Journal of Pharmacy & BioAllied Sciences
Home
Current issue
Instructions
Submit article
J Pharm Bioallied Sci. 2012 Jan-Mar; 4(1): 27–42.
doi: 10.4103/0975-7406.92727
PMCID: PMC3283954

A pharmacological appraisal of medicinal plants with antidiabetic potential

Vasim Khan, Abul Kalam Najmi, Mohd. Akhtar, Mohd. Aqil,[1] Mohd. Mujeeb,[2] and K. K. Pillai
Department of Pharmacology, Jamia Hamdard, New Delhi, India
[1]Department of Pharmaceutics, Jamia Hamdard, New Delhi, India
[2]Department of Pharmacognosy and Phytochemistry, Jamia Hamdard, New Delhi, India
Address for correspondence: Dr. Abul Kalam Najmi, E-mail: aknajmi@hotmail.com
Received June 14, 2011; Revised July 29, 2011; Accepted August 7, 2011.

Abstract

Diabetes mellitus is a complicated metabolic disorder that has gravely troubled the human health and quality of life. Conventional agents are being used to control diabetes along with lifestyle management. However, they are not entirely effective and no one has ever been reported to have fully recovered from diabetes. Numerous medicinal plants have been used for the management of diabetes mellitus in various traditional systems of medicine worldwide as they are a great source of biological constituents and many of them are known to be effective against diabetes. Medicinal plants with antihyperglycemic activities are being more desired, owing to lesser side-effects and low cost. This review focuses on the various plants that have been reported to be effective in diabetes. A record of various medicinal plants with their established antidiabetic and other health benefits has been reported. These include *Allium sativa*, *Eugenia jambolana*, *Panax ginseng*, *Gymnema sylvestre*, *Momrodica charantia*, *Ocimum sanctum*, *Phyllanthus amarus*, *Pterocarpus marsupium*, *Trigonella foenum graecum* and *Tinospora cordifolia*. All of them have shown a certain degree of antidiabetic activity by different mechanisms of action.

KEY WORDS: Antioxidant, diabetes mellitus, hypoglycemic, medicinal plants

Diabetes mellitus is a global health crisis, which has been persistently affecting the humanity, irrespective of the socioeconomic profile and geographic location of the population. According to an estimate, one person is detected with diabetes every 5 s somewhere in the world, while someone dies of it every 10 s.[1] Diabetes mellitus has attained a pandemic form. Hence, it is

very important to control diabetes and its complications to alleviate the human suffering. Scientists are desperately trying to manage this crippling disorder. Because plants are of enormous medicinal importance, they are being extensively explored for their use against diabetes. Herbal drugs can be quite acceptable as these drugs are known to cause less adverse effects.[2] They are quite popular in developing countries.[3] The increased admiration of herbal medicines for diabetes may be due to the side-effects associated with the conventional antidiabetic drugs.[4] The World Health Organization (WHO) has also substantiated the utilization of herbal remedies for the management of diabetes.[5] Till date, numerous medicinal plants have been reported to be effective in diabetes, yet plenty of research is still needed to be done. This article focuses on the various plants that could be effective in the treatment of diabetes mellitus.

Prevalence of Diabetes Around the World

Diabetes is a metabolic disorder critically afflicting the population of both developed and developing countries. According to the Diabetes Atlas, the global prevalence of diabetes is estimated to be 4.6%, representing 151 million people, and is expected to go up to 333 million people by 2025. Recent reports have estimated an increase in these figures, with the global prevalence reaching up to 6.6%, representing 285 million people in 2010 and by 2030, it will rise up globally up to 7.8% (438 million people). Also, individual national prevalence rates from over 1% to almost 31% have been reported, severely affecting the developing countries and, more specifically, the lower socioeconomic groups. Diabetes is rapidly emerging as a major public health challenge. In 2010, diabetes will share 11.6% of the entire international healthcare expenses, much of which will comprise hospital admissions and medications. According to the International Diabetes Federation (IDF), the overall cost assessment for the global prevention and treatment of diabetes will run up to US$490 billion by 2030.[1] The occurrence of diabetes is higher in men than in women, but more women are reported to be suffering from diabetes than men. A notable increase in the proportion of people suffering from diabetes with >65 years of age is also reported.[6] Studies have indicated a shocking rise in the prevalence of diabetes in India.[2] According to the WHO, India had 31.7 million diabetic subjects in the year 2000, and this number would increase up to 79.4 million by the year 2030.[6] Currently, India has the highest number of diabetic patients, and India is being called the diabetic capital of the world.[7] Studies have shown a significant age-related prevalence in the urban population, largely among the people with sedentary life style.[8]

Pathophysiology of Diabetes Mellitus

Diabetes mellitus is divided into two main types: type I (insulin -dependent diabetes mellitus or IDDM) and type II (non -insulin -dependent diabetes mellitus or NIDDM). IDDM occurs due to insulin insufficiency because the body does not generate any insulin and patients entirely depend on an exogenous supply of insulin. IDDM is more pronounced in children and young adults. It causes severe damage to the pancreatic β-cells. It is categorized as autoimmune (immune mediated) diabetes (type 1A) or idiopathic diabetes with β -cell destruction (type 1B), although the precise description of the later is still unknown.[9] Patients suffering from NIDDM are unable to respond to insulin and can be treated with exercise, diet management and medication.

Mostly, its onset is in adulthood, largely occurring in obese people over 40 years of age. NIDDM is the most widespread type. It indicates a condition with disturbed carbohydrate and fat metabolism. Hypertension, hyperlipidemia, hyperinsulinemia and atherosclerosis are often allied with diabetes. Both the types demonstrate some frequent symptoms like high blood sugar levels, unusual thirst, extreme hunger, frequent urination, extreme weakness, blurred vision etc. Although the pathophysiology of diabetes is not entirely understood, many studies indicate the participation of free radicals in the pathogenesis of diabetes[10] and its complications.[11–13] Free radicals are proficient enough of damaging cellular molecules, proteins, lipids and DNA, leading to alternation of cell functions. In fact, the abnormalities in lipids and proteins are one of the key reasons for the development of diabetic complications. During diabetes, free radicals oxidize the lipoproteins, and various irregularities of lipoprotein metabolism also occur in very low-density lipoprotein (VLDL), low-density lipoprotein (LDL) and high-density lipoprotein (HDL) in diabetes.[2] Different extracellular proteins are also modified into glycoprotein due to high blood glucose, which is associated with severe diabetic complications.[14] Reactive oxygen species (ROS) are being reported to be formed in different tissues in diabetes[15,16] by various sources such as the nonenzymatic glycosylation reaction,[17] the electron transport chain in mitochondria[18] and membrane -bound NADPH oxidase.[19,20] ROS are also involved in the progression of insulin resistance as well as pancreatic β-cell dysfunction.[21] Also, advanced glycation end products (AGEs) are produced by non -enzymatic glycosylation of proteins, which tends to mount up on long -lived molecules in tissues creating abnormalities in cell and tissue functions.[22,23] AGEs also play a role in improved vascular permeability in both micro- and macro-vascular structures by sticking to specific macrophage receptors, which leads to free radical production and endothelial dysfunction. AGEs, produced on nucleic acids, may also lead to altered gene expression and mutation. In diabetes, oxidative stress coexists along with decrease in the antioxidant status, which can lead to the detrimental effects due to free radicals.[24] Vitamins C and E, the natural antioxidants, have been reported to decrease the oxidative stress in experimental diabetes.[25] Numerous plant products have been reported to have a significant antioxidant activity, which may be of some benefit in diabetes.[26,27]

Conventional Treatment

Diabetes is a multidimensional disorder and its management needs firm adherence to the prescribed treatment plan. The contemporary treatment of diabetes is focused on suppressing and controlling blood glucose to a normal level. The common agreement on management of type II diabetes is transformation in lifestyle along with appropriate diet and weight control. However, antidiabetic drugs are needed as these measures cannot provide satisfactory results. Antidiabetic drug therapy includes insulin injections and oral hypoglycemic drugs. These drugs act by various mechanisms to control the blood glucose level. However, many side-effects such as hypoglycemia, lactic acid intoxication and gastrointestinal upset, etc. have been reported in patients.[28] Because the antidiabetic medication may sometimes involve prescribing more than one drug at the same time, which can augment the severity of these side-effects, efforts are being made to find a suitable antidiabetic and antioxidant therapy.

Medicinal Plants with Antidiabetic Activity and other Beneficial Effects

There are various herbal antidiabetic remedies used in various traditional systems of medicine prevailing around the world, although only some of them have been scientifically assessed for their efficacy. A list of the various medicinal plants with their antidiabetic and associated useful effects is given in Table 1.

Aegle marmelos (Bengal quince*, Bel†): Family - Rutaceae

The leaf extract *of Aegle marmelos (A. marmelos)*, when given to alloxanized rats, has shown to reduce the blood sugar, urea, liver glycogen and serum cholesterol and also improve digestion. Along with this, it has also checked the peak rise in blood sugar in the oral glucose tolerance test (OGTT).[150,174] Reduction in oxidative stress along with decreased blood glucose level has also been reported with the methanolic extract in alloxanized rats as apparent from the significant diminution in lipid peroxidation along with restored antioxidant enzyme levels.[175] Treatment of streptozotocin-diabetic rats with the leaf extract of *A. marmelos* demonstrated superior functional state of pancreatic β-cells as it facilitates in the regeneration of damaged pancreas.[176] Further investigation has revealed the presence of various important chemical constituents such as scopoletin and umbelliferone, which provides additional therapeutic benefits (in hyperthyroidism and collagen-mediated diabetic nephropathy).[177,178]

Allium cepa (Onion*): Family - Amaryllidaceae

The ether extract of *Allium cepa* (*A. cepa*) has shown antihyperglycemic activity in diabetic rabbits.[179] Also, a 1 ml solution (0.4 g A. *cepa*/rat) when given to streptozotocin -diabetic rats causes an augmentation in fasting serum diabetic HDL levels, demonstrating alleviation of hyperglycemia along with considerable antioxidant activity.[180] Moreover, when diabetic patients were administered a single oral dose of onion juice, it markedly controlled the post-prandial glucose levels.[181] *A. cepa* is also reported to have a hypolipidemic effect. Administration of S-methyl cysteine sulfoxide (SCMS), a sulfur-containing amino acid from onion, significantly controlled the levels of blood glucose as well as lipids and also normalized the activities of glucose 6 -phophatase and 3 -hydroxy -3 -methylglutaryl coenzyme -A (HMG Co -A) reductase in alloxanized rats.[182] A new compound, (S(S) R(C)) -S -(3 -pentenyl) -L -cysteine sulfoxide, which is obtained from the seed extract of *A. cepa* var. *tropeana* has also been reported to contain antioxidant properties.[183]

Allium sativa (Garlic*): Family - Amaryllidaceae

When the aqueous extract of garlic [Figure 1] is given orally to sucrose-fed rabbits, it considerably improved hepatic glycogen and free amino acid content, reduced fasting blood glucose and triglyceride levels in serum.[184] Also, garlic extract administered to streptozotocin-diabetic rats not only decreased the blood glucose level but also inhibited the lipid peroxidation and inhibited the superoxide formation. This study has also recommended its long-term use in preventing diabetic complications. However, the extrapolation of these results to humans needs further research.[52] Most recent findings have also proposed that aged garlic extract inhibits the generation of glycation -derived free radicals and AGEs *in vitro*. S -allyl cysteine, [Figure 1] a chief ingredient of aged garlic, is a potent antioxidant that can inhibit AGEs synthesis and, thus, deserves more attention.[185] Evidence also proposes that the antioxidative, anti -inflammatory

and antiglycative properties of garlic are accountable for its role in preventing diabetes and its complications.[186] Allicin, [Figure 1] a sulfur -containing compound isolated from garlic, is the reason for its pungent odor and also has considerable hypoglycemic action,[187] which is thought to be due to the augmented hepatic metabolism, insulin release and/or insulin-sparing effect.[188] Researchers have also reported that allicin contains considerable antioxidant[189] and antimalarial activities.[190] S -allyl cysteine sulfoxide (SACS), the precursor of allicin and garlic oils, is reported to control lipid peroxidation better than glibenclamide and insulin and also stimulated *in vitro* insulin release from the β-cells isolated from normal rats.[191] Ajoene, [Figure 1] obtained from garlic, has been reported to show antithrombotic, anti -tumor, antifungal and antiparasitic properties,[192] thus making garlic a useful plant.

Caesalpinia bonducella (Gray Nicker*): Family - Fabaceae

The aqueous and ethanolic extracts of *Caesalpinia bonducella* (*C. bonducella*) demonstrated potent hypoglycemic activity in chronic type II diabetes. These extracts also improved glycogenesis, thereby escalating the liver glycogen content.[193] Aqueous and 50% ethanolic extracts of *C. bonducella* seeds have also shown antihyperglycemic and hypolipidemic activities in streptozotocin -diabetic rats.[194] Oral administration of seed extracts to alloxanized rats not only produced considerable lowering of the blood urea nitrogen levels but it also lowered the elevated cholesterol as well as LDL levels, confirming that the drug also has the potential to show antidiabetic as well as antihyperlipidemic effects. This antihyperglycemic action may be due to obstruction in absorption of glucose.[195]

Capparis deciduas (Kerda†, Kair†, Karir†): Family - Capparaceae

Hypoglycemic effect was reported in alloxanized rats fed with the fruit powder of the *Capparis decidua* (*C. decidua*) plant. The powdered extract also significantly decreased the alloxan -induced lipid peroxidation in erythrocytes, kidney and heart. *C. decidua* is also reported to alter antioxidant enzyme levels and decreases oxidative stress.[196] The antidiabetic potential may be due to the alkaloids present in it. When the alkaloid-rich fraction of *C. decidua* plant was given to streptozotocin -diabetic rats, it demonstrated promising results, establishing its claim for further purification and categorization of the individual alkaloids.[197]

Coccinia indica (Ivy Gourd*, Little Gourd*): Family - Cucurbitaceae

The combined extract of *Coccinia indica* (*C. indica*) with *Musa paradisiaca* has shown a defensive effect against diabetes through β-cell regeneration in streptozotocin -diabetic albino rats.[198] Also, an aqueous -methanol extract of *C. indica* along with *Musa paradisiaca*, *Tamarindus indica* and *Eugenia jambolana* provided considerable defense against testicular dysfunction along with lowering of blood glucose.[199] In a study on diabetic patients, dried extracts of *C. indica*, when administered, helped to restore the normal activities of lipoprotein lipase, glucose -6 -phosphatase and lactate dehydrogenase,[200] while in a double -blind, placebo -controlled, randomized trial on type 2 diabetic patients, the alcoholic extract of the herb significantly decreased the fasting and postprandial blood glucose levels in the experimental group as compared with the placebo group. However, no considerable alterations in the serum lipid levels were observed.[201]

Eriobotrya japonica (Loquat†): Family - Rosaceae

Eriobotrya japonica (E. japonica) has been reported to show a distinct hypoglycemic action in normal and alloxanized rabbits and mice.[202–204] Studies have revealed that 300 mg/kg of the leaf extract in streptozotocin-diabetic mice induced significant decrease in plasma glucose concentration, glycosylated serum protein, total cholesterol, triglycerides and oxidative stress.[205] The leaf extracts of *E. japonica* are also known to inhibit 11β-hydroxy steroid dehydrogenase (HSD) type 1, preferentially over 11β -HSD2, which might add to the antidiabetic effect of the plant.[206] Further, studies demonstrated that sesquiterpene glycosides and polyhydroxylated triterpenoids are the active ingredients of *E. japonica* accountable for controlling diabetes mellitus.[207] Also, the total triperpene acid fraction from the leaves demonstrated a high anti -diabetic potential beside hypolipidemic and antioxidant profile in alloxan and streptozotocin-diabetic mice.[208]

