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Pharmacological Evaluation of "Sugar Remedy," A Polyherbal Formulation, on Streptozotocin-Induced Diabetic Mellitus in Rats

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ABSTRACT

In the present study, Sugar Remedy, a polyherbal formulation (manufactured by Umalaxmi Organics Pvt Ltd, Jodhpur, Rajasthan, India) was evaluated for its antihyperglycemic, antihyperlipidemic, and antioxidant effects against normal and streptozotocin (STZ)-induced diabetic rats. Type II diabetes was induced in male Wistar rats by administration of a single intraperitoneal (IP) injection of STZ at a dose of 60 mg/kg. Effects of three different doses of Sugar Remedy suspension (185, 370, and 740 mg/kg/day, orally) and Metformin (500 mg/kg/day, orally) administered for 21 days were studied on parameters such as blood glucose, lipid profile, and antioxidant levels. Results were analyzed using one-way analysis of variance (ANOVA) followed by Dunnett's test. No significant changes were noticed in blood glucose, serum lipid levels, and kidney parameters in normal rats treated with Sugar Remedy suspension alone. The efficacy of Sugar Remedy as an antihyperglycemic, antihyperlipidemic, and antioxidant agent in STZ-induced diabetes was comparable to that of the standard, 500 mg/kg of Metformin. Present findings provide experimental evidence that Sugar Remedy has significant antihyperglycemic, antihyperlipidemic, and antioxidative effects in diabetic experimental rats. Hence, Sugar Remedy may be regarded as a promising natural and safe remedy for the prevention or delay of diabetic complications.

Key words: Ayurveda, Diabetes mellitus, Hyperlipidemia, Streptozotocin, Sugar remedy

INTRODUCTION

Polyherbal drugs as Ayurvedic medicines are considered to be more effective for the management of diabetes. Diabetes mellitus (DM) represents a syndrome of metabolic disorders and complex pathophysiological interactions between hyperglycemia, insulin resistance, and dysfunction of the β-cells of pancreas. The available antidiabetic measures, such as oral hypoglycemic agents and insulin, do not effectively control the delayed diabetic complications like nephropathy, neuropathy, retinopathy, and cardiovascular diseases.[1] Oxidative tissue injury has been suggested to play an important role in the pathogenesis of diabetes and associated complications.[2] The antihyperglycemic effects of various plants are credited to their ability to restore the function of pancreatic tissues by causing an increase in the insulin output or by inhibiting the intestinal absorption of glucose or by the facilitation of metabolites in insulin-dependent processes.[3] Herbal products are generally

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considered to be least toxic and free from side effects when compared with their synthetic counterparts.[4]

Sugar Remedy is claimed to be a unique formulation that helps in holistic management of blood glucose and diabetes-related complications. Each 100 g of Sugar Remedy contains the following as the major constituents: Bitter melon extract: 50 g; gudmar extract: 16.7 g; ashwagandha extract: 8.4 g; jamun extract: 4.2 g; shilajit extract: 4.2 g; fenugreek extract: 4.2 g; triphala extract: 4.2 g; cinnamon extract: 4.2 g; and vijaysar extract: 4.2 g. The combined role of the key ingredients present in Sugar Remedy [Table 1] in lowering the blood glucose level and, thus, improving the hepatic and renal functions, lipid profile, and antioxidant activity is evidenced from previous studies performed on individual herbs, revealing their activities which are the following: Karela by insulin secretion, inhibition of glucose reabsorption in the gut, and increase of peripheral glucose utilization;[5] gudmar by regulation of β-cell function and by its antioxidant activity;[6-8] fenugreek and cinnamon by improving digestion, metabolism and reduction in insulin resistance and increasing hepatic glycogenesis;[9] jamun by increasing the pancreatic secretion of insulin;[10] shilajit by improving the neurogenic function associated with diabetes and through its pancreatotrophic action;[11] and vijaysar by pancreatic β-cell regranulation.[12]

In the present study, attempts have been made to establish the scientific validity for the antihyperglycemic property of Sugar Remedy using streptozotocin (STZ)-induced diabetic model in rats. The results of the study can serve as a step toward the development of an antihyperglycemic herbal therapy for diabetes.

