Traditional and Economic Valuation of Edible Plants Used for the Treatment of Diabetes

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Abstract

Diabetes has emerged as one of the major health problems of the modern world. It is often described as a syndrome rather than a disease. It is considered to result in abnormalities in carbohydrate, fat and protein metabolism. It signifies a condition where body is unable to regulate carbohydrate metabolism due to partial or complete absence of insulin. Inadequate regulation of the blood sugar in turn starts a cascade of imbalances in the fat and protein metabolism. These impose serious consequences to the health of patients. The complications that ensue due to glycation of proteins and deposition of fat are diabetic nephropathy, retinopathy and cardiovascular disorders. Thus diabetes along with its related complications result in high incidences of morbidity and mortality among the sufferers. As per the recent estimates the incidence of diabetes are increasing at alarming rates worldwide. India in particular is termed as the diabetes capital of the world. The conventional antidiabetic drugs are oral hypoglycaemic drugs and insulin therapy. These interventions are effective in the management of diabetes,

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however, they do not treat it and some of them have serious side effects. Medicinal plants offer highly attractive alternative to synthetic antidiabetic agents. In this chapter the plants with antidiabetic potential are described with focuses on edible plants. The use of edible antidiabetic plants or products remains the mainstay of the chapter. Individual plants have been described with respect to the biological source, geographical origin and distribution, traditional uses along with their biologically active compounds and pharmacological reports.

Keywords

Edible plants · Traditional and economic valuation · Diabetes · Hypoglycaemic drugs

3.1 Introduction

Diabetes is a metabolic syndrome with high personal, social and economical impacts. It is defined as syndrome as it results in metabolic disorders like obesity, hypertension and dyslipidaemia, etc. These associated abnormalities result in high incidences of cardiovascular morbidity and mortality in diabetes (Ahamad et al. 2019). The number of individuals diagnosed with diabetes is increasing rapidly. India being the part of the International Diabetes Federation (IDF) for the Southeast Asia (SEA) region. As per its estimates, the number of people with diabetes in the world is 415 million while in the SEA region there are 78 million people affected by the disease; it is slated to rise to 140 million by 2040. Moreover, there have been 77 million cases of diabetes in 2019 in India that is expected to rise to 101.0 million and 134.2 million by 2030 and 2040, respectively (IDF 2019).

Disease has always been considered as a disruption by the people all over the world. It poses social, mental and economic challenge to people. Different communities have devised practices and traditions to overcome diseases and stay healthy. Man has always explored the use of plants, animals and minerals to develop agents to prevent or mitigate diseases and to maintain health. Medicinal plants and animals and their products have been used throughout the globe from the beginning of human civilization. Plants have served man for food, clothes, shelter and as remedies for ailments. Edible plants in the form of vegetables and spices are reported beneficial in several human ailments including diabetes. Since the ancient days, mankind has explored natural resources and used them as a remedy for the cure against the diseases. The traditional systems such as Ayurveda, Unani, Chinese traditional medicine and Homeopathy are examples of prominent traditional systems used for the treatment of diseases (Fabricant and Farnsworth 2001).

Plants have an unsurmountable advantage in the search for new drugs owing to their age-old human use. Based on this historical perspective, the compounds derived from medicinal plants can be expected to have least human toxicity. Besides, the diversity of chemical compounds resulting due to the evolutionary development of plants is often equal or superior to those by the combinatorial chemistries

(Newman et al. 2003). Alternative medicines like Ayurveda, Unani, Kampo and Traditional Chinese Medicine use natural products as effective interventions that have become a significant part of the therapeutic regimes against cancers, diabetes, malaria, arthritis, inflammation, liver diseases and neuro-degenerative diseases (Patwardhan et al. 2004). World Health Organization has found that a significant part of the world's population (about 65%) uses traditional medicines for their basic health care. These medicines are used in the primary healthcare system especially in the developing nations (Farnsworth et al. 1985). It is also estimated that about 80% of the world's population have used herbal medicines at least once in their life time, this includes people from developed countries.

The utilization of plants as drugs is a vital component of the complementary healthcare practices in India. Here most practitioners of the traditional systems formulate and dispense their recipes for different diseases. The interest in these medicines is growing rapidly among populations because of the increased evidences of their effectiveness (Dubey et al. 2004). The high cost of synthetic drugs also plays a part in making people to opt for traditional medicines. During the last few decades, the utilization of herbal drugs has expanded globally and day-by-day its popularity is increasing. As an extension of the increased use of medicinal plants for the prevention and treatment of diseases, edible plants are being widely used for therapeutic and preventive purposes. This has given rise to the concept of nutraceuticals and functional foods. Diabetes continues to be one of the major challenges to the wellbeing of a large part of world population. Researchers are looking for safe and effective drugs from natural sources especially for the management of diabetes. As per ethnobotanical reports there are about 800 plants that are beneficial against diabetes (Alarcon-Aguilara et al. 1998; Grover et al. 2002). Several edible plants have proven to be antidiabetic activity using presently available experimental methods. In this chapter, an effort has been made to compile data on the traditional and economic valuation of edible plants used for the treatment of diabetes.

3.2 Current Therapies for Diabetes Mellitus

Type 1 and 2 diabetes mellitus are incurable chronic conditions but have been managed since insulin became medically available in 1921. Type 1 DM is mainly treated by the administration of exogenous insulin and exercise. Type 2 DM is treated by oral hypoglycaemics and insulin supplementation. For improvement of insulin availability mainly exogenous insulin preparations, sulphonylureas and meglitinides are used. For the treatment of insulin resistance biguanides, thiazolidinediones, dipeptidyl peptidase IV inhibitors (DPP-IV) and sodium-dependent glucose transporter (SGLT) inhibitors are used. The conventional drug therapies for diabetes include the use of oral hypoglycaemic drugs and insulin injection. None of these regimens result in recovery from diabetes. Moreover, these drugs are associated with several adverse effects. Plants are the source of hypoglycaemic drugs that are widely used in several traditional systems for the management of diabetes and its related conditions. Many medicinal plants have been

investigated for their role in diabetes management. These plants may delay the onset and progression of diabetes or rectify the underlying abnormalities through multiple mechanisms. Several plants and their extracts have been subjected to trials in experimental animals and humans and were found to be effective (Grover et al. 2002). Newman and Cragg (2016) reported that a total of 52 drug molecules were discovered between 1981 and 2014; out of which seven drugs were natural products or natural product derivatives; 23 were derived biological sources and four drugs were of synthetic origin. Eleven drugs were synthesized that mimic natural products and seven drugs were synthesized with natural products as the pharmacophore for the treatment of diabetes.