Eugenia jambolana (Jambul†): Family - Myrtaceae

Decoction of *Eugenia jambolana* (*E. jambolana*) seed kernel is used as a domestic preparation for diabetes and it also forms a key ingredient of several antidiabetic herbal formulations. The pulp extract of Eugenia demonstrated hypoglycemic activity promptly than the seed extract in streptozotocin-diabetic mice. Increased serum insulin levels and inhibition of insulinase activity from liver and kidney was observed on oral administration of the extract in diabetic rats.[209] Ethanolic extract of Eugenia seed kernel also established its antioxidant potential along with hypoglycemic effect in streptozotocin-diabetic rats.[210] Combination treatment of lower dose of glimepiride together with ethanolic Eugenia seed extract showed potent hypoglycemic as well as antihyperglycemic activities without stern hypoglycemia in normal rats, concluding its possible use in considerable dose reduction of standard drugs.[211] However, examination of the Brazilian Eugenia fruit has uncovered no beneficial effect of the plant extract in diabetic rats.[212]

Ginseng species: - Family - Araliaceae

Ginseng root has been used since long because of its medicinal properties. Medicinally important ginseng species include *Panax ginseng* (*Asian ginseng**) [Figure 2] and *Panax quinquefolius* (American ginseng*). The main chemical constituents of the entire ginseng species are ginsenosides, polysaccharides, peptides, polyacetylenic alcohol and fatty acids, with ginsenosides being the most important pharmacological constituent.[213] Ginsenosides have been the object of countless researches as they are believed to be the key principles behind the efficacy and potential effects of ginseng. Therefore, it is also imperative to assess its worth using various analytical techniques.[214] Animal study data indicate that both Asian ginseng[215,216] and American ginseng[217,218] have a prominent hypoglycemic effect, which may be due to ginsenoside Rb -2 [Figure 2] and, more specifically, because of panaxans I, J, K and L in type 1 diabetic models.[219–222] American ginseng has also been reported to inhibit the tumor necrosis factor -alfa (TNF -α)-stimulated free fatty acid release and also attenuated the TNFα -inhibition of adiponectin secretion.[136] Hypoglycemic activity of ginseng has also been established by clinical studies.[223,224] However, a few adverse effects of ginseng have been observed, most common of which are nervousness and excitation, which are diminished with continued use or

dosage reduction. Massive overdose of drug can lead to ginseng abuse syndrome.[225] The suggested dosage is 1 - 3 g of the plant's crude root daily or 200 - 600 mg of standardized extract.[226]

Gymnema sylvestre (Gymnema*, Australian cow plant*): Family - Asclepiadaceae

Gymnema sylvestre (*G. sylvestre*) has been used in the treatment of diabetes since ages. Assessment of the alcoholic extract of *G. sylvestre* on insulin secretion from the islets of langerhans and several pancreatic β-cell lines of rats has uncovered that the extract stimulated insulin release from several β-cells and islets, due to increased cell permeability.[227] The ethanolic extract of Gymnema displayed hypoglycemic and antihyperglycemic activity in rats when given alone or in combination with any standard drug, and could be used for dose reduction of the standard drug.[211] Recently, an active compound, dihydroxy gymnemic triacetate, has been isolated from its acetone extract. When it was given orally to streptozotocin-diabetic rats, it produced considerable hypoglycemia along with hypolipidemic effects.[228] In a study on type 2 diabetic subjects, the *G. sylvestre* extract was given daily to 22 patients along with oral hypoglycemic drugs, which improved blood sugar control. Five patients were able to retain blood sugar control with Gymnema extract without the help of oral medication.[229] One of its side-effects may be reduction/loss of taste sensation. The recommended dosage of *G. sylvestre* extract is 400 - 600 mg/day.[230]

Mangifera indica (Mango*): Family - Anacardiaceae

Although no change in blood glucose level was reported when the aqueous mango extract was given to streptozotocin-diabetic rats, antidiabetic activity was observed when the aqueous extract was given before/along with glucose, which could be due to decreased intestinal glucose absorption.[231] Analysis of the peel extract of *Mangifera indica* (*M. indica*) [Figure 3] in rats revealed their potential to ameliorate diet-induced change in serum lipids, thyroid dysfunctions and hyperglycemia, which could be due to polyphenols and ascorbic acid present in the test peel extract.[80] Lupeol, [Figure 3] a triterpene found in mango, is acknowledged to display antioxidant, antilithiatic and antidiabetic effects and is also established to be valuable in combating oxidative stress-induced cellular injury of mouse liver by modulating cell -growth regulators.[232] Also, mangiferin, [Figure 3] a xanthone glucoside, isolated from mango leaves possesses considerable antidiabetic, antihyperlipidemic and antiatherogenic properties as obvious from lowering of fasting glucose level, decrease in total cholesterol, triglycerides and LDL -cholesterol along with elevation of the HDL -cholesterol level and diminution of atherogenic index in diabetic rats.[233]

Momordica charantia (Bitter gourd*, Karela†): Family - Cucurbitaceae

It is commonly used as an antidiabetic agent. Extracts from various parts of the plant have shown hypoglycemic activity in different animal models. Ethanolic extracts of *Momordica charantia* (*M. charantia*) showed hypoglycemic and antihyperglycemic effect in normal and streptozotocin-diabetic rats, which could be due to inhibition of glucose -6 -phosphatase and stimulation of hepatic glucose - 6 -phosphate dehydrogenase activity.[234] Studies concerning

mechanism of bitter gourd in alloxanized rats suggested its potential antidiabetic, antihyperlipidemic and other valuable effects in amelioration of diabetic complications. Furthermore, it restores the altered histological architecture of the islets of Langerhans.[235] The latest finding on high -fat -fed rats treated with bitter gourd extract showed better insulin sensitivity, glucose tolerance and insulin signaling. Detection of the possible mechanism of these effects may unlock novel therapeutic targets for the management of obesity/dyslipidemia -induced insulin resistance.[236] Aqueous seed extract of Momordica also provides notable protection against lipid peroxidation in streptozotocin-diabetic rats due to its antioxidant activity.[237,238] Antidiabetic screening of Momordica on differentiating 3T3 -L1 adipocytes has shown inhibition of TNF-α -stimulated free fatty acid release and attenuation of TNF-α -induced inhibition of adiponectin secretion.[136] Animal studies have suggested many parallels between the actions of metformin and bitter gourd.[239] Recent extensive screening has identified triterpenoids to be the hypoglycemic components present in Momordica that may be responsible for insulin resistance and in activation of AMP -activated protein kinase.[240] Polypeptide p, isolated from the fruit, seeds and tissues of *M. charantia* showed significant hypoglycemic effect in human.[241] Because diet is one of the approaches in the management of diabetes mellitus, there is scope for exploiting the antidiabetic potency of Momordica to the maximum extent.[242] However, there are insufficient evidences to recommend it for type 2 diabetes mellitus due to a lack of significant data on morbidity, expected expenditure, etc.[243] Traditionally, it is used to cure numerous disorders. A number of studies have authenticated its use in diabetes and its complications as antibacterial, antiviral, anticancer, abortifacient, etc. However, only a few reports showing positive results on its clinical use are available.[244]

Ocimum sanctum (Holy basil*, Tulsi†): Family - Lamiaceae

Ocimum sanctum (*O. sanctum*) is known for its therapeutic benefits since ancient times. The aqueous extract of *O. sanctum* leaves demonstrated considerable decrease in blood sugar level in both normal and alloxanized rats.[245] Marked fall in fasting blood glucose along with decrease in uronic acid, total cholesterol, triglyceride and total lipid level point toward its health-benefitting effects.[246] Administration of the ethanolic leaf extract has been reported to lessen the plasma glucose level along with increase in the renal glycogen content, while skeletal muscle and hepatic glycogen levels are decreased in streptozotocin-diabetic rats.[247] This plant is also known to possess antimicrobial, adaptogenic, hepatoprotective, anti -inflammatory, anti -carcinogenic, neuroprotective, cardio -protective, mosquito repellent and numerous other therapeutic activities.[52,248]

Phyllanthus amarus (Stonebreaker*, Seed-Under-Leaf*): Family - Phyllanthaceae

Traditionally, *Phyllanthus amarus* (*P. amarus*) is used in the treatment of diabetes. The methanolic extract of *P. amarus* was found to reduce the blood sugar in alloxanized diabetic rats along with potential antioxidant activity.[249] Complete inhibition of TNF-α -stimulated free fatty acid release and attenuation of TNF-α -induced inhibition of adiponectin secretion was observed while screening its antidiabetic effects on 3T3 -L1 adipocytes.[136] *P. amarus* is a potential diuretic and hypotensive drug for humans.[250] Interestingly, other plants of the Phyllanthus species also possess medicinal properties.[93,251–253]

Psidium guajava (Common guava*): Family - Myrtaceae

Various studies revealed that various parts of *Psidium guajava* have antidiabetic property. The aqueous guava leaf extract showed hypoglycemic activity in alloxanized and streptozotocin-diabetic rats, which is attributed to the various tannins, flavonoids and other chemical constituents of the plant.[254,255] In a different study, anti -hyperglycemic activity of the ethanol extract of stem bark of the plant was assessed on normal, alloxanized and normal glucose-loaded rats, and the results showed that the extract displayed considerable hypoglycemic activity in all except normal and glucose-loaded rats.[256] Antidiabetic property was also observed when the butanol-soluble fraction of the leaves was given to Lepr db/Lepr db mice.[257] The leaf extract of guava was shown to inhibit the α-glucosidase activity in the small intestine of diabetic mice.[258] Considerable hypolipidemic activity has also been reported when the aqueous extract of the raw fruit peel was given to streptozotocin-diabetic rats, besides hypoglycemic and antidiabetic activity.[259]

Pterocarpus marsupium (Indian kino tree*): Family - Fabaceae

Pterostilbene, obtained from *Pterocarpus marsupium* (*P. marsupium*) wood, showed hypoglycemic activity in dogs.[260] Flavonoids obtained from *P. marsupium* have been reported to cause pancreatic β-cell regranulation.[261] The flavanoid fraction has also showed antihyperlipidemic activity.[262] Also, the aqueous extract of the latex of *P. marsupium* was found to possess marked α-glucosidase inhibitory activity.[76] One of the active principles of Pterocarpus, (-) epicatechin, has insulinogenic action. It stimulate oxygen uptake in fat cells and tissue slices of different organs, and also enhances the glycogen content of the rat diaphragm in a dose-dependent manner.[263]

Trigonella foenum graecum (Fenugreek*): Family - Fabaceae

Fenugreek seeds are frequently used as a constituent of spices. Oral administration of the plant extract produced lowering of the blood glucose levels in both normal as well as diabetic rats.[264] Administration of fenugreek seeds also enhanced glucose metabolism and stabilized creatinine kinase activity in heart, skeletal muscle and liver of diabetic rats.[265] Fenugreek plant has also been reported to show antioxidant activity.[266,267] Further, daily oral treatment of its steroids to diabetic rats demonstrated a significant decrease of blood glucose level and a substantial enhancement of the area of insulin -immunoreactive β-cells along with considerable reduction in sperm shape abnormality and improved sperm count.[268] 4-hydroxyisoleucine, isolated from fenugreek seeds, exhibits marked potential as an anti -diabetic agent by suppressing progression of type II diabetes in the db/db mice model, as apparent from improvement of insulin sensitivity and glucose uptake in peripheral tissue.[269] When fenugreek oil is given to alloxanized rats, notable reduction in renal toxicity besides improved hematological status and antidiabetic effect has also been accounted, which could be due to the immunomodulatory activity and insulin stimulation action of fenugreek.[270] Fenugreek seeds are also known to possess a hypolipidemic effect[271] and also offer antilithogenic potential due to its encouraging effect on cholesterol metabolism.[272] Its seed has also been shown to be effective in the prevention of retinopathy and other diabetic complications when used alone or in combination with sodium orthovandate.[273,274] The seed extract also considerably repressed

the 7, 12 -dimethylbenz (α) anthracene (DMBA) -induced mammary hyperplasia and reduced its incidence.[275] It has shown no genotoxic effect, and has a wide safety margin. Also, adding the fenugreek seed extract to foodstuffs for diabetic patients is predicted to be safe.[276]

Tinospora cordifolia (Guduchi†): Family - Menispermiaceae

Tinospora cordifolia (*T. cordifolia*) is extensively employed for treating diabetes mellitus in the traditional system of medicine.[277–279] Oral administration of the root extract of *T. cordifolia* led to a considerable decrease in blood and urine glucose and in lipids in alloxanized rats and also prevented reduction in body weight.[280] Also, the aqueous root extract of the plant resulted in considerable decrease in blood glucose and brain lipids in alloxanized rats. Although the extract showed significant antihyperglycemic effect, its effect was comparable only to 1 unit/kg of insulin.[281] It is also accounted that the daily administration of the aqueous or alcoholic extract of *T. cordifolia* reduces the blood glucose level and enhances glucose tolerance in rodents.[282]

Stevia rebaudina (Sweet Leaf*, Sugar leaf*): Family - Asteraceae

Stevioside, [Figure 4] a natural sweetener obtained from the plant *Stevia rebaudiana* (*S. rebaudiana*), [Figure 4] has been used in the treatment of diabetes since a long time. It stimulates secretion of insulin via a direct action on the pancreatic cells, and is thought to have significant antidiabetic potential.[283,284] However, a comparative study between *S. rebaudiana* and stevioside has revealed that the hypoglycemia due to *S. rebaudiana* leaves was partially mediated by inhibition of hepatic gluconeogenesis and did not involve stevioside and peroxisome proliferator -activated receptor -gamma (PPAR -γ) receptors activation.[285] Rebaudioside, [Figure 4] a new diterpene glycoside, also possesses insulinotropic effects and may provide support in the treatment in type 2 diabetes mellitus.[286] A study of stevioside on insulin -sensitive lean (Fa/ -) and insulin -resistant obese (Fa/Fa) Zucker rats revealed the skeletal muscle glucose transport system to be one of its possible sites of action.[287] Stevioside is also reported to exercise antihyperglycemic, insulinotropic, blood pressure lowering and glucagonostatic effects in type 2 diabetic Goto - kakizaki rats, proving its worth in the treatment of type 2 diabetes and metabolic syndrome.[284,288] Stevioside and steviol may have a potential as an antihyperglycemic agent. While investigating their effects on insulin release from normal mouse islets and the β -cell line INS -1, it came to appear that the insulinotropic effects of stevioside and steviol were significantly reliant on the prevailing glucose concentration, and that they also stimulate insulin secretion by acting on pancreatic β-cells.[289]

Conclusion

The number of people suffering from diabetes mellitus has been increasing dramatically over the past few decades, and this demands special attention towards its management. The few conventional therapies available are either expensive or often related with adverse effects; therefore, various traditional therapies with antihyperglycemic effect are increasingly sought by patients. Medicinal plants provide better alternatives as they are generally less-toxic and affordable; yet, their safety and efficacy needs more evaluation by controlled clinical studies. Although herbs are less likely to have drawbacks of the conventional drugs used for diabetes,

potential herb -drug interactions should be kept in mind for those receiving conventional antidiabetic medications. Taking all these details into account, further research is required to validate the antidiabetic effects of medicinal plants.

Footnotes

Source of Support: Nil

Conflict of Interest: None declared.

