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Review Article

Antidiabetic activity of plants, fruits and vegetables: a review

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ABSTRACT

The goal of the current study is appreciated various plants, fruits, vegetables used for antidiabetic activity. Diabetes mellitus is the most conventional diseases in the world. It is the fourth leading reason of death in the most developed countries and it is epidemic in the developing and newly industrialized countries. Diabetes mellitus is a terrible disease found in all areas of the world and is coming a weighty threat to mankind health. It is a serious threat to be met within 21st century. Some traditional plants, fruits, vegetables may have the improvement of diabetic complications and maintain the metabolic disorders. Some studies have assured the benefits of medicinal plants, vegetables, fruits with hypoglycemic effects in the administration of diabetes mellitus. Several medicinal plants, vegetables, fruits have been reported in the literature as having been used to control diabetes. The current investigation, attention is focused on practical studies performed on hypoglycemic fruits, plants, vegetables. These review effective principles derived from natural products are offering a great opportunity to appreciate not only entirely new chemical compounds of antidiabetic agents, but also modern lead compound and potentially relevant action. In total, this review represents the outline of plants, fruits, vegetables within the hypoglycemic natures, reported in the literature.

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1. Introduction

Diabetes mellitus is a conventional disease that is invading the citizens of both civilized and civilizing countries. It is predicted that 25% of the world demography is affected by this disease. It is responsible by the abnormality of carbohydrate metabolism which is associated to low insulin level in blood or impervious to target organs to insulin [1]. It can be classified into two categories:

Type 1 is an insulin-dependent diabetes mellitus (IDDM) when body cannot generate any insulin. It mostly occurs in children, young and adults. In whole diabetes disease, Type 1 diabetes is 5–10% of diabetes. It leads to inability to release insulin results in low rates of glucose uptake into muscles and adipose tissue [2].

Type 2 is noninsulin-dependent diabetes mellitus (NIDDM), in which the body cannot generate enough, or improper use of secreted insulin is the most common form of the disease. This type is accounting for 90–95% of diabetes. Type 2 diabetes is closing widespread proportions, due to propagation in elderly people, and a greater prevalence of obesity and sedentary lifestyles. It generally occurs in obese particular and is associated with hypertension and dyslipidemia [2].

The aim of this treatment is to reduce insulin resistance and to stimulate insulin secretion. Diabetes is a metabolic disorder which can not produce or improperly produce insulin, a hormone that is requisite to convert sugar, starches, and other food into energy. Diabetes mellitus is characterized by constant high blood sugar level. Human body has to control the blood glucose levels at a very minute range which is done with insulin and glucagon. The activity of glucagon is responsible the liver to release glucose from its cells into the blood and produce energy [2].

Herbal medicines are used for controlling of diabetes in civilizing countries where the price of accustomed medicines are a burden to the population [3]. The fruits, vegetables and plant families included that are showed the species hypoglycemic effects including Asteraceae, Leguminosae, Lamiaceae, Rosaceae, Moraceae, Cucurbitaceae, Euphorbiaceae, Liliaceae and Araliaceae and more other families. Some studies had ensured the benefits of traditional plants that are showed hypoglycemic effects in the administration of diabetes mellitus. Now-a-days, modern allopathic medicine are used of natural polymers like guar gum, gum Arabic, gum acacia, etc. [4]. The pharmacological benefit of gums derived from natural origin resides in their ability to decrease the thermal value of consumed diet by decreasing absorption of carbohydrates from the gastrointestinal tract [5]. But, now Villegas and co-workers reported that adherence to vegetables (including green leafy vegetables, cruciferous vegetables, allium vegetables, yellow vegetables, tomatoes and others) and are inversely related with the risk of type 2 diabetes mellitus in a large number of populations [6]. Sweet, sour and bitter taste fruits are used in our daily life without knowing their nutrients.

