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RESEARCH ARTICLE
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A COMPREHENSIVE REVIEW ON PHYTOCHEMICALS WITH ANTI-DIABETIC ACTIVITY: MECHANISMS AND APPLICATIONS

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ABSTRACT
Diabetes mellitus is a chronic metabolic disorder characterized by impaired glucose homeostasis, insulin resistance, and long-term complications affecting multiple organ systems. The search for effective and safer alternatives to conventional antidiabetic drugs has led to growing interest in phytochemicals derived from medicinal plants. Phytochemicals such as flavonoids, alkaloids, phenolics, terpenoids, and glycosides have demonstrated significant antidiabetic potential through diverse mechanisms, including inhibition of carbohydrate-digesting enzymes, enhancement of insulin secretion, and modulation of glucose uptake and antioxidant activity. This review comprehensively explores the diverse classes of phytochemicals with antidiabetic properties, highlighting their mechanisms of action, pharmacological potential and clinical relevance. Further, the application of these bioactive compounds in functional foods, nutraceuticals and pharmaceutical formulations is discussed, along with challenges such as bioavailability, toxicity, and regulatory considerations. The integration of phytochemicals in diabetes management holds promise for the development of novel, plant-based therapeutics, paving the way for improved treatment strategies.

Keywords: Phytochemicals, Diabetes mellitus, Insulin resistance, Antioxidants, Natural products, Drug discovery

INTRODUCTION
Diabetes mellitus (DM) is a chronic disease caused by inherited and/or acquired deficiency in production of insulin by the pancreas, or by the ineffectiveness of the insulin produced. Such a deficiency results in increased concentrations of glucose in the blood, which in turn damage many of the body's systems, in particular the blood vessels and nerves. As the numbers of people with diabetes multiply worldwide, the disease takes an ever-increasing proportion of national and international health care budgets. It is projected to become one of the world's main disablers and killers within the next 25 years. Regions with greatest potential are Asia and Africa, where DM rates could rise to two- to three-folds than the present rates. Apart from currently available therapeutic options, many herbal medicines have been recommended for the treatment of diabetes. Traditional plant medicines are used throughout the world for a range of diabetic presentations [1]. The prevalence of diabetes in the world was estimated to be 2.8% for all ages in 2000, and that is

expected to increase to approximately 4.4% in 2030. Diabetes-related deaths will increase to 366 million by 2030. The World Health Organization (WHO) estimates that 415 million people will be affected by diabetes in 2015, and this is expected to rise to 642 million by 2040, worldwide. Currently, the numbers of diabetic patients have significantly increased in the population between 45 and 64 years of age in many countries, particularly in China, India, and Southeast Asia. Of various DM subtypes, T2DM, which is characterized by chronic metabolic imbalance, beta-cell failure and insulin resistance, and can be alleviated by changing lifestyle by dietary control and exercise, is the most common type, accounting for more than 90% of all DM patients. The onset of T2DM can be attributed to behavioural, environmental, and genetic factors, leading to insulin resistance and deficiency. Importantly, the involvements of several factors in T2DM that cause resistance of target tissues to insulin, usually resulting from abnormal insulin secretion. T2DM is a common and increasingly prevalent disease and is a major public health problem worldwide [2]. Importantly, prevalence surveys indicate that, in 2017, there are 425 million people with DM in the world. In 2045, estimations suggest that this number will reach 629 million people. Despite the high economic cost for DM treatment ($ 727 million dollars in 2017), there is still a large part of the population without access to pharmacotherapy, or even with the availability of drug treatment, seeking treatment options in traditional medicine. In fact, a variety of plants with possible antidiabetic properties is used in traditional medicine. Approximately 800 plants have been identified with antidiabetic effect, and more than 200 bioactive compounds have been identified with this potential [3].

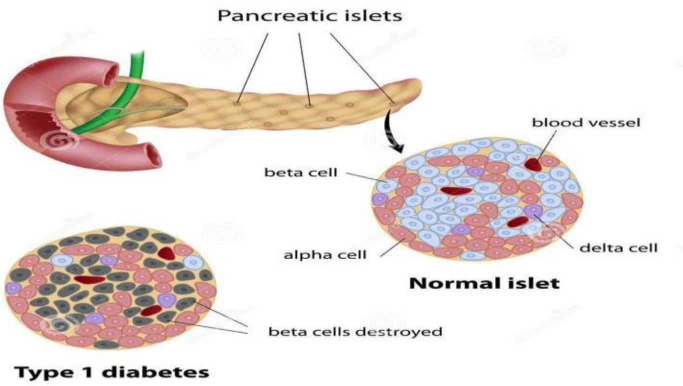

Fig.1 Normal Pancreas Compare to DM affects Pancreas

Types of Diabetes:

- Type-1
- Type-2
- Gestational Diabetes Mellitus

Type-1 DM:

The type-1 diabetes mellitus also known as Insulin dependent diabetes mellitus (IDDM) / juvenile onset diabetes mellitus, in type 1 Diabetes, the pancreatic b-cells undergo autoimmune destruction by CD4+ and CD8+ T cells and macrophages which result in insulin deficiency.

