

## A Review on Role of Plant(s) Extracts and its Phytochemicals for the Management of Diabetes

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### Abstract

The present review focused on plant extracts or phytochemicals role in diabetes management has been tried by many researchers. I have attempted to compile a list of total 419 plant species belongs to 133 families have been used for *in-vitro* and *in-vivo* studies. The plant extract or phytochemicals have involved in decreasing or increasing or stimulating different mechanisms in reducing diabetes and they have been listed in tabular form. By this review, few molecules are used in diabetes management and they possess molecular mechanisms or involved in signal transduction to initiate the insulin production or utilization of blood glucose level bring down to normal stage. The researchers have used different parts of the plant extracts or individual phytochemicals for antidiabetic activities. This review brings the researcher data on antidiabetic activities of different plant extracts role in reducing of diabetic problems.

**Keywords:** Plant extracts; Antidiabetic activity; Mechanism of action

### Introduction

Diabetes mellitus is characterized by alterations in the metabolism of carbohydrate, fat and protein, is caused by a relative or absolute deficiency of insulin secretion and different levels of insulin resistance and it is resulting from both genetic predisposition and favoring environmental factors. In the patients, late complications develop consisting of alterations and failure of various organs (especially the non-insulin sensitive ones) including the eyes (retinopathy with vision loss), kidneys (nephropathy leading to renal failure), nerves (peripheral and autonomic neuropathy), heart and blood vessels (precocious and severe cardiovascular, cerebrovascular and peripheral vascular atherosclerosis) [1,2].

People with diabetes is increasing due to population growth, aging, urbanization and increasing prevalence of obesity and physical inactivity. Globally the prevalence of diabetes was estimated to be 2.8 % in 2000 and 4.4 % in 2030. Worldwide, the total number of people with diabetes is projected to rise from 171 million in 2000 to 366 million in 2030 [3]. More than 80% of diabetes deaths take place in low- and middle-income countries (WHO, 2011). Comparative data was given by differentiating Diabetes Mellitus 1 (DM 1) and Diabetes Mellitus 2 (DM 2)(Table 1).

The recent survey studies of diabetes of the International Diabetic Federation (IDF) estimate about 8.3 % of adults, over all 382 million people all over the world and in India about 65.1 million people were having diabetes. It will reach beyond 592 million in further 25 years. Presently, still 175 million people were undiagnosed. Unknowingly there was the vast number of people were suffering from the diabetic complications. But 80 % of diabetic affected people were from low and middle income countries. This is becoming a great threat to the human beings and stepping towards an alarming rate [4].

Prevalence of diabetes and impaired glucose tolerance were estimated from the data provided by 219 countries and territories for the year 2013. These were grouped under seven IDF regions. AFR (Africa) 20 M, EUR (Europe) 56 M, MENA (Middle East and North Africa) 35 M, NAC (North America and Caribbean) 37 M, SACA (South and Central America) 24 M, SEA (South East Asia) 72 M, WP (West Pacific) 138 M and 382 M people were suffering from diabetes

worldwide (Table 2). Table 3 predicting the diabetes prevalence in 2035 compared with existing data of 2013 of 10 top countries [4].

The projections of top ten countries from the current prevalence indicates that, China remains the top most country in having highest diabetic people, i.e., around 98.4 million in 2013 and an estimate of 142.7 million by 2035. India stands behind the China in having second highest diabetic people, i.e. around 65.1 million in 2013 and an estimate of 109 million by 2035.

Diabetes is a complex multisystemic disorder characterized by a relative or absolute insufficiency of insulin secretion and disturbances in carbohydrate, protein and lipid metabolism [5]. The International

Feature	Type 1 DM	Type 2 DM
Frequency	10-20%	80-90%
Age at onset	Early (below 35 years)	Late (after 40 years)
Type of onset	Abrupt and severe	Gradual and insidious
Weight	Normal	Obese/non-obese
Family history	<20%	About 60%
Genetic locus	Unknown	Chromosome 6
Pathogenesis	Autoimmune destruction of $\beta$ -Cells	Insulin resistance, impaired insulin secretion
Islet cell antibodies	Yes	No
Blood insulin level	Decreased insulin	Normal or increased insulin
Islet cell changes	Insulinitis, $\beta$ -cell depletion	No insulinitis, later fibrosis of islets.
Clinical management	Insulin and diet	Diet, exercise, oral drugs, insulin
Acute complications	Ketoacidosis	Hyperosmolar coma

Table 1: Comparing type 1 and type 2 diabetes mellitus [28].

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IDF Code	Seven IDF regions	Prevalence of diabetes for 2013 (M-millions)	Diabetic deaths under 60 years of age people in 2013 (%)	Diabetic expenditure (USD) in 20 to 79 years of age group (Billions)
AFR	Africa	20 M	76	4
EUR	Europe	56 M	28	147
MENA	Middle East and North Africa	35 M	50	14
NAC	North America and Caribbean	37 M	38	263
SACA	South and Central America	24 M	44	26
SEA	South East Asia	72 M	55	6
WP	West Pacific	138 M	44	88

**Table 2:** Diabetic prevalence, deaths and expenditure estimated from the data provided by 219 countries and territories for the year 2013 [4].

Top 10	Countries	Diabetic people in 2013 (millions)	Countries	Diabetic people by 2035 (millions)
1	China	98.4	China	142.7
2	India	65.1	India	109
3	USA	24.4	USA	29.7
4	Brazil	11.9	Brazil	19.2
5	Russian Federation	10.9	Mexico	15.7
6	Mexico	8.7	Indonesia	14.1
7	Indonesia	8.5	Egypt	13.1
8	Germany	7.6	Pakistan	12.8
9	Egypt	7.5	Turkey	11.8
10	Japan	7.2	Russian Federation	11.2

**Table 3:** Top 10 diabetic countries/ territories under 20-79 years of age group in 2013 and expected to be in 2035.

Diabetes Federation has predicted that the number of individuals with diabetes will increase from 240 million in 2007 to 380 million in 2025 with 80% of the disease burden in low and middle-income countries [6].

Modern lifestyle, advanced food habits, less physical work, mental workloads and other parameters may be responsible for diabetes which was seen in high income families. It is confirmed by a survey conducted by IDF that, low income groups were having least diabetes prevalence when compared to the groups of increased income groups.

It is expected to be the biggest economic burden of national health services, families, social health services and countries to manage the diabetes and its complications. For diabetes itself, it accounts 10.8% of gross expenditure on health worldwide in 2013. 90 % of countries were spent 5-18% of overall health expenditure for only to the diabetes management. Expenditure on health involves spending by individual diabetic people, families or health systems or government on diabetes management.

Around 548 billion USD was spent on the management of diabetes and its complications in 2013 all over the world. It may be even projected to exceed 627 billion USD by 2035. In terms of International Dollars (ID), the expenditure on diabetes management was estimated 581 billion ID in 2013 and 678 billion ID at 2035. It is estimated that, an average of 1,437 USD (1,522 ID) was spent on diabetes management globally per person in the year 2013.

It is unfortunate that the most diabetic prevalent regions were spending less amount in treating diabetes and the proportion of deaths due to diabetes in these regions were very high. It was found that, highest diabetic mortality, i.e., 76% in Africa and 55% in South-East Asia.

Ethnobotanical information indicates that more than 800 plants are used as traditional remedies for the treatment of diabetes due to their effectiveness, less side effects and low cost [7]. Plant extracts or individual phytochemical or group of phytochemical has exhibited the many reactions or mechanisms to reduce the diabetes status. These

extracts decreased or increased or stimulates the number reactions to reduce or minimize the risks of the diabetes in animal experiments. The Tables 4 and 5 clearly indicated the different process are carried out by plant extracts/ phytochemicals in reducing the problem of diabetes. Based on these evidences conclude that, all the plant extracts reported have not had similar mechanisms of action and serving various processes by inhibiting or increasing or stimulating to minimize the diabetes in animals. The plant extracts have evidence that, they recovered the various organs get affected of malfunctioned due to diabetes. The extracts have ability to change in the structure and functions of affected parts viz., regeneration of  $\beta$ -cells of pancreas, initiation of receptor and ligand interactions in productions of insulin, activation of signal transduction for production of insulin and reduction of blood glucose level, initiation of number of liver enzymes for conversion of sugar into various products or limiting the production of byproducts etc. Some of the extracts have acted as insulin like activity or induce the activity of insulin and some the extracts inhibited the activity of enzymes viz.,  $\alpha$ -amylase,  $\alpha$ -glucosidase etc. The growth of herbal research in the diabetes management of diabetes was increase from past 20 years. The Asia stands first followed by Africa. The use of plant parts percent as follows, leaves (35%) followed by whole plant (12%), fruits (13%), seed (12%), root (9%), stem (8%), aerial (7%) and flower parts (2%).

Several studies have shown protection in body weight loss, anti-diabetic activity [8,9], reduction in serum cholesterol, serum triglyceride, total protein and blood urea [10] and recovery in liver glycogen content.

Insulin is secreted in pancreatic  $\beta$ -cells in response to increase in postprandial blood glucose level. Glucose seems to be the nutrient responsible for insulin secretion and the process called glucose stimulated insulin secretion[11]. Glucose transporters, GLUT1 allow the glucose molecules to enter into the cells and start the first phase of insulin secretion. Glucose-6-phosphate is phosphorylated from glucose by glucokinase enzyme [12]. The generation of ATP by glycolysis, the Krebs cycle and the respiratory chain close the ATP-sensitive  $K^+$  channel (KATP) [13], allowing sodium ( $Na^+$ ) entry without balance. These two

Family	Number of plants	Family	Number of plants
Acanthaceae	08	Liliaceae	04
Achariaceae	01	Linaceae	01
Acoraceae	01	Loganiaceae	06
Actinidaceae	01	Loranthaceae	02
Agavaceae	02	Lythraceae	05
Aizoaceae	04	Palmaceae	01
Alangiaceae	01	Papilionaceae	01
Alliaceae	01	Passifloraceae	01
Apiaceae	03	Piperaceae	04
Annoaceae	03	Malvaceae	05
Araceae	01	Melastomataceae	01
Araliaceae	04	Meliaceae	02
Arecaceae	02	Menispermaceae	03
Asteraceae	13	Moraceae	05
Amaranthaceae	05	Moringaceae	01
Anacardiaceae	03	Meliantaceae	01
Apocynaceae	06	Mimosaceae	02
Asclepidaceae	04	Molluginaceae	01
Balanitaceae	01	Myricaceae	02
Basellaceae	01	Myrsinaceae	01
Berberidaceae	03	Myrtaceae	07
Bignoniaceae	06	Musaceae	02
Bixaceae	01	Nyctaginaceae	03
Bombacaceae	05	Nymphaeaceae	03
Boraginaceae	03	Oleaceae	04
Brassicaceae	03	Onagraceae	01
Burseraceae	02	Orchidaceae	02
Caesalpiniaceae	04	Oxalidaceae	02
Campanulaceae	01	Pandanaceae	03
Capparaceae	02	Papilionaceae	01
Capparidaceae	03	Phyllanthaceae	02
Caricaceae	01	Piperaceae	04
Caryophyllaceae	02	Poaceae	02
Celastraceae	03	Polygalaceae	03
Cecropiaceae	03	Polygonaceae	02
Chenopodiaceae	07	Polypodiaceae	01
Chrysobalanaceae	01	Portulacaceae	03
Costaceae	03	Primulaceae	01
Combretaceae	10	Punicaceae	01
Compositae	10	Rhamnaceae	02
Convolvulaceae	06	Rhizophoraceae	02
Crassulaceae	01	Rosaceae	10
Crussulaceae	01	Rubiaceae	07
Cucurbitaceae	06	Ranunculaceae	04
Cupressaceae	01	Rutaceae	02
Dilleniaceae	01	Salicaceae	01
Ebenaceae	04	Salvadoraceae	03
Elaeagnaceae	01	Sapindaceae	03
Equisetaceae	02	Sapotaceae	04
Eucommiaceae	01	Scrophulariaceae	02
Euphorbiaceae	07	Solanaceae	12
Fabaceae	14	Sterculiaceae	06
Fagaceae	01	Strelitziaceae	01
Flacourtiaceae	01	Symplocaceae	01
Fomitopsidaceae	01	Tiliaceae	01
Geraniaceae	01	Theaceae	01
Gentianaceae	07	Thymelaeaceae	02
Hericaceae	01	Verbenaceae	05
Hippocrateaceae	02	Violaceae	01
Hypericaceae	01	Vitaceae	01

Hypodoxiaceae	01	Ulmaceae	01
Irvingiaceae	01	Umbelliferae	03
Juglandaceae	01	Urticaceae	04
Labiatae	05	Xanthorrhoeaceae	02
Lamiaceae	04	Zingiberaceae	06
Lauraceae	04	Zygophyllaceae	04
Leguminosae	09		

Note: total 419 plants from 133 families.

**Table 4:** Number family plants were selected which were exhibited as antidiabetic plants.

events depolarize the membrane and open voltage-dependent T-type calcium ( $Ca^{2+}$ ) and sodium ( $Na^{+}$ ) channels.  $Na^{+}$  and  $Ca^{2+}$  entry further depolarizes the membrane and voltage-dependent calcium channels open. This activation increases intracellular  $Ca^{2+}$  ( $[Ca^{2+}]_i$ ) [14], this leads to the fusion of insulin containing secretory granules, plasma membrane in the first phase of secretion of insulin [15,16].

The intracellular glucose has been utilized by insulin in several ways. The increased level of insulin influences the activity of gluconeogenic enzymes that results in the initiation of hepatic glycolysis. All types of cells contain hexokinase. Hexokinase D or glucokinase is more specific for glucose and differ with other forms of hexokinase in kinetic and regulatory properties, which has been found in hepatocytes [17]. Hexokinase plays a central role in the maintenance of glucose homeostasis, it catalyzes the conversion of glucose to glucose-6-phosphate. Also, hexokinase is an important regulator of glucose storage and disposal in the liver [18].

Second, insulin secreting phase is triggered by metabolic coupling signals which are generated through the glucose metabolism apart from increasing in the ATP/ADP ratio. Metabolism and anaplerosis cycles were processed by the participation of some coupling factors in the mitochondria. This involves the NADPH, maleate, citrate, acyl-co-A, pyruvate, glutamate and isocitrate [19]. Glucose induced secretion of insulin was also contributed by CAMKII and diverse signalling pathways [20,21], PKA [22,23], PKC [24,25] and  $\gamma$ PKG [26,27]. Most secretagogues and insulin secretory potentiators, neurotransmitters, nutritive substances and hormones were come across in the modulation of insulin secretion through these pathways.

The present review was aimed to role of plants in diabetes management *in-vitro* and *in-vivo* conditions was discussed in Table 4. This report gives a brief information on plant extracts mechanism of action in reducing diabetes.

## Materials and Methods

Totally 419 plants belonging to 133 families information were collected and studied and based on family wise distinguished and made in tabulated form (Table 5). All the plants have possessed different mechanisms of activities by increasing or decreasing or stimulation of reaction in diabetes management (Table 6).

## Conclusion

The data presented based on findings from different reports clearly tells that the use and role of plant extracts or phytochemicals in diabetes management by possessing different mechanisms. Only few plants have shown the clear mechanism in *in-vivo* conditions and other plants have shown only strong in *in-vitro* conditions. Hence, more work has to be carried out to find solutions for management of diabetes by using plant extracts. This review gives the a brief information on plants role in diabetes management.