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ANTIDIABETIC ACTIVITY OF PLANTS

Some plants, plant parts are showed their pharmacological activities and these actions are obtained from aqueous or alcoholic extracts of plants and plant parts, these processes are continue and recognized some important compounds, these compound provide a new drugs. Mainly these compounds are obtained the plant nature. In this article, we describe the plant natures that are involved to diabetes disorder [7].

Allium cepa

Allium cepa is a plant that is obtained from Liliaceae family. Generally it called Onion and is commonly used as vegetable that had strong antidiabetic properties. Onions are improved metabolic condition of diabetic mellitus, probably because of their hypoglycemic and hypocholesterolemic effect [8]. The plant extract are decreased the blood cholesterol levels and decreasing lipid peroxidation process [9]. The active principles compound are showed that alkyl propyldisulfide and S-methyl cysteine sulfoxide that have an anti-diabetic and anti-hyperlipidemic effect, that means help to control of insulin [10].

Alangium lamarckii

Alangium lamarckii (A. lamarckii) is a plant that is obtained from Alangiaceae family. Alcoholic leaves extract of these plants are showed to antidiabetic activity. *A. lamarckii* have desired antidiabetic activity in STZ nicotinamide induced diabetic mice [11].

Brassica juncea

Brassica juncea is commonly used as food items in Indian sub-continent. *B. juncea* is a regional medicinal plant which belongs to Cruciferae family. *B. juncea* aqueous seed extract has a significant hypoglycemic activity which was investigated in STZ induced diabetic male albino mice [12].

Coccinagrdis

Hypoglycemic activity was evaluated in alcoholic extracts of *Coccinagrdis* (C. grandis) leaves. Alcoholic extract of these plants are showed hypoglycemic activity that are proved by clinically to mice. In this experiment, we said that alcoholic extract of leaves of C. grandis showed significant hypoglycemic effect on blood glucose level in mice [13].

Caesalpinia digyna

Caesalpinia digyna (C. digyna) is obtained from Fabaceae family. Its roots extract has antidiabetic activity. Alcoholic root extract of C. digyna are showed the antidiabetic activity and that's why the glucose level of plasma are decreased. These plants are generally used in regional of a country as a food. The main compound of hypoglycemic activity is glibenclamide [14].

Catharanthus roseus

Catharanthus roseus is a plant that is obtained from Alangiaceae family. Hypoglycemic effect of the methanolic leaf extract of *Catharanthus roseus* (C. roseus) in alloxan induced diabetic mice. The levels of blood glucose were significantly decreased when it is used as food. The main compounds of C. roseus are Glibenclamide and Metformin [15].

Centaurium erythraea

Centaurium erythraea is a plant that is obtained from Gentianaceae family. Aqueous leaf extract of *Centaurium erythraea* (C. erythraea) has antidiabetic activity. These extract are decreased the blood glucose level and show the desired activity [16].

Eugenia jambolana

Eugenia jambolana (E. jambolana) is known as Jamun or Indian blackberry has been indicated in Ayurveda, an ancient system of Indian medicine, for use in D.M. In accordance to its claimed anti-diabetic effect in traditional medicine, E. jambolana has been reported to have hypoglycemic effects both in experimental models and clinical studies. It is member of Myrtaceae family [17].

Poriacocos

Poriacocos are the member of Polyporaceae family. The leaf and seed extract of *Poriacocos* shows significant antidiabetic activity. The main compound of *Poriacocos* is triterpene dihydrotrametenolic acid and these compound mainly show an anti-hyperglycemic effect in a mouse. This compound is basically occurred to promote the release of insulin secretion [18]. This natural product is a new type of insulin-sensitizing drug [19].

Psidium guajava

The aqueous extract of *Psidium guajava* leaves have a good effect to lower blood glucose which belongs to Myrtaceae family [20]. The main compounds of these plants are glycoprotein, flavonoid glycosides such as strictinin, isostrictinin and pedunculagin that have antidiabetic activity. These compound are mainly improved the sensitivity of insulin.