MATERIALS AND METHODS

Animals and grouping

Male Wistar rats, 7-8 weeks old and weighing 150-220 g, were used for the present study. The rats were randomly distributed to different groups with six animals in each. Animals were provided with standard pellets and drinking water *ad libitum* and were maintained at 12 h light and dark cycle. The protocol of the experiment (1258/ac/09/CPCSEA) was approved by the Institutional Animal Ethics Committee (IAEC), and the experiments were conducted in accordance with the guidelines as per the "Guide for the Care and Use of Laboratory Animals" and with permission from the "Committee for the Purpose of Control and Supervision of Experiments on Animals" (CPCSEA).

Drugs and chemicals

Sugar Remedy was obtained from Umalaxmi Organics Pvt Ltd, Jodhpur, India. The formulation was suspended in water for the preparation of an oral dosage formulation and administered by per oral (PO) route in different doses, twice daily for 21 days, while the control group was treated with water. STZ was obtained Sigma Aldrich Co, Mumbai, India. Metformin (Glyciphage, Franco-Indian Pharmaceuticals Pvt Ltd) was obtained from Rina's Pharma, Jodhpur, India.

Induction of diabetes

Diabetes was induced in overnight fasted rats by the intraperitoneal (IP) injection of STZ dissolved in freshly prepared citrate

Table 1. Formulated herbal drugs with antidiabetic properties

Plant name	Ayurvedic name	Plant part used	Plant family	Antidiabetic and other beneficial effects in traditional medicine	Chemical constituents
Momordica charantia	Bitter melon	Fruits and leaves	Cucurbitaceae	Insulin secretion, inhibition of glucose reabsorption in guts, preservation of islet β-cells and their functions, increase of peripheral glucose utilization, and suppression of gluconeogenic enzymes	Charantin, Momordica, Momordicin, Charantin, and Galactose-binding lectin
Gymnema sylvestre	Gudmar	Leaves	Asclepiadaceae	Regeneration of β-cell, reduce blood glucose level, increase plasma insulin level and hypolipidemic	Gymnemic acids 1-4 and Gurmarin
Withania somnifera	Ashwagandha	Leaves	Solanaceae	Decrease blood sugar level	Withanine, Somnine, Withaferine, Withanolides
Syzygium cumini	Jamun	Fruit	Myrtaceae	Increasing either the pancreatic secretion of insulin or its release from bound insulin	Gymnemic acids, Saponins, Stigmasterol, Quercitol, Betaine, Choline
Asphaltum	Shilajit	-	-	Pancreatotrophic action	Dibenzo-alpha-pyrones and related metabolites, small peptides
Trigonella foenum-graecum	Fenugreek	Seeds	Fabaceae	Antidiabetic and Reduces insulin resistance	Trigonelline, Galactomannan, Diosgenin Nicotinic acid, Coumarin, 4-hydroxyleucine and Hydroxyisoleucine
Phyllanthus emblica Terminalia bellirica Terminalia chebula	Triphala	Fruit	Phyllanthaceae Combretaceae	Antidiabetic	Epicatechin
Cinnamomum Zeylanicum	Cinnamon	Bark	Lauraceae	α-Glucosidase inhibition, antioxidant and antidiabetic	Volatile oil, Tannin Mannitol, Calcium oxalate
Pterocarpus marsupium	Vijaysar	Heart-wood	Fabaceae	Hypoglycemic, improve hyperlipidema, antihyperglycemic and prevent mucosal ulceration	(-)-Epicatechin, Aurones, Pterostilbene, Marsupol, Isoliquiritigenin

buffer (0.1 M, pH 4.5) in a volume of 1 ml/kg body weight at a dose of 60 mg/kg body weight.[13] Diabetes was confirmed 72 h after the injection by determining the blood glucose concentration. Only those animals with blood glucose level of >200 mg/dl (mild diabetes)[14,15] were used for the experiment. The diabetic animals were allowed free access to tap water and pelleted diet and were maintained at room temperature in plastic cages.

Acute toxicity studies

To study any possible toxic effects, mortality, and/or changes in the behavioral pattern, acute toxicity studies were performed according to Organisation for economic co-operation and development (OECD) guidelines 423, December 2001. Experiments were carried out in normal rats and they were kept under closed observation for 24 h. All symptoms including changes in awareness, mood, motor activity, posture activity, and mortality were recorded. No toxicity or mortality was observed with Sugar Remedy up to a dose of 1000 mg/kg body weight.[16]

