- Review paper

# A Review on Anti-diabetic Plants

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**ABSTRACT**: Diabetes mellitus is a common metabolic disorder whose prevalence is rapidly increasing all over the world. According to WHO, diabetes will be the seventh leading cause of death in 2030. Since long back, plants have been used to heal or combat illness and are the source of many modern medicines. In view of the above aspects, the present review provides information about the antidiabetic plants, available through literature source from various database. From the present study it is evident that most of the plants having anti-diabetic properties belong to the family Moraceae, Cucurbitaceae, Liliaceae, Anacardiaceae, Myrtaceae, Fabaceae, Solanaceae, Asteraceae and many others. The hypoglycemic activities are contained in different parts of these plants like leaf, rhizomes, fruits, bark, seeds or other parts which differ from species to species. It is also evident from this review that the mode of action and dosage of administration differs from plant to plant.

**Key words**: Diabetes mellitus, medicinal plant, extract, hypoglycemic, antidiabetic.

## INTRODUCTION

Diabetes mellitus is characterized as metabolic disorders defined by increased glucose levels (hyperglycemia) of blood because of failings in insulin secretion, insulin action or both. Insulin is produced by beta cells of the pancreas which use glucose from digested food as an energy source. When the pancreas either cannot make insulin or the insulin it does make is not enough and can not function properly, glucose builds up in the blood at a high level and frequently secrete through urine which is classical symptom of diabetes mellitus.[1]

Different clinical form of diabetes has been recognized. Type 1 diabetes, previously called insulin-dependent diabetes mellitus (IDDM) or juvenile-onset diabetes, is prevalent in 5-10 % of all diagnosed cases of diabetes.[2] Autoimmune disorders, environmental and genetic factors are known to be responsible for this form of diabetes.[1,3] Type 2 diabetes was also formerly known as non-insulin-dependent diabetes mellitus (NIDDM) or adult-onset diabetes includes majority of diagnosed cases of diabetes and is associated with several risk factors such as obesity, impaired glucose tolerance, family history of diabetes, prior history of gestational diabetes, physical inactivity, cardiovascular diseases, hypertension and race/ethnicity.[1,4] About 2-5 % of all pregnant women suffers from gestational diabetes mellitus (GDM) but usually disappears when a pregnancy is over. Other particular types of diabetes result from specific hereditary disorders, drugs, malnutrition, surgery, infections, and different ailments are also present though in extremely uncommon cases. Diabetes mellitus if untreated for long time causes retinopathy, neuropathy, nephropathy, heart attack, stroke and peripheral vascular disease.[1]

Currently available therapies for diabetes include insulin and various oral anti-diabetic agents such as sulfonylureas, biguanides and glinides.[5] Many of

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them have a number of serious adverse effects; therefore, the search for more effective and safer anti-diabetic agents is one of the important areas of investigation. There are numerous products from medicinal plants which are not only good and beneficial for human health but also crucial for the existence.[6] Attentions were also drawn by the researchers to discover new agents from plants having anti-diabetic activities.[7] This review compiles the plants that have been reported to exhibit activity from 1953 to 2017. This compilation will benefit future researchers to find anti-diabetic principles from the plants which could be used for the treatment of diabetes.

## MATERIALS AND METHODS

Literature survey was conducted on online database including CAS, Science Direct and PubMed. In addition, manual searches were carried out in books and journals. For this review, all the data has been systematically compiled following the rigorous collection of information from the available sources.

## RESULTS AND DISCUSSION

Our literature review from the mentioned sources identified 82 species from 48 plant families with significant antidiabetic activity or constituents. The recognized plants have been described according to their family.

### Acanthaceae

*Andrographis paniculata* (Sambiloto): The effect of Sambiloto on pancreatic beta cells has been examined and the results concluded it as a very strong, dose dependent insulinotropic agent.[8]

### Amaryllidaceae

*Allium cepa:* The ether extract (given orally at a dose of 0.25 gm/kg body weight) of the juice obtained by expression of *A. cepa* has significant blood sugar level lowering effect both in normal and alloxan-induced diabetic rabbits. This hypoglycemic action of the extract may be due to the increased insulin like activity.[9]

*Alium sativum:* The effect of the juice of garlic (*A. sativum*) and onion was investigated on glucose utilization in rabbit. The hypoglycemic effect of these agents was compared to that of tolbutamide and control group (dist. water). The study revealed that both the onion and garlic are effective in controlling the hyperglycemic effect.[10] *Alium sativum* contains S-allyl cysteine sulphoxide (**1**), a sulfur containing amino acid which is the precursor of allicin and garlic oil had significant anti-diabetic effects in alloxan-induced diabetic rats.[11]