Table 1 Having Antidiabetic Activity in the List of Plants Name

Plant Name	Family	Parts used	References
<i>Alangium lamarckii</i>	Alangiaceae	Leaves	[11]
<i>Allium Cepa</i>	Liliaceae	All parts	[8-10]
<i>Brassica juncea</i>	Cruciferae	Seeds	[12]
<i>Coccinagrdis</i>	Cucurbitaceae	Leaves	[13]
<i>Caesalpinia digyna</i>	Fabaceae	Roots	[14]
<i>Catharanthus roseus</i>	Apocynaceae	Leaves	[15]
<i>Centaurium erythraea</i>	Gentianaceae	Leaves	[16]
<i>Eugenia jambolana</i>	Myrtaceae	Seeds, Leaves, Barks	[3, 17]
<i>Poriacocos</i>	Polyporaceae	Roots & Leaves	[18, 19]
<i>Psidium guajava L.</i>	Myrtaceae	Leaves	[20]

<i>Ocimum sanctum</i>	Lamiaceae	Aerial parts	[21]
<i>Opuntia streptacantha</i>	Cactaceae	Leaves	[22]
<i>Solanum xanthocarpum</i>	Solanaceae	Leaves	[23]
<i>Ophiopogon japonicus</i>	Asparagaceae	Roots	[24]
<i>Cyclocaryapaliurus</i>	Cyclocaryaceae	Barks	[25]
<i>Berberis vulgaris</i>	Berberidaceae	Roots	[26]
<i>Setaria italica</i>	Poaceae	Seeds	[27]
<i>Hybanthus enneaspermus</i>	Violaceae	Whole plant	[28]
<i>Cassia auriculata</i>	Caesalpiniaceae	Leaves	[29]
<i>Enicostemma littorale</i>	Gentianaceae	Whole plants	[30]
<i>Symplocos cochinchinensis</i>	Symplocaceae	Leaves	[31]
<i>Viscum schimperi</i>	Viscaceae	Aerial parts	[32]
<i>Vitex negundo</i>	Lamiaceae	Leaves	[33]
<i>Lippa nodiflora</i>	Verbenaceae	Whole plant	[34]
<i>Embelia ribes</i>	Myrsinaceae	Berries	[35]
<i>Dillenia indica</i>	Dilleniaceae	Leaves	[36]
<i>Costus speciosus</i>	Costaceae	Rhizomes	[37]
<i>Albizia odoratissima</i>	Mimosaceae	Barks	[38]
<i>Axonopus compressus</i>	Poaceae	Leaves	[39]
<i>Pterocarpus marsupium</i>	Leguminosae	Bark	[72]
<i>Azadirachta indica</i>	Meliaceae	Leaves	[73]
<i>Aloe vera</i>	Liliaceae	Leaves	[73]
<i>Andrographis paniculata</i>	Acanthaceae	Leaves	[73]
<i>Annona squamosa</i> Linn.	Annonaceae	Leaves, fruits	[73]
<i>Cinnamomum tamala</i>	Lauraceae	Leaves	[73]
<i>Pterocarpus marsupium</i>	Fabaceae	Barks	[73]
<i>Swertia chirayita</i>	Gentianaceae	Barks	[73]
<i>Trigonella foenum-graecum</i>	Fabaceae	Leaves, seeds	[73]
<i>Agrimonia pilosa</i> Ledeb.	Rosaceae	Leaves	[74]
<i>Anisodutanguticus</i> Pascher	Solanaceae	Leaves	[74]
<i>Ephedra distachya</i> L.	Ephedraceae	Leaves	[74]