Biochemical estimations

Blood glucose estimation was done using a glucometer and with Trinder's enzymatic method using an autoanalyzer.[17] Lipid profile was checked with an autoanalyzer using the following methods: Cholesterol oxidase-phenol + aminophenazone (CHOD-PAP) end point method was used for cholesterol estimation, phosphotungstic acid end point method for high density lipoprotein (HDL) estimation, and glycerol-3-phosphate oxidase (GPO)-Trinder end point method was used for triglyceride estimation.[18,19] Very low density lipoprotein (VLDL) and low density lipoprotein (LDL) fractions were calculated by using Friedewald's equation as follows:[20]

VLDL = triglycerides/5

LDL = TC – (HDL + VLDL)

Physiological profile of kidneys was estimated by Jaffe's method Initial Rate for creatinine and modified Trinder's method, end point for uric acid, using autoanalyzer.[21]

Antioxidant activity in liver tissue homogenate

By the end of the treatment period, on the next day of administering the last dose of the respective treatments, immediately after collection of blood, the animals were euthanized with an overdose of ether and their livers were excised, washed with ice-cold normal saline, and weighed. Then, a 10% liver tissue homogenate was prepared by homogenizing in ice-chilled phosphate-buffered saline (PBS; pH 7.4) using a tissue homogenizer. The homogenate was centrifuged at 10,000 rpm for 4°C using a refrigerated centrifuge and the supernatant was used for the determination of various antioxidant parameters like reduced glutathione (GSH), superoxide dismutase (SOD), catalase (CAT), and malondialdehyde (MDA) levels.[22-25]

Statistical analysis

Results are expressed as mean ± standard error of mean (SEM) and statistical difference was evaluated using one-way analysis of variance (ANOVA) followed by Dunnett's test. Data were considered statistically significant at a $P \leq 0.01$ and highly significant at a $P < 0.001$. All the above statistical analyses were done on Prism software.

RESULTS

Effect of sugar remedy on blood glucose levels

STZ treatment produced significant increase in blood glucose levels (347.50 ± 21.90 mg/dl) with respect to the control group (109.47 ± 3.46 mg/dl). The hyperglycemia was pronounced after 21st day of administering STZ. As shown in Table 2, the administration of 740 mg/kg of Sugar Remedy or 500 mg/kg of Metformin significantly reversed (129.72 ± 8.25 mg/dl and 128.2 ± 12.46 mg/dl, respectively) the increase in blood glucose concentration induced by STZ. Such an effect was more obvious with high dose of Sugar Remedy (740 mg/kg body weight).

Effect of sugar remedy on the lipid profile

STZ produced significant increases in serum triglycerides (153.63 ± 3.77 vs. 78.61 ± 7.35 mg/dl in normal control rats), serum cholesterol (123.17 ± 0.78 vs. 76.35 ± 3.06 mg/dl in normal control rats), LDL (80.96 ± 1.02 vs. 30.04 ± 1.90 mg/dl in normal control rats), and VLDL (30.73 ± 0.72 vs. 16.67 ± 1.37 mg/dl in normal control rats), as well as marked reduction in serum HDL levels (11.48 ± 0.67 vs. 29.60 ± 1.10 mg/dl in normal control rats). As shown in Table 3, treatment with 740 mg/kg of Sugar Remedy reduced the levels of serum cholesterol, triglycerides, VLDL, and LDL (81.20 ± 1.64, 102.35 ± 1.55, 20.47 ± 0.31, and 36.95 ± 1.37 mg/dl, respectively), which was comparable to the levels in control group (76.35 ± 3.06, 78.61 ± 7.35, 16.67 ± 1.37, and 30.04 ± 1.90 mg/dl, respectively). Metformin at a dose of 500 mg/kg also produced the same effect (80.16 ± 1.01, 99.63 ± 3.01, 19.92 ± 0.60, and 33.97 ± 0.85 mg/dl, respectively). Increase in HDL levels was also much pronounced in animals treated with 740 mg/kg of Sugar Remedy or 500 mg/kg of Metformin (23.78 ± 1.00 and 26.26 ± 0.56 mg/dl, respectively) which was comparable to the normal control animals (29.60 ± 1.10 mg/dl).

