

Recent Advances in Indian Herbal Drug Research

Guest Editor: Thomas Paul Asir Devasagayam

Indian Herbs and Herbal Drugs Used for the Treatment of Diabetes

Manisha Modak¹, Priyanjali Dixit¹, Jayant Londhe¹, Saroj Ghaskadbi¹, and Thomas Paul A. Devasagayam^{2,*}

¹Department of Zoology, University of Pune, Pune 411007, India

²Radiation Biology and Health Sciences Division, Bhabha Atomic Research Centre, Mumbai 400085, India

Received 19 September, 2006; Accepted 6 December, 2006

Summary Traditional Medicines derived from medicinal plants are used by about 60% of the world's population. This review focuses on Indian Herbal drugs and plants used in the treatment of diabetes, especially in India. Diabetes is an important human ailment afflicting many from various walks of life in different countries. In India it is proving to be a major health problem, especially in the urban areas. Though there are various approaches to reduce the ill effects of diabetes and its secondary complications, herbal formulations are preferred due to lesser side effects and low cost. A list of medicinal plants with proven antidiabetic and related beneficial effects and of herbal drugs used in treatment of diabetes is compiled. These include, *Allium sativum*, *Eugenia jambolana*, *Momordica charantia*, *Ocimum sanctum*, *Phyllanthus amarus*, *Pterocarpus marsupium*, *Tinospora cordifolia*, *Trigonella foenum graecum* and *Withania somnifera*. One of the etiologic factors implicated in the development of diabetes and its complications is the damage induced by free radicals and hence an antidiabetic compound with antioxidant properties would be more beneficial. Therefore information on antioxidant effects of these medicinal plants is also included.

Key Words: medicinal plant, India, antidiabetic, antioxidant, diabetes

Introduction

In the last few years there has been an exponential growth in the field of herbal medicine and these drugs are gaining popularity both in developing and developed countries because of their natural origin and less side effects. Many traditional medicines in use are derived from medicinal plants, minerals and organic matter [1]. A number of medicinal plants, traditionally used for over 1000 years named rasayana are

present in herbal preparations of Indian traditional health care systems [2]. In Indian systems of medicine most practitioners formulate and dispense their own recipes [3]. The World Health Organization (WHO) has listed 21,000 plants, which are used for medicinal purposes around the world. Among these 2500 species are in India, out of which 150 species are used commercially on a fairly large scale. India is the largest producer of medicinal herbs and is called as botanical garden of the world [3]. The current review focuses on herbal drug preparations and plants used in the treatment of diabetes mellitus, a major crippling disease in the world leading to huge economic losses.

*To whom correspondence should be addressed.

Tel: +91-22-25593948 Fax: +91-22-25505151

E-mail: tpauld2001@yahoo.co.in

Diabetes and Significance

Diabetes is a chronic disorder of carbohydrate, fat and protein metabolism characterized by increased fasting and post prandial blood sugar levels. The global prevalence of diabetes is estimated to increase, from 4% in 1995 to 5.4% by the year 2025. WHO has predicted that the major burden will occur in developing countries. Studies conducted in India in the last decade have highlighted that not only is the prevalence of diabetes high but also that it is increasing rapidly in the urban population [4]. It is estimated that there are approximately 33 million adults with diabetes in India. This number is likely to increase to 57.2 million by the year 2025.

Diabetes mellitus is a complex metabolic disorder resulting from either insulin insufficiency or insulin dysfunction. Type I diabetes (insulin dependent) is caused due to insulin insufficiency because of lack of functional beta cells. Patients suffering from this are therefore totally dependent on exogenous source of insulin while patients suffering from Type II diabetes (insulin independent) are unable to respond to insulin and can be treated with dietary changes, exercise and medication. Type II diabetes is the more common form of diabetes constituting 90% of the diabetic population. Symptoms for both diabetic conditions may include: (i) high levels of sugar in the blood; (ii) unusual thirst; (iii) frequent urination; (iv) extreme hunger and loss of weight; (v) blurred vision; (vi) nausea and vomiting; (vii) extreme weakness and tiredness; (viii) irritability, mood changes etc.

Though pathophysiology of diabetes remains to be fully understood, experimental evidences suggest the involvement of free radicals in the pathogenesis of diabetes [5] and more importantly in the development of diabetic complications [6–8]. Free radicals are capable of damaging cellular molecules, DNA, proteins and lipids leading to altered cellular functions. Many recent studies reveal that antioxidants capable of neutralizing free radicals are effective in preventing experimentally induced diabetes in animal models [9, 10] as well as reducing the severity of diabetic complications [8].

For the development of diabetic complications, the abnormalities produced in lipids and proteins are the major etiologic factors. In diabetic patients, extra-cellular and long lived proteins, such as elastin, laminin, collagen are the major targets of free radicals. These proteins are modified to form glycoproteins due to hyperglycemia. The modification of these proteins present in tissues such as lens, vascular wall and basement membranes are associated with the development of complications of diabetes such as cataracts, microangiopathy, atherosclerosis and nephropathy [11]. During diabetes, lipoproteins are oxidized by free radicals. There are also multiple abnormalities of lipoprotein metabolism in very low density lipoprotein (VLDL), low density lipoprotein (LDL), and high density lipoprotein (HDL) in diabetes. Lipid peroxidation

is enhanced due to increased oxidative stress in diabetic condition. Apart from this, advanced glycation end products (AGEs) are formed by non-enzymatic glycosylation of proteins. AGEs tend to accumulate on long-lived molecules in tissues and generate abnormalities in cell and tissue functions [12, 13]. In addition, AGEs also contribute to increased vascular permeability in both micro and macrovascular structures by binding to specific macrophage receptors. This results in formation of free radicals and endothelial dysfunction. AGEs are also formed on nucleic acids and histones and may cause mutations and altered gene expression.

As diabetes is a multifactorial disease leading to several complications, and therefore demands a multiple therapeutic approach. Patients of diabetes either do not make enough insulin or their cells do not respond to insulin. In case of total lack of insulin, patients are given insulin injections. Whereas in case of those where cells do not respond to insulin many different drugs are developed taking into consideration possible disturbances in carbohydrate-metabolism. For example, to manage post-prandial hyper-glycaemia at digestive level, glucosidase inhibitors such as acarbose, miglitol and voglibose are used. These inhibit degradation of carbohydrates thereby reducing the glucose absorption by the cells. To enhance glucose uptake by peripheral cells biguanide such as metformin is used. Sulphonylureas like glibenclamide is insulinotropic and works as secretagogue for pancreatic cells. Although several therapies are in use for treatment, there are certain limitations due to high cost and side effects such as development of hypoglycemia, weight gain, gastrointestinal disturbances, liver toxicity etc [14]. Based on recent advances and involvement of oxidative stress in complicating diabetes mellitus, efforts are on to find suitable antidiabetic and antioxidant therapy.

Medicinal plants are being looked up once again for the treatment of diabetes. Many conventional drugs have been derived from prototypic molecules in medicinal plants. Metformin exemplifies an efficacious oral glucose-lowering agent. Its development was based on the use of *Galega officinalis* to treat diabetes. *Galega officinalis* is rich in guanidine, the hypoglycemic component. Because guanidine is too toxic for clinical use, the alkyl biguanides synthalin A and synthalin B were introduced as oral anti-diabetic agents in Europe in the 1920s but were discontinued after insulin became more widely available. However, experience with guanidine and biguanides prompted the development of metformin. To date, over 400 traditional plant treatments for diabetes have been reported, although only a small number of these have received scientific and medical evaluation to assess their efficacy. The hypoglycemic effect of some herbal extracts has been confirmed in human and animal models of type 2 diabetes. The World Health Organization Expert Committee on diabetes has recommended that traditional medicinal herbs be further investigated.