Increases	Decreases	Stimulation of reactions
Liver hexokinase	Adipogenesis of 3T3-L1 cells	Activated the PKB by SV473 and thr 308 phosphorylation
Pancreatic secretion of insulin from $\beta$ -cells of islets	Lipolysis in 3T3-4 adipocytes	Consumption of proinsulin to insulin
Spleen increase	$\alpha$ -amylase, $\alpha$ -glucosidase, glutathione, glycogen	Sizes of $\beta$ -cells of pancreas
Glyconeogenesis and gluconeogenesis	Absorption of glucose from Gastrointestinal tract	Liver ACC phosphorylation and muscle GLUT4
Blood urea	Aldose reductase activity	Activation of opioid $\mu$ receptor of peripheral tissues
Glucose metabolism and uptake	Activity of disaccharides in the intestine	Expression of insulin receptor $\alpha$ subunit
Glycogen content	Blood glucose nitrogen	Insulin receptor substrate-1
High Density Lipoproteins Cholesterol (HDL-C)	Bilirubin	Phosphatidylinositol 3 kinase (PI3K)
mRNA expansion of PPAR $\alpha$ and PPAR $\gamma$	Glycosylated HbA1 level	Amino acids
Urine output and water intake	Glucose reabsorption	CYP through CYP2C9 and glutathione-S-transferase, insulin like effects stimulates insulin secretion
Lipid profiles	Basal endogenous glucose	Blood hormone insulin and albumin level
Insulin secretion	Plasma thiobarbituric acid reactive substances	ATP sensitive potassium channel in pancreas $\beta$ -cells
Fasting glucose level	Hydroperoxide and glucoplasmin	CYP1A2, CYP2C9, CYP2C19, CYP2D6, 3A4,
Liver enzymes SOD (SuperOxide Dismutase), catalase, Glutathione peroxidase (GPx)	Glycosylated haemoglobin	Pregnane X receptor
Insulin binding on insulin receptor	Serum alkaline phosphatase	GSK3 phosphorylation in L6 myotubes help for glycogen synthesis
Glycoxyase 1 activity in liver	Lucose tolerance level	Regeneration of $\beta$ -cells
Creatinine kinase level in tissues	Food and water intake	Post-prandial blood glucose
Glucosylated hba1c	Free radical formation in tissues	Restoring insulin level
Urea nitrogen	Glucose absorption in intestine	Protective function of heart
Peripheral glucose utilization	Monoaldehyde	Intiates the insulin release
Liver glycogen and serum insulin	Glycosylated Hb	Halt the oxidase stress and dylipidema
Free fatty acids	Malondialdehyde level in liver and tissues	Stimulates glycohemesis
Haemoglobin	Plasma lipid and insulin level	Insulin secretagogue activity
Melonydialdehyde total protein	Plasma triglycerides-ALT, AST, aminotransferase level	Effect of pancreas $\beta$ -cells count
Glucose absorption	Blood glucose/serum glucose level	Tubular necrosis and mild fatty acid changes in kidney and liver
c-peptide level	Activities of glucose-6-phosphatase, fructose-6-biphosphatase, total cholesterol and triglycerides, lipid accumulation, in differentiated adipocytes	Liver enzymes activation (ALP, GPT, GGT, GOT etc)
cAMP in pancreas islets	CYP2C9, CYP2C19, CYP2D6, CYP3A4 and glucose transporter (GLUT4)	Swelling and necrotic cells in pancreas
B-cells function and survive	LDL-C and high density lipoprotein cholesterol	Expression of homeostatin enzymes (glucokinase, glucose-6-phosphatase, phosphophenol pyruvate carboxykinase, glucose-6-phosphate dehydrogenase, insulin II
Glucose uptake in MAC-12 hepatocytes L6 myotubes	Serum creatinine	Protein kinase activation in liver and skeletal muscle
	Serum glutamate oxaloacetate transaminase (SGOT), SGPT (pyruvate)	Insulin like activity
	Urea, uric acid	Stimulates muscle cells glucose and amino acid uptake
	Activation of epinephrine on glucose metabolism	Glycation inhibitors
	Urinary glucose	
	Neoglycogenesis	

**Table 5:** Role of plant extracts and its phytochemicals in decrease or increase or stimulation of reactions for the management of diabetes through different process.

Plant Name	Extracts or Active phytochemical	Mechanism of action	References
<b>Primulaceae</b>			
<i>Aegiceras corniculatum</i> (L.) Blanco	Flavonoids, alkaloids, terpenoids, tannins and steroids	Reduction in blood glucose, glycosylated hemoglobin, decrease in the activities of glucose-6 phosphatase and fructose 1, 6-bisphosphatase and increase activity of liver hexokinase	[29]
<b>Areaceae</b>			
<i>Areca catechu</i>	Plant extract (arecaine and arecoline)	Reduction in blood glucose levels, pancreatic secretion of insulin from existing $\beta$ -cells of islets	[30]
<i>Chamaerops humilis</i> L.	Leaf extract	Decreased plasma glucose level, increase in the weight, decreased total cholesterol and triglycerides	[31]
<b>Acanthaceae</b>			
<i>Acanthus ilicifolius</i>	Plant extracts (flavonoids, alkaloids, terpenoids, tannins, and steroids)	Reduced the blood glucose level and better regeneration of $\beta$ -cells	[32]
<i>Andrographis paniculata</i> Nees	Plant extract (diterpenoid lactone andrographoloid)	Increase glucose metabolism	[33, 34]
	Plant extract	Reduced lipid accumulation in differentiated adipocytes.	[35]
<i>Andrographis paniculata</i> Nees	Glibenclamide, glimepiride, glipizide, nateglinide, rosiglitazone, pioglitazone, repaglinide	Inhibit CYP2C9, CYP2C19, CYP2D6, CYP3A4 and glucose transporter (GLUT4)	[36, 37, 38]
	Leaves extract	Increase in glucose uptake, reduction in plasma glucose, plasma insulin, total cholesterol, low density lipoprotein (LDL)-C triglyceride, glucose-6- phosphatase and fructose -1, 6- bisphosphatase levels, glycogen content (liver and muscle), high density lipoprotein (HDL) cholesterol, hexokinase increased	[39]
<i>Andrographis lineata</i>	Leaves extract	Increase in glucose uptake, reduction in plasma glucose, plasma insulin, total cholesterol, low density lipoprotein (LDL)-C triglyceride, glucose-6- phosphatase and fructose -1, 6- bisphosphatase levels, glycogen content (liver and muscle), high density lipoprotein (HDL) cholesterol, hexokinase increased	[39]
<i>Asystasia gangetica</i>	Leaves extract	$\alpha$ -glucosidase and $\alpha$ -amylase enzyme inhibition	[40]
<i>Acanthus ilicifolius</i>	Root extract	Decreased blood glucose levels and better regeneration of $\beta$ -cells	[32]
<i>Barleria montana</i>	Leaves extract	Reduction of blood glucose levels	[41]
<i>Graptophyllum pictum</i>	Purple leaves extract	Reducing blood glucose levels	[42]
<b>Rhizophoraceae</b>			
<i>Ceriops roxburghiana</i> or <i>Ceriops decandra</i>	Plant extract	Insulin-stimulatory effect	[43]
<i>Bruguiera gymnorrhiza</i>	Plant extract	Decreased total cholesterol, triglycerides, VLDL and LDL with increase in HDL, having a protective function for the heart	[44]
<b>Annoaceae</b>			
<i>Anemarrhena asphodeloids</i>	Rhizome extract	Reduced blood glucose levels	[45]
<i>Annona squamosa</i>	Plant extract	Fasting plasma glucose, serum insulin levels, serum lipid profiles, changes in body weight, liver glycogen and pancreatic TBARS	[46]
	Plant extract	Reduced the levels of blood glucose, lipids and lipid peroxidation, increased the plasma insulin activities	[47]
	Leaves extract (acetogenins-squamosin B, squamosamide, reticulatin-2, isosquamosin)	Hypoglycemic and antihyperglycemic activities, increased plasma insulin level	[46]
<i>Polyalthia longifolia</i>	Stem bark extract	Antihyperglycemic activity	[48]
	Leaves extract	$\alpha$ -amylase and $\alpha$ -glucosidase enzymes inhibitory activity	[49]
<b>Asteraceae</b>			
<i>Artemisia pallens</i>	Aerial part extract (germacranolide)	Blood glucose lowering and moderate hypoglycaemic effect	[50]
<i>Artemisia amygdalina</i>	Plant extracts	Reduced the glucose levels, cholesterol, triglycerides, low density lipoproteins (LDL), serum creatinine, serum glutamate pyruvate transaminase (SGPT), serum glutamate oxaloacetate transaminase (SGOT) and alkaline phosphatase (ALP) and regenerative/protective effect on $\beta$ -cells of pancreas	[51]
<i>Elephantopus scaber</i>	28Nor-22(R)Witha 2,6,23-trienolid	Reduced the blood glucose levels and restoring the insulin levels	[2]
	Root and leaves extract	Regeneration of islet $\beta$ -cells	[52]
<i>Smallanthus sonchifolius</i>	caffeic, chlorogenic and three dicaffeoilquinic acids, enhydrin, the major sesquiterpene lactone	Reduce the post-prandial glucose	[53]



<i>Achillea fragrantissima</i> (Forsk.) Sch. Bip	acacetin-6-C-(600-acetyl-b-D-glucopyranoside)-8-C-a-L-arabinopyranoside (5) alongside with four known compounds: chondrillasterol (1), quercetin-3,6,7-trimethyl ether (chrysoresinol-D) (2), isovitexin-40-methyl ether (3) and isovitexin (4)	Delay the absorption of ingested carbohydrates, reducing the postprandial glucose and most significant $\alpha$ -glucosidase inhibitory activity	[54]
<i>Achillea santolina</i> L.	Flavonoids such as luteolin, quercetin, cosmosiin, hyperoside and cynaroside, terpenoids. Essential oil (1,8-cineole, fragranol, fragranyl acetate and terpin-4-ol)	Inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase	[55, 56]
<i>Ambrosia maritima</i> L.	terpenoids, flavonoids and coumarins	Blood glucose level reduced, change on post-prandial blood glucose	[57]
<i>Varthemia iphionoides</i> Boiss and Blanche	Eudesmane sesquiterpene, flavonoids: jaceidine, kumatakenine, xanthomicrol, seven 3-methoxyflavones. essential oil	Inhibitory activity of pancreas $\alpha$ -amylase, decreased the blood glucose levels and hypoglycaemic activity	[58]
<i>Vernonia anthelmintica</i>	Seeds extract	Reduction in plasma glucose, HbA1(C), cholesterol, triglycerides, LDL, VLDL, free fatty acids, phospholipids and HMG-CoA reductase, plasma insulin, protein, HDL and hepatic glycogen	[59]
<i>Silybum marianum</i>	Plant extract	Creatinine concentration and glucose levels decreased, liver enzymes such as aspartate aminotransferase (AST), alanine aminotransferase (ALT) reduced	[60]
<i>Caledula officinalis</i>	Plant extract	Blood glucose and urine sugar lowered, body weight found to be highly significant, normal levels of blood glucose, urine sugar and serum lipid, increases the total haemoglobin level	[61]
<i>Stevia rebaudiana</i>	Leaves extract	Rise of serum insulin levels and reduction in hyperglycemia or hyperlipidemia and increase the <i>m</i> -RNAs expansion of PPAR $\alpha$ and PPAR $\gamma$ , recovery of $\beta$ -cells	[62]
<i>Anacyclus pyrethrum</i>	Root extract (alkaloids, flavonoids, phytosteroids and also glycosides)	$\alpha$ -amylase inhibitory effect	[63]
<b>Strelitziaceae</b>			
<i>Ravenala madagascariensis</i> Sonn	Leaves extract	Reducing the blood glucose levels	[64]
<b>Alliaceae</b>			
<i>Allium sativum</i>	Garlic extract	Hypoglycaemic and hypolipidaemic activity	[65]
	Garlic extract	Lowered serum glucose, cholesterol and triglyceride levels, increased the urine output and water intake	[66]
	Rhizome extract	Lowers blood pressure and improves lipid profile, decreases serum glucose, triglycerides, cholesterol, urea, uric acid, increases serum insulin levels	[67]
	Plant extract	Inhibition glycogen-metabolizing enzymes	[68]
<b>Meliaceae</b>			
<i>Azadirachta indica</i> A.Juss	Azadirachtin and nimbin	Improves peripheral glucose uptake by inhibiting action of epinephrine on glucose metabolism	[69]
	Leaves extract (nimbidin, nimbin, nimbidol, nimboesterol)	Glycogenolytic effect due to epinephrine action was blocked	[70]
	Plant extract	Increasing insulin secretion from $\beta$ -cells of pancreas	[68]
<i>Trichilia emetica</i>	Extract of flavonoid-rich fractions	Antihyperglycemia, antilipidemia and antihypertensive activities	[71]
<b>Palmaceae</b>			
<i>Areca catechu</i> L.	Plant extract	Reducing and normalizing the elevated fasting blood glucose levels	[72]
<b>Basellaceae</b>			
<i>Basella rubra</i> L.	Leaves extract	Fasting blood glucose levels reduced	[73]
	Leaves extract	Decrease in blood sugar level and increased level of liver enzymatic Super Oxide Dismutase (SOD), Catalase (CAT), Glutathione peroxidase (GPx)	[74]
<b>Bixaceae</b>			
<i>Bixa orellana</i> L.	Plant extract (oleo-resin)	Increase plasma insulin level and insulin binding on insulin receptor	[75]
<b>Melanthaceae</b>			
<i>Bersama engleriana</i> Gurke	Leaf extract	Decrease in BG (blood glucose), TG (triglycerides), TC (total cholesterol) and increase in LDL-C (low density lipoprotein cholesterol), HDL-C (high density lipoprotein cholesterol) level	[76]
	Leaves extract	Reduced the blood glucose level	[77]
<b>Leguminosae</b>			
<i>Bauhinia forficata</i>	Plant extract	Reductions in plasma glucose, triglycerides, total cholesterol and HDL-cholesterol	[78]
	Decoction	Reduction in serum and urinary glucose, urinary urea and inhibition of neoglycogenesis	[79]