References

1. Colagiuri R. Diabetes: A pandemic, a development issue or both? Expert Rev Cardiovasc Ther. 2010;8:305–9. [PubMed: 20222807]
2. Modak M, Dixit P, Londhe J, Ghaskadbi S, Devasagayam TP. Indian herbs and herbal drugs used for the treatment of diabetes. J Clin Biochem Nutr. 2007;40:163–73. [PMCID: PMC2275761] [PubMed: 18398493]
3. Ali H, Houghton PJ, Soumyanath A. α-amylase inhibitory activity of some Malaysian plants used to treat diabetes; with particular reference to *Phyllanthus amarus*. J Ethnopharmacol. 2006;107:449–55. [PubMed: 16678367]
4. Marles R, Farnsworth NR. Plants as sources of antidiabetic agents. In: Wagner H, Farmsworth NR, editors. Economic and Medicinal Plant Research. UK: Academic Press Ltd; 1994. pp. 149–87.
5. Bailey CJ, Day C. Traditional plant medicines as treatments for diabetes. Diabetes Care. 1989;12:553–64. [PubMed: 2673695]
6. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. Diabetes Care. 2004;27:1047–53. [PubMed: 15111519]
7. Mohan V, Sandeep S, Deepa R, Shah B, Varghese C. Epidemiology of type 2 diabetes: Indian scenario. Indian J Med Res. 2007;125:217–30. [PubMed: 17496352]
8. Gupta A, Gupta R, Sarna M, Rastogi S, Gupta VP, Kothari K. Prevalence of diabetes, impaired fasting glucose and insulin resistance syndrome in an urban Indian population. Diabetes Res Clin Pract. 2003;61:69–76. [PubMed: 12849925]
9. Alberti KG, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications.Part 1: Diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. Diabet Med. 1998;15:539–53. [PubMed: 9686693]
10. Mattecci E, Giampietro O. Oxidative stress in families of type I diabetic patient. Diabetes Care. 2000;23:1182–6. [PubMed: 10937519]
11. Oberlay LW. Free radicals and diabetes. Free Radic Biol Med. 1988;5:113–24. [PubMed: 3075947]
12. Baynes JW, Thorpe SR, Suzanne R. The role of oxidative stress in diabetic complications. Curr Opin Endocrinol Diabetes Obes. 1996;3:277–84.
13. Lipinski B. Pathophysiology of oxidative stress in diabetes mellitus. J Diabetes Complications. 2001;15:203–10. [PubMed: 11457673]
14. Glugliano D, Ceriello A, Paolisso G. Oxidative stress and diabetic vascular complications. Diabetes Care. 1996;19:257–67. [PubMed: 8742574]

15. Baynes JW, Thorpe SR. Role of oxidative stress in diabetic complications: A new perspective on an old paradigm. Diabetes. 1999;48:1–9. [PubMed: 9892215]
16. Dandona P, Thusu K, Cook S, Snyder B, Makowski J, Armstrong D, et al. Oxidative damage to DNA in diabetes mellitus. Lancet. 1996;347:444–5. [PubMed: 8618487]
17. Sakurai T, Tsuchiya S. Superoxide production from nonenzymatically glycated protein. FEBS Lett. 1988;236:406–10. [PubMed: 2842191]
18. Brownlee M. Biochemistry and molecular cell biology of diabetic complications. Nature. 2001;414:813–20. [PubMed: 11742414]
19. Harrison D, Griendling KK, Landmesser U, Hornig B, Drexler H. Role of oxidative stress in atherosclerosis. Am J Cardiol. 2003;91:7A–11.
20. Mohazzab KM, Kaminski PM, Wolin MS. NADH oxidoreductase is a major source of superoxide anion in bovine coronary artery endothelium. Am J Physiol. 1994;266:H2568–72. [PubMed: 8024019]
21. Evans JL, Goldfine ID, Maddux BA, Grodsky GM. Oxidative stress and stress-activated signalling pathways: A unifying hypothesis of type 2 diabetes. Endocr Rev. 2002;23:599–622. [PubMed: 12372842]
22. Brownlee M. Advanced protein glycosylation in diabetes in diabetes and ageing. Annu Rev Med. 1996;46:223–34. [PubMed: 7598459]
23. Elgawish A, Glomb M, Friendlander M, Monnier VM. Involvement of hydrogen peroxide in collagen cross-linking by high glucose *in vitro* and *in vivo*. J Biol Chem. 1999;271:12964–71. [PubMed: 8662699]
24. Collier A, Wilson R, Bradley H, Thomson JA, Small M. Free radical activity is type 2 diabetes. Diabet Med. 1990;7:27–30. [PubMed: 2137060]
25. Garg MC, Bansal DD. Protective antioxidant effect of vitamins C and E in streptozotocin induced diabetic rats. Indian J Exp Biol. 2000;38:101–4. [PubMed: 11218824]
26. Anjali P, Manoj KM. Same comments on diabetes and herbal therapy. Anc Sci Life. 1995;15:27–9.
27. Jain SR, Sharma SN. Hypoglycemic drugs of Indian indigenous origin. Planta Med. 1967;15:439–42. [PubMed: 5603487]
28. Li WL, Zheng HC, Bukuru J, De Kimpeb N. Natural medicines used in the traditional Chinese medical system for therapy of diabetes mellitus. J Ethnopharmacol. 2004;92:1–21. [PubMed: 15099842]
29. Wadood A, Wadood N, Shah SA. Effects of *Acacia arabica* and *Caralluma edulis* on blood glucose levels on normal and alloxan diabetic rabbits. J Pak Med Assoc. 1989;39:208–12. [PubMed: 2509753]
30. Wu HS, Zhu DF, Zhou CX, Feng CR, Lou YJ, Yang B, et al. Insulin sensitizing activity of ethyl acetate fraction of *Acorus calamus* L. *in vitro* and *in vivo*. J Ethnopharmacol. 2009;123:288–92. [PubMed: 19429374]
31. Wu HS, Li YY, Weng LJ, Zhou CX, He QJ, Lou YJ. A fraction of *Acorus calamus* L. extract devoid of β-asarone enhances adipocyte differentiation in 3T3-L1 cells. Phytother Res. 2007;21:562–4. [PubMed: 17335118]
32. Al-awadi FM, Gumaa KA. Studies on the activity of individual plants of an antidiabetic plant mixture. Acta Diabetol Lat. 1987;24:37–41. [PubMed: 3618079]
33. Ajabnoor MA. Effect of aloes on blood glucose levels in normal and alloxan diabetic mice. J Ethnopharmacol. 1990;28:215–25. [PubMed: 2109811]

34. Davis RH, Maro NP. Aloe vera and gibberellins, anti-inflammatory activity in diabetes. J Am Podiatr Med Assoc. 1989;79:24–6. [PubMed: 2724102]
35. Chen W, Lu Z, Viljoen A, Hamman J. Intestinal drug transport enhancement by *Aloe vera*. Planta Med. 2009;75:587–95. [PubMed: 19214949]
36. Rajasekaran S, Ravi K, Sivagnanam K, Subramanian S. Beneficial effects of *Aloe vera* leaf gel extract on lipid profile status in rats with streptozotocin diabetes. Clin Exp Pharmacol Physiol. 2006;33:232–7. [PubMed: 16487267]
37. Rajasekaran S, Sivagnanam K, Subramanian S. Modulatory effects of *Aloe vera* leaf gel extract on oxidative stress in rats treated with streptozotocin. J Pharm Pharmacol. 2005;57:241–6. [PubMed: 15720789]
38. Panda S. The effect of *Anethum graveolens* L.(dill) on corticosteroid induced diabetes mellitus: Involvement of thyroid hormones. Phytother Res. 2008;22:1695–7. [PubMed: 18814208]
39. Kaleem M, Asif M, Ahmed QU, Bano B. Antidiabetic and antioxidant activity of *Annona squamosa* extract in streptozotocin-induced diabetic rats. Singapore Med J. 2006;47:670–5. [PubMed: 16865205]
40. Gupta RK, Kesari AN, Murthy PS, Chandra R, Tandon V, Watal G. Hypoglycaemic and antidiabetic effect of ethanolic extract of leaves of *Annona squamosa* L. in experimental animals. J Ethanopharmacol. 2005;99:75–81.
41. Gupta RK, Kesari AN, Watal G, Murthy PS, Chandra R, Tandon V. Nutritional and hypoglycaemic effect of fruit pulp of *Annona squamosa* in normal healthy and alloxan-induced diabetic rabbits. Ann Nutr Metab. 2005;49:407–13. [PubMed: 16230844]
42. Panda S, Kar A. Antidiabetic and antioxidative effects of *Annona squamosa* leaves are possibly mediated through quercetin-3-O-glucoside. Biofactors. 2007;31:201–10. [PubMed: 18997283]
43. Chempakam B. Hypoglycaemic activity of arecoline in betel nut *Areca catechu* L. Indian J Exp Biol. 1993;31:474–5. [PubMed: 8359856]
44. Liu M, Wu K, Mao X, Wu Y, Ouyang J. *Astragalus polysaccharide* improves insulin sensitivity in KKAy mice: Regulation of PKB/GLUT4 signaling in skeletal muscle. J Ethnopharmacol. 2010;127:32–7. [PubMed: 19800959]
45. Wang N, Zhang D, Mao X, Zou F, Jin H, Ouyang J. *Astragalus polysaccharides* decreased the expression of PTP1B through relieving ER stress induced activation of ATF6 in a rat model of type 2 diabetes. Mol Cell Endocrinol. 2009;307:89–98. [PubMed: 19524131]
46. Mao XQ, Yu F, Wang N, Wu Y, Zou F, Wu K, et al. Hypoglycemic effect of polysaccharide enriched extract of *Astragalus membranaceus* in diet induced insulin resistant C57BL/6J mice and its potential mechanism. Phytomedicine. 2009;16:416–25. [PubMed: 19201177]
47. Mao XQ, Wu Y, Wu K, Liu M, Zhang JF, Zou F, et al. *Astragalus polysaccharide* reduces hepatic endoplasmic reticulum stress and restores glucose homeostasis in a diabetic KKAy mouse model. Acta Pharmacol Sin. 2007;28:1947–56. [PubMed: 18031609]
48. Shen P, Liu MH, Ng TY, Chan YH, Yong EL. Differential effects of isoflavones, from *Astragalus membranaceus* and *Pueraria thomsonii*, on the activation of PPAR-α, PPAR-γ, and adipocyte differentiation *in vitro*. J Nutr. 2006;136:899–905. [PubMed: 16549448]
49. Wu Y, Ou-Yang JP, Wu K, Wang Y, Zhou YF, Wen CY. Hypoglycemic effect of *Astragalus polysaccharide* and its effect on PTP1B. Acta Pharmacol Sin. 2005;26:345–52. [PubMed: 15715932]

50. Tan BK, Tan CH, Pushparaj PN. Anti-diabetic activity of the semi-purified fractions of *Averrhoa bilimbi* in high fat diet fed-streptozotocin-induced diabetic rats. Life Sci. 2005;76:2827–39. [PubMed: 15808883]
51. Pushparaj PN, Tan BK, Tan CH. The mechanism of hypoglycemic action of the semi-purified fractions of *Averrhoa bilimbi* in streptozotocin-diabetic rats. Life Sci. 2001;70:535–47. [PubMed: 11811898]
52. Chandra A, Mahdi AA, Singh RK, Mahdi F, Chander R. Effect of Indian herbal hypoglycemic agents on antioxidant capacity and trace elements content in diabetic rats. J Med Food. 2008;11:506–12. [PubMed: 18800899]
53. Chattopadhyay RR, Chattopadhyay RN, Nandy AK, Poddar G, Maitra SK. Preliminary report on antihyperglycemic effect of fraction of fraction of fresh leaves of *Azadirachta indica* (Beng neem) Bull Calcutta Sch Trop Med. 1987b;35:29–35.
54. Chattopadhyay RR, Chattopadhyay RN, Nandy AK, Poddar G, Maitra SK. The effect of fresh leaves of *Azadiracta indica* on glucose uptake and glycogen content in the isolated rat hemidiaphragm. Bull Calcutta Sch Trop Med. 1987b;35:8–12.
55. Biswas K, Chattopadhyay I, Banerjee RK, Bandyopadhyay U. Biological activities and medicinal properties of neem (*Azadiracta indica*) Curr Sci. 2002;82:1336–45.
56. Roop JK, Dhaliwal PK, Guraya SS. Extracts of *Azadirachta indica* and *Melia azedarach* seeds inhibit folliculogenesis in albino rats. Braz J Med Biol Res. 2005;38:943–7. [PubMed: 15933789]
57. Oliveira AC, Endringer DC, Amorim LA, das Graças L Brandão M, Coelho MM. Effect of the extracts and fractions of Baccharis trimera and *Syzygium cumini* on glycaemia of diabetic and non-diabetic mice. J Ethnopharmacol. 2005;102:465–9. [PubMed: 16055289]
58. Suba V, Murugesan T, Arunachalam G, Mandal SC, Saha BP. Anti-diabetic potential of *Barleria lupulina* extract in rats. Phytomedicine. 2004;11:202–5. [PubMed: 15070173]
59. Suba V, Murugesan T, Rao RB, Ghosh L, Pal M, Mandal SC, Saha BP. Antidiabetic potential of *Barleria lupulina* extract in rats. Fitoterapia. 2004;75:1–4. [PubMed: 14693212]
60. Khalil NM, Pepato MT, Brunetti IL. Free radical scavenging profile and myeloperoxidase inhibition of extracts from antidiabetic plants: *Bauhinia forficata* and *Cissus sicyoides*. Biol Res. 2008;41:165–71. [PubMed: 18949134]
61. De Sousa E, Zanatta L, Seifriz I, Creczynski-Pasa TB, Pizzolatti MG, Szpoganicz B, Silva FR. Hypoglycemic effect and antioxidant potential of kaempferol-3,7-O-(α)-dirhamnoside from Bauhinia forficata leaves. J Nat Prod. 2004;67:829–32. [PubMed: 15165145]
62. Singh J, Kakkar P. Antihyperglycemic and antioxidant effect of *Berberis aristata* root extract and its role in regulating carbohydrate metabolism in diabetic rats. J Ethnopharmacol. 2009;123:22–6. [PubMed: 19429334]
63. Yoshikawa M, Murakami T, Kadoya M, Matsuda H, Muraoka O, Yamahara J, et al. Medicinal stuff. III sugar beet. Hypoglycaemic oleanolic acid oligosaccharides, betavulgarosides I, II, III and IV, from the root of Beta vulgaris L. Chem Pharm Bull (Tokyo) 1996;44:1212–7. [PubMed: 8814952]
64. Ponnusamy S, Ravindran R, Zinjarde S, Bhargava S, Ravi Kumar A. Evaluation of traditional Indian antidiabetic medicinal plants for human pancreatic amylase inhibitory effect *in vitro*. Evid Based Complement Alternat Med 2011. 2011:pii: 515647.
65. Kim HY, Yokozawa T, Cho EJ, Cheigh HS, Choi JS, Chung HY. *In vitro* and *in vivo* antioxidant effects of mustard leaf (Brassica juncea) Phytother Res. 2003;17:465–71. [PubMed: 12748980]