Major hindrance in amalgamation of herbal medicine in modern medical practices is lack of scientific and clinical data proving their efficacy and safety. There is a need for conducting clinical research in herbal drugs, developing simple bioassays for biological standardization, pharmacological and toxicological evaluation, and developing various animal models for toxicity and safety evaluation. It is also important to establish the active component/s from these plant extracts.

Indian Medicinal Plants with Antidiabetic and Related Beneficial Effects

There are many herbal remedies suggested for diabetes and diabetic complications. Medicinal plants form the main ingredients of these formulations. A list of medicinal plants with antidiabetic and related beneficial effects is given in Table 1 [15]. A list of such formulations is given in Table 2.

Acacia arabica: (Babul)

It is found all over India mainly in the wild habitat. The plant extract acts as an antidiabetic agent by acting as secretagogue to release insulin. It induces hypoglycemia in control rats but not in alloxanized animals. Powdered seeds of *Acacia arabica* when administered (2,3 and 4 g/kg body weight) to normal rabbits induced hypoglycemic effect by initiating release of insulin from pancreatic beta cells [16].

Aegle marmelos: (Bengal Quince, Bel or Bilva)

Administration of aqueous extract of leaves improves digestion and reduces blood sugar and urea, serum cholesterol in alloxanized rats as compared to control. Along with exhibiting hypoglycemic activity, this extract also prevented peak rise in blood sugar at 1h in oral glucose tolerance test [17].

Allium cepa: (onion)

Various ether soluble fractions as well as insoluble fractions of dried onion powder show anti-hyperglycemic activity in diabetic rabbits. *Allium cepa* is also known to have anti-oxidant and hypolipidaemic activity. Administration of a sulfur containing amino acid from *Allium cepa*, S-methyl cysteine sulphoxide (SMCS) (200 mg/kg for 45 days) to alloxan induced diabetic rats significantly controlled blood glucose as well as lipids in serum and tissues and normalized the activities of liver hexokinase, glucose 6-phosphatase and HMG Co A reductase [18, 19]. When diabetic patients were given single oral dose of 50 g of onion juice, it significantly controlled post-prandial glucose levels [20].

Allium sativum: (garlic)

This is a perennial herb cultivated throughout India. Allicin, a sulfur-containing compound is responsible for its pungent odour and it has been shown to have significant hypo-

glycemic activity [21]. This effect is thought to be due to increased hepatic metabolism, increased insulin release from pancreatic beta cells and/or insulin sparing effect [22]. Aqueous homogenate of garlic (10 ml/kg/day) administered orally to sucrose fed rabbits (10 g/kg/day in water for two months) significantly increased hepatic glycogen and free amino acid content, decreased fasting blood glucose, and triglyceride levels in serum in comparison to sucrose controls [23].

S-allyl cystein sulfoxide (SACS), the precursor of allicin and garlic oil, is a sulfur containing amino acid, which controlled lipid peroxidation better than glibenclamide and insulin. It also improved diabetic conditions. SACS also stimulated *in vitro* insulin secretion from beta cells isolated from normal rats [24]. Apart from this, *Allium sativum* exhibits antimicrobial, anticancer and cardioprotective activities.

Aloe vera and *Aloe barbadensis*

Aloe, a popular houseplant, has a long history as a multi-purpose folk remedy. The plant can be separated into two basic products: gel and latex. Aloe vera gel is the leaf pulp or mucilage, aloe latex, commonly referred to as "aloe juice," is a bitter yellow exudate from the pericyclic tubules just beneath the outer skin of the leaves. Extracts of aloe gum effectively increases glucose tolerance in both normal and diabetic rats [25]. Treatment of chronic but not single dose of exudates of *Aloe barbadensis* leaves showed hypoglycemic effect in alloxanized diabetic rats. Single as well as chronic doses of bitter principle of the same plant also showed hypoglycemic effect in diabetic rats. This action of *Aloe vera* and its bitter principle is through stimulation of synthesis and/or release of insulin from pancreatic beta cells [26]. This plant also has an anti-inflammatory activity in a dose dependent manner and improves wound healing in diabetic mice [27].

Azadirachta indica: (Neem)

Hydroalcoholic extracts of this plant showed anti-hyperglycemic activity in streptozotocin treated rats and this effect is because of increase in glucose uptake and glycogen deposition in isolated rat hemidiaphragm [28, 29]. Apart from having anti-diabetic activity, this plant also has anti-bacterial, antimalarial, antifertility, hepatoprotective and antioxidant effects [30].

Caesalpinia bonducella

Caesalpinia bonducella is widely distributed throughout the coastal region of India and used ethnically by the tribal people of India for controlling blood sugar. Both the aqueous and ethanolic extracts showed potent hypoglycemic activity in chronic type II diabetic models. These extracts also increased glycogenesis thereby increasing liver glycogen content [31]. Two fractions BM 169 and BM 170 B could

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

Plant Name	Ayurvedic/common name/herbal formulation	Antidiabetic and other beneficial effects in traditional medicine	References
<i>Annona squamosa</i>	Sugar apple	Hypoglycemic and antihyperglycemic activities of ethanolic leaf-extract, Increased plasma insulin level	[61–63]
<i>Artemisia pallens</i>	Davana	Hypoglycemic, increases peripheral glucose utilization or inhibits glucose reabsorption	[64]
<i>Areca catechu</i>	Supari	Hypoglycemic	[65]
<i>Beta vulgaris</i>	Chukkander	Increases glucose tolerance in OGTT	[66]
<i>Boerhavia diffusa</i>	punarnava	Increase in hexokinase activity, decrease in glucose-6-phosphatase and fructose bis-phosphatase activity, increase plasma insulin level, antioxidant	[67–69]
<i>Bombax ceiba</i>	Semul	Hypoglycemic	[70]
<i>Butea monosperma</i>	palasa	Antihyperglycemic	[71]
<i>Camellia sinensis</i>	Tea	Anti-hyperglycemic activity, antioxidant	[72, 73]
<i>Capparis decidua</i>	Karir or Pinju	Hypoglycemic, antioxidant, hypolipidaemic	[35]
<i>Caesalpinia bonducella</i>	Sagarghota, Fevernut	Hypoglycemic, insulin secretagogue, hypolipidemic	[74, 31, 32]
<i>Coccinia indica</i>	Bimb or Kanturi	Hypoglycemic	[36]
<i>Embllica officinalis</i>	Amla, Dhatriphala, a constituent of herbal formulation, “Triphala”	Decreases lipid peroxidation, antioxidant, hypoglycemic	[75–77]
<i>Eugenia uniflora</i>	Pitanga	Hypoglycemic, inhibits lipase activity	[78]
<i>Encostema littorale</i>	krimihrita	Increase hexokinase activity, Decrease glucose 6-phosphatase and fructose 1,6 bisphosphatase activity. Dose dependent hypoglycemic activity	[79, 80]
<i>Ficus bengalensis</i>	Bur	Hypoglycemic, antioxidant	[81]
<i>Gymnema sylvestre</i>	Gudmar or Merasingi	Anti-hyperglycemic effect, hypolipidemic	[82, 83]
<i>Hemidesmus indicus</i>	Anantamul	Anti snake venom activity, anti-inflammatory	[84]
<i>Hibiscus rosa-sinensis</i>	Gudhal or Jasson	Initiates insulin release from pancreatic beta cells	[85]
<i>Ipomoea batatas</i>	Sakkargand	Reduces insulin resistance	[86]
<i>Momordica cymbalaria</i>	Kadavanchi	Hypoglycemic, hypolipidemic	[87, 88]
<i>Murraya koenigii</i>	Curry patta	Hypoglycemic, increases glycogenesis and decreases gluconeogenesis and glycogenolysis	[89]
<i>Musa sapientum</i>	Banana	Antihyperglycemic, antioxidant	[90–92].
<i>Phaseolus vulgaris</i>	Hulga, white kidney bean	Hypoglycemic, hypolipidemic, inhibit alpha amylase activity, antioxidant. Altered level of insulin receptor and GLUT-4 mRNA in skeletal muscle	[93–95]
<i>Punica granatum</i>	Anar	Antioxidant, anti-hyperglycemic effect	[96]
<i>Salacia reticulata</i>	Vairi	inhibitory activity against sucrase, α -glucosidase inhibitor	[97]
<i>Scoparia dulcis</i>	Sweet broomweed	Insulin-secretagogue activity, antihyperlipidemic, hypoglycemic, antioxidant	[98–100]
<i>Swertia chirayita</i>	Chirata	Stimulates insulin release from islets	[101]
<i>Syzygium alternifolium</i>	Shahajire	Hypoglycemic and antihyperglycemic	[102]
<i>Terminalia bellerica</i>	Behada, a constituent of “Triphala”	Antibacterial, hypoglycemic	[103]
<i>Terminalia chebula</i>	Hirda	Antibacterial, hypoglycemic	[103]
<i>Tinospora crispa</i>		Anti-hyperglycemic, stimulates insulin release from islets	[104]
<i>Vinca rosea</i>	Sadabahar	Anti-hyperglycemic	[105]
<i>Withania somnifera</i>	Ashvagandha, winter cherry	Hypoglycemic, diuretic and hypocholesterolemic	[106]