3.3 Traditional Edible Plants Used in Diabetes

Since ancient times plants are recognized to fulfil human necessities like food, clothes, shelter and remedies for ailments. Since the time immemorial, mankind has explored natural resources and used them as a remedy against diseases. The traditional system of medicines such as Ayurveda, Unani and Homeopathy are examples of the traditional practices adopted by different cultures for treating diseases. Plants have been used as medicinal agents for the treatment of various ailments in different ancient civilizations. The knowledge of medicinal values of these plants was inherited from generation to generation. It is imperative to use medicinal plants that have been properly documented and researched. This is also needed to ensure safe use of natural products as therapeutic and medicinal agents. Higher medicinal plants have several advantages in drug discovery compared to synthetic drugs because they have a long history of use by humans as food and spices that are generally regarded as safe (Lahlou 2007). In the traditional systems of medicine, several edible plants are reputed to have beneficial effects in diabetes, and their efficacy is also proven by experimental studies. The following section highlights the use of some common medicinal plants in diabetes. Table 3.1 compares the key features related to the composition and mechanisms of action of antidiabetic medicinal plants:

3.3.1 *Aegle marmelos* (Bael)

Aegle marmelos L. (Rutaceae) fruit pulp is traditionally considered useful in the management of diabetes. The alcoholic leaf concentrate of *A. marmelos* showed marked enhancement in the ability to neutralize the excess glucose in glucose-challenged rats (Sachdewa et al. 2001). Water extract of *A. marmelos* fruits is known to show a hypoglycemic impact in streptozotocin-induced diabetic rats at the dose of 125 and 250 mg/kg two times per day. After 4 weeks, the blood glucose level was brought back to the normal (Kamalakkannan and Prince 2003). The impact of methanolic concentrate of *A. marmelos* has been screened on glucose carrier (Glut-4), peroxisome proliferator activator receptor (PPAR-γ) and

Table 3.1 Traditional edible plants with antidiabetic activity

Plants	Edible part	Bioactive phytochemicals	Pharmacological action	References
Aegle marmelos	Fruits	Aqueous extract	Inhibits α-glucosidase enzyme	Kamalakkannan and Prince (2003)
Allium cepa	Bulb	Scillaren A and B	Hypoglycaemic effect	Islam et al. (2008)
Allium sativum	Bulb	S-allyl cysteine	Antidiabetic effect	Sheela and Augusti (1992)
Carica papaya	Fruits	Quercetin, Kaempferol flavonoids and β-sitosterol	Hypoglycaemic effect	Kaur et al. (2019)
Camellia sinensis	Leaves	Caffeine and Epigallocatechin gallate	Antidiabetic effect	Sabu et al. 2002)
Cinnamomum tamala	Leaves	Essential Oils	Antidiabetic effect	Kumar et al. (2012a, b)
Cinnamomum zeylanicum	Bark	Essential Oils	Inhibits α-glucosidase enzyme	Kaskoos (2019)
Coriandrum sativum	Fruits	Essential Oils	Antidiabetic effect	Naquvi et al. (2012)
Cucumis sativus	Fruits	Syringic and *p*-coumaric acids	Hypoglycaemic effect	Shah et al. (2013), Jamal et al. (2011)
Curcuma longa	Rhizome	Curcumin, Ferulic acid	Decreases insulin resistance	Na et al. (2011)
Eugenia jambolana	Fruits	β-sitosterol, quercetin, kaempferol	Antihyperglycemic effects	Jana et al. (2015)
Ficus racemosa	Fruits	α-Amyrin acetate	Hypoglycaemic effect	Ahmed and Urooj (2010)
Magniferaindica	Fruits	Mangiferin	Antidiabetic effect	Irondi et al. (2016)
Malus domestica	Fruits	α-amylase and quercetin	Antidiabetic effect	Patel et al. (2012, 2015)
Momordica charantia	Fruits	Peptides and Charantin	Increases insulin release and decreases insulin resistance, and inhibits α-amylase and α-glucosidase enzymes	Ahmed et al. (1998), Anun et al. (2006), Fuangchan et al. (2011), Perumal et al. (2015), Raish et al. (2016), Singh et al. (1989), Singh and Gupta (2007)

(continued)

Table 3.1 (continued)

Plants	Edible part	Bioactive phytochemicals	Pharmacological action	References
Moringa oleifera	Immature green pods	Flavonoids	Hypoglycaemic effect	Gilani (1992)
Murraya koenigii	Leaves	Essential oils	Antidiabetic effect	Arulselvan et al. (2006)
Nigella sativa	Seeds	Thymoquinone	Antihyperglycemiceffects	Sangi et al. (2015)
Ocimum sanctum	Aerial parts	Eugenol, caffeic acid, *p*-coumaric acid	Antidiabetic effect	Singh et al. (2016)
Olea europaea	Fruits and oil	Oleuropein	Decreases fasting blood glucose levels.	Khalili et al. (2017), Lepore et al. (2015)
			Increases insulin secretion and sensitivity.	
Punica granatum	Fruits	Gallic acid	Hypoglycaemic effect	Middha et al. (2013)
Psidium guajava	Fruits	Gallic acid and Carotenoids	Antidiabetic effect	Barbalho et al. (2012)
Rosa damascena	Flowers	Flavonoids	Inhibits α-glucosidase enzyme	Gholamhoseinian et al. (2009)
Trichosanthes dioica	Fruits and Seeds	Tetra and pentacyclic triterpenes, Cucurbitacin B, Charantin	Antihyperglycemic effects	Rai et al. (2008)
Trigonella foenum-graecum	Seeds	4-Hydroxy-isoleucine	Increases insulin release	Yoshikawa et al. (1997)
Zingiber officinale	Rhizome	Shogaol and gingerol	Hypoglycaemic effect	Akhani et al. (2004)

phosphatidylinositol kinase (PI-3 kinase) engaged with glucose transport. It was found active at 100 ng/mL dose and was compared with insulin and rosiglitazone. Umbelliferone galactoside from the stem bark of this plant demonstrated significant decrease in fasting glucose level and improved insulin level in STZ-induced diabetic rat. It also markedly truncated glycated haemoglobin, glucose-6-phosphatase and improved the hexokinase activities (Kumar et al. 2013).

3.3.2 *Allium cepa* (Onion)

Allium cepa (Liliaceae) is one of the widely cultivated plants used as vegetable and for flavouring around the world. The main onion producing states in India are Maharashtra, Madhya Pradesh, Karnataka, Tamil Nadu, etc. Sulphur compounds present in the onions are responsible for the flavour of the onion that is affected by the type of water supply used in cultivation (Jose and Krishnakumar 2017). Quercetin and its glycosides are the most abundant flavonoids in onion (Marrelli et al. 2019). Antidiabetic properties of aqueous onion extract and the compounds isolated from onion and their synthesized derivatives were screened. All the samples exhibited significant antihyperglycemic and antihyperlipidemic effects in diabetic rats (Islam et al. 2008).

3.3.3 *Allium sativum* (Garlic)

Allium sativum Linn (Liliaceae) is another widely consumed and cultivated plants. Its fresh and dried rhizomes are used. Garlic and its disulfur compounds have been used for their antimicrobial, hypolipidemic, antithrombic, hypoglycaemic and antitumor effects (Thomson and Ali 2003). Its alcoholic extract exhibited potent activity in diabetic rats (Eidi et al. 2006). Its rhizomes contain S-allyl cysteine sulphoxide that has antidiabetic effect in rats with alloxan induced diabetes (Sheela and Augusti 1992).

3.3.4 *Carica papaya* (Papaya)

Carica papaya Linn (Caricaceae) is a medicinally important plant from Central America and cultivated in tropical regions in Africa and Asia. *C. papaya* serves as tenderizing agent, digestant and medicine against a wide range of diseases. It contains quercetin, kaempferol and sterols. Some of these compounds exhibited hypoglycaemic effects. Payapa has antibacterial, antifungal, hypoglycaemic, anticancer, cytotoxic, anti-thrombocytopenic, antihypertensive effects. It also shows anti-HIV, antihyperlipidemic, anti-inflammatory, antifertility, antiparasitic, anthelmintic, anti-arthritic, antiulcer and nephroprotective activities (Kaur et al. 2019). Aqueous extract of papaya seeds showed antidiabetic and antihyperlipidemic

activities in the STZ and nicotinamide-induced diabetic rats (Venkateshwarlu et al. 2013).