<i>Acacia arabica</i> Willd	Seed (arabin)	Initiate release of insulin	[80]
<i>Glycyrrhiza glabra</i> Linn.	Root extract (triterpenoid, saponin, glycyrrhizin)	Lowers plasma glucose level	[81]
<i>Trigonella foenum graecum</i>	Seed extract	Decrease blood glucose concentration	[82]
	Plant extract	Increasing the glyoxalase 1 activity in liver and the creatine kinase levels in tissues	[68]
<i>Glycyrrhizae uralensis</i>	Tetra- and penta-O-galloyl- $\beta$ -D-glucose	Potent aldose reductase inhibitory activities	[83]
<i>Cyamopsis tetragonolobus</i>	Plant extract	Increasing glucose utilization, reduction in absorption of glucose from gastrointestinal tract	[68]
<b>Oxalidaceae</b>			
<i>Averrhoa bilimbi</i> L.	Leaf extract	Lowered blood glucose and triglyceride concentrations, change in the total cholesterol and HDL-cholesterol, no difference in liver thiobarbituric acid reactive substances (TBARS) and cytochrome P <sub>450</sub> values	[84]
	Leaf extract	Increase serum insulin level	[85, 86]
<i>Biophytum sensitivum</i>	Amentoflavone	Insulotrophic effects i.e. improvement in synthesis and release of insulin from the $\beta$ -cells of Langerhans	[87]
<b>Amaranthaceae</b>			
<i>Beta vulgaris</i>	Phenolics and betacyanins	Pancreatic regeneration and antihyperlipidemic activity	[88]
	Plant extract	Repairs damaged $\beta$ -cells, increases insulin levels, enhance the sensitivity of insulin, inhibit glucose, oxidase and glucose absorption and suppresses the activity of disaccharides in the intestine	[89]
<i>Achyranthus aspera</i> L	Plant extract	Decrease blood sugar	[90]
<i>Amaranthus spinosus</i> Linn.	Plant extract	Lowered the plasma and hepatic lipids, urea, creatinine levels and lipid peroxidation	[91]
<i>Amaranthus caudatus</i> , <i>Amaranthus spinosus</i> and <i>Amaranthus viridis</i>	Plant extract	Serum cholesterol, serum triglyceride, high density lipoprotein, low density lipoprotein	[92]
<i>Aerva lanata</i> Linn Juss	Aerial parts extract	Reduce the blood glucose level, lipid profile, increase body weight and reduce serum glutamate-oxaloacetate transaminase (SGOT), serum glutamate-pyruvate transaminase (SGPT), creatinine, alkaline phosphatase (ALP), blood urea nitrogen (BUN) and total bilirubin to normal level	[93]
<b>Compositae</b>			
<i>Atractylode japonica</i>	Rhizome extract (three glycans, atractans A, B and C)	Significant hypoglycemic actions	[94]
<i>Artemisia amygdalina</i>	Plant extracts	Reduced glucose levels in diabetic rats. Cholesterol, triglycerides, low density lipoproteins (LDL), serum creatinine, serum glutamate pyruvate transaminase (SGPT), serum glutamate oxaloacetate transaminase (SGOT), and alkaline phosphatase (ALP) reduced	[51]
<i>Bidens pilosa</i>	Aerial parts extract,	Decreased blood glucose and increased serum insulin levels, improved glucose tolerance, decreased HbA1C levels and protected islet structure	[95]
<i>Lactuca indica</i>	Lactucain A, B and C	Lowering of plasma glucose	[96]
<i>Eclipta alba</i> Linn.	Leaves extract (cliptin alkaloid)	Decrease activity of glucose-6-phosphatase and fructose-1-6, bisphosphatase	[97]
<i>Gynura procumbens</i>	Leaves extract	Lowers plasma glucose level	[98]
<i>Xanthium strumarium</i>	Fruits extract, Phenolic compound, caffeic acid	Increase glucose utilization	[99]
<i>Tridax procumbens</i>	Plant extract	Blood glucose reduction and hypoglycemic activities	[100]
<i>Sphaeranthus hirtus</i> Willd	Plant extract	Fasting plasma glucose, serum insulin, serum lipid profiles, magnesium levels, glycosylated hemoglobin, changes in body weight and liver glycogen levels	[101]
<i>Achillea fragrantissima</i> (Forssk.) Sch. Bip.	Aerial parts (acacetin-6-C-(600-acetyl-b-D-glucopyranoside)-8-C-a-L-arabinopyranoside)	$\alpha$ -glucosidase inhibitory activity	[54]
<b>Caryophyllaceae</b>			
<i>Spergularia purpurea</i> (Pers.) G. Don. Fil	Plant extract	Decrease in blood glucose levels, potent inhibitory effect on basal endogenous glucose production	[102]
<i>Paronychia argentea</i>	Plant extract	$\alpha$ -amylase inhibitory activity	[103]
<b>Myrsinaceae</b>			
<i>Maesa indica</i>	Stem bark extract	Reduction in blood glucose level, $\alpha$ -glucosidase inhibition activity	[104]
<b>Salicaceae</b>			
<i>Casearia esculenta</i>	Root extract	Reduction in plasma thiobarbituric acid reactive substances (TBARS), hydroperoxide and ceruloplasmin and elevation in plasma reduced glutathione (GSH), ascorbic acid (vitamin C) and $\alpha$ -tocopherol (vitamin E)	[105]
	Root extract (3-hydroxymethyl xylitol)	Total cholesterol, triglyceride, free fatty acid and phospholipid (LDL-C and VLDL-C in plasma) levels, increased in plasma and tissues, the plasma HDL-C decreased	[106]
<b>Pandanaceae</b>			

<i>Pandanus fascicularis</i> Lamk	Flavonoid extract	Increased secretion of insulin	[107]
	Carbohydrates, proteins, amino acids, saponins, tannins, phenolic compounds, alkaloids & flavonoids	Reduced blood glucose level	[108]
<i>Pandanus odoratus</i>	4-hydroxybenzoic acid	Hypoglycemic effect and increased serum insulin and liver glycogen content	[109]
	Root extract	Decrease plasma glucose level	[110]
<i>Pandanus odoratissimus</i>	Root extract	Reduce the increased blood glucose, reduce the increased blood urea, inhibit the body weight reduction	[111]
<b>Nyctaginaceae</b>			
<i>Boerhavia diffusa</i>	Plant extract	Reduction of glycosylated haemoglobin and increase in total haemoglobin level and glucose-6-phosphatase, fructose-1,6-bisphosphatase decreased	[112]
	Leaves and plant extract (alkaloid punarnavaine, punarnavoside)	Increase in hexokinase activity, decrease in glucose-6-phosphatase and fructose bis-phosphatase activity, increase plasma insulin	[113]
<i>Bougainvillea glabra</i> L.	Alkaloids, flavonoids, saponins & cardiac glycosides	Reduced the total cholesterol, triglyceride and Low-Density Lipoprotein Cholesterol (LDLCholesterol), increased the High-Density Lipoprotein Cholesterol (HDL-C)	[114]
	Plant extract	Reduction in fasting blood serum glucose	[115]
<i>Pisonia alba</i> Span.	Vitamin A, alkaloids, proteins & fats	Decrease in blood glucose, serum glutamate pyruvate transaminase (SGPT), serum glutamate oxaloacetate transaminase (SGOT), serum alkaline phosphatase (SALP), cholesterol, triglycerides levels and increase in HDL levels	[116]
	Plant extract	$\alpha$ -glucosidase inhibitory	[117]
<b>Crassulaceae</b>			
<i>Bryophyllum pinnatum</i> (Lam.) Kurz	Leaves extract	Close to normal blood glucose level	[118]
<b>Sapindaceae</b>			
<i>Cardiospermum halicacabum</i> L.	Plant extract	Inhibitory effect on glucose diffusion,	[119]
	Leaf extract	Increase in levels of blood glucose and glycosylated haemoglobin (HbA1c) and decreases insulin levels and haemoglobin (Hb) and reduction in glucokinase and elevation in gluconeogenic enzymes such as glucose-6-phosphatase and fructose-1, 6-bisphosphatase, decreased plasma glucose and HbA1c and insulin and Hb levels	[120]
<i>Blighia sapida</i> K. Kong	Terpenoids, phenol, alkaloids, tannins	Halt oxidative stress and dyslipidemia	[121]
<i>Papaya capensis</i> L	Leaf and stem bark extract	Body weight induced and blood glucose levels reduced	[122]
<b>Cecropiaceae</b>			
<i>Cecropia obtusifolia</i> Bertol.	Leaves extract (flavone, isoorientin & 3-caffeoylquinic)	Lowered the plasma glucose levels	[123]
	Leaves extract	Reduction of glucose and HbA1c, no changes in cholesterol, triglycerides ALT, AST, ALKP or insulin	[124]
<i>Cecropia pachystachya</i> Mart.	Leaf extract	Reduction in the blood glucose levels	[125]
<i>Musanga cecropioides</i> R. Br. Ex Bennet	Bark extract	Lowered the fasting plasma glucose levels	[126]
<b>Anacardiaceae</b>			
<i>Anacardium occidentale</i> Linn	Inner bark extract	Reduction in plasma glucose level	[127]
	Stem bark extract	Increases in plasma glucose, total cholesterol, triglyceride, total cholesterol/HDL-cholesterol ratio, malonyldialdehyde, total protein, urea and creatinine	[128]
<i>Mangifera indica</i> Linn.	Leaf extract (mangiferin)	Reduction of intestinal absorption of glucose	[129]
	Fruits and leaves extract	Reduces the glucose absorption and stimulates glycogenesis in liver	[130]
<i>Pistacia atlantica</i>	Plant extract	Inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase	[102]
	Plant extract	$\alpha$ -amylase inhibitory activity	[131]
<b>Loganiaceae</b>			
<i>Strychnos henningsii</i> Gilg.	Stem bark extract	Decreased the blood glucose level, feed and water intake as well as triacylglycerol, luose tolerance level effectively reduced	[132]
<i>Strychnos potatorum</i> Linn.	Root extract	Reduced fasting blood sugar, increased body weight along with decreased food and water intake	[133]
	Seed extract	Reduces blood sugar	[134]
<i>Strychnos nux-vomica</i> Linn.	Plant extract (phenols, flavonoids, terpenoids, tannins, saponins and proteins)	$\alpha$ -amylase inhibition	[135]
<i>Anthocleista djalonensis</i> A. Chev	Root extract	Reduction in fasting blood glucose level	[136]
<i>Anthocleista vogelii</i>	Stem bark extract	Maximum reduction in FBG	[137]
<b>Scrophulariaceae</b>			



<i>Bacopa monnieri</i> L.	Aerial parts	Decrease in the blood glucose level, increased peripheral glucose utilisation in the diaphragm	[138]
	Becosine, triterpene	Elevation of glycosylated hemoglobin and decreased the levels of malondialdehyde (MDA) and increased the levels of reduced glutathione (GSH) and activities of superoxide dismutase (SOD) and catalase (CAT)	[139]
<i>Scoparia dulcis</i> L.	Plant extract	Inhibition of blood glucose level, increasing postprandial glucose in body	[140]
	Plant extract	Elevated biochemical parameter and glucose level reduced gradually	[141]
	Plant extract	Decreased free radical formation in tissues, decrease in thiobarbituric acid reactive substances (TBARS) and hydroperoxides (HPX) and increase in the activities of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), reduced glutathione (GSH) and glutathione-S-transferase (GST) clearly	[142]
<i>Picrorrhiza kurroa</i> Royle ex. Benth	Plant extract (picrorrhizin, kutkin)	Decrease serum glucose	[143]
<i>Scoparia dulcis</i> Linn.	Leaves extract	Decrease glycosylated Hb and increased total Hb, insulin-secretagogue activity	[144]
<i>Rehmannia glutinosa</i>	Tuberous extract	$\alpha$ -glucosidase activity	[145]
<b>Theaceae</b>			
<i>Camellia sinensis</i>	Caffeine and catechins, Epigallocatechingallate	Inhibits development of insulin resistance, hypoglycemia and other metabolic effects and decreases glucose absorption from intestine	[146, 147]
	Leaves extract (polyphenols)	Increase insulin secretion	[148]
<b>Equisetaceae</b>			
<i>Equisetum myriochaetum</i> Schlecht and Cham	Aerial parts extract	Reduced the blood glucose levels, no significant changes in the insulin levels	[149]
<i>Equisetum arvense</i> L.	Plant extract	Blood sugar decreased	[150]
<b>Capparaceae</b>			
<i>Cleoma droserifolia</i> (Forsk.) Delil	Terpenes, flavonoids (quercetin, kaempferol, and isorhamnetin) and phenolic acids.	Hypoglycaemic efficacy via potentiation of peripheral and hepatic insulin sensitivity, decreasing hepatic glucose output and intestinal glucose absorption, insulin induction activity; restored the blood glucose level, plasma malondialdehyde and urine sugar to near the physiological values	[151, 152]
<i>Buchholzia coriacea</i>	Seeds extract	Blood glucose reduction	[153]
<b>Capparidaceae</b>			
<i>Capparis deciduas</i>	Stem extract	Blood glucose level decreases and hypoglycemic activity	[154]
<i>Gynandropsis gynandra</i>	Plant extract (phytosterols, triterpenes, flavonoids, carbohydrates and alkaloids)	Blood glucose level decrease	[155]
<i>Crataeva nurvala</i> Buch. Ham.	Plant extract	Blood glucose level and prevented body weight loss	[156]
	Polyphenols and flavonoids	Blood glucose levels reduced	[157]
<b>Ebenaceae</b>			
<i>Diospyros melanoxyton</i> Roxb.	Bark extract (triterpenoids, steroids, alkaloids, flavonoids & tannins)	Reversed the diabetes-induced hyperlipidemia and studies of pancreas revealed its effects on $\beta$ -cells count	[158]
	Leaves extract	Reduce fasting serum glucose, elevation of serum cholesterol, triglyceride, urea and creatinine levels	[159]
<i>Diospyros lotus</i> L.	Fruits extract	Decrease in glucose level, recovered the body weight, parenchymal and portal inflammation and lymphocytes had been replaced by few eosinophils in the liver	[160]
<i>Euclea undulata</i> Thunb. Var <i>myrtina</i>	Root bark extract	Lowered fasting blood glucose levels, elevated cholesterol and triglyceride levels	[161]
	Root bark extract (triterpene, $\alpha$ -amyrin-3O- $\beta$ -(5-hydroxy) ferulic acid (1), betulin (2), lupeol (3) and epicatechin (4))	Lowers blood glucose levels, ability to inhibit $\alpha$ -glucosidase	[162]
<i>Capparis deciduas</i> Edgew	Powder	Hypoglycemic, hypolipidaemic	[163]
<b>Sterculiaceae</b>			
<i>Triplochiton scleroxylon</i> Schumann	Bark extract	Decreased plasma glucose and malondialdehyde concentrations, tubular necrosis and mild fatty changes in the kidneys and liver	[164]
	Bark extract	Activities of liver function enzymes viz. Alkaline phosphatase (ALP), glutamate pyruvate transaminase (GPT), gamma glutamyl transferase (GGT) and glutamate oxaloacetate transaminase (GOT)	[165]
	Plant extract	Reduction in plasma glucose and malondialdehyde	[166]
<i>Helicteres isora</i> L.	Root juice	Reduction in plasma glucose, triglyceride and insulin levels, reduction in plasma triglyceride, plasma lipid and insulin levels	[167]
	Fruits extract	Produce a significant uptake of glucose	[159]
<i>Diospyros melanoxyton</i> Roxb.	Leaves extract	Reduce fasting serum glucose	[158]
	Bark extract (steroids, tannins, alkaloids and triterpenoids)	Effects on $\beta$ -cells count, beneficial effects on blood glucose and hyperlipidemia	[167]

