Journal of Ayurvedic and Herbal Medicine 2024; 10(2): 56-66

Review Article

ISSN: 2454-5023
J. Ayu. Herb. Med.
2024; 10(2): 56-66
Received: 23-04-2024
Accepted: 14-06-2024

www.ayurvedjournal.com
DOI: 10.31254/jahm.2024.10206

A review: Anti-Diabetic Plants and its Recent Application

Prasad Deshmukh, Amruta Phuse, Sangam Nimkar, Dipti Ruikar, Aditya Raut

Department of Pharmaceutics, P. R. Pote Patil College of Pharmacy, Amravati, Maharashtra, India

ABSTRACT

Recent studies have emphasized the therapeutic possibilities of plant-based treatments in the management of diabetes, demonstrating their wide range of bioactive substances and mechanism of action. Diabetes mellitus is a common chronic illness that puts communities at serious danger all around the entire world. Over the last thirty years, diabetes has been seen as more serious than a mild lifestyle disease. The elderly has a substantial influence on people of all ages, contributing to both illness and mortality. Diabetes has a number of causes, including high blood pressure, pancreatic illnesses, obesity, stress, poor diet, and so on. There were 422 million people with diabetes in 2014 compared to 108 million in 1980. Between 2000 and 2019, there was a 3% rise in age-specific diabetes mortality rates. An estimated 2 million individuals lost their lives to diabetes-related kidney disease in 2019. Because they contain significant phytochemicals with therapeutic properties, herbal remedies provide enormous promise for treating a wide range of illnesses. Diabetes is a severe metabolic illness that may be treated with a number of commercially accessible drugs. These over-the-counter medications come with a number of drawbacks and are costly. The use of herbal medications is growing in popularity since they are less expensive and have better therapeutic results with fewer adverse effects. Herbal medicines are becoming more and more popular worldwide, and plants are a rich source of chemicals that prevent diabetes. As a result, a thorough analysis of plants that prevent diabetes has been carried out. Additionally, manual searches were carried out in secondary sources and supplemental publications. To get access to up-to-date research and a comprehensive list of references, guidance was obtained from specialists in the domains of Ayurveda, Siddha, Unani, and homoeopathy. This article offers helpful information on the many medicinal plants that may be used to treat issues related to diabetes. To learn more about these plants' mechanisms and active ingredients, additional research may be done. Additionally, we are going to discuss about the latest research on the anti-diabetic properties of the following plants: Alstonia scholaris, Annona Squamosa, Momordica charantia, Cinnamon, Fenugreek, Allium sativum, Neem, Ocimum sanctum, Ginseng berry, and Aloe vera. The data provided above consists of many researches that identify potential curative phytoconstituents for the treatment of diabetes mellitus

Keywords: Diabetes mellitus, Ayurveda, herbal medicine, Antidiabetic study, Hyperglycemic, Hypoglycemic.

INTRODUCTION

In 1980, there were 108 million persons with diabetes; by 2014, there were 422 million. Age-specific diabetes death rates increased by 3% between 2000 and 2019. An estimated 2 million people died in 2019 from diabetes and renal damage induced by the condition. Because diabetes damages nerve and reduces blood flow, many patients with the disease experience foot difficulties [1].

Diabetes mellitus is a metabolic disorder characterized by hyperglycaemia, glycosuria, hyperlipidaemia, negative nitrogen balance and sometimes ketonemia [2]. Diabetes is caused by the body's inability to produce or respond to the pancreatic hormone insulin. One of the important physiological actions of insulin is to control blood glucose levels [3].

Diabetes mellitus can be divided into two main types, Type 1, "Juvenile Diabetes Mellitus" (Insulin Dependent Diabetes Mellitus) and Type 2, "Adult type" (Non-Insulin Dependent Diabetes Mellitus). In diabetes type 1, the pancreas does not make insulin, because the body's immune system attacks the islet cells in the pancreas that make insulin. In diabetes type 2, the pancreas makes less insulin than used to, and your body becomes resistant to insulin.

Antidiabetic drug**,** any drug that works to lower abnormally high glucose (sugar) levels in the blood, which are characteristic of the endocrine system disorder known as diabetes mellitus. The most common side effects of most diabetes drugs are gastrointestinal disturbances, which include constipation, vomiting, nausea, diarrhoea, and indigestion. headache, vertigo, and trembling rash that is itchy and allergic Joint pain and swelling, soreness in the muscles, A rare yet serious consequence is acute pancreatitis. Additional rare adverse effects include low platelets, lung disease, liver inflammation and jaundice, bruising, and bleeding [4].

***Corresponding author:**
Dr. Prasad R Deshmukh
Department of pharmaceutics, P. R. Pote Patil College of Pharmacy, Amravati, Maharashtra, India
Email:
prasad.deshmukh37@gmail.com

Natural herbal remedies have been used for thousands of years in human medicine because they provide beneficial therapeutic ingredients for a wide range of disorders. Crude medications can be safely, effectively, and satisfactorily analysed by experts in the field so that they can be incorporated into modern healthcare facilities. It guarantees these natural ingredients' efficacy, safety, and quality.

Plants are powerful herbal remedies and natural antioxidants in part because they contain anti-diabetic substances like alkaloids, tannins, phenolic acids, and flavonoids, which enhance the function of pancreatic tissues by either reducing intestinal glucose absorption or increasing insulin secretion [5].

The use of medicinal plants to treat diabetes is now again being studied. Prototypic compounds found in medicinal plants have been the source of many traditional drugs. One example of a successful oral glucose-lowering medication is metformin. Galega officinalis was used to treat diabetes, which served as the basis for its development [6]. Our primary objective of this review is to focus on the extracts of anti diabetic plants. The review aims to collect and analyse the study of anti-diabetic phytoconstituents, which comprises a great potential for its effect.

Main Text

- ***Aloe Vera***

Figure 1: *Aloe Vera*

Plant profile

The botanical name of *Aloe Vera* is Aloe barbadensis miller. The synonyms of *Aloe Vera* are Ghritkumari and in Marathi- Korphad.

It belongs to Asphodelaceae (Liliaceae) family, and is a shrubby or arborescent, perennial, xerophytic, succulent, pea- green color plant (Fig 1).

The Chemical constituents of Aloe Vera was found Aloin, Barbaloin, β-barboloin and Isobarbaloin, Emodin, Anthraquinone.

Aloe Vera plants are used for Antidiabetics, Anticancer, Anticancer, Antioxidant.

It grows mainly in the dry regions of Africa, Asia, Europe, America and many parts of India including North West Himalaya region.

Restoring damaged pancreatic beta cells and their normal function can be achieved through the use of Aloe vera. All beta cells have deteriorated, but Aloe vera contains compounds that can help reduce blood sugar levels and act similarly to insulin. A total of 20 Wistar strain rats were selected and divided into four groups based on the dosage they received: 250 mg/dl, 350 mg/dl, and 1000 mg/dl. Following acclimation, rats were injected with streptozotocin on the eighth day. For a period of nine days, Aloe vera extract was given as a treatment. Data analysis involved the use of Paired t Test and ANOVA. 350 mg/kgBW of Aloe vera extract was found to be the most effective dose based on the ANOVA results. The chromium, alprogen, and flavonoids found in Aloe vera contribute to improving the function of the pancreas beta cells involved in producing insulin. This will help protect the pancreatic islets of Langerhans cells and improve the sensitivity of the insulin receptor cells [7].

