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Herbal option for diabetes: an overview

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ABSTRACT

The most spreading disease nowadays is diabetes. In a fast changing world, a number of means to treat diabetes naturally are explored by experts and clinicians today. Long-term use of insulin and other oral hypoglycemic agent will create unwanted side effects, resulting uncontrolled increase in blood sugar as well as complications with heart diseases also diabetics are highly prone to different types of microorganism and it will affect immune system of body. To avoid such problems herbal medications has greater advantages. Instead of using these types of allopathic formulations, it is beneficial to use Ayurvedic formulations for better management of diabetes mellitus. In this review, around a hundred of herbal plants were showing hypoglycemic activity and still they are using as home remedies for the effective treatment for diabetes mellitus.

1. Introduction

In the last few years there has been an exponential growth in the field of herbal medicine and these drugs are gaining popularity both in developing and developed countries because of their natural origin and less side effects.

Many traditional medicines in use are derived from medicinal plants, minerals and organic matter[1].

Diabetes mellitus, often simply referred as diabetes, is a group of metabolic diseases in which a person has high blood sugar, either because the body does not produce enough insulin, or because cells do not respond to the insulin that is produced. Diabetes mellitus is one of the common metabolic disorders, and 2.8% of the population suffer from this disease throughout the world and it may cross 5.4% by the year 2025. diabetes mellitus is group of many different disease because, hyperglycemia causes damage to eyes, kidneys, nerves, heart and blood vessels. Diabetes is one of the causes of renal end- stage disease. It is caused by inherited and/or acquired deficiency in production of insulin by the pancreas or by the effectiveness, of the insulin produced. However, it is believed that uncontrolled high blood sugar leads to the development of kidney damage especially high blood pressure is also present. Hyperglycemia generates more reactive oxygen species and attenuates anti-oxidative mechanism through glycation of the scavenging enzymes. Therefore, oxidative stress has been considered to be a common pathogenic factor of the diabetic. Traditionally herbal folk, medicine is most popular, which have antioxidant property, and 1000 side effects. Due to antioxidant property and these drugs give good results and reduce the blood glucose level, therefore, some herbal folk medicinal plant have been reported which are useful in diabetes treatment now days more than 400 plants are being used in different forms for hypoglycemic effects all the claims practitioners or users therefore a proper scientific evaluation & Screening of plant by Pharmacological tests followed by chemical investigation is necessary[2].

2. Types of diabetes

2.1. Type I: diabetes mellitus

This results when the pancreas produces insufficient amounts of insulin to meet the body's needs. A trigger- either an illness or stress-causes the immune system to attack and destroy the beta cells of the pancreas. As

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a result, pancreas stops producing insulin. The primary treatment for Type I diabetes is to take insulin injections everyday to survive. This form of diabetics is also called insulin dependent diabetes mellitus (IDDM). Type I develops suddenly in childhood or Adolescence[2].

2.2. Type II: diabetes mellitus

This result when the pancreas produces insulin, but the cells are unable to use it efficiently; this effect is called 'insulin resistance'. Type II diabetes is far more common than Type I and approximately 90% of all diabetes cases are Type ll. There is a strong genetic predisposition for Type ll diabetes. Age obesity and sedentary lifestyle are also risk factors. This form of diabetes is called non-insulin dependent diabetes mellitus (NIDDM). Type ll mainly affects people over age 40 and is more common in overweight people[2].

2.3. Gestational diabetes mellitus (GDM)

This is glucose intolerance being recognized during pregnancy. It can complicate pregnancy leading to prenatal morbidity and mortality, so clinical detection is important. Gestational diabetes is fully treatable but requires careful medical supervision throughout the pregnancy. About 20%-50% of affected women develop type 2 diabetes later in life[2].

2.4. Other specific types of diabetes

Maturity onset diabetes of youth (MODS) is due to impaired insulin secretion minimal or no insulin resistance, so hyperglycemia is noticed at an early stage. Genetic inability to convert proinsulin to insulin causes mild hyperglycemia Pathological features of diabetes mellitus are due to the Following factors:

1) Decrease in utilization of glucose by the body cells. This results in increase in blood glucose concentration to 300 to 1 200 mg/di.

2) Increase in mobilization of fats from the fat storage areas. This results abnormal fat metabolism and deposition of cholesterol in arterial walls causing atherosclerosis.