Table 2. Effect of Sugar remedy on serum glucose levels

Groups	0 day	7th day	14th day	21st day
Normal control	109.47±3.46	109.93±3.86	109.66±3.36	108.21±3.00
Diabetic control	347.50±21.90	342.76±21.48	345.78±23.03	350.26±26.95
Std. metformin (500 mg/kg)	318.83±20.24^{ns}	214.03±19.32^{c}	166.56±12.82^{c}	128.20±12.46^{c}
Sugar remedy (185 mg/kg)	307.16±10.84^{b}	258.85±11.35^{c}	193.48±8.14^{c}	146.52±2.93^{c}
Sugar remedy (370 mg/kg)	334.66±23.87^{b}	245.68±32.18^{c}	188.68±20.40^{c}	135.22±4.94^{c}
Sugar remedy (740 mg/kg)	327.33±16.97^{b}	225.65±10.44^{c}	170.35±7.31^{c}	129.72±8.25^{c}

All values in tables are expressed as mean±S.E.M; ^{a,b,c}denotes statistically significantly mean, ns non significant, $^{a}P<0.05$, $^{b}P<0.01$, $^{c}P<0.0001$

Effect of sugar remedy on kidney and liver parameters

STZ-diabetic (DC) rats exhibited higher serum creatinine (2.55 ± 0.18 mg/dl) and uric acid (9.26 ± 0.18 mg/dl) levels as compared to those of normal control rats (0.86 ± 0.05 and 3.26 ± 0.09 mg/dl, respectively) [Table 4]. Chronic treatment with 740 mg/kg of Sugar Remedy significantly reduced the elevated creatinine as well as uric acid levels in diabetic rats (1.01 ± 0.24 mg/dl and 4.33 ± 0.39 mg/dl, respectively), which was comparable to the levels in Metformin (500 mg/kg) treated animals (1.69 ± 0.21 and 6.09 ± 1.17 mg/dl, respectively).

Aspartate transaminase (AST) level was significantly reduced in rats treated with 740 mg/kg of Sugar Remedy (83.69 ± 1.45 U/l) or 500 mg/kg of Metformin (86.35 ± 10.40 U/l) when compared to diabetic control rats (102.00 ± 8.38 U/l). Similarly, alanine transaminase (ALT) level was significantly reduced in rats treated with 740 mg/kg of Sugar Remedy or 500 mg/kg of Metformin (33.02 ± 3.80 U/l and 45.15 ± 1.33 U/l, respectively), when compared to diabetic control rats (88.60 ± 5.62 U/l). This indicates that Sugar Remedy also improved the liver physiology and may have hepatoprotective effects [Table 4].

Effect of sugar remedy on the antioxidant parameters in liver

DC rats showed a significant decrease in SOD, CAT, and GSH levels (6.06 ± 0.10, 0.59 ± 0.01 units/min/mg protein and 1.80 ± 0.10 units/mg protein, respectively) when compared with the normal control animals (17.89 ± 1.42, 1.30 ± 0.63 units/min/mg protein and 4.58 ± 1.42 mg/g protein, respectively). Thiobarbituric acid reactive substances (TBARS) significantly increased following STZ administration (46.41 ± 0.51 nmol/mg protein) in DC rats when compared to normal control rats (24.10 ± 0.51 nmol/mg protein). Administration of Sugar Remedy in various doses for 21 days produced a marked increase in the antioxidant (SOD, GSH, and CAT) levels, whereas it produced a significant decrease in the prooxidant parameter (TBARS) [Table 5].

DISCUSSION

DM is one of the most common chronic diseases, and is associated with hyperlipidemia and co-morbidities such as obesity and hypertension. Hyperlipidemia is a metabolic complication of both

Table 3. Effect of Sugar remedy on lipid profile

Groups	Lipid profile parameters				
	Cholesterol	Triglyceride	HDL	VLDL	LDL
Normal control	76.35±3.06	78.61±7.35	29.60±1.10	16.67±1.37	30.04±1.90
Diabetic control	123.17±0.78	153.63±3.77	11.48±0.67	30.73±0.72	80.96±1.02
Std. metformin (500 mg/kg)	80.16±1.0^{c}	99.63±3.01^{c}	26.26±0.56^{c}	19.92±0.60^{c}	33.97±0.85^{c}
Sugar remedy (185 mg/kg)	101.20±1.47^{b}	125.05±2.27^{ns}	12.97±0.88^{ns}	25.01±0.45^{ns}	63.22±1.20^{b}
Sugar remedy (370 mg/kg)	89.33±1.34^{c}	113.96±3.32^{b}	20.21±0.70^{b}	22.79±0.66^{c}	46.32±1.04^{b}
Sugar remedy (740 mg/kg)	81.20±1.64^{c}	102.35±1.55^{c}	23.78±1.00^{c}	20.47±0.31^{c}	36.95±1.37^{c}