Following the crushing and drying process, the plant was soaked in methanol. The production of AGEs, fructosamine, CML, and carbonyl protein was significantly reduced by the methanol extract of aloe vera (AVM). The enzymes alpha-amylase and alpha-glucosidase were significantly inhibited by AVM. Throughout the four weeks of the trial, there was a significant increase in the concentration of thiol groups. Through the utilization of various assays such as BSA/glucose, BSA-methylglyoxal, and arginine-methylglyoxal, the methanol extract of aloe vera has shown potential in reducing postprandial glucose levels, suggesting that it could help prevent diabetic complications associated with AGE [8].

We have obtained a new compound, 6'-O-(E)–cinnamoyl-7-methoxy-aloin A, from aloe vera (1). The initial name for the A. vera report was chysalodin (2). We utilized the HR-ESI mass and 1/2D-NMR spectra to identify these kinds of structures. We examined the isolated compounds' inhibitory effects on α-glucosidase using a spectrophotometer. An examination of the enzyme's kinetics unveiled the process of ligand-enzyme binding: the ligand attaches to the active site of the enzyme in a competitive manner. This discovery indicates that anthraquinone dimer (2) could serve as the foundation for a new category of α-glucosidase inhibitors [9].

The leaf latex of Aloe pulcherrima has been used as a treatment for diabetes. We utilized the dinitro salicylic acid test to evaluate the α-amylase inhibitory activity of the A. pulcherrima leaf latex, while the glucose oxidase assay was employed to ascertain the inhibitory effects of sucrase and maltase. To determine the effectiveness of latex in reducing blood glucose levels, oral treatment was administered to normoglycemic, glucose-loaded, and streptozotocin-induced diabetic mice. In a diabetes mouse model induced by streptozotocin, there was a significant decrease in blood glucose levels during the first week and a slight decrease in the second week. With the increase in A. pulcherrima leaf latex dosages, there was a corresponding decrease in glucose levels. The leaf latex of the plant demonstrated a potent antidiabetic effect, supporting its traditional uses [10].

Exploring the antiglycation properties of two isolated substances, aloin and aloe-emodin, along with leaf extracts from A. arborescens. The phytoconstituent was quantitatively assessed through high performance liquid chromatography (HPLC) analysis in methanolic and hydroalcoholic extracts. Examining the antiglycation and antiradical qualities of the two extracts using bovine serum albumin (BSA) and 1,1-diphenyl-2-picrylhydrazil (DPPH) assays, along with aloin and aloe-emodin. Moreover, the cytotoxicity in HT-29 human colon adenocarcinoma cells was evaluated using the 3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyl tetrazolium bromide (MTT) assay. Overall, the results

show that the A. arborescens extracts, whether methanolic or hydroalcoholic, effectively reduce glycation and free-radical presence without causing harm. Moreover, the results show that aloin and aloe-emodin exhibit less potent antiglycation and antiradical properties when compared to the two extracts. Based on the permeability investigation, aloe-emodin is the sole substance capable of passing through HT-29 cellular membranes [11].

❖ ***Momordica charantia***

Fig 2: *Momordica charantia*

Plant profile

Momordica charantia is also called as Bitter Gourd, Karela. *Momordica charantia* L., a member of the Cucurbitaceae family, has traditionally been used as herbal medicine and as a vegetable (Fig 2).

Functional ingredients of M. charantia play important roles in body health and human nutrition, which can be used directly or indirectly in treating or preventing hyperglycaemia-related chronic diseases in humans.

The Chemical constituents of *Momordica charantia* found to be Charantin, Momordicin, Carbohydrate, Ascorbic Acid, Alkaloids, Glucoside, Saponins, Mucilage.

It is used for Antidiabetics, Anticancer, Anti-inflammation, Antivirus.

It is tropical plant that is widely cultivated in Asia, India, East Africa, and South America.

The aqueous extracts from Tamarindus Indica and Momordica charantia seeds have demonstrated potent antidiabetic effects by reducing glucose levels in diabetic adipocytes. Upon the addition of plant extracts, a significant decrease in blood sugar levels was observed after seven and fourteen days. As expected, adipocytes treated with glucose showed a substantial change in their lipid profiles, affecting total cholesterol (TC), triglyceride (TGL), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and very low-density lipoprotein (VLDL), when compared to control adipocytes. The levels of glucose-6-phosphatase, glucose-oxidizing enzyme, and glucose-phosphorylating enzyme were significantly reduced in the group that received the extract. After seven days of extract supplementation, the parameters were not reset to a controlled level. However, after 14 days of supplementation, each variable returned to the control level. Highlighting the potential benefits of Tamarindus Indica and Momordica charantia seed extract supplements in managing diabetes could pave the way for innovative antidiabetic treatments [12].

Streptozocin induced type-2 diabetic rat models were administered with water, glibenclamide, and M. dioica extracts at a dose of 1.25 g/kg body weight (bw) for 28 days. The extract of M. dioica demonstrated a notable reduction in serum glucose level 120 minutes after eating. Administering the extract to diabetic model rats led to a decrease in serum cholesterol levels. Throughout the following 28 days of treatment, insulin levels decreased in all groups. The study findings indicated that extended use of M. dioica had a positive impact on the blood sugar and lipid levels of rats with type-2 diabetes, suggesting further investigation is required to pinpoint the key component [13].

Using computational methods, researchers identify the most effective antidiabetic peptides derived from M. charantia hypoglycemic polypeptide-P. Through the molecular docking approach, the study evaluated the binding affinity and interaction patterns of peptides with four receptor proteins, including insulin receptor agonists and inhibitors of sodium-glucose cotransporter 1, dipeptidyl peptidase-IV, and glucose transporter 2. Thirty-seven peptides were docked with the receptors in the body We have selected the top eight ligands: EPGGGG, TSEP, EKAI, LKHA, EALF, VAEK, and DFGAS. Regarding the insulin and SGLT1 receptor proteins, a specific peptide, EPGGGG, showed activity. The selected ligands showed excellent adherence to drug-like evaluation criteria and demonstrated positive effects in treating diabetes [14].

Assessing the impact of using aqueous bitter gourd extract (Momordica charantia) encapsulated double emulsion-based functional mayonnaise on normal and streptozotocin-induced type 2 diabetes in albino male Wister rats. The researcher's findings demonstrated a noteworthy anti-diabetic effect in streptozotocin-induced diabetic male albino Wistar rats. This effect was characterized by reduced blood glucose and HbA1c levels, along with increased body weight, hemoglobin, and plasma insulin [15].

Bitter melon (Momordica charantia) is a medicinal food recognized for its established hypoglycemic and antihyperlipidemic effects. The fruits of Momordica charantia L. (bitter melon) were obtained in dried form, finely powdered, and underwent reflux extraction with 70% alcohol twice for 1 hour each. Following the filtration of the extraction solutions, they were merged and subjected to vacuum evaporation for UPLC-QTOF-MS analysis. Based on the microbiological analysis, MC had a significant effect on the diversity and overall structure of gut microbiota. The study improved the prevalence of short-chain fatty acid (SCFAs)-producing genera and boosted fecal SCFAs content in a specific way. The study indicates that M. charantia fruit (MC) may have a positive effect on hyperlipidemia by affecting gut microbes and increasing SCFAs production [16].

