results from impaired insulin secretion, response, or both, is its defining feature (1, 2). Diabetes, often known as blood sugar is defined by the World Health Organization (WHO) as a chronic metabolic condition characterized by high blood glucose (or blood sugar) levels that, over time, may cause serious damage to the cardiovascular system, circulatory system, eyes, nerves and kidneys (3). Type 2 diabetes is the most prevailing type of the disease and primarily affects adults. This type of diabetes appears when the body develops insulin resistance or is unable to make a sufficient amount of it. Notably, during the past three decades, the development of type 2 diabetes prevalence has risen in countries of different income levels. Conversely, Type 1 diabetes, also known as insulin-dependent diabetes or juvenile diabetes, is a persistent condition in which the pancreas is unable to produce enough insulin or any insulin at all naturally. Access to reasonably priced treatments, such as insulin, is vital for the existence of those with diabetes. By 2025, there will be a worldwide understanding to stop the increase in obesity and diabetes. About 422 million people worldwide experience diabetes, most of whom live in middle and low-income nations. Annually, the illness is directly responsible for 1.6 million deaths. Both the number of cases and the prevalence of diabetes have significantly elevated during the last several years (4). Diabetes-related complications include tachycardia, hypotension, polyphagia, wasting, polydipsia, pruritus, and wasting after weight loss (5). As a result, all types of diabetes mellitus might present with severe symptoms such as neuropathy, nephropathy, retinopathy, dyslipidemia, ischemia cardiac arrest, and cardiomyopathy due to diabetes (6, 7). There are three main categories for diabetes mellitus (DM). β-cell destruction causes absolute insulin insufficiency, which is the hallmark of type I diabetes (T1DM), also known as insulin-dependent diabetes or juvenile-onset diabetes. Patients diagnosed with type 1 diabetes must take insulin daily since they are at risk of ketoacidosis. It primarily affects children and adolescents and makes up only 5–10% of the total population with diabetes (8, 9). Peripheral tissue insensitivity to insulin production and different levels of insufficient insulin response to activation of glucose are the causes of type II diabetes (T2DM) referred to as non-insulin-dependent diabetes. T2DM is responsible for 90–95% of all cases of diabetes. Gestational diabetes, sometimes referred to as type III diabetes (T3DM), is characterized by glucose resistance throughout pregnancy. Studies show that most instances end with childbirth, but they don't say if the illness lasts until infancy or not. 9.2% of pregnant women have gestational diabetes (10). Monogenic diabetes, a hereditary condition, and diabetes associated with cystic fibrosis are less prevalent forms. With a global incidence of 346 million (6.1%) among adults in 2011, diabetes is a substantial source of illness and mortality, according to global figures from the World Health Organization (WHO) (11). By 2030, 439 million people (7.7% of the population) are predicted to have a diabetes diagnosis, and the number of diabetes-related fatalities is predicted to rise by two-thirds between 2008 and 2030. By 2030 there will be 578 million (10.2%) more diagnosed cases, and by 2045, there will be 700 million cases (12). Diabetes is today acknowledged as one of the most serious disorders, despite advances in science, technology, and pharmaceuticals as well as in the treatment and management of the disease (13). Natural compounds produced from plants have been used as substitutes for manufactured pharmaceuticals as antidiabetic treatments. Approximately 400 natural plant remedies for diabetic mellitus may be found in the historical context; many of these have disappeared from Western society. Nonetheless, some continue to be utilized by proponents of alternative medicine or used as adjuncts in addition to traditional treatments, especially in developing countries (14). With the discovery of several hypoglycemic substances, certain therapies have shown hypoglycemic effects in diabetic patients who are not insulin-dependent as well as in animal models (15). The widely used spice garlic (Allium sativum L., Liliaceae) is used as an herbal remedy and has a lengthy background of treating different human medical conditions. Garlic (*Allium sativum* L., Liliaceae) is a unique organic source of sulfur-rich bioactive components that may find use in the processing of functional foods or nutraceuticals that prevent and treat a variety of ailments (16). Garlic is anti-inflammatory, anti-cancer, antihypertensive, anti-atherogenic, and liver-protective. antibacterial, immune-regulating, and bloodthinning properties in both human and animal studies (17-19). Moreover, garlic has been recognized as an antidote against chemical and natural poisonous substances (20). Conventional medical practices in Europe, India, and the Middle East have long recognized garlic's beneficial effects on diabetes control. Remarkably, a third of diabetic patients turn to complementary and alternative medicine, with the most common remedy being garlic (14). Interestingly, garlic is ranked sixth in terms of effectiveness and safety among herbal remedies recommended by Italian herbalists to improve glycemic management (21). Garlic has been shown to enhance oral tolerance to glucose in animal tests, while certain investigations did not show any effect on specific glycemic regulatory markers such as fasting blood glucose (22). In diabetic individuals, garlic has hypoglycemic properties that dramatically lower plasma glucose levels (23). Furthermore, administration of the primary bioactive components of garlic, called organosulfur compounds, has been associated with elevated insulin levels (16). Nowadays, lipid profiles are improved and blood pressure is lowered by using commercially available garlic formulations, such as garlic oil, powdered garlic, and tablets (24). Garlic's usage in conventional medicine is supported by recent research that shows it can be beneficial against a variety of ailments when taken raw or in preparation (16, 19). This study investigates the physiological and biological roles of garlic, building on prior research and providing insight into the mechanisms behind the plant's antidiabetic properties. We hope that this study will highlight the benefits of garlic as a healthy food, and medicinal plant and promote its efficacy in the management and treatment of diabetes mellitus.