Table 2. Formulated Herbal Drugs with antidiabetic properties

Drug	Company	Ingredients
Diabecon	Himalaya	<i>Gymnema sylvestre</i> , <i>Pterocarpus marsupium</i> , <i>Glycyrrhiza glabra</i> , <i>Casearia esculenta</i> , <i>Syzygium cumini</i> , <i>Asparagus racemosus</i> , <i>Boerhavia diffusa</i> , <i>Sphaeranthus indicus</i> , <i>Tinospora cordifolia</i> , <i>Swertia chirata</i> , <i>Tribulus terrestris</i> , <i>Phyllanthus amarus</i> , <i>Gmelina arborea</i> , <i>Gossypium herbaceum</i> , <i>Berberis aristata</i> , <i>Aloe vera</i> , Triphala, <i>Commiphora wightii</i> , shilajeet, <i>Momordica charantia</i> , <i>Piper nigrum</i> , <i>Ocimum sanctum</i> , <i>Abutilon indicum</i> , <i>Curcuma longa</i> , <i>Rumex maritimus</i>
Diasulin		<i>Cassia auriculata</i> , <i>Coccinia indica</i> , <i>Curcuma longa</i> , <i>Emblica officinalis</i> , <i>Gymnema sylvestre</i> , <i>Momordica charantia</i> , <i>Scoparia dulcis</i> , <i>Syzygium cumini</i> , <i>Tinospora cordifolia</i> , <i>Trigonella foenum graecum</i>
Pancreatic tonic 180 cp	ayurvedic herbal supplement	<i>Pterocarpus marsupium</i> , <i>Gymnema sylvestre</i> , <i>Momordica charantia</i> , <i>Syzygium cumini</i> , <i>Trigonella foenum graecum</i> , <i>Azadirachta indica</i> , <i>Ficus racemosa</i> , <i>Aegle marmelos</i> , <i>Cinnamomum tamala</i>
Ayurveda alternative herbal formula to Diabetes:	Chakrapani Ayurveda	Gurmar (<i>Gymnema sylvestre</i>) Karela (<i>Momordica charantia</i>) Pushkarmool (<i>Inula racemosa</i>) Jamun Gutli (<i>Syzygium cumini</i>) Neem (<i>Azadirachta indica</i>) Methika (<i>Trigonella foenum graecum</i>) Guduchi (<i>Tinospora cordifolia</i>)
Bitter gourd Powder	Garry and Sun natural Remedies	Bitter gourd (<i>Momordica charantia</i>)
Dia-care	Admark Herbals Limited	Sanjeevan Mool; Himej, Jambu beej, Kadu, Namejav, Neem chal.
Diabetes-Daily Care	Nature's Health Supply	Alpha Lipoic Acid, Cinnamon 4% Extract, Chromax, Vanadium, Fenugreek 50% extract, <i>Gymnema sylvestre</i> 25% extract <i>Momordica</i> 7% extract, Licorice Root 20% extract
Gurmar powder	Garry and Sun natural Remedies	Gurmar (<i>Gymnema sylvestre</i>)
Epinsulin	Swastik Formulations	vijaysar (<i>Pterocarpus marsupium</i>)
Diabecure	Nature beaute sante	<i>Juglans regia</i> , <i>Berberis vulgaris</i> , <i>Erythrea centaurium</i> , <i>Millefolium</i> , <i>Taraxacum</i>
Diabeta	Ayurvedic cure Ayurvedic Herbal Health Products	<i>Gymnema sylvestre</i> , <i>Vinca rosea</i> (Periwinkle), <i>Curcuma longa</i> (Turmeric), <i>Azadirachta indica</i> (Neem), <i>Pterocarpus marsupium</i> (Kino Tree), <i>Momordica charantia</i> (Bitter Gourd), <i>Syzygium cumini</i> (Black Plum), <i>Acacia arabica</i> (Black Babhul), <i>Tinospora cordifolia</i> , <i>Zingiber officinale</i> (Ginger)
Syndrex	Plethico Laboretaries	Germinated Fenugreek seed extract

increase secretion of insulin from isolated islets. The aqueous and 50% ethanolic extracts of *Caesalpinia bonducella* seeds showed antihyperglycemic and hypolipidemic activities in streptozotocin (STZ)-diabetic rats [32]. The antihyperglycemic action of the seed extracts may be due to the blocking of glucose absorption. The drug has the potential to act as antidiabetic as well as antihyperlipidemic [33].

Capparis decidua

This is found throughout India, especially in dry areas. Hypoglycemic effect was seen in alloxanized rats when the rats were fed with 30% extracts of *Capparis decidua* (*C. decidua*) fruit powder for 3 weeks. This extract also reduced alloxan induced lipid peroxidation significantly in erythrocytes, kidney and heart. *C. decidua* was also found to alter superoxide dismutase and catalase enzyme levels to reduce oxidative stress [34]. *C. decidua* additionally showed hypolipidaemic activity [35].

Coccinia indica

Dried extracts of *Coccinia indica* (*C. indica*) (500 mg/kg body weight) were administered to diabetic patients for 6 weeks. These extracts restored the activities of enzyme lipoprotein lipase (LPL) that was reduced and glucose-6-phosphatase and lactate dehydrogenase, which were raised in untreated diabetics [36]. Oral administration of 500 mg/kg of *C. indica* leaves showed significant hypoglycemia in alloxanized diabetic dogs and increased glucose tolerance in normal and diabetic dogs.

Eugenia jambolana: (Indian gooseberry, jamun)

In India decoction of kernels of *Eugenia jambolana* is used as household remedy for diabetes. This also forms a major constituent of many herbal formulations for diabetes. Antihyperglycemic effect of aqueous and alcoholic extract as well as lyophilized powder shows reduction in blood glucose level. This varies with different level of diabetes. In mild diabetes (plasma sugar >180 mg/dl) it shows 73.51%

reduction, whereas in moderate (plasma sugar >280 mg/dl) and severe diabetes (plasma sugar >400 mg/dl) it is reduced to 55.62% and 17.72% respectively [21]. The extract of jamun pulp showed the hypoglycemic activity in streptozotocin induced diabetic mice within 30 min of administration while the seed of the same fruit required 24 h. The oral administration of the extract resulted in increase in serum insulin levels in diabetic rats. Insulin secretion was found to be stimulated on incubation of plant extract with isolated islets of Langerhans from normal as well as diabetic animals. These extracts also inhibited insulinase activity from liver and kidney [37].