<i>Herba Epimedii</i>	Berberidaceae	Leaves	[74]
<i>Nymphaea stellata</i>	Nymphaeaceae	Leaves	[74]
<i>Nelumbo nucifera</i> Gaertn	Nymphaeaceae	Root, rhizomes, seeds	[74]
<i>Prunella vulgaris</i> L.	Labiatae	Leaves	[74]
<i>Radix Angelicae Sinensis</i>	Umbelliferae	Roots	[74]
<i>Radix Clematidis</i>	Chinensis	Roots and rhizomes	[74]
<i>Rehmannia glutinosa</i> Libosch	Scrophulariaceae	Roots	[74]
<i>Panax quinquefolius</i>	Araliaceae	Roots and rhizomes	[74]
<i>Phragmites communis</i> Trin	Gramineae	Rhizomes	[74]
<i>Semen Coicis</i>	Gramineae	Seeds	[74]
<i>Aconitum Carmichaeli</i>	Ranunculaceae	Roots	[74]
<i>Adansonia digitata</i>	Bombacaceae	Stem bark	[74]
<i>Olea europaea</i>	Oleaceae	Leaves	[74]

Antidiabetic Activity of Fruits

In our dietary food, fruits are most one that helps to maintain our body physiology by their valuable specific components. Plants fruits contain many other pharmacological properties such as antioxidant, antibacterial, diuretics agents, anticancer, anti-inflammatory, antidiabetic, antifungal properties. Now in the world diabetes is common disease. In this article we describe antidiabetic properties of fruits.

Psidium guajava

Psidium guajava Linn. is a member of the Myrtaceae family which is native to tropical and subtropical countries [20]. Its fruit is conventionally used as food, juice and jam. The another conventional uses of *Psidium guajava* Linn (Guava) are as traditional medicine. It has the significance pharmacologic activities of the alcoholic extract of the fruit, leaf, bark or roots in this plant and are showing antioxidant, hepatoprotective, anti-allergy, anti-microbial, anti-genotoxic, anti-plasmodial, cytotoxic, anti-spasmodic, cardioactive, anti-cough, anti-diabetic, anti-inflammatory and anti-nociceptive activities in vitro and/or in animal models [40]. It has same compound in guava leaves that are some polyphenols, pedunculagin, casuarinin and isostrictinin [41-43].

Mangifera indica

Mangifera indica is the most popular tropical fruits which is obtained from Anacardiaceae family. Most parts (fruit, seeds, pulp, stem bark, roots, and leaves) of the plant have medicinal properties [44]. The components of C-glucoside xanthone of *M. indica* are control diabetes mellitus. These compounds are showing the antidiabetic activity [45].

Aeglemarmelos

Aeglemarmelos is a plant that is known as bael tree in natively. Its fruits are eaten in freshly or dried and the other parts of the plant such as leaves and small shoots are also used in many purposes in some countries. It is obtained from rutaceae family. It is an exoteric medicinal plant in the Siddha and Ayurvedic systems of medicine and folk medicines used to treat antidiabetic activity. The leaves, fruits, and stems of plants contain some compound such as askimianin, sterol, lupeol, marmin and aegelin. In pharmacological purpose, both the fruit and root showed hypoglycemic activities [46-50].

Punicagranatum

Punicagranatum is a deciduous shrub or small tree. Its fruit has pharmacological and therapeutic properties that are antidiabetic activity. It is obtained from lythraceae family. This plant is used to treat diabetes mellitus in some countries such as India and China. The flowers of Punicagranatum are also used for maintain of diabetes mellitus. Oral administration of the aqueous ethanolic extract of Punicagranatum flowers are decreased the significant blood glucose level [51, 52].

Citrulluscolocynthis

Citrulluscolocynthis fruits are generally used for its board range of medicinal uses such as pharmaceutical and nutraceutical potential which are obtained from cucurbitaceae family. These fruits are showed antioxidant, antidiabetes properties [53].