Investigative Scheme

The focus of the current study is on the hypoglycemic properties of garlic (*Allium sativum* L., Liliaceae) in vitro and/or in animal experiments. To do this, we have compiled the most recent research from reputable PubMed, Scopus, Science Direct, Web of Science, and Google Scholar databases were included about the antidiabetic qualities of garlic. To emphasize the significance of garlic as a hypoglycemic agent is the goal. Furthermore, we have examined the essential bioactive substances in *Allium sativum* L., Liliaceae, and explored the biological function of *Allium sativum* L., Liliaceae in producing hypoglycemic effects, focusing on similar mechanisms of action.

Pharmaceuticals for Oral Hypoglycemia

Multiple oral hypoglycemic drugs work as antidiabetic agents via different mechanisms in table 1. Although synthetic oral hypoglycemic medications are the primary means of diabetic management, they are not a cure for the disease's consequences. Furthermore, they worsen the condition by displaying prominent adverse effects, including diarrhea, hyperlipidemia, weight gain, gastrointestinal distress, nausea, heart failure, and liver disorders (25). There are several disadvantages to using these oral hypoglycemic medications, such as toxicity and drug resistance (lower efficacy). Furthermore, these drugs might be costly at times, rendering them unavailable to most people (26). Due to these restrictions and the rising incidence of diabetes mellitus, scientists are looking at natural plant-based products as a potential substitute for synthetic antidiabetic medications. *Allium sativum* is one of the most popular spices in the world and one of the earliest herbal remedies to be identified. It has a long history of being used medicinally to treat a wide range of human health issues. This includes using it to treat diabetes and its concomitant conditions, as it has low toxicity.

Garlic's Bioactive Compounds:

Numerous bioactive substances, such as polysaccharides, phenolic compounds, saponins, and organosulfur compounds, are found in garlic (27-29). The sulfur-containing organic compounds are the main active ingredients in garlic among them. Figure 1 depicts the molecular structures of several key compounds, including allicin (diallyl thiosulfonate), S-allyl-l-cysteine (SAC), diallyl disulfide (DADS), aE/Z-ajoene, S-allyl-l-cysteine sulfoxide (alliin), diallyl sulfide (DAS) and diallyl trisulfide (DATS). (16, 25, 28, 30). Most of these chemicals are derived from β-glutamyl-S-allyl-l-cysteine, which is the main sulfur-containing amino acid that is odorless and present in fresh, undamaged garlic bulbs. Its characteristics have been well-researched. Interestingly, the primary bioactive component in unprocessed aqueous garlic extract is revealed to be diallyl thiosulfonate (allicin). Dicing or crushing garlic releases the alliinase enzyme, which then converts alliin and other sulfur-substituted molecules into allicin. Thus, whole garlic doesn't contain any thiosulfates (Figure 1).