Islet cell antibodies are found in nearly 85% of the patients, and most of them act against the glutamic acid decarboxylase (GAD) found inside the beta-cells of the pancreas. The metabolic disorders related to type 1 diabetes mellitus are a result of deficiency of insulin secretion caused by the immune destruction of islets of Langerhans of the pancreas. Besides, pancreatic alpha-cells start to function abnormally and secrete an excessively large amount of glucagon in the patients with type 1 diabetes mellitus, which further aggravates the metabolic disorders already caused by insulin deficiency. A deficiency of insulin causes lipolysis to occur at an uncontrolled rate which causes the amount of free fatty acids in the blood to rise resulting in a reduction of glucose metabolism in the peripheral tissues. The deficit of insulin also causes a reduction of glucokinase enzyme in the liver and the GLUT-4 transporter protein in adipose tissue resulting in an inability of the target tissues to respond normally to insulin. Majority of cases are autoimmune (type 1A) antibodies that destroy β cells are detectable in blood, but some are idiopathic (type 1B) - no β cell antibody is found in all type1 cases circulating insulin levels are low or very low, and patients are more prone to ketosis. This type is less common and has a low degree genetic predisposition.[4]

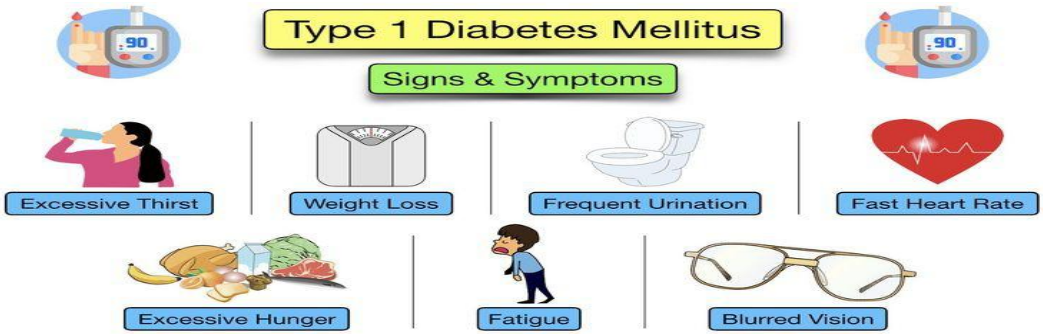

Fig.2 Signs & Symptoms of type -1 DM

Type-2 DM:

Type 2 diabetes mellitus is characterized by insulin resistance, where the body's tissues respond poorly to insulin, often accompanied by reduced insulin secretion. While insulin is produced, it either isn't sufficient or doesn't function properly. Early on, this condition can be managed or even reversed with lifestyle changes and medications that improve insulin sensitivity or reduce liver glucose production. Type 2 diabetes is primarily influenced by genetics and lifestyle factors such as obesity, lack of physical activity, poor diet, stress, and urbanization. It accounts for 90% of diabetes cases and typically occurs in individuals over 40, though it can also develop in younger people with risk factors.[5]

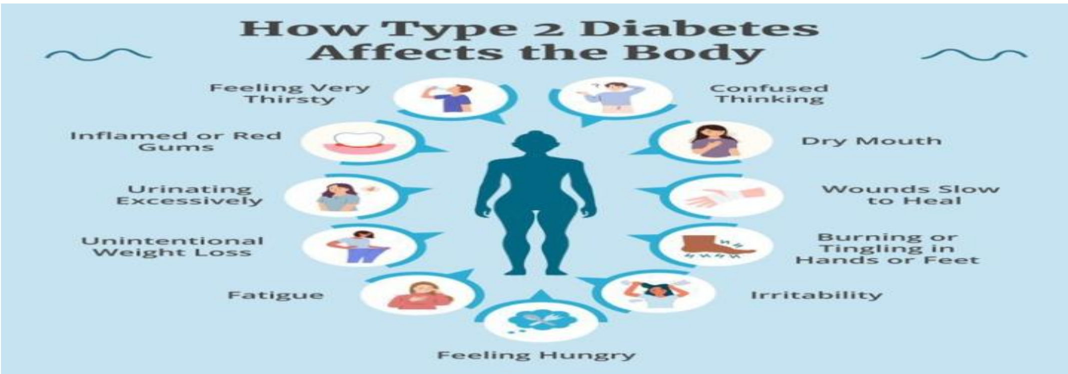

Fig.3 Symptoms of Type -2 DM

Gestational Diabetes Mellitus:

Gestational diabetes is defined as hyperglycemia with first onset during pregnancy and is one of the common pregnancy complications. An estimated 21 million obstetric patients aged 20 to 49 years around the world are affected by GDM, and the incidence rate is up to 16.7%. The GDM is the initial normal glucose metabolism during pregnancy which affected 5 to 6% to 15 to 20% of pregnant women and 85% of live births worldwide [6]. It occurs in women with a family history of diabetes or certain ethnic backgrounds. Proper management is crucial to prevent complications for both the mother and baby, and the condition typically resolves after childbirth, though it increases the risk of Type 2 diabetes later in life. Managing GDM through diet, exercise, or medication is essential for a healthy pregnancy. [5]