3.3.5 *Camellia sinensis* (Tea)

Camellia sinensis (syn. *Thea sinensis*) belongs to the family Theaceae that occurs as an evergreen bush indigenous to Assam (India), China and Japan. It grows to about 9 m height, however, in cultivated tea gardens it is pruned to 1.2–1.5 m height (Duke 2001). Today tea is one of the most consumed beverages besides coffee. The flavour of the tea is due to volatile oils and its stimulant activity is because of caffeine. Its astringent taste is due to tannins that is controlled by letting it ferment. Other tea-like beverages are produced using the leaves or blossoms of different medicinal plants (Yamamoto et al. 1997; Mahmood et al. 2010). Epigallocatechin gallate from tea leaves decreases lipid peroxidation and content of hydroxyl and superoxide radicals when tested in vitro. The effective level required to inhibit superoxide, hydroxyl and lipid peroxidation radicals to half was found to range from 10 to 136 mg/mL. Administration of green tea polyphenols to rodents at 500 mg/kg BW extended the glucose tolerance time to 60 min. Green tea polyphenols were additionally found to diminish sugar levels in diabetic rats. Its pre-treatment for 2 weeks blunted the surge in glucose levels on allox an administration (Sabu et al. 2002).

3.3.6 *Cinnamomum tamala* (Indian Bay Leaf)

Cinnamomum tamala (Lauraceae), commonly known as Indian Bay Leaf, Tejpat or Malabar Leaf, is native to India, Bhutan and China. The leaf volatile oil contains a high proportion of monoterpenes consisting of sabinene, β-ocimene and myrcene along with some sesquiterpenes, namely germacrene A and α-gurjunene (Mir et al. 2004). *C. tamala* is used for lipid lowering activity, antidiabetic activity, antioxidant activity, anti-diarrhoeal activity, gastroprotective activity, stimulant, astringent, diuretic, carminative, antifungal activity, reno-protective properties and immuno-modulatory property (Pravin et al. 2013). Oral administration of volatile cinnamon oil and its main constituent have antihyperglycemic and antihyperlipidemic effects in rats with STZ-induced diabetes (Kumar et al. 2012b).

3.3.7 *Cinnamomum zeylanicum* (Cinnamon)

Cinnamomum zeylanicum Blume (Lauraceae) is fundamentally for its aroma and essence in different industries. It is also used for flavouring foods, cosmetics and medicines (Huang et al. 2007). The cinnamon species barks are the sources of flavours utilized worldwide in cookery, traditional and modern medicines (Sangal 2011; Vangalapati et al. 2012). The oil is emmenagogue, liver tonic, anti-inflammation, antisapasmodic and carminative (Kirtikar and Basu 1984). The main

constituents of cinnamon oil are cinnamaldehyde. It is responsible for its aromatic smell and the biological activities (Yeh et al. 2013). The steam-distilled oil from *C. zeylanicum* has antioxidant (Chericoni et al. 2005) and antidiabetic effects (Lee et al. 2013; Kaskoos 2019).

3.3.8 *Coriandrum sativum* (Coriander)

Coriandrum sativum Linn (Apiaceae) has its origin from Eastern Mediterranean and it is used as a spice. One of the major producers of coriander is India along with China and Russia. Its fruits are used in curry powder. Leaves are known as Cilantro and are used for garnishing and in preparing chutney, sauces and curries. Fruits are carminative and spasmolytic in action. The dried coriander fruits contain about 0.1–0.3% of volatile oil. The major components in the oil of coriander fruits are linalool (corinaderol), neryl acetate, γ-terpinene and pinene. The pharmacological actions of *C. sativum* include antioxidant, antiseptic, antihyperglycemic, hepatoprotective and antihyperlipidemic effects (Asgarpanah and Kazemivash 2012). Aqueous extract of *C. sativum* reduces blood glucose level and thus exhibits antidiabetic effect (Naquvi et al. 2012).

3.3.9 *Cucumis sativus* (Cucumber)

Cucumis sativus belongs to the family Cucurbitaceae. Genus *Cucumis* having two types of subgenus which are present in African and Asian regions. Cucumber is indigenous to the Himalayan region of northern India (Pune, Maharashtra, Uttar Pradesh, Himachal Pradesh) and is domesticated in China, Europe and America (Mukherjee et al. 2013). *C. sativus* is a well-known food and with known therapeutic uses in Ayurveda. Extract of *C. sativus* showed hypoglycaemic effect in rabbits (Shah et al. 2013). HPLC analysis determined that five compounds present in the extract inhibited β-glucosidase activity. Two major compounds, namely syringic and *p*-coumaric acids are well known to reduce blood glucose levels (Jamal et al. 2011).

3.3.10 *Curcuma longa* (Turmeric, Haldi)

Curcuma longa L. (Zingiberaceae) is found in the tropical and subtropical areas. It is a perennial herb with about 1 m high stem (Eigner and Scholz 1999). In Asia it is mainly grown in China and India. In India it is locally known as Haldi. The bright yellow colour of rhizomes is due to the presence of fat-soluble polyphenol called curcuminoids. Major constituents of *C. longa* are curcuminoids such as curcumin, demethoxycurcumin and bisdemethoxycurcumin (Chauhan and Mehla 2015). It has anticoagulant, antioxidant, antimicrobial, immunological, anti-inflammatory, anti-cancer, antidiabetic effects (Mehrotra et al. 2013; Labban 2014). Turmeric is

regarded as antidiabetic in the Indian sub-mainland (Zhang et al. 2013; Arun and Nalini 2002; Na et al. 2011).

3.3.11 *Eugenia jambolana* (Jamun)

Eugenia jambolana (Syn. *Syzygium cumini*) belongs to family Myrtaceae. Its fruits are popularly known as Jamun or Indian blackberry. It has been indicated in Ayurveda for use against diabetes. Several antidiabetic compounds have been isolated from *E. jambolana* such as sterols: sitosterol; flavonoids: quercetin, kaempferol, myricetin; and polyphenols: gallic acid and ellagic acid. *E. jambolana* has shown hypoglycaemic effects in animal models and human trials (Ravi et al. 2004; Sharma et al. 2006; Jana et al. 2015).

3.3.12 *Ficus racemosa* (Indian Fig Tree)

Ficus racemosa (Moraceae) is considered sacred and an important medicinal plant in India. Genus *Ficus* has more than 800 members that include trees, epiphytes and shrubs in tropical and subtropical regions. It is found in Bengal and Central India. Its bark, fruits, leaves, seeds and root latex are traditionally used against varied diseases. The bark is considered particularly useful in asthma, diarrhoea, epilepsy, gastritis, inflammatory disorders, diabetes, infections and sexual disorders. *F. racemosa* bark has shown a strong hypoglycaemic in in-vitro studies (Ahmed and Urooj 2010).

3.3.13 *Mangifera indica* (Mango)

Mangifera indica (Anacardiaceae) is commonly known as mango. According to Ayurveda, its different parts are associated with various medicinal properties. *M. indica* is the source of medicinally or pharmacological active polyphenols and carotenes. *M. indica* possesses various pharmacological activities such as antioxidant, radioprotective, immunomodulatory, antiallergic, lipolytic, antidiabetic, anti-bone resorption, antitumor, anti-inflammatory, antimicrobial and antiparasitic (Shah et al. 2010). *M. indica* kernel powder is useful in diabetes and related complications (Irondi et al. 2016).