### Anacardiaceae

*Rhus coriaria:* The lyophilized extract of Sumac, *R. coriaria* had a healing effect on diabetes and diabetes-related complications.[12]

*Spondias mombin*: The leaves of *S. mombin* were found to suppress the production of glucose by inhibiting α-amylase/α-glucosidase activity which is one of the therapeutic approaches for decreasing postprandial hyperglycemia and a strategy for evaluating antidiabetic activity.[13]

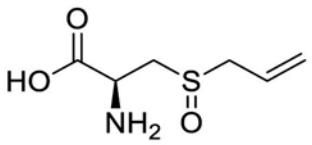
### Apiaceae

*Angelica decursiva:* The plant *A. decursiva* and its coumarins are useful as potential functional food ingredients for the prevention and treatment of type 2 diabetes.[14]

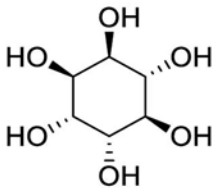
### Apocynaceae

*Gymnema sylvestre:* The leaves of *G. sylvestre* extract, when administered orally increased the circulating insulin levels in alloxan-induced diabetic rabbits. It has also been found that during the treatment serum lipid levels (e.g. cholesterol, triglycerides, and phospholipids) were significantly decreased.[15]

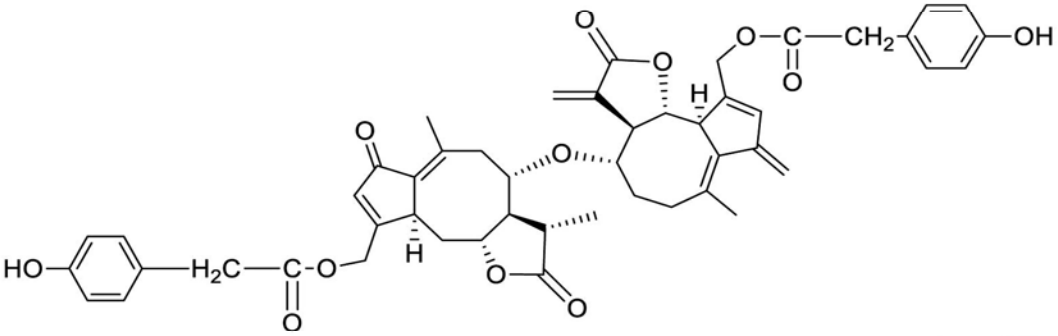
*Vinca rosea* (*Catharanthus roseus*): The blood sugar lowering effect of aqueous extract of whole plant of *V. rosea* (except root), in normal fasting and diabetic rat, rabbit and also in dogs were demonstrated. It was observed that *V. rosea* cause the fall of fasting blood sugar in normal and diabetic rats to the extent of 20 and 10 %, respectively.[16]



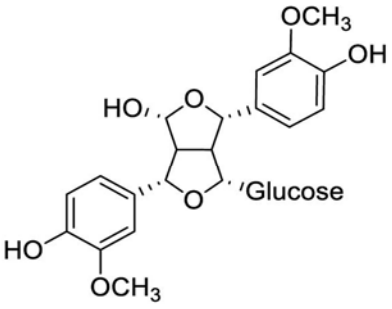
S-allyl cysteine sulphoxide (**1**)



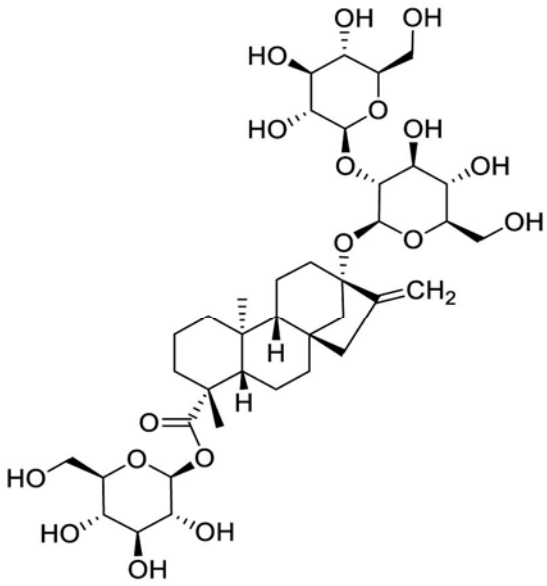
L-chiro-inositol (**2**)



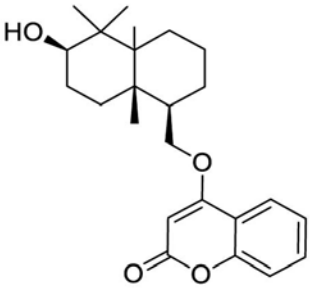
Latucain C (**3**)