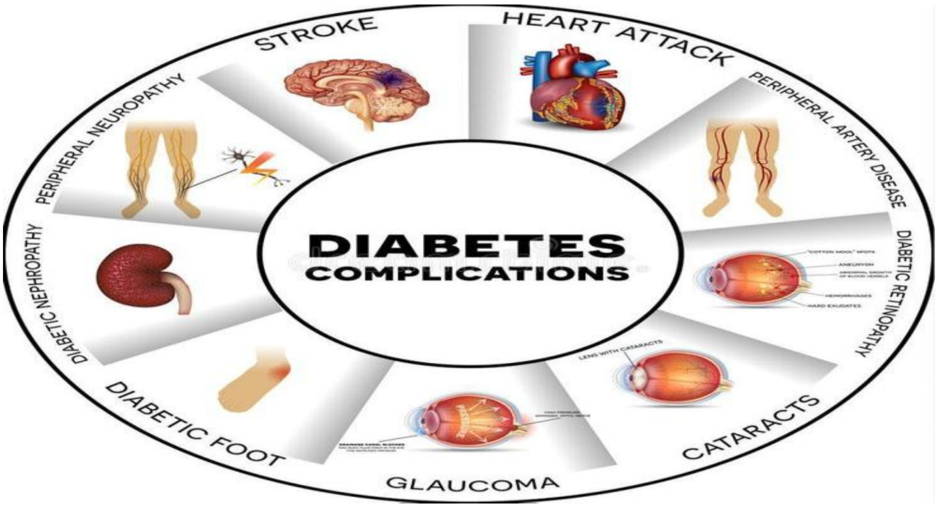

Fig.4 Complication of DM

Treatment of diabetes:

The treatment of diabetes involves both drug and non-drug strategies to maintain proper blood glucose levels. Here's an overview of the major components:

A) Drug treatment for diabetes:

Anti-diabetic drugs are used to lower blood glucose levels, and they can be broadly divided into insulin and oral medications. The choice of medication depends on the type of diabetes and individual patient factors like age and overall health.

Type 1 Diabetes:

This is caused by the body's inability to produce insulin. Therefore, insulin therapy is mandatory for these patients. Insulin can be administered through injections or inhalation.

Type 2 Diabetes:

In type 2 diabetes, the body becomes resistant to insulin. Drug treatment for this type focuses on: Increasing insulin production from the pancreas (e.g., sulfonylureas, meglitinides), Enhancing the sensitivity of cells to insulin (e.g., metformin, thiazolidinediones), Reducing glucose absorption from the gastrointestinal tract (e.g., alpha-glycosidase inhibitors). Other injectable drugs like Exenatide (a GLP-1 receptor agonist) and Pramlintide (an amylin analogue) are also used, particularly in combination with other medications.

B) Non-Drug Treatment for Diabetes:

Non-drug management is equally important for all types of diabetes. It includes: Dietary management: A balanced diet, low inϖ refined sugars and rich in fiber, helps control blood sugar. Exercise: Regular physical activity improves insulinϖ sensitivity and helps a maintain healthy body weight. Monitoring blood glucose levels: This is crucial for adjusting treatment as needed and preventing complications. Together, these strategies help maintain optimal blood glucose levels and reduce the risk of diabetes-related complications. [5]

INSULIN:

Insulin was discovered in 1921 by willium banting and best who demonstrated the hypoglycemic action of an extract of pancreas prepared after degeneration of the exocrine part due to ligation of pancreatic duct. It was first obtained in pure crystalline form in 1926 and the chemical structure was fully worked out in 1956 by sanger. Insulin is a peptide hormone produced by beta cells of the pancreatic islets encoded in humans by the insulin gene. It is made up of the 51 amino acids. contain 2 chains: A and B. A chain with 21 amino acid, B chain with 30 amino acids.

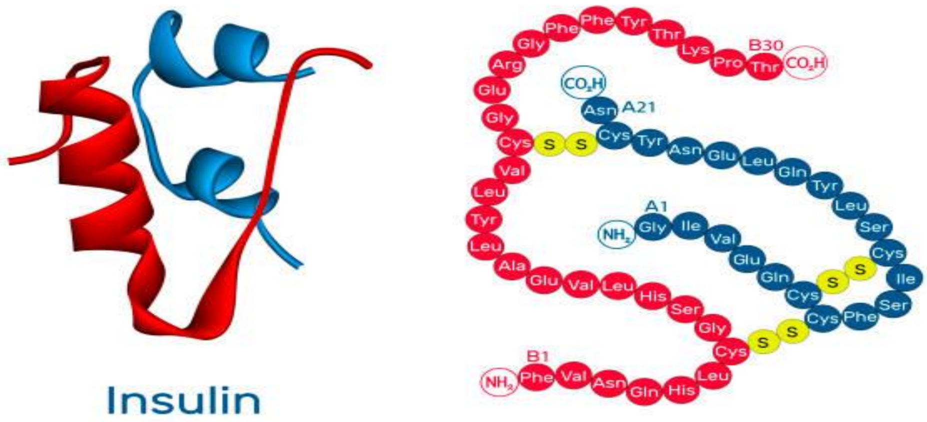

Fig: 5 Human Insulin Structure

Insulin Mediated Glucose Uptake:

The insulin plays the most prominent role. Insulin is powerful anabolic hormone regulates the transport of glucose into the cell through translocation of glucose transporter from an intracellular pool to the plasma membrane mainly in metabolically active tissues like skeletal muscles, adipose tissue, or liver (GLUT4). This translocation occurs through multiple steps of PI3K/AKT signalling pathway. In this chapter, we will focus on molecular events leading to GLUT4 translocation, starting with activation of insulin receptors through signalling cascade involving phosphatidylinositol 3-kinase (PI3K) and protein kinase B (PKB) and finally, the action of their effectors. We will present regulatory mechanisms and modulators of insulin-mediated glucose uptake.

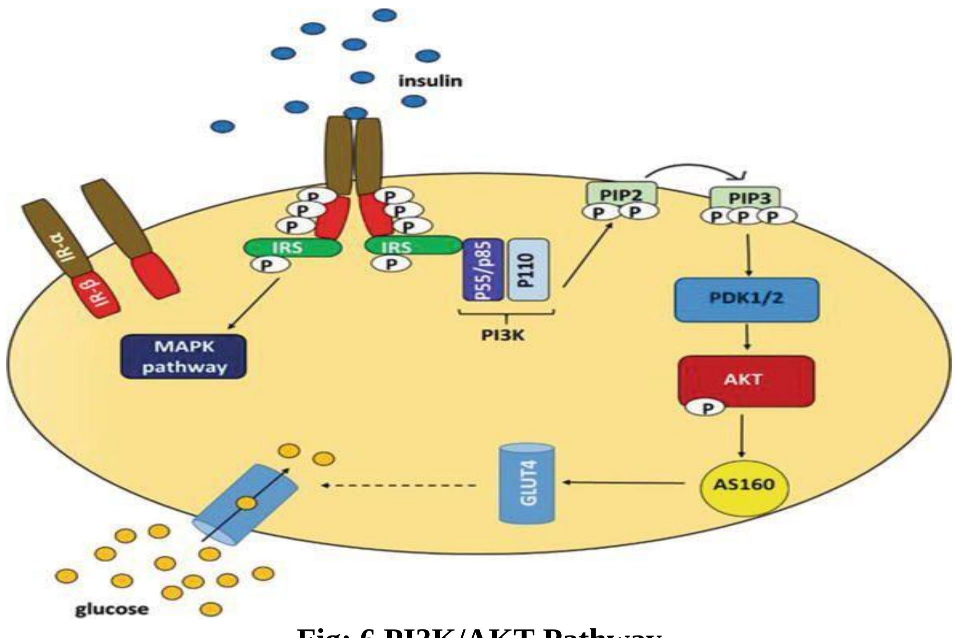

Fig: 6 PI3K/AKT Pathway

Insulin is usually given subcutaneously, either by injections or by an insulin pump. Research is underway of other routes of administration. In acute care settings, insulin may also be given intravenously. There are several types of insulin, characterized by the rate which they are metabolized by the body. Insulin is essential for the treatment of type1 diabetes. For many years it was assumed, as an act of faith, that normalizing plasma glucose would prevent diabetic complications. The diabetes control and complications trial (American diabetes association, 1993) showed that this faith was well placed: type diabetic patients were randomly allocated to intensive or conventional management.[5]

Methodology:

Why We Chose Medicinal Plants:

Challenges in the Treatment of DM. Existing approaches to the management of DM relied on keeping BGLs with normal limits via administration of appropriate medications together with lifestyle modifications. So far, the accessible medicines for DM are various preparations of insulin and oral antihyperglycemic agents. Older oral hypoglycemics are sulphonylureas, alpha glucosidase inhibitors, thiazolidinediones, and biguanides , while the newer medicines include incretin-based therapies, sodium-glucose cotransporter 2 (SGLT-2) inhibitors, glucokinase activators, and injectable glucagon-like peptide (GLP-1) agonists .medicines are used either as monotherapy or in combination to achieve better treatment outcomes ,conventional and newer agents are still with their shortcomings, and successful treatment of diabetes is being a global challenge requiring further investigations. In fact, these medications are associated with unnecessary drug reactions or side effects including hepatocellular injury, exacerbate renal diseases, blood dyscrasias, gastrointestinal irregularities, hypoglycemia, hypersensitivity reactions, weight gains, and lactic acidosis, which decrease their effectiveness and compliance rates.

For instance, 3.9 and 32.7% severe and no severe hypoglycemic events were reported in 826 (2.8%) patients during their most recent year of sulfonylurea treatment, respectively. Clearly, the weight gain associated with the use of thiazolidinediones (pioglitazone and rosiglitazone), sulphonylureas (glibenclamide), and insulin is also the major drawback for treating diabetes. Several drawbacks have been reported associated with the use of antihyperglycemic medications, such as decreasing effectiveness and increasing adverse effects and toxicities. For instance, sulphonylureas lose their efficacy after six years of therapy in nearly 44% of patients, while BG lowering medicines are stated to be unable to control hyperlipoproteinemia.