3) Tissues get depleted form protein i.e. protein depletion in tissues[2].

3. Role of insulin and glucagon

Glycogen synthesized, stored and secreted by the alpha-cells of islets of langerhans. Glucose is the major regulator of glucagons secretion, hyperglycemia inhibits while hypoglycemia stimulate the release or glucagons. The release of insulin from the beta cells of pancreas is stimulated by increase blood glucose level. Thus, glucagons and insulin is mutually antagonist to each other in functions. Herbal drug with antidiabetic activity from ancient period, peoples are using herbal plants as home remedies for treatment of diabetes. The treatment is design to control Glucose level in blood. This is the immediate goal, which is to stabilize the blood sugar and eliminate the symptoms of high blood sugar. The long-term goals of herbal treatments are to prolong life, improve the quality of life, relieve symptoms, and prevent complications[2].

4. Indian medicinal plants with antidiabetic and related beneficial effects

There are many herbal remedies suggested for diabetes and diabetic complications. Medicinal plants form the main ingredients of these formulations. The main advantage of herbal drug is that, it is safer and cured disease with less side effect and have safer than synthetic drug. Some of the herbal used for treatment of diabetes are as follows:

A list of medicinal plants with antidiabetic and related beneficial effects are given in Table 1[3].

5. Antidiabetic activity reported on following plants

5.1. Acacia arabica: (Babhul)

The chloroform extracts of Acacia arabica (Leguminosae) bark in diabetic rats at 250 and 500 mg/kg, *p.o.* for two weeks, significantly decreased the serum glucose level andrestored total cholestrol (TC), triglyceride (TG), high density lipoprotein (HDL) and low density lipoprotein (LDL) level. Moreover chloroform extract of Benincasa hispida fruit, Tinispora cordifolia stem, Ocimum sanctum (O. sanctum) areal parts and Jatropha curcus leaves were shown the similar effect in the diabetic rats[4].

5.2. Achyranthes rubrofusca (Devil's horsewhip, prickly chaff-flower)

The aqueous and ethanolic extracts of Achyranthes rubrofusca (Amaranthaceae) leaves in diabetic rats were investigated for antidiabetic activity. It decreased the blood glucose level significantly, pancreatic enzyme such as superoxide dismutase (SOD), catalase (CAT) and glutathione level were significantly increased in the treated group in the control group. Further aqous extract showed better result compared to the etanolic extract[5].

5.3. Aegle marmelos: (Bengal Quince, Bel or Bilva)

Administration of aqueous extract of leaves improves digestion and reduces blood sugar and urea, serum cholesterol in alloxanized rats as compared to control. Along with exhibiting hypoglycemic activity, this extract also prevented peak rise in blood sugar at 1h in oral glucose tolerance test[6].

Table 1
Indian medicinal plants with antidiabetic and related beneficial properties.