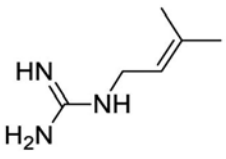
Lactucaside (**4**)



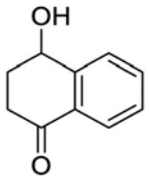
Stevioside (**5**)



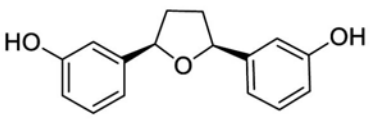
Foetidin (**6**)



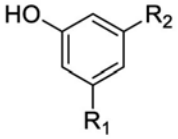
Galegine (**7**)



4-droxy-alpha-tetralone (**8**)



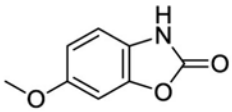
Ammaniol (**9**)



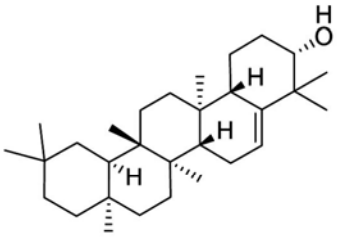
$R_1$= $O(C=O)OCH_2CH_3$

$R_2$ = $(CH_2)_7CH=CHCH_2CH=CH(CH_2)_4CH_3$

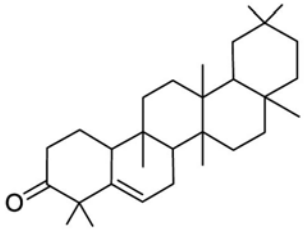
Embeliphenol A (**10**)



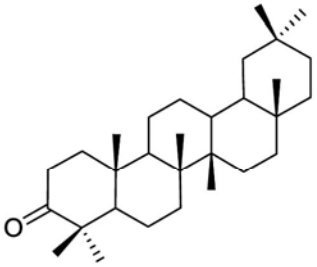
Coixol (**11**)



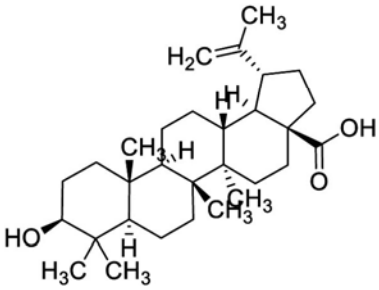
Glutinol (**12**)



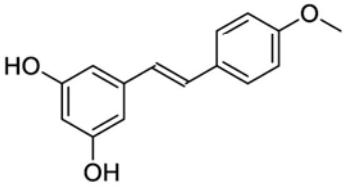
Glutone (**13**)



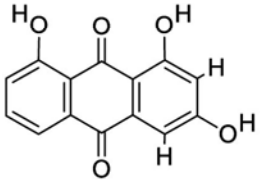
Friedlin (**14**)



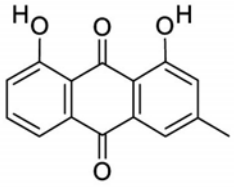
Betulinic acid (**15**)



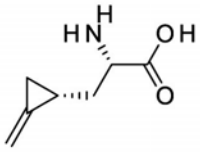
Desoxyrhapontigenin (**16**)



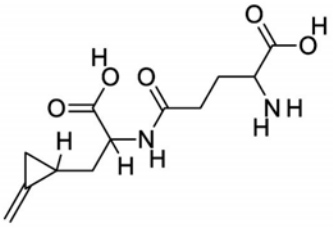
Emodin (**17**)



Chrysophanol (**18**)



Hypoglycin A (**19**)



Hypoglycin B (**20**)