3.3.14 *Malus domestica* (Apple)

Malus domestica (Syn. *M. communis*, *M. pumila*) belongs to the family Rosaceae. Flavonoids are the main phytochemical compounds present in apple that are particularly concentrated in its peels. These include procyanidins, catechins, chlorogenic acid, phloridzin and quercetin. The apple pomace also contains some catechins, procyanidin and phloridzin but in much lower concentrations than in the peels with

the exception of chlorogenic acid that is in higher quantity in the pomace. Pharmacologically consumption of an apple can also be related to a lower risk for diabetes and related complications because apple contains a higher concentration of quercetin (Patel et al. 2012). *M. domestica* extracts showed the highest alpha-amylase inhibitory activity which attributes to its antidiabetic potential (Patel et al. 2015).

3.3.15 *Momordica charantia* (Bitter gourd)

Momordica charantia Linn. belongs to Cucurbitaceae with its fruits known as bitter gourd. It is used in several traditional functional foods and medicines in Asia. Its consumption is particularly beneficial in diabetes. Cucurbitane-type triterpenoids are present in the plant. Charantin is the main constituents of its fruits and is reported to effective antidiabetic effect (Ahamad et al. 2017). Charantin was found to produce a gradual and significant fall in glucose when administered to normal rabbits. However, the impact was inconsistent in alloxan induced diabetes in rabbits. On pancreatectomy, the hypoglycaemic effect was found to be moderate. Thus chirantin was postulated to improve insulin release and sensitivity (Lotlikar and Rao 1966). A peptide found in its seeds and fruits, namely Polypeptide-P, was also found to be hypoglycaemic when administered in gerbils (Khanna et al. 1981). The water extract of fruits stimulated release of insulin from mice pancreas (Welihinda et al. 1982). Alcoholic extract of *M. charantia* fruits increases glucose uptake in hepatic tissues and muscles and thus prevents post-prandial hyperglycemia (Chandrasekar et al. 1989).

3.3.16 *Moringa oleifera* (Drumsticks)

Moringa oleifera Lam. (Moringaceae) is an uncommonly nutritious vegetable plant with various potential uses. It is a useful tree with almost each of its parts are utilized for food and other beneficial property. Its young pods are commonly known as drumsticks and are most utilized part of the tree. It has a light green colour and a slight asparagus taste. The blossoms are eatable when cooked, having a taste like mushrooms. The roots are shredded and utilized as a condiment (Fahey 2005). The main chemical constituents responsible for its pharmacological activities are flavonoids namely apigenin, quercetin and kaempferol. The leaves of the plant when mixed to the diet lower the blood glucose level in diabetics even though the plasma level did not alter much, indicating the blood glucose response to the leaves was not because of insulin secretion (Gilani 1992).

3.3.17 *Murraya koenigii* (Curry Leaves or Curry-Patta)

Murraya koenigii (Rutaceae) varies from being a pubescent shrub to a small tree. It has faint aromatic smell and is locally known as Curry-patta in India. Its leaves are

used as a spice in India. Its leaves, bark and the roots are tonic, stomachic, stimulant and carminative in action as per the traditional systems of medicine (Nayak et al. 2010). The main constituents of its leaf volatile oil are α-pinene, sabinene, β-pinene, β-caryophyllene and limonene. The extracts of its leaves exhibited antihyperglycemic activity in experimental rats. The observed antidiabetogenic effect was because of antioxidant action of *M. koenigii* (Arulselvan et al. 2006; Arulselvan and Subramanian 2007).

3.3.18 *Nigella sativa* (Black Cumin)

Nigella sativa (Ranunculaceae) is native to South of Europe and is common Mediterranean region. It is also found widely in India, Middle East, Asia and Africa (Al-Ghamdi 2001). Black cumin, as its seed is commonly referred to, is used as medicine and spice as such or as oil. It is beneficial in the treatments of respiratory, digetsive, kidney and liver function, circulatory and immune system ailments (Dwivedi 2004). The significant hypoglycaemic activity has been reported with the use of seeds of *Nigella* and is attributed to their volatile oil. Clinical investigations have supported the antidiabetic effect of the plant (Anwar-ul-Hassan et al. 2004; Al-Hader et al. 1993). Thymoquinone present in its seeds is reported to have beneficial effects in STZ-induced diabetes in rats (Sangi et al. 2015).

3.3.19 *Ocimum sanctum* (Basil or Tulsi)

Ocimum sanctum (Lamiaceae) is a widely distributed medicinal herb used in traditional systems of medicine. In Ayurveda and Siddha systems, the plant is recommended as antimicrobial, antiprotozoal, anti-inflammatory, antiallergic, antimalarial, anthelmintic, antidiarrheal, antihypertensive, cardioprotective, CNS depressant, memory enhancer, anti-hypercholesterolaemic, hepatoprotective, chemo-preventive, antidiabetic, antithyroid, antiulcer, antioxidant, anticancer, immune stimulant, antifertility, anti-arthritic, antiasthmatic and anticoagulant (Pandey and Madhuri 2010). Its leaves contain volatile oil, phenolics, lignans, flavonoids, terpenoids, fixed oil, mucilage, polysaccharides and β-sitosterol. Seed oil is rich in triglycerides with linolenic acid as the major content (Singh and Chaudhuri 2018). Eugenol, the main constituent of its oil, combats diabetes by bringing down blood glucose through α-glucosidase inhibition. It also prevents glycation thereby offering relief in diabetic complications (Singh et al. 2016).

3.3.20 *Olea europaea* (Olive)

The olive tree belonging to family Oleaceae is one of the main cultivated crops that grows predominantly in Mediterranean nations. Olives are considered an important part of the diet in Arabian nations. Oleuropein is a predominant phenolic compound

present in its leaves and is responsible for its valuable antidiabetic activity (Ahamad et al. 2019). Decoctions of olive leaves have been traditionally used against diabetes (Mootoosamy and Mahomoodally 2014). Treatment with oleuropein demonstrated significant glucose lowering effect in diabeticrats (Khalili et al. 2017). Oleuropein administration also improved glucose utilization (Poudyal et al. 2010), improved insulin sensitivity (Lepore et al. 2015) and decreased insulin resistance (Kim et al. 2014). It is also reported to decrease fasting glucose concentration in diabetic rats (Nekooeian et al. 2014).

3.3.21 *Punicagranatum* (Pomegranate)

Punica granatum (Lythraceae) is cultivated in the Mediterranean, tropical and sub-tropical areas on a large scale. Fruits are very popular as pomegranate throughout the world. It is produced in central Asia, the USA, Russia, China and Japan for fruit production. In the traditional Unani system, flowers serve as astringent, haemostatic, antibacterial and antifungal. It is also used in wound healing, bronchitis, diarrhoea, digestive problems, dermal interacted wounds and diabetes. It has antiparasitic, blood tonic and antiulcer uses in Ayurveda. Chemical constituents of *P. granatum* are ellagic acid, punicalagin, flavonoids, anthocyanidins, anthocyanins, flavonols and flavones. *P. granatum* flower extract improves the insulin sensitivity and decreases blood glucose level in rats (Dipak et al. 2012). Punicalagin and punicalin are the major tannins which exhibit antihyperglycaemic effect. Valoneic acid dilactone which possesses antidiabetic property is present in the Punica peel (Middha et al. 2013).

