

Isolation of Bioactive Compounds of Plant origin for Anti-Diabetic Activities

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Abstract: India is a developing country, where, nearly 80% of the population is still dependent on traditional medicines which are mostly extracted from plants and are well known as Traditional Medicines of plant origin. These traditional medicines proved to be more affordable, easily accessible, clinically effective and relatively less adverse effects than modern drugs. The attention on the application of phytochemical constituents of medicinal plants in the pharmaceutical industry has increased significantly. Plant-derived secondary metabolites are small molecules or macromolecules biosynthesized in plants including steroids, phenolic, alkaloids, lignans, carbohydrates and glycosides, that possess a diversity of biological properties beneficial to humans, such as their antimicrobial, anti-allergic, anti-cancer, anti-diabetic, anti-oxidant and anti-inflammatory activities. The use of medicinal plant extracts and their isolated bio-active compounds for the management of diabetes mellitus has been tremendously increased in recent decades. The present study is aimed at providing in-depth information on medicinal flora that has been widely used all over the world traditional healthcare system for the management of diabetes mellitus. Diabetes mellitus (DM) is a metabolic syndrome. Diabetes has become more common in recent years. Chemically generated drugs are used to lessen the effects of DM and its following repercussions due to unpleasant side effects such as gastro-intestinal issues, weight gain, and heart failure. On the other hand, medicinal plants could be a good source of anti-diabetic medications. Diabetes, a chronic physiological dysfunction affecting people of different age groups worldwide. It is a chronic disease which is a result of metabolic disorders in pancreatic β -cells that have hyperglycemia. Hyperglycemia can be caused by a deficiency of insulin production by pancreatic (Type 1 diabetes mellitus) or insufficiency of insulin production in the phase of insulin resistance (Type 2 diabetes mellitus). The current medications of diabetes mellitus focus on controlling and lowering blood glucose levels in the vessel to a normal level. However, most modern drugs have many side effects causing some serious medical problems during the treatment. Therefore, traditional medicines have been used for a long time and are known to play an important role as alternative medicines. This review focuses on anti-diabetic plants,

along with their bioactive constituents, chemical characterization, and plant-based diets for diabetes management. The purpose of this review is to highlight anti-diabetic plants and plant-derived bioactive compounds that have anti-diabetic properties. It also provides researchers with data that may be used to build future strategies, such as identifying promising bioactive molecules to make diabetes management easier.

Keywords: Diabetes mellitus; medicinal plants; anti-diabetic; bioactive compound.

INTRODUCTION

The diabetes mellitus is a very common and widespread disease. It is affecting the citizens of both developed and developing countries. Diabetes mellitus is taken from the Greek word diabetes, meaning siphon- to pass through and the Latin word mellitus meaning sweet. The term "diabetes" was first used by Apollonius. Mering and Minkowski, in 1889, discovered the role of the pancreas in the pathogenesis of diabetes. In 1921 Fraderick Banting and Charles Herbert Best, working in the laboratory of J.J.R. Macleod at the University of Toronto, were first to isolate insulin from dog pancreas and it was later purified by James B Collip, leading to the availability of an effective treatment for diabetes in 1922. Diabetes mellitus is a metabolic disease and is defined by serious higher glucose levels occurring due to abnormalities in the production of Insulin, or insulin resistance also some individuals can have both reasons (Kharroubi and Darwish, 2015). According to the International Diabetes Federation (IDF) data in 2019, 463 million adults (20-79 years) have been suffered from DM, and this number is projected to reach 700 million by 2045 (International Diabetes Federation, 2019). Despite being a non-communicable disorder, diabetes is considered one of the five biggest morbidities worldwide (Kharroubi and Darwish, 2015). Prevention and control of DM is a major challenge and requires good lifestyle towards more physical

activity and less calorie intake avoiding sedentary habits. This disease is characterized by abnormally high plasma glucose levels, leading to major complications, such as neuropathy, retinopathy and cardiovascular disease (Bell, 2001). This health disease is a persistent metabolic defect caused by the total (or relative) defect of insulin. Most of the people of the world are affected by type 2 diabetes. It is universal health problem (Cooke and Plotnick, 2008).