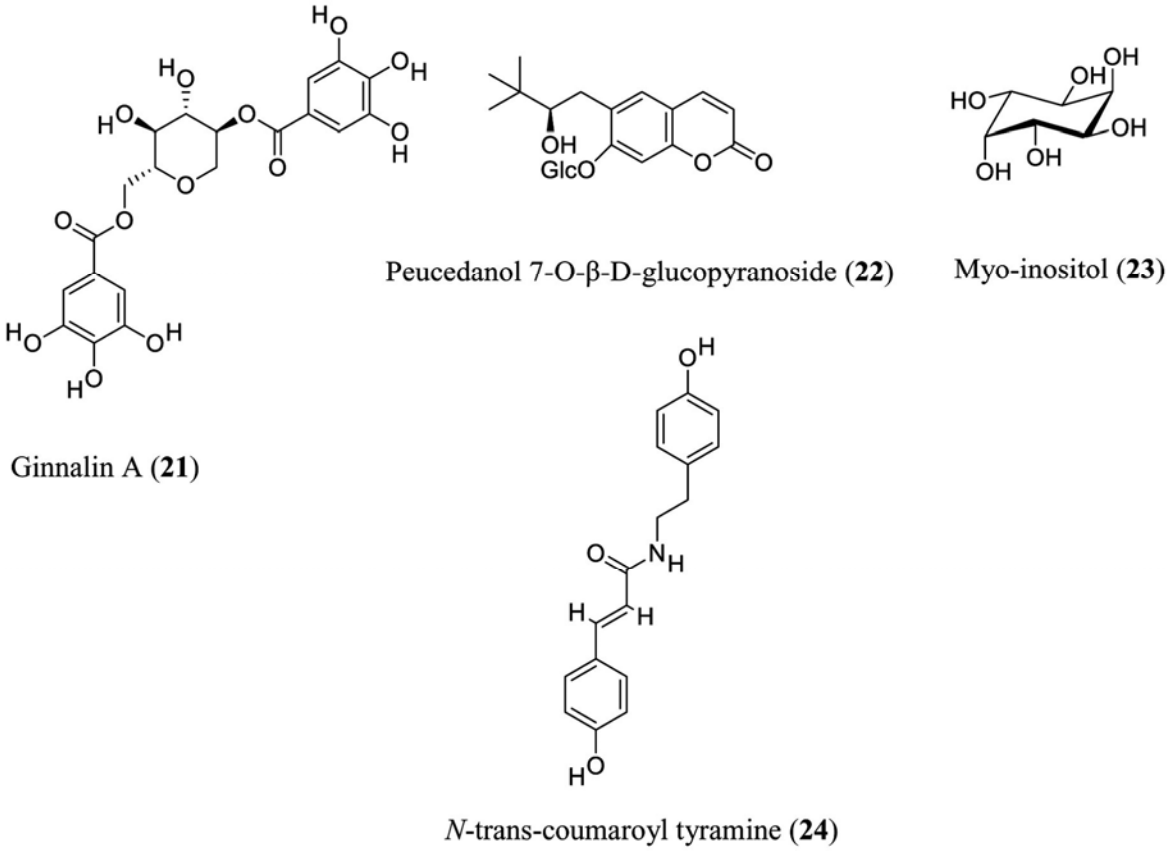



Figure 1. Active constituents reported from anti-diabetic plants.

**Araliaceae**

*Panax ginseng:* Korean red ginseng (KRG), a heat-processed Korean ginseng (*P. ginseng*), has long history as an herbal remedy for anti-diabetic effect via the stimulation of insulin release in a glucose-independent manner.[17]

*Panax notoginseng: P. notoginseng* roots was evaluated as a candidate to improve hyperglycemia by *in vitro* muscle cells screening test.[18]

**Arecaceae**

*Phoenix dactylifera* L.: The effectiveness of hydroalcoholic extract of *P. dactylifera* leaves was evaluated in animal models of type II diabetes. The result of evaluation confirmed the ethnopharmacological significance of the plant and could be taken further for the development of an effective pharmaceutical drug against diabetes.[19]

**Aristolochiaceae**

*Aristolochia ringens:* The ethanolic extract of *A. ringens* root demonstrated promising anti-hyperglycemic activity and the data so found established its usage in folkloric decoctions for the management of diabetes.[20]

**Asclapiadaceae**

*Cry7ptostegia grandiflora:* The aqueous solution of ethanolic extract of the aerial parts of *C. grandiflora* was found to produce significant hypoglycemia in normal rabbits but no action was observed in alloxan-induced diabetic rabbits.[21]

**Asphodelaceae**

*Aloe vera: Aloe vera* juice in combination with glibenclamide significantly reduced fasting blood glucose level within two weeks and triglycerides within four weeks. It showed no effect on cholesterol

levels and also had no toxic effects on kidney or liver function as assessed by blood chemistry. The results supported the use of *Aloe vera* in the treatment of diabetes.[22]

**Asteraceae**

*Ageratina petiolaris:* L-chiro-inositol (**2**) isolated from the aqueous extract of *A. petiolaris* was found to have significant hypoglycemic activity. These results support the traditional use of this plant for the treatment of type 2 diabetes.[23]

*Gynura divaricata:* The ethyl acetate and n-butanol extracts of dried *G. divaricata* was found to have significant effects on lowering blood glucose level in diabetes.[24]

*Gynura procumbens:* The aqueous extract of *G. procumbens* has been found with hypoglycemic effect by the promotion of glucose uptake in muscles.[25] The ethanolic extract of the plant leaves has been found to improve glucose tolerance as well as decrease serum cholesterol, triglycerides in streptozotocin-induced diabetic and normal rats.[26,27]