Examining the antidiabetic effects and potential mechanism of saponins (SMC) and polysaccharides (PMC) from M. charantia in streptozotocin (STZ)-induced type 2 diabetic mice with high-fat diet. Three different dosages of SMC (L-SMC: 20 mg/kg, M-SMC: 40 mg/kg, H-SMC: 80 mg/kg) have demonstrated a particular therapeutic effect on type 2 diabetic mice, with the 40 mg/kg dosage being recognized as the most effective for preventing and treating diabetes. According to the study results, giving SMC orally, specifically M-SMC at 40 mg/kg, showed greater effectiveness compared to PMC at 500 mg/kg. Significant enhancements were observed in body weight, fasting blood glucose levels, insulin resistance, and the ratio of hepatic

phosphorylated adenosine monophosphate-activated protein kinase (p-AMPK)/total protein. Moreover, it aided in the restoration of the pancreatic β cells that were harmed by STZ [17].

Utilizing ultrasound-microwave technology, M. charantia powder was effectively extracted through a one-step ATPE process with isopropyl alcohol and (NH4)2SO4. We used an aqueous extract of Momordica charantia (AEMC) to investigate the effects of insulin and glucagon-like peptide-1 (GLP-1) hormone on different factors in both healthy and diabetic wistar rats, such as plasma concentrations, tissue glycogen, glycosylated hemoglobin, and fasting blood glucose (FBG). Male Wistar rats, both normal and diabetic, received AEMC intraperitoneally at a dosage of 300 mg/kg body weight daily for 28 days. An elevation in tissue glycogen, serum insulin, and GLP-1 was observed with AEMC in both healthy and diabetic Wistar rats, whereas FBG and glycosylated hemoglobin decreased in diabetic Wistar rats. Considering an alternative method for diabetes management: the effectiveness of M. charantia fruit extracts in reducing blood sugar levels [18].

❖ ***Cinnamon***

Figure 3: *Cinnamon*

Plant profile

Synonyms of *Cinnamon* are Cinnamon Bark, Ceylon Cinnamon, Kalmi-Dalchini *Cinnamon* consists of the dried inner bark of the shoots of coppiced trees of Cinnamomum zeylanicum Nees, Family Lauraceae (Fig 3).

Chemical constituents of Cinnamon 0.5 to 6.0 percent of volatile oil, cinnamic aldehyde (60-70%) and eugenol (4%), tannin and mucilage The uses of Cinnamon are Antidiabetic, Anti-inflammatory, Antitumor, Antimicrobial Cinnamomum zeylanicum is mostly found in Sri Lanka and South India.

Exploring the impact of cinnamon on acetylcholinesterase (AChE) activity and oxidative defects in streptozotocin (STZ)-induced diabetes-related memory dysfunction. The study analysed AChE enzyme activity and oxidative variables in the Diabetic (Dia) group compared to the control group. The level of antioxidants decreased significantly in the Dia group in comparison to the Control group. The study suggests that the hydro-ethanolic extract of cinnamon may enhance memory restoration in diabetic conditions by reducing AChE activity and oxidative damage [19].

Cinnamon extract helps reduce streptozotocin-induced type 1 diabetes in rats. We used two-dimensional gel electrophoresis to identify the molecular target of cinnamon in adipocytes. We utilized mice with Type 2 diabetes to study the impact of cinnamon extract on glucose tolerance, acyl-CoA synthetase long chain family member 1 (ACSL1) expression, and associated signal molecules in a live setting. In 3T3-L1 adipocytes, CE reduced ACSL1 mRNA and protein levels while enhancing glucose uptake and activating AMPK signaling. In mice adipose tissue, CE enhanced glucose tolerance and decreased ACSL1 expression [20].

C. zeylanicum is widely recognized as a potent alternative for managing diabetes. Cinnamaldehyde is a significant component (65-80%) of bark oil extracted from C. Zeylonicum, which appears to lower plasma blood glucose levels with greater efficiency than metformin. It improves the expression of proteins related to glucose transport, insulin signaling, and helps regulate dyslipidemia. A study revealed a reduction in glucose levels in diabetic rats when given cinnamon [21].

This study thoroughly examined the anti-hyperglycaemic properties of the four main commercial cinnamon types used globally (Chinese; Cinnamomum cassia [CC], Indonesian; C. burmanii [IC], Vietnamese; C. loureirii [VC], and Ceylon; C. zeylanicum [SC]). Analyzing with LC-MS revealed clear variations in the phytochemical compositions of cinnamon. All varieties of cinnamon demonstrated strong species-specific effects on inhibiting the function of starch digestion enzymes. Ceylon cinnamon demonstrated superior bioactive and anti-nutrient profiles, enzyme inhibitory activity, as well as effects on starch digestion. Thus, CC demonstrated the highest effectiveness against α-amylase. Cinnamon showcases anti-hyperglycaemic properties, but its benefits vary depending on the species, with the most beneficial properties observed in Ceylon cinnamon [22].

This study focuses on assessing the substantial inhibitory impact of cinnamon on CYP2D. Rats with induced diabetes and normal rats. By employing isolated perfusion of rat livers, the researchers assessed the metabolic activity of CYP2D in the study groups. Cinnamon has a notable impact on decreasing the production of CYP2D-mediated metabolism of tramadol in both the control group and diabetic group. This research clearly demonstrates the substantial inhibitory impact of cinnamon on CYP2D [23].

Researched the impact of Cinnamomi cassiae extract (Cinnamon bark: Lauraceae) on the anti-diabetic effect in a type II diabetic animal model (C57BIKsj db/db). A significant reduction in blood glucose concentration was observed in a dose-dependent manner ($P < 0.001$), with the most pronounced effect seen in the 200 mg/kg group compared to the control. These findings indicate that cinnamon extract plays a role in regulating blood glucose levels and lipids, and it may also help lower blood glucose by enhancing the susceptibility to insulin [24].

❖ ***Fenugreek***

Figure 4: *Fenugreek*

Plant profile

Fenugreek is called as Trigonella foenumgraecum, Methi. *Fenugreek* is an annual plant belongs to the family Fabaceae (Leguminosae). The biological name of *Fenugreek* is Trigonella foenum graecum. The fenugreek seed is the famous spices in human food (Fig 4).

Chemical constituents found in *Fenugreek* such as 35% alkaloids, trigonelline, more than 10 mg of flavonoid per gram of seed, volatile and fixed oils.

Uses of *Fenugreek* are Antidiabetic Anticancer Anti-inflammatory. Trigonelline is considered as the most important metabolite of fenugreek, which is very effective in treating diabetes and decreasing blood cholesterol.

Fenugreek is an aromatic, 30-60 cm tall, annual herb, cultivated throughout the country.

This research examined the effects of Fenugreek seeds (Trigonella foenum graecum) powder on a group of people who were not insulin-dependent diabetic patients. The results showed a decrease in blood glucose levels with the use of fenugreek seed powder. Consistent use of this powder is recommended for individuals managing their blood sugar levels. The study findings indicate that fenugreek seed powder can be a valuable supportive treatment for preventing and managing long-term complications of diabetes [25].