Plant Name	Ayurvedic/common Name/herbal formulation	Antidiabetic and other beneficial effects in traditional medicine
Annona squamosa	Sugar apple	Hypoglycemic and antihyperglycemic activities of ethanolic leaf-extract, increases plasma insulin level
Artemisia pallens	Davana	Hypoglycemic, increases peripheral glucose utilization or inhibits glucose reabsorption
Areca catechu	Supari	Hypoglycemic
Beta vulgaris	Chukkander	Increases glucose tolerance in OGTT
Boerhavia diffusa	punarnava	Increase in hexokinase activity, decrease in glucose-6-phosphatase and fructose bis-phosphatase activity, increases plasma insulin level, antioxidant
Bombax ceiba	Semul	Hypoglycemic
Butea monosperma	palasa	Antihyperglycemic
Camellia sinensis	Tea	Anti-hyperglycemic activity, antioxidant
Capparis decidua	Karir or Pinju	Hypoglycemic, antioxidant, hypolipidaemic
Caesalpinia bonducella	Sagarghota, Fevernut	Hypoglycemic, insulin secretagogue, hypolipidemic
Coccinia indica	Bimb or Kanturi	Hypoglycemic
Emblica officinalis	Amla, Dhatriphala	Decreases lipid peroxidation, antioxidant, hypoglycemic
Eugenia uniflora	Pitanga	Hypoglycemic, inhibits lipase activity
Enicostema littorale	krimihrita	Increase hexokinase activity, Decrease glucose 6-phosphatase and fructose 1, 6 bisphosphatase activity. Dose dependent hypoglycemic activity
Ficus bengalenesis	Bur	Hypoglycemic, antioxidant
Gymnema sylvestre	Gudmar or Merasingi	Anti-hyperglycemic effect, hypolipidemic
Hemidesmus indicus	Anantamul	Anti snake venom activity, anti-inflammatory
Hibiscus rosa-sinesis	Gudhal or Jasson	Initiates insulin release from pancreatic beta cells
Ipomoea batatas	Sakkargand	Reduces insulin resistance
Momordica cymbalaria	Kadavanchi	Hypoglycemic, hypolipidemic
Murraya koenigii	Curry patta	Hypoglycemic, increases glycogenesis and decreases gluconeogenesis and glycogenolysis
Musa sapientum	Banana	Antihyperglycemic, antioxidant
Phaseolus vulgaris	Hulga, white kidney bean	Hypoglycemic, hypolipidemic, inhibit alpha amylase activity, antioxidant. Alters level of insulin receptor and GLUT-4 mRNA in skeletal muscle
Punica granatum	Anar	Antioxidant, anti-hyperglycemic effect
Salacia reticulata	Vairi	Inhibitotory activity against sucrose, α-glycosidase inhibitor
Scoparia dulcis	Sweet broomweed	Insulin-secretagogue activity, antihyperlipidemic, hypoglycemic, antioxidant
Swertia chirayita	Chirata	Stimulates insulin release from islets
Syzygium alternifolium	Shahajire	Hypoglycemic and antihyperglycemic
Terminalia belerica	Behada, a constituent of"Triphala"	Antibacterial, hypoglycemic
Terminalia chebula	Hirda	Antibacterial, hypoglycemic
Tinospora crispa	Guduchi	Anti-hyperglycemic, stimulates insulin release from islets
Withania somnifera	Ashvagandha, winter cherry	Hypoglycemic, diuretic and hypocholesterolemic

5.4. Allium sativum: (garlic)

This is a perennial herb cultivated throughout India. Allicin, a sulfur-containing compound is responsible for its pungent odour and it has been shown to have significant hypoglycemic activity. This effect is thought to be due to increased hepatic metabolism, increased insulin release from pancreatic beta cells and/or insulin sparing effect. Aqueous homogenate of garlic (10 mL/kg/d) administered orally to sucrose fed rabbits (10 g/kg/d in water for two months) significantly increased hepatic glycogen and free amino acid content, decreased fasting blood glucose, and triglyceride levels in serum in comparison to sucrose controls. S-allyl cystein sulfoxide (SACS), the precursor of allicin and garlic oil, is a sulfur containing amino acid, which controlled lipid peroxidation better than glibenclamide and insulin. It also improved diabetic conditions. SACS also stimulated in vitro insulin secretion from beta cells isolated from normal rats. Apart from this, Allium sativum exhibits antimicrobial, anticancer and cardioprotective activities[7].

5.5. Andrographis paniculata (Creat, Kariyat, Indian Echinacea)

The oral administration of ethanol extract of Andrographis paniculata (Acanthaceae) in diabetic rats at a dose of 100 and 200 mg/kg, *p.o.* for 30 d treatment, significantly decreased the blood glucose level. Further it restored TG, TC, phospholipids, glycocylated haemoglobin, alanine transaminase (ALT), aspartate transaminase (AST), acid phosphate (ACP) and alkaline phosphate (ALP) level which indicates its anti-diabetic activity[8].

5.6. Argyriea cuneata (Purple Morning Glory, Purple Convolvulus)

The anti-diabetic activities of ethanol extract of leaves of Argyriea cuneata (Convolvulaceae) in diabetic rats were investigated and found to have significant anti-diabetic as well as lipid lowering potential[9].

5.7. Azadirachta indica: (Neem)

Hydroalcoholic extracts of this plant showed antihyperglycemic activity in streptozotocin treated rats and this effect is because of increase in glucose uptake and glycogen deposition in isolated rat hemidiaphragm. Apart from having anti-diabetic activity, this plant also has anti-bacterial, antimalarial, antifertility, hepatoprotective and antioxidant effects[10].