*Lactuca indica*: Latucain C (**3**) and Lactucaside (**4**) were isolated from *L. indica* showed significant anti-diabetic activity.[28]

*Stevia rebaudiana:* Stevioside (**5**), a natural sweetener and a diterpene glycoside was isolated from *S. rebaudiana* (Bertoni) that had been used as an anti-hyperglycemic agent for the treatment of diabetes for decades.[29]

**Boraginaceae**

*Tournefortia hirsutissima:* The butanolic extract of *T. hirsutissima* have been reported to significantly lower the plasma glucose levels in diabetes.[30]

**Brassicaceae**

*Brassica juncea: B. juncea* was studied on carbohydrate metabolism on rats. It demonstrated significant hypoglycemic activity.[31]

**Buddlejaceae**

*Buddleja saligna:* The *B. saligna*, a South African medicinal plant has anti-diabetic properties. The hexane fraction showed the most promising activity with regards to its anti-diabetic ($IC_{50}$ = 260 ± 0.112 µg/ml) activities.[32]

**Cecropiaceae**

*Cecropia obtusifolia:* The aqueous extract of *C. obtusifolia* was found to have a significant hypoglycemic property with no adverse effects and that the mechanism of action is not brought about by stimulating the insulin secretion. The results support the fact that the extract of *C. obtusifolia* has great potential to be further developed into a phytomedicine.[33]

**Celastraceae**

*Salacia hainanensis:* Isolated compounds of the methanolic extract of the roots of *S. hainanensis* had stronger inhibitory activity towards α-glucosidase.[34]

**Clusiaceae**

*Garcinia mangostana: G. mangostana*, including its pericarp reduced blood sugar level possibly by increasing the population of insulin-producing β-cells. Thus, the findings demonstrated that the plant could be a potential candidate in the management of diabetes owing to its hypoglycemic effect.[35]

**Cucurbitaceae**

*Coccinia indica:* The water-soluble fraction of the alcoholic extract of the root of *C. indica* was found to have significant hypoglycemic action in alloxan-induced diabetic (AID) rabbits.[36] It was observed that the hyperglycemia induced by somatotropin and corticotropin in albino rats can be controlled or lowered by parenteral administration of the alcoholic extract of the plant *C. indica*.[37] In a double blind controlled trial, it was found that the tablets made from the homogenized and freeze-dried leaves of *C. indica* have hypoglycemic action in diabetic patient at a dose of 3 tablets twice daily. It was also reported that the tablet was devoid of any toxic or undesirable effects.[38]

*Momordica charantia:* It was shown that the fruits of *M. charantia* contains an antidiabetic principle. But the seed showed no activity. The centrifuged material of water extract was found to be more active than the alcoholic extract.[39] The effect of

*M. charantia* was investigated on streptozotocin-induced type 2 diabetes mellitus in rats which showed that it caused a significant reduction of serum glucose. It also induced significant increase of serum insulin and improved histopathological changes of the pancreas. So, it can be concluded that *M. charantia* presents excellent anti-diabetic activities and thus has great potential as a new source for diabetes treatment whether it is used for prophylaxis or treatment.[40]

*Momordica foetida:* A compound, foetidin (**6**) was isolated from the fruits of *M. foetida*, that decreased the blood glucose level of fasting normal rats. The action was equivalent to the action of 1 unit insulin/kg body weight.[41]

*Cucurbita ficifolia:* The hypoglycemic properties of *C. ficifolia* can be explained, in part, by its effect as a secretagogue for insulin through an increased released $Ca^{++}$ from the calcium reservoir, endoplasmic reticulum. Therefore, the mechanism of action of *C. ficifolia* is different from those of the currently used hypoglycemic drugs, such as sulfonylureas. These results support that *C. ficifolia* may be a potential natural resource for new agents to control type 2 diabetes mellitus.[42]

**Equisetaceae**

*Equisetum myriochaetum:* The water extract of the aerial parts of *E. myriochaetum* was found to show hypoglycemic effect in type 2 diabetic patients starting from 90 min after its administration.[43]

**Euphorbiaceae**

*Croton cajucara: Trans*-dehydrocrotonin (t-DCTN), a 19-nor-clerodane diterpene, was isolated from the bark of *C. cajucara* which exhibited a significant hypoglycemic activity in alloxan-induced diabetic rats but not in normal rats, at oral doses of 25 and 50 mg/kg body weight. The drug also effectively lowered the blood sugar levels in glucose-fed normal rats. The hypoglycemic effect of t-DCTN was almost comparable to that produced by glibenclamide (2 mg/kg), a clinically useful drug.[44]