<i>Diospyros lotus</i> L.	Fruit extract	Decrease in glucose level, recovered the body weight	[168]
<i>Abroma augusta</i> Linn	Roots and leaves, alkaloids	Lowering blood sugar	[169]
<i>Euclea undulata</i> Thunb. Var myrtina	Root bark extract	Lowered fasting blood glucose and elevated cholesterol and triglyceride levels	[161]
	Root bark (triterpene, $\alpha$ -amyrin-3O- $\beta$ -(5-hydroxy) ferulic acid (1), in addition to three known compounds; betulin (2), lupeol (3) and epicatechin (4).)	Lowers blood glucose levels, ability to inhibit $\alpha$ -glucosidase	[162]
<b>Fomitopsidaceae</b>			
<i>Fomitopsis pinicola</i> (Swartz. Fries) Karst.	Fruit body extract	Increased serum fructosamine levels and cells of the pericentral regions have swelling and some necrotic cells observed in the pancreas	[170]
<b>Lauraceae</b>			
<i>Cinnamomum zeylanicum</i>	Leaves extract	Reduced the blood glucose level	[171]
	Bark extract	Increased HDL-cholesterol (HDL) and tissue glycogen levels and regulation and expression of glucose homeostatic enzymes, glucokinase (GK), glucose-6-phosphatase (G6Pase), phosphoenol pyruvate carboxykinase (PEPCK), glucose-6-phosphate dehydrogenase (G-6-PDH) and Insulin II	[172]
	Bark extract, volatile oil, tannin, mannitol, ca. oxalate	Elevation in plasma insulin	[173]
<i>Cinnamomum tamala</i> Fr. Nees.	Leaf extract	Decrease in the levels of fasting blood glucose and urine sugar, increase in body weight, decrease in peroxidation products, viz., thiobarbituric acid reactive substances, reduced glutathione and glycogen content	[174]
	Leaves extract	Lowered the blood glucose level and maintained body weight and lipid-profile parameters	[172]
<i>Cinnamomum verum</i> J. S. Presl	Bark extract	Reduces the blood glucose and elevates the plasma insulin level	[175]
<i>Persea americana</i> Mill.	Leaves extract	Reduction in the blood glucose levels	[176]
	Leaves extract	Reduced blood glucose levels and improved the metabolic state, the Protein Kinase B activation was observed in the liver and skeletal muscle	[177]
<b>Burseraceae</b>			
<i>Commiphora africana</i>	Stem bark extract	Decrease in the blood glucose levels	[178]
<b>Hericiaceae</b>			
<i>Hericium erinaceus</i> (Bull.) Pers.	Fruiting bodies extract	Effects on blood glucose, serum triglyceride and total cholesterol levels	[179]
	Fruiting bodies extract	Decrease in serum glucose and a rise in serum insulin level and attenuated lipid disorders. Increased the activities of CAT, SOD and GSH-Px (glutathione peroxidase) and GSH (glutathione) and reduced MDA (malondialdehyde) level in the liver tissue	[180]
<b>Vitaceae</b>			
<i>Cissus sicyoides</i> L.	Leaves extract	Decrease in plasma triglycerides and blood glucose and triglyceride, Aspartate (AST) and alanine (ALT) aminotransferases levels	[181]
	Aerial parts	Serum levels of glucose and increased cholesterol and triglyceride levels	[182]
<b>Musaceae</b>			
<i>Musa paradisiaca</i> L.	Stem juice	Decrease in serum glucose, triglycerides, cholesterol, SGOT and SGPT	[183]
	Flower extract	Concentrations permanent hyperglycemia	[184]
<i>Musa sapientum</i> Linn.	Flower extract	Reduce blood glucose & glycosylated Hb	[185]
<b>Costaceae</b>			
<i>Costus afer</i> Ker Gawl.	Stem extract (flavonoids, saponins and phenols)	Serum elevation of alanine aminotransferase (ALT), aspartate aminotransferase (AST) and alkaline phosphatase (ALP) and increase in the levels of thiobarbituric acid reactive species (TBARS) expressed as malondialdehyde in the liver	[186]
<i>Costus igneus</i> (L)	Leaves extract (alkaloids, flavonoids, phenolic compounds and steroids)	Prevented body weight loss	[187]
<i>Costus pictus</i>	Leaves extract	Hypoglycaemic activity	[188]
<b>Thymelaeaceae</b>			
<i>Phaleria macrocarpa</i>	Fruit pericarp extract	Lowered blood glucose	[189]
<b>Verbenaceae</b>			
<i>Clerodendrum capitatum</i>	Leaves extract (saponins, flavonoids, alkaloids, tannins, glycosides)	Hypoglycemic and hypolipidemic effects	[190]
<i>Clerodendrum serratum</i>	Leaves extract	Reduction of blood glucose level and exhibited better glucose utilization	[191]
<i>Tectona grandis</i> L.	Root extract	Reduces blood glucose level	[192]
<i>Premna corymbosa</i> (Burm. F.) Rottl	Leaves extract	Reduction in total cholesterol, LDL cholesterol, VLDL cholesterol and improvement in HDL cholesterol	[193]
	Root extract	Reduction of blood glucose	[194]

<b>Convolvulaceae</b>			
<i>Merremia tridentata</i> (L.) Hall. F.	Root extract	Increase in serum insulin, body weight and glycogen content in liver and skeletal muscle, reduction in the levels of serum triglyceride and total cholesterol and antilipidperoxidative effect in the pancreas	[195]
<i>Ipomoea aquatica</i> Forsk	Leaves extract (carotene)	Reduce fasting blood sugar& serum glucose level	[196]
<i>Ipomoea batata</i> Linn.	Seed extract (alkaloid, fatty oil, asparagines )	Lower serum glucose level	[197]
<i>Cuscuta reflexa</i>	Leaf extract	$\alpha$ -glucosidase inhibitor	[198]
<i>Merremia emarginata</i> Burm. F.	Plant extract	Decrease in blood glucose, serum urea and serum creatinine and increase in body weight, insulin and protein level, reduction of HbA1C and increase in total hemoglobin level. The hexokinase increased, glucose-6-phosphatase, fructose-1, 6-bisphosphatase decreased. Pancreatic $\beta$ -cells regenerated	[199]
<i>Evolvulus alsinoides</i>	Plant extract	Inhibitory effect on alpha amylase and alpha glucosidase	[200]
<b>Verbeceae</b>			
<i>Lantana camera</i>	Leaves extract	Reduction of blood glucose	[201]
	Fruit extract	Antihyperglycemic activity and improvement in body weight, HbA1c profile, regeneration of liver cells	[202]
<b>Bignoniaceae</b>			
<i>Dolichandrone falcatai</i> Seem.	Leaves extract	Reduction in blood glucose level	[203]
	Leaves extract	Reductions of blood glucose, lipid parameters except HDL-C serum enzymes increased HDL-C, increase in plasma insulin	[204]
<i>Dolichandrone atrovirens</i>	Leaves bark extract	Inhibited $\alpha$ -glucosidase, $\alpha$ -amylase and glucose-6-phosphatase	[205]
<i>Kigelia pinnata</i> Jacq.	Flower extract	Reduced blood glucose, serum cholesterol and triglycerides levels. High density lipoprotein-cholesterol level improved	[206]
<i>Kigelia africana</i> (Lam.)	Plant extract	Reduction in blood glucose levels	[207]
<i>Tabebuia rosea</i> (Bertol) DC	Plant extract	Reduction of blood glucose levels	[208]
<i>Tecoma stans</i>	Plant extract	Intestinal $\alpha$ -glucosidase inhibition by decreasing the postprandial hyperglycaemia, reduced cholesterol and triglycerides levels	[208]
	Plant extract	Stimulating glucose uptake in both insulin-sensitive and insulin-resistant murine and human adipocytes without proadipogenic or antiadipogenic side effects	[209]
<b>Eucommiaceae</b>			
<i>Eucommia ulmoides</i> Oliv.	Powdered leaf extract	Blood glucose lower, the plasma insulin and C-peptide higher, lower plasma urea nitrogen levels	[210]
	Leaves extract (new flavonol glycoside, quercetin 3-O- $\alpha$ -L-arabinopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranoside (1), and known flavonols kaempferol 3-O- $\beta$ -D-glucopyranoside (astragalin) (2), quercetin 3-O- $\beta$ -D-glucopyranoside (isoquercitrin) (3))	Exhibited glycation inhibitory activity of aminoguanidine, a known glycation inhibitor	[211]
	Quercetin 3-O- $\alpha$ -L-arabinopyranosyl-(1 $\rightarrow$ 2)- $\beta$ -D-glucopyranoside Kaempferol 3-O- $\beta$ -D-glucopyranoside (astragalin) Quercetin 3-O- $\beta$ -D-glucopyranoside (isoquercitrin)	Glycation inhibitors	[148]
<b>Hippocrateaceae</b>			
<i>Salacia fruticosa</i> Heyne ex Lawson	Leaves extract	Reduction in blood glucose levels	[212]
<i>Salacia reticulata</i> Wight	Leaves extract	Inhibited the postprandial elevation of the plasma glucose and insulin levels and intestinal $\alpha$ -glucosidase activities	[213]
	Root bark extract	Improved glucose tolerance and reduced fasting blood glucose, fructosamine and glycosylated hemoglobin levels	[214]
<b>Flacourtiaceae</b>			
<i>Flacourtia jangomas</i> Raeusch.	Leaves and stem extract	Eeduction in FBG level	[215]
	Fruit extract	Fasting blood glucose level, body weight, liver and muscle glycogen and serum lipid profiles evaluated and reduces the fasting blood glucose level and increases the glycogen level and serum lipid profile improvement	[216]
	Flavonoids, saponins, carbohydrates, steroids, tannins & phenols	Altered biochemical parameters, cholesterol and triglycerides	[215]
<b>Orchidaceae</b>			
<i>Nervilia plicata</i> (Andrews) Schltr.	Stem extract	Blood glucose levels and decrease in the blood glucose, serum urea and creatinine levels. LPP levels of kidney and pancreas decrease	[217]

<i>Nervilia aragoana</i> Gaud	Stem extract	Blood glucose levels and decrease in the blood glucose, serum urea and creatinine levels. LPP levels of kidney and pancreas decrease	[218]
<b>Rutaceae</b>			
<i>Clausena anisata</i> Burm.f.	Roots extract	Stimulate secretion of insulin	[218]
<i>Murraya koenigii</i> (L) Spreng	Leaves extract	Increase glycogenesis, decrease glycogenolysis and gluconeogenesis	[219]
<b>Rubiaceae</b>			
<i>Gardenia taitensis</i> A. P. de Candolle	Alkaloids, phytosterols, carbohydrates & saponins	Reduction in blood sugar, significant reduction in total cholesterol, LDL cholesterol, VLDL cholesterol and improvement in HDL cholesterol	[220]
<i>Xeromphis uliginosa</i> Retz	Root extract	Reduced the blood glucose	[221]
<i>Morinda tinctoria</i>	Fruit extracts	Inhibitory effect on glucose diffusion	[222]
<i>Nauclea latifolia</i> Sm.	Leaf extract	Lowered the fasting blood glucose	[223]
	Leaves extract	Increases in their MCV and MCH, reduction in WBC and lymphocyte levels increased	[224]
	Leaves extract	Lowered the blood glucose level	[225]
	Root extract	Reduction in fasting Blood Glucose levels	[226, 227]
<i>Neolamarckia cadamba</i>	Stem bark extract	Antihyperglycemic activity	[228]
<i>Anthocephalus indicus</i> A. Rich	Leaf extract	Reduction in blood glucose, total cholesterol, triglycerides, HDL and LDL	[229]
<i>Rubia cordifolia</i> Linn	Root extract	Inhibited the $\alpha$ -amylase and $\alpha$ -glucosidase	[230]
<b>Nymphaeaceae1</b>			
<i>Nelumbo nucifera</i> Gaertn.	Rhizome and flower extract	Restores the normal levels of Hb, HbA, d RBC, WBC and platelets	[231]
	Rhizome extract (nuciferin, normuciferin)	Reduce blood sugar level	[232]
	Dried flower extract	Depression of the peak rise in fasting blood sugar after glucose load	[233]
	Seeds inorganic compounds	Insulin secretion or its actions in a synergetic manner	[234]
<i>Nymphaea stellata</i> Willd.	Flower extract	Decreased the blood glucose level, glycosylated hemoglobin, cholesterol, triglycerides, phospholipids, LDL, VLDL and increase in liver glycogen, insulin and HDL level. Increased the hexokinase, LDH activity and decreased the glucose 6-phosphatase activity	[235]
	Leaves extract	Plasma glucose level increased and affected the plasma level of cholesterol and triglyceride	[236]
<i>Nymphaea pubescens</i> Willd.	Tuber extract	reductions of blood glucose, lipid parameters except HDL-C, serum enzymes and increased HDL-C	[237]
	Leaves extract	Declines of blood glucose, lipid parameters except HDLcholesterol, serum enzymes and increased HDL-C	[238]
<b>Oleaceae</b>			
<i>Olea europaea</i> L.	Leaf extract	Decrease in blood glucose level	[239]
	Leaves extract, Oleuropeoside	Potiation of glucose, induced insulin released and increase peripheral uptake of glucose	[240]
	Leaf extract	Decreased the serum glucose, total cholesterol, triglycerides, urea, uric acid, creatinine, aspartate amino transferase (AST) and alanine amino transferase (ALT), increased the serum insulin	[241]
<i>Nyctanthes arbor-tristis</i> L.	Root extract	Hypoglycemic activity	[242]
	Flower and leaves extract	Lowered blood serum glucose levels	[243]
<i>Abies pindrow</i> Royle	Plant extract	Insulin secretagogue activity	[244]
<i>Juniperus communis</i> Linn.	Fruit extract	Increase peripheral glucose consumption and induce insulin secretion	[245]
<b>Boraginaceae</b>			
<i>Heliotropium zeylanicum</i> (Burm.F) Lamk	Plant extract	Decreased the blood glucose level and increased the body weight, food intake and liquid intake, decreased thiobarbituric acid reactive substances and increased, reduced glutathione, superoxide dismutase and catalase	[246]
<i>Heliotropium indicum</i>	Plant extract (alkaloids, steroids, triterpenes, saponins and tannins)	Antihyperglycemic activity	[247]
<i>Tournefortia hirsutissima</i> L.	Plant extract	Lowered the plasma glucose levels	[248]
<b>Passifloraceae</b>			
<i>Passiflora mollissima</i> Bailey	Leaves extract	Lowered the blood sugar level	[249]
<b>Piperaceae</b>			
<i>Piper betle</i> L.	Leaf extract	Reduced the external glucose load, spleen had increased	[250]
<i>Piper sarmentosum</i> Roxb.	Plant extract	Fasting blood sugar level was reduced	[251]
<i>Piper longum</i>	Root extract	Decrease in FBG levels, decrease in the activities of liver and renal functional markers	[252]
<i>Piper nigrum</i> L	Seeds extract	Reduces glucose and serum lipid levels	[253]
<b>Araceae</b>			
<i>Anaphyllum wightii</i> Schott.	Rhizome extract	$\alpha$ - amylase and $\alpha$ -glucosidase inhibitory activity	[254]
	Tubers extract	Decrease in fasting blood sugar level	[255]
<b>Polygalaceae</b>			