Mangifera indica: (Mango)

The leaves of this plant are used as an antidiabetic agent in Nigerian folk medicine, although when aqueous extract given orally did not alter blood glucose level in either normoglycemic or streptozotocin induced diabetic rats. However, antidiabetic activity was seen when the extract and glucose were administered simultaneously and also when the extract was given to the rats 60 min before the glucose. The results indicate that aqueous extract of *Mangifera indica* possess hypoglycemic activity. This may be due to an intestinal reduction of the absorption of glucose [38].

Momordica charantia: (bitter gourd)

Momordica charantia is commonly used as an antidiabetic and antihyperglycemic agent in India as well as other Asian countries. Extracts of fruit pulp, seed, leaves and whole plant was shown to have hypoglycemic effect in various animal models. Polypeptide p, isolated from fruit, seeds and tissues of *M. charantia* showed significant hypoglycemic effect when administered subcutaneously to langurs and humans [39]. Ethanolic extracts of *M. charantia* (200 mg/kg) showed an antihyperglycemic and also hypoglycemic effect in normal and STZ 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 [40].

Ocimum sanctum: (holy basil)

It is commonly known as Tulsi. Since ancient times, this plant is known for its medicinal properties. The aqueous extract of leaves of *Ocimum sanctum* showed the significant reduction in blood sugar level in both normal and alloxan induced diabetic rats [41]. Significant reduction in fasting blood glucose, uronic acid, total amino acid, total cholesterol, triglyceride and total lipid indicated the hypoglycemic and hypolipidemic effects of tulsi in diabetic rats [42]. 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. Renal glycogen content increased 10 fold while skeletal muscle and hepatic glycogen levels decreased by 68

and 75% respectively in diabetic rats as compared to control [43]. This plant also showed antiasthmatic, antistress, antibacterial, antifungal, antiviral, antitumor, gastric antiulcer activity, antioxidant, antimutagenic and immunostimulant activities.

Phyllanthus amarus: (bhuiawala)

It is a herb of height up to 60 cm, from family Euphorbiaceae. It is commonly known as Bhuiamala. It is scattered throughout the hotter parts of India, mainly Deccan, Konkan and south Indian states. Traditionally it is used in diabetes therapeutics. Methanolic extract of *Phyllanthus amarus* was found to have potent antioxidant activity. This extract also reduced the blood sugar in alloxanized diabetic rats [44]. The plant also shows antiinflammatory, antimutagenic, anticarcinogenic, antidiarrhoeal activity.

Pterocarpus marsupium:

It is a deciduous moderate to large tree found in India mainly in hilly region. Pterostilbene, a constituent derived from wood of this plant caused hypoglycemia in dogs [45, 46] showed that the hypoglycemic activity of this extract is because of presence of tannates in the extract. Flavonoid fraction from *Pterocarpus marsupium* has been shown to cause pancreatic beta cell regranulation [47]. Marsupin, pterosupin and liquiritigenin obtained from this plant showed antihyperlipidemic activity [48]. (-) Epicatechin, its active principle, has been found to be insulinogenic, enhancing insulin release and conversion of proinsulin to insulin *in vitro*. Like insulin, (-) epicatechin stimulates oxygen uptake in fat cells and tissue slices of various organs, increases glycogen content of rat diaphragm in a dose-dependent manner [49].

Trigonella foenum graecum: (fenugreek)

It is found all over India and the fenugreek seeds are usually used as one of the major constituents of Indian spices. 4-hydroxyleucine, a novel amino acid from fenugreek seeds increased glucose stimulated insulin release by isolated islet cells in both rats and humans [50]. 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 [51]. Administration of fenugreek seeds also improved glucose metabolism and normalized creatinine kinase activity in heart, skeletal muscle and liver of diabetic rats. It also reduced hepatic and renal glucose-6-phosphatase and fructose -1,6-biphosphatase activity [52]. This plant also shows antioxidant activity [53, 54].

Tinospora cordifolia: (Guduchi)

It is a large, glabrous, deciduous climbing shrub belonging to the family Menispermaceae. It is widely distributed

throughout India and commonly known as Guduchi. Oral administration of the extract of *Tinospora cordifolia* (*T. cordifolia*) roots for 6 weeks resulted in a significant reduction in blood and urine glucose and in lipids in serum and tissues in alloxan diabetic rats. The extract also prevented a decrease in body weight. [55] *T. cordifolia* is widely used in Indian ayurvedic medicine for treating diabetes mellitus [56–58]. Oral administration of an aqueous *T. cordifolia* root extract to alloxan diabetic rats caused a significant reduction in blood glucose and brain lipids. Though the aqueous extract at a dose of 400 mg/kg could elicit significant anti-hyperglycemic effect in different animal models, its effect was equivalent to only one unit/kg of insulin [59]. It is reported that the daily administration of either alcoholic or aqueous extract of *T. cordifolia* decreases the blood glucose level and increases glucose tolerance in rodents [60].

Herbal Drug Formulations

Many formulations (see Table 2) are in the market and are used regularly by diabetic patients on the advice of the physicians.

Diabecon manufactured by ‘Himalaya’ is reported to increase peripheral utilization of glucose, increase hepatic and muscle glucagon contents, promote B cells repair and regeneration and increase c peptide level. It has antioxidant properties and protects B cells from oxidative stress. It exerts an insulin like action by reducing the glycated haemoglobin levels, normalizing the microalbuminuria and modulating the lipid profile. It minimizes long term diabetic complications.

Epinsulin marketed by Swastik formulations, contains epicatechin, a benzopyran, as an active principle. Epicatechin increases the cAMP content of the islet, which is associated with increased insulin release. It plays a role in the conversion of proinsulin to insulin by increasing cathepsin activity. Additionally it has an insulin-mimetic effect on osmotic fragility of human erythrocytes and it inhibits Na/K ATPase activity from patient’s erythrocytes. It corrects the neuropathy, retinopathy and disturbed metabolism of glucose and lipids. It maintains the integrity of all organ systems affected by the disease. It is reported to be a curative for diabetes, Non Insulin Dependant Diabetes Mellitus (NIDDM) and a good adjuvant for Insulin Dependant Diabetes Mellitus (IDDM), in order to reduce the amount of needed insulin. It is advised along with existing oral hypoglycemic drugs. And is known to prevent diabetic complication. It has gentle hypoglycemic activity and hence induces no risk of being hypoglycemic.

Pancreatic Tonic (ayurvedic herbal supplement): Pancreas Tonic is a botanical mixture of traditional Indian Ayurvedic herbs currently available as a dietary supplement.

Bitter gourd powder marketed by Garry and Sun. It lowers blood & urine sugar levels. It increases body’s resistance

against infections and purifies blood. Bitter Gourd has excellent medicinal virtues. It is antidotal, antipyretic tonic, appetizing, stomachic, antibilious and laxative. The bitter Gourd is also used in native medicines of Asia and Africa. The Bitter gourd is specifically used as a folk medicine for diabetes. It contains compounds like bitter glycosides, saponins, alkaloids, reducing sugars, phenolics, oils, free acids, polypeptides, sterols, 17-amino acids including methionine and a crystalline product named p-insulin. It is reported to have hypoglycemic activity in addition to being antihemorrhoidal, astringent, stomachic, emmenagogue, hepatic stimulant, anthelmintic and blood purifier.