**Fabaceae**

*Cassia aurticulata:* The blood sugar lowering effect of seeds extract of *C. aurticulata* in normal fasting and diabetic rat, rabbit and also in dogs were found. It was observed that the fall of fasting blood sugar in normal and diabetic rats occurs to the extent of 28% and 17% for *C. aurticulata* seed extract, respectively.[16]

*Galega officinalis* Linn.: Guanidine and related compounds that led to the development of biguanides were isolated from French lilac plant *G. officinalis*.[45] Galegine (**7**) was isolated from the plant exhibited a great similarity in activity to the anti-diabetic drug metformin.[46]

*Glycine soja*, *Mucuna pruriens*, and *Dolichos biflorus:* When normal albino rats were fed *G. soja*, *M. pruriens*, and *D. biflorus* in diets, blood sugar was found to be lowered by 29.6%, 39.0% and 42.0% respectively (1968).[47]

*Hedysarum polybotrys:* A purified polysaccharide was isolated from *H. polybotrys* that improved hyperglycemia and hyperlipidemia associated with type 2 diabetes through several mechanisms such as increased insulin secretion, inhibition of lipid peroxidation, promotion of sensitivity to insulin, suppression of gluconeogenesis and reduction in the biosynthesis fatty acid, cholesterol and cell cytokines related to insulin resistance, and it could be a useful adjunct therapy to a proven first-line therapy for type 2 diabetes using metformin.[48]

*Lathyrus sativus:* The insulin-mimetic activities of *L. sativus* had been reported and indicated that it has been used in some traditional medicines to ameliorate diabetic symptoms.[49]

*Securigera securidaca:* The seeds of *S. securidaca* exhibited hypoglycemic activities. The seeds were found to increase the insulin levels.[50]

**Gentianaceae**

*Enicostemma littorale:* The aqueous extract of *E. littorale* was found to decrease the plasma glucose level accompanied by a decrease in the level of glycosylated hemoglobin and glucose-6-phosphatase

activity in liver. The potent anti-diabetic properties of *E. littorale* has been reported for the first time in this study.[51]

*Swertia kouitchensis:* Ten new xanthone glycosides, kouitchensides A-J, and 11 known analogs obtained from n-butanol fraction of *S. kouitchensis* displayed potent inhibitory effects against the α-glucosidase activity.[52]

**Geraniaceae**

*Geranium dielsiaum* (pasuchaca): The methanolic extract of pasuchaca has been reported to have α-glucosidase activity to delay carbohydrate digestion and subsequent lowering of the blood glucose level, thereby leading to prevention and cure of diabetes.[53]

**Ginkgoaceae**

*Ginkgo biloba:* The n-hexane fractions of both the methanol extracts of green and yellow leaves of *G. biloba* has been reported to have high α-glucosidase inhibitory activity.[54]

**Graminae**

*Stigma maydis:* Polysaccharides from *S. maydis* showed prominent effect on alloxan-induced types 1 and 2 diabetes.[55]

**Helicteraceae**

*Helicteres angustifolia:* The aqueous root extract of *H. angustifolia* was found to possess significant α-glucosidase inhibitory activity and moderated enhanced glucose consumption, with low cytotoxic and acute toxicity.[56]

**Lauraceae**

*Persea duthieion:* The extract/fractions of *P. duthieion* had significant anti-hyperglycemic activity equally supported by body weight recovery.[57]

**Lythraceae**

*Ammannia multiflora:* 4-hydroxy-alpha-tetralone (**8**) and 3,3'-(2*R*,5*R*)-tetrahydrofuran-2,5-diyldiphenol (ammaniol) (**9**) were isolated from *A. multiflora* through repeated chromatographic separation that showed potent anti-hyperglycemic activity and increased glucose uptake.[58]

**Meliaceae**

*Azadirachta indica:* The leaves of *A. indica* extract with the combination of extracts of *S. jambolana* (Myrtaceae) seeds, of *M. charantia* (Cucurbitaceae) fruits demonstrated promising hypoglycemic effects in diabetic rabbits.[59]

**Moraceae**

*Ficus bengalensis:* A glycoside was isolated from the bark of *F. bengalensis* which was able to lower the blood sugar level of normal rabbits but not in diabetic animals.[60] A clinical study was performed with the crude aqueous extract of the bark of *F. bengalensis* in 12 normal and 6 diabetic patients. 100 ml of 10% aqueous extract was administered orally and blood sugar was determined after 2 and 4 hours of administration. Mild hypoglycemic action was observed in diabetic patients but the extract failed to show hypoglycemic action in normal human being.[61] Flavonoids were isolated from alcoholic extract of the bark of *F. bengalensis* was effective as oral hypoglycemic agents to fasting normal rabbits.[62] It was found that the milky sap of the plant *F. bengalensis* causes initial lowering of fasting blood sugar in rats but subsequently the basal fasting level was found to be higher than that of control rats. A significant effect was seen on glucose tolerance after 3$^{rd}$ week of administration.[63] It was demonstrated that the aqueous extract of the bark of the plant have no significant effect on fasting blood sugar of normal rabbits but a moderate lowering of fasting blood sugar was observed in alloxan-induced diabetic rabbits.[64]