66. Yokozawa T, Kim HY, Cho EJ, Yamabi N, Choi JS. Protective effects of mustard leaf (*Brassica juncea*) against diabetic oxidative stress. J Nutr Sci Vitaminol (Tokyo) 2003;49:87–93. [PubMed: 12887153]
67. Somani R, Kasture S, Singhai AK. Antidiabetic potential of *Butea monosperma* in rats. Fitoterapia. 2006;77:86–90. [PubMed: 16376023]
68. Panda S, Jafri M, Kar A, Meheta BK. Thyroid inhibitory, antiperoxidative and hypoglycemic effects of stigmasterol isolated from *Butea monosperma*. Fitoterapia. 2009;80:123–6. [PubMed: 19105977]
69. Sharma N, Garg V. Antidiabetic and antioxidant potential of ethanolic extract of *Butea monosperma* leaves in alloxan-induced diabetic mice. Indian J Biochem Biophys. 2009;46:99–105. [PubMed: 19374261]
70. Sharmna N, Garg V. Antihyperglycemic and antioxidative potential of hydroalcoholic extract of *Butea monosperma* Lam flowers in alloxan-induced diabetic mice. Indian J Exp Biol. 2009;47:571–6. [PubMed: 19761041]
71. Gomes A, Vedasiromoni JR, Das M, Sharma RM, Ganguly DK. Antihyperglycemic effect of black tea (*Camellia sinensis*) in rats. J Ethanopharmacol. 1995;45:223–6.
72. Devasagayam TP, Kamat JP, Mohan H, Kesavan PC. Caffeine as an antioxidant: Inhibition of lipid peroxidation induced by reactive oxygen species. Biochim Biophys Acta. 1996;1282:63–70. [PubMed: 8679661]
73. Eddouks M, Lemhadri A, Michel JB. Caraway and caper: Potential anti-hyperglycaemic plants in diabetic rats. J Ethnopharmacol. 2004;94:143–8. [PubMed: 15261975]
74. Chandramohan G, Al-Numair KS, Sridevi M, Pugalendi KV. Antihyperlipidemic activity of 3-hydroxymethyl xylitol, a novel antidiabetic compound isolated from *Casearia esculenta* (Roxb.) root in streptozotocin-diabetic rats. J Biochem Mol Toxicol. 2010;24:95–101. [PubMed: 20146230]
75. Prakasam A, Sethupathy S, Pugalendi KV. Effect of *Casearia esculenta* root extract on blood glucose and plasma antioxidant status in streptozotocin diabetic rats. Pol J Pharmacol. 2003;55:43–9. [PubMed: 12856825]
76. Abesundara KJ, Matsui T, Matsumoto K. α-glucosidase inhibitory activity of some Sri Lanka plant extracts, one of which, *Cassia auriculata*, exerts a strong antihyperglycemic effect in rats comparable to the therapeutic drug acarbose. J Agric Food Chem. 2004;52:2541–5. [PubMed: 15113153]
77. Gupta S, Sharma SB, Bansal SK, Prabhu KM. Antihyperglycemic and hypolipidemic activity of aqueous extract of *Cassia auriculata* L. leaves in experimental diabetes. J Ethnopharmacol. 2009;123:499–503. [PubMed: 19473793]
78. Salahuddin M, Jalalpure SS, Gadge NB. Antidiabetic activity of aqueous bark extract of *Cassia glauca* in streptozotocin-induced diabetic rats. Can J Physiol Pharmacol. 2010;88:153–60. [PubMed: 20237590]
79. Lee MJ, Rao YK, Chen K, Lee YC, Tzeng YM. Effect of flavonol glycosides from *Cinnamomum osmophloeum* leaves on adiponectin secretion and phosphorylation of insulin receptor β in 3T3-L1 adipocytes. J Ethnopharmacol. 2009;126:79–85. [PubMed: 19682565]
80. Parmar HS, Kar A. Possible amelioration of atherogenic diet induced dyslipidemia, hypothyroidism and hyperglycemia by the peel extracts of *Mangifera indica, Cucumis melo* and *Citrullus vulgaris* fruits in rats. Biofactors. 2008;33:13–24. [PubMed: 19276533]
81. Parmar HS, Kar A. Antidiabetic potential of *Citrus sinensis* and *Punica granatum* peel extracts in alloxan treated male mice. Biofactors. 2007;31:17–24. [PubMed: 18806305]

82. Parmar HS, Kar A. Medicinal values of fruit peels from *Citrus sinensis, Punica granatum,* and *Musa paradisiaca* with respect to alterations in tissue lipid peroxidation and serum concentration of glucose, insulin, and thyroid hormones. J Med Food. 2008;11:376–81. [PubMed: 18598183]
83. Parmar HS, Kar A. Antiperoxidative, antithyroidal, antihyperglycemic and cardioprotective role of *Citrus sinensis* peel extract in male mice. Phytother Res. 2008;22:791–5. [PubMed: 18412146]
84. Chau CF, Huang YL, Lee MH. *In vitro* hypoglycemic effects of different insoluble fibre-rich fractions prepared from the peel of *Citrus sinensis* L. Liucheng. J Agric Food Chem. 2003;51:6623–6. [PubMed: 14558787]
85. Adeneye AA. Methanol seed extract of *Citrus paradisi* Macfad lowers blood glucose, lipids and cardiovascular disease risk indices in normal Wistar rats. Nig Q J Hosp Med. 2008;18:16–20. [PubMed: 19062465]
86. Sánchez-Salgado JC, Ortiz-Andrade RR, Aguirre-Crespo F, Vergara-Galicia J, León-Rivera I, Montes S, et al. Hypoglycemic, vasorelaxant and hepatoprotective effects of *Cochlospermum vitifolium* (Willd.) Sprengel: A potential agent for the treatment of metabolic syndrome. J Ethnopharmacol. 2007;109:400–5. [PubMed: 16978815]
87. Chika A, Bello SO. Antihyperglycaemic activity of aqueous leaf extract of *Combretum micranthum* (Combretaceae) in normal and alloxan-induced diabetic rats. J Ethnopharmacol. 2010;129:34–7. [PubMed: 20219661]
88. Shirwaikar A, Rajendran K, Punitha IS. Antidiabetic activity of alcoholic stem extract of *Coscinium fenestratum* in streptozotocin-nicotinamide induced type 2 diabetic rats. J Ethnopharmacol. 2005;97:369–74. [PubMed: 15707777]
89. Devi VD, Urooj A. Hypoglycemic potential of *Morus indica*. L and *Costus igneus* Nak.-a preliminary study. Indian J Exp Biol. 2008;46:614–6. [PubMed: 18814491]
90. Bavarva JH, Narasimhacharya AV. Antihyperglycemic and hypolipidemic effects of *Costus speciosus* in alloxan induced diabetic rats. Phytother Res. 2008;22:620–6. [PubMed: 18444247]
91. Zhao Y, Son YO, Kim SS, Jang YS, Lee JC. Antioxidant and anti-hyperglycemic activity of polysaccharide isolated from *Dendrobium chrysotoxum* Lindl. J Biochem Mol Biol. 2007;40:670–7. [PubMed: 17927899]
92. Omoruyi FO. Jamaican bitter yam sapogenin: Potential mechanisms of action in diabetes. Plant Foods Hum Nutr. 2008;63:135–40. [PubMed: 18594988]
93. Krishnaveni M, Mirunalini S. Therapeutic potential of *Phyllanthus emblica* (Amla): The ayurvedic wonder. J Basic Clin Physiol Pharmacol. 2010;21:93–105. [PubMed: 20506691]
94. Bhattacharya A, Chatterjee A, Ghosal S, Bhattacharya SK. Antioxidant activity of active tannoid principles of *Emblica officinalis* (Amla) Indian J Exp Biol. 1999;37:676–80. [PubMed: 10522157]
95. Kumar KC, Muller K. Medicinal plants from Nepal, II.Evaluation as inhibitors of lipid peroxidation in biological membranes. J Ethanopharmacol. 1999;64:135–9.
96. Devasagayam TP, Subramanian M, Singh BB, Ramanathan R, Das NP. Protection of plasmid pBR322 DNA by flavonoids against single-strand breaks induced by singlet molecular oxygen. J Photochem Photobiol B. 1995;30:97–103. [PubMed: 8558371]
97. Augusti KT, Daniel RS, Cherian S, Sheela CG, Nair CR. Effect of leucoperalgonin derivative from *Ficus benagalnesis* Linn. on diabetic dogs. Indian J Med Res. 1994;99:82–6. [PubMed: 8005644]

98. Singh RK, Mehta S, Jaiswal D, Rai PK, Watal G. Antidiabetic effect of *Ficus bengalensis* aerial roots in experimental animals. J Ethnopharmacol. 2009;123:110–4. [PubMed: 19429348]
99. Campillo JE, Perez C, Ramiro JM, Torres MD. Hypoglycemic activity of an aqueous extract from *Ficus carica* in streptozotocin diabetic rats (Abstract) Diabetologia. 1991;34(Suppl 2):A–181.
100. Torres MD, Dominguez E, Romero A, Campillo JE, Perez C. Hypoglycemic and hypolipidemic activity of an aqueous extract from *Ficus carica* in streptozotocin diabetic rats (Abstract) Diabetologia. 1993;36(Suppl 1):A–181.
101. Perez C, Dominguez E, Ramiro A, Campillo J, Torres MD. A study on the glycemic balance in streptozotocin diabetic rats treated with an aqueous extract of *Ficus carica* leaves. Phytother Res. 1996;10:82–6.
102. Ahmed F, Urooj A. *In vitro* studies on the hypoglycemic potential of *Ficus racemosa* stem bark. J Sci Food Agric. 2010;90:397–401. [PubMed: 20355059]
103. Jouad H, Maghrani M, Eddouks M. Hypoglycaemic effect of *Rubus fructicosis* L. and *Globularia alypum* L. in normal and streptozotocininduced diabetic rats. J Ethnopharmacol. 2002;81:351–6. [PubMed: 12127236]
104. Ramkumar KM, Lee AS, Krishnamurthi K, Devi SS, Chakrabarti T, Kang KP, et al. *Gymnema montanum* H. protects against alloxan-induced oxidative stress and apoptosis in pancreatic β-cells. Cell Physiol Biochem. 2009;24:429–40. [PubMed: 19910683]
105. Ananthan R, Latha M, Ramkumar KM, Pari L, Baskar C, Narmatha Bai V. Effect of *Gymnema montanum* leaves on serum and tissue lipids in alloxan diabetic rats. Exp Diabesity Res. 2003;4:183–9. [PMCID: PMC2478603] [PubMed: 15061646]
106. Yeo J, Kang YJ, Jeon SM, Jung UJ, Lee MK, Song H, et al. Potential hypoglycemic effect of an ethanol extract of *Gynostemma pentaphyllum* in C57BL/KsJ-db/db mice. J Med Food. 2008;11:709–16. [PubMed: 19053864]
107. Prabhakar Reddy P, Tiwari AK, Ranga Rao R, Madhusudhana K, Rama Subba Rao V, Ali AZ, et al. New *Labdane* diterpenes as intestinal α-glucosidase inhibitor from antihyperglycemic extract of *Hedychium spicatum* (Ham.Ex Smith) rhizomes. Bioorg Med Chem Lett. 2009;19:2562–5. [PubMed: 19332371]
108. Aslan M, Deliorman Orhan D, Orhan N, Sezik E, Yesilada E. *In vivo* antidiabetic and antioxidant potential of Helichrysum plicatum ssp. *Plicatum capitulums* in streptozotocin-induced-diabetic rats. J Ethnopharmacol. 2007;109:54–9. [PubMed: 16949229]
109. Boopathy Raja A, Elanchezhiyan C, Sethupathy S. Antihyperlipidemic activity of *Helicteres isora* fruit extract on streptozotocin induced diabetic male Wistar rats. Eur Rev Med Pharmacol Sci. 2010;14:191–6. [PubMed: 20391957]
110. Kumar G, Banu GS, Murugesan AG, Pandian MR. Hypoglycaemic effect of *Helicteres isora* bark extract in rats. J Ethnopharmacol. 2006;107:304–7. [PubMed: 16839725]
111. Chakrabarti R, Vikramadithyan RK, Mullangi R, Sharma VM, Jagadheshan H, Rao YN, et al. Antidiabetic and hypolipidemic activity of *Helicteres isora* in animal models. J Ethnopharmacol. 2002;81:343–9. [PubMed: 12127235]
112. Vijayakumar M, Govindarajan R, Rao GM, Rao ChV, Shirwaikar A, Mehrotra S, et al. Action of *Hygrophila auriculata* against streptozotocin-induced oxidative stress. J Ethnopharmacol. 2006;104:356–61. [PubMed: 16289604]
113. Erasto P, Adebola PO, Grierson DS, Afolayan AJ. An ethnobotanical study of plants used for the treatment of diabetes in Eastern Cape Province, South Africa. Afr J Biotechnol. 2005;4:1458–60.

114. Owira PM, Ojewole JA. 'African potato' (*Hypoxis hemerocallidea corm*): A plant-medicine for modern and 21st century diseases of mankind.- A review? Phytother Res. 2009;23:147–52. [PubMed: 18693293]
115. Zibula SM, Ojewole JA. Hypoglycaemic effects of *Hypoxis hemerocallidea corm* 'African Potato' methanolic extract in rats. Med J Islam World Acad Sci. 2000;13:75–8.
116. Ojewole JA. Antinociceptive, anti-inflammatory and antidiabetic properties of *Hypoxis hemerocallidea* Fisch. and C.A. Mey. (Hypoxidaceae) corm ['African Potato'] aqueous extract in mice and rats. J Ethnopharmacol. 2006;103:126–34. [PubMed: 16191469]
117. Mahomed IM, Ojewole JA. Hypoglycemic effect of *Hypoxis hemerocallidea* corm (African potato) aqueous extract in rats. Methods Find Exp Clin Pharmacol. 2003;25:617–23. [PubMed: 14671679]
118. Chakrabarti R, Damarla RK, Mullangi R, Sharma VM, Vikramadithyan RK, Rajagopalan R. Insulin sensitizing property of *Indigofera mysorensis* extract. J Ethnopharmacol. 2006;105:102–6. [PubMed: 16326056]
119. Ju JB, Kim JS, Choi CW, Lee HK, Oh TK, Kim SC. Comparison between ethanolic and aqueous extracts from Chinese juniper berries for hypoglycemic and hypolipidemic effects in alloxan-induced diabetic rats. J Ethnopharmacol. 2008;115:110–5. [PubMed: 17964099]
120. Hou W, Li Y, Zhang Q, Wei X, Peng A, Chen L, et al. Triterpene acids isolated from *Lagerstroemia speciosa* leaves as α-glucosidase inhibitors. Phytother Res. 2009;23:614–8. [PubMed: 19107840]
121. P S, Zinjarde SS, Bhargava SY, Ravikumar A. Potent α-amylase inhibitory activity of Indian Ayurvedic medicinal plants. BMC Complement Altern Med. 2011;11:5. [PMCID: PMC3037352] [PubMed: 21251279]
122. Chen X, Liu Y, Bai X, Wen L, Fang J, Ye M, et al. Hypoglycemic polysaccharides from the tuberous root of Liriope spicata. J Nat Prod. 2009;72:1988–92. [PubMed: 19874043]
123. Chen X, Bai X, Liu Y, Tian L, Zhou J, Zhou Q, et al. Anti-diabetic effects of water extract and crude polysaccharides from tuberous root of *Liriope spicata* var. prolifera in mice. J Ethnopharmacol. 2009;122:205–9. [PubMed: 19330907]
124. Cemek M, Kağa S, Simşek N, Büyükokuroğlu ME, Konuk M. Antihyperglycemic and antioxidative potential of *Matricaria chamomilla* L. in streptozotocin-induced diabetic rats. J Nat Med. 2008;62:284–93. [PubMed: 18404309]
125. Rao BK, Kessavulu MM, Giri R, Appa Rao C. Antidiabetic and hypolipidemic effects of *Momordica cymbalaria* Hook fruit powder in alloxan-diabetic rats. J Ethanopharmacol. 1999;67:103–9.
126. Hansawasdi C, Kawabata J. α-glucosidase inhibitory effect of mulberry (Morus alba) leaves on Caco-2. Fitoterapia. 2006;77:568–73. [PubMed: 17071014]
127. Khan BA, Abraham A, Leelamma S. Hypoglycaemic action of *Murraya koenigii* (curry leaf) and *Brassica juncea* (mustard): Mechanism of action. Indian J Biochem Biophys. 1995;32:106–8. [PubMed: 7642200]
128. Arulselvan P, Senthilkumar GP, Sathish Kumar D, Subramanian S. Anti-diabetic effect of *Murraya koenigii* leaves on streptozotocin induced diabetic rats. Pharmazie. 2006;61:874–7. [PubMed: 17069429]
129. Dhanabal SP, Sureshkumar M, Ramanathan M, Suresh B. Hypoglycaemic effect of ethanolic extract of *Musa sapientum* on alloxan induced diabetes mellitus in rats and its relation with antioxidant potential. J Herb Pharmacother. 2005;5:7–19. [PubMed: 16260406]