All values in tables are expressed as mean±S.E.M; $^{a;b;c}$denotes statistically significantly mean, ns non significant, $^{a}P<0.05$, $^{b}P<0.01$, $^{c}P<0.0001$. HDL: High density lipoprotein; VLDL:Very low; density lipoprotein; LDL:Low density lipoprotein

Table 4. Effect of sugar remedy on serum creatinine and uric acid levels

Groups	Liver and kidney parameters			
	AST	ALT	Creatinine	Uric acid
Normal control	56.90±3.01	30.37±1.63	0.86±0.05	3.26±0.09
Diabetic control	102.00±8.38	88.6±5.62	2.55±0.18	9.26±0.18
Std. metformin (500 mg/kg)	86.35±10.40^{c}	45.15±1.33^{c}	1.69±0.21^{c}	6.09±1.17^{c}
Sugar remedy (185 mg/kg)	95.58±3.25^{ns}	67.7±3.30^{b}	1.99±0.98^{b}	8.54±0.47^{ns}
Sugar remedy (370 mg/kg)	85.48±3.26^{b}	39.24±2.76^{c}	1.21±0.06^{c}	5.43±0.94^{c}
Sugar remedy (740 mg/kg)	83.69±1.45^{c}	33.02±3.80^{c}	1.01±0.24^{c}	4.33±0.39^{c}

All values in tables are expressed as mean±S.E.M; $^{a;b;c}$denotes statistically significantly mean, ns non significant, $^{a}P<0.05$, $^{b}P<0.01$, $^{c}P<0.0001$.
AST:Aspartate transaminase; ALT: Alanine transaminase

Table 5. Effect of sugar remedy on antioxidant parameters

Groups	Antioxidant parameters			
	SOD (units/min/mg protein)	GSH (units/mg protein)	CATALASE (units/min/mg protein)	TBARS (nmoles/mg protein)
Normal control	17.89±1.42	4.58±1.42	1.30±0.63	24.10±0.51
Diabetic control	6.06±0.10	1.80±0.10	0.59±0.01	46.41±0.51
Std. metformin (500 mg/kg)	15.86±0.16^{b}	3.39±3.44^{b}	1.19±0.26^{b}	29.23±1.09^{c}
Sugar remedy (185 mg/kg)	8.38±0.24^{ns}	2.39±0.99^{ns}	0.70±0.04^{ns}	39.62±0.27^{c}
Sugar remedy (370 mg/kg)	13.74±0.18^{a}	3.20±1.16^{a}	0.91±0.15^{a}	34.46±0.29^{c}
Sugar remedy (740 mg/kg)	14.96±0.17^{a}	3.41±1.56^{b}	0.94±0.16^{a}	29.08±0.45^{c}

All values in tables are expressed as mean±S.E.M; $^{a;b;c}$denotes statistically significantly mean, ns non significant, $^{a}P<0.05$, $^{b}P<0.01$, $^{c}P<0.0001$. SOD: Superoxide dismutase; GSH: Glutathione; TBARS: Thiobarbituric; acid reactive substances

clinical and experimental diabetes.[26] STZ, a β-cytotoxin, induces "chemical diabetes" in a wide variety of animal species, including rats, by selectively damaging the insulin-secreting β-cells of the pancreas. IP injection of STZ produces fragmentation of DNA of the β-cells of pancreas, which stimulates poly (ADP-ribose) and depletes nicotinamide adenine dinucleotide (NAD) ultimately leading to the destruction of β-cells. It is evidenced by the clinical symptoms of hyperglycemia and hypoinsulinemia. The serum glucose, lipid, and cholesterol values for the rats are in agreement with those expected for STZ-diabetic rats.[27-30]

Decrease in blood glucose levels was found to be more effective with Sugar Remedy in doses of 370 and 740 mg/kg. Metformin showed rapid normalization of blood glucose due to its insulin releasing effects. Treatment with polyherbal formulation Sugar Remedy caused significant decrease in fasting serum glucose (FBG) level near to that of healthy control rats. The plant extracts may involve one or more compounds which decrease the blood glucose levels, suggesting that the natural constituents could act synergistically to induce a hypoglycemic effect as described by Marles *et al*.[31-33] These effects might be achieved by facilitating insulin release from pancreatic β-cells, inhibiting glucose absorption in the gut, stimulating glycogenesis in the liver, and/or increasing glucose utilization by the body. These compounds also exhibited antioxidant and hypolipidemic activities, restored the enzymatic functions, and helped in repair and regeneration of pancreatic islets and the alleviation of liver and renal damage.[31,34-42]