The symptoms of diabetes often include frequent urination also known as polyuria, increased thirst and increased appetite. If left untreated, diabetes can cause many health complications. Acute complications can include hyperosmolar hyperglycemic state, diabetic ketoacidosis or a non-ketonic hyperosmolarity that can cause a person to suffer a lack of water in the body and, insufficient treatment can cause mortality (Adler et al., 2021). Serious long-term complications include cardiovascular disease, chronic kidney disease, weight loss, stroke, foot ulcers, damage to the eyes or blurred eyesight, damage to the nerves and cognitive impairment.

There are two different types of diabetes such as type 1 diabetes mellitus (T1DM) (lack of insulin production) type 2 diabetes mellitus (T2DM) (resistance to insulin activity) and gestational diabetes mellitus is a term used to describe diabetes that develops during pregnancy (Gilor et al., 2016). Diabetes mellitus is divided into three main types: Type 1 diabetes (insulin-dependent diabetes mellitus) is an autoimmune disorder developing when insulin-producing cells of the pancreas in the body have been destroyed and the pancreas produces little or no insulin. A person who is suffering from type 1 diabetes must take insulin daily to live. The type 1 diabetes is known to develop most often in children and young adults. The other one is Type 2 diabetes, which is also known as another term “insulin-independent diabetes mellitus” which accounted for more than 90% of diagnosed cases of DM in adults. It is a diagnosis in which the pancreas produces enough insulin but the body cannot use the insulin effectively, a condition called insulin resistance. The third one is Gestational diabetes mellitus (GDM). GDM is defined as “a kind of glucose intolerance that develops in the second and third trimesters of pregnancy, resulting in hyperglycemia of varying severity” (Chiefari et al., 2017).

MANAGEMENT OF DIABETES MELLITUS

According to the ninth edition 2019 of the International Diabetes Federation (IDF) Diabetes Atlas released by IDF, as of 2019, the total adult population in the age group of 20-79 years stands at 463 million who live with diabetes mellitus, which is set to increase to 578 million by 2030 (International Diabetes Federation, 2019). There is one patient who dies of diabetes mellitus every 6 s, this rate is higher than death rates from human immunodeficiency virus (HIV) (1.5 million), tuberculosis (1.5 million) and malaria (0.6 million), combined (Medagama and Bandara, 2014; Alqathama et al., 2020 and Kesavdev et al., 2017). The estimated prevalence of diabetes in men aged 20-79 years is slightly higher than in women (9.6% vs 9.0%). Nowadays, diabetes mellitus has risen along with rapid cultural and social changes, such as aging, population, less physical activities, dietary, and so on. The cost associated with diabetes includes increasing health services, an economic burden. In underdeveloped nations (especially in rural regions), pharmaceutical medications and insulin used to treat diabetes are rare, expensive, and have substantial side effects. Treatment costs are expensive and unaffordable in developing nations, which is a major basic barrier for DM. In light of this, phototherapy and the use of natural items with anti-diabetic properties are often the first lines of treatment and care (Chinsebu, 2019). The present treatment of DM is focussed on controlling and lowering blood glucose levels in the vessel to a normal level (Knight, 2005). The mechanisms of both modern and traditional medicines to lower blood glucose concentration are (Bhoyar et al., 2011; Wang et al., 2013; Thule, 2012):

- 1) To stimulate β -cell of the pancreatic islet or islet of Langerhans to release more insulin;
- 2) Inhibit the action of hormones which increases blood glucose concentration;
- 3) Increase the sensitivity of insulin receptor site;
- 4) Inhibit hydrolysis of glycogen in liver;
- 5) Enhance the use of glucose in tissues and organ.