3.3.22 *Psidium guajava* (Guava)

Psidium guajava (Syn. *P. fragrans*, *P. pomiferum*, *P. cujavus*) belonging to Myrtaceae family is a significant restorative plant found in tropical and subtropical areas that is broadly utilized as food and in folk medicine worldwide (Gutiérrez et al. 2008). Leaf, seed and bark of *P. guajava* contain different bioactive compounds in which are helpful in attaining well-being. Leaves mainly contain phenolic compounds such as isoflavonoids, rutin, gallic acid, catechin, epicatechin besides naringenin and kaempferol. The fruit pulp contains vitamin C and carotenoids. The seeds and barks have glycosides, carotenoids and polyphenols. Its parts have hepatoprotective, antioxidant, anti-diarrhoeal, anti-inflammatory, anticancer, antimicrobial, antispasmodic, antihyperglycemic and analgesic effects (Barbalho et al. 2012). The ethanolic extract of its stem bark exhibits antidiabetic properties (Mukhtar et al. 2006).

3.3.23 *Rosadamascena* (Rose)

Rosa genus belongs to family Rosaceae and consists of more than 200 species and 20,000 cultivars (Cuizhi and Robertson 2003). Flowers are used for decorative, perfumery and medical purposes. They are utilized as nursery plants, cut blossoms or indoor plants. Rose oil acquired by water distillation of petals contains citronellol, geraniol and nerol as a major chemical compound. The flower oil is widely used in many industries as perfume and flavouring as well as for making various types of food items (Khan and Ur-Rehman 2005; Hassanein 2010). Oral administration of the methanolic extract exhibited significant reduction in blood glucose after maltose loading and inhibited post-prandial hyperglycaemia comparable to that by acarbose in normal and diabetic rats. The effect is believed to be through the inhibition of carbohydrate metabolizing enzymes (Gholamhoseinian et al. 2008, 2009).

3.3.24 *Trichosanthes dioica* (Pointed Gourd or Parwal)

Trichosanthes dioica Roxb. (Cucurbitaceae) is one of the edible cucurbits distributed in tropical Asia and Australia. It is an annual herb; fruits commonly referred to as 'Pointed Gourd' and 'Parval' in India. Charak Samhita mentions that it protects human body organs like heart, liver, spleen, etc. The phytochemicals present in its fruits and leaves include tetra- and pentacyclic triterpenes, glycosides, alkaloids, flavonoids, carbohydrates, fixed oils, steroids, tannins, phenols, vitamins A and C. Cucurbitacin B and charantin are main the constituents of fruits. Seeds contain a large number of peptides. Seed extract contains 7-oxihydrokarounidol-3-benzoate. Two main phytosterols, namely 24α- and 24β-ethylcholest-7-enol are reported from its fruits (Kumar et al. 2012a). The seed extract of *T. dioica* has shown potential antihyperglycemic activity (Rai et al. 2008). Lupeol, a dietary triterpene is present in *T. dioica*. The plant has been extensively studied for anti-inflammatory, antidiabetic, anticancer, reno-protective, antimicrobial and hepatoprotective effects (Khandaker et al. 2018).

3.3.25 *Trigonella foenum-graecum* (Fenugreek)

Trigonella foenum-graecum Linn. belongs to family Papilionaceae and is an aromatic, annual herb, commonly known as Fenugreek. It is 30–60 cm tall and cultivated in different regions of the world. It is a reputed spice and is cultivated throughout the world (Kirtikar and Basu 1985). It is used as antipyretic, antidiabetic, antioxidant, anthelmintic and gastroprotective (Jayaweera 1981; Toppo et al. 2009). Fenugreek is antihyperglycemic and hypocholesterolemic in effect (Khosla et al. 1995). The compounds reported from the plant are 4-hydroxy isoleucine, saponins and polysaccharides. Trigonelline and choline are the major alkaloids in the plant (Yoshikawa et al. 1997).

3.3.26 *Zingiber officinale* (Ginger)

Zingiber officinale (Zingiberaceae) is generally utilized as a spice and is commonly known as ginger. For quite a long-time ginger is the key ingredient in several Ayurvedic, Unani and Chinese medicine formulations. Ginger has expectorant, anticancer, immunomodulatory, anti-inflammatory, hypoglycaemic, hypolipidemic and anti-emetic effects (Ali and Blunden 2008; Ajith and Aswathy 2008). Ginger contains several potential bioactive substances, mainly gingerols, shogaols, bisabolene, geranial, zingiberenes and neral (Al-Amin et al. 2006). The juice from ginger rhizomes exhibits anti-hyperglycaemic activity in both normal and STZ-induced diabetes in rats (Akhani et al. 2004).

3.4 Economic Valuation of Edible Plants Used in Diabetes

Edible plants have immense medicinal and pharmacological values. Successful strategies for selecting plant candidate for isolation, characterization and drug discovery involves selection of plants based on traditional or ethnomedicinal use. Edible plants in the form of food and spices are consumed on large scale throughout the world. The medicinal value of such plants makes them more valuable for mankind. Several edible plants traditionally have been used for the management of diabetes such as Bitter gourd, Fenugreek, Olive, Turmeric, Ginger, Garlic, Black cumin, Cinnamon, etc. These edible plants are cultivated on large scale for consumption as food and spices. Table 3.2 presents the list of common traditional plants and their parts used in India for the management of diabetes.

3.5 Conclusion

Medicinal plants are considered as good candidates in drug discovery due to their chemical diversity and long history of use as food, drugs and spices by humans. Plants are considered as a unique source of newer chemical structures and scaffolds for drug discovery programmes. Natural products have always played a key role in modern drug discovery. It is highlighted by the fact that about more than the half of the recently approved drugs are derived or devised from natural products. This is predominantly because of recent advances in the field of extraction, isolation, characterization and pharmacological screening methods of natural products. In recent decades an ever-increasing number of drugs were discovered from natural products. Folklore medicines are generally utilized in rural areas due to their easy accessibility and cost effectiveness. Thus it is very important to manage diabetes with plants and their products that are accessible and affordable. Edible antidiabetic plant drugs make the proposition doubly beneficial as envisioned by Hippocrates in his proclamation '*Let food be thy medicine and medicine be thy food*'.

Table 3.2 List of common traditional plants and their parts used in India for the management of diabetes

Plants	Common name	Edible part
Aegle marmelos	Bael	Fruits
Allium cepa	Onion	Bulb
Allium sativum	Garlic	Bulb
Carica papaya	Papaya	Fruits
Camellia sinensis	Tea	Leaves
Cinnamomum tamala	Indian Bay Leaf	Leaves
Cinnamomum zeylanicum	Cinnamon	Bark
Coriandrum sativum	Coriander	Fruits
Cucumis sativus	Cucumber	Fruits
Curcuma longa	Turmeric	Rhizome
Eugenia jambolana	Jamun	Fruits
Ficus racemosa	Gular	Fruits
Mangifera indica	Mango	Fruits
Malus domestica	Apple	Fruits
Momordica charantia	Bitter gourd	Fruits
Moringa oleifera	Drumsticks	Immature pods
Murraya koenigii	Curry leaves	Leaves
Nigella sativa	Black Cumin	Seeds
Ocimum sanctum	Basil or Tulsi	Aerial parts
Olea europaea	Olive	Drupes and oil
Punica granatum	Pomegranate	Fruits
Psidium guajava	Guava	Fruits
Rosa damascena	Rose	Petals
Trichosanthes dioica	Pointed Gourd	Fruits
Trigonella foenum-graecum	Fenugreek	Seeds
Zingiber officinale	Ginger	Rhizome

References

Ahamad J, Amin S, Mir SR (2017) *Momordica charantia*: review on phytochemistry and pharmacology. Res J Phytochem 11:53–65