Three essential sulfur-containing compounds are found in aqueous garlic extract and garlic homogenate: 1-propenyl allyl thiosulfonate, γ-l-glutamyl-S-alkyl-l-cysteine, and allyl methyl thiosulfonate (31). Significantly, compared to heated garlic, raw garlic's organosulfur components are frequently easier to digest (16, 32). Alliin adds umami, salty, and sweet flavors to food additives and is distinguished by its water solubility and odorlessness. After eating, S-allyl-l-cysteine sulfoxide is mostly absorbed entirely from the small intestine, where it partially breaks down into pyruvic acid, ammonia, and allyl sulfenic acid. DADS and DAS are produced by further converting allyl sulfenic acid. Numerous in vivo actions of alliin have been observed, such as the inhibition of diabetes, ischemia of the heart, harm to the liver, platelet aggregation, and rise of blood ethanol levels. Alliin itself is important for various physiological processes, even though its metabolites may have some impacts (33). On the other hand, saponin is the essential active ingredient in traditional medicine—is made of glycosyl groups of steroids connected to triterpenes and is more stable when cooked (22, 29). Purple garlic has around 40 times higher saponin levels than white garlic, which is noteworthy. Purple garlic is the only source of many saponin compounds that have been found, including Proto-degalactotigonin, proto-degalactoside D1, sativoside B1-rhamnose, sativoside R1, degalactotigonin-rhamnose, and proto-degalactotigonin-rhamnose (29). Garlic also has more phenolic chemicals than many popular vegetables—over 20 in total. Rutin, gallic acid, quercetin, β-resorcylic acid, pyrogallol, and protocatechuic acid are among the main phenolic chemicals found in garlic (34, 35). Furthermore, aged garlic extract is the only source of the potential antioxidant N-α-(1-deoxy-d-fructose-1-yl)-l-arginine (Fructose-Arginine), which lacks raw or heating treatment preparations (36). Garlic oil that has been steam-distilled also contains dimethyl, diallyl, and allyl methyl monosulfides to hexasulfides. Nonetheless, the industry uses a typical commercial formulation of garlic extract that includes substances like diallyl tetrasulfide (DATeS), All of the following: dimethyl trisulfide (DMTS), allyl methyl trisulfide (AMTS), pentasulfide (PS), hexasulfide (HS), allyl methyl disulfide (AMDS), allyl methyl tetrasulfide (AMTeS), and amyglyc disulfide (AMDS) (16, 19, 30, 37). Garlic oil contains vinyl dithiins, allyl sulfides, and ajoenes are found in greater concentrations in extracted garlic oil using ether (38). Garlic also contains 1% galactose, 14% glucose, and 85% fructose (39). The bioactive compounds of garlic have been studied using different processing techniques. Notably, the heat processing that black garlic, a processed food product, undergoes causes chemical reactions that alter its composition. Compositional changes arose from the thermal processing of raw garlic using nuclear magnetic resonance-based analysis, finding 38 components that were impacted (40).