Table 2 Having Antidiabetic Activity in the List of Plant Fruits Name

Plant Fruits Name	Family	Parts used	References
<i>Psidium guajava</i>	Myrtaceae	Fruits, leaf, bark or roots	[20], [40-43]
<i>Mangifera indica</i>	Anacardiaceae	Fruit, seeds, bark, leaves	[44, 45]
<i>Aeglemarmelos</i>	Rutaceae	leaves, fruits, and stems	[46-50]
<i>Punicagranatum</i>	Lythraceae	Fruits	[51, 52]
<i>Citrulluscolocynthis</i>	Cucurbitaceae	Fruits	[53]
<i>Chaenomelessinensis</i>	Rosaceae	Fruits	[54]
<i>Solanumtorvum</i>	Solanaceae	Fruits	[55]
<i>Vacciniumarctostaphylos</i>	Ericaceae	Fruit	[56]
<i>Ficus religiosa</i> Linn.	Moraceae	Fruits	[57]
<i>Abelmoschus Esculentus</i>	Malvaceae	Fruits	[58]

Antidiabetic Activity of Vegetables

Everyday we take vegetable with our daily food. Some vegetable have medicinal uses such as antidiabetic, anti-inflammatory, antifungal and so on. Some vegetables are described in this article about their antidiabetic properties.

Zingiberofficinale

Ginger (*Zingiber officinale* Rosc.) is a creeping perennial with thick tuberous rhizome which spreads underground. It is member of Zingiberaceae family. Ginger is a rich source of volatile oil. Zingiberol, Aframodial, zingiberene, phellandrene, gingerols, shogaols and linalool are important constituents of these vegetable. These are used in diabetes mellitus [59].

Lycopersiconesculentum

Lycopersiconesculentum belongs to the nightshade family, Solanaceae. Its local name is tomato. There are some chemical compounds that are some vitamins, minerals, organic compounds etc. These are having antidiabetic properties [60, 61].

Allium cepa

The onion (*Allium cepa* L.) is a vegetable and is the most widely cultivated species of the *Allium* genus. It is obtained from Amaryllidaceae family. The vegetable contains 89% water, 4% sugar, 2% fiber, 1% protein and 0.1% fat. Onions contain low amounts of essential nutrients. It is used as antidiabetic in daily life [62].

Allium sativum

Allium sativum is a species in the genus *Allium* and its family is Amaryllidaceae. It is generally known as garlic. Chemical components of *Allium sativum* have anti-hyperglycemic activity such as allicin, S-allyl cysteine sulfoxide. The mechanism of allicin can enhance serum insulin releasing by effectively combining with compounds like cysteine [63].

Momordicacharantia

Momordicacharantia L. is used in traditional medical practices to treat diabetic mellitus. It is obtained from Cucurbitaceae family. It is also a nutritious vegetable. Some experimental practices on animals and humans purposes that this vegetable has a possible activity in glycemic control. Chemical components of *Momordicacharantia* L. has anti-hyperglycemia such as Charantin; Vicine. The extract of fruit juice and seed powder of *Momordicacharantia* caused a widely reducing in fasting blood glucose and improved glucose in normal and diabetic animals and in humans. A wide range of compounds have been isolated from *Momordicacharantia* are polypeptide compound (p-insulin), the sterol glycoside mixture charantin and the pyrimidine nucleoside vicine have been identified as the orally anti-diabetic activities for humans and animals [64, 65].

Artocarpusheterophyllus

Artocarpusheterophyllus Lam. are plants that are known as Jackfruit. It is obtained from Moraceae family. The plant is showing some pharmacological activities such as antibacterial, anti-inflammatory, antioxidant and anti-diabetic properties. Chemical components of *Artocarpusheterophyllus* Lam. are Cycloartenone, β -sitosterol. These compounds have anti-hyperglycemia activity [66].

Table 3 Having Antidiabetic Activity in the List of Plant Vegetables Name

Vegetables Name	Family	Parts used	References
<i>Zingiberofficinale</i>	Zingiberaceae	Rhizomes	[59]
<i>Lycopersiconesculentum</i>	Solanaceae	Fruits, Leaves	[60, 61]
<i>Allium cepa</i>	Amaryllidaceae	All parts	[62]
<i>Allium sativum</i>	Amaryllidaceae	Rhizomes	[63]
<i>Momordicacharantia</i>	Cucurbitaceae	Fruits, Leaves	[64, 65]
<i>Artocarpusheterophyllus</i>	Moraceae	Integral parts	[66]
<i>Beta vulgaris</i>	Amaranthaceae	Leaves,	[67]
<i>Brassica nigra</i>	Brassicaceae	Seeds, Flowers, Leaves	[68]
<i>Eruca sativa</i>	Brassicaceae	Flowers, Leaves	[69, 70]
<i>Brassica oleracea</i>	Brassicaceae	Flowers, Leaves	[71]