Currently, there are 6 main classes of modern medicines which are being used all over the world for controlling blood glucose levels and 2 classes of injections (Colberg et al., 2016). The tablets are known as biguanides (metformin), sulfonylureas, thiazolidinediones (glitazones), meglitinides (glinides), α -glucosidase inhibitors and DPP-4

inhibitors. The classes of medications given by injection are incretin mimetics and insulin (DeFronzo, 1999; Goldberg et al., 2005; Home et al., 2007; Singh et al., 2007; Siconolfi et al., 1990; Simonson et al., 1984; Lebovitz, 2019; Perfetti and Ahmad, 2000; Hanefeld et al., 2000 and Jovanovic et al., 2000). Mechanisms of these medications have been reported. However, most modern drugs have many side effects and adverse effects, causing some serious medical problems during medication processing.

Besides modern medication, traditional medicines have been used for a long time and play an important role as alternative medicines (Yakubu et al., 2020; Chan et al., 2012; Harris, 2000 and Preethi, 2013). According to WHO, a plant-based traditional system of medicine is still the chief support of about 75-80% of the world population mainly in developing countries having a diversity of plants. Traditional medicines are usually the first choice for primary healthcare of patients in developing countries because of better cultural acceptability, better compatibility with the human body and lesser side effects than modern therapies. Recently, some medicinal plants have been reported to be useful in diabetes worldwide and have been used as antidiabetic remedies. More than 800 plant species having hypoglycemic activity have been available in the literature (Patel et al., 2012), however, investigating new antidiabetic drugs from natural plants has still been attractive because they contain phytoconstituents that demonstrate alternative and safe effects on the treatment of diabetes mellitus. Most plants contain bioactive compounds such as phenolics, alkaloids, flavonoids, glycosides, carotenoids, terpenoids, etc., that have been proved to have antidiabetic activities.

MEDICINAL PLANTS CONTAINING BIO-ACTIVE COMPOUNDS FOR ANTI-DIABETIC ACTIVITY

Many medicinal plants are so in need of discovery for their mechanism of action as anti-diabetic agents. These traditional medicinal plants are popular due to their low toxicity and very economical nature.

This review article covers various reported medicinal anti-diabetic plants and the bioactive compounds contained in them which act as insulin in affected individuals or patients.

The hypoglycemic and anti-diabetic effects of several plants used as traditional anti-diabetic remedies have been proved, and the mechanism of hypoglycemic activity of these plants have been studied effectively (Aggarwal and Aggarwal, 2011; Kayarohanam and Kavimani, 2015 and Sidhu and Sharma, 2013).

This information would be very beneficial to all health professionals, researchers and scholars who are doing research in the field of pharmacology and therapeutics to develop anti-diabetic drugs to cure diabetes mellitus. This review focuses on the mechanism of traditional herbal and natural medicines from traditional plants for diabetes treatment.

- *Tinospora cordifolia* (Guduchi or Giloy)

It is commonly known as heart-leaved moonseed or “Amrita” or “Guduchi” or “Giloy”. In India, this plant has been reported as the main source of treatments for many ailments such as fever and other urinary diseases in folk medicine. During the 2020-22 COVID-19 outbreak in India, the Ministry of Ayush recommended use of *Tinospora cordifolia* as a home remedy for immune support.

Phytochemistry

Tinospora cordifolia has been reported to contain numerous constituents belonging to different chemical classes of secondary metabolites such as terpenoids, alkaloids, glucosides, essential oils, phenolic constituents, steroids, aliphatic compounds, and polysaccharides. Leaves of this plant are a rich source of proteins, flavonoids, glycosides and alkaloids (Kumar et al., 2017 and Rajalakshmi and Anita, 2016). These active compounds have been exposed to several biological activities, including anti-inflammatory, antiseptic, antimicrobial, anti-cancer and antidiabetic activities.

Anti-diabetic Activity

Tinospora cordifolia, containing polysaccharide isolated from this plant exposed the β -cell regenerative properties which could be pointed to develop antidiabetic medicine with few side effects (Sangeetha et al., 2011). Oral administration of the extract of *Tinospora cordifolia* roots for two weeks experimented with induced type 2 diabetic rats resulted in this plant can promote insulin secretion and inhibit glucogenolysis process and therefore improve the regulation of blood glucose level in the body (Patel and Mishra, 2011). In addition, the

powdered stem of *Tinospora cordifolia* at the oral dose of 50 mg/kg of body weight significantly reduced the fasting blood glucose and HbA1c levels by 9% and 14%, respectively in type 2 diabetic patients (Kumar, 2016).