Ahamad J, Toufeeq I, Khan MA, Ameen MSM, Anwer ET, Uthirapathy S (2019) Oleuropein: a natural antioxidant molecule in the treatment of metabolic syndrome. Phytother Res 33(12):3112–3128

Ahmed F, Urooj A (2010) In vitro studies on the hypoglycemic potential of *Ficus racemosa* stem bark. J Sci Food Agric 90(3):397–401

Ahmed I, Adeghate E, Sharma AK, Pallot DJ, Singh J (1998) Effects of *Momordica charantia* fruit juice on islet morphology in the pancreas of streptozotocin diabetic rats. Diabetes Res Clin Pract 40:145–151

Ajith TA, Aswathy MS (2008) Protective effect of *Zingiber officinale* roscoe against anticancer drug doxorubicin-induced acute nephrotoxicity. Food Chem Toxicol 46(9):3178–3181

Akhani SP, Vishwakarma SL, Goyal RK (2004) Anti-diabetic activity of *Zingiber officinale* in streptozotocin-induced type I diabetic rats. J Pharm Pharmacol 56(1):101–105

Al-Amin ZM, Thomson M, Al-Qattan KK, Shalaby RP, Ali M (2006) Anti-diabetic and hypolipidaemic properties of ginger (*Zingiber officinale*) in streptozotocin-induced diabetic rats. Br J Nutr 96:660–666

Alarcon-Aguilara FJ, Roman-Ramos R, Perez-Gutierrez S, Aguilar-Contreras A, Contreras-Weber CC, Flores-Saenz JL (1998) Study of the anti-hyperglycaemic effects of plants used as antidiabetics. J Ethnopharmacol 61:101–110

Al-Ghamdi MS (2001) The anti-inflammatory, analgesic, and antipyretic activity of *Nigella sativa*. J Ethnopharmacol 76:45–48

Al-Hader A, Aqel M, Hasan Z (1993) Hypoglycemic effects of the volatile oil of *Nigella sativa*. Int J Pharmacogn 31:96–100

Ali BH, Blunden G (2008) Some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale* Roscoe): a review of recent research. Food Chem Toxicol 46(2):409–420

Anun SY, Adisakwattana S, Yao CY, Sangvanich P, Roengsumran S, Hsu WH (2006) Slow acting protein extract from fruit pulp of *Momordica charantia* with insulin secretagogue and insulinomimetic activities. Biol Pharm Bull 29(6):1126–1131

Anwar-ul-Hassan G, Qaiser J, Muhammad AK (2004) A review of medicinal uses and pharmacological activities of *Nigella sativa*. Pak J Biol Sci 7(4):441–451

Arulselvan P, Subramanian SP (2007) Beneficial effects of *Murraya koenigii* leaves on antioxidant defense system and ultrastructural changes of pancreatic beta-cells in experimental diabetes in rats. Chem Biol Interact 165(2):155–164

Arulselvan P, Senthilkumar GP, Sathish KD, Subramanian S (2006) Antidiabetic effect of *Murraya koenigii* leaves on streptozotocin induced diabetic rats. Pharmazie 61(10):874–877

Arun N, Nalini N (2002) Efficacy of turmeric on blood sugar and polyol pathway in diabetic albino rats. Plant Foods Hum Nutr 57(1):41–52

Asgarpanah J, Kazemivash N (2012) Phytochemistry, pharmacology and medicinal properties of *Coriandrumsativum* L. Afr J Pharm Pharmacol 6(31):2340–2345

Barbalho SM, Farinazzi-Machado FMV, de Alvares Goulart R, Brunnati AC, Otoboni AM, Ottoboni B (2012) *Psidiumguajava* (Guava): a plant of multipurpose medicinal applications. Med Aromat Plants 1(104):2167–0412

Chandrasekar B, Mukherjee B, Mukherjee SK (1989) Blood sugar lowering potentiality of selected Cucurbitaceae plants of Indian origin. Indian J Med Res 90:300–305

Chauhan NB, Mehla J (2015) Ameliorative effects of nutraceuticals in neurological disorders, Chapter 27. In: Bioactive nutraceuticals and dietary supplements in neurological and brain disease (prevention and therapy). Academic Press, London, pp 245–260

Chericoni S, Prieto JM, Iacopini P, Cioni P, Morelli I (2005) *In vitro* activity of the essential oil of *Cinnamomum zeylanicum* and eugenol in peroxynitrite-induced oxidative processes. J Agric Food Chem 53(12):4762–4765

Cuizhi G, Robertson KR (2003) *Rosa linnaeus*, Sp. Flora China 9:339–381

Dipak G, Axay P, Manodeep C, Jagdish KV (2012) Phytochemical and pharmacological profile of *Punicagranatum*. Int J Pharm 3(2):65–68

Dubey NK, Kumar R, Tripathi P (2004) Global promotion of herbal medicine: India's opportunity. Curr Med 86:37–41

Duke JA (2001) The handbook of medicinal herbs. CRC Press, Boca Raton, FL; New York, NY; Washington, DC, pp 93–94

Dwivedi SN (2004) Herbal remedies among tribals of Sidhi district of Madhya Pradesh. J Econ Taxon Bot 28(3):675–686

Eidi A, Eidi M, Esmaeili E (2006) Antidiabetic effect of garlic (*Allium sativum* L.) in normal and streptozotocin-induced diabetic rats. Phytomedicine 13(9–10):624–629

Eigner D, Scholz D (1999) Ferula asa-foetida and *Curcumalonga* in traditional medical treatment and diet in Nepal. J Ethnopharmacol 67:1–6

Fabricant DS, Farnsworth NR (2001) The value of plants used in traditional medicine for drug discovery. Environ Health Perspect 109(Suppl 1):69–75

Fahey JW (2005) *Moringa oleifera*: a review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. Trees Life J 1:5

Farnsworth NR, Akerele O, Bingel AS, Soejarto DD, Guo Z (1985) Medicinal plants in therapy. Bull WHO 63:965–981

Fuangchan A, Sonthisombat P, Seubnukarn T, Chanouan R, Chotchaisuwat P, Sirigulsatien V et al (2011) Hypoglycemic effect of bitter melon compared with metformin in newly diagnosed type 2 diabetes patients. J Ethnopharmacol 134(2):422–428

Gholamhoseinian A, Fallah H, Sharifi-far F, Mirtajaddini M (2008) The inhibitory effect of some Iranian plant's tracts on the alpha glucosidase. Iran J Basic Med Sci 11:1–9

Gholamhoseinian A, Fallah H, Sharififar F (2009) Inhibitory effect of methanol extract of *Rosa damascena* Mill. flowers on α-glucosidase activity and postprandial hyperglycemia in normal and diabetic rats. Phytomedicine 16:935–941

Gilani AH (1992) Antidiabetic herbs. Phytother Res 8:87

Grover JK, Yadav S, Vats V (2002) Medicinal plant with antidiabetic potential. J Ethnopharmacol 8:81–100

Gutiérrez RMP, Mitchell S, Solis RV (2008) *Psidiumguajava*: a review of its traditional uses, phytochemistry and pharmacology. J Ethnopharmacol 117(1):1–27

Hassanein AMA (2010) Improved quality and quantity of winter flowering in rose (*Rosa* spp.) by controlling the timing and type of pruning applied in autumn. World J Agric Sci 6(3):260–267

Huang TC, Fu HY, Ho CT, Tan D, Huang YT, Pan M (2007) Induction of apoptosis by cinnamaldehyde from indigenous cinnamon *Cinnamomum osmophloeum* Kaneh through reactive oxygen species production, glutathione depletion, and caspase activation in human leukemia K562cells. Food Chem 103(2):434–443