130. Pari L, Umamaheswari J. Antihyperglycemic activity of Musa sapientum flowers: Effect on lipid peroxidation in alloxan- induced diabetic rats. Phytother Res. 2000;14:136–8. [PubMed: 10685115]
131. Pari L, Maheswari JU. Hypoglycaemic effect of *Musa sapientum* L. in alloxan-induced rats. J Ethanopharmacol. 1999;68:321–5.
132. El SN, Karakaya S. Olive tree (*Olea europaea*) leaves: Potential beneficial effects on human health. Nutr Rev. 2009;67:632–8. [PubMed: 19906250]
133. Baumgartner RR, Steinmann D, Heiss EH, Atanasov AG, Ganzera M, Stuppner H, et al. Bioactivity-guided isolation of 1,2,3,4,6-Penta-O-galloyl-D-glucopyranose from *Paeonia lactiflora* roots as a PTP1B inhibitor. J Nat Prod. 2010;73:1578–81. [PubMed: 20806783]
134. Jain S, Bhatia G, Barik R, Kumar P, Jain A, Dixit VK. Antidiabetic activity of *Paspalum scrobiculatum* Linn. in alloxan induced diabetic rats. J Ethnopharmacol. 2010;127:325–8. [PubMed: 19900528]
135. Brai BI, Odetola AA, Agomo PU. Hypoglycemic and hypocholesterolemic potential of *Persea americana* leaf extracts. J Med Food. 2007;10:356–60. [PubMed: 17651074]
136. Babish JG, Pacioretty LM, Bland JS, Minich DM, Hu J, Tripp ML. Antidiabetic screening of commercial botanical products in 3T3-L1 adipocytes and db/db mice. J Med Food. 2010;13:535–47. [PubMed: 20521979]
137. Tormo MA, Gil-Exojo I, Romero de Tejada A, Campillo JE. Hypoglycaemic and anorexigenic activities of an α-amylase inhibitor from white kidney beans (*Phaseolus vulgaris*) in wistar rats. Br J Nutr. 2004;92:785–90. [PubMed: 15533267]
138. Pari L, Venkateswaran S. Protective role of Phaseolus vulgaris on changes in the fatty acid composition in experimental diabetes. J Med Food. 2004;7:204–9. [PubMed: 15298769]
139. Knott RM, Grant G, Bardocz S, Pusztai A, De Carvalho AF, Hesketh JE. Alternations in the level of insulin receptor and GLU-4 mRNA in skeletal muscle from rats fed a kidney bean (*Phaseolus vulgaris*) diet. Int J Biochem. 1992;24:897–902. [PubMed: 1612180]
140. Okada Y, Okada M, Sagesaka Y. Screening of dried plant seed extracts for adiponectin production activity and tumor necrosis factor-α inhibitory activity on 3T3-L1 adipocytes. Plant Foods Hum Nutr. 2010;65:225–32. [PubMed: 20717728]
141. Kasabri V, Afifi FU, Hamdan I. *In vitro* and *in vivo* acute antihyperglycemic effects of five selected indigenous plants from Jordan used in traditional medicine. J Ethnopharmacol. 2011;133:888–96. [PubMed: 21093568]
142. Zhang H, Yang F, Qi J, Song XC, Hu ZF, Zhu DN, et al. Homoisoflavonoids from the fibrous roots of *Polygonatum odoratum* with glucose uptake-stimulatory activity in 3T3-L1 adipocytes. J Nat Prod. 2010;73:548–52. [PubMed: 20158245]
143. Jafri MA, Aslam M, Javed K, Singh S. Effect of *Punica granatum* Linn.(Flowers) on blood glucose level in normal and alloxan induced diabetic rats. J Ethnopharmacol. 2000;70:309–14. [PubMed: 10837992]
144. Katz SR, Newman RA, Lansky EP. *Punica granatum*: Heuristic treatment for diabetes mellitus. J Med Food. 2007;10:213–7. [PubMed: 17651054]
145. Huang TH, Peng G, Kota BP, Li GQ, Yamahara J, Roufogalis BD, et al. Anti-diabetic action of *Punica granatum* flower extract: Activation of PPAR-g and identification of an active component. Toxicol Appl Pharmacol. 2005;207:160–9. [PubMed: 16102567]
146. Li Y, Wen S, Kota BP, Peng G, Li GQ, Yamahara J, et al. *Punica granatum* flower extract, a potent α-glucosidase inhibitor, improves postprandial hyperglycemia in Zucker diabetic fatty rats. J Ethnopharmacol. 2005;99:239–44. [PubMed: 15894133]

147. Shukla S, Chatterji S, Mehta S, Rai PK, Singh RK, Yadav DK, et al. Antidiabetic effect of *Raphanus sativus* root juice. Pharm Biol. 2011;49:32–7. [PubMed: 20687786]
148. Taniguchi H, Muroi R, Kobayashi-Hattori K, Uda Y, Oishi Y, Takita T. Differing effects of water-soluble and fat-soluble extracts from Japanese radish (*Raphanus sativus*) sprouts on carbohydrate and lipid metabolism in normal and streptozotocin-induced diabetic rats. J Nutr Sci Vitaminol (Tokyo) 2007;53:261–6. [PubMed: 17874832]
149. Taniguchi H, Kobayashi-Hattori K, Tenmyo C, Kamei T, Uda Y, Sugita-Konishi Y, et al. Effect of Japanese radish (*Raphanus sativus*) sprout (Kaiware-daikon) on carbohydrate and lipid metabolisms in normal and streptozotocin-induced diabetic rats. Phytother Res. 2006;20:274–8. [PubMed: 16557609]
150. Karunanayake EH, Welihinda J, Sirimame SR, Sinnadorai G. Oral hypoglycemic activity of some medicinal plants of Sri lanka. J Ethnopharmacol. 1984;11:223–31. [PubMed: 6492834]
151. Algandaby MM, Alghamdi HA, Ashour OM, Abdel-Naim AB, Ghareib SA, Abdel-Sattar EA, et al. Mechanisms of the antihyperglycemic activity of *Retama raetam* in streptozotocin-induced diabetic rats. Food Chem Toxicol. 2010;48:2448–53. [PubMed: 20538037]
152. Cheng XJ, Di L, Wu Y. Hyperglycemic effect of polysaccharides from *Rhodiola sachalinensis* A. China. J Chin Materia Med. 1993;18:557–9.
153. Gao D, Li Q, Liu Z, Feng J, Li J, Han Z, et al. Antidiabetic potential of *Rhodiola sachalinensis* root extract in streptozotocin-induced diabetic rats. Methods Find Exp Clin Pharmacol. 2009;31:375–81. [PubMed: 19798452]
154. Ojewole JA. Hypoglycemic effect of *Sclerocarya birrea* [(A. Rich.) Hochst.] [Anacardiaceae] stem-bark aqueous extract in rats. Phytomedicine. 2003;10:675–81. [PubMed: 14692729]
155. Dimo T, Rakotonirina SV, Tan PV, Azay J, Dongo E, Kamtchouing P, et al. Effect of *Sclerocarya birrea* (Anacardiaceae) stem bark methylene chloride/methanol extract on streptozotocin-diabetic rats. J Ethnopharmacol. 2007;110:434–8. [PubMed: 17141993]
156. Gondwe M, Kamadyaapa DR, Tufts M, Chuturgoon AA, Musabayane CT. *Sclerocarya birrea* [(A. Rich.) Hochst.] [Anacardiaceae] stem-bark ethanolic extract (SBE) modulates blood glucose, glomerular filtration rate (GFR) and mean arterial blood pressure (MAP) of STZ-induced diabetic rats. Phytomedicine. 2008;15:699–709. [PubMed: 18406590]
157. Ojewole JA, Mawoza T, Chiwororo WD, Owira PM. *Sclerocarya birrea* (A. Rich) Hochst. [‘Marula’] (Anacardiaceae): A review of its phytochemistry, pharmacology and toxicology and its ethnomedicinal uses. Phytother Res. 2010;24:633–9. [PubMed: 20013815]
158. Chadwick WA, Roux S, Van de Venter M, Louw J, Oelofsen W. Anti-diabetic effects of *Sutherlandia frutescencs* in Wistar rats fed a diabetogenic diet. J Ethnopharmacol. 2007;109:121–7. [PubMed: 16939705]
159. Ojewole JA. Analgesic, anti-inflammatory and hypoglycemic effects of *Sutherlandia frutescens* R. BR. (variety Incana E. MEY.) [Fabaceae] shoot aqueous extract. Methods Find Exp Clin Pharmacol. 2004;26:409–16. [PubMed: 15349136]
160. Dewanjee S, Maiti A, Das AK, Mandal SC, Dey SP. Swietenine: A potential oral hypoglycemic from *Swietenia macrophylla* seed. Fitoterapia. 2009;80:249–51. [PubMed: 19239921]
161. Panda SP, Haldar PK, Bera S, Adhikary S, Kandar CC. Antidiabetic and antioxidant activity of *Swietenia mahagoni* in streptozotocin-induced diabetic rats. Pharm Biol. 2010;48:974–9. [PubMed: 20731547]

162. Lam SH, Chen JM, Kang CJ, Chen CH, Lee SS. α-Glucosidase inhibitors from the seeds of *Syagrus romanzoffiana*. Phytochemistry. 2008;69:1173–8. [PubMed: 18221760]
163. Rao BK, Rao CH. Hypoglycaemic and antihyperglycemic activity of *Syzygium alternifolium* (Wt.) Walp. seed extracts in normal and diabetic rats. Phytomedicine. 2001;8:88–93. [PubMed: 11315761]
164. Nagappa AN, Thakurdesai PA, Venkat Rao N, Singh J. Antidiabetic activity of *Terminalia catappa* Linn fruits. J Ethnopharmacol. 2003;88:45–50. [PubMed: 12902049]
165. Pareek H, Sharma S, Khajja BS, Jain K, Jain GC. Evaluation of hypoglycemic and anti-hyperglycemic potential of *Tridax procumbens* (Linn.) BMC Complement Altern Med. 2009;9:48. [PMCID: PMC2790435] [PubMed: 19943967]
166. Martineau LC, Couture A, Spoor D, Benhaddou-Andaloussi A, Harris C, Meddah B, et al. Anti-diabetic properties of the Canadian lowbush blueberry *Vaccinium angustifolium* Ait. Phytomedicine. 2006;13:612–23. [PubMed: 16979328]
167. Wang L, Zhang XT, Zhang HY, Yao HY, Zhang H. Effect of *Vaccinium bracteatum* Thunb. leaves extract on blood glucose and plasma lipid levels in streptozotocin-induced diabetic mice. J Ethnopharmacol. 2010;130:465–9. [PubMed: 20553830]
168. Eid HM, Martineau LC, Saleem A, Muhammad A, Vallerand D, Benhaddou-Andaloussi A, et al. Stimulation of AMP-activated protein kinase and enhancement of basal glucose uptake in muscle cells by quercetin and quercetin glycosides, active principles of the antidiabetic medicinal plant *Vaccinium vitis-idaea*. Mol Nutr Food Res. 2010;54:991–1003. [PubMed: 20087853]
169. Beaulieu LP, Harris CS, Saleem A, Cuerrier A, Haddad PS, Martineau LC, et al. Inhibitory effect of the Cree traditional medicine wiishichimanaanh (*Vaccinium vitis-idaea*) on advanced glycation end product formation: Identification of active principles. Phytother Res. 2010;24:741–7. [PubMed: 19927274]
170. Gyang SS, Nyam DD, Sokomba EN. Hypoglycaemic activity of *Vernonia amygdalina* (chloroform extract) in normoglycemic and alloxan-induced hyperglycemic rats. J Pharm Bioresour. 2004;1:61–6.
171. Osinubi AA. Effects of *Vernonia amygdalina* and chlorpropamide on blood glucose. Med J Islam World Acad oSci. 2008;16:115–9.
172. Adallu B, Radhika B. Hypoglycaemic, diuretic and hypocholesterolemic effect of Winter cherry (*Withania somnifera*, Dunal) root. Indian J Exp Biol. 2000;38:607–9. [PubMed: 11116534]
173. Jatwa R, Kar A. Amelioration of metformin-induced hypothyroidism by *Withania somnifera* and *Bauhinia purpurea* extracts in Type 2 diabetic mice. Phytother Res. 2009;23:1140–5. [PubMed: 19170137]
174. Ponnachan PT, Paulose CS, Panikkar KR. Effect of leaf extract of *Aegle marmelos* in diabetic rats. Indian J Exp Biol. 1993;31:345–7. [PubMed: 8359833]
175. Sabu MC, Kuttan R. Antidiabetic activity of *Aegle marmelos* and its relationship with its antioxidant properties. Indian J Physiol Pharmacol. 2004;48:81–8. [PubMed: 15270373]
176. Das AV, Padayatti PS, Paulose CS. Paulose CS. Effect of leaf extract of Aegle marmelos (L.) Correa ex Roxb. on histological and ultra structural changes in tissues of streptozotocin induced diabetic rats. Indian J Exp Biol. 1996;34:341–5. [PubMed: 8698423]
177. Panda S, Kar A. Evaluation of the antithyroid, antioxidative and antihyperglycemic activity of scopoletin from *Aegle marmelos* leaves in hyperthyroid rats. Phytother Res. 2006;20:1103–5. [PubMed: 17078113]