In spite of the extensive improvement made in the management of DM using various antihyperglycemic medicines in the past, the results of treatment are still far from successful. Because of the limitations of these agents, there remains a clear need for the identification of new antidiabetic drugs.) Therefore, seeking extra safe and effective antidiabetic medicines from plant sources is becoming an active area of research in the scientific community.[7]

Mechanism of Medicinal Plants in Diabetes Mellitus:

Possible Mechanism of Act ions of Medicinal Plants in Treating DM. Bioactive compounds that are obtained from various MPs have been reported to have potent BG-lowering potentials mechanism of lowering BGL might be a result of activation of releasing insulin from ß-cells, reduction of glucose absorption, stimulation of glycogenesis, and/or enhancement of glucose. In addition to lowering BGL, secondary metabolites obtained from MPs have the capacity to restore the impaired ß-cells and terminate oxidative stress on ß-cells. Furthermore, inhibiting cellular apoptosis, reducing renal glucose reabsorption, enhancing the metabolic rate of oxygen consumption, and promoting glucose transporter (GLUT-2) expression and translocation of GLUT-4 are also important mechanisms in diabetic mellitus treated with certain secondary metabolites that are responsible for antidiabetic effects. Blocking pancreatic β-cell K+ channel, stimulating cyclic adenosine monophosphate (cAMP), and providing some essential elements (calcium, zinc, magnesium, manganese, and copper) for the β-cell are also some mechanisms that are possibly participated in β-cell dysfunction found in DM. Blocking the actions of α-amylase and α-glycosidase enzymes, which are essential for carbohydrate digestion, is used as an optional treatment approach for type 2 diabetes.

Folkloric MPs with antihyperglycemic effects via inhibition of these enzymes and their free radical scavenging potentials are becoming promising modalities in treating type 2 DM and associated complications. Medicinal plants have central roles to discover newer medicines and have begun to get greater attention as sources of bioactive constituents as well as antioxidants. Antioxidant activity has a protective effect in restoring β-cell function in diabetes. Because free radicals are known to damage and mutation of cells, and hence, oxidative stress has a vital role in the pathogenesis of DM and its complications, MPs with antioxidant effect will have paramount importance in treating diabetes and its complications via scavenging free radicals.[7]

RESULT AND DISCUSION:

In this article, we discuss medicinal plants used for diabetic mellitus. Medicinal plants have been used for centuries in folk medicine. The medicinal plants in the treatment and management of several ailments and diseases, including diabetes. Traditionally the medicinal plants are used in daily food preparation especially in Tamilnadu, more over south India like. Now the development of science and medicinal technology: the traditionally used spices are identified as having medicinal value phytoconstituents and proved scientifically. There are thousands of plants identified for use in the treatment of diabetes mellitus. Now we discuss some plants that have antidiabetic activity, their Phyto-constituents and effects.

S. No	Biological Name	Family	Parts Used	Phytomolecules	Activity	Reference
1	*Mangifera indica*	*Anacardiaceae*	Leaves/ Stem bark	Phenolic Acid, Benzophenones, Flavonoids.	Inhibits glucose absorption in the gut.	[8]
2	*Azadirachta indica*	*Meliaceae*	Bark	Isoprenoids, Alkaloids, Flavonoids.	Inhibits key enzymes linked to diabetes.	[9]
3	*Caesalpinia crista*	*Caesalpiniaceae*	Seed	Flavonoids, Tannins, Alkaloids, Saponins.	Shows antidiabetic and wound healing properties.	[10]
4	*Caesalpinia volkensii*	*Fabaceae*	Leaf	Sterols, Flavones, Chalcones, Flavonoids.	Has antidiabetic, anti-malarial, and pain-relieving effects.	[11]
5	*Sarcopoterium spinosum*	*Rosaceae*	Root	Corilagin, Pedunculagin, Castalagin.	Used traditionally for diabetes, anti-inflammation, and wound repair.	[12]
6	*Cocos nucifera*	*Arecaceae*	Flower	Alkaloids, Flavonoids, Triterpenoids.	Has an antidiabetic and antioxidant property.	[13]
7	*Sida acuta*	*Malvaceae*	Root	Diterpenes, Alkaloids, Steroids, Lactones.	Lowers blood glucose via extra-pancreatic pathways.	[14]
8	*Withania coagulans*	*Solanaceae*	Fruit	Amino Acids, Fatty Oils, Essential Oils.	Improves insulin sensitivity.	[15]
9	*Salacia chinensis*	*Hippocrateaceae*	Roots	Salacinol, Kotalanol, Mangiferin.	Inhibits enzyme activity to reduce diabetes.	[16]
10	*Rheum emodi*	*Polygonaceae*	Root	Stilbene, Rhaponticin.	Enhances glucose utilization and mimics insulin.	[17]
11	*Leucas aspera*	*Lamiaceae*	Stem, flower, fruit, and leaves	Terpenoids, Glycosides, Flavonoids, Alkaloids, Saponins.	Inhibits glycosylation and reduces haemoglobin levels.	[18]
12	*Justicia adhatoda*	*Acanthaceae*	Leaves, root	Alkaloids (Vasicine, Vasicinone).	Reduces blood sugar and tissue lipids.	[19]
13	*Ficus amplissima*	*Moraceae*	Bark	Flavonoids, Saponins, Glycosides, Alkaloids.	Shows anti-hyperglycaemic activity.	[20]
14	*Helicteres isora*	*Sterculiaceae*	Root	Carbohydrates, Fat, Protein.	Reduces blood glucose, cholesterol, and triglycerides.	[21]
15	*Ficus religiosa*	*Moraceae*	Leaves, stem	Flavonoids, Beta Sitosteryl-D-Glucoside.	Used mainly for Type 2 diabetes mellitus.	[22]