Dia-Care manufactured by Admark Herbs Ltd. is claimed to be effective for both Type 1, Type 2 diabetes within 90 days of treatment and cures within 18 months. Persons taking insulin will eventually be liberated from the dependence on it. The whole treatment completes in 6 phases, each phase being of 90 days. Approx. 5 grams (1 tea spoon) powder is mixed with 1/2 glass of water, stirred properly and kept overnight. Only the water and not the sediment must be taken in the morning on empty stomach. To the remaining medicine fresh water is added and kept for the whole day and is consumed half an hour before dinner. The taste of the drug is very bitter. It is a pure herbal formula without any side effects.

Diabetes-Daily Care manufactured by Nature’s Health Supply is a Unique, Natural Formula, which effectively and safely Improves Sugar Metabolism. Diabetes Daily Care™ was formulated for type 2 diabetics and contains all natural ingredients listed in Table 2 in the proportion optimal for the body’s use.

Gurmar powder manufactured by Garry and Sun is an anti-diabetic drug, which suppresses the intestinal absorption of saccharides, which prevents blood sugar fluctuations. It also correlates the metabolic activities of liver, kidney and muscles. Gurmar stimulates insulin secretion and has blood sugar reducing properties. It blocks sweet taste receptors when applied to tongue in diabetes to remove glycosuria. It deadens taste of sweets and bitter things like quinine (effects lasts for 1 to 2 hours). Besides having these properties, it is a cardiac stimulant and diuretic and corrects metabolic activities of liver, kidney and muscles.

DIABETA, a formulation of Ayurvedic Cure, available in the capsule form is an anti-diabetic with combination of proven anti-diabetic fortified with potent immunomodulators, antihyperlipidemics, anti-stress and hepatoprotective of plant origin. The formulation of Diabeta is based on ancient ayurvedic references, further corroborated through modern research and clinical trials. Diabeta acts on different sites in differing ways to effectively control factors and pathways leading to diabetes mellitus. It attacks the various factors, which precipitate the diabetic condition, and corrects the degenerative complications, which result because of diabetes.

Diabeta is safe and effective in managing Diabetes Mellitus as a single agent supplement to synthetic anti-diabetic drugs. Diabeta helps overcome resistance to oral hypoglycemic drugs when used as adjuvant to cases of uncontrolled diabetes. Diabeta confers a sense of well-being in patients and promotes symptomatic relief of complaints like weakness, giddiness, pain in legs, body ache, polyuria and pruritis.

Syndrex manufactured by Plethico Laboratory contains extracts of germinated fenugreek seed. Fenugreek is used as an ingredient of traditional formulations over 1000 years. We are currently studying the mechanism of this antidiabetic drug using animal model on one hand and cultured islet cells on the other.

Thus many different plants have been used individually or in formulations for treatment of diabetes and its complications. One of the major problems with this herbal formulation is that the active ingredients are not well defined. It is important to know the active component and their molecular interaction, which will help to analyse therapeutic efficacy of the product and also to standardize the product. Efforts are now being made to investigate mechanism of action of some of these plants using model systems.

References

- [1] Grover, J.K., Yadav, S., and Vats, V.: Medicinal plants of India with antidiabetic potential. *J. Ethnopharmacol.*, **81**, 81–100, 2002.
- [2] Scartezzini, P. and Sproni, E.: Review on some plants of Indian traditional medicine with antioxidant activity. *J. Ethnopharmacol.*, **71**, 23–43, 2000.
- [3] Seth, S.D. and Sharma, B.: Medicinal plants of India. *Indian J. Med. Res.*, **120**, 9–11, 2004.
- [4] Ramachandran, A., Snehalatha, C., and Viswanathan, V.: Burden of type 2 diabetes and its complications- the Indian scenario. *Curr. Sci.*, **83**, 1471–1476, 2002.
- [5] Matteucci, E. and Giampietro, O.: Oxidative stress in families of type 1 diabetic patients. *Diabetes Care*, **23**, 1182–1186, 2000.
- [6] Oberlay, L.W.: Free radicals and diabetes. *Free Radic. Biol. Med.*, **5**, 113–124, 1988.
- [7] Baynes, J.W. and Thorpe, S.R.: The role of oxidative stress in diabetic complications. *Curr. Opin. Endocrinol.*, **3**, 277–284, 1997.
- [8] Lipinski, B.: Pathophysiology of oxidative stress in diabetes mellitus. *J. Diabet. Complications*, **15**, 203–210, 2001.
- [9] Kubish, H.M., Vang, J., Bray, T.M., and Phillips, J.P.: Targeted over expression of Cu/Zn superoxide dismutase protects pancreatic beta cells against oxidative stress. *Diabetes*, **46**, 1563–1566, 1997.
- [10] Naziroglu, M. and Cay, M.: Protective role of intraperitoneally administered vitamin E and selenium on the oxidative defense mechanisms in rats with diabetes induced by streptozotocin. *Biol. Stress Elem. Res.*, **47**, 475–488, 2001.
- [11] Glugliano, D., Ceriello, A., and Paolisso, G.: Oxidative stress and diabetic vascular complications. *Diabet. Care*, **19**, 257–267, 1996.
- [12] Brownlee, M.: Advanced protein glycosylation in diabetes in diabetes and ageing. *Ann. Rev. Med.*, **46**, 223–234, 1996.
- [13] Elgawish, A., Glomb, M., Friendlander, M., and Monnier, V.M.: Involvement of hydrogen peroxide in collagen cross-linking by high glucose *in vitro* and *in vivo*. *J. Biol. Chem.*, **271**, 12964–12971, 1999.
- [14] Dey, L., Anoja, S.A., and Yuan, C-S.: Alternative therapies for type 2 diabetes. *Alternative Med. Rev.*, **7**, 45–58, 2002.
- [15] Dixit, P.P., Londhe, J.S., Ghaskadbi, S.S., and Devasagayam, T.P.A.: Antidiabetic and related beneficial properties of Indian medicinal plants, in *Herbal Drug Research- A twenty first century perspective*, eds. By Sharma, R.K. and Arora, R., Jaypee brothers medical publishers (New Delhi, India) Limited, pp. 377–386, 2006.
- [16] Wadood, A., Wadood, N., and Shah, S.A.: Effects of *Acacia arabica* and *Caralluma edulis* on blood glucose levels on normal and alloxan diabetic rabbits. *J. Pakistan Med. Assoc.*, **39**, 208–212, 1989.
- [17] Karunanayake, E.H., Welihinda, J., Sirimanne, S.R., and Sinnadorai, G.: Oral hypoglycemic activity of some medicinal plants of Sri Lanka. *J. Ethnopharmacol.*, **11**, 223–231, 1984.
- [18] Roman-Ramos, R., Flores-Saenz, J.L., and Alaricon-Aguilar, F.J.: Antihyperglycemic effect of some edible plants. *J. Ethnopharmacol.*, **48**, 25–32, 1995.
- [19] Kumari, K., Mathew, B.C., and Augusti, K.T.: Antidiabetic and hypolipidaemic effects of S-methyl cysteine sulfoxide, isolated from *Allium cepa* Linn. *Ind. J. Biochem. Biophys.*, **32**, 49–54, 1995.
- [20] Mathew, P.T. and Augusti, K.T.: Hypoglycemic effects of onion, *Allium cepa* Linn. on diabetes mellitus- a preliminary report. *Ind. J. Physiol. Pharmacol.*, **19**, 213–217, 1975.
- [21] Sheela, C.G. and Augusti, K.T.: Antidiabetic effects of S-allyl cysteine sulphoxide isolated from garlic *Allium sativum* Linn. *Indian J. Exp. Biol.*, **30**, 523–526, 1992.
- [22] Bever, B.O. and Zahnd, G.R.: Plants with oral hypoglycemic action. *Quart. J. Crude Drug Res.*, **17**, 139–146, 1979.
- [23] Zacharias, N.T., Sebastian, K.L., Philip, B., and Augusti, K.T.: Hypoglycemic and hypolipidaemic effects of garlic in sucrose fed rabbits. *Ind. J. Physiol. Pharmacol.*, **24**, 151–154, 1980.
- [24] Augusti, K.T. and Sheela, C.G.: Antiperoxide effect of S-allyl cysteine sulfoxide, an insulin secretagogue in diabetic rats. *Experientia*, **52**, 115–120, 1996.
- [25] Al-Awadi, F.M. and Gumaa, K.A.: Studies on the activity of individual plants of an antidiabetic plant mixture. *Acta Diabetologica*, **24**, 37–41, 1987.
- [26] Ajabnoor, M.A.: Effect of aloes on blood glucose levels in normal and alloxan diabetic mice. *J. Ethnopharmacol.*, **28**, 215–220, 1990.
- [27] Davis, R.H. and Maro, N.P.: *Aloe vera* and gibberellins, Anti-inflammatory activity in diabetes. *J. Am. Pediat. Med. Assoc.*, **79**, 24–26, 1989.
- [28] Chattopadhyay, R.R., Chattopadhyay, R.N., Nandy, A.K., Poddar, G., and Maitra, S.K.: Preliminary report on anti-