178. Ramesh B, Pugalendi KV. Effect of umbelliferone on tail tendon collagen and haemostatic function in streptozotocin-diabetic rats. Basics Clin Pharmacol Toxicol. 2007;101:73–7.
179. Roman-Ramos R, Flores-Saenz JL, Alaricon-Aguilar FJ. Antihyperglycemic effect of some edible plants. J Ethnopharmacol. 1995;48:25–32. [PubMed: 8569244]
180. Campos KE, Diniz YS, Cataneo AC, Faine LA, Alves MJ, Novelli EL. Hypoglycaemic and antioxidant effects of onion, *Allium cepa*: Dietary onion addition, antioxidant activity and hypoglycemic effects on diabetic rats. Int J Food Sci Nutr. 2003;54:241–6. [PubMed: 12775373]
181. Mathew PT, Augusti KT. Hypoglycaemic effects of onion, *Allium cepa* Linn. on diabetes mellitus- a preliminary report. Indian J Physiol Pharmacol. 1975;19:213–7. [PubMed: 1223000]
182. Kumari K, Mathew BC, Augusti KT. Antidiabetic and hypolipidemic effects of S-methyl cysteine sulfoxide, isolated from *Allium* cepa Linn. Indian J Biochem Biophys. 1995;32:49–54. [PubMed: 7665195]
183. Dini I, Tenore GC, Dini A. S-alkenyl cysteine sulfoxide and its antioxidant properties from *Allium cepa* var. *tropeana* (red onion) seeds. J Nat Prod. 2008;71:2036–7. [PubMed: 19035837]
184. Zacharias NT, Sebastian KL, Philip B, Augusti KT. Hypoglycaemic and hypolipidemic effects of garlic in sucrose fed rabbits. Indian J Physiol Pharmacol. 1980;24:151–4. [PubMed: 7380530]
185. Ahmad MS, Ahmed N. Antiglycation properties of aged garlic extract: Possible role in prevention of diabetic complications. J Nutr. 2006;136(Suppl 3):796S–799S. [PubMed: 16484566]
186. Liu CT, Sheen LY, Lii CK. Does garlic have a role as an antidiabetic agent? Mol Nutr Food Res. 2007;51:1353–64. [PubMed: 17918164]
187. Sheela CG, Augusti KT. Antidiabetic effects of S-allyl cysteine sulfoxide isolated from garlic *Allium sativum* Linn. Indian J Exp Biol. 1992;30:523–6. [PubMed: 1506036]
188. Bever BO, Zahnd GR. Plants with oral hypoglycemic action. Q J Crude Drug Res. 1979;17:139–49.
189. Okada Y, Tanaka K, Sato E, Okajima H. Kinetic and mechanistic studies of allicin as an antioxidant. Org Biomol Chem. 2006;4:4113–7. [PubMed: 17312965]
190. Coppi A, Cabinian M, Mirelman D, Sinnis P. Antimalarial activity of allicin, a biologically active compound from garlic cloves. Antimicrob Agents Chemother. 2006;50:1731–7. [PMCID: PMC1472199] [PubMed: 16641443]
191. Augusti KT, Shella CG. Antiperoxide effect of S-allyl cysteine sulfoxide, an insulin secretagouge in diabetic rats. Experientia. 1996;52:115–20. [PubMed: 8608811]
192. Ledezma E, Apitz-Castro R. Ajoene the main active compound of garlic (*Allium sativum*): A new antifungal agent. Rev Iberoam Micol. 2006;23:75–80. [PubMed: 16854181]
193. Chakrabarti S, Biswas TK, Rokeya B, Ali L, Mosihuzzaman M, Nahar N, et al. Advanced studies on the hypoglycemic effect of *Caesalpinia bonducella* F. in type 1 and 2 diabetes in Long Evans rats. J Ethanopharmacol. 2003;84:41–6.
194. Sharma SR, Dwiedi SK, Swarup D. Hypoglycaemic, antihyperglycemic and hypolipidemic activities of *Caesalpinia bonducella* seeds in rats. J Ethanopharmacol. 1997;58:39–44.
195. Kannur DM, Hukkeri VI, Akki KS. Antidiabetic activity of *Caesalpinia bonducella* seed extracts in rats. Fitoterapia. 2006;77:546–9. [PubMed: 16905279]
196. Yadav P, Sarkar S, Bhatnagar D. Lipid peroxidation and enzymes in erythrocytes and tissues in aged diabetic rats. Indian J Exp Biol. 1997;35:389–92. [PubMed: 9315241]

197. Sharma B, Salunke R, Balomajumder C, Daniel S, Roy P. Anti-diabetic potential of alkaloid rich fraction from *Capparis decidua* on diabetic mice. J Ethnopharmacol. 2010;127:457–62. [PubMed: 19837152]
198. Mallick C, De D, Ghosh D. Correction of protein metabolic disorders by composite extract of *Musa paradisiaca* and *Coccinia indica* in streptozotocin-induced diabetic albino rat: An approach through the pancreas. Pancreas. 2009;38:322–9. [PubMed: 19169172]
199. Mallick C, Mandal S, Barik B, Bhattacharya A, Ghosh D. Protection of testicular dysfunctions by MTEC, a formulated herbal drug, in streptozotocin induced diabetic rat. Biol Pharm Bull. 2007;30:84–90. [PubMed: 17202665]
200. Kamble SM, Kamlakar PL, Vaidya S, Bambole VD. Influence of *Coccinia indica* on certain enzymes in glycolytic and lipolytic pathway in human diabetes. Indian J Med Sci. 1998;52:143–6. [PubMed: 9770877]
201. Kuriyan R, Rajendran R, Bantwal G, Kurpad AV. Effect of supplementation of *Coccinia cordifolia* extract on newly detected diabetic patients. Diabetes Care. 2008;31:216–20. [PubMed: 18000183]
202. El-Hossary GA, Fathy MM, Kassem HA, Kandil ZA, Abdel Latif HA. Phytochemical and biological investigations of *Eriobotrya japonica* L. growing in Egypt. Bull Fac Pharm. 2000;38:129–42.
203. Noreen W, Wadood A, Hidayat HK, Wahid SA. Effect of *Eriobotrya japonica* on blood glucose levels of normal and alloxan-diabetic rabbits. Planta Med. 1988;54:196–9. [PubMed: 3174854]
204. Roman-Ramos R, Flores-Saenz JL, Partida-Hernandez G, Lara- Lemus A, Alarcon-Aguilar F. Experimental study of the hypoglycemic effect of some antidiabetic plants. Arch Invest Med (Mex) 1991;22:87–93. [PubMed: 1819981]
205. Lü H, Chen J, Li WL, Ren BR, Wu JL, Zhang HQ. Hypoglycemic effect of the total flavanoid fraction from folium Eriobotryae. Phytomedicine. 2009;16:967–71. [PubMed: 19427773]
206. Gumy C, Thurnbichler C, Aubry EM, Balazs Z, Pfisterer P, Baumgartner L, et al. Inhibition of 11 β-hydroxysteroid dehydrogenase type 1 by plant extracts used as traditional antidiabetic medicines. Fitoterapia. 2009;80:200–5. [PubMed: 19535018]
207. De Tommasi N, De Simone F, Cirino G, Cicala C, Pizza C. Hypoglycemic effects of sesquiterpene glycosides and polyhydroxylated triterpenoids of Eriobotrya japonica. Planta Med. 1991;57:414–6. [PubMed: 1798792]
208. Lü H, Chen J, Li WL, Ren BR, Wu JL, Kang HY, et al. Hypoglycemic and hypolipidemic effects of the total triterpene acid fraction from Folium Eriobotryae. J Ethnopharmacol. 2009;122:486–91. [PubMed: 19429317]
209. Acherekar S, Kakliji GS, Pote MS, Kelkar SM. Hypoglycemic activity of *Eugenia jambolana* and *Ficus bengalensis*: Mechanism of action. In vivo. 1991;5:143–7. [PubMed: 1768783]
210. Ravi K, Ramachandran B, Subramanian S. Protective effect of *Eugenia jambolana* seed kernel on tissue antioxidants in streptozotocin-induced diabetic rats. Biol Pharm Bull. 2004;27:1212–7. [PubMed: 15305024]
211. Yadav M, Lavania A, Tomar R, Prasad GB, Jain S, Yadav H. Complementary and comparative study on hypoglycemic and antihyperglycemic activity of various extracts of *Eugenia jambolana* seed, *Momordica charantia* fruits, *Gymnema sylvestre*, and Trigonella

foenum graecum seeds in rats. Appl Biochem Biotechnol. 2010;160:2388–400. [PubMed: 19904502]
212. Pepato MT, Mori DM, Baviera AM, Harami JB, Vendramini RC, Brunetti IL. Fruit of the jambolana tree (*Eugenia jambolana* Lam.) and experimental diabetes. J Ethnopharmacol. 2005;96:43–8. [PubMed: 15588649]
213. Attele AS, Wu JA, Yuan CS. Ginseng pharmacology: Multiple constituents and multiple actions. Biochem Pharmacol. 1999;58:1685–93. [PubMed: 10571242]
214. Christensen LP. Ginsenosides chemistry, biosynthesis, analysis, and potential health effects. Adv Food Nutr Res. 2009;55:1–99. [PubMed: 18772102]
215. Liu CX, Xiao PG. Recent advances on ginseng research in China. J Ethnopharmacol. 1992;36:27–38. [PubMed: 1501490]
216. Ohnishi Y, Takagi S, Miura T, Usami M, Kako M, Ishihara E, et al. Effect of ginseng radix on GLUT2 protein content in mouse liver in normal and epinephrine-induced hyperglycemic mice. Biol Pharm Bull. 1996;19:1238–40. [PubMed: 8889050]
217. Oshima Y, Sato K, Hikino H. Isolation and hypoglycemic activity of quinquefolans A, B, and C, glycans of Panax quinquefolium roots. J Nat Prod. 1987;50:188–90. [PubMed: 3655794]
218. Martinez B, Staba EJ. The physiological effects of Aralia, Panax and Eleutherococcus on exercised rats. Jpn J Pharmacol. 1984;35:79–85. [PubMed: 6379247]
219. Konno C, Sugiyama K, Kano M, Takahashi M, Hikino H. Isolation and hypoglycemic activity of panaxans A, B, C, D, and E, glycans of Panax ginseng roots. Planta Med. 1984;50:434–6. [PubMed: 6522508]
220. Konno C, Murakami M, Oshima Y, Hikino H. Isolation and hypoglycemic activity of panaxans Q, R, S, T, and U, glycans of Panax ginseng roots. J Ethnopharmacol. 1985;14:69–74. [PubMed: 4087924]
221. Yokozawa T, Kobayashi T, Oura H, Kawashima Y. Studies on the mechanism of the hypoglycemic activity of ginsenoside-Rb2 in streptozotocin-diabetic rats. Chem Pharm Bull (Tokyo) 1985;33:869–72. [PubMed: 4017130]
222. Oshima Y, Konno C, Hikino H. Isolation and hypoglycemic activity of panaxans I, J, K and L, glycans of Panax ginseng roots. J Ethnopharmacol. 1985;14:255–9. [PubMed: 4094469]
223. Sotaniemi EA, Haapakoski E, Rautio A. Ginseng therapy in non-insulin-dependent diabetic patients. Diabetes Care. 1995;18:1373–5. [PubMed: 8721940]
224. Vuksan V, Sievenpiper JL, Koo VY, Francis T, Beljan-Zdravkovic U, Xu Z, et al. American ginseng (*Panax quinquefolius* L) reduces postprandial glycemia in nondiabetic subjects and subjects with type 2 diabetes mellitus. Arch Intern Med. 2000;160:1009–13. [PubMed: 10761967]
225. Punnonen R, Lukola A. Oestrogen-like effect of ginseng. Br Med J. 1980;281:1110. [PMCID: PMC1714565] [PubMed: 7191760]
226. Schulz V, Hansel R, Tyler VE. Rational phytotherapy. Agents that Increase Resistance to Diseases. New York, NY: Springer- Verlag; 1998. pp. 269–72.
227. Persaud SJ, Al-Majed H, Raman A, Jones PM. *Gymnema sylvestre* stimulates insulin release *in vitro* by increased membrane permeability. J Endocrinol. 1999;163:207–12. [PubMed: 10556769]
228. Daisy P, Eliza J, Mohamed Farook KA. A novel dihydroxy gymnemic triacetate isolated from *Gymnema sylvestre* possessing normoglycemic and hypolipidemic activity on STZ-induced diabetic rats. J Ethnopharmacol. 2009;126:339–44. [PubMed: 19703537]

229. Baskaran K, Kizar Ahamath B, Radha Shanmugasundaram K, Shanmugasundaram ER. Antidiabetic effect of a leaf extracts from *Gymnema sylvestre* in non-insulin-dependent diabetes mellitus patients. J Ethnopharmacol. 1990;30:295–300. [PubMed: 2259217]
230. Mozersky RP. Herbal products and supplemental nutrients used in the management of diabetes. J Am Osteopath Assoc. 1999;99(12 Suppl):S4–9. [PubMed: 10659523]
231. Aderibigbe AO, Emudianughe TS, Lawal BA. Antihyperglycemic effect of *Mangifera indica* in rat. Phytother Res. 1999;13:504–7. [PubMed: 10479762]
232. Prasad S, Kalra N, Shukla Y. Hepatoprotective effects of lupeol and mango pulp extract of carcinogen induced alteration in Swiss albino mice. Mol Nutr Food Res. 2007;51:352–9. [PubMed: 17340578]
233. Muruganandan S, Srinivasan K, Gupta S, Gupta PK, Lal J. Effect of mangiferin on hyperglycemia and atherogenicity in streptozotocin diabetic rats. J Ethnopharmacol. 2005;97:497–501. [PubMed: 15740886]
234. Shabib BA, Khan LA, Rahman R. Hypoglycemic activity of *Coccinia indica* and *Momordica charantia* in diabetic rats: Depression of the hepatic gluconeogenic enzymes glucose-6-phosphatase and fructose-1, 6-biphosphatase and elevation of liver and red-cell shunt enzyme glucose-6-phosphate dehydrogenase. Biochem J. 1993;292:267–270. [PMCID: PMC1134299] [PubMed: 8389127]
235. Fernandes NP, Lagishetty CV, Panda VS, Naik SR. An experimental evaluation of the antidiabetic and antilipidemic properties of a standardized *Momordica charantia* fruit extract. BMC Complement Altern Med. 2007;7:29. [PMCID: PMC2048984] [PubMed: 17892543]
236. Sridhar MG, Vinayagamoorthi R, Arul Suyambunathan V, Bobby Z, Selvaraj N. Bitter gourd (*Momordica charantia*) improves insulin sensitivity by increasing skeletal muscle insulin-stimulated IRS-1 tyrosine phosphorylation in high-fat-fed rats. Br J Nutr. 2008;99:806–12. [PubMed: 17942003]
237. Sathishsekar D, Subramanian S. Antioxidant properties of *Momordica Charantia* (bitter gourd) seeds on Streptozotocin induced diabetic rats. Asia Pac J Clin Nutr. 2005;14:153–8. [PubMed: 15927932]
238. Sitasawad SL, Shewade Y, Bhonde R. Role of bittergourd fruit juice in STZ-induced diabetic state *in vivo* and *in vitro*. J Ethnopharmacol. 2000;73:71–9. [PubMed: 11025141]
239. McCarty MF. Does bitter melon contain an activator of AMP-activated kinase? Med Hypotheses. 2004;63:340–3. [PubMed: 15236800]
240. Cheng HL, Huang HK, Chang CI, Tsai CP, Chou CH. A cell-based screening identifies compounds from the stem of *Momordica charantia* that overcome insulin resistance and activate AMP-activated protein kinase. J Agric Food Chem. 2008;56:6835–43. [PubMed: 18656931]
241. Khanna P, Jain SC, Panagariya A, Dixit VP. Hypoglycemic activity of polypeptide-p from a plant source. J Nat Prod. 1981;44:648–55. [PubMed: 7334382]
242. Platel K, Srinivasan K. Plant foods in the management of diabetes mellitus: Vegetables as potential hypoglycemic agents. Nahrung. 1997;41:68–74. [PubMed: 9188186]
243. Ooi CP, Yassin Z, Hamid TA. *Momordica charantia* for type 2 diabetes mellitus. Cochrane Database Syst Rev. 2010;(2):CD007845. [PubMed: 20166099]
244. Grover JK, Yadav SP. Pharmacological actions and potential uses of *Momordica charantia*: A review. J Ethnopharmacol. 2004;93:123–32. [PubMed: 15182917]
245. Vats V, Grover JK, Rathi SS. Evaluation of antihyperglycemic and hypoglycemic effect of *Trigonella foenum graecum Linn, Ocimum sanctum Linn* and *Pterocarpus marsupium Linn* in normal and alloxanized diabetic rats. J Ethanopharmacol. 2002;79:95–100.