16	*Costus igneus*	*Costaceae*	Leaves	Steroids, Alkaloids.	Improves glycemic control and insulin secretion.	[23
17	*Ferula asafoetida*	*Apiaceae*	Root	Resins.	Stimulates pancreatic beta cells to secrete insulin.	[24]
18	*Lawsonia inermis*	*Lythraceae*	Leaves	Tannins, Saponins, Flavonoids, Terpenoids.	Shows hypoglycemic and other medicinal properties.	[25]
19	*Combretum micranthum*	*Combretaceae*	Leaves	Alkaloids, Tannins, Glycosides, Flavonoids.	Has potent antidiabetic and lipid-lowering effects.	[26]
20	*Ricinus communis*	*Euphorbiaceae*	Root	Alkaloids, Terpenoids, Flavonoids.	Promising for diabetes treatment with high safety.	[27]
21	*Syzygium cumini*	*Myrtaceae*	Seed kernels	Flavonoids, Saponins, Triterpenoids.	Kernel extract shows better hypoglycemic activity.	[28]
22	*Murraya koenigii*	*Rutaceae*	Leaf	Alkaloids, Flavonoids, Glycosides.	Shows hypoglycemic and antioxidant activity.	[29]
23	*Aerva lanata*	*Amaranthaceae*	Leaf	Alkaloids, Steroids, Kaempferol.	Inhibits α-amylase and α-glucosidase, acting as an antidiabetic agent.	[30]
24	*Aeglemarmelos*	*Rutaceae*	Leaf and Seed	Aegeline, Coumarin, Flavonoid, Alkaloid.	Decreases glucose levels, decreases glycosylated haemoglobin.	[31-38]
25	*Allium cepa*	*Alliaceae*	Bulb	Allylpropyldisulphide, S-Methylcysteine Sulphoxide.	Inhibit alpha amylase thereby decrease the blood glucose level and anti-oxidant properties.	[39,40]
26	*Allium sativum*	*Alliaceae*	Root	Diallyldisulphideoxide ,Ajoene, Allylpropyldisulfide,S-Allylcysteine, S-Allyl Mercaptocysteine.	Decreases glucose levels, decreases lipid levels, increases insulin levels, decreases oxidative stress.	[41,42,43]
27	*Aloe barbadensis*	*Asphodelaceae*	Leaf	Lophenol,24-Methyl-Lophenol,24-Ethyllophenol.	Improve Insulin sensitivity, decrease the triglycerides and sugar level.	[49]
28	*Brassica juncea*	*Brassicaceae*	Leaf	Isorhamnetin, Diglucoside.	Reducing serum glucose level and preventing insulin resistance.	[46]
29	*Lepidium sativum*	*Brassicaceae*	Seed	Flavonoids, Alkaloids, Coumarins, Glycosinolates.	Decreases glucose levels and triglycerides.	[47]