- *Gymnema sylvestre* (Gurmar)

Gymnema sylvestre is a perennial woody vine native to Asia, Africa and Australia. It has been used in Ayurvedic medicine. Common names include gymnema, Australian cowplant, and Periploca of the woods, and the Hindi term gurmar, which means “sugar destroyer”. It belongs to the Apocynaceae family. So far, this plant has been widely used in several countries around the world in treating diabetes.

Phytochemistry

The phytoconstituents of *Gymnema sylvestre* consist of many groups containing bioactive compounds that are Triterpene saponins, Dammarene saponins, Oleanane saponins, Triterpenoidsaponins, Gurmarin, Gymnemasins A, Gymnemasins B,

Gymnemasins C, Gymnemasins D, Gymnemanol, Gymmestrogenin, Flavonol glycoside and Sterols.

Anti-diabetic Activity

The major biological active ingredient of *Gymnema sylvestre* is Gymnemic acids- a group of triterpenoid saponins isolated and identified successfully. Several studies have reported that the main biological activity of this plant is antidiabetic activity (Khan et al., 2019).

In the investigation of S. Sathya et al., the aqueous extract of *Gymnema sylvestre* leaf informed hypoglycemic activity in normal and alloxan-induced diabetic rats (Sathya et al., 2008) by reducing glucose concentration. Other research on *Gymnema sylvestre* extracts suggested that this extract could stimulate the release of insulin in vitro by permeabilizing the β -cell (Persaud et al., 1999). According to the literature, the action of Gymnemic acids in diabetic treatment was reported to be able to stimulate pancreatic cell production, thereby increasing insulin production, increase insulin sensitivity and insulin activity, help to control and stabilize blood glucose concentration in the body.

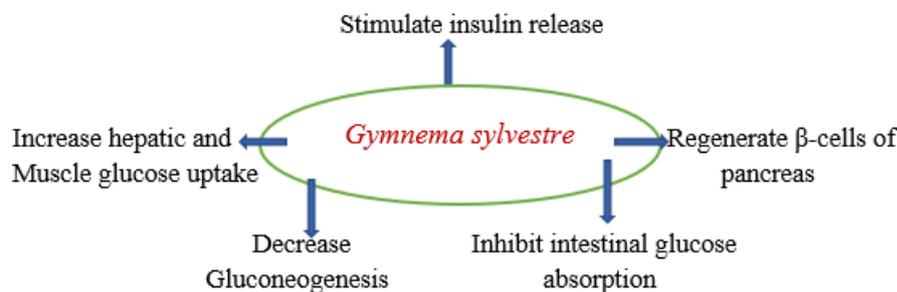


Figure 1. Mechanisms of *Gymnema sylvestre* in the antidiabetic activity.

- *Ocimum sanctum* (holy basil)

It is a small tree, upto 1 m tall, commonly known as ‘Sacred basil’ or ‘Holy basil’ or Tulsi and is grown as a household plant in many countries for medicinal purposes like Vietnam and India. It belongs to the Lamiaceae family. The whole plant has a pleasant aroma.

Phytochemistry

The phytochemistry of *Ocimum sanctum* is identified in all parts of this plant. It contains many types of nutrients and bioactive compounds. However, the quantity of constituents depends on many natural factors, including growing, harvesting, and storage conditions (Rahman et al., 2011 and Singh and Chaudhuri, 2018).

In leaf extract of *Ocimum sanctum*, volatile oil was extracted and identified chemical compositions contained many major components like methyleugenol, eugenol, and p-caryophyllen. Its essential oil contains various bioactive compounds, such as esters, aliphatic aldehydes, phenolic acids and terpenoids. This herb also consists of a diversity of secondary metabolites, including phenolics, flavonoids, lignans, steroids, terpenoids, fatty acids and their derivatives. These components have been mainly studied for therapeutic purposes because of their biological and pharmacological effects, including anti-inflammatory, antimicrobial, anticancer, antioxidant, antifungal, antiviral, antitumor, gastric antiulcer activity, antimutagenic, immunostimulant activities, antibacterial, antiasthmatic, antistress and anti-diabetic activity.