246. Rai V, Iyer U, Mani UV. Effect of tulsi (*Ocimum sanctum*) leaf powder supplementation on blood sugar levels, serum lipids and tissue lipid in diabetic rats. Plant foods Hum Nutr. 1997;50:9–16. [PubMed: 9198110]
247. Vats V, Yadav SP, Grover JK. Ethanolic extract of *Ocimum sanctum* leaves partially attenuates streptozotocin induced alteration in glycogen content and carbohydrate metabolism in rats. J Ethanopharmacol. 2004;90:155–60.
248. Mondal S, Mirdha BR, Mahapatra SC. The science behind sacredness of Tulsi (*Ocimum sanctum* Linn.) Indian J Physiol Pharmacol. 2009;53:291–306. [PubMed: 20509321]
249. Raphael KR, Sabu MC, Kuttan R. Hypoglycemic effect of methanol extract of *Phyllanthus amarus* Schum and Thonn on alloxan induced diabetes mellitus in rats and its relation with antioxidant potential. Indian J Exp Biol. 2002;40:905–9. [PubMed: 12597020]
250. Srividya N, Periwal S. Diuretic, hypotensive and hypoglycemic effect of *Phyllanthus amarus*. Indian J Exp Biol. 1995;33:861–4. [PubMed: 8786163]
251. Shabeer J, Srivastava RS, Singh SK. Antidiabetic and antioxidant effect of various fractions of Phyllanthus simplex in alloxan diabetic rats. J Ethnopharmacol. 2009;124:34–8. [PubMed: 19375496]
252. Sharma P, Parmar J, Verma P, Sharma P, Goyal PK. Anti-tumor activity of *Phyllanthus niruri* (a medicinal plant) on chemical-induced skin carcinogenesis in mice. Asian Pac J Cancer Prev. 2009;10:1089–94. [PubMed: 20192590]
253. Kumar S, Kumar D, Deshmukh RR, Lokhande PD, More SN, Rangari VD. Antidiabetic potential of *Phyllanthus reticulatus* in alloxan-induced diabetic mice. Fitoterapia. 2008;79:21–3. [PubMed: 17855019]
254. Mukhtar HM, Ansari SH, Ali M, Naved T, Bhat ZA. Effect of water extract of *Psidium guajava* on alloxan induced diabetic rats. Pharmazie. 2004;59:734–5. [PubMed: 15497764]
255. Ojewole JA. Hypoglycemic and hypotensive effects of *Psidium guajava* Linn.(Myrtaceae) leaf aqueous extract. Methods Find Exp Clin Pharmacol. 2005;27:689–95. [PubMed: 16395418]
256. Mukhtar HM, Ansari SH, Bhat ZA, Naved T, Singh P. Antidiabetic activity of an ethanol extract obtained from the stem bark of *Psidium guajava* (Myrtaceae) Pharmazie. 2006;61:725–7. [PubMed: 16964719]
257. Oh WK, Lee CH, Lee MS, Bae EY, Sohn CB, Oh H, et al. Antidiabetic effects of extracts from *Psidium guajava*. J Ethnopharmacol. 2005;96:411–5. [PubMed: 15619559]
258. Wang B, Liu HC, Hong JR, Li HG, Huang CY. Effect of *Psidium guajava* leaf extract on α-glucosidase activity in small intestine of diabetic mouse. Sichuan Da Xue Xue Bao Yi Xue Ban. 2007;38:298–301. [PubMed: 17441354]
259. Rai PK, Mehta S, Watal G. Hypolipidemic and hepatoprotective effects of *Psidium guajava* raw fruit peel in experimental diabetes. Indian J Med Res. 2010;131:820–4. [PubMed: 20571173]
260. Haranath PS, Ranganthrao K, Anjaneyulu CR, Ramnathan JD. Studies on the hypoglycemic and pharmacological actions of some stilbenes. Indian J Med Sci. 1958;12:85–9. [PubMed: 13524919]
261. Chakravarty BK, Gupta S, Gambhir SS, Gode KD. Pancreatic β-cell regeneration. A novel antidiabetic mechanism of *Pterocarpus marsupium* Roxb. Indian J Pharmacol. 1980;12:123–7.
262. Jahromi MA, Ray AB. Antihyperlipidemic effect of flavonoids from *Pterocarpus marsupium*. J Nat Prod. 1993;56:989–94. [PubMed: 8377021]
263. Ahmad F, Khalid P, Khan MM, Rastogi AK, Kidwai JR. Insulin like activity in (-) epicatechin. Acta diabetol Lat. 1989;26:291–300. [PubMed: 2698039]

264. Khosla P, Gupta DD, Nagpal RK. Effect of *Trigonella foenum* graceum (fenugreek) on blood glucose in normal and diabetic rats. Indian J Physiol Pharmacol. 1995;39:173–4. [PubMed: 7649611]
265. Gupta D, Raju J, Baquer NZ. Modulation of some gluconeogenic enzyme activities in diabetic rat liver and kidney: Effect of antidiabetic compounds. Indian J Exp Biol. 1999;37:196–9. [PubMed: 10641146]
266. Ravikumar P, Anuradha CV. Effect of fenugreek seeds on blood lipid peroxidation and antioxidants in diabetic rats. Phytother Res. 1999;13:197–201. [PubMed: 10353156]
267. Dixit P, Ghaaskadbi S, Mohan H, Devasagyam TP. Antioxidant properties of germinated fenugreek seeds. Phytother Res. 2005;19:977–83. [PubMed: 16317656]
268. Hamden K, Jaouadi B, Carreau S, Aouidet A, El-Fazaa S, Gharbi N, et al. Potential protective effect on key steroidogenesis and metabolic enzymes and sperm abnormalities by fenugreek steroids in testis and epididymis of surviving diabetic rats. Arch Physiol Biochem. 2010;116:146–55. [PubMed: 20507258]
269. Singh AB, Tamarkar AK, Narender T, Srivastava AK. Antihyperglycemic effect of an unusual amino acid (4-hydroxyisoleucine) in C57BL/KsJ-db/db mice. Nat Prod Res. 2010;24:258–65. [PubMed: 20140804]
270. Hamden K, Masmoudi H, Carreau S, Elfeki A. Immunomodulatory, β-cell, and neuroprotective actions of fenugreek oil from alloxan-induced diabetes. Immunopharmacol Immunotoxicol. 2010;32:437–45. [PubMed: 20100065]
271. Vijayakumar MV, Pandey V, Mishra GC, Bhat MK. Hypolipidemic effect of fenugreek seeds is mediated through inhibition of fat accumulation and up regulation of LDL receptor. Obesity (Silver Spring) 2010;18:667–74. [PubMed: 19851306]
272. Reddy RL, Srinivasan K. Fenugreek seeds reduce atherogenic diet-induced cholesterol gallstone formation in experimental mice. Can J Physiol Pharmacol. 2009;87:933–43. [PubMed: 19935901]
273. Preet A, Siddiqui MR, Taha A, Badhai J, Hussain ME, Yadava PK, et al. Long-term effect of *Trigonella foenum* graecum and its combination with sodium orthovanadate in preventing histopathological and biochemical abnormalities in diabetic rat ocular tissues. Mol Cell Biochem. 2006;289:137–47. [PubMed: 16718375]
274. Preet A, Gupta BL, Siddiqui MR, Yadava PK, Baquer NZ. Restoration of ultra structural and biochemical changes in alloxan-induced diabetic rat sciatic nerve on treatment with Na3VO4 and Trigonella-a promising antidiabetic agent. Mol Cell Biochem. 2005;278:21–31. [PubMed: 16180085]
275. Amin A, Alkaabi A, Al-Falasi S, Daoud SA. Chemopreventive activities of *Trigonella foenum* graecum (Fenugreek) against breast cancer. Cell Biol Int. 2005;29:687–94. [PubMed: 15936223]
276. Flammang AM, Cifone MA, Erexson GL, Stankowski LF., Jr Genotoxicity testing of a fenugreek extract. Food Chem Toxicol. 2004;42:1769–75. [PubMed: 15350674]
277. Stanely Mainzen Prince P, Menon VP. Antioxidant action of *Tinospora cordifolia* root extract in alloxan diabetic rats. Phytother Res. 2001;15:213–8. [PubMed: 11351355]
278. Price PS, Menon VP. Antioxidant activity of *Tinospora cordifolia* roots in experimental diabetes. J Ethnopharmacol. 1999;65:277–81. [PubMed: 10404427]
279. Mathew S, Kuttan G. Antioxidant activity of Tinospora cordifolia and its usefulness in the amelioration of cyclophosphamide-induced toxicity. J Exp Clin Cancer Res. 1997;16:407–11. [PubMed: 9505214]

280. Stanely Mainzen Prince P, Menon VP. Antioxidant action of *Tinospora cordiflora* roots in chemical induced diabetes in rats. Phytother Res. 2003;17:410–3. [PubMed: 12722152]
281. Dhaliwal KS. Method and composition for treatment of diabetes. US patent 5886029. 1999
282. Gupta SS, Verma SC, Garg VP, Rai M. Antidiabetic effect of *Tinospora cordifolia* I. Effect on fasting blood sugar level, glucose tolerance and adrenaline induced hyperglycemia. Indian J Med Res. 1967;55:733–45. [PubMed: 6056285]
283. White JR, Jr, Kramer J, Campbell RK, Bernstein R. Oral use of a topical preparation containing an extract of *Stevia rebaudiana* and the chrysanthemum flower in the management of hyperglycemia. Diabetes Care. 1994;17:940. [PubMed: 7956646]
284. Jeppesen PB, Gregersen S, Alstrup KK, Hermansen K. Stevioside induces antihyperglycemic, insulinotropic and glucagonostatic effects *in vivo*: Studies in the diabetic Goto-Kakizaki (GK) rats. Phytomedicine. 2002;9:9–14. [PubMed: 11924770]
285. Ferreira EB, de Assis Rocha Neves F, da Costa MA, do Prado WA, de Araújo Funari Ferri L, Bazotte RB. Comparative effects of *Stevia rebaudiana* leaves and stevioside on glycaemia and hepatic gluconeogenesis. Planta Med. 2006;72:691–6. [PubMed: 16732523]
286. Abudula R, Jeppesen PB, Rolfsen SE, Xiao J, Hermansen K. Rebaudioside A potently stimulates insulin secretion from isolated mouse islets: Studies on the dose-, glucose-, and calcium-dependency. Metabolism. 2004;53:1378–81. [PubMed: 15375798]
287. Lailerd N, Saengsirisuwan V, Sloniger JA, Toskulkao C, Henriksen EJ. Effects of stevioside on glucose transport activity in insulin-sensitive and insulin-resistant rat skeletal muscle. Metabolism. 2004;53:101–7. [PubMed: 14681850]
288. Jeppesen PB, Gregersen S, Rolfsen SE, Jepsen M, Colombo M, Agger A, et al. Antihyperglycemic and blood pressure-reducing effects of stevioside in the diabetic Goto-Kakizaki rat. Metabolism. 2003;52:372–8. [PubMed: 12647278]
289. Jeppesen PB, Gregersen S, Poulsen CR, Hermansen K. Stevioside acts directly on pancreatic β-cells to secrete insulin: actions independent of cyclic adenosine monophosphate and adenosine triphosphatesensitive K+-channel activity. Metabolism. 2000;49:208–14. [PubMed: 10690946]