5.8. Barleria prionitis (Kantsaria, Vajradanti)

Alcoholic extracts of leaf and root of *Barleria prionitis* (Acanthaceae) in diabetic rats at 200 mg/kg, *p.o.* for 14 d treatment, significantly decrease blood glucose and glycosylated hemoglobin level. Moreover serum insulin and liver glycogen level weresinificantly increased[11].

5.9. Capparis deciduas: (Ker, Teet, Dela)

The aqueous and ethanolic extract of *Capparis deciduas* (Capparaceae) stem in diabetic rats at 250 and 500 mg/kg, *p.o.* for 21 d treatment significantly decreased the blood glucose level which signified its anti-diabetic potential[12].

5.10. Cassia grandis (Coral Shower Tree, Pink shower tree, Horse cassia, stinking-toe)

The aqueous and ethanolic extracts of *Cassia grandis* (leguminosae) in diabetic rats at the dose level of 150 mg/kg, *p.o.* for 10 d treatment, significantly decreased the blood glucose, TC, and TG level for providing its anti-diabetic potential[13].

5.11. Ceriops decandra (mangrove)

The anti-diabetic activity of ethanolic extract of the leaves Ceriops decandra (Rhizophoraceae) in diabetic rats at 30, 60, 120 mg/kg, *p.o.* for 30 d treatment were investigated. Extract treated group modulated all the parameters such as blood glucose, hemoglobin, liver glycogen and some carbohydrate metabolic enzymes. Further 120 mg/kg, *p.o.* dose level was found to be more significant compared to other tested dose level[14].

5.12. Coccinia indica: (kundru, dondakaya, kovakkai and tindora)

Coccinia indica (*C. indica*) widely used in traditional treatment of diabetes mellitus in sub-Saharan Africa and Southeast Asia. Pectin isolated from the fruits of C. indica has hypoglycemic activity. Alcoholic extract of plant was found to be active in reducing blood glucose level, then this extract was subjected to further fractionation to evaluate its biochemical parameters effecting diabetes and results suggested toluene as an active fraction. The exact action of these principles may be due to their β-cell restorative properties against alloxan induced damage[15,16].

5.13. Colocasia esculenta (Elephant-ear, Taro, Cocoyam, Dasheen, Chembu)

Ethanol extract of Colocasia esculenta (Araceae) in diabetic rats at 400 mg/kg, *p.o.* for 14 d, significantly decreased the blood glucose level and prevented loss of body weight. Its indicate its anti-diabetic potential[16].

5.14. Costus igneus (Spiral Flag)

Ethanolic extract of leaves of costus igneus (Costaceae) extracts in diabetes albino rats showed significant reduction of blood glucose level and prevented body weight loss indicating its anti-diabetic potential[17].

5.15. Eucalyptus citriodora (Lemon)

Aqueous extract of Eucalyptus citriodora (Myarteceae) leaf in diabetic rats at 250 and 500 mg/kg, *p.o.* for 21 d treatment, significantly reduced the blood glucose level which confirms its anti-diabetic potential[18].

5.16. Eugenia jambolana: (Indian gooseberry, jamun)

In India decoction of kernels of *Eugenia jambolana* is used as household remedy for diabetes. This also forms a major constituent of many herbal formulations for diabetes. Antihyperglycemic effect of aqueous and alcoholic extract as well as lyophilized powder shows reduction in blood glucose level. This varies with different level of diabetes. In mild diabetes (plasma sugar >180 mg/dL) it shows 73.51% reduction, whereas in moderate (plasma sugar >280 mg/dL) and severe diabetes (plasma sugar >400 mg/dL) it is reduced to 55.62% and 17.72% respectively. The extract of jamun pulp showed the hypoglycemic activity in streptozotocin induced diabetic mice within 30 min of administration while the seed of the same fruit required 24 h. The oral administration of the extract resulted in increase in serum insulin levels in diabetic rats. Insulin secretion was found to be stimulated on incubation of plant extract with isolated islets of Langerhans from normal as well as diabetic animals. These extracts also inhibited insulinase activity from liver and kidney[19,20].