- hyperglycemic effect of fraction of fresh leaves of *Azadiracta indica* (Beng neem). *Bull. Calcutta. Sch. Trop. Med.*, **35**, 29–33, 1987.
- [29] Chattopadhyay, R.R., Chattopadhyay, R.N., Nandy, A.K., Poddar, G., and Maitra, S.K.: The effect of fresh leaves of *Azadiracta indica* on glucose uptake and glycogen content in the isolated rat hemidiaphragm. *Bull. Calcutta. Sch. Trop. Med.*, **35**, 8–12, 1987.
- [30] Biswas, K., Chattopadhyay, I., Banerjee, R.K., and Bandyopadhyay, U.: Biological activities and medicinal properties of neem (*Azadiracta indica*). *Curr. Sci.*, **82**, 1336–1345, 2002.
- [31] Chakrabarti, S., Biswas, T.K., Rokeya, B., Ali, L., Mosihuzzaman, M., Nahar, N., Khan, A.K., and Mukherjee, B.: Advanced studies on the hypoglycemic effect of *Caesalpinia bonducella* F. in type 1 and 2 diabetes in Long Evans rats. *J. Ethnopharmacol.*, **84**, 41–46, 2003.
- [32] Sharma, S.R., Dwivedi, S.K., and Swarup, D.: Hypoglycemic, antihyperglycemic and hypolipidemic activities of *Caesalpinia bonducella* seeds in rats. *J. Ethnopharmacol.*, **58**, 39–44, 1997.
- [33] Kannur, D.M., Hukkeri, V.I., and Akki, K.S.: Antidiabetic activity of *Caesalpinia bonducella* seed extracts in rats. *Fitoterapia*. In press.
- [34] Yadav, P., Sarkar, S., and Bhatnagar, D.: Lipid peroxidation and antioxidant enzymes in erythrocytes and tissues in aged diabetic rats. *Indian J. Exp. Biol.*, **35**, 389–392, 1997.
- [35] Agarwal, V. and Chauhan, B.M.: A study on composition and hypolipidemic effect of dietary fiber from some plant foods. *Plant Foods Human Nutr.*, **38**, 189–197, 1988.
- [36] Kamble, S.M., Kamlakar, P.L., Vaidya, S., and Bambole, V.D.: Influence of *Coccinia indica* on certain enzymes in glycolytic and lipolytic pathway in human diabetes. *Indian J. Med. Sci.*, **52**, 143–146, 1998.
- [37] Acharekar, S., Kaklij, G.S., Pote, M.S., and Kelkar, S.M.: Hypoglycemic activity of *Eugenia jambolana* and *ficus bengalensis*: mechanism of action. *In vivo*, **5**, 143–147, 1991.
- [38] Aderibigbe, A.O., Emudianughe, T.S., and Lawal, B.A.: Antihyperglycemic effect of *Mangifera indica* in rat. *Phytother. Res.*, **13**, 504–507, 1999.
- [39] Khanna, P., Jain, S.C., Panagariya, A., and Dixit, V.P.: Hypoglycemic activity of polypeptide- p from a plant source. *J. Nat. Prod.*, **44**, 648–655, 1981.
- [40] Shibib, B.A., Khan, L.A., and Rahman, R.: Hypoglycemic activity of *Coccinia indica* and *Momordica charantia* in diabetic rats: depression of the hepatic gluconeogenic enzymes glucose-6-phosphatase and fructose-1, 6-biphosphatase and elevation of liver and red-cell shunt enzyme glucose-6-phosphate dehydrogenase. *Biochem. J.*, **292**, 267–270, 1993.
- [41] Vats, V., Grover, J.K., and Rathi, S.S.: Evaluation of anti-hyperglycemic and hypoglycemic effect of *Trigonella foenum-graecum* Linn, *Ocimum sanctum* Linn and *Pterocarpus marsupium* Linn in normal and alloxanized diabetic rats. *J. Ethnopharmacol.*, **79**, 95–100, 2002.
- [42] Rai, V., Iyer, U., and Mani, U.V.: Effect of Tulasi (*Ocimum sanctum*) leaf powder supplementation on blood sugar levels, serum lipids and tissue lipid in diabetic rats. *Plant Food For Human Nutrition*, **50**, 9–16, 1997.
- [43] Vats, V. and Yadav, S.P.: Grover, Ethanolic extract of *Ocimum sanctum* leaves partially attenuates streptozotocin induced alteration in glycogen content and carbohydrate metabolism in rats. *J. Ethnopharmacol.*, **90**, 155–160, 2004.
- [44] Raphael, K.R., Sabu, M.C., and Kuttan, R.: Hypoglycemic effect of methanol extract of *Phyllanthus amarus* on alloxan induced diabetes mellitus in rats and its relation with antioxidant potential. *Indian J. Exp. Biol.*, **40**, 905–909, 2002.
- [45] Haranath, P.S.R.K., Ranganathrao, K., Anjaneyulu, C.R., and Ramnathan, J.D.: Studies on the hypoglycemic and pharmacological actions of some stilbenes. *Ind. J. Medl. Sci.*, **12**, 85–89, 1958.
- [46] Joglekar, G.V., Chaudhary, N.Y., and Aiaman, R.: Effect of Indian medicinal plants on glucose absorption in mice. *Indian J. Physiol. Pharmacol.*, **3**, 76–77, 1959.
- [47] Chakravarty, B.K., Gupta, S., Gambhir, S.S., and Gode, K.D.: Pancreatic beta cell regeneration. A novel anti-diabetic mechanism of *Pterocarpus marsupium* Roxb. *Ind. J. Pharmacol.*, **12**, 123–127, 1980.
- [48] Jahromi, M.A., Ray, A.B., and Chansouria, J.P.N.: Anti-hyperlipidemic effect of flavonoids from *Pterocarpus marsupium*. *J. Nat. Prod.*, **56**, 989–994, 1993.
- [49] Ahmad, F., Khalid, P., Khan, M.M., Rastogi, A.K., and Kidwai, J.R.: Insulin like activity in (–) epicatechin. *Acta Diabetol. Lat.*, **26**, 291–300, 1989.
- [50] Sauvaire, Y., Petit, P., Broca, C., Manteghetti, M., Baissac, Y., Fernandez-Alvarez, J., Gross, R., Roy, M., Leconte, A., Gomis, R., and Ribes, G.: 4-hydroxyisoleucine: a novel amino acid potentiator of insulin secretion. *Diabetes*, **47**, 206–210, 1998.
- [51] Khosla, P., Gupta, D.D., and Nagpal, R.K.: Effect of *Trigonella foenum graecum* (fenugreek) on blood glucose in normal and diabetic rats. *Indian J. Physiol. Pharmacol.*, **39**, 173–174, 1995.
- [52] Gupta, D., Raju, J., and Baquer, N.Z.: Modulation of some gluconeogenic enzyme activities in diabetic rat liver and kidney: effect of antidiabetic compounds. *Indian J. Expt. Biol.*, **37**, 196–199, 1999.
- [53] Ravikumar, P. and Anuradha, C.V.: Effect of fenugreek seeds on blood lipid peroxidation and antioxidants in diabetic rats. *Phytother. Res.*, **13**, 197–201, 1999.
- [54] Dixit, P.P., Ghaskadbi, S.S., Hari M., and Devasagayam, T.P.A.: Antioxidant properties of germinated fenugreek seeds. *Phytother. Res.*, **19**, 977–983, 2005.
- [55] Stanely, P., Prince, M., and Menon, V.P.: Hypoglycemic and hypolipidemic action of alcohol extract of *Tinospora cordifolia* roots in chemical induced diabetes in rats. *Phytother. Res.*, **17**, 410–413, 2003.
- [56] Stanely, M., Prince, P., and Menon, V.P.: Antioxidant action of *Tinospora cordifolia* root extract in alloxan diabetic rats. *Phytother. Res.*, **15**, 213–218, 2001.
- [57] Price, P.S. and Menon, V.P.: Antioxidant activity of *Tinospora cordifolia* roots in experimental diabetes. *J. Ethnopharmacol.*, **65**, 277–281, 1999.