Diabetes is the metabolic disorder which may be considered as a chief cause of high financial loss which may in turn exclude the improvement of nations. Overall, uncontrolled diabetes promote some chronic complications such as heart disease, blindness and renal failure. In order to exclude this type serious health problem and the developments of research into new hypoglycemic and potentially antidiabetic agents are of great achievements. In the present review article, achievements are indicated to the profile of plants, fruits and vegetables which have antidiabetic activity. Some families of plants, fruits, vegetables with the most potent hypoglycemic effects includes: Ericaceae, Malvaceae, Lamiaceae, Liliaceae, Cucurbitaceae, Asteraceae, Moraceae, Rosaceae, Euphorbiaceae, Leguminosae, and Araliaceae. The most commonly studied species are: *Alangium lamarkii*, *Allium Cepa*, *Brassica juncea*, *Coccinagrandis*, *Caesalpinia digyna*, *Catharanthus roseus*, *Centaurium erythraea*, *Eugenia jambolana*, *Poriacocos*, *Psidium guajava* L., *Ocimum sanctum*, *Opuntia streptacantha*, *Solanum xanthocarpum*, *Ophiopogon japonicus*, *Mangifera indica*, *Punicagranatum*, *Chaenomeles sinensis*, *Solanum torvum*, *Zingiber officinale* Rosc, *Lycopersicon esculentum* Miller. The majority of the experiments ensured the benefits of medicinal plants, fruits, vegetables with antidiabetic effects in the maintaining of diabetes mellitus. The numerous mechanisms of actions have been submitted for these plants, fruits, vegetables extracts. Some experimental hypotheses relate to their effects on the activity of pancreatic β cells synthesis and the increase in the protective or inhibitory effect against insulinase and the increase of the insulin sensitivity or the insulin-like activity of the plants, fruits, vegetables extracts. Some enzymes are inhibited of intestinal glucose absorption and reduction of carbohydrates, reduction of the effect of glutathione. All of these actions may be responsible for the reduction and or abolition of diabetic complications.

CONCLUSIONS

In conclusion, this paper had presented a list of anti-diabetic plants, fruits, vegetables and their uses parts and their family which are used in the treatment of diabetes mellitus. It showed that these plants, fruits, vegetables have hypoglycemic effects. Some bioactive drugs isolated from plants, fruits and vegetables having hypoglycemic effects showed antidiabetic activity normally and sometimes even more active than known oral hypoglycemic agents such as daonil, tolbutamide and chlorpropamide. However, many other active drug compounds obtained from plants, fruits and vegetables and these has not been well characterized in desire conditions. More practical and experimental events must be carried out to evaluate the mechanism of action of medicinal plants, fruits, vegetables with antidiabetic effect.

In this review article, we discussed about traditional medicinal plants for the treatment or maintaining of diabetes mellitus disorder. Traditional medicinal plants, fruits and vegetables are mostly used for rural areas and because the availability of plentiful amount of medicinal plants those areas. Therefore, maintaining diabetes mellitus with plant derived compounds which are capable and do not require laborious pharmaceutical synthesis seems highly attractive. In the present review an attempt has been made to experiment the antidiabetic medicinal plants and may be useful to the health professionals, scientists and scholars working in the field of

pharmacology and therapeutics to develop antidiabetic drugs. It is expected that with the progress of medicinal chemistry and pharmacology and show the antidiabetic agents. Actually, in the recent study, it was reported that some triterpenoids derived are promising antidiabetic agents. Basically some plants are showed principally in antidiabetic nature in many areas of the world.

CONFLICT OF INTEREST

We declare that we have no conflict of interest between the authors.

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