Anti-diabetic Activity

In Hannan’s study, there are four fractions of *Ocimum sanctum* including the ethanol, aqueous, butanol, and ethyl acetate fractions prepared to elucidate the mechanism of antihyperglycemic activity of this plant showed in literature (Hannan et al., 2006). This result proved that these fractions could stimulate insulin secretion. This study also indicates that the ethanol extract could decrease blood glucose concentration and increase insulin secretion, thereby this plant is a potential herb in diabetic treatment. The aqueous extract of leaves of *Ocimum sanctum* showed the significant reduction in blood sugar level in both normal and alloxan induced diabetic rats (Vats et al., 2002). Significant reduction in fasting blood glucose, uronic acid, total amino acid, total cholesterol, triglyceride and total lipid indicated the hypoglycemic and hypolipidemic effects of tulsii in diabetic rats (Rai et al., 1997). Oral administration of plant extract (200 mg/kg) for 30 days led to decrease in the plasma glucose level by approximately 9.06 and 26.4% on 15 and 30 days of the experiment respectively. These evidences support that *Ocimum sanctum* has many benefits in the management of diabetes, and this plant should be encouraged to be a potential anti-diabetic activity (Kapoor, 2008).

- *Momordica charantia* (Bitter Melon)
Momordica charantia commonly known as bitter melon; Goya; bitter apple; bitter gourd; bitter squash; balsam-pear; is a tropical and subtropical vine of family Cucurbitaceae, widely grown in Vietnam, India, China, East Africa, South-North

Asia, Central and South America and Caribbean for its edible fruit. Besides using *Momordica charantia* as a vegetable, it is supposed to be a herbal medicine, used as folk medicine. In traditional medicine of India, different parts of the plant are used as claimed treatments for diabetes, and as a stomachic, laxative, antibilious, emetic, anthelmintic agent, for the treatment of cough, respiratory diseases, skin diseases, wounds, ulcer, gout, and rheumatism. Its bioactivities, such as anti-inflammatory activity, anti-oxidant activity, anti-viral activity, anti-cancer activity, anti-bacterial activity, etc. and especially anti-diabetic activity (Saeed et al., 2016).

Phytochemistry

The important phytochemicals of this plant are fatty acids, amino acids, alkaloids, steroids, momordicosides (A, B, C, D, E, G, F₁, F₂, I, K, L), phenolic compounds, acyl glucosyl sterols, steroidal saponin, carbohydrates, vitamins, and minerals, etc (Saeed et al., 2016; Dandawate et al., 2016; Ibrahim et al., 2010; Tan et al., 2014; Popovich et al., 2010; Chuang et al., 2006; Ahmad et al., 2012; Keller et al., 2011 and Sasa et al., 2009).

Anti-diabetic Activity

Extracts of fruit pulp, seed, leaves and whole plant was shown to have hypoglycemic effect in various animal models. The fruits, seeds and callus of *Momordica charantia* contain some insulin-like proteins (Khanna et al., 1981) which are homologous to human insulin, and it produced consistent hypoglycemic effect when tested on rats, gerbils, langurs and human beings (Dans et al., 2007).

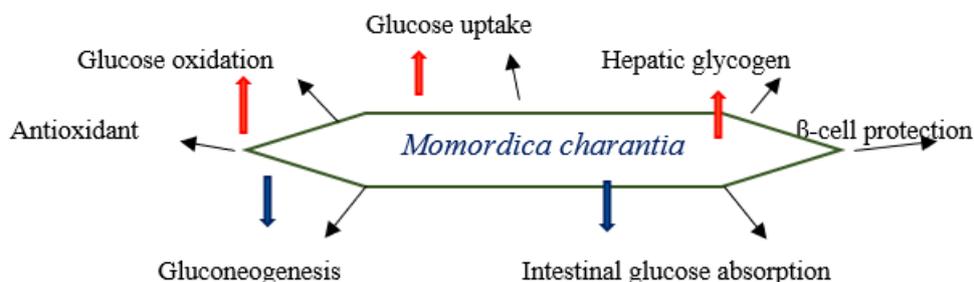


Figure 2. Bioactive compounds and their effects in *Momordica charantia*

Many research papers have shown that its bioactivities significantly decrease blood glucose levels. These investigations on bitter melon also depicted that it can increase the glucose tolerance of normal and diabetic mice and also humans (Keller et