5.17. Ficus bengalensis (Banyan tree)

The aqueous extract of *Ficus bengalensis* (*F. bengalensis*) (Moraceae) bark in both insulin dependent diabetes mellitus (IDDM) and Non-insulin dependent diabetes mellitus (NIDDM) rats at 1.25 g/kg, *p.o.* for 4 weeks, significantly decreased the plasma glucose and serum lipids level. Its

show anti-diabetic potential of F.bengalensis[21].

5.18. Heinsia crinata (bush apple)

The ethanolic leaf extract of Heinsia crinata (Rubiaceae) in diabetic rats for 2 weeks, significantly reduce the fasting blood glucose levels. It indicates its anti-diabetic potential[22].

5.19. Helicteres isora (East Indian Screw Tree, Nut Leaved Screw Tree)

The antihyperglycemic and hypolipidemic activities of butanol and aqueous ethanol extracts of Helicteres isora (Sterculiaceae) root in diabetic rats at 250 mg/kg for 10 d treatment were investigated. Extract treated group showed decreased level of blood glucose, TC, TG and urea. Further histological examination showed the restoration of pancreatic islet, kidney glomeruli, and liver to its normal size and therefore signified its anti-diabetic potential[23].

5.20. Ipomoea reniformis (Mouse Ear)

The ethanolic and aqueous extracts of stem of Ipomoea reniformis (I. reniformis) (Convolvulus) in diabetic rats at 300 and 600 mg/kg, *p.o.* for 12 d treatment, significantly decrease the blood glucose and lipid level. From the obtained data it was found that I. reniformis have significant anti-diabetic antihyperlipidaemic potential[24].

5.21. Juglans regia (walnut)

Anti-diabetic effects of methanolic extract of Juglans regia (J. regia) (Juglandaceae) leaves was estimated in diabetic male wistar rats at 250 mg/kg, *p.o.* for three weeks. J.ragia significantly decreases the blood glucose, TG and TC level. Further it increased GPX, SOD and cell antibody level significantly and therefore signified its anti-diabetic potential[25].

5.22. Lantana aculeate (Spanish Flag, Red (yellow, wild) Sage)

The anti diabetic effect of ethanolic extrct of the dried mature roots of lantana aculeate (Verbenaceae) in diabetic rats at 25, 50 and 100 mg/kg, *p.o.* for 30 d treatment, was assessed. The plant significantly reduced the blood glucose level. Further it decrease the TC and TG level and increased insulin and glucogen concentration in a dose-dependent manner, justifying its anti-diabetic potential[26].

5.23. Limonia acidissima (Wood Apple)

Methanolic extract of Limonia acidissima (Rutaceae) in diabetic rats at 200 and 400 mg/kg, *p.o.* for 21 d treatment, significantly decreased the blood glucose and malondialdehyde (MDA) level. Further the activity of antioxidant enzymes such as SOD, CAT were found in higher the treated group compared to the control group which show the anti-diabetic and antioxidant potential for the plant[27].

5.24. Luffa aegyptiaca (Sponge Gourd, Loofah, Smooth luffa)

The alcoholic and aqueous extracts of Luffa aegyptiaca (Cucurbitaceae) in diabetic rats at 100 mg/kg, *p.o.* for 15 d treatment significantly decrease the blood glucose of hyperglycemic rats which signifies its anti-diabetic potential[28].

5.25. Mangifera indica: (Mango)

The leaves of this plant are used as an antidiabetic agent in Nigerian folk medicine, although when aqueous extract given orally did not alter blood glucose level in either normoglycemic or streptozotocin induced diabetic rats. However, antidiabetic activity was seen when the extract and glucose were administered simultaneously and also when the extract was given to the rats 60 min before the glucose. The results indicate that aqueous extract of Mangifera indica possess hypoglycemic activity. This may be due to an intestinal reduction of the absorption of glucose[29].

5.26. Medicago sativa: (alfalfa, Buffalo Herb, Lucerne, Purple Medic)

Intraperitoneal administration of streptozocin resulted in a reduction in hyperglycaemia. The manganese content of alfalfa (45.5 mg/kg) was reported to be a active principle responsible for ahypoglycaemic affect documented for the herb[30].