Hypoglycemic Effects

Because of its glucoregulatory, blood-pressure-lowering, and cholesterol-reducing properties garlic and its constituents have been linked to a potential future in the treatment of chronic metabolic syndrome (41). Many studies have demonstrated that garlic is effective in lowering blood glucose levels in people and a variety of animal models of type 1 and type 2 diabetes (42, 43). Studies on the glucoregulatory effects of garlic extract and different organosolvent garlic constituents on O-GlcNAc transferase (OGT) in rabbits with spontaneous and alloxan-induced diabetes were conducted in the 1970s. According to their research, a variety of garlic extracts, including those made using diethyl ether, petroleum ether, and ethyl alcohol, showed hypoglycemic properties. These results were linked to decreased levels of fasting blood glucose (FBG) in models with diabetes and increased OGT in both normal and diabetic animals (44). Allicin is the bioactive compound of the garlic (45, 46). According to their findings, garlic's hypoglycemic effect is mainly caused by sulfur-enrichment chemicals found in garlic juice (47). In rats with slightly induced diabetes from alloxan, allicin showed a decrease in FBG and a rise in OGT, but it had a limited effect on FBG in healthy rats. Moreover, investigators noticed serum insulin-like action, suggesting enhanced absorption of glucose in the diaphragm of rats subjected to allicin and suffering from moderate alloxan-induced diabetes (46). Other investigations showed improved OGT after treatment with decoction-prepared garlic (48). and lowered blood glucose levels after freshly steamed garlic eating in normal animals (49). When fresh garlic was administered to diabetic rats, the anti-diabetic effects on FBG were also noticeable (50). Significant antidiabetic effects were observed in a variety of garlic preparations, including aqueous garlic extract (51), garlic oil (52), garlic powder (53-55), garlic leaf extract (56), mixed garlic (57), garlic bulb (48), matured garlic extract (58), minced garlic (59, 60), garlic pulp (61), and garlic ethanol extract of garlic (62).

Preclinical Trials:

Ethanol-extracted steamed garlic did not affect normal rats' random blood sugar values (49). Similarly, when garlic powder was fed to streptozotocin (STZ)-induced diabetic mice and it was found no hypoglycemic effects on fasting blood glucose (FBG) (17, 57). In STZ-diabetes mellitus (DM) rats, an aqueous garlic extract was likewise shown to not affect FBG (63). On the other hand, oral glucose tolerance (OGT) was enhanced in diabetic mice given garlic oil (59, 60). Variations in the degree of β-cell damage among different animal models, test dosages and duration, types of garlic preparations utilized, and variables examined (e.g., FBG or OGT) might all be contributing factors to discrepancies in these findings. Moreover, studies showed that alliin, which is the precursor of garlic extract, has anti-diabetic properties similar to those of glibenclamide. These effects include a considerable reduction in blood glucose, serum lipids, and enzyme activity (64, 65). Similarly, the impact of diallyl disulfide (DADS) and garlic oil on rats with diabetes caused by streptozotocin on renal function and glycemic management was also studied (59). The findings showed that DADS and garlic oil had no discernible effects on fasting blood glucose levels. Garlic oil mainly enhanced oral glucose tolerance at different times and reduced proteinuria after 16 16-week periods, even though it didn't have an immediate effect on oral glucose tolerance in diabetics. However, neither renal function nor oral glucose tolerance was significantly affected by DADS (66). The inadequacy of garlic to maintain normal blood sugar homeostasis is indicated by its inability to lower FBG concentrations in healthy mice. Garlic's incapacity to reduce abnormally elevated FBG concentrations in diabetes, however, may be due to minimal residual β-cell mass in the employed model, which lacks basal insulin concentrations high enough to demonstrate changes in glucose clearance at a first-order level (50, 60). Several study groups have reported that administering garlic extract lowers blood glucose, total cholesterol, and triglyceride levels when assessing the hypoglycemic effect of garlic by oral glucose tolerance testing (OGT) following a glucose challenge (62). In streptozotocin-induced diabetic rats, aged garlic extract showed a dose-dependent antidiabetic activity (67). Furthermore, studies on garlic oil have shown that it has anti-inflammatory and antioxidant qualities that improve oral glucose resistance and insulin sensitivity in a dose-dependent way. The hypoglycemic impact of garlic extract has also been demonstrated to lower oxidative stress (68). In diabetic mice, raw garlic showed promise in promoting proteinuria and reducing blood glucose, cholesterol, and triacylglycerides (69). Research on the effects of raw garlic on oxidative stress, metabolic diseases, and insulin tolerance demonstrated that therapy with Allium sativum L dramatically reduced blood sugar levels in rats given fructose (70). Additionally, studies emphasize the preventive effect of a garlic component called alliin against metabolic risk factors (71). They found that administering alliin to diet-induced obese mice improves glucose homeostasis and increases insulin sensitivity.