- [58] Mathew, S. and Kuttan, G.: Antioxidant activity of *Tinospora cordifolia* and its usefulness in the amelioration of cyclophosphamide-induced toxicity. *J. Exp. Clin. Cancer Res.*, **16**, 407–411, 1997.
- [59] Dhaliwal, K.S.: *Method and composition for treatment of diabetes*. US Patent 5886029, 1999.
- [60] Gupta, S.S., Varma, S.C.L., Garg, V.P., and Rai, M.: Antidiabetic effect of *Tinospora cordifolia*. I. Effect on fasting blood sugar level, glucose tolerance and adrenaline induced hyperglycemia. *Indian J. Exp. Biol.*, **55**, 733–745, 1967.
- [61] Kaleem, M., Asif, M., Ahmed, Q.U., and Bano, B.: Antidiabetic and antioxidant activity of *Annona squamosa* extract in streptozotocin-induced diabetic rats. *Singapore Med. J.*, **47**, 670–675, 2006.
- [62] Gupta, R.K., Kesari, A.N., Murthy, P.S., Chandra, R., Tandon, V., and Watal, G.: Hypoglycemic and antidiabetic effect of ethanolic extract of leaves of *Annona squamosa* L. in experimental animals. *J. Ethnopharmacol.*, **99**, 75–81, 2005.
- [63] Gupta, R.K., Kesari, A.N., Watal, G., Murthy, P.S., Chandra, R., and Tandon, V.: Nutritional and hypoglycemic effect of fruit pulp of *Annona squamosa* in normal healthy and alloxan-induced diabetic rabbits. *Ann. Nutr. Metab.*, **49**, 407–413, 2005.
- [64] Subramonium, A., Pushpangadan, P., Rajasekharan, A., Evans, D.A., Latha, P.G., and Valsaraj, R.: Effects of *Artemisia pallens* Wall. On blood glucose levels in normal and alloxan-induced diabetic rats. *J. Ethnopharmacol.*, **50**, 13–17, 1996.
- [65] Chempakam, B.: Hypoglycemic activity of arecoline in betel nut *Areca catechu* L. *Ind. J. Exp. Biol.*, **31**, 474–475, 1993.
- [66] Yoshikawa, M., Murakami, T., Kadoya, M., Matsuda, H., Muraoka, O., Yamahara, J., and Murakami, N.: Medicinal foodstuff. III. Sugar beet. Hypoglycemic oleanolic acid oligoglycosides, betavulgarosides I, II, III and IV, from the root of *Beta vulgaris* L. *Chemical and Pharmaceutical Bulletin*, **44**, 1212–1217, 1996.
- [67] Pari, L. and Amarnath Satheesh, M.: Antidiabetic activity of *Boerhavia diffusa* L. effect on hepatic key enzymes in experimental diabetes. *J. Ethnopharmacol.*, **91**, 109–113, 2004.
- [68] Satheesh, M.A. and Pari, L.: Antioxidant effect of *Boerhavia diffusa* L. in tissues of alloxan induced diabetic rats. *Indian J. Exp. Biol.*, **42**, 989–992, 2004.
- [69] Pari, L. and Amarnath Satheesh, M.: Antidiabetic effect of *Boerhavia diffusa*: effect on serum and tissue lipids in experimental diabetes. *J. Med. Food.*, **7**, 472–476, 2004.
- [70] Saleem, R., Ahmad, M., Hussain, S.A., Qazi, A.M., Ahmad, S.I., Qazi, H.M., Ali, M., Faizi, S., Akhtar, S., and Hussain, S.N.: Hypotensive, hypoglycemic and toxicological studies on the flavonol C-glycoside shamimin from *Bombax ceiba*. *Planta Medica*, **5**, 331–334, 1999.
- [71] Somani, R., Kasture, S., and Singhai, A.K.: Antidiabetic potential of *Butea monosperma* in rats. *Fitoterapia.*, **77**, 86–90, 2006.
- [72] Gomes, A., Vedasiromoni, J.R., Das, M., Sharma, R.M., and Ganguly, D.K.: Antihyperglycemic effect of black tea (*Camellia sinensis*) in rats. *J. Ethnopharmacol.*, **45**, 223–226, 1995.
- [73] Devasagayam, T.P.A., Kamat, J.P., Mohan, H., and Kesavan, P.C.: Caffeine as an antioxidant: Inhibition of lipid peroxidation induced by reactive oxygen species in rat liver microsomes. *Biochim. Biophys. Acta.*, **1282**, 63–70, 1996.
- [74] Chakrabarti, S., Biswas, T.K., Seal, T., Rokeya, B., Ali, L., Azad Khan, A.K., Nahar, N., Mosihuzzaman, M., and Mukherjee, B.: Antidiabetic activity of *Caesalpinia bonducella* F. in chronic type 2 diabetic model in Long-Evans rats and evaluation of insulin secretagogue property of its fractions on isolated islets. *J. Ethnopharmacol.*, **97**, 117–122, 2005.
- [75] Bhattacharya, A., Chatterjee, A., Ghosal, S., and Bhattacharya, S.K.: Antioxidant activity of active tannoid principles of *Embllica officinalis* (amla). *Indian J. Exp. Biol.*, **37**, 676–680, 1999.
- [76] Kumar, K.C.S. and Muller, K.: Medicinal plants from Nepal, II. Evaluation as inhibitors of lipid peroxidation in biological membranes. *J. Ethnopharmacol.*, **64**, 135–139, 1999.
- [77] Devasagayam, T.P.A., Subramanian, M., Singh, B.B., Ramanathan, R., and Das, N.P.: Protection of plasmid pBR322 DNA by flavonoids against single-strand breaks induced by singlet molecular oxygen. *J. Photochem. Photobiol.*, **30**, 97–103, 1995.
- [78] Arai, I., Amagaya, S., Komatsu, Y., Okada, M., Hayashi, T., Kasai, M., Arisawa, M., and Momose, Y.: Improving effects of the extracts from *Eugenia uniflora* on hyperglycemia and hypertriglyceridemia in mice. *J. Ethnopharmacol.*, **68**, 307–314, 1999.
- [79] Maroo, J., Vasu, V.T., and Gupta, S.: Dose dependent hypoglycemic effect of aqueous extract of *Enicostema littorale blume* in alloxan induced diabetic rats. *Phytomedicine.*, **10**, 196–199, 2003.
- [80] Vijayvargia, R., Kumar, M., and Gupta, S.: Hypoglycemic effect of aqueous extract of *Enicostema littorale Blume* (chhota chirayata) on alloxan induced diabetes mellitus in rats. *Indian J. Exp. Biol.*, **38**, 781–784, 2000.
- [81] Augusti, K.T., Daniel, R.S., Cherian, S., Sheela, C.G., and Nair, C.R.: Effect of Leucoperalgonin derivative from *Ficus bengalensis* Linn. on diabetic dogs. *Indian J. Med. Res.*, **99**, 82–86, 1994.
- [82] Chattopadhyay, R.R.: A comparative evaluation of some blood sugar lowering agents of plant origin. *J. Ethnopharmacol.*, **67**, 367–372, 1999.
- [83] Preuss, H.G., Jarrell, S.T., Scheckenbach, R., Lieberman, S., and Anderson, R.A.: Comparative effects of chromium, vanadium and *Gymnema sylvestre* on sugar-induced blood pressure elevations in SHR. *J. Am. Coll. Nutr.*, **17**, 116–123, 1998.
- [84] Alam, M.I. and Gomes, A.: Viper venom-induced inflammation and inhibition of free radical formation by pure compound (2-hydroxy-4-methoxy benzoic acid) isolated and purified from anantamul (*Hemidesmus indicus* R. BR) root extract. *Toxicol.*, **36**, 207–215, 1998.
- [85] Sachadeva, A. and Khemani, L.D.: A preliminary investigation