<i>Melastoma malabathricum</i>	Leaves extract	The increased body weight, decreased blood glucose, glycosylated haemoglobin and other biochemical parameters level and altered lipid profiles	[256]
<i>Polygala chinensis</i> L	Plant extract	Reductions of blood glucose, lipid parameters except HDL-C, serum enzymes and increased HDLC and in serum insulin	[257]
<i>Polygala javana</i>	Leaves extract	Reductions of blood glucose, lipid parameters except HDL-C, serum enzymes and increased HDLC and in serum insulin	[258]
<b>Combretaceae</b>			
<i>Combretum micranthum</i>	Leaf extract	Hypoglycaemic activity	[259]
<i>Combretum lanceolatum</i>	Flower extract (quercetin)	Reduction in glycemia, glycosuria and urinary urea levels and increase in liver glycogen content, phosphorylation levels of adenosine monophosphate-activated protein kinase increased in liver, inhibition of gluconeogenesis, urinary urea reduced and skeletal muscle mass increased by activation of adenosine monophosphate-activated protein kinase	[260]
<i>Terminalia belerica</i> Roxb.	Plant extract	Decrease in glutathione, serum lipid peroxidation elevated, decreased serum glucose level	[261]
<i>Terminalia chebula</i>	Fruit extract	The glycogen content of liver increased, reduction in blood glucose level on adrenaline induced hyperglycemia resulting from inhibition of $\alpha 2$ receptor of pancreatic $\beta$ -cells, thus promoting further insulin release	[262]
	Fruit extract	Decreases blood glucose levels by enhancing secretion of insulin from $\beta$ -cells of Langerhans or through extra pancreatic mechanism. Inhibits glycosylation end products, which contribute to renal damage	[263]
<i>Terminalia pallida</i> Brandis	Fruit extract	Antihyperglycemic activity	[264]
<i>Terminalia superba</i>	Leaves extract	Normalization of fasting blood glucose levels, reduction in polyphagia and polydipsia and weight gain	[265]
<i>Terminalia catapa</i>	Fruit extract	Improvement in parameters like body weight and lipid profile regeneration of beta-cells of pancreas	[266]
	Plant extract	Change in body weight and lipid profile along with serum creatinine, serum urea and serum alkaline phosphatase, regeneration of beta cells of pancreas	[267]
<i>Swertia chirata</i>	Leaves extract	Reduction in blood glucose level	[268]
	Swertichirin	Blood sugar lowering effect, lowers blood sugar level by stimulation of insulin release from islets of Langerhans	[269]
	Plant extract	Fall in blood sugar, effective in regulating blood sugar levels	[270]
<i>Swertia chirayita</i>	Plant extract	Effects on cholesterol and triglyceride level	[271]
	Plant extract	Reduction of fasting blood glucose level, cholesterol level and triglyceride level	[272]
	Root extract (swertiamarin)	Hypoglycemic activity	[272]
<b>Polypodiaceae</b>			
<i>Hemionitis arifolia</i> (Burm.) Moore.	Plant extract	Serum glucose levels, liver glycogen content and body weight	[273]
<b>Crussulaceae</b>			
<i>Bryophyllum pinnatum</i>	Plant extract	Drop in the BGL	[117]
<b>Moraceae</b>			
<i>Ficus bengalensis</i>	Bark extract	Decreased the blood glucose level, restored the levels of serum electrolytes, glycolytic enzymes and hepatic cytochrome P-450 dependent enzyme systems and decreased the formation of liver and kidney lipid peroxides	[274]
	Bark extract, tannin	Rising serum insulin	[275]
<i>Ficus religiosa</i> Linn.	Plant extract, tannin	Initiating release of insulin	[276]
<i>Morus alba</i>	Leaves extract	Increases the $\beta$ -cell number in diabetic islets. Reduces levels of glycosylated hemoglobin. Decreases triglycerides, cholesterol and VLDL, restores elevated levels of blood urea	[277]
	Plant extract	Protection of pancreatic $\beta$ -cells from degeneration and diminish lipid peroxidation	[278]
<i>Morus indica</i> L.	Leaves extract	Increase glucose uptake	[279]
<i>Morus bomoyisis</i>	Plant extract	Regeneration of $\beta$ -cells of the islets of Langerhans	[68]
<b>Violaceae</b>			
<i>Hybanthus enneaspermus</i> (L.) F. Muell	Plant extract (flavonoids, flavonol, phenols)	Increase in the body weight and decrease in the blood glucose level	[280]
	Plant extract	Increased utilization of the glucose by hemidiaphragm	[281]
<b>Onagraceae</b>			



<i>Jussiaea suffruticosa</i> L.	Plant extract	Plasma glucose concentration fell	[282]
<b>Aizoaceae</b>			
<i>Mollugo nudicaulis</i> Lam.	Plant extract	Decrease in the level of blood glucose, cholesterol, triglycerides, low density lipoprotein (LDL), lipid peroxidation, liver glycogen, serum creatinine, urea, uric acid and liver marker enzymes such as AST, ALT, ALP, increase in high density lipoprotein (HDL), superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione-S-transferase (GST), reduced glutathione (GSH), Vitamin C	[283]
<i>Mollugo pentaphylla</i>	Aerial parts extract	Reduces blood glucose level	[284]
	Aerial parts	Decrease in the blood glucose level	[285]
	Plant extract	Reduction in blood glucose	[286]
<i>Trianthema portulacastrum</i> L.	Plant extract	Antihyperglycemic effect	[287]
<i>Zaleya decandra</i> L. N. Burm. F.	Root extract	Restored the levels of glucose, cholesterol, triglycerides, total proteins, urea, creatinine, lipid peroxidation level, changes in necrosis and degeneration in liver and pancreas	[288]
<b>Balanitiaceae</b>			
<i>Balanites aegyptiaca</i> (L.) Delile	Fruits extract	Increased basal glucose uptake, accelerated the triglyceride accumulation in pre-adipocytes undergoing differentiation	[289]
<b>Asclepidaceae</b>			
<i>Gymnema sylvestre</i> R.	Plant extracts	The fasting blood glucose, cholesterol and serum triglyceride content reduced and elevation in the level of serum HDL-cholesterol	[290]
	Plant extract	Decreased plasma glucose, ALT, AST, triglycerides, total cholesterol, LDL-cholesterol, malondialdehyde and increased insulin, HDL-cholesterol and erythrocyte superoxide dismutase levels	[291]
	Plant extract	Reduction of glucose concentration and urea, uric acid and creatinine levels increased	[292]
	Leaves and callus extract	Increase the weight of the whole body, liver, pancreas and liver glycogen content, increases the regeneration of $\beta$ -cells	[293]
	Leaf extract (gymnemic acid, quercital)	Lowers plasma glucose level	[294]
	Plant extract	Regeneration of $\beta$ -cells of the islets of Langerhans	[68]
<i>Caralluma attenuata</i>	Seeds extract	Improve the alterations in blood glucose levels, serum triglyceride, serum cholesterol, liver glycogen, glycosylated haemoglobin and body weight	[295]
<i>Cryptolepis sanguinolenta</i> R.	Plant extract (cryptolepine)	Increase glucose uptake by 3T3-L1 cells	[296]
<i>Sarcostemma secamone</i>	Plant extract	Increased body weight, decreased blood glucose, glycosylated haemoglobin and biochemical parameters level and altered lipid profiles	[297]
<b>Molluginaceae</b>			
<i>Glinus oppositifolius</i>	Aerial parts	Decrease in the blood glucose level	[285]
<b>Xanthorrhoeaceae</b>			
<i>Aloe vera</i> (L.) Burm. Fil.	Leaf extract (lophenol (phytosterols), 4-methylenecycloartanol)	Maintains glucose homeostasis by interfering with carbohydrate metabolizing enzymes. Increases production and release of insulin	[298, 299]
	Leaves gel	Hypoglycemic activity, decreases fasting glucose levels, hepatic transaminases, plasma and liver cholesterol, triglycerides, free fatty acids and phospholipids. Improves plasma insulin level. Restores normal levels of LDL and HDL and cholesterol reduces levels of hepatic phosphatidylcholine hydroperoxide and hypocholesteremic efficacy, diminishes degenerative changes in kidney tissues	[300]
	Pioglitazone, repaglinide	Enhancement in adipose tissue insulin signaling pathway	[301, 302]
<i>Aloe barbadensis</i> Miller	Leaves extract (barbaloin, isobarbaloin, resin)	Stimulating synthesis and/or release of insulin	[303]
<b>Liliaceae</b>			
<i>Liriope spicata</i>	Tuberous root extract	Decrease of fasting blood glucose and improvement of insulin resistance and serum lipid metabolism, liver histological analysis showed that TLSP, LSP1 and LSP2 ameliorated the hepatocyte hypertrophy and decreased the lipid accumulation, TLSP (total polysaccharides), LSP1 and LSP2 (new polysaccharides) effectively inhibited hepatic gluconeogenesis and increased hepatic glycolysis and hepatic glycogen content. Increased the expression of insulin-receptor $\alpha$ subunit, insulin-receptor substrate-1, phosphatidylinositol 3-kinase and peroxisome proliferators-activated receptors $\gamma$	[304]
	Tuberous root extract	Lowering total cholesterol (TC), triglyceride (TG) and low-density lipoprotein (LDL) cholesterol levels, elevated the relative high density lipoprotein (HDL) cholesterol level (HDL/TC) in serum	[305]
<i>Allium sativum</i> Linn	Root extract, allin, allicin	Antihyperglycemic and antinociceptive effect	[306]
<i>Allium cepa</i> Linn.	Bulb, Protein, carbohydrate, vit. A,B,C, allyl propyldisulphide	Stimulating effects on glucose utilization and antioxidant enzyme	[307]
	Plant extract	Increasing insulin secretion from beta cells of pancreas	[68]

<i>Asparagus racemosus</i> Willd.	Root extract	Decreased the blood glucose level, fluid intake and considerably increased the body weight	[308]	
	Root extract	High density lipoproteins cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), very low density lipoprotein cholesterol (VLDL-C), total cholesterol (TC), triglycerides (TG), glycosylated haemoglobin (HbA1C), urea, creatinine, serum glutamate oxaloacetate transaminase(SGOT), serum glutamate pyruvate transaminase (SGOT), acid phosphatase (ACP) and alkaline phosphatase (ALP), reduction of blood glucose, lipid profiles	[309]	
	Root extract	Suppressed postprandial hyperglycaemia after sucrose ingestion and increased unabsorbed sucrose content in gut and inhibited the absorption of glucose during in situ glucose. Enhanced glucose transport and insulin action in 3T3-L1 adipocytes, decreased serum glucose, increased pancreatic insulin, plasma insulin, liver glycogen and inhibition of carbohydrate digestion and absorption, enhancement of insulin secretion and action in the peripheral tissue	[310]	
<b>Berberidaceae</b>				
<i>Berberis lyceum</i> Royle	Root extract	Glucose tolerance, glycosylated haemoglobin, serum lipid profiles and body weight	[311]	
<i>Berberis aristata</i> DC.	Stem extract	Reduced the blood glucose, significant reduction of serum, total cholesterol and triglycerides and increase in HDL cholesterol level	[312]	
	Root extract	Antihyperglycemic activity	[313]	
<i>Casearia esculenta</i> Roxb.	Plant extract	Reduced the blood glucose	[314]	
<b>Fagaceae</b>				
<i>Quercus infectoria</i>	Root extract	Reduced the blood glucose	[315]	
<b>Cucurbitaceae</b>				
<i>Momordica charantia</i> Linn.	Charantin, sterol, momordicin	Mimics insulin activity by stimulating muscle cells glucose and aminoacid uptakes, decreases hepatic gluconeogenesis	[316, 317]	
	Fruit extract (momordicine alkaloid, ascorbic acid)	Reduce blood glucose level	[318]	
	A trypsin inhibitor, named <i>Momordica charantia</i> insulin receptor (IR)-binding protein (mclRBP)	Stimulates both the glucose uptake in cells and the glucose clearance	[319]	
	Glibenclamide, glimepiride, glipizide, nateglinide, rosiglitazone	CYP, through CYP2C9 and glutathione S-transferase and insulin-like effects and stimulate insulin secretion	[320]	
	Plant extract	Acting like insulin	[68]	
	Polypeptide-p	Hypoglycemic effects in gerbils, langurs and huma	[321]	
	Four cucurbitane glycosides, momordicosides Q, R, S, and T, and stereochemistry-established karaviloside XI	In both L6 myotubes and 3T3-L1 adipocytes, stimulated GLUT4 translocation to the cell membrane—an essential step for inducible glucose entry into cells, increased activity of AMP-activated protein kinase (AMPK), a key pathway mediating glucose uptake and fatty acid oxidation, strong effect to stimulate GLUT4 translocation by several fold in both cell types to a level that was comparable to maximal insulin and AICAR stimulation, highly potent in stimulating GLUT4 translocation in insulin responsive cells	[322]	
	Four cucurbitane glycosides, momordicosides Q, R, S, and T, and stereochemistry-established karaviloside XI	Increased the tyrosine phosphorylation of insulin receptor substrate isoform 1 and the phosphorylation of Akt only in the presence of insulin in insulin-resistant cells, they are insulin sensitizers, enhanced the phosphorylation of AS160 (Akt substrate of 160 kDa), the migration of glucose transporter-4 and glucose uptake of insulin-resistant cells in the absence of insulin, they substitute for insulin to promote glucose clearance and insulin-sensitizing and insulin-substitution functions	[323]	
	<i>Momordica cymbalaria</i> Fenzl ex naud in	Metformin and berberine	Activate AMPK, as weak mitochondrial poisons and elevated intracellular AMP levels ensuring as a function of reduced mitochondrial respiration trigger increased AMPK activity, the upstream AMPK kinase, LKB1, is required for AMPK activation by metformin	[324]
		Seeds extract	Potent inhibition of $\alpha$ -glucosidase and $\alpha$ -amylase	[325]
<i>Coccinia indica</i>	$\beta$ -amyrin, Lupeol, cucurbitacin B	Glucose synthesis is inhibited by suppression of gluconeogenic enzymes like glucose-6-phosphatase and fructose-1, 6-bisphosphatase. Activates glucose-6-phosphate dehydrogenase by promoting glucose oxidation. Hypoglycemic effect by insulin secretagogue activity	[326]	
<i>Coccinia grandis</i>	Plant extracts	Reduce the blood glucose level	[327]	
	Fruit extract	Reduces blood glucose and glycosylated hemoglobin content. Lowers blood glucose by depressing its synthesis, depression of glucose 6-phosphatase and fructose 1,6, bisphosphatase and enhancing glucose oxidation pathway through activation of glucose 6-phosphate dehydrogenase	[328]	
<i>Cucurbita maxima</i> Duchesne	Seed extract	Exhibited decrease in glucose and triacylglycerides	[329]	