Clinical Trials

Although different laboratory experiments have demonstrated that garlic and its formulations are effective antidiabetic agents in a variety of animal models, there hasn't been much research done on how these effects translate to people. Conflicting results from a small number of human studies have made more research necessary (55, 72-74). Treatment with garlic powder, garlic, garlic oil, and garlic tablets (Kwai and Allicor) has demonstrated a significant decrease in blood glucose levels. Nevertheless, ethyl acetate extract, fresh garlic, and garlic powder were not shown to significantly alter blood glucose levels in subsequent studies (75, 76). Furthermore, the effectiveness of garlic supplements in treating type II diabetes mellitus was demonstrated by a thorough meta-analysis involving 768 participants from nine randomized controlled studies that significantly lower fructosamine and glycosylated hemoglobin, indicating their efficacy (77). However, it is still unknown how important garlic is, how it is prepared, and how long it should be taken by diabetes people.

Mode of action:

Different modes of action are required for anti-diabetic drugs due to impaired insulin sensitivity and secretion, which are hallmark aspects of diabetes. These medications may decrease blood sugar-raising hormones, enhance microcirculation, elevate the number and responsiveness of insulin receptors, scavenge free radicals, raise the concentration of glycogen, treat protein and lipid metabolic dysregulation, prevent lipid peroxidation, and improve the utilization of blood glucose by organs. They can also stimulate insulin release by activating β-cells in pancreatic islets (26, 78, 79).

Plant extracts have been suggested as antidiabetic drugs; they work in several ways, such as affecting the development of pancreatic β-cells, improving the inhibitory effects of insulinase, increasing insulin sensitivity, and displaying insulin-like activity. Other mechanisms include intestinal glucose absorption suppression, hepatic glycogen synthesis, decreased glycogenolysis, glycemic index, peripheral glucose intake, and glutathione minimization (80). Popular spice garlic affects blood sugar levels in several ways, including acting as an insulin replacement, blocking insulinase activity, raising insulin secretion, promoting β-cell regeneration, increasing the amount of glycogen in the liver, and preventing the absorption of carbohydrates through plant fiber (15, 56, 59, 62, 81, 82). Furthermore, it is hypothesized that disulfide compounds prevent insulin deactivation by reacting with endogenous thiol-containing molecules, such as serum albumin, glutathiones, and cysteine, which are thought to resemble insulin (15). This shows that in hepatic and muscle cells, promoting glycogen synthesis and suppressing glucose production and glycogen breakdown directly reduce glucose levels (59). However, research findings generally suggest that garlic has a hypoglycemic impact through two main modes of action: as an insulin-sensitizing agent and as an insulin-releasing agent (22).

Mechanism of Insulin Secretagogue:

β-cells are triggered to secrete insulin by secretagogues. When it comes to people with type 1 diabetes, who have insufficient β-cell mass, alternatives to exogenous insulin are usually investigated. Moreover, insulin Secretagogue treatment is frequently successful for people diagnosed with type 2 diabetes (T2DM) who have a β-cell mass that is close to average but insufficient insulin responsiveness to blood glucose stimulation. Garlic's hypoglycemic impact may be explained by an increase in peripheral insulin-like response, which can arise by direct activation of residual β-cells from the pancreas or indirect release of GIT hormones linked to insulin secretion from the pancreas (45). Garlic's hypoglycemic action may be explained by the release of fixed insulin or the direct metabolite impact of sulfur compounds, which are especially prevalent during hypoglycemia (83). Garlic's sulfur-containing substances, such as flavonoids, allyl propyl disulfide (APDS), and disulfide oxide (allicin), competitively block the liver's insulin deactivation sites, lowering blood sugar levels and raising free insulin levels as a result. By disrupting the sulfhydryl domain, these organosulfur compounds can modify the function of proteins. The main active ingredient in garlic, allicin, probably works against substances that inhibit the action of insulin, including cysteine, by freeing the insulin from its deactivation (84). According to research, administering SACS to alloxan-diabetic animals raised blood insulin levels and promoted the formation of insulin by β-cells of the pancreas in rats given normal blood glucose activation (85, 86). Similar to the well-known antidiabetic medication glibenclamide, SACS showed improvement in diabetic rat symptoms (87). As a substitute, researchers suggested an alternative mechanism (65). They proposed that S-allyl cysteine sulfoxide (SACS), an antioxidant derived from garlic, had a beneficial effect on the management of diabetes.