This research aimed to evaluate the effects of fenugreek combined with a controlled diet on prediabetic patients with fasting blood glucose (FBG) and glycosylated haemoglobin (HbA1c). Designing the research on an interventional parallel randomized control trial. Adding fenugreek to your diet can help lower blood glucose levels. Analysis indicates a notable decrease in FBG levels over the 24 months in the study group, along with a significant reduction in HbA1c specifically in the 24th month. Adding fenugreek to your diet may work together with controlling your diet to improve FBG and HbA1c levels [26].

Many medications are readily accessible for diabetes treatment. Their side effects and high costs emphasize the importance of natural herbal medicines. The Trigonella foenum-graecum herb shows great promise in the prevention and treatment of diabetes compared to other plant species, thanks to its special active ingredients like alkaloids, flavonoids, steroids, and saponins. Trigonella foenum-graecum's bioactive compounds exhibit potent antidiabetic properties [27].

The study focused on examining the cardioprotective effects of fenugreek seed on diabetic rats. Animals with diabetes received treatment using fenugreek seed extract for a duration of six weeks. Rats without diabetes were used as the control group. The extract of fenugreek seeds significantly enhanced metabolism, reduced oxidative stress, and decreased the apoptosis index. A study indicates that fenugreek seed could help safeguard the cardiac structure in STZ-induced diabetic rats by reducing oxidative stress and apoptosis [28].

This study examined how Trigonella foenum-graecum seed powder solution impacted the lipid profile of recently diagnosed type II diabetic patients. They were divided into two groups: the treatment group, who consumed Trigonella foenum-graecum seed powder solution orally twice a day for one month, and the control group. A healthcare professional collected a blood sample from every single participant before and after the study. This study demonstrated that administering Trigonella foenum-graecum seed powder solution significantly improved lipid metabolism in type II diabetic patients without any negative effects [29].

❖ ***Allium Sativum***

Figure 5: *Allium Sativum*

Plant profile

Synonyms of *Allium Sativum* are Allium and in Hindi Lasan.

Garlic is the ripe bulb of Allium sativum Linn., belonging to family Liliaceae Chemical Constituents of *Allium Sativum* are Allicin, a yellow liquid responsible for the odour of garlic, is the active principle of the drug (Fig 5). It is miscible with alcohol, ether, and benzene and decomposes on distilling. The other constituents reported in Garlic are alliin, volatile and fatty oils, mucilage and albumin Alliin, another active principle, is odourless, crystallized from water, acetone and practically insoluble in absolute alcohol, chloroform, acetone, ether, and benzene.

It mostly used as Antidiabetics, liver disorders, tuberculosis, facial paralysis, high blood pressure, and bronchitis.

Garlic occurs in central Asia, southern Europe, and United States. It is widely cultivated in India.

Mice in Kunming were given different doses of garlic polysaccharide (GP) for five weeks following the induction of insulin resistance by a high-oil-high-sugar diet and streptozotocin (STZ). Administering GP intragastrically effectively improved the symptoms of polyphagia and polydipsia in diabetic mice. The fasting blood glucose (FBG) in the high-dose GP (DGH) group was 42% lower than that in the diabetic model (DC) group, demonstrating its hypoglycemic effect. The GP could potentially influence hepatic glycogen metabolism by controlling the levels of glucokinase (GK), glycogen synthase (GS), and phosphoenolpyruvate carboxykinase (PEPCK). With a low relative molecular weight (MW) of 2.0 kDa, GP primarily comprises a 2,1-β-D-Fruf backbone with 20.7% side chains. This composition has shown a benefit on hypoglycemia, suggesting it may serve as a useful supplement for addressing hyperglycemia [30].

The silver nanoparticles were synthesized from the bulbs of Allium sativum, characterized using UV–visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), scanning electron microscope (SEM), High-resolution transmission electron microscopy (HRTEM), Energy-dispersive X-ray analysis (EDAX) analysis, and studied for their impact on starch digestion inhibition. The research demonstrated that

the silver nanoparticles produced from A. sativum exhibit significant antidiabetic effects by lowering blood sugar levels through enhanced glucose utilization, reduced hepatic glucose production, and the suppression of certain enzymes. This shows great potential as a nanomedicine for diabetes treatment [31].

The phenolic extract of Allium sativum demonstrated significant dose-dependent inhibition of α-amylase and α-glucosidase ($p < 0.05$). It is worth noting that the extract showed a significant inhibitory effect on α-glucosidase, with a half maximal inhibitory concentration of 53.75 µg/mL, which was higher than the value observed for the standard acarbose. Through docking simulation, it was determined that morellinol and phentolamine exhibited the highest binding affinity to α-glucosidase, with mean affinity values of -7.3 and -7.1 kcal/mol, respectively. These compounds demonstrated strong binding to the enzyme's active site residues and displayed favorable drug-like and pharmacokinetic properties for potential clinical use [32].

We determined the non-cytotoxic concentration of allithiamine using MTT, apoptosis, and necrosis assays. Following that, the cells were separated into three categories: one group was treated with M199 medium as the control, another with 30 mMol/L glucose, and the last one with 30 mMol/L glucose along with allithiamine. An investigation was conducted on the impact of allithiamine on advanced glycation end-products (AGEs) levels, nuclear factor- kB (NF-κB) activation, release of pro-inflammatory cytokines such as interleukin-6 (IL-6), interleukin-8 (IL-8), and tumor necrosis factor-α (TNF-α), and oxidative stress induced by H2O2. We discovered that the rise in AGE levels due to hyperglycemia was effectively reduced by allithiamine, leading to a decrease in pro-inflammatory responses. Allithiamine has the potential to reduce hyperglycemia-induced endothelial dysfunction through its strong antioxidant and anti-inflammatory properties, which work independently of transketolase activity [33].

A total of twenty-four adult male Wistar rats were randomly assigned to four groups: control, diabetic, diabetic treated with garlic, and garlic-treated normal rats. The serum was used to determine glucose level and liver enzymes activities through a colorimetric assay. Outcome Glucose level, liver enzymes activities, Malondialdehyde (MDA), Hepatic total oxidant status (TOS), levels showed significant changes in diabetic rats compared to control rats ($p<0.01$). However, after consumption of garlic, these levels returned closer to normal ($p<0.05$). In the conclusion study demonstrated the hypoglycemic and antioxidant properties of garlic in the livers of rats with type 1 diabetes [34].

❖ ***Neem***

Figure 6: *Neem*

Plant profile

Neem is also known as Azadirachta indica, margosa, nimtree or Indian lilac, is a tree in the mahogany family Meliaceae (Fig 6).

The most important active constituent is azadirachtin and the others are nimbolinin, nimbin, nimbidin, nimbidol, sodium nimbinate, gedunin, salannin, and quercetin. Neem is used as an Antidiabetics, treatment of inflammation, infections, fever, skin diseases and dental disorders. Neem tree is found throughout the country. India has maximum number of Neem trees (more than 18 million) and which are distributed in 70-75% geographical area of this country.

This research was conducted to assess the antioxidant, antidiabetic, and anti-inflammatory properties of the crude ethanolic extract of both younger and mature leaves of Azadirachta indica. The YLE and MLE extracts were given to streptozotocin-induced diabetic rats. The impact seen with YLE was notably higher than with MLE [35].