al., 2011; Sasa et al., 2009; Khanna et al., 1981; Dans et al., 2007 and Jiang et al., 2016). Many studies have proved that the bioactive constituents for *Momordica charantia* have considerable antidiabetic activities. An investigation on the

antidiabetic activities of *Momordica charantia* fruit juice in streptozotocin-induced diabetic rats showed that this herb possesses the ability to enhance insulin secretion of pancreatic β -cells, elevate of serum insulin level, decrease insulin resistance, improve β -cell function, increase glucose utilization in a dose of 10 mL/kg/day for 14 days (Mahmoud et al., 2017). In cells of the pancreas, *Momordica charantia* can be able to renew or recover the partially destroyed cells and encourage the secretion of insulin. Other studies also investigated the inhibition of diabetes-related enzymes, such as α -glucosidase and α -amylase from *Momordica charantia* extracts (Poovitha and Parani, 2016). Ethanolic extracts of *Momordica charantia* (200 mg/kg) showed an antihyperglycemic and also hypoglycemic effect in normal and streptozotocin-induced diabetic rats. This may be because of inhibition of glucose-6-phosphatase besides fructose-1,6-biphosphatase in the liver and stimulation of hepatic glucose-6-phosphate dehydrogenase activities (Shibib et al., 1993).

- *Aloe vera*
Aloe vera is a succulent plant species of the genus *Aloe*. It is a popular houseplant which has a long history as a multipurpose folk remedy. It is the most applied medicinal plant especially in the cosmetic industry, topical medication and antidiabetic medication. This traditional medicinal plant belongs to the family Liliaceae. *Aloe vera* is considered native only to the south-east, North Africa, Sudan and neighbouring countries, China, India and temperate continents.

Phytochemistry

Phytoconstituents in the plant are acetylated mannans, polymannans, anthraquinone C-glycosides, anthrones, alkaloids, flavonoids, saponins, tannins, phenols, vitamins, carbohydrates and minerals and several other aromatic compounds (Patel et al., 2012). These compounds have been proven for various pharmacological activities, such as anticancer, antidiabetic, antimicrobial, antioxidant and so on.

Anti-diabetic Activity

Extracts of aloe gum effectively increases glucose tolerance in both normal and diabetic rats (Al-Awadi and Gumaa, 1987). The experiment on diabetic rats treated with *Aloe vera* water extract orally led to reducing significant blood glucose levels. It was

analysed that this extract is antidiabetic in nature with fewer or very less side effects. Its less expensive cost is also a very significant benefit of *Aloe vera* in the production of medicine against diabetes mellitus.

- *Trigonella foenum graecum* (Fenugreek)
Trigonella foenum graecum is an annual plant in the family fabaceae. It is commonly known as fenugreek or methi. It is extensively grown in Mediterranean and Asian nations. Its seeds and leaves are common ingredients in dishes from the Indian subcontinent, and have been used as a culinary ingredient since ancient times. It is used as a herb, spice, and vegetable. It is useful in traditional practices for treating dysmenorrhea, inflammation, diabetes, obesity, or any human disorder.

Phytochemistry

Constituents of fenugreek include flavonoids, alkaloids, coumarins, vitamins, essential oils, proteins, and steroidal saponins. Recent pharmacological research has revealed that fenugreek includes several active compounds that modulate glycolipid metabolism and improve insulin resistance. In addition, 4-hydroxy isoleucine was discovered to have a significant impact on lowering insulin resistance. A range of elements in fenugreek seeds, including galactomannan, phenolic compounds, and fibres, have been discovered to have hypoglycemic effects.