*Ficus carica:* The ethyl acetate extract of *F. carica* leaves had a significant effect on enzymes responsible for carbohydrate metabolism with promising hypoglycemic and hypolipidemic activities.[65]

*Ficus glomerata:* In a comparative study it was observed that the aqueous extract of the bark of *F. glomerata* and *F. bengalensis* were effective in the reduction of blood sugar level of normal as well as alloxan-induced diabetic rats.[66]

*Ficus reliogiosa:* Beta sitosteryl D-glucoside was isolated from the bark of *F. reliogiosa* and it was reported that the blood sugar level lowering effects of

this compound can be compared to that of tolbutamide.[67]

**Musaceae**

*Musa sapientum* Linn.: The plant bark juice was investigated in diabetic gastroparesis and its effect on pharmacokinetic of metformin. It had been found that the bark juice significantly reduced the blood glucose level in the diabetic rats and it effectively managed diabetic gastroparesis and thereby improved the bioavailability of metformin when administered with the bark juice.[68]

**Myrsinaceae**

*Embelia ribes:* A new alkenylresorcinol, embeliphenol A (**10**) isolated from the ethyl acetate extract of the stems of *E. ribes* possessed significant α-glucosidase inhibitory activity in a concentration-dependent manner.[69]

**Myrtaceae**

*Eugenia jambolana* (*Syzygium cuminii*): The blood sugar lowering effect of fruit extract of *E. jambolana* in normal fasting and diabetic rat, rabbit and also in dogs were demonstrated. It was observed that the fall of fasting blood sugar (FBS) in normal and diabetic rats occurs to the extent of 25% and 12% for the plant fruit extract, respectively. But *E. jambolana* fruits and seeds caused 20% and 50% rise in FBS within 2 hours which was followed by lowering effect.[16]

**Nelumbonaceae**

*Nelumbo nucifera:* Oral administration of the ethanolic extract of rhizomes of *N. nucifera* markedly decreased the blood sugar level of normal, glucose-fed hyperglycemic and streptozotocin-induced diabetic rats when compared with control animals. The extract improved glucose tolerance and potentiated the action of exogenously injected insulin in normal rats.[70]

**Orchidaceae**

*Dendrobium candidum*, *D. chrysotoxum*, *D. loddigesii*, *D. nobile*, *D. officinale:* The plants of the *Dendrobium* genus is one of the largest in the family of Orchidaceae. The genera include the plants *D. candidum*, *D. chrysotoxum, D. loddigesii*, *D. nobile, D. officinale* manifested with significant anti-diabetic activities.[71]

**Plantaginaceae**

*Scoparia dulcis* (Sweet Broomweed): The compounds coixol (**11**), glutinol (**12**), glutione (**13**), friedlin (**14**) and betulinic acid (**15**) isolated from *S. dulcis* demonstrated noticeable anti-diabetic action. However, coixol (**11**) were found to be very potent and mildly active in secreting insulin from mice with islet and MTN-6 pancreatic beta cells.[72]

**Polygonaceae**

*Rheum undulatum:* A stilbene, desoxyrhapontigenin (**16**) and two anthraquinones, emodin (**17**) and chrysophanol (**18**) were isolated from cultivated Korean rhubarb rhizomes (*R. undulatum*), which were found to reduce postprandial hyperglycemia.[73]

**Ranunculaceae**

*Coptis chinensis***:** The effects of *C. chinensis* polysaccharide (CCP) was investigated on hyperglycemia and glucose intolerance in high-fat diet (HFD)-induced diabetes. The results suggested that CCP has potential as an anti-diabetic agent, to suppress hyperglycemia and improve glucose intolerance by increasing glucose uptake.[74]

**Rosaceae**

*Eriobotrya japonica:* Sesquiterpene glycosides and polyhydroxylated triterpenoids were isolated from methanol extract of *E. japonica* and their hypoglycemic effect was studied in genetically induced diabetic mice (C57BL/KS-DB/DB/Ola) and normoglycemic rats. The sesquiterpene glycoside and the polyhydroxylated triterpenoids produced a marked inhibition of glycosuria. Furthermore, the compounds were able to reduce blood glucose levels in normoglycemic rats.[75]