Neem leaves are rich in phytochemicals such as nimbin, nimbolide, nimbidin, and azadirachtin. They can act as antioxidants to reduce glucose levels in diabetic rats and provide various health benefits [36].

Using a higher dose of neem oil has shown to be more effective than a lower dose of Azadirachta indica in managing higher levels of glucose in diabetes. It can be a valuable alternative remedy for diabetes, provided precautions are taken to prevent extract toxicity [37].

Neem contains a variety of compounds that can be beneficial for managing diabetes. Neem compounds like rutin and quercetin demonstrate hypoglycemic/antihyperglycemic effects, while nimidin aids in weight management [38].

Neem showed significant enhancements in endothelial function, reduction in oxidative stress, and systemic inflammation compared to the placebo. The effectiveness was notable with all the doses, yet there was no impact on platelet aggregation or lipid profile [39].

❖ ***Ocimum sanctum***

Figure 7: *Ocimum sanctum*

Ocimum sanctum commonly known as Holy Basil, Tulsi, Tulasi.

Tulsi consists of fresh and dried leaves of Ocimum sanctum Linn., belonging to family Lamiaceae (Fig 7).

The leaves of Ocimum sanctum contain 0.7% volatile oil comprising about 71% eugenol and 20% methyl eugenol. It is used as Antidiabetic, Antifertility, Anticancer, Antifungal, Antimicrobial, Hepatoprotective,

Cardioprotective, Antiemetic, Antispasmodic, Analgesic, Adaptogenic and Diaphoretic actions.

It is originated in north central India and now grows native throughout the eastern world topics Three phytocompounds (1S-α-pinene, β-pinene, and dehydro-p-cymene) from O. tenuiflorum have been identified as potential inhibitors of the DPP4 protein. The DPP4 enzyme is crucial for maintaining glucose balance in the body. DPP4 focuses on and deactivates incretin hormones like glucagon-like peptide-1 (GLP-1) and gastric inhibitory polypeptide (GIP) as natural substrates, crucial for controlling the insulin secretion post meals. Due to the deactivation of incretins, hyperglycemic conditions persist and lead to diabetes mellitus [40].

We have studied the pharmacological hypoglycemic effects of Ocimum sanctum in diabetic rats. At a dosage of 250 mg/kg, Ocimum sanctum showed substantially decreased glucose levels compared to the control group. Ocimum sanctum is a significant different resource for managing diabetes mellitus by reducing elevated blood glucose levels, which warrants further investigation through oral hypoglycemic therapy [41].

The methanolic extracts of ocimum sanctum demonstrate a notable anti-hyperglycemic effect by enhancing glucose tolerance and reducing blood glucose levels in experimental animals. The levels of total cholesterol (TC), triglycerides (TG), low density lipoproteins (LDL), and very low-density lipoproteins (VLDL) were significantly decreased, while the high-density lipoproteins (HDL) level was elevated in the animals that received methanolic extracts. The pancreas histopathology showed significant regeneration of β cells and cellular expansion of islets of Langerhans in the animals treated with methanolic extracts [42].

❖ ***Ginseng berry***

Figure 8: *Ginseng Berry*

It is also known as Panax Ginseng Berry. Ginseng, the root of Panax species is a well-known conventional and perennial herb belonging to family Araliaceae. It is a short underground rhizome that is associated with the fleshy root (Fig 8).

Chemical constituents of *Ginseng berry* such as ginseng saponins, ginseng oils and phytosterol, carbohydrates and sugars, organic acids, nitrogenous substances, amino acids and peptides, vitamins and minerals, and certain enzymes The ginseng berry has various bioactivities, including antidiabetic, anticancer, anti-inflammatory, and antioxidative properties.

It is found in various countries China, Korea, and Japan that is also known as the king of all herbs and famous for many years worldwide.

Analysis of the biochemical data revealed that the red ginseng extract intervention led to significant improvements in total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), serum glucose (GLU), and fasting insulin (FINS) levels within four weeks. Analysis of metabolic pathways revealed significant regulation in D-arginine and D-ornithine metabolism, D-glutamine and D-glutamate metabolism, taurine and hypotaurine metabolism, arginine biosynthesis, and tryptophan metabolism. In general, the findings showed that red ginseng extract had positive effects on Type 2 Diabetes Mellitus (T2DM) [43].

The ginseng berry (GB) ginsenoside treatment led to a notable decrease in blood glucose levels, an increase in serum superoxide dismutase (SOD) content, and a decrease in malondialdehyde content. Analyzing metabolic pathways revealed that GB ginsenoside influenced various metabolic processes to contribute to the treatment of T2DM. GB controlled the secretion of bile acids, stimulated the GLP-1 pathway, enhanced insulin secretion, facilitated fat and triglyceride breakdown, suppressed 5α - reductase activity, decreased weight and insulin resistance, leading to the enhancement and management of T2DM [44].

Ginsenoside Rg5 effectively enhanced hyperglycemia symptoms, restored intestinal barrier function, alleviated inflammation associated with metabolic endotoxemia, and normalized gut microbiota imbalance in the colon by reducing Firmicutes/Bacteroidetes ratios. Rg5 can serve as a valuable probiotic agent that helps restore gut microbiota balance and addresses metabolic issues linked to type 2 diabetes mellitus [45].

Exploring the potential antidiabetic effects of Swertia chirayata and Panax ginseng leaf extraction on male Wistar rats. The gold thio glucose method was utilized to induce diabetes in rats. Following the oral administration of ethanolic extract of swertia chirayat and panax ginseng. Panax ginseng contains alkaloids, carbohydrates, flavonoids, and tannins that demonstrate significant anti-diabetic activity ($P< 0.05$) [46].

❖ ***Alstonia scholaris***

Figure 9: *Alstonia scholaris*

Alstonia scholaris, commonly called blackboard tree, scholar tree, milkwood or devil's tree in English, is an evergreen tropical tree in the Dogbane Family (Apocynaceae) (Fig 9).

It contains various iridoids, alkaloids, coumarins, flavonoids, leucoanthocyanins, reducing sugars, simple phenolics, steroids, saponins and tannins.

It is used for Antidiabetic, to cure diarrhoea, Tuberculosis The plant is grown in the lowland and mountain rainforests of India, the Asia-Pacific, Southern China and Queensland.

This work examined the effects of the methanol extract of Alstonia scholaris root on normoglycemic, glucose-loaded, and streptozotocin (STZ)-induced diabetic rats. We utilized one-way analysis of variance (ANOVA) and Dunnett's t-test for the statistical analysis of the data. In STZ-induced diabetic rats, the blood sugar levels decreased by 44.28 percent ($p < 0.01$) and 56.66 percent ($p < 0.001$), respectively. The research findings on Alstonia scholaris root extract indicate its potential for developing a novel herbal medication for diabetes treatment [47].

The toxicity of Pulai crude extract was evaluated using the Brine Shrimp Lethality Test (BSLT) method, which revealed an LC50 value of 461 µg/mL, suggesting moderate toxicity. Conducting tests on the *in vitro* inhibition activity of the α-glucosidase enzyme yielded an IC50 value of 152.99 µg/mL. 96% of the ethanol crude extract The Pulai bark (Alstonia scholaris R. Br) demonstrated bioactivity, with flavonoids, alkaloids, and tannins content playing a significant role in inhibiting the activity of the α-glucosidase enzyme [48].