<i>Cucurbita moschata</i>	Stem extract ((22 <i>E</i> ,24 <i>R</i> )-24-methyl-6β-methoxy-5α-cholesta-7,22-diene-3β,5-diol and 3β-hydroxy-(22 <i>E</i> ,24 <i>R</i> )-ergosta-5,8,22-trien-7-one) (ferulic acid, syringaresinol and (22 <i>E</i> ,24 <i>R</i> )-24-methyl-6β-methoxy-5α-cholesta-7,22-diene-3β,5-diol)	Insulin-like activity in normal cells mediated by AMP-activated protein kinase. Exhibited an insulin sensitizing and/or insulin substitution function in insulin-resistant cells	[330]
<i>Luffa aegyptiaca</i> Mill.	Seed extract	Lactagogue activity	[331]
<b>Linaceae</b>			
<i>Linum usitatissimum</i> L.	Seeds extract	Reduces fasting blood sugar levels, total cholesterol, reduced the carbohydrate absorption from gut	[332]
<b>Chenopodiaceae</b>			
<i>Anabasis articulata</i> (Forssk) Moq.	Saponins	Decreased the glycaemia and greatest decrease of blood glucose	[333]
	Aerial parts	Increase in blood glucose and cortisol levels, blood hormone insulin concentration and α-fetoprotein, decrease blood tumor necrosis factor α (TNF-α), blood fructosamine, hemoglobin (Hb) and albumin levels	[334]
<i>Beta vulgaris</i> Linn	Leaves extract	Reduce blood glucose level by regeneration of β cells	[335]
<i>Spinacia oleracea</i> L.	Leaf extract	Decreased SGOT, SGPT	[336]
	Leaves extract	Reduction in fasting blood glucose levels	[337]
<i>Suaeda fruticosa</i>	Aerial part extract	Decrease in blood glucose levels, levels of plasma insulin unchanged	[338]
<b>Cupressaceae</b>			
<i>Juniperus phoenicea</i> L.	Leaves extract	α-amylase and pancreatic lipase inhibitory atocttaivl iptihes	[339]
<b>Symplocaceae</b>			
<i>Symplocos cochinchinensis</i> (Lour.) S. Moore.	Bark extract	Decrease in blood glucose and increase in plasma insulin and liver glycogen, decrease in serum TC, TG, LDL-C levels and increase in HDL-C, restored the altered plasma enzymes (SGOT, SGPT and ALP), total protein, urea and creatinine levels	[340]
	Bark extract	α-glucosidase inhibition, insulin dependent glucose uptake in L6 myotubes, pancreatic beta cell regeneration in RIN-m5F and reduced triglyceride accumulation in 3T3L1 cells, protection from hyperglycemia induced the generation of reactive oxygen species in HepG2 cells with moderate antiglycation and PTP-1B inhibition	[341]
<b>Portulacaceae</b>			
<i>Talinum portulacifolium</i> Forssk.	Leaves extract	The blood glucose, lipid profile and alondialdehyde decreased, liver glycogen and reduced glutathione increased, pancreas regeneration	[342]
<i>Talinum paniculatum</i>	Three quinolizidine alkaloids: Javaberine A, Javaberine A hexaacetate and Javaberine B hexaacetate	Inhibitors of TNF-α production by macrophages and fat cells	[83]
<i>Portulaca oleracea</i> L.	Seeds extract	Improve the blood glucose levels, serum triglyceride, serum cholesterol, liver glycogen, glycosylated haemoglobin and body weight	[295]
	Plant extract	Reduces the fasting blood glucose and increases the glycogen level in the liver, elevated serum glutamate oxaloacetate transaminase (SGOT), glutamate pyruvate transaminase (SGPT) and alkaline phosphatase (SALP) decreased, reduced glutathione (GSH) and catalase levels, the HDL/LDL ratio improved and cholesterol and triglycerides levels decreased. The pancreas showed regeneration	[343]
	Plant extract (polysaccharide)	Reduction in blood glucose	[344]
	Plant extract (Polysaccharide)	Decrease in the concentration of fasting blood glucose (FBG), total cholesterol (TC) and triglyceride (TG), increased the concentration of high-density lipoprotein cholesterol (HDLc) and serum insulin level	[345]
<b>Tiliaceae</b>			
<i>Triumfetta pilosa</i> Roth	Plant extract	Lowered the blood glucose levels, prevented alterations in kidney pathology	[346]
<b>Acoraceae</b>			
<i>Acorus calamus</i> L.	Rhizome extract	Plasma insulin, tissue glycogen, glucose- 6-phosphate dehydrogenase levels increased significantly and pancreas regeneration	[347]
<b>Labiatae</b>			
<i>Ocimum sanctum</i> Linn.	Leaves extract	Sustained oral hypoglycaemic activity	[348]
	Leaves extract	Drop in the fasting blood sugar, post prandial blood glucose level, drop in the glycosylated haemoglobin (HBA1c)	[349]
	Leaves extract	Increased the levels of superoxide dismutase, reduced glutathione and total thiols, reduction in peroxidised lipid levels	[350]
	Leaves extract, V.oil, phenol, aldehyde, fixed oil, alkaloid, tannin, ascorbic acid	Lowering blood sugar level	[351]
	Plant extract	Reduction absorption of glucose from gastrointestinal tract	[68]

<i>Ocimum tenuiflorum</i> L.	Leaves extract	Lowers blood glucose level, modulates cellular antioxidant defense system. Improves $\beta$ -cell function and enhances insulin secretion. Inhibits absorption of glucose from the intestine	[350]
<i>Ajuga iva</i> L. (Schreber)	14,15-dihydroajugapitin, Ecdysones and phytoecdysteroids. Iridoids, such as 8-O-acetylharpagide	The hyperglycaemia and preventing diabetic complications in liver, pancreas and kidneys. Acute and subchronic antihyperglycemic effects in normoglycemic	[352, 353]
	Plant extract	Decrease plasma glucose level	[354]
<i>Leucas lavandulaefolia</i>	Plant extract	Reduce blood glucose level	[355]
<i>Salvia miltiorrhiza</i>	Abietane-type diterpenoids: Danshenols A and B Dihydrotanshinone I, Tanshinone I Cryptotanshinone, Tanshinone IIA, (-)-Danshexinkun A	Aldose reductase inhibitory activity	[356]
<b>Geraniaceae</b>			
<i>Geranium graveolens</i> L.	Essential oils	Dual inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase	[56]
<b>Araliaceae</b>			
<i>Panax quinquefolius</i>	Berry extract (ginsenosides)	Improved the glucose tolerance and reduction in serum insulin levels, reduced plasma cholesterol levels, body weight changes	[357]
	Root extract	The glycogen and high density lipoprotein (HDL) contents increased, levels of plasma cholesterol and low density lipoprotein (LDL) concentration	[358]
<i>Panax ginseng</i> Mey	Root and plant extract (glycans, panaxans)	Lowering blood sugar level	[359]
	Woody root extract	Decreased serum levels of aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyl transpeptidase (GGT) enzymes, total cholesterol (TC), triglycerides (TG) and low density lipoproteins (LDL-c) and improved atherogenic index. Blood glucose and leptin hormone decreased and increased activities of superoxide dismutase (SOD), glutathione peroxidase (GPx) and catalase (CAT)	[360]
	Woody root extract (pioglitazone, repaglinide)	Stimulate and increase in insulin action and secretion, decrease in $\beta$ -cell mass	[361, 362, 363]
	Plant extract	Acting like insulin and increasing insulin secretion from beta cells of pancreas	[68]
<i>Hedera helix</i> L.	Leaf extract	Reduced the blood glucose level through extra-pancreatic actions by stimulated insulin release	[364]
	Leaves extract	Reduced the blood glucose level	[365]
<i>Aralia elata</i>	Plant extract	Inhibition of aldose reductase activity	[68]
<b>Ulmaceae</b>			
<i>Holoptelea integrifolia</i> (Roxb.)	Steroids & glycosides	Inhibiting ATP-sensitive potassium channels in pancreatic beta cells, cell membrane depolarization, which causes voltage-dependent calcium channels to open, which causes an increase in intracellular calcium in the beta cell, which stimulates insulin release	[366]
<b>Hypericaceae</b>			
<i>Hypericum perforatum</i> L.	Leaves extract	Reduction in plasma glucose level, serum total cholesterol, triglycerides, glucose-6-phosphatase levels. Tissue glycogen content, HDL-cholesterol, glucose-6-phosphate dehydrogenase increased	[367]
	Glibenclamide, glimepiride, glipizide, nateglinide, rosiglitazone, pioglitazone, repaglinide	CYP 1A2, 2C9, 2C19, 2D6 and 3A4; activator of the pregnane X receptor and improving beta-cell function and survival; inhibitors of adipogenesis of 3T3-L1 cells	[368, 369]
<b>Chrysobalanaceae</b>			
<i>Parinari excelsa</i>	Bark extract	Decrease of blood glucose	[370]
<b>Juglandaceae</b>			
<i>Juglans regia</i> L.	Leaves extract	FBS, HbA1c decreased and $\beta$ -cells number increased	[371]
	Leaves extract	Serum fasting HbA1C and blood glucose levels decreased and the insulin level increased	[372]
	Leaves extract	Decrease in blood glucose, glycosylated hemoglobin, LDL, triglyceride, and total cholesterol and increase in insulin and HDL level	[373]
<b>Phyllanthaceae</b>			
<i>Phyllanthus amarus</i>	Phyllanthin	Decline in blood glucose and significant recovery in body weight, reduction in the activities of glucose-6-phosphatase and fructose-1-6-disphosphatase in liver, increase in the activity of glucokinase in liver	[374]
	Plant extract	Reduction on the glucose level, no visible lesion seen in the liver, kidney and pancreas	[375]
	Plant extract (three pure pentacyclic triterpenoids, oleanolic acid, ursolic acid and lupeol)	$\alpha$ -amylase inhibition activity	[376]
	Plant extract	$\alpha$ -amylase inhibitory activity	[377]
<i>Phyllanthus emblica</i>	Fruit extract	Increases the residual sucrose content throughout the gut after sucrose ingestion, inhibition of intestinal disaccharidase enzyme activity, reduced intestinal glucose absorption	[378]

<b>Rosaceae</b>			
<i>Prunus amygdalus</i>	Seeds extra	Hypoglycemic activity	[379]
<i>Potentilla fulgens</i> L.	Root extract	Blood glucose reduced, glucose tolerance improved	[380]
<i>Sarcopoterium spinosum</i>	Plant extract	Inhibited lipolysis in 3T3-L1 adipocytes and induced glucose uptake in these cells in AML-12 hepatocytes and L6 myotubes. GSK3 beta phosphorylation induced in L6 myotubes, increased glycogen synthesis	[381]
	Plant extract	Inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase	[56]
	Plant extract	Reduced fasting blood glucose and improved insulin sensitivity and inhibited PTEN and activated PKB by a mechanism which is independent of ser473 and thr308 phosphorylation	[382]
<i>Alchemilla vulgaris</i> L.	Polyphenols, flavonoids, tannins, gallic acid.	Weight reduction in obese subjects, despite lack of antihyperglycemic activity	[383]
<i>Sarcopoterium spinosum</i> (L.) Spach. [Syn <i>Poterium spinosum</i> ]	Triterpenoids, $\alpha$ -tocopherol, proanthocyanidines	Hypoglycaemic effect viz. insulinotropic and insulin sensitizing. Starch blocker due to duality of inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase	[384, 56]
<i>Parinari excelsa</i> Sougue	Seed extract	Alanine aminotransferase (ALT), aspartate transaminase (AST), lipid peroxidation, triglycerides, cholesterol and glutathione did not change significantly, glucose and total protein levels reduced and presence of fatty cells in the liver	[385]
<i>Rosa canina</i> L.	Fruit extract	Hypoglycemic effect in normoglycemic plus glucose-hyperglycemic	[386]
<i>Agrimony eupatoria</i> L.	Leaves extract	Insulin releasing and insulin like activity	[387]
<i>Rubus fruticosus</i>		Decrease in the blood glucose levels, reduction of serum lipids and liver enzymes	[388]
<i>Prunus persica</i>	Leaves extract	Reduction in blood glucose	[389]
<b>Apocynaceae</b>			
<i>Gymnema sylvestre</i>	Gymnemic acid	Hypoglycemic activity of gymnemic acid is due to regeneration of islet cells, stimulation of insulin release, increase glucose uptake by cells, inhibition of glucose absorption and suppression of gluconeogenic enzymes and sorbitol dehydrogenase	[390]
<i>Catharanthus roseus</i> G.Don	Leaves, twigs and flower extracts, indole alkaloid, vincristine, vinblastin	Increase metabolisation of glucose	[391]
	Leaves extract (vincristine, vinblastine)	$\beta$ -cell rejuvenation, regeneration and stimulation	[392]
<i>Cryptolepis sanguinolenta</i>	Cryptolepine, an indoloquinoline alkaloid	Decrease in glucose transport and absorption, reductions in plasma glucose, total cholesterol, triglyceride and LDL cholesterol, increased sizes of $\beta$ cells of the pancreas	[393]
<i>Nerium oleander</i> L.	Leaves extract	Induce post prandial hyperglycemia by acting as $\alpha$ -glucosidase inhibitors	[394]
<i>Rauwolfia serpentina</i>	Leaves, root extract	Decrease in glucose level	[395]
<i>Calotropis gigantea</i>	Seeds extract	Decrease the blood glucose levels	[396]
<b>Poaceae</b>			
<i>Zea mays</i> L.	Feruloylated oligosaccharide. Flavone C-glycosides and sesquiterpenes. Phenolics (proto-catechuic acid mainly). Hydroxycinnamic acids. Anthocyanins (liviert 3-glucoside and liviert-3-(6"-Qmalonylglucoside)	<i>In vitro</i> inhibition of glycation. Suppressed the progression of diabetic glomerular sclerosis. Decreasing blood glucose and protective action on the kidney and pancreas injury. Inhibition of hyperglycaemia-relevant $\alpha$ -glucosidase. Antidiabetic activity due to PPAR activation. Possible renoprotective role in diabetic nephropathy	[397, 398, 399, 400, 401]
<i>Cynodon dactylon</i>	Plant extract	Decline in blood glucose, cholesterol and triglycerides, elevated plasma cholesterol and urea level	[402]
<b>Polygonaceae</b>			
<i>Rheum ribes</i> Linn.	Tannins and hydroxyanthracene derivatives (rhein, physcion, aloe-emodin, chrysophanol, physcion-8-O-glucoside, aloe-emodin-8-O-glucoside, sennoside A, rhaponticin), minerals, phenolics (pyrocatechol) and flavonoids (quercetin equivalents).	Insulin releasing effects and hypoglycemic activity, inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase	[403, 404, 56]
<i>Antigonon leptopus</i> Hook & Arn.	Aerial parts extract	Fall in fasting blood glucose levels	[405]
	Leaves extract	Reduced the fasting blood glucose level	[406]
	Aerial parts, leaves, flower, stem bark	Inhibit the cholesterol synthesis pathway and increased HDL/LDL ratio due to activation of LDL receptors in hepatocyte, responsible for taken up LDL into the liver and reduced the LDL level of serum. Changes in body weight, serum insulin, aspartate transaminase, alanine transaminase, serum triglycerides, serum cholesterol and total serum proteins	[407]
<i>Rumex maritimus</i>	Aerial plants	Decrease in blood glucose levels	[408]
<b>Rhamnaceae</b>			
<i>Zizyphus spina-christi</i> (L.) Desf.	Saponin glycosides, flavonoids. essential oil, amino acid, carbohydrate and lipid composition	Insulinotropic hypoglycaemic effects in diabetic rats	[409, 410]