Anti-diabetic Activity

Clinical investigations have indicated that 2-3 g of fenugreek gum per day is beneficial in managing blood sugar levels. The fenugreek gum thickens and creates a gel in the stomach, trapping sugars, lipids and starch-hydrolyzing amylase enzymes, resulting in a slowdown of sugar absorption, which is beneficial to diabetic and obese people (Rahman et al., 2022; Zameer et al., 2017; Rahman et al., 2022; Bhattacharya et al., 2022; Mominur Rahman et al., 2021; Rahman et al., 2021 and Rahman et al., 2022). Oral administration of 2 and 8 g/kg of plant extract produced dose dependent decrease in the blood glucose levels in both normal as well as diabetic rats (Khosla et al., 1995).

- *Aegle marmelose* (Bengal Quince, Bael or Bilva)
Aegle marmelose, commonly known as bael, golden apple, Japanese bitter orange, is a rare species of tree native to the Indian subcontinent and Southeast

Asia. It is present in India, Bangladesh, Sri Lanka, and Nepal as a naturalized species. The tree is considered to be sacred by Hindus.

Phytochemistry

The bael tree contains furocoumarins, including xanthoxol and the methyl ester of alloimperatorin, as well as flavonoids, rutin and marmesin; a number of essential oils; and, alkaloids. Every part of the plant (root, leaf, trunk, and fruits) is used in the management of wide variety of disorders as dysentery, piles, dyspepsia, jaundice, scrofula, indigestion, and chronic fever in traditional medicine (Jayaweera, 1982).

Anti-diabetic Activity

The leaves, bark, roots, fruits, and seeds are used in traditional medicine to treat various illnesses. Based on the scientific investigations, the water extract of dry flower of *Aegle marmelose* exerted potent hypoglycemic and antihyperglycemic activities (Kumari et al., 2013). A reduction in serum glucose concentration as 15% and 21% was observed in healthy and alloxan-induced diabetic rats at a single dose experiment (200 mg/kg), respectively.

- *Syzygium cumini* or *Eugenia jambolana* (Jamun)
Syzygium cumini, commonly known as Malabar plum, Java plum, black plum, jamun, jaman, jambul, or jambolana, is an evergreen tropical tree in the flowering plant family Myrtaceae, and favoured for its fruit, timber, and ornamental value. It is native to the Indian subcontinent, adjoining regions of Southeast Asia, including Myanmar, Sri Lanka, and the Andaman Islands. The fruit has a combination of sweet, mildly sour and astringent flavour and tends to colour the tongue purple. Plants of this family are known to be rich in volatile oils which are reported for their use in medicine. The fruit has been used in traditional medicine.

Phytochemistry

The plant is rich in compounds containing anthocyanins, glucoside, ellagic acid, isoquercetin, kaemferol and myricetin. The seeds are claimed to contain alkaloid, jambosine, and glycoside jambolin or antimellin, which halts the diastatic conversion of starch into sugar. The leaves are rich in acylated flavonol glycosides, quercetin, myricetin, myricetin 3-O-4-acetyl-L-rhamnopyranoside, triterpenoids, esterase, galloyl carboxylase, and tannin. The stem is rich in betulinic acid, friedelin, epi-friedelanol, β -

sitosterol, eugenin and fatty acid ester of epi-friedelanol, β -sitosterol, quercetin kaempferol, myricetin, gallic acid and ellagic acid, bergenins, flavonoids and tannins. The vast number of literatures found in the database revealed that the extracts of different parts of jambolana showed significant pharmacological actions. Hence identification of such active compounds is useful for producing safer drugs in the treatment of various ailments including diabetes. It is used for the treatment of sore throat, stomachic, bronchitis, asthma, thirst, biliousness, dysentery, diuretic and antidiabetic. It is also a good blood purifier.

Anti-diabetic Activity

In India decoction of kernels of *Eugenia jambolana* is used as household remedy for diabetes. This also forms a major constituent of many herbal formulations for diabetes. Antihyperglycemic effect of aqueous and alcoholic extract as well as lyophilized powder shows reduction in blood glucose level (Kumar et al., 2013). The extract of jamun pulp showed the hypoglycemic activity in streptozotocin induced diabetic mice within 30 min of administration while the seed of the same fruit required 24 hr. The oral administration of the extract led to the increase in serum insulin levels in diabetic rats. Insulin secretion was found to be stimulated on incubation of plant extract with isolated islets of Langerhans from normal as well as diabetic animals. Mycaminose, isolated from the seeds of *Syzygium cumini* was found to produce a remarkable reduction in blood glucose level. It was suggested that the mode of action of mycaminose is similar to Glibenclamide, a commercially available anti-diabetic drug (Kumar et al., 2013).