Administering the ethanolic leaf extract of A. Scholaris orally multiple times reduced the levels of Mean blood glucose (MBG), HbA1c, and TC in diabetic rats. It successfully improved various antioxidant markers and enzyme activities in diabetic rats when compared to those that did not receive treatment. The leaf extracts of A. Scholaris show promising antidiabetic effects in rats with STZ-induced diabetes. Overall, the ethanolic leaf extract of A. Scholaris showed superior antidiabetic effects compared to its aqueous counterpart. There has been a notable enhancement in serum insulin, glycosylated Hb, and oxidative stress parameters of the kidney, such as superoxide dismutase, catalase, and reduced glutathione, in diabetic rats treated with HEAS (hydroalcoholic extract of A. scholaris bark) [49].

❖ ***Annona squamosa***

Figure 10: *Annona squamosa*

It has many other regional names such as custard apple (India), anon (Portuguese), and noi-na (Thailand).

Annona squamosa L. (custard apple) belongs to the family Annonaceae (Fig 10).

Annona squamosa is used for diabetes, treating cardiac ailments, thyroid-related disorders, and cancer. *Annona squamosa* contains phenolics, annonaceous acetogenins, saponins, flavonoids, alkaloids, glycosides, alkaloids, steroids, and terpenoids Tropical fruit cultivated in the West Indies, South and Central America, Ecuador, Peru, Brazil, India, Mexico, the Bahamas, Bermuda, and Egypt.

Annona squamosa demonstrates a reduction in non-fasting glucose levels, capillary glucose levels during an oral glucose tolerance test (OGTT), and enhancement in insulin response. The sugar apple peel has shown positive effects on glucose level regulation in both healthy and diabetic rats, possibly through the insulin signaling pathway. This could potentially serve as an alternative treatment for managing glucose levels in prediabetes and T2DM [50].

Testing the effects of an 80% v/v ethanolic extract of A. squamosa (EEAS) leaves on insulin secretion from clonal pancreatic BRIN BD11 β-cells and mouse islets, along with studying the impact of EEAS on membrane potential and intracellular calcium ion concentration. Rutin, proanthocyanidin, and squafosacin G were tentatively recognized as the anti-hyperglycemic phytomolecules in the EEAS extract of A. squamosa through HPLC and liquid chromatography-mass spectrometry (LC-MS) analysis [51].

The purpose of this study was to examine the potential hypoglycemic effects of different extracts derived from Egyptian Annona squamosa leaves. The study specifically focused on the ethanolic and aqueous extracts, as well as a combination of both. The experiment aimed to evaluate the effectiveness of these extracts in reducing hyperglycemia induced by alloxan in rats. The combination of ethanol and aqueous extracts has a more pronounced impact on the biochemical markers compared to using the aqueous and ethanolic extracts separately [52].

This study aimed to analyze the methanolic leaf extracts of various global custard apple germplasms to determine the genotypes with the most potent combination of antioxidants and antidiabetic properties. There was a wide range of variability among custard apple genotypes for both α-amylase inhibition and DPPH radical scavenging activity. The study demonstrated that smaller fruit sizes were associated with increased antidiabetic and antioxidant activities, along with higher levels of total phenolic acids [53].

CONCLUSION

A significant number of medications now in use have derived from botanical sources. Due to their growing popularity, it is wise to explore medicinal plant extracts as potential sources for novel antidiabetic hypoglycemia drugs. Diabetes mellitus continues to pose a substantial worldwide health problem, resulting in millions of fatalities each year. The data provided above consists of many researches that identify potential curative phytoconstituents for the treatment of diabetes mellitus. Determining the relative potency of different phytoconstituents as antidiabetic substances is challenging. Also study the various evaluating methods to prove qualitatively and quantitatively efficiency. Each phytoconstituent has distinct qualities that may effectively treat various forms of diabetes mellitus.

List of Abbreviations

ANOVA: Analysis of variance

AVM: Methanol Extract of Aloe Vera
AGEs: Advanced glycation end products
HR-ESI-MS: High resolution electrospray ionization mass spectrometry
NMR: Nuclear Magnetic Resonance
HPLC: High performance liquid chromatography
BSA: Bovine serum albumin
(DPPH): 1,1-diphenyl-2-picrylhydrazil
(MTT): 3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyl tetrazolium bromide
TC Total cholesterol
TGL: Triglyceride
HDL: High-density lipoprotein
LDL: Low-density lipoprotein
VLDL: Very low-density lipoprotein
SGLT1: Sodium-glucose cotransporter 1
MC: Momordica charantia
UPLC-Q-TOF-MS: Ultra-high-performance liquid chromatography with quadrupole time-of-flight mass spectrometry
SCFAs: Short-chain fatty acid
SMC: Saponins Momordica charantia
PMC: Polysaccharides Momordica charantia
STZ: Streptozotocin
ATPE: Aqueous two-phase extraction
AEMC: Aqueous extract of Momordica charantia
GLP-1: Glucagon-like peptide-1
FBG: Fasting blood glucose
AChE: Acetylcholinesterase
Dia: Diabetic
ACSL1: acyl-CoA synthetase long chain family member 1
CE: Cinnamon extract
AMPK: Activated protein kinase
CC: Cinnamomum cassia
GP: garlic polysaccharide
GK: Glucokinase
GS: Glycogen synthase
PEPCK: Phosphoenolpyruvate carboxykinase
FTIR: Fourier Transform Infrared Spectroscopy
SEM: Scanning electron microscope
HRTEM: High-resolution transmission electron microscopy
EDAX: Energy-dispersive X-ray analysis
IL: Interleukin
NF-kB: Factor nuclear κB
TNF-α: Tumor necrosis factor-α
MDA: Malondialdehyde
TOS: Hepatic total oxidant status
YLE: younger leaves extract
MLE: Mature leaves extracts
GIP: Gastric inhibitory polypeptide
GLU: Serum glucose
FINS: Fasting insulin
T2DM: Type 2 Diabetes Mellitus
GB: Ginseng berry
SOD: Superoxide dismutase
BSLT: Brine Shrimp Lethality Test
MBG: Mean blood glucose
HEAS: Hydroalcoholic extract of A. scholaris bark
OGTT: Oral glucose tolerance test
EEAS: Ethanolic extract of A. squamosa

Acknowledge

We would like to acknowledge P. R. Pote Patil College of Pharmacy, Amravati, Maharashtra 444604.

Conflict of interest

There is no conflict of interest.

Funding

None declared.