IDF (2019) Diabetes atlas, 9th edn. IDF, Brussels. https://www.diabetesatlas.org/en/sections/demographic-and-geographic-outline.html. Accessed 18 Nov 2020

Irondi EA, Oboh G, Akindahunsi AA (2016) Antidiabetic effects of *Mangifera indica* kernel flour supplemented diet in streptozotocin induced type 2 diabetes in rats. Food Sci Nutr 4(6):828–839

Islam MS, Choi H, Loots DT (2008) Effects of dietary onion (*Allium cepa* L.) in a high-fat diet streptozotocin-induced diabetes rodent model. Ann Nutr Metab 53:6–12

Jamal P, Barkat AA, Amid A (2011) Response surface optimization of the process conditions for anti-diabetic compounds from *Cucumissativus*. Afr J Biotechnol 10(81):18788–18794

Jana K, Bera TK, Ghosh D (2015) Antidiabetic effects of *Eugenia jambolana* in the streptozotocin-induced diabetic male albino rat. Biomark Genom Med 7(3):116–124

Jayaweera DMA (1981) *Medicinal plant*: Part III. Royal Botanic Garden, Peradeniya, p 225

Jose S, Krishnakumar K (2017) A review on phytochemical and pharmacological studies on *Allium cepa*. Asian J Pharm Anal Med Chem 5(1):32–36

Kamalakkannan N, Prince PS (2003) Hypoglycaemic effect of water extracts of *Aegle marmelos* fruits in streptozotocin diabetic rats. J Ethnopharmacol 87:207–210

Kaskoos RA (2019) GC/MS profile and in-vitro antidiabetic activity of *Cinnamomum zeylanicum* Blume., bark and *Trachyspermum ammi* (L.) Sprague, seeds. J Essent Oil-Bear Plants 22(2):535–544

Kaur M, Talniya NC, Sahrawat S, Kumar A, Stashenko EE (2019) Ethnomedicinal uses, phytochemistry and pharmacology of *Caricapapaya* plant: a compendious review. Mini Rev Org Chem 16(5):463–480

Khalili A, Nekooeian AA, Khosravi MB (2017) Oleuropein improves glucose tolerance and lipid profile in rats with simultaneous renovascular hypertension and type 2 diabetes. J Asian Nat Prod Res 19(10):1011–1021

Khan MA, Ur-Rehman S (2005) Extraction and analysis of essential oil of *Rosa* species. Int J Agric Biol 6:973–974

Khandaker M, Akter S, Imam MZ (2018) *Trichosanthesdioica* Roxb.: a vegetable with diverse pharmacological properties. Food Sci Human Wellness 7(1):34–48

Khanna P, Jain SC, Panagaritya A, Dixit VP (1981) Hypoglycaemic activity of polypeptide-*P* from a plant source. J Nat Prod 44:648–655

Khosla P, Gupta DD, Nagpal RK (1995) Effect of *Trigonella foenum-graecum* (fenugreek) on serum lipids in normal and diabetic rats. Indian J Pharm 27:89–93

Kim SW, Hur W, Li TZ, Lee YK, Choi JE, Hong SW et al (2014) Oleuropein prevents the progression of steatohepatitis to hepatic fibrosis induced by a high-fat diet in mice. Exp Mol Med 46:e92. https://doi.org/10.1038/emm.2014.10

Kirtikar KR, Basu BD (1984) Indian medicinal plants, vol III, 2nd edn. Lalit Mohan Basu, Allahabad, pp 210–215

Kirtikar KR, Basu BD (1985) Indian medicinal plants, vol I, 2nd edn. Lalit Mohan Basu, Allahabad, pp 700–701

Kumar N, Singh S, Manvi RG (2012a) *Trichosanthes dioica* Roxb.: an overview. Pharmacogn Rev 6(11):61

Kumar S, Vasudeva N, Sharma S (2012b) GC-MS analysis and screening of antidiabetic, antioxidant and hypolipidemic potential of *Cinnamomumtamala* oil in streptozotocin induced diabetes mellitus in rats. Cardiovasc Diabetol 11(1):95

Kumar V, Ahmad D, Verma A, Anwar F, Ali M, Mujeeb M (2013) Umbelliferone β-D-galactopyranoside from *Aegle marmelos* (L.) corr. an ethnomedicinal plant with antidiabetic, antihyperlipidemic and antioxidative activity. BMC Complement Altern Med 13:273

Labban L (2014) Medicinal and pharmacological properties of turmeric (*Curcuma longa*): a review. Int J Pharm Bio Sci 5:17–23

Lahlou M (2007) Screening of natural products for drug discovery. Expert Opin Drug Discovery 2(5):697–705

Lee SC, Xu WX, Lin LY, Yang JJ, Liu CT (2013) Chemical composition and hypoglycemic and pancreas-protective effect of leaf essential oil from indigenous cinnamon (*Cinnamomum osmophloeum* Kanehira). J Agri Food Chem 61(20):4905–4913

Lepore SM, Morittu VM, Celano M, Trimboli F, Oliverio M, Procopio A et al (2015) Oral administration of oleuropein and its semisynthetic peracetylated derivative prevents hepatic steatosis, hyperinsulinemia, and weight gain in mice fed with high fat cafeteria diet. Int J Endocrinol 2015:431453. https://doi.org/10.1155/2015/431453

Lotlikar MM, Rao R (1966) Pharmacology of a hypoglycaemic principle isolated from the fruits of *Momordica charantia* Linn. Indian J Pharm 28(5):129–133

Mahmood T, Akhtar N, Ali KB (2010) The morphology, characteristics, and medicinal properties of *Camellia sinensis* tea. J Med Plant Res 4(19):2028–2033

Marrelli M, Amodeo V, Statti G, Conforti F (2019) Biological properties and bioactive components of *Allium cepa* L.: focus on potential benefits in the treatment of obesity and related comorbidities. Molecules 24(1):119

Mehrotra S, Agnihotri G, Singh S, Jamal F (2013) Immunomodulatory potential of *Curcuma longa*: a review. South Asian J Exp Biol 3:299307

Middha SK, Usha T, Pande V (2013) A review on antihyperglycemic and antihepatoprotective activity of eco-friendly *Punicagranatum* peel waste. Evid Based Complement Alternat Med 2013:656172

Mir SR, Ali M, Kapoor R (2004) Chemical composition of essential oil of *Cinnamomum tamala* Nees et Eberm. leaves. Flavr Fragr J 19(2):112–114

Mootoosamy A, Mahomoodally MF (2014) Ethnomedicinal application of native's remedies used against diabetes and related complications in Mauritius. J Ethnopharmacol 151:413–444

Mukherjee PK, Nema NK, Maity N, Sarkar BK (2013) Phytochemical and therapeutic potential of cucumber. Fitoterapia 84:227–236

Mukhtar HM, Ansari SH, Bhat ZA, Naved T, Singh P (2006) Antidiabetic activity of an ethanol extract obtained from the stem bark of *Psidiumguajava* (Myrtaceae). Pharmazie 61(8):725–727

Na LX, Zhang YL, Li Y et al (2011) Curcumin improves insulin resistance in skeletal muscle of rats. Nutr Metab Cardiovasc Dis 21(7):526–533

Naquvi KJ, Ali M, Ahamad J (2012) Antidiabetic activity of aqueous extract of *Coriandrum sativum* L. fruits in streptozotocin induced rats. Int J Pharm Pharm Sci 4(1):239–240