30	*Raphanus sativus*	*Brassicaceae*	Root	Flavonoids, Alkaloids, Saponins, Glycosinolate.	Decreases glucose levels, decreases lipid levels, decreases insulin levels.	[48]
31	*Beta vulgaris*	*Chenopodiaceae*	All parts of plant	Sugarbeetpectin, Polydextrose.	Enhanced glucose uptake, increase insulin sensitivity.	[44,45]
32	*Momordica charantia*	*Cucurbitaceae*	Full plant	Charantin, Momordicin, Galactose-Binding Lectin Nonbitter,Diosgenin,Cholesterol, Lanosterol,Beta Sitosterol,Cucurbitacinglycoside.	Decreases glucose levels, decreases glycosylated haemoglobin, decreases oxidative stress, increases glycogen levels, decreases lipid peroxidation.	[53-59]
33	*Artemisia sphaerocephala*	*Asteraceae*	Fruit	Polysaccharide.	Decreases glucose levels, decreases lipid levels, increases glucose tolerance.	[62,63]
34	*Taraxacumofficinale*	*Asteraceae*	Fruit	Terpen.	Decreases glucose levels by increase glucose uptake	[64]
35	*Terminaliachebula*	*Combretaceae*	Seed Fruit	Paliticacid,Beta-Sitosterol,Daucosterol,Shikimic,Gallic,Tnacontanoic.	Decreases glucose levels by increase insulin secretion.	[68,69]
36	*Ziziphusspina-christi*	*Rhamnaceae*	Leaf	Christinin-A, Fatty acid.	Decreases glucose levels and triglycerides.	[70]
37	*Morindacitrifolia*	*Rubiaceae*	Fruit	Saponin, Triterpene, Steroid, Flavonoid.	Decreases glucose levels and increase insulin sensitivity	[66,67]
38	*Psidiumguajava*	*Myrtaceae*	Leaf Fruit	Terpen,Flavonoid, Strictinin,Isostrictinin,Pedunculagin, Polysaccharide.	Decreases glucose levels in blood and anti-oxidant properties.	[49,50]
39	*Syzygiumjam bolanum*	*Myrtaceae*	Fruit	Anthocyanin,Citric, Malic,Gallicacid.	Decreases glucose levels, increases hepatic glycogen levels.	[51,52]
40	*Terminalia brownii Fresen.*	*Combretaceae*	Stem bark	Tannins, Saponins, Polyphenols, Flavonoids, Terpenoids, and Steroids.	Exhibits α-glucosidase inhibitory activity	[71]
41	*Artemisia afra Jacq. ex Willd*	*Asteraceae*	Aerial parts	Tannins, Saponins, Chromophores, Phosphosteroid, Withanoids, Flavonoids, and Anthraquinone.	Demonstrates α-glucosidase and α-amylase inhibitory activities.	[72]

42	*Stevia Rebaudiana Bertoni*	*Asteraceae*	Leaf	Alkaloids, Steroids, Phenols, and Flavonoids.	Contains steroids, flavonoids which has been shown to have antidiabetic and anti-inflammatory effects.	[73]
43	*Pentas schimperiana (A. Rich).*	*Rubiaceae*	Leaf	Flavonoids, Saponins, Steroids, and Tannins.	Exhibits antioxidant and anti-inflammatory activities, which can help manage diabetes.	[74]
44	*Aloe Megalacantha Baker*	*Asphodelaceae*	Leaf	Alkaloids, Flavonoids, Phenols, Tannins, Saponins, Glycosides, Anthraquinone & Terpenoids.	Contains aloin, which has been shown to have antidiabetic and anti-inflammatory effects.	[75]
45	*Melia azedarach Linn.*	*Meliaceae*	Leaf	Alkaloids, Flavonoids, Triterpenoids,Limonoids.	Exhibits α-glucosidase inhibitory activity and improves insulin sensitivity.	[76]
46	*Hagenia Abyssinica*	*Rosaceae*	Flower	Saponins, Tannins, Terpenoids, Phenols, Flavonoids, Glycosides, Steroids, and Anthraquinones.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[77]
47	*Bersama abyssinica Fresen*	*Melianthaceae*	Seeds	Acarbose Alkaloids, Glycosides, Flavonoids, Steroids, Phenols, Tannins, Triterpene, Anthraquinone, Polysterols, and Coumarins.	Exhibits α-glucosidase inhibitory activity.	[78]
48	*Aloe Megalacantha Baker*	*Asphodelaceae*	Leaf	Aloe-Emodin, Chrysophanic acid, Flavonoids, Saponins.	Contains aloin, which has been shown to have antidiabetic and anti-inflammatory effect,	[79]
49	*Aloe Monticola Reynolds*	*Asphodelaceae*	Leaf	Aloesin,Aloenin,Aloeresin D,Aloin A, Aloin B.	Exhibits antioxidant and anti-inflammatory activities, which can help manage diabetes.	[80]
50	*Aloe pulcherrima Gilbert and Sebsebe*	*Asphodelaceae*	Leaf	Flavonoids, Anthraquinone, Saponins, Glycosides, Tannins, Phenols, and Alkaloids.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[80]
51	*Datura stramonium Linn.*	*Solanaceae*	Seed	Saponins, Alkaloids, Flavonoids, Phenols, Tannins, Terpenoids, Glycosides, and Steroids.	Exhibits α-glucosidase inhibitory activity.	[81]