5.27. Momordica charantia: (bitter gourd)

Anti-Hyperglycemic and anti-oxidative potential of aqueous extracts of *Momordica charantia* (*M. charantia*) (Cucurbitaceae) pulp in diabetic rats for 30 d treatment were investigated. M. charantia extract significantly decreased the blood glucose levels. Moreover all the other parameter was significantly restored in the treated group compared to control group. Further similar activity was found with the T.foenum graecum extract treatment[31].

5.28. Mukia maderaspatana (Madras Pea Pumpkin, Agumaki)

The methenolic root extract of Mukia maderaspatana (Cucurbitaceae) in diabetic rats at a dose of 500 mg/kg, *p.o.* for 21 d treatment, significantly decreased the blood TC, TG, LDL, phospholipids and very-low density lipoprotein (VLDL) level. Further it decrease serum oxaloacetate transamineses (SGOT), serum glutamate pyruvate transamineses (SGPT), alkaline phosphateses (ALP) and increased total protein (TP) content significantly at tested dose level[32].

5.29. Nymphaea pubescens (White Water Lily, White Lotus)

The ethanolic extract of Nymphaea pubescens (Nymphaeaceae) in diabetic rats at 200 and 400 mg/kg, *p.o.* after 14 d treatment significantly reduced the blood glucose level. Further histopathological examination of pancreas revealed its regenerative potential corroborating its anti-diabetic potential[33].

5.30. Ocimum gratissimum (Vana Tulsi)

The methanolic extract of Ocimum gratissimum (Lamiaceae) in diabetic wistar rat at 500 mg/kg, *p.o.* showed significant reduction of blood glucose level. Moreover methanolic extracts of Ocimum americanum, O. sanctum and Ocimum basilicum also show similar effect in the diabetic rats, with maximum potential in case of O. sanctum compared to the other tested extracts[34].

5.31. Paspalum scrobiculatum (kodo-millet)

Aqueous and ethanolic extracts of Paspalum scrobiculatum (Poaceae) in diabetic rats at 250 and 500 mg/kg, *p.o.* for 15 d treatment, significantly reduces the blood glucose level and lipid parameters. Further extract treated group showed a significance increase in liver glycogen contents and a significant decreased in glycated haemoglobin level. Moreover 500 mg/kg, *p.o.* dose level showed more significant anti-diabetic activity compared to the 250 mg/kg, *p.o.* dose level[35].

5.32. Phoenix dactylifera (Date Palm, True Date, Medjool Palm, Medjool Date Palm)

The phoenix dactylifera (*P. dactylifera*) (Arecaceae) leaf extract in diabetes wistar rats at 100, 200, and 400 mg/kg, *p.o.* and its fractions at 50, 100, and 200 mg/kg, *p.o.* for 14 d treatment, significantly reduced blood glucose, TC, TG level and water intake and increase plasma insulin level significantly compare to control group. The data obtained from experiment showed that P. dactylifera have anti-diabetic potential[36].

5.33. Phyllanthus amarus: (bhuiawala)

It is a herb of height up to 60 cm, from family Euphorbiaceae. It is commonly known as Bhuiamala. It is scattered throughout the hotter parts of India, mainly Deccan, Konkan and south

Indian states. Traditionally it is used in diabetes therapeutics. Methanolic extract of Phyllanthus amarus was found to have potent antioxidant activity. This extract also reduced the blood sugar in alloxanized diabetic rats. The plant also shows antiinflammatory, antimutagenic, anticarcinogenic, antidiarrhoeal activity[37].

5.34. Phyllanthus niruri (Bahupatra, Bhuiamla)

The methanol extract of aerial parts of Phyllanthus niruri (Euphorbiaceae) in diabetic rats significantly reduced the blood glucose, TC and TG in a dose-related manner. Moreover histological studies showed that extract had imparted cell regenerative power in drug treated group which boosted its anti-diabetic potential[38].

5.35. Phyllanthus simplex (Kaya-an)

Various fractions of phyllanthus simplex (Euphorbiaceae) such as petroleum ether (200 and 400 mg/kg), ethyl acetate (100 and 200 mg/kg), methanol (125 and 250 mg/kg), water fraction (150 and 300 mg/kg) were investigated for their anti-diabetic potential. Methanol (125 and 250 mg/kg) and aqoues fractions (150 and 300 mg/kg) showed significant anti hyperglycemic effect. The active fraction also restored the antioxidant enzymes levels in liver and kidney[39].