Nayak A, Mandal S, Banerji A, Banerji J (2010) Review on chemistry and pharmacology of *Murraya koenigii* Spreng (Rutaceae). J Chem Pharm Res 2(2):286–299
Nekooeian AA, Khalili A, Khosravi MB (2014) Effects of oleuropein in rats with simultaneous type 2 diabetes and renal hypertension: a study of antihypertensive mechanisms. J Asian Nat Prod Res 16(9):953–962
Newman DJ, Cragg GM (2016) Natural products as sources of new drugs from 1981 to 2014. J Nat Prod 79:629–661
Newman DJ, Cragg GM, Snader KM (2003) Natural products in therapeutic. J Nat Prod 66:1022
Pandey G, Madhuri S (2010) Pharmacological activities of *Ocimumsanctum* (tulsi): a review. Int J Pharm Sci Rev Res 5(1):61–66
Patel V, Kaswala R, Chakraborty M, Kamath JV (2012) Phytochemical and pharmacological profile of *Malusdomestica*: an overview. Int J Cur Biomed Phar Res 2(2):334–338
Patel I, Padse O, Ingole Y (2015) Comparative analysis of antioxidant and antidiabetic activity for apple (*Malusdomestica*), banana (*Musaparadisiaca*) and kiwi (*Actinidiadeliciosa*). In: National Conference "ACGT", vol 2015, pp 13–14
Patwardhan B, Vaidya ADB, Chorghade M (2004) Ayurveda and natural products drug discovery. Curr Sci 86(6):789–799
Perumal V, Khoo WC, Abdul-Hamid A, Ismail A, Saari K, Murugesu S et al (2015) Evaluation of antidiabetic properties of *Momordica charantia* in streptozotocin induced diabetic rats using metabolomics approach. Int Food Res J 22(3):1298–1206
Poudyal H, Campbell F, Brown L (2010) Olive leaf extract attenuates cardiac, hepatic, and metabolic changes in high carbohydrate, high fat-fed rats. J Nutr 140(5):946–953
Pravin B, Krishnkant L, Shreyas J, Ajay K, Priyanka G (2013) Recent pharmacological review on *Cinnamomumtamala*. Res J Pharm, Biol Chem Sci 4(4):916–921
Rai PK, Jaiswal D, Diwakar S, Watal G (2008) Antihyperglycemic profile of Trichosanthes dioica. Seeds in experimental models. Pharm Biol 46(5):360–365
Raish M, Ahmad A, Jan BL, Alkharfy KM, Ansari MA et al (2016) *Momordica charantia* polysaccharides mitigate the progression of STZ induced diabetic nephropathy in rats. Int J Biol Macromol 91:394–399
Ravi K, Sivagnanam K, Subramanian S (2004) Anti-diabetic activity of *Eugenia jambolana* seed kernels on streptozotocin-induced diabetic rats. J Med Food 7(2):187–191
Sabu MC, Smitha K, Ramadasan K (2002) Anti-diabetic activity of green tea polyphenols and their role in reducing oxidative stress in experimental diabetes. J Ethnopharmacol 83:109–116
Sachdewa A, Raina D, Srivastava AK, Khemani LD (2001) Effect of *Aegle marmelos* and *Hibiscus rosa sinensis* leaf extract on glucose tolerance in glucose-induced hyperglycaemic rats (Charles foster). J Environ Biol 22:53–57
Sangal A (2011) Role of cinnamon as beneficial antidiabetic food adjunct: a review. Adv Appl Sci Res 2(4):440–450
Sangi SMA, Sulaiman MI, Abd El-wahab MF, Ahmedani EI, Ali SS (2015) Antihyperglycemic effect of thymoquinone and oleuropein, on streptozotocin-induced diabetes mellitus in experimental animals. Pharmacogn Mag 11(Suppl 2):S251–S257
Shah KA, Patel MB, Patel RJ, Parmar PK (2010) *Mangiferaindica* (mango). Pharmacogn Rev 4(7):42
Shah P, Dhande S, Joshi Y, Kadam V (2013) A review on *Cucumissativus* (Cucumber). Res J Pharmacogn Phytochem 5(2):49–53
Sharma SB, Nasir A, Prabhu KM, Murthy PS (2006) Antihyperglycemic effect of the fruit-pulp of *Eugenia jambolana* in experimental diabetes mellitus. J Ethnopharmacol 104(3):367–373
Sheela CG, Augusti KT (1992) Antidiabetic effects of S-allyl cysteine sulphoxide isolated from garlic *Allium sativum* Linn. Indian J Exp Biol 30(6):523–526
Singh D, Chaudhuri PK (2018) A review on phytochemical and pharmacological properties of Holy basil (*Ocimumsanctum* L.). Ind Crop Prod 118:367–382

Singh N, Gupta M (2007) Regeneration of *β*-cells in islets of Langerhans of the pancreas of alloxan diabetic rats by acetone extract of *Momordica charantia* (Linn.) (bitter gourd) fruits. Indian J Exp Biol 45:1055–1062

Singh N, Tyagi SD, Agarwal SC (1989) Effect of long term feeding of acetone extract of *Momordica charantia* (whole plant powder) on alloxan diabetic albino rats. Indian J Physiol Pharmacol 33:97–100

Singh P, Jayaramaiah RH, Agawane SB, Vannuruswamy G, Korwar AM, Anand A et al (2016) Potential dual role of eugenol in inhibiting advanced glycation end products in diabetes: proteomic and mechanistic insights. Sci Rep 6:18798

Thomson M, Ali M (2003) Garlic (*Allium sativum*): a review of its potential use as an anti-cancer agent. Curr Cancer Drug Targets 3:67–81

Toppo FA, Akhand R, Pathak AK (2009) Pharmacological actions and potential uses of *Trigonella foenum-graecum*: a review. Asian J Pharm Clin Res 2(4):29–38

Vangalapati M, Sree Satya N, Surya Prakash D, Avanigadda S (2012) A review on pharmacological activities and clinical effects of cinnamon species. Res J Pharm, Biol Chem Sci 3(1):653–663

Venkateshwarlu E, Dileep P, Rakesh KRP, Sandhya P (2013) Evaluation of antidiabetic activity of *Caricapapaya* seeds on streptozotocin-induced type-II diabetic rats. J Adv Sci Res 4(2):38–41

Welihinda J, Arvidson G, Gylfe E, Hellman B, Karlsson E (1982) The insulin-releasing activity of the tropical plant *Momordica charantia*. Acta Biol Med Germ 41:1229–1240

Yamamoto T, Kim M, Juneja LR (eds) (1997) Chemistry and application of green tea. CRC Press, Boca Raton, FL; New York, NY; Washington, DC, pp 109–121

Yeh HF, Luo CY, Lin CY, Cheng SS, Hsu YR, Chang ST (2013) Methods for thermal stability enhancement of leaf essential oils and their main constituents from indigenous cinnamon (*Cinnamomum osmophloeum*). J Agric Food Chem 61(26):6293–6298

Yoshikawa M, Murakami T, Komatsu H, Murakami N, Yamahara J, Matsuda H (1997) Medicinal foodstuffs: IV. Fenugreek seeds (1): structures of trigoneosides Ia, Ib, IIb, IIIa and IIIb new furostanol saponins from the seeds of Indian *Trigonella foenum- graecum* L. Chem Pharm Bull 45:81–87

Zhang D-W, Fu M, Gao S-H, Liu JL (2013) Curcumin and diabetes: a systematic review. Evid Based Complement Alternat Med 2013:636053. https://doi.org/10.1155/2013/636053