REFERENCES

1. Metrics I. Evaluation, Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2016 (GBD 2016) Results. 2017. Institute for Health Metrics and Evaluation Seattle; 2019.
2. Tripathi KD. Essentials of medical pharmacology. 5th ed. New Delhi: Jaypee Brothers Medical Publishers (P) LTD; 2003:235-249.
3. Thomas JA, Stringer JL. Antidiabetic drug. In: Encyclopedia Britannica. January 5, 2024. Accessed January 30, 2024. https://www.britannica.com/science/antidiabetic-drug
4. Kumar S, Shachi K, Prasad NK. Diabetes mellitus and allopathic medication increase the risk of cancer malignancy, but no side effect associated with the use of antidiabetic herbal medicine. Curr Res Diabetes Obes J. 2020;13(4):555868. https://doi.org/10.19080/crdoj.2020.13.555868
5. Alamgir ANM. Therapeutic use of medicinal plants and their extracts: Volume 1. Springer International Publishing AG; 2017. http://dx.doi.org/10.1007/978-3-319-63862-1
6. Bailey CJ, Turner RC. Metformin. N Engl J Med. 1996;334(9):574-579. https://doi.org/10.1056/nejm199602293340906
7. Arif T, Pitoyo J, Sudjarwo E. The effect of Aloe vera extract on blood glucose levels in streptozotocin-induced rats. J Ners Kebidanan. 2022;9(2):178-185. https://doi.org/10.26699/jnk.v9i2.ART.p178-185
8. Muñiz-Ramirez A, Perez RM, Garcia E, Garcia FE. Antidiabetic activity of Aloe vera leaves. Evid Based Complement Alternat Med. 2020; 2020:6371201. https://doi.org/10.1155%2F2020%2F6371201
9. Kim JH, Cho CW, Lee JI, et al. An investigation of the inhibitory mechanism of α-glucosidase by chysalodin from Aloe vera. Int J Biol Macromol. 2020; 147:314-318. https://doi.org/10.1016/j.ijbiomac.2020.01.076
10. Amare GG, Meharie BG, Belayneh YM. Evaluation of antidiabetic activity of the leaf latex of Aloe pulcherrima Gilbert and Sebsebe (Aloaceae). Evid Based Complement Alternat Med. 2020; 2020:8899743. https://doi.org/10.1155/2020/8899743
11. Froldi G, Baronchelli F, Marin E, Grison M. Antiglycation activity and HT-29 cellular uptake of Aloe-emodin, aloin, and Aloe arborescens leaf extracts. Molecules. 2019;24(11):2128. https://doi.org/10.3390/molecules24112128

12. Saxena M, Prabhu SV, Mohseen M, et al. Antidiabetic effect of Tamarindus indica and Momordica charantia and downregulation of tet-1 gene expression by Saroglitazar in glucose feed adipocytes and their involvement in the type 2 diabetes-associated inflammation in vitro. Biomed Res Int. 2022; 2022:9565136. https://doi.org/10.1155/2022/9565136
13. Hassan MM, Uddin S, Bhowmik A, et al. Phytochemical screening and antidiabetic effects of fruit rind of Momordica dioica Roxb. on streptozocin induced type 2 diabetic rats. Heliyon. 2022;8(1):e08771. https://doi.org/10.1016/j.heliyon.2022.e08771
14. Arif R, Ahmad S, Mustafa G, et al. Molecular docking and simulation studies of antidiabetic agents devised from hypoglycemic polypeptide-P of Momordica charantia. Biomed Res Int. 2021; 2021:5561129. https://doi.org/10.1155%2F2021%2F5561129
15. Choudhary U, Sabikhi L, Kapila S. Double emulsion-based mayonnaise encapsulated with bitter gourd extract exhibits improvement in vivo anti-diabetic action in STZ induced rats. 3 Biotech. 2021;11(8):363. https://doi.org/10.1007%2Fs13205-021-02910-9
16. Zhang F, Zhang X, Yu J, et al. The gut microbiota confers the lipid-lowering effect of bitter melon (Momordica charantia L.) in high-fat diet (HFD)-induced hyperlipidemic mice. Biomed Pharmacother. 2020; 131:110667. https://doi.org/10.1016/j.biopha.2020.110667
17. Wang Q, Wu X, Shi F, Liu Y. Comparison of antidiabetic effects of saponins and polysaccharides from Momordica charantia L. in STZ-induced type 2 diabetic mice. Biomed Pharmacother. 2019; 109:744-750. https://doi.org/10.1016/j.biopha.2018.09.098
18. Bhat GA, Khan HA, Alhomida AS, et al. GLP-I secretion in healthy and diabetic Wistar rats in response to aqueous extract of Momordica charantia. BMC Complement Altern Med. 2018;18(1):2227. https://doi.org/10.1186/s12906-018-2227-4
19. Farazandeh M, Asghari AA, Shabab S, et al. Protective effects of cinnamon on acetylcholinesterase activity and memory dysfunction in diabetic rats. J Complement Integr Med. 2023;20(2):387-394. https://doi.org/10.1515/jcim-2022-0201
20. Nishikai-Shen T, Hosono-Fukao T, Ariga T, et al. Cinnamon extract improves abnormalities in glucose tolerance by decreasing Acyl-CoA synthetase long-chain family 1 expression in adipocytes. Sci Rep. 2022;12(1):12574. https://doi.org/10.1038/s41598-022-13421-9
21. Sharma S, Mandal A, Kant R, et al. Is cinnamon efficacious for glycaemic control in type-2 diabetes mellitus? J Pak Med Assoc. 2020;70(11):2065-2069. doi:33341863
22. Hayward NJ, McDougall GJ, Farag S, et al. Cinnamon shows antidiabetic properties that are species-specific: Effects on enzyme activity inhibition and starch digestion. Plant Foods Hum Nutr. 2019;74(4):544-552. https://doi.org/10.1007/s11130-019-00760-8
23. Taheri A, Lavasani H, Kasirzadeh S, et al. Changes in CYP2D enzyme activity following induction of type 2 diabetes, and administration of cinnamon and metformin: An experimental animal study. Xenobiotica. 2018;48(10):984-989. https://doi.org/10.1080/00498254.2017.1390626
24. Kim SH, Hyun SH, Choung SY. Anti-diabetic effect of cinnamon extract on blood glucose in db/db mice. J Ethnopharmacol. 2006;104(1-2):119-123. https://doi.org/10.1016/j.jep.2005.08.059
25. Lee JS, Jeon SM, Park EM, et al. Cinnamate supplementation enhances hepatic lipid metabolism and antioxidant defense systems in high cholesterol-fed rats. J Med Food. 2003;6(3):183-191. https://doi.org/10.1089/10966200360716616
26. Addepalli SK, Nigam N, Kumar S. Antidiabetic effect and preference of fenugreek with dietary modifications in patients with prediabetes: An interventional parallel randomized study. J Diabetol. 2022;13(1):83-94. https://doi.org/10.4103/jod.jod_40_21
27. Tabassum H, Ahmad IZ. Trigonella foenum-graecum and its bioactive compounds having potential antidiabetic activity. In: Fenugreek: Biology and Applications. Springer; 2021:447-480. https://doi.org/10.1007/978-981-16-1197-1_19
28. Bafadam S, Mahmoudabady M, Niazmand S, Rezaee SA, Soukhtanloo M. Cardioprotective effects of Fenugreek (Trigonella foenum-graecum) seed extract in streptozotocin-induced diabetic rats. J Cardiovasc Thorac Res. 2021;13(1):28. https://doi.org/10.34172/jcvtr.2021.01
29. Geberemeskel GA, Debebe YG, Nguse NA. Antidiabetic effect of fenugreek seed powder solution (Trigonella foenum-graecum L.) on hyperlipidemia in diabetic patients. J Diabetes Res. 2019; 2019:8507453. https://doi.org/10.1155/2019/8507453
30. Xie C, Gao W, Li X, Luo S, Wu D, Chye FY. Garlic (Allium sativum L.) polysaccharide ameliorates type 2 diabetes mellitus (T2DM) via the regulation of hepatic glycogen metabolism. NFS J. 2023; 31:19-27. https://doi.org/10.1016/j.nfs.2023.02.004
31. Jini D, Sharmila S, Anitha A, Pandian M, Rajapaksha RMH. In vitro and in silico studies of silver nanoparticles (AgNPs) from Allium sativum against diabetes. Sci Rep. 2022;12(1):22109. https://doi.org/10.1038/s41598-022-24818-x
32. Adelusi TI, Boyenle ID, Tolulope A, et al. GCMS fingerprints and phenolic extracts of Allium sativum inhibit key enzymes associated with type 2 diabetes. J Taibah Univ Med Sci. 2023;18(2):337-347. https://doi.org/10.1016/j.jtumed.2022.09.011
33. Biró A, Markovics A, Fazekas MÉ, et al. Allithiamine alleviates hyperglycaemia-induced endothelial dysfunction. Nutrients. 2020;12(6):1690. https://doi.org/10.3390/nu12061690
34. Behrouj H, Ziamajidi N, Abbasalipourkabir R, Goodarzi MT, Saidijam M. Hypoglycemic and antioxidant effects of oral administration of garlic extract in the livers of type 1 diabetic rats. J Basic Clin Physiol Pharmacol. 2019;30(2):245-250. https://doi.org/10.1515/jbcpp-2018-0124
35. Mohammed A, Kumar R, Ashfaq F, et al. Young and mature leaves of Azadirachta indica (neem) display different antidiabetic and antioxidative effects. Egypt J Basic Appl Sci. 2023;10(1):316-328. https://doi.org/10.1080/2314808X.2023.2196191
36. Moaty AAA, El-Kholie EA, Adarous RA. The anti-diabetic effect of Neem leaves (Azadirachta indica) in alloxan-induced