5.36. Pongamia pinnata (Indian Beech, Poongam Oil Tree)

The standardized ethanolic extract of Pongamia pinnata (*P. pinnata*) (Fabaceae) in diabetic rats was tested for its anti-diabetic potential. After 21 d treatment it was found that P.pinnata Posseses significant anti-diabetic activity[40].

5.37. Solanum nigrum (Black Night Shade, Makoy, Deadly Nightshade)

Antihyperglycemic and hypolipidemic effects of aqueous leaf extract of solanum nigrum (S.nigrum) (solanaceae) in diabetic rats at 200, 400 mg/kg b.w. for 21 d treatment were investigated. Extracts of S. nigrum significantly reduced blood glucose and other lipid parameter. Similar effect was also found with Musa extract. These finding show the anti-diabetic potential of these two plants[41].

5.38. Sphenostylis stenocarpa (Africa yam bean, Wild yam bean)

The methanolic extract of seeds of Sphenostylis stenocarpa (Leguminoseae) in diabetic rats at doses of 200, 400 and 600 mg/kg, *p.o.*, significantly reduce the blood glucose level. Moreover, 600 mg/kg, *p.o.* was found to be more significant compared to other tested dose level[42].

5.39. Taraxacum officinale Weber: (Dandelion)

Hypoglycaemic activity has been described in normal, but not in diabetic rabbits, following oesophagal administration of dandelion[43].

5.40. Tinospora cordifolia: (Guduchi)

It is a large, glabrous, deciduous climbing shrub belonging to the family Menispermaceae. It is widely distributed throughout India and commonly known as Guduchi.

Oral administration of the extract of Tinospora cordifolia (*T. cordifolia*) roots for 6 weeks resulted in a significant reduction in blood and urine glucose and in lipids in serum and tissues in alloxan diabetic rats. The extract also prevented a decrease in body weight. *T. cordifolia* is widely used in Indian ayurvedic medicine for treating diabetes mellitus. Oral administration of an aqueous *T. cordifolia* root extract to alloxan diabetic rats caused a significant reduction in blood glucose and brain lipids. Though the aqueous extract at a dose of 400 mg/kg could elicit significant antihyperglycemic effect in different animal models, its effect was equivalent to only one unit/kg of insulin. It is reported that the daily administration of either alcoholic or aqueous extract of T. cordifolia decreases the blood glucose level and increases glucose tolerance in rodents[44-49].

5.41. Trigonella foenum graecum: (fenugreek)

The anti-diabetic activity of ethanol extract of Trigonella foenum-graecum (Fabaceae) seeds in diabetic rats at 2 g/kg, 1 g/kg and 0.1 g/kg, *p.o.* was investigated and it was found to have significant blood glucose lowering capacity. Further among all the tested dose level, 1 g/kg, *p.o.* was found to be more significant comparing to other dose levels[50].

5.42. Triumfetta rhomboidea (Diamond Bur Bark; Bur Bush; Chinese Bur)

Treatment with ethanolic extract of Triumfetta rhomboidea (T. rhomboidea) (Malvaceae) in diabetes rats at doses of 100, 200, and 400 mg/kg, *p.o.*, significantly decrease the blood glucose level in dose dependent manner. From the data it was found that T. rhomboidea has significant anti-diabetic potential[51].

5.43. Tumera diffusa Willd : (Damiana)

Hypoglycaemic activity has been reported in mice following both oral and intraperitoneal administration of damiana[52].

5.44. Vaccinium arctostaphylos (Caucasian whortleberry)

The ethanolic extract of Vaccinium arctostaphylos (V. arctostaphylos) (Ericaceae) fruit in diabetic male rats for 3 weeks, significantly decreased the blood glucose and triglyceride level. However it increase the erythrocyte SOD, glutathione peroxidase, catalase activities and expression of GLUT-4 and INS genes. These findings indicates anti-diabetic potential of V. arctostaphyl[53].

5.45. Vernonia amygdalina (Bitter-tea vernonia)

The anti-diabetic activity of the various combinations of metformin (50 mg/kg) and aqous extracts of the leaves of Vernonia amygdalina (Asteraceae) (100 mg/kg) in diabetic rats were investigated. Extract and metformin at the ratios of 1:1 and 2:1 were given to both normoglycemic and diabetic. From the data it was found that, blood glucose level was decreased more significantly by the drug combination compared to the single treatment of drug in the diabetic rats[54].