<i>Zizyphus sativa</i> Gaertn	Leaves extract, tannin	Dose dependent reduction in blood glucose level	[411]
<b>Lythraceae</b>			
<i>Punica granatum</i>	Leaves extract	Increase in glycogen content in the liver, cardiac and skeletal muscle; it significantly reduced intestinal glucose absorption, blood glucose and serum lipids [Total Cholesterol (TC), Triglycerides (TG), Low Density Lipoproteins (LDL) and High Density Lipoproteins (HDL)]	[412]
	Fruit rinds extract	Maintaining the blood glucose levels within the normal limits, biochemical findings histopathology of MEPEG, VAD	[413]
	Husk extract	Increase in the concentration of glucose, triglycerides, cholesterol, LDL cholesterol, VLDL cholesterol and a decrease in the level of HDL cholesterol and hemoglobin content	[414]
<i>Lagerstroemia speciosa</i> (L.) Pers.	Leaf powder or decoction	Reduced blood and urinary glucose levels	[415]
	Corosolic acid (Glucosol™)	Glucose transport-stimulating activity	[416]
<i>Trapa natans</i> L.	Fruit peel extract	Improved oral glucose tolerance, exhibited hypoglycaemic effect	[417]
	Fruit peel extract	Reducing and normalizing the elevated fasting blood glucose levels	[418]
<i>Sonneratia alba</i>	Leaves extract	Reduced significantly the sugar	[419]
<i>Lythrum salicaria</i>	Plant extract	Reduction of lactic dehydrogenase and $\gamma$ -glutamyl transpeptidase	[68]
<b>Melastomataceae</b>			
<i>Memecylon umbellatum</i> Burm	Leaf extract	Lower serum glucose	[420]
	Leaves extract	Inhibition of glucose	[421]
<b>Brassicaceae</b>			
<i>Brassica juncea</i> L.	Seed extract	Serum insulin levels were depletion	[422]
<i>Brassica nigra</i>	Seeds extract	Fasting serum glucose reduced, increase in glycosylated hemoglobin and serum lipids	[423]
<i>Lepidium sativum</i> L.	Seed extract	Decrease in blood glucose levels, no changes in basal plasma insulin concentrations	[424]
	Seed total alkaloid	Suppressed blood glucose, cholesterol, triglyceride and urea level, potentiation of pancreatic secretion of insulin from the remaining islet $\beta$ -cells	[425]
<b>Mimosaceae</b>			
<i>Mimosa pudica</i> L.	Leaves extract	Blood glucose level reduced, body weight increased	[426]
	Leaves extract	Reduction in the elevated serum glucose level, hepatic and renal enzymes reduced	[427]
<i>Albizia odoratissima</i> Benth.	Bark extract	reduced the blood sugar and serum cholesterol level, triglycerides, serum glutamic-oxaloacetic transaminase, serum glutamic-pyruvic transaminase, alkaline phosphatase and decrease level of total proteins	[177]
	Bark extract	reduction in Blood Glucose Level	[68]
<b>Burseraceae</b>			
<i>Commiphora africana</i> (A.Rich.) Engl.	Stem bark extract (alkaloids, tannins, flavonoids, steroids and saponins)	decrease in the blood glucose levels	[177]
<b>Sapotaceae</b>			
<i>Mimusops elengi</i> L.	Leaf extract	increases the serum glucose level	[428]
	Bark extract	Blood glucose, serum insulin, glycosylated haemoglobin and liver glycogen, glucokinase, glucose-6-phosphatase and glucose-6-phosphate dehydrogenase	[429]
	Leaves extract	Carbohydrate metabolic enzymes such as glucokinase, glucose-6-phosphate dehydrogenase and glycogen content in liver and kidney and gluconeogenic enzymes such as glucose-6-phosphatase, fructose 2,6 bis-phosphatase levels increased	[430]
<i>Madhuca indica</i> J. F. Gmel.	Bark extract	HDL-c increased, GLB reduction, inhibited the $\alpha$ -amylase	[431]
<i>Mimusops elengi</i> L.	Flower extract	Decreased serum glucose level	[432]
<i>Madhuca longifolia</i>	Bark extract	Increased glucose uptake at the tissue level and/or an increase in pancreatic $\beta$ -cell function, or due to inhibition of intestinal glucose absorption	[433]
<b>Ranunculaceae</b>			
<i>Nigella sativa</i> L.	Essential oils, proteins, alkaloids & saponins	Increased insulinemia and HDL-cholesterol, decreased OGTT (Oral Glucose Tolerance Test) and tended to decrease liver and muscle triglyceride content, stimulated muscle and liver ACC phosphorylation and increased muscle Glut4	[434]
<i>Aconitum carmichaelii</i>	Aconitine	Improvement in peripheral glucose uptake is due to activation of opioid $\mu$ receptors of peripheral tissues, lowering plasma glucose levels	[435]
<i>Coptis japonica</i>	Roor extract, Five isoquinoline alkaloids, Berberine chloride Berberine sulfate, Berberine iodide Palmatine sulfate, Palmatine chloride	Aldose reductase inhibitor	[436]
<i>Paeonia lactiflora</i>	Tetra- and penta-O-galloyl- $\beta$ -D-glucose	Potent aldose reductase inhibitory activities	[81]
<b>Moringaceae</b>			

<i>Moringa oleifera</i> Lam.	Root extract	Increased lipid peroxide, increased IL-6 and decreased antioxidant enzyme in the serum and kidney tissue homogenate compared with that of the negative control group. Immunoglobulins (IgA, IgG), fasting blood sugar and glycosylated hemoglobin increased. Albumin decreased and liver enzymes and $\alpha$ -amylase were not affected. The renal functions and potassium and sodium levels in G2 increased. Urine analysis showed glucosuria and increased potassium, sodium, creatinine, uric acid and albumin levels. Kidney and pancreas tissues showed pathological alterations	[437]
	Pods extract	Reduction in serum glucose and nitric oxide, with increases in serum insulin and protein levels, degenerative changes in $\beta$ -cells	[438]
<b>Myricaceae</b>			
<i>Myrcia uniflora</i> Barb. Rodr.	Leaf extract	Reduced the hyperglycemia, polyphagia, polydipsia, urine volume and the urinary excretion of glucose and urea, no effect on the weight of epididymal and retroperitoneal adipose tissue, or on the concentrations of pancreatic and serum insulin	[439]
<i>Myrcia bella</i>	Leaves extract	Reduced the fasting blood glucose, water and food intake and increased hepatic glycogen. Total cholesterol and triglycerides were reduced, increased the expression of IRS-1, PI3-K and AKT in the livers	[440]
<b>Euphorbiaceae</b>			
<i>Ricinus communis</i>	Leaves extract	The decreased cholesterol, HDL, LDL, triglyceride and insulin, increased SGOT, SGPT, ALP, ACP and glucose	[441]
	Root extract	Difference in alkaline phosphatase, serum bilirubin, creatinine, serum glutamate oxaloacetate transaminase, serum glutamate pyruvate transaminase	[442]
<i>Embellica officinalis</i> Gaertn	Fruits extracts, Vit.C, tannin	Reduce 5-hydroxymethylfurfural, creatinine albumin level	[443]
<i>Phyllanthus amarus</i>	Plant extract (alkaloids)	Decrease blood glucose level	[444]
<i>Beyeria leshnaultii</i>	Plant extract	Reduced lipid accumulation in differentiated adipocytes	[35]
<i>Euphorbia drumondii</i>	Plant extract	Reduced lipid accumulation in differentiated adipocytes	[35]
<i>Euphorbia hirta</i>	Plant extract (phenols, flavonoids, terpenoids, tannins, saponins and proteins)	$\alpha$ -amylase inhibition	[445]
<i>Mallotus repandus</i>	Stem extract	-amylase inhibitory activity and reduced FBG level	[446]
<b>Celastraceae</b>			
<i>Salacia oblonga</i> Wall	Root bark	Thiobarbituric acid reactive substances, conjugated dienes, hydroperoxides. The activity of antioxidant enzymes such as superoxide dismutase, catalase, GSHPxase and GSSGRase increased	[447]
	Root extract	Inhibition of $\alpha$ -glucosidase activity	[447]
	Plant extract	Serum insulin was increased, plasma HbA1c decreased. The serum Triacyl Glycerol (TG) levels decreased and increase in HDL-cholesterol	[448]
<i>Salacia reticulata</i> Wight	Stem and root extract	Inhibition of $\alpha$ -glucosidase activity	[449, 450]
<i>Salacia chinensis</i>	3, 22 -Dihydroxyolean-12-en-29-oic acid, Tingenone, Tingenine B, Regeol A, Triptocalline A, Mangiferin	Aldose reductase inhibitory activity	[451]
<b>Gentianaceae</b>			
<i>Swertia punicea</i>	Methyl swertianin and bellidifolin	Improved the oral glucose tolerance and lowered fasting serum insulin (FINS), lower serum total cholesterol (TC), low density lipoprotein cholesterol (LDL) and triglyceride (TG) levels and increased relative high density lipoprotein cholesterol (HDL) concentrations (HDL/TC), improve insulin resistance by enhancing insulin signaling, expression levels of insulin-receptor alpha subunit (InsR-alpha), insulin-receptor substrate-1 (IRS-1) and phosphatidylinositol 3-kinase (PI3K), increased hepatic glycogen content, decreased glucokinase (GK) and increased glucose-6-phosphatase (G6Pase) activities	[452]
<i>Swertia bimaculata</i>	Plant extracts with corymbiferin	Fasting blood glucose levels decreased, serum insulin levels increased. The oral glucose tolerance was improved. The lowered serum total cholesterol, low density lipoprotein (LDL) and triglyceride levels and increased ratio of HDL (high density lipoprotein)/LDL observed. The insulin sensitivity improved on the basis of increased expressions of insulin-receptor substrate-2, phosphatidylinositol 3-kinase and Ser/Thr kinase AKT2	[453]
<i>Swertia kouitchensis</i>	Plant extract	Inhibit the activity of $\alpha$ -amylase and $\alpha$ -glucosidase and stimulate insulin secretion	[454]
<i>Enicostemma littorale</i> Blume	Plant extract, Swertiamarine glycoside	Decrease glycosylated Hb and glucose 6 phosphatase	[455, 456, 457]
<i>Gentiana oliveri</i> Griseb.	Flower extract, Iso-orientin C-glycoside	Lowers plasma glucose level	[458]
<i>Anthocleista vogelii</i>	Plant extract (stem bark)	Maximum reduction in Fasting Blood Glucose	[459]
<b>Caesalpinaceae</b>			
<i>Caesalpinia digyna</i>	Root extract	Decrease the post prandial increase of blood glucose, $\alpha$ -glucosidase, $\alpha$ -amylase inhibition	[460]

<i>Cassia auriculata</i>	Flower extract	Increase utilization of glucose through increase glycolysis	[461]
	Flower extract (mixed catechins, caffeine and quercetin)	Inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase activities, SOD, CAT and GPx activities increased	[462]
	Bark extract	Elevation in the levels of fasting blood glucose, glycosylated hemoglobin (HbA1c), serum insulin, C-peptide and liver enzyme	[463]
<i>Cassia fistula</i>	Leaves extract	Hypoglycemic activity decreases blood glucose level	[464]
<i>Cassia occidentalis</i>	Plant extract	Differences observed in serum lipid profiles (cholesterol and triglyceride), serum protein, and changes in body weight	[465]
<b>Menispermaceae</b>			
<i>Tinospora cardifolia</i> Willd.	Tinosporone, tinosporic acid, Columbin, Tinosporaside, Cordifolioside A	Decreased blood glucose by level and increased glucose tolerance is correlated with regeneration of beta cells of islets of langerhans	[466]
	Root extract, Berberine, starch	Decrease blood glucose and brain lipid	[467]
	Stem extract	Decreases blood glucose level through glucose metabolism, inhibitory effect on adrenaline-induced hyperglycemia	[468]
	Plant extract	Regeneration of $\beta$ -cells of the islets of Langerhans	[68]
<i>Tinospora crispa</i> Linn.	Stem extract	Anti-hyperglycemic, stimulates insulin release from islets	[469]
<i>Coscinium fenestratum</i> Calebr	Stem extract, berberine, glycoside, saponin	Increase enzymatic antioxidants	[470]
<b>Myrtaceae</b>			
<i>Eugenia jambolana</i> Lam.	Seed, fruit, leaves, kernel	Lowers plasma glucose level	[471, 472]
	Plant extract	Increasing insulin secretion from $\beta$ -cells of pancreas	[68]
<i>Eucalyptus globulus</i> Labill	Leaves extract, Essential oil, cineol	Increase insulin secretion from clonal pancreatic beta line (BRIN-BD 11)	[387]
<i>Myrtus communis</i> L.	Leaves extract, V.oil mirtii oleum	Lower blood glucose level	[473]
<i>Syzygium cumini</i> Linn	Seed extract	Decrease blood glucose level	[474]
<i>Syzygium malaccense</i>	Casuarine 6-O- $\alpha$ -glucoside	$\alpha$ -Glucosidase inhibitor	[83]
<i>Psidium guajava</i>	Plant extract	Decreased blood glucose levels	[475]
	Leaves extract	Inhibited the $\alpha$ -glucosidase and $\alpha$ -amylase enzymes	[476]
<i>Myrcia multiflora</i>	Myrciacitrin I, II, III, IV and V	Aldose reductase inhibitory activity	[477]
<b>Malvaceae</b>			
<i>Grewia asiatica</i> L	cyanidin 3- glucoside	Hypoglycemic effect is mainly result of improving glucose utilization by cells	[478]
	Plant extract	Increasing glucose utilization	[80]
<i>Hibiscus rosa sinensis</i> Linn.	Plant extract	Stimulate insulin secretion from $\beta$ -cells	[479]
<i>Anoda cristata</i>	Plant extract, acacetin and diosmeti	$\alpha$ -glucosidases inhibitors, insulin secretagogues, glucose entrapment	[480]
<i>Althaea rosea</i> (Linn.) Cavan	Flower extract (three new dihydroflavonol glycosides, named as roseaflavanonoliosides A (1), B (2) and C (3))	Decrease serum triglyceride and glucose levels, gene expressions on AMPK, IRS2, PI3K, AKT and GLUT4 in liver up-regulated. Hepatic cell glucose uptake using 2-NBDG as a glucose uptake indicator, the glucose uptake increasing level	[481]
<i>Abelmoschus esculentus</i>	Plant extract	Abnormal expression of genes (carboxylesterase 2, stearyl-Coenzyme A desaturase 1, insulin-like growth factor 1 and insulin-like growth factor binding protein 2 binding protein)	[482]
<b>Campanulaceae</b>			
<i>Lobelia chinensis</i>	Two new pyrrolidine alkaloids : radicamines A and B	$\alpha$ -glucosidase inhibitor	[483]
<b>Lamiaceae</b>			
<i>Marrubium vulgare</i>	Marrubiin	Promotes insulin release from $\beta$ -cells of islets of langerhans or and inhibit process of insulin breakdown	[484]
<i>Origanum majorana</i>	6-Hydroxyapigenin, 6-Hydroxyapigenin-7-O- $\beta$ -D-glucopyranoside, 6-Hydroxyluteolin-7-O- $\beta$ -D-glucopyranoside	$\alpha$ -glucosidase inhibitor	[485]
	6-Hydroxyapigenin-7-O-(6-O-feruloyl)- $\beta$ -D-glucopyranoside, 6-Hydroxyluteolin-7-O-(6-O-feruloyl)- $\beta$ -Dglucopyranoside		
<i>Hyssopus officinalis</i>	(7S,8S)-Syringoylglycerol 9-O- $\beta$ -D-glucopyranoside (7S,8S)-Syringoylglycerol-9-O-(6'-O-cinnamoyl)- $\beta$ -Dglucopyranoside	$\alpha$ -glucosidase inhibitor	[83]