- of the possible hypoglycemic activity of *Hibiscus rosa-sinensis*. *Biomed. Environ. Sci.*, **12**, 222–226, 1999.
- [86] Kusano, S. and Abe, H.: Antidiabetic activity of whites skinned potato (*Ipomoea batatas*) in obese Zucker fatty rats. *Biolog. Pharmaceut. Bull.*, **23**, 23–26, 2000.
- [87] Nagaraju, N.: *Biochemical studies on some medicinal plants of Rayalaseema region*. PhD thesis. S.V. University, Tirupathi, 1992.
- [88] Rao, B.K., Kessavulu, M.M., Giri, R., and Apparao, C.: Antidiabetic and hypolipidemic effects of *Momordica cymbalaria* Hook fruit powder in alloxan-diabetic rats. *J. Ethnopharmacol.*, **67**, 103–109, 1999.
- [89] Khan, B.A., Abraham, A., and Leelamma, S.: Hypoglycemic action of *Murraya koenigii* (curry leaf) and *Brassica juncea* (mustard) mechanism of action. *Ind. J. Biochem. Biophys.*, **32**, 106–108, 1995.
- [90] Dhanabal, S.P., Sureshkumar, M., Ramanathan, M., and Suresh, B.: Hypoglycemic effect of ethanolic extract of *Musa sapientum* on alloxan induced diabetes mellitus in rats and its relation with antioxidant potential. *J. Herb. Pharmacother.*, **5**, 7–19, 2005.
- [91] Pari, L. and Umamaheswari, J.: Antihyperglycaemic activity of *Musa sapientum* flowers: effect on lipid peroxidation in alloxan diabetic rats. *Phytother. Res.*, **14**, 136–138, 2000.
- [92] Pari, L. and Maheswari, J.U.: Hypoglycemic effect of *Musa sapientum* L. in alloxan-induced diabetic rats. *J. Ethnopharmacol.*, **68**, 321–325, 1999.
- [93] Tormo, M.A., Gil-Exojo, I., Romero de Tejada, A., and Campillo, J.E.: Hypoglycemic and anorexigenic activities of an alpha-amylase inhibitor from white kidney beans (*Phaseolus vulgaris*) in Wistar rats. *Br. J. Nutr.*, **92**, 785–790, 2004.
- [94] Pari, L. and Venkateswaran, S.: Protective role of *Phaseolus vulgaris* on changes in the fatty acid composition in experimental diabetes. *J. Med. Food.*, **7**, 204–209, 2004.
- [95] Knott, R.M., Grant, G., Bardocz, S., Pusztai, A., de, Carvalho, A.F., and Hesketh, J.E.: Alterations in the level of insulin receptor and GLUT-4 mRNA in skeletal muscle from rats fed a kidney bean (*Phaseolus vulgaris*) diet. *Int. J. Biochem.*, **24**, 897–902, 1992.
- [96] Jafri, M.A., Aslam, M., Javed, K., and Singh, S.: Effect of *Punica granatum* Linn. (flowers) on blood glucose level in normal and alloxan induced diabetic rats. *J. Ethnopharmacol.*, **70**, 309–314, 2000.
- [97] Yoshikawa, M., Murakami, T., Yashiro, K., and Matsuda, H.: Kotalanol, a potent α -glucosidase inhibitor with thiosugar sulfonium sulphate structure, from antidiabetic Ayurvedic medicine *Salacia reticulata*. *Chem. Pharma. Bulletin*, **46**, 1339–1340, 1998.
- [98] Pari, L. and Latha, M.: Antidiabetic effect of *Scoparia dulcis*: effect on lipid peroxidation in streptozotocin diabetes. *Gen. Physiol. Biophys.*, **24**, 13–26, 2005.
- [99] Pari, L. and Latha, M.: Antihyperlipidemic effect of *Scoparia dulcis* (sweet broomweed) in streptozotocin diabetic rats. *J. Med. Food.*, **9**, 102–107, 2006.
- [100] Latha, M., Pari, L., Sitasawad, S., and Bhonde, R.: Insulin-secretagogue activity and cytoprotective role of the traditional antidiabetic plant *Scoparia dulcis* (Sweet Broomweed). *Life Sci.*, **75**, 2003–2014, 2004.
- [101] Saxena, A.M., Bajpai, M.B., Murthy, P.S., and Mukherjee, S.K.: Mechanism of blood sugar lowering by a Swerchirin-containing hexane fraction (SWI) of *Swertia chirayita*. *Ind. J. Exp. Biol.*, **31**, 178–181, 1993.
- [102] Rao, B.K. and Rao, C.H.: Hypoglycemic and anti-hyperglycemic activity of *Syzygium alternifolium* (Wt.) Walp. seed extracts in normal and diabetic rats. *Phytomedicine.*, **8**, 88–93, 2001.
- [103] Sabu, M.C. and Kuttan, R.: Antidiabetic activity of medicinal plants and its relationship with their antioxidant property. *J. Ethnopharmacol.*, **81**, 155–160, 2002.
- [104] Noor, H. and Ashcroft, S.J.: Pharmacological characterization of the anti-hyperglycemic properties of *Tinospora crispa* extract. *J. Ethnopharmacol.*, **62**, 7–13, 1998.
- [105] Chattopadhyay, S.R., Sarkar, S.K., Ganguly, S., Banerjee, R.N., and Basu T.K.: Hypoglycemic and anti-hyperglycemic effect of *Vinca rosea* Linn. *Ind. J. Physiol. Pharmacol.*, **35**, 145–151, 1991.
- [106] Adallu, B. and Radhika, B.: Hypoglycemic, diuretic and hypocholesterolemic effect of winter cherry (*Withania somnifera*, Dunal) root. *Indian J. Exp. Biol.*, **38**, 607–609, 2000.