5.46. Zaleya decandra (horse purslanes)

Effect of ethanolic extract of Zaleya decandra (Aizoaceae) roots in diabetes rats at 200 mg/kg, *p.o.* for 15 d treatment, significantly restored the levels of glucose, TG, TC, TP, urea creatinine, lipid peroxidation level, and antioxidant enzymes. Histopathologigal studies showed significant regenerative power in the extract treated group compared to control group[55].

5.47. Zea mays: (Corn Silk, Indian corn)

Cornsilk is a proven diuretic. It is plentiful, cheap, and commonly used to treat cystitis, pyelitis, oliguria, and edema. It possesses hypoglycemic, antimicrobial, cholinergic and hypotensive properties. Cornsilk has more or less confirmed oral hypoglycemic activity. In one study the herb produced a constant hypoglycemic effect in starving rabbits. The active principle is not known[56].

5.48. Zizyphus mauritiana (Jujube, Chinese Apple, Indian plum)

The petroleum ether and aqueous extract of Zizyphus mauritiana (Rhamnaceae) at 200 and 400 mg/kg, *p.o.* doses, significantly restored the elevated biochemical parameters such as glucose, urea, creatinine, TG, TC, HDL, LDL, hemoglobin and glycosylated hemoglobin. From the obtained data it was found that this plant had significant anti-diabetic potential[57].

6. Other Herbal Plants with Antidiabetic Potential

Other herbal plants with antidiabetic activity are Abroma august Linn. Acacia modesta Wall, Acacia nilotica Linn, Aconitum ferox Wall,Adhatoda vasika Nees, Adiantum capillusveneris Linn, Adiantum incisum Forsk, Albizia stipulate Sensu Barker, Alpinia galangal Wild, Anacardium occidentale Linn, Areca catechu Linn, Bauhinia semla Wunderlin, Benincasa hispida Cong, Bougainvillea spectabilis Willd, Brassica oleracea Linn, Casearia esculenta Roxb, Cassia auriculata Linn, Cassia fistula Linn, Cassia sophera Linn, Catharanthus roseus G.Don, Citrus aurantium Linn, Clerodendurm Phlomidis Linn, Coccinia indica Wight, Cynara scolymus Linn, Daucus carota Linn, Dolichos lablab Linn, Emblica officinalis Gaertn, Enicostemma littorale Blume, Ensete superbum Roxb, Eriodendron anfractuodum DC, Erythrina indica Lam, Ficus begalensis Linn, Ficus racemosa Linn, Glycine max Merrill, Gymnema sylvestre R.Br. Herlicteres isora Linn, Hordeum vulgare Linn, Indigofera arecta Hochst, Ipomoea nil Linn, Lagerstroemia speciosa Pers. Lupinus albus Linn, Mangifera indica Linn,

Morus alba Linn, Mucuna prurita Hiik, Murraya kienigii Linn, muasa sapeintum Linn, Nigella sativa Linn, Nymphaea ouchale Burm, Ocimum sanctum Linnm Olea europaea Linn, Orchis mascula Linn, Orthosiphon spiralis Merill,Pinus roxburghii Sarg, Portulaca oleracea Linn, Prunus persica Batsch, Pterocarpus marsupium Roxb Punica granatum Linn, Quercus infectoria Olivier, Rauvolfia serpentine Benth, Ricinus communis Linn, Rivea cuneata Wight, Salacia macrosperma Wight,Saussurea lappa C.B.Clarke, Scoparia dulcis Linn, Securigera securidaca Linn, Spathodea campanulata Beauv, Strychnos potatorum Linn, Swertia chirayita Roxb, Tecoma stans Linn, Trifolium alexandrinum Linn, Trigonella foenumgraecum Linn, Urtica diocal Linn, Xanthium strumarium Linn[58].

The herbal drugs discussed in review have shown potent antidiabetic activity. The synthetic formulation available in market, though they are showing excellent clinical and pharmacological activity in diabetics but they have significant adverse effect hence herbal drugs are preferred over synthetic drug to avoid serious side effects and adverse effects.

Conflict of interest statement

We declare that we have no conflict of interest.

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