52	*Cathaedulis Forsk*	*Celastraceae*	Leaf	Alkaloids, Flavonoids, Quercetin.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[82]
53	*Otostegia integrifolia Benth.*	*Lamiaceae*	Leaf	Phenols, Saponins, Reducing Sugars, and Flavonoids.	Exhibits α-glucosidase inhibitory activity.	[83]
54	*Calpurnia aurea (Ait.) Benth.*	*Fabaceae*	Seed	Alkaloids, Phenols, Flavonoids, and Terpenoids.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[84]
55	*Caylusea abyssinica (Fresen.)*	*Resedaceae*	Leaf	Saponins, Flavonoids, and Alkaloids.	Exhibits α-glucosidase inhibitory activity.	[85]
56	*Becium grandiflorum Lam.*	*Lamiaceae*	Leaf	Flavonoids Terpenoids, Tannins, Saponins, Phenols, and Steroids.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[86]
57	*Calpurnia aurea (Ait.) Benth.*	*Fabaceae*	Leaf	Phenols, Alkaloids, Terpenoids, and Flavonoids.	Exhibits α-glucosidase inhibitory activity.	[87]
58	*Acanthus polystachyus Delile*	*Acanthaceae*	Root	Tannins, Flavonoids, Saponins, Polyphenols, Terpenoids, Glycosides, Anthraquinone.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[88]
59	*Justicia Schimperiana T. Anderson*	*Acanthaceae*	Leaf	Alkaloids, Phenols, and Terpenoids.	Exhibits α-glucosidase inhibitory activity.	[89]
60	*Aloe debrana*	*Asphodelaceae*	Leaf	Flavonoids, Phenols, Triterpenoids, Photosterols.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[90]
61	*Croton macrostachys Hocsht. ex Del*	*Euphorbiaceae*	Root	Alkaloids, Phenols, Tannins, Terpenoids, Saponins, Phlobatannins, and Flavonoids.	Exhibits α-glucosidase inhibitory activity.	[91]
62	*Lens culinaris*	*Fabaceae*	Seed	Polyphenols, Flavonoids, Saponins, Triterpenoids, Phytates, Lectins Phytosterols, and Defensins.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[92]

63	*Indigofera spicata Forsk*	*Fabaceae*	Leaf	Alkaloids, Glycoside, Tannins, Saponins, Phytosterols, Flavonoids, and Diterpenes.	Exhibits α-glucosidase inhibitory activity.	[93]
64	*Vigna radiate*	*Fabaceae*	Grain	Nthocyanin and Bound Phenolic Acids.	Shows antioxidant, anti-inflammatory effects.	[94]
65	*Ajuga remota Benth*	*Lamiaceae*	Leaf	Phenols, Flavonoids, Saponins, Tannins, and Steroids.	Exhibits α-glucosidase inhibitory activity.	[95]
66	*Tymus vulgaris L.*	*Lamiaceae*	Leaf	Phenols and Flavonoids.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[96]
67	*Salvia tiliifolia Vahl.*	*Lamiaceae*	Aerial parts	Alkaloid, Saponins Flavonoids, and Phytosterols.	Exhibits α-glucosidase inhibitory activity.	[97]
68	*Hibiscus deflersii Schweinf ex*	*Malvaceae*	Leaf	Phytosterols, Flavonoids, and Glycosides.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[98]
69	*Moringa stenopetala Baker*	*Moringaceae*	Leaf	Alkaloids, Flavonoids, Tannins, Saponins, Terpenoids.	Exhibits α-glucosidase inhibitory activity and improves insulin sensitivity.	[99]
70	*Myrtus communis L.*	*Myrtaceae*	Leaf	Polyphenols, Tannins, and Glucosides.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[100]
71	*Psidium guajava L.*	*Myrtaceae*	Leaf	Alkaloids, Phenols, Flavonoids, Tannins, and Saponins.	Exhibits α-glucosidase inhibitory activity.	[101]
72	*Caylusea abyssinica (Fresen.)*	*Resedaceae*	Leaf	Saponins, Flavonoids, and Alkaloids.	Shows antioxidant and anti-inflammatory effects, which can help manage diabetes.	[102]
73	*Capsicum frutescens L.*	*Solanaceae*	Fruit	Phenols and Flavonoids.	Exhibits α-glucosidase inhibitory activity and improves insulin sensitivity.	[103]

Table: 1. Plants used for anti-Diabetic

Above the medicinal plants have good antidiabetic activity, which is confirmed by the extraction and fractionation of the plant parts are used for in vivo studies such as aqueous, methanol, ethanol, butanol, hydroalcoholic extraction, chloroform, and petroleum ether fraction. The models for used invitro studies of chromogenic DNSA & in vivo studies of tSTZ-induced diabetic mice. Alloxan-induced diabetic mice. The phytochemicals antidiabetic activity compares to standard drugs such as Acarbose and glibenclamide. From the evaluation, the identified herbs are proved to have potent antidiabetic activity.

CONCLUSION

Finally, we concluded above Phytochemicals have emerged as promising natural agents in the management of diabetes mellitus due to their diverse mechanisms of action, including enzyme inhibition, insulin sensitization, glucose uptake modulation, and antioxidant activity. This review highlights the significant pharmacological potential of flavonoids, alkaloids, phenolics, terpenoids, and glycosides in regulating glucose metabolism and reducing diabetes-associated complications. Their integration into functional foods, nutraceuticals, and pharmaceutical formulations offers a novel and potentially safer alternative to conventional antidiabetic therapies. Despite their therapeutic promise, challenges such as low bioavailability, potential toxicity, and regulatory constraints remain critical barriers to their widespread clinical application. Future research should focus on advanced formulation strategies, rigorous preclinical and clinical evaluations, and exploring synergistic phytochemical combinations to enhance efficacy and therapeutic outcomes. The development of standardized, evidence-based phytochemical therapeutics could pave the way for more effective, sustainable, and patient-friendly approaches in diabetes management.

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CONFLICT OF INTERESTS

We have No conflict interest.

AUTHOR CONTRIBUTIONS

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