<i>Otostegia persica</i>	Root extract	Decreased serum glucose and HDL levels	[486]
	Root extract	Decreased serum glucose	[487]
<b>Fabaceae</b>			
<i>Trigonella foenum</i>	Seed extract	Tremendous increase in the glucose content of blood, liver and pancreas, increase in hyperglycemia	[488]
	Seed extract	Decreased blood glucose, serum cholesterol, SGOT (serum glutamate oxaloacetate transaminase) and SGPT (serum glutamate pyruvate transaminase) levels	[489]
<i>Trigonella foenum graecum</i>	Trigonelline (1-methylpyridinium-3-carboxylate) 4-hydroxyisoleucine (2-amino-4-hydroxy-3-methylpentanoic acid), sotolon, vicine, withaferin-A	Diminishes the carbohydrate metabolism by inhibiting intestinal enzyme $\alpha$ -amylase. It stimulates glucose dependant insulin secretion from pancreatic beta cells to induce hypoglycemia.	[490]
	Seed extract	Decreases s post prandial blood glucose level	[491]
<i>Pterocarpus marsupium</i>	Plant extract	Protective effect by correcting glycosylated hemoglobin (HbA1c), serum protein, insulin, alkaline and acid phosphatase (ALP and ACP) and albumin levels, protein and glycogen altered towards normal	[492]
	Woof-bark extract	Blood glucose, plasma insulin, glycosylated haemoglobin, serum lipid profile [total cholesterol, triglycerides, low density lipoprotein - cholesterol (LDL-C), very low density lipoprotein - cholesterol (VLDL-C) and high density lipoprotein-cholesterol(HDL-C)] serum protein, albumin, globulin, A/G ratio, serum enzymes [Serum glutamate pyruvate transaminases (SGPT), serum glutamate oxaloacetate transaminases (SGOT) and alkaline phosphatase (ALP)], antioxidant enzymes lipoprotein peroxidation (LPO), reduced glutathione (GSH), glutathione peroxidase (GPx), glutathione reductase (GR), erythrocytes (catalase (CAT) and superoxide dismutase (SOD)	[493]
	(-)-Epicatechin (flavonoid)	Anti-hyperglycemia and insulinogenic activity	[494]
	Marsupsin and pterostilbene (phenolic constituents)	Anti-hyperglycemic activity	[495]
	Plant extract	Increasing insulin secretion from $\beta$ -cells of pancreas	[82]
<i>Lupinus albus</i> Linn.	Seed extract, alkaloid, fatty oil, asparagines	Lower serum glucose level	[496]
<i>Lupinus perennis</i>	Three quinolizidine alkaloids: Lupanine, 13- $\alpha$ -Hydroxylupanine, 17-Oxo-lupanine	Glucose-induced insulin release enhancement from isolated rat islet cells was dependent on the glucose concentration	[497]
<i>Securigera securidaca</i>	Seeds extract	Exhibited hypoglycemic and hypolipidemic activities, reduced the levels of serum glucose, total cholesterol, and LDL-cholesterol and increased the level of HDL-cholesterol	[498]
<i>Acacia tetragonophylla</i>	Plant extract	Reduced lipid accumulation in differentiated adipocytes.	[35]
<i>Pterocarpus marsupium</i>	Plant extract	Reduced lipid accumulation in differentiated adipocytes.	[35]
<i>Acacia catechu</i>	Plant extract	Reduction of blood glucose level	[499]
<i>Bauhinia forficata</i>	Plant extract	Reductions in plasma glucose, triglycerides, total cholesterol and HDL-cholesterol, levels of LDL not altered	[77]
	Decoction	Reduction in serum and urinary glucose and urinary urea	[79]
<i>Clitoria ternatea</i>	Leaves and flower extract	Enzymatic glycation, glucose uptake by yeast cells and $\alpha$ -amylase inhibition	[500]
<i>Cajanus cajan</i>	Root extract	Decrease in fasting serum glucose and blood glucose level	[82]
<i>Tamarindus indica</i>	Seeds extract	Decrease in fasting serum glucose and blood glucose level	[501]
<i>Medicago sativa</i>	Plant extract	Increasing insulin secretion from $\beta$ -cells of pancreas	[82]
<i>Cyamopsis tetragonoloba</i>	Plant extract	Reduction absorption of glucose from gastrointestinal tract	[82]
<b>Papilionaceae</b>			
<i>Phaseolus vulgaris</i>	Pod, seed and plant extract	Hypoglycemic, hypolipidemic, inhibit $\alpha$ -amylase activity	[502]
<b>Bombacaceae</b>			
<i>Ceiba pentandra</i> (L) Gaertner	Root bark extract	Reduced the intake of both food and water, levels of blood glucose, serum cholesterol, triglyceride, creatinine and urea, improves impaired glucose tolerance, no effect in the level of hepatic glycogen. lowering blood glucose, reducing serum cholesterol and triglyceride concentrations	[503]
	Bark extract	Decreased blood glucose level, total cholesterol and triglycerides level, prevented degeneration of liver and pancreas, and increased serum insulin level and liver glycogen content	[504]
	Root bark extract	Lowering blood glucose, serum cholesterol and triglyceride concentrations	[505]
<i>Adansonia digitata</i> L.	Stem bark extract (tannins, carbohydrates, terpenes, saponins, flavonoids & alkaloids)	Reduction in the blood glucose levels	[506]
	Fruit pulp extract (glycosides, flavonoids, tannins, saponins, terpenoids and steroids)	Reduction of serum glucose	[507]

<b>Hypodoxiaceae</b>			
<i>Curculigo orchoides</i>	Plant extract	Enhanced glucose uptake and reduced lipid accumulation in differentiated adipocytes	[35]
	Root tubers	Hypoglycemic activity	[508]
<b>Solanaceae</b>			
<i>Withania somnifera</i> Dunal	Root and leaves extract (flavonoids)	Levels of urine sugar, blood glucose, HbA1C, G6P, AST, ALT, ACP, ALP, serum lipids except high density lipoprotein-bound cholesterol (HDL-c) and tissues of liver, kidney and heart lipids increased, Hb, total protein, albumin, albumin:globulin (A:G) ratio, tissues protein and glycogen decreased	[509]
	Root and leaves extract	Levels of blood glucose, AST, ALT, ALP, LDH, serum lipids except high density lipoprotein-bound cholesterol (HDL-c) increased, but total protein albumin, albumin: globulin (A : G) ratio,	[510]
	Root extract, withanine, somnine, withaferine, withanolides	Decrease blood sugar level, increase in urine sodium, urine volume, decrease in serum cholesterol, triglycerides, LDL (low density lipoproteins) and VLDL (very low density lipoproteins) cholesterol	[510]
<i>Solanum nigrum</i> L.	Alkaloids, flavonoids, phenolics & micronutrients	Restore the function of pancreatic tissues by causing an increase in insulin output or inhibit the intestinal absorption of glucose or facilitation of metabolites in insulin-dependent process, effect on protecting $\beta$ -cells and smoothing out fluctuation in glucose levels	[511]
	Leaves extract	Changes in body weight, consumption of food and water, volume of urine and levels of glucose	[512]
<i>Capsicum frutescens</i> Linn.	Plant extract, capsaicin, pritein	Increase insulin secretion and reduction of insulin binding on the insulin receptor	[513]
<i>Lycium shawii</i> Roem and Schult	Aerial part extract	All morphological, biochemical, haematological and spermatogenic changes, in mortality, body weight changes and any change in vital organs	[514]
<i>Capsicum annum</i>	Capsaicin	Insulin producing cells are protected from autoreactive T cells, binding of capsaicin to the VR1 receptors activates pancreatic macrophages	[515]
<i>Solanum trilobatum</i> L.	Leaf extract	Changes in body weight, serum lipid profiles and liver glycogen levels	[516]
<i>Datura stramonium</i>	Leaves extract	$\alpha$ -amylase enzyme inhibitory activity	[517]
<i>Sonneratia alba</i> Sm.	Leaf extract	Reduced blood sugar level	[518]
<i>Sonneratia caseolaris</i>	Plant extract	Reducing glucose blood	[519]
<i>Lycium barbarum</i>	Glibenclamide, glimepiride, glipizide, nateglinide, rosiglitazone	Improve glucose transport, CYP2C9 inhibitor and GLUT4 trafficking and intracellular insulin signaling	[520, 521]
<b>Caricaceae</b>			
<i>Carica papaya</i> L.	Seed extract	Decreased blood glucose and cholesterol, triacylglycerol and amino-transferases blood levels, prevented hepatocyte disruption, accumulation of glycogen and lipids	[522]
	Seed extracts	Decreased blood glucose levels, Serum Glutamate Oxaloacetate Transaminase (SGOT), Serum Glutamate Pyruvate Transaminase (SGPT) levels and lipid profiles decreased	[523]
<b>Apiaceae</b>			
<i>Carum carvi</i> L.	Seeds extract	Decreased serum glucose	[524]
<i>Eryngium carlinae</i>	Plant extract	Reduced the levels of creatinine, uric acid, total cholesterol and triglycerides	[525]
	Centellasaponin A	Aldose reductase inhibitory activity	[83]
<i>Centella asiatica</i>	Plant extract	Inhibition of $\alpha$ -glucosidase activity, decreased plasma glucose, triglyceride and total cholesterol levels	[526]
<b>Elaegnaceae</b>			
<i>Hippophae rhamnoides</i> L.	Seed extract	Lowered the serum glucose, triglyceride and nitric oxide, increased serum superoxide dismutase activity and glutathione levels	[527]
	Seeds extract	Increase of blood glucose, TBARS (thiobarbituric acid reactive substances) level, reduction in GSH (tissue glutathione) content	[528]
<b>Irvingiaceae</b>			
<i>Irvingia gabonensis</i> (Aubry-Lecomte) Baill.	Seed extract	Fall in glucose level, lowered serum TG level	[529]
	Seed extract	Decreased the elevated serum total cholesterol, triglycerides and LDL-cholesterol levels atherogenic index increasing HDL-cholesterol	[530]
<b>Umbelliferae</b>			
<i>Ferula persica</i> Wild.	Plant extract	$\alpha$ -amylase inhibitory activity	[103]
<i>Carum carvi</i> Linn.	Fruits extract, oil, resin, carvone, fixed oil	Decrease in blood glucose level, alleviated their body weight loss, decrease in total cholesterol and low-density lipoprotein cholesterol levels, no change in triglyceride and high density lipoprotein cholesterol levels	[531]
<b>Urticaceae</b>			
<i>Urtica dioica</i> L.	Polyphenolics, Flavonoids, Essential oil, Lignan glucosides, Carotenoids.	$\alpha$ -amylase and $\alpha$ -glucosidase inhibitory activity, reduction of intestinal glucose absorption and enhancement of insulin secretion by Langerhans Isletes, protective activities of $\beta$ -cells of Langerhans, Proliferation of the $\beta$ -cells, enhanced glucose uptake in L6-GLUT4myc myoblast cells, enhancing glucose utilization and plausible activation of the human peroxisome proliferator-activated receptor in glucose homeostasis. Protective effect on hepatocytes, neuro-protective effect	[532-537]



<i>Laportea ovalifolia</i> Scham and Thonn.	Aerial part extract	Lowering of serum total cholesterol, triglycerides, LDL cholesterol, TC/HDL-C and increase in HDL cholesterol	[538]
<i>Urtica parviflora</i>	Leaves extract	Effect on intestinal glucose absorption	[539]
<i>Urtica dioica</i> Linn	Leaves extract	Increase insulin secretion	[540]
	Leaves extract	Increase in FIRI, blood glucose and insulin, decrease in leptin and no change in TG, HDL, LDL, LDL/HDL ratio, VLDL, ALT and ALP, decreased serum glucose, insulin, LDL and leptin and LDL/HDL ratio and FIRI, increased serum TG, VLDL and AST	[541]
<b>Salvadoraceae</b>			
<i>Salvadora oleoides</i> Decne	Aerial part extract	Reduction in blood glucose and beneficial effects on the lipid profile	[542]
<i>Salvadora persica</i>	Plant extract	Decreased the blood glucose, total cholesterol (TC), triglycerides (TG), LDL, VLDL and elevation of HDL, accelerated the regeneration of $\beta$ -cells	[543]
	Plant extract	Reduction in blood glucose and effect on lipid profile	[544]
<i>Salvadora lavandulifolia</i>		Blood glucose, total cholesterol (TC), triglycerides (TG), LDL, VLDL and elevation of HDL, regeneration of $\beta$ -cells of pancreas	[543]
<b>Zingiberaceae</b>			
<i>Zingiber officinale</i>	Sesquiterpene ( $\beta$ -Sesquiphellandrene)	Improving insulin sensitivity and reduces fasting blood glucose and improves serum insulin level	[545]
	Rhizome extract, Sesquiterpene	Increase insulin level and decrease fasting glucose level	[546]
	Rhizome extract	Lowers plasma glucose level	[547]
	Plant extract	Increasing glucose utilization	[278]
<i>Aframomum melegueta</i> (Rosc) K.	Leaf extract	Increase in alkaline phosphatase with no signs of steatosis or cirrhosis and decrease in blood glucose	[548]
<i>Alpinia galanga</i>	Leaves extract	Serum glucose, serum triglyceride level decreased, inhibition of $\alpha$ -glucosidase	[549]
<i>Costus pictus</i>	Leaves and callus extract	$\alpha$ -amylase and $\alpha$ -glucosidase inhibitory activity	[550]
<i>Curcuma aromatica</i>	Rhizome extract	Serum glucose glyceride level decreased, total protein increased	[551]
<i>Alpinia calcarata</i>	Rhizome extract	Inhibition of $\alpha$ -glucosidase activity and enhanced the glucose uptake in hemidiaphragm	[552]
<b>Chenopodiaceae</b>			
<i>Suaeda fruticosa</i>	Aerial parts	Decrease in blood glucose levels, plasma cholesterol	[553]
<i>Anabasis articulata</i> (Forssk) Moq.	Leaves extract	Decrease of blood glucose	[554]
	Leaves extract	Increases the blood hormone insulin concentration and $\alpha$ -fetoprotein, decrease blood tumor necrosis factor $\alpha$ (TNF- $\alpha$ ) and blood fructosamine	[333]
<i>Spinacia oleracea</i> L.	Plant extract	Decreased SGOT and SGPT	[335]
	Plant extract	Reduction in fasting blood glucose levels	[337]
<b>Bombacaceae</b>			
<i>Adansonia digitata</i> L.	Aerial parts (glycosides, flavonoids, tannins, saponins, terpenoids and steroids)	Reduction of serum glucose	[505]
	Stem bark extract	Reduction in the blood glucose levels	[505]
<b>Zygophyllaceae</b>			
<i>Peganum harmala</i> Linn.	Flavonoid glycosides and major $\beta$ -carboline alkaloids (harmaline, harmine, harmalol, harmol and tetrahydroharmine).	Antidiabetic activity in C57BL/KsJ-db/db	[555]
<i>Tribulus terrestris</i> Linn.	Saponin and harmine	Decrease serum glucose	[556]
<i>Zygophyllum gaetulum</i>	Aerial part extract	Reduction in blood glucose concentration	[557]
<i>Zygophyllum geslini</i>	Aerial part extract	Decrease in blood sugar	[558]
<b>Alangiaceae</b>			
<i>Alangium lamarkii</i> Thw.	Leaves extract	Decreased the blood plasma glucose level, restored the lipid profile and improvement in liver glycogen, body weight	[559]
<b>Punicaceae</b>			
<i>Punica granatum</i> Linn	Seed extract, Vit.C, protein, tannin, gallic acid, pelletierine	Reduce blood sugar level	[560]
<b>Loranthaceae</b>			
<i>Viscum album</i> Linn.	Plant extract	$\alpha$ -glucosidase inhibitor	[561]
<i>Loranthus micranthus</i>	Leaves extract	Inhibition of $\alpha$ -amylase, $\alpha$ -glucosidase, sucrase and glucose	[562]
<b>Agavaceae</b>			
<i>Sansevieria roxburghiana</i>	Leaves extract	Normalized blood glucose levels, serum biochemical parameters; decreased lipid peroxidation and recovered GSH and CAT	[563]
<i>Sansevieria trifasciata</i>	Leaves and rhizomes extract	Decrease of fasting blood glucose level	[564]
<b>Achariaceae</b>			
<i>Hydnocarpus wightiana</i>	Seed extract	Blood glucose levels decreased	[40]
<b>Combretaceae</b>			

<i>Terminalia bellerica</i>	Bark extract	Inhibition of $\alpha$ -amylase and $\alpha$ -glucosidase activity	[565]
<b>Actinidaceae</b>			
<i>Actinidia kolomikta</i>	Root extract	$\alpha$ -glucosidase inhibitory activity in the small intestine	[566]
<b>Dilleniaceae</b>			
<i>Tetracera indica</i>	Leaves extract	Reduce triglyceride accumulation on 3T3-L1 cells, 2-deoxy-D-[3H] glucose uptake activity increased	[567]

**Table 6:** Details of plants and phytochemicals having antidiabetic activity and their mechanism of action.

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