Figures and Tables

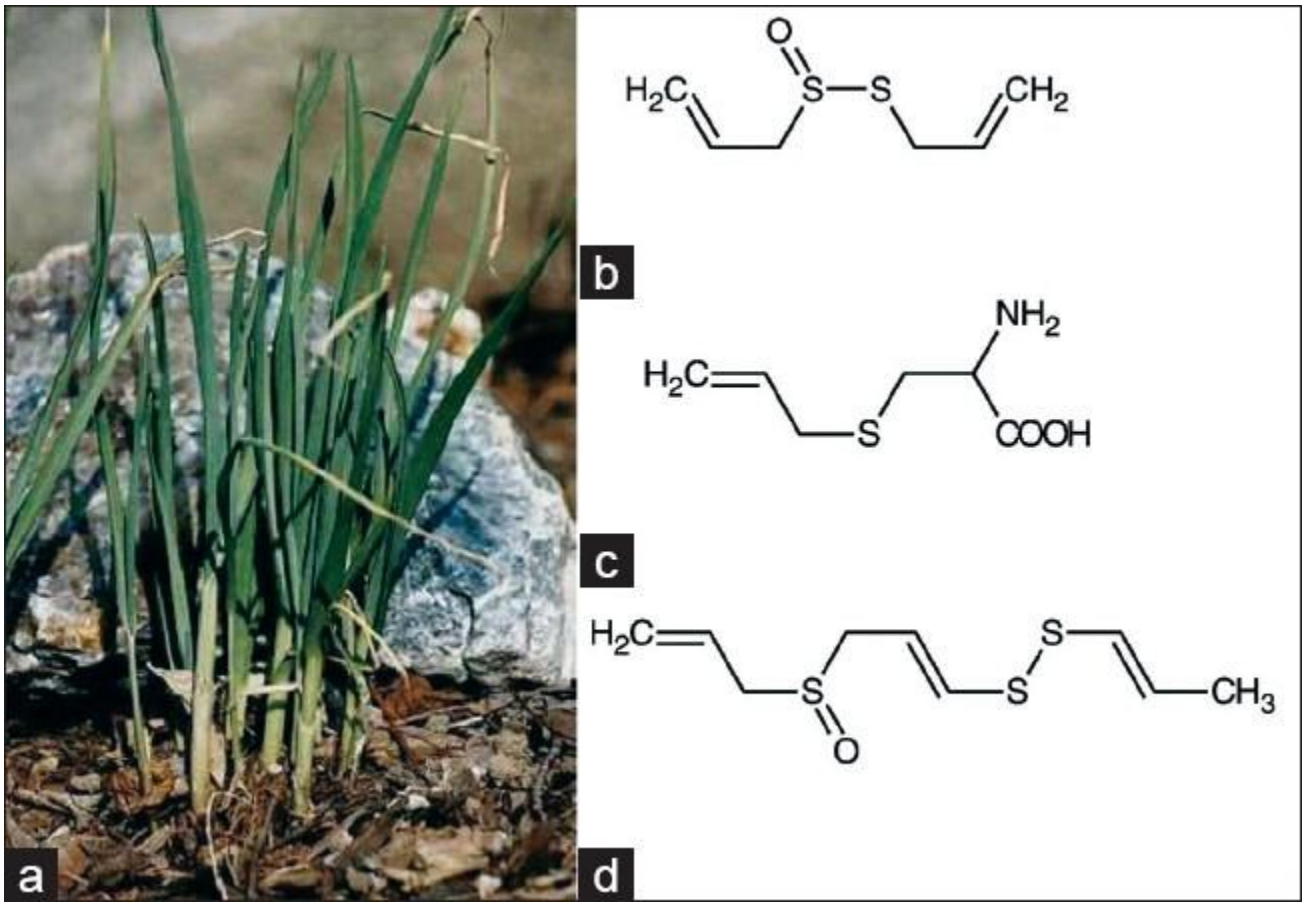
Table 1

Plant name	Traditional/common name	Part used	Antidiabetic effect and other important effects	Reference
Acacia arabica (Leguminosae)	Guar gum*, Gum Arabic*	Seeds	Hypoglycemic, stimulate pancreatic β-cells for insulin release	[29]
Acorus calamus (Araceae)	Sweet flag* or Calamus*	Radix	Hypoglycemic, increased glucose consumption, decrease in triglyceride, free fatty acid, insulin sensitizer	[30,31]
Aloe vera (Liliaceae)	True or medicinal aloe*	Aloe gel, leaves	Hypoglycemic, hypolipidemic, antioxidant, increases glucose tolerance, stimulation of synthesis and/or release of insulin from pancreatic β-cells, enhanced insulin transport, anti -inflammatory	[32-37]
Anethum graveolens (Umbelliferae)	Dill*	Leaves	Hypoglycemic, antioxidant, decrease in serum insulin level	[38]
Annona squamosa (Annonaceae)	Sugar apple*	Leaves	Hypoglycemic, antihyperglycemic, antioxidant, increased plasma insulin level	[39-42]
Areca catechu (Palmae)	Betel nut*, supari†	Fruit	Hypoglycemic	[43]
Astragalus membranaceus (Leguminosae)	Yellow leader*	Root	Hypoglycemic, hypolipidemic, decrease in insulin resistance, potential insulin sensitizer, decreased expression of protein tyrosine phosphatase 1B (PTP1B)	[44-49]
Averrhoa bilimbi (Oxalidaceae)	Bilimbi†, cucumber tree* or tree sorrel*	Leaves	Hypoglycemic, hypolipidemic	[50, 51]
Azadirachta indica (Meliaceae)	Neem†	Leaves, seeds	Antihyperglycemic, antioxidant, antibacterial, antimalarial, antifertility, hepatoprotective	[52,53-56]
Baccharis trimera (Asteraceae)	-	Aerial parts of plant	Hypoglycemic	[57]
Barleria lupulina (Acanthaceae)	-	Aerial parts	Antihyperglycemic	[58,59]
Bauhinia forficata (Fabaceae)	Pata de Vaca†	Leaves	Hypoglycemic, antioxidant effect, useful in preventing diabetic complications	[60,61]
Berberis aristata (Berberidaceae)	Barberries* or pepperidge bushes*	Root	Antihyperglycemic, antioxidant	[62]
Beta vulgaris (Chenopodiaceae)	Chukkander†, beetroot* or garden beet*	Root	Increase in glucose tolerance	[63]
Bixa orellana (Bixaceae)	Achiote†, aploppas†	Leaves	Concentration-independent inhibition of human pancreatic α-amylase	[64]
Brassica juncea (Brassicaceae)	Mustard greens*, indian mustard*, chinese mustard* and leaf mustard*	Leaves	Hypoglycemic, antioxidant	[65,66]
Butea monosperma (Papilionaceae)	Palasa†, flame of the forest*	Bark, leaves, flower	Hypoglycemic, antihyperglycemic, antioxidant, thyroid inhibitory effect	[67-70]
Camellia sinensis (Theaceae)	Tea*	Leaves	Anti-hyperglycemic, antioxidant	[71,72]
Capparis spinosa (Capparaceae)	Caper bush*	Fruit	Antihyperglycemic, no change in basal insulin level	[73]
Carum carvi (Apiaceae)	Caraway*, meridian fennel*	Fruit	Antihyperglycemic, no change in basal insulin level	[73]
Casearia esculenta (Salicaceae)	-	Root	Antihyperglycemic, antihyperlipidemic, antioxidant	[74,75]
Cassia auriculata (Caesalpiniaceae)	Ranawara† or avaram†, avaram senna*	Leaves, flowers	Antihyperglycemic and hypolipidemic activity, α-glucosidase inhibitory activity	[76,77]
Cassia glauca (Caesalpiniaceae)	-	Leaves, bark	Antihyperglycemic, antihyperlipidemic	[78]
Cinnamomum osmophloeum (Lauraceae)	Pseudocinnamomum* or indigenous cinnamon*	Leaves	Enhanced adinopectin secretion and activation of insulin-signaling pathway	[79]
Cinnamomum verum (Lauraceae)	True cinnamon*, ceylon cinnamon*	Leaves	Concentration-dependant inhibition of human pancreatic α-amylase	[64]
Citrullus vulgaris (Cucurbitaceae)	Water melon*	Peel of fruit	Hypoglycemic, antihyperlipidemic, amelioration of thyroid dysfunction, inhibit lipid peroxidation	[80]
Citrus sinensis (Rutaceae)	Sweet orange*	Peel of fruit	Antihyperglycemic, antiperoxidative, antithyroid, insulin stimulating property, hypolipidemic, cardioprotective	[81-84]
Citrus paradisi (Rutaceae)	Grapefruit*	Seeds	Hypoglycemic, hypolipidemic, decrease in cardiovascular risk factors	[85]
Cochlospermum vitifolium (Cochlospermaceae)	-	Bark	Hypoglycemic, vasorelaxant and hepatoprotective properties	[86]
Combretum micranthum (Combretaceae)	Kinkeliba†	Leaves	Antihyperglycemic	[87]
Coscinium fenestratum (Menispermaceae)	-	Stem	Antidiabetic , hypolipidemic	[88]
Costus igneus (Costaceae)	Fiery costus* or spiral flag*	Leaves	Hypoglycemia	[89]

Plant name	Traditional/common name	Part used	Antidiabetic effect and other important effects	Reference
Costus speciosus (Costaceae)	Crape ginger*	Root	Anti-hyperglycemic, antihyperlipemic and antioxidative effects	[90]
Curcuma longa (Zingiberaceae)	Turmeric*	Rhizome	Concentration-dependant inhibition of human pancreatic α-amylase	[64]
Dendrobium chrysotoxum (Orchidaceae)	Golden-bow dendrobium* or fried-egg orchid*	Stem	Antioxidant and anti -hyperglycemic	[91]

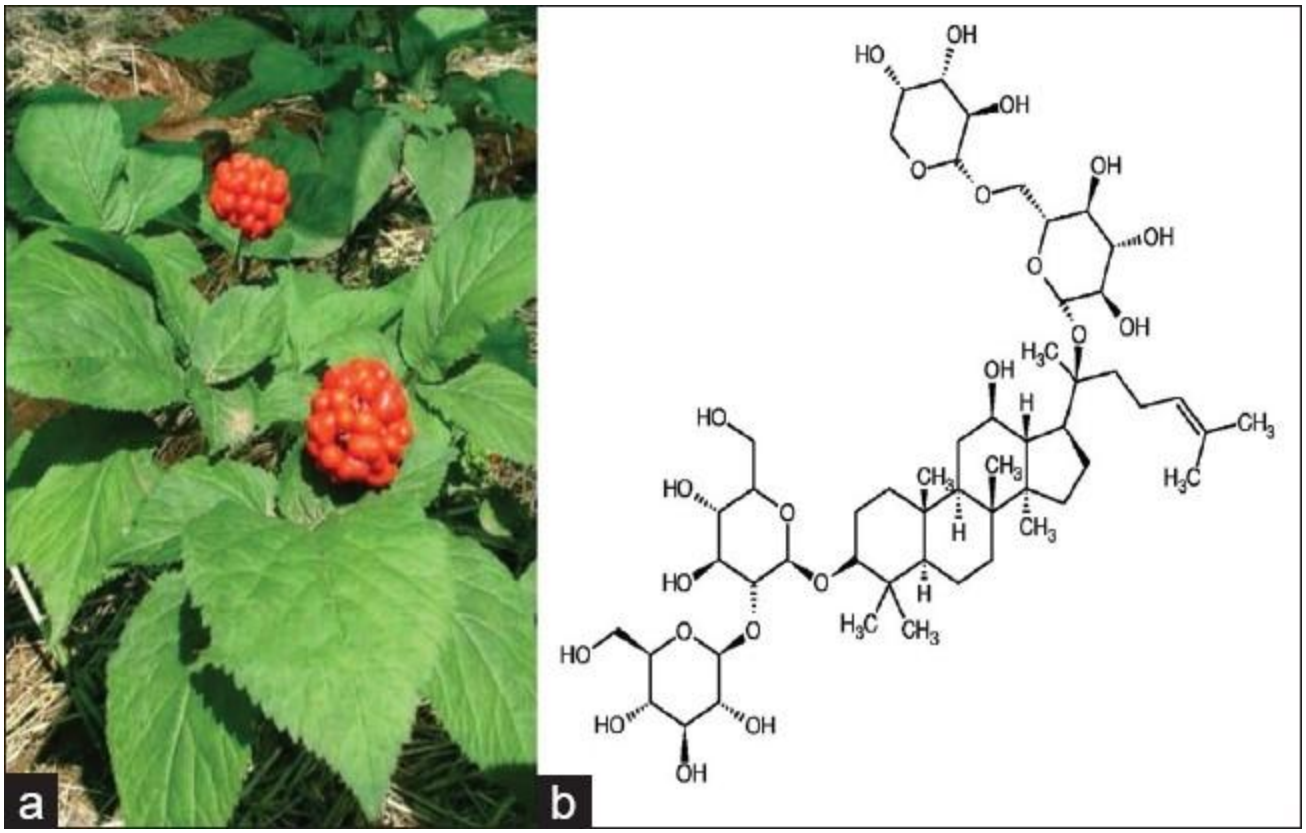
Medicinal plants with antidiabetic and other medicinal properties

Figure 1



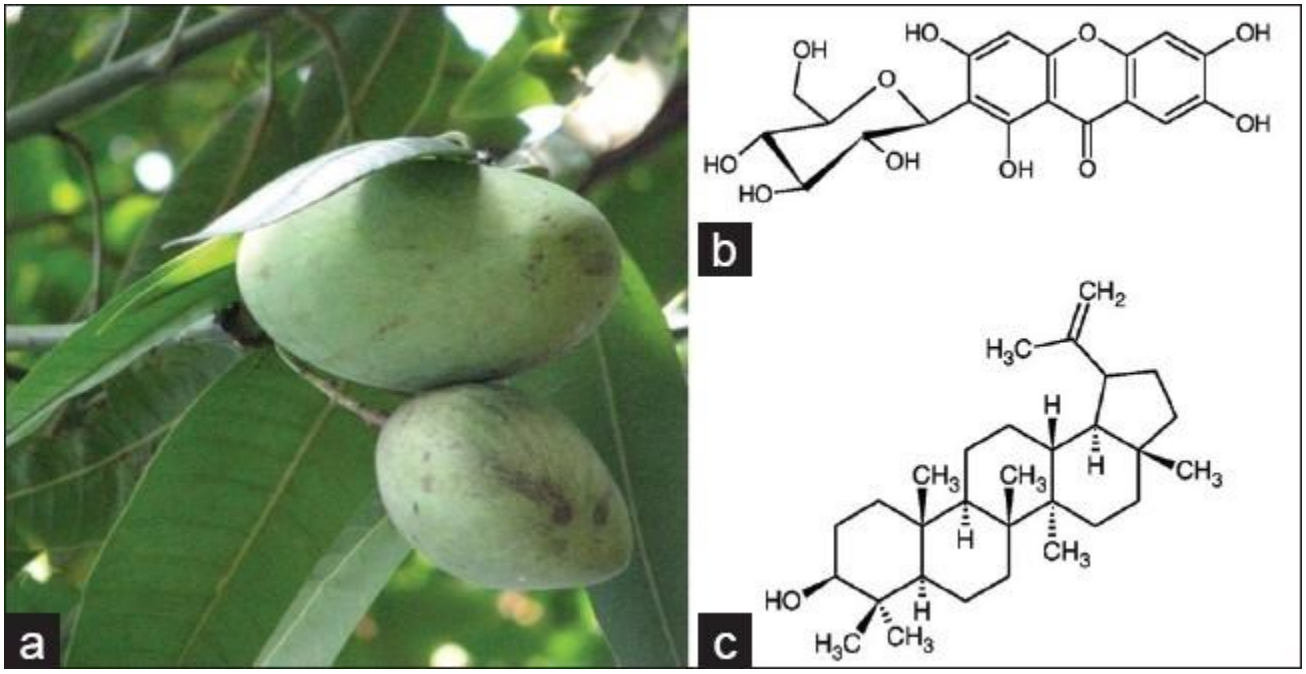
Garlic and its antidiabetic constitutents. (a) *Allium sativa* (garlic), (b) allicin, (c) S-allyl cysteine, (d) ajoene a

Figure 2



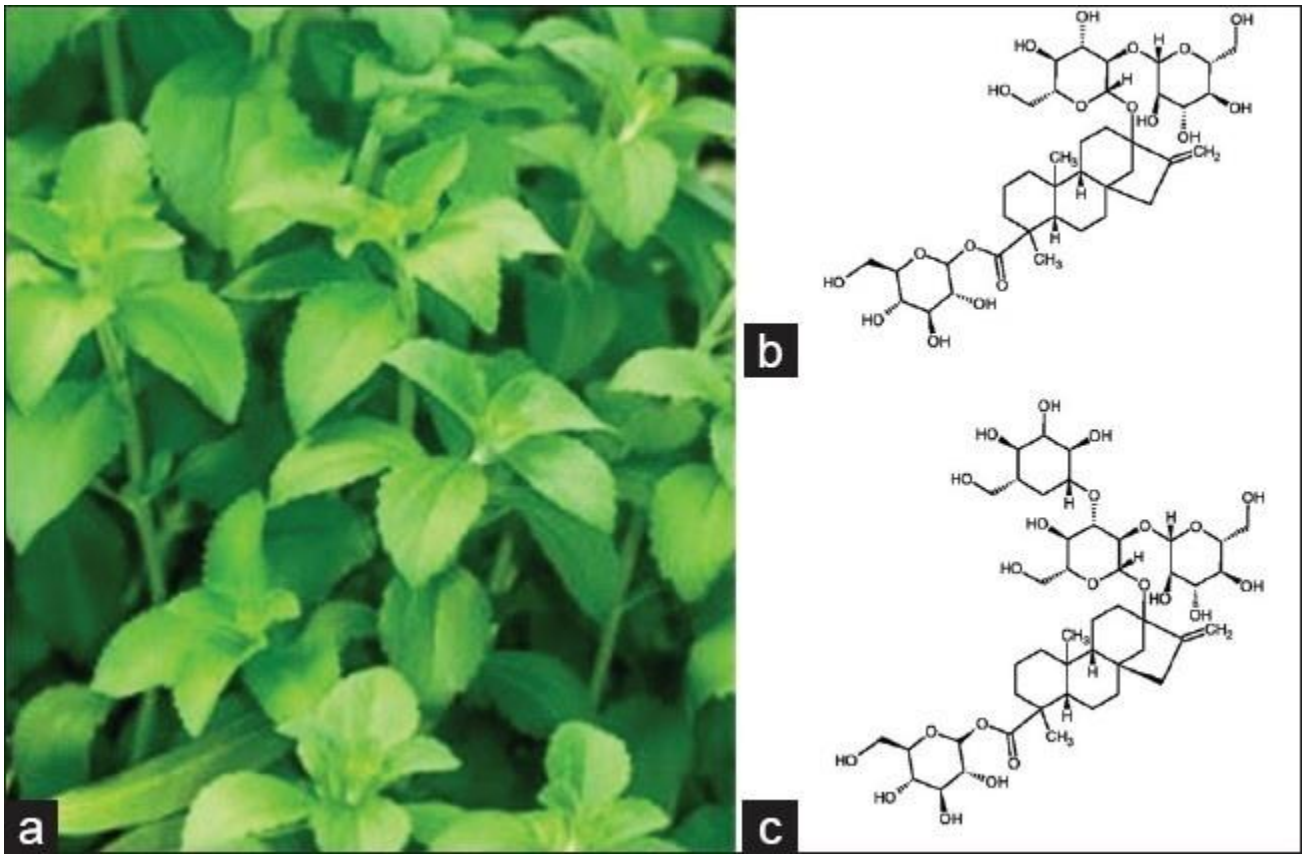
Ginseng and its antidiabetic constituent. (a) Panax ginseng (Asian ginseng), (b) Ginsenoside Rb2

Figure 3



Mango and its antidiabetic constituents. (a) *Mangifera indica* (mango), (b) mangiferin, (c) lupeol

Figure 4



Stevia and its antidiabetic constituents. (a) *Stevia rebaudiana* (sweet leaf), (b) stevioside, (c) rebaudioside

---