Mechanism Sensitizing to Insulin

There is a long-standing correlation between obesity and insulin sensitivity, and it has been proposed that lipids prevent muscles from using insulin-stimulated glucose by blocking glycolysis. Researchers have shown that abnormalities in insulin-stimulated glucose transport are associated with lipid-induced insulin sensitivity in skeletal muscle. Insulin resistance is demonstrated by the steatotic liver, which is defined by intrahepatic fat that makes up at least 5% of the liver's weight. This inhibits the liver's ability to produce glucose and stimulates the synthesis of glycogen. Novel protein kinases C are activated by intracellular lipid buildup, namely diacylglycerol, which also interferes with insulin signaling in the liver and muscles (88). Allicin, a chemical found in garlic, works by boosting endogenous insulin action by decreasing glucose-6-phosphatase activity and raising the liver's synthesis of alpha-glucan phosphorylase (45). Research has demonstrated that in diabetic rats, SACS increases the amount of glycogen in the liver. Insulin resistance indices and glucose disappearance rates are improved by providing therapy with garlic extract and its sulfur-enrichment component DATS, indicating the possibility of garlic chemicals acting as insulin sensitizers (65). Compounds found in garlic increase insulin sensitivity and secretion, especially in skeletal muscle, which is important for the body's insulin-induced glucose consumption. Garlic oil and DATS have been shown to significantly reduce insulin resistance index, basal insulin concentration, and insulin secretion in streptozotocin-induced diabetic rats, all of which help enhance glycemic management. Additionally, chemicals found in garlic may lower peripheral nonesterified fatty acid concentrations, which may have a beneficial effect on insulin secretion. By preventing the production of advanced glycation products (AGEs), which contribute to aging and chronic difficulties associated with diabetes, garlic has been demonstrated to avoid the long-term effects of the disease. Numerous biological actions of garlic, which include anti-inflammatory, cardiovascular, hepatoprotective, digestive, and renal system protection qualities, all contribute to its potential as an antidiabetic drug in addition to its anti-glycation benefits.

Adverse Effects:

Clinical research has shown that using garlic is frequently linked to several symptoms, chief among them being body odor and garlic breath (89). Garlic ingestion has been associated with allergic reactions, such as photoallergy, pemphigus, angioedema, generalized urticaria, allergic contact dermatitis, and anaphylaxis. Case studies have shown that fresh garlic, when applied topically beneath occlusive dressings, can cause burns platelet dysfunction, and coagulation problems, which can result in bleeding. When nursing, women who eat garlic may observe changes in their baby's behavior. Garlic also can decrease the efficacy of anti-AIDS drugs like saquinavir while increasing the pharmacological effects of anticoagulants like warfarin and fuindione, therefore use with caution (90). Breath odor is the most common adverse reaction to ingesting garlic, especially when the plant is consumed raw. Significant adverse effects include nausea and vomiting, which highlight the need for caution when consuming large amounts of garlic. Although anaphylaxis and topical garlic burns are uncommon, garlic is usually thought to be harmless. In rare instances of garlic allergy, protein allinase causes IgE-mediated hypersensitivity reactions—has been linked. Garlic is therefore discouraged when taking anticoagulant medicine (13). Unusual occurrences highlight the significance of moderation, such as spontaneous spinal or epidural hematoma associated with excessive garlic usage.

Perspective on Future Directions:

The review highlights garlic (*Allium sativum* L.) as a potentially interesting topic for future studies on diabetes mellitus. To support the possible health advantages of garlic for people, however, thorough systematic pharmacological investigations and clinical trials are necessary, with a special emphasis on comprehending garlic's adverse effects and safety concerns.