diabetic rats. J Med Plants Res. 2022;16(5):127-134. https://doi.org/10.21608/mkas.2022.214619
37. Hassanein H, Salem FEH, Farag MA, Ahmed AM. Sustainable hypoglycemic action of neem oil on male rabbits and its impact on some glucose regulating hormones. Egypt Acad J Biol Sci C Physiol Mol Biol. 2021;13(1):189-209. https://doi.org/10.21608/eajbsc.2021.191605
38. Maji S. Role of Neem leaves in diabetes and obesity. In: Role of Phytochemicals in Human Physiological Disorders: Diabetes and Obesity. Scholars' Press; 2020:85-102. https://doi.org/10.3390/molecules27134278
39. Pingali U, Ali MA, Gundagani S, Nutalapati C. Evaluation of the effect of an aqueous extract of Azadirachta indica (Neem) leaves and twigs on glycemic control, endothelial dysfunction, and systemic inflammation in subjects with type 2 diabetes mellitus: A randomized, double-blind, placebo-controlled clinical study. Diabetes Metab Syndr Obes. 2020; 13:4401-4412. https://doi.org/10.2147/dmso.s274378
40. Sajal H, Patil SM, Raj R, et al. Computer-aided screening of phytoconstituents from Ocimum tenuiflorum against diabetes mellitus targeting DPP4 inhibition: A combination of molecular docking, molecular dynamics, and pharmacokinetics approaches. Molecules. 2022;27(16):5133. https://doi.org/10.3390/molecules27165133
41. Ganga S, Madasu KR, Sharma J, Dutta S. Anti-diabetic activity of ethanolic extract of Ocimum dry leaves powder in STZ-induced rats. Int J Health Sci. 2022;6(3):8112763.
42. Kumar V, Srivastav AK. A study on anti-diabetic activity of Aegele marmelos, Musa paradisiaca, and Ocimum sanctum. Ann Rom Soc Cell Biol. 2021;25(5):5999-6015. https://doi.org/10.31024/ajpp.2022.8.5.4
43. Yang Z, Wang D, Li Y, et al. Untargeted metabolomics analysis of the anti-diabetic effect of Red ginseng extract in type 2 diabetes mellitus rats based on UHPLC-MS/MS. Biomed Pharmacother. 2022; 146:112495. https://doi.org/10.1016/j.biopha.2021.112495
44. Wang H, Huang R, Li H, et al. Serum metabolomic analysis of the anti-diabetic effect of Ginseng berry in type II diabetic rats based on ultra-high-performance liquid chromatography-high resolution mass spectrometry. J Pharm Biomed Anal. 2021; 196:113897. https://doi.org/10.1016/j.jpba.2021.113897
45. Wei Y, Yang H, Zhu C, Deng J, Fan D. Hypoglycemic effect of ginsenoside Rg5 mediated partly by modulating gut microbiota dysbiosis in diabetic db/db mice. J Agric Food Chem. 2020;68(18):5107-5117. https://doi.org/10.1021/acs.jafc.0c00605
46. Begum SAS, Rao M, Ramachandra MS. Evaluation of antidiabetic activity of Swertia chirayita and Panax ginseng. Eur J Pharm Med Res. 2019;7(2):516-522. https://doi.org/10.4103/0974-8490.157997
47. Jethi S, Mishra SK, Satapathy KB. Study of anti-diabetic activity of Alstonia Scholaris (L.) R. Br. root extract. Int J Health Sci. 2022;6(S3):9056-9066. https://doi.org/10.53730/ijhs.v6nS3.8225
48. Zuraida S, Sulistiyani. Alstonia scholaris R. Br bark extract as diabetes medicine. IOP Conf Ser Earth Environ Sci. 2020;528(1):012050. https://doi.org/10.1088/1755-1315/528/1/012050
49. Bandawane DD, Jadhav SB, Juvekar AR. Exploration of protective effect of hydroalcoholic extract of Alstonia scholaris bark in STZ-induced early diabetic nephropathy model in rats. Indian Drugs. 2019;56(8):47-55. https://doi.org/10.53879/id.56.08.11482
50. Ponce-Sánchez C, Oidor-Chan VH, Álvarez-Ramírez EL. Chemical profile and study of the antidiabetic effect of Annona squamosa L. peel. Waste Biomass Valorization. 2024;15(2):1053-1063. https://doi.org/10.1007/s12649-023-02217-1
51. Ansari P, Hannan JMA, Seidel V, Abdel-Wahab YH. Polyphenol-rich leaf of Annona squamosa stimulates insulin release from BRIN-BD11 cells and isolated mouse islets, reduces (CH2O) n digestion and absorption, and improves glucose tolerance and GLP-1 (7-36) levels in high-fat-fed rats. Metabolites. 2022;12(10):995. https://doi.org/10.3390/metabo12100995
52. El-Baz DM, Hssan AK. Effects of Egyptian Annona squamosa leaves extracts against alloxan-induced hyperglycemia in rats. World J Pharm Pharm Sci. 2019;8(2):145-163. https://doi.org/10.20959/wjpps20193-13297
53. Kumar Y, Chandra AK, Shruti S, Gajera HP. Evaluation of antidiabetic and antioxidant potential of custard apple (Annona squamosa) leaf extracts: A compositional study. Int J Chem Stud. 2019;7(4):889-895. https://doi.org/10.3390/biom11050614

HOW TO CITE THIS ARTICLE
Deshmukh P, Phuse A, Nimkar S, Ruikar D, Raut A. A review: Anti-Diabetic Plants and its Recent Application. J Ayu Herb Med 2024;10(2):56-66. DOI: 10.31254/jahm.2024.10206