FUTURE PERSPECTIVE

Diabetes disease is an irregular lifestyle origin syndrome that is not easy to define. Herbal treatment is an alternative way used to control it. The use of bioactive compounds plays a very vital role in diabetes control. Accuracy of herbal medicine targeting a definite type of antioxidant in precise cells in a limited period of time can be useful in treatment of diabetes disease.

Modern lifestyle changes, control of diet, taking a balanced diet etc. are the basic and effective methods and may prevent the disease. The satisfactory phytochemical bioactive compounds contained in such herbal medications may be used as a strategy to

get better glucose/insulin homeostasis through better insulin sensitivity, leading to preservation, and function of pancreatic islets of a prediabetic state. The use of novel compounds from plants and chemical libraries based on natural products will be expanded in the drug discovery process in the future.

CONCLUSION

In this review we discussed about various medicinal plants for the treatment of Diabetes mellitus. This study revealed that these plants have hypoglycaemic effects and can be effectively implicated in the management of diabetic and metabolic complications avoiding notable side effects exerted by conventional drugs. Technological advancements allowed researchers to investigate the phytoconstituents, resulting in the isolation or synthesis of several successful medicinal medications and innovative lead compounds that potentially serve as a foundation for future drugs. For good results in this area, it is very vital to take a cross-disciplinary attitude that includes traditional

and pharmacological knowledge, phytochemistry, botany, analytical chemistry, appropriate biological screening methodologies, and modern drug development tools.

Diabetes and its consequences are currently on the rise throughout the world, and it is projected to climb much further in the future. Plant-based remedies, particularly traditional medicinal mixes, have been stressful in the treatment of diabetes, despite the availability of anti-diabetic medicines. As a result, traditional plant-derived bioactive chemical treatments for diabetes are currently being promoted due to their safety and lack of adverse effects when compared to manufactured drugs. These investigations will greatly aid research into the discovery of antidiabetic medications from innovative natural product leads utilizing medicinal chemistry methodologies, as well as the exploration of their mechanistic activities via pharmacological studies. As a result, this study briefly summarizes the active components and pharmacological effects of various commonly used plants in diabetes treatment.

Table 1: Multimodal activities of listed herbs in the effective control of diabetic symptoms.

S.No.	Herb	Botanical name	Part used	Type of extract	Cases	Outcome (effects)
1.	Holy basil	<i>Ocimum sanctum</i>	leaves	Methanol	Streptokinin induced diabetic rats	Increase glucose uptake, antioxidant, increase insulin sensitivity, regeneration of pancreatic β -cell, α -amylase and α -glucosidase inhibitor (Choudhury et al., 2018)
2.	Bitter Melon	<i>Momordica charantia</i>	fruit	Aqueous extract	Alloxan-induced diabetic mice	Stimulate glucose utilization, protection of β -cell, downregulate MAPKs and NF-kB, upregulate PPAR, modulation of PTP1B, enhance glucose uptake, stimulate insulin secretion (Choudhury et al., 2018)
3.	<i>Aloe vera</i>	<i>Aloe barbadensis miller</i>	Leaves	Methanol	Streptokinin induced diabetic rats	Increase secretion of insulin from pancreatic β -cells, antioxidant, anti-inflammatory, inhibiting pancreatic α amylase activity, increase insulin sensitivity (Choudhury et al., 2018)
4.	Fenugreek	<i>Trigonella foenum graecum</i>	Seed	Methanol	STZ-induced diabetic guinea pigs	Prevent catabolism, antioxidant, modulating insulin secretion, regeneration of pancreatic β -cell, improve glucose utilization, and slow down glucose absorption (Choudhury et al., 2018)

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