CONCLUSION

Around the world, *Allium sativum* L. is a widely utilized spice and earliest known botanical remedy boasting a lengthy history of therapeutic usage for a variety of ailments and health-related issues. Based on research done in several animal models and human cell lines, bioactive components of garlic, such as organosulphur (S-allyl cysteine, diallyl sulfide, trisulfide, disulfide, ajoene, and alliin), are strong antidiabetic medicines. By acting as an insulin-sensitizing agent and as an insulin-releasing agent, the bioactive components in Allium sativum and their medicinal dosages can provide antidiabetic effects (i.e., improving glucose regulation and reducing the symptoms of diabetes).

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Table 1: Oral Hypoglycemic Agents and Their Classes (91)

Drug Class	Specific Drug
Sulfonylureas	Glimepiride, Glyburide, Gliclazide, Glimepiride
Biguanides	Metformin
α-Glucosidase Inhibitors	Acarbose, Miglitol, Voglibose
Thiazolidinediones	Pioglitazone, Rosiglitazone
Non-Sulfonylurea Secretagogues	Meglitinide, Repaglinide
SGLT2 inhibitors	Dapagliflozin, Canagliflozin
Cycloset	Bromocriptine

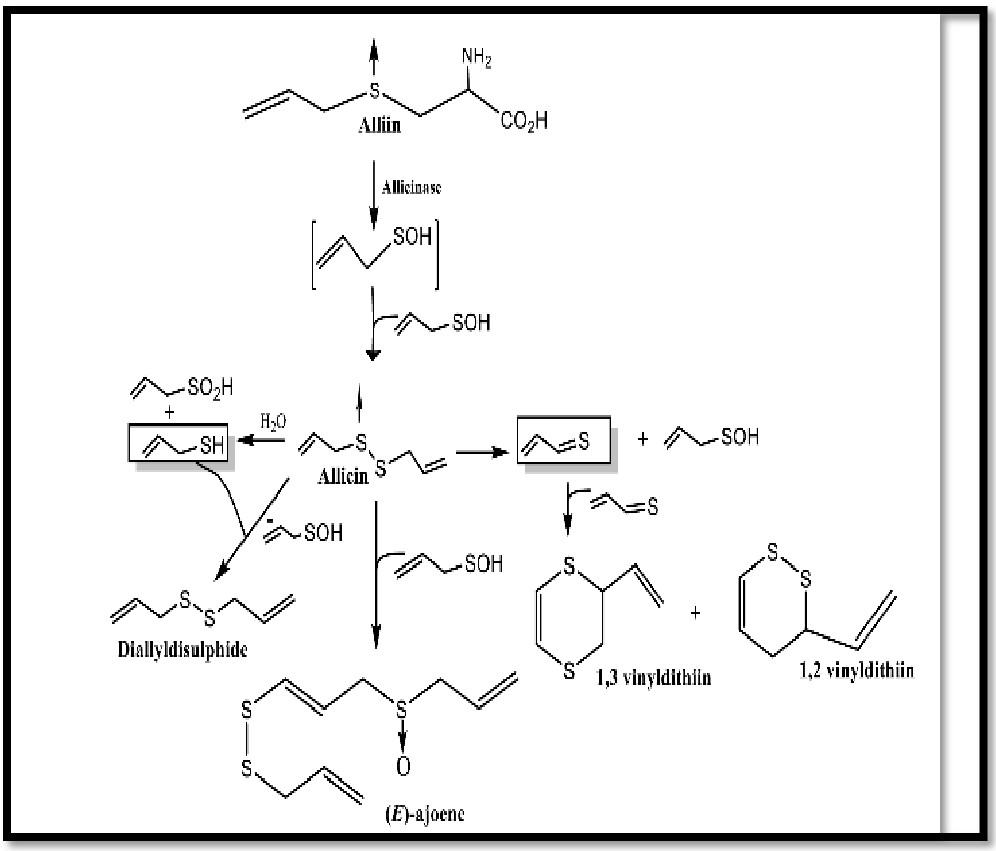

Figure 1: Production of sulfur-substituted molecules by the enzymatic interaction of alliin with alliinase (30).