*Prunus cerasus:* The ethyl acetate extracts of *P. cerasus* pulps and seeds promoted acute and subchronic hypoglycemic effects in alloxan-induced diabetic mice. The pulp extract has more pronounced effect.[76]

**Rubiaceae**

*Morinda citrifolia*: Noticeable anti-diabetic effects of fermented *M. citrifolia* fruit juice extract was observed in animal models.[77]

**Rutaceae**

*Aegle marmelose:* The leaf extract of *A. marmelose* was found to have potential anti-diabetic effect in alloxan-induced animal model. The results indicated that the active principle in *A. marmelose* leaf extract has the similar hypoglycemic activity to insulin treatment.[78]

*Murraya koenigii:* The effect of *M. koenigii* was studied on carbohydrate metabolism using rats as experimental animals where the plants showed significant hypoglycemic effect.[31]

**Salantalaceae**

*Viscum schimperi: V. schimperi* extract and its different fractions inhibited protein glycation. So, *V. schimperi* could be useful in the management of diabetic complications based on its inhibition of advanced glycation end product formation.[79]

**Salicaceae**

*Casearia esculenta:* A detailed study was performed on the plant *C. esculenta* which was found to contain reducing sugars, glycosides, tannins but are devoid of alkaloids and saponins. The roots of the plant were extracted with water, alcohol, petroleum ether, ether and acetone. It was observed that only the alcoholic extract showed significant hypoglycemic activities 2 hours after administration of the extract in albino rats. But prolonged administration of the water, pet. ether, acetone extracts did not cause any significant change in blood sugar level. However, glucose tolerance was favorably influenced by prolonged treatment of the aqueous and alcoholic extract.[80]

**Salvadoraceae**

*Salvadora persica* Linn.: The roots of *S. persica* was found to be significantly effective when compared with control in the treatment of hyperlipidemia and hyperglycemia in diabetic rats. Therefore, it may be beneficial to diabetic patients.[81]

**Sapindaceae**

*Blighia sapida:* Two hypoglycemic principles called hypoglycin A (**19**) and B (**20**) were isolated from the fruits of *B. sapida*. Of these two compounds, hypoglycin A was twice as active as hypoglycin B. About the mechanism of action, it was suggested that the hypoglycins are thought to act through inhibition of the β-oxidase enzyme, blocking the oxidation of long chain fatty acids, thus causing accumulation of unmetabolized fatty acids and making them unavailable for energy production. The compounds were found to show activity by oxidizing large amounts of glucose, thus causing a decrease of liver glycogen and a drop of glucose to hypoglycemic levels.[82]

*Acer pycnanthum:* Ginnalin A (**21**) obtained from *A. pycnanthum* exhibited potent α-glucosidase inhibitory activity. The results suggest that α-glucosidase inhibition is influenced by the number of galloyl groups.[83]

**Solanaceae**

*Lycium barbarum:* A study was conducted on a polysaccharide isolated from *L. barbarum* (LBP) that decreased the concentration of fasting blood glucose levels (FBG), total cholesterol (TC) and triglyceride (TG) in diabetic patients.[84]

*Hyoscyamys albus:* Calystegines ($A_3$, $A_5$, $A_5$ glycosides, $B_1$, $B_2$, $B_4$, $N_1$) that was isolated from *H. albus* seeds are potent anti-diabetic agents with anti-hyperglycemic and hypolipidemic effects, and a protective function on pancreas in streptozotocin induced diabetes.[85]

**Umbelliferae**

*Peucedani radix:* A coumarin, a cyclitol, peucedanol 7-O-β-D-glucopyranoside (**22**) and myo-inositol (**23**) were obtained from 80% ethanolic extract of *P. radix* (Umbelliferae). Both compounds were found to inhibit postprandial hyperglycemia.[86]

**Zingiberaceae**

*Aframomum melegueta*: The ethyl acetate fraction of the ethanolic extract of the fruit of *A. melegueta* possessed potent hypoglycemic effect in type-2 diabetes.[87]

**Zygophyllaceae**

*Larrea tridentata:* A pure compound was obtained from the creosote bush *L. tridentata* which showed a significant decrease in plasma glucose concentration in case of type-2 diabetes. In addition, improved oral glucose tolerance and the ability of insulin to lower plasma glucose concentrations were also raised.[88]

*Tribulus terrestris:* A lead structure, *N*-trans-coumaroyl tyramine (**24**) was isolated from *T. terrestris* extracts exhibited anti-diabetic effect via significant inhibition of α-glucosidase enzyme.[89]

## CONCLUSION

From the present work, it may be concluded that a great number of plants have been confirmed as anti-diabetic agents. Future researchers may undertake appropriate studies to obtain potent anti-diabetic compounds from these plants.

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