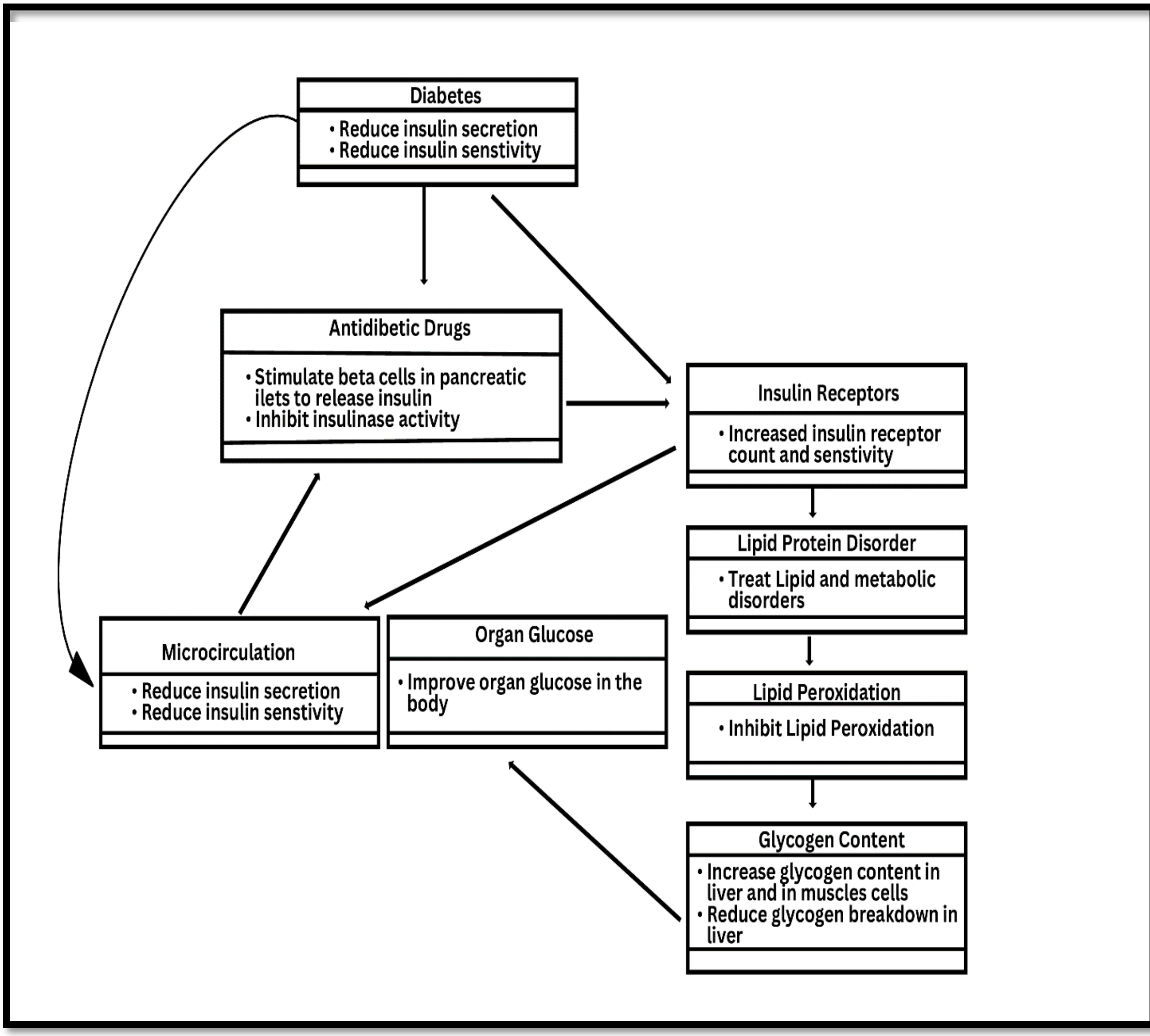

Figure 2: Mechanisms of Antidiabetic Interventions