Insulin deficiency may be responsible for dyslipidemia because insulin has an inhibitory action on 3-hydroxy-3-methyl-glutaryl-CoA (HMG-CoA) reductase, a key enzyme that is rate limiting in the metabolism of cholesterol-rich LDL particles.[43] The development of hypertriglyceridemia in uncontrolled diabetes in humans (possibly in insulin-deficient STZ-diabetic rats) may be due to a number of metabolic abnormalities that occur sequentially. Acute insulin deficiency initially causes an increase in free fatty acid mobilization from the adipose tissue, resulting in increased secretion of VLDL and triglycerides from the liver.[44] In diabetic rats, there is a decrease in lipoprotein lipase activity,[45] resulting in impaired clearance of VLDL and chylomicrons from the plasma.[46]

Administration of Sugar Remedy decreased the levels of tissue free fatty acids and phospholipids. Accumulation of triglycerides is one of the risk factors in coronary heart disease (CHD). The significant increase in the level of triglycerides in the liver and kidney of diabetic control rats may be due to the lack of insulin. Under normal conditions, insulin activates the enzyme lipoprotein lipase and hydrolyzes triglycerides. Sugar Remedy reduces triglycerides in the tissues of STZ-induced diabetic rats and may prevent the progression of CHD.[47]

The decreased activities of CAT and SOD in the diabetic group may be a response to the increased production of H2O2 and O2 by the auto-oxidation of glucose and nonenzymatic glycation. Hepatic SOD and CAT activities were reduced during diabetes and this may result in a number of harmful effects due to the accumulation of hydrogen peroxides and superoxide radicals. Administration of Sugar Remedy caused decreased lipid peroxidation, which is associated with increased SOD and CAT activities, indicating that Sugar Remedy can reduce reactive oxygen free radicals and improve the activities of the hepatic antioxidant enzymes. The antioxidative activity of Sugar Remedy gains further evidence from the quantification of TBARS in hepatic tissues, as an inverse relationship was found between the activities of antioxidant enzymes and the quantity of free radicals, which is in agreement with previous reports.[48,49] In diabetes, AST and ALT activities are increased,[50] which may be due to the cellular damage.[51] The plant extract was observed to normalize the levels of these enzymes, which indicates that it has a promising antidiabetic effect without inducing toxicity.

Administration of Sugar Remedy and Metformin reduced the lipid peroxidative markers in the liver and kidney tissues of diabetic rats. This indicates that Sugar Remedy inhibits oxidative damage due to the antiperoxidative effect of its ingredients. This could be correlated with previous studies reporting that *Momordica charantia*,[52] *Gymnema sylvestre*,[53] *Withania somnifera*,[54] *Syzygium cumini*,[55] *Asphaltum*,[11] *Trigonella foenum-graecum*,[56] *Triphala*,[57] *Cinnamomum zeylanicum*,[58] and *Pterocarpus marsupium*[59] (ingredients of Sugar Remedy) have antiperoxidative and antihyperlipidemic effects in diabetic animals.

The antidiabetic and antihyperlipidemic effects of Sugar Remedy may be due to the effect of active constituents of different plants, viz., momorcharin and momordicin isolated from M. *charantia*; gymnemic acids 1-4 and gurmarin from G. *sylvestre*; withanine, somnine, withaferine, and withanolides from W. *somnifera*; gymnemic acids, saponins, stigmasterol, quercitol, betaine, and choline from S. *cumini*; dibenzo-alpha-pyrones and related metabolites, and small peptides from Asphaltum; trigonelline and scopoletin from T. *foenum-graecum*; epicatechin from *P*. *emblica*; volatile oil, tannin, mannitol, and calcium oxalate from C. *zeylanicum*; and (−)-epicatechin, aurones, pterostilbene, marsupol, and isoliquiritigenin from P. *marsupium*, which may be responsible for scavenging the free radicals liberated by STZ in diabetic rats.[9-11,60-62]

CONCLUSION

On the basis of the aforementioned results, it may be concluded that Sugar Remedy has significant antihyperglycemic, antihyperlipidemic, and antioxidative effects in diabetic experimental rats. Hence, Sugar Remedy may be regarded as a promising natural and safe remedy for the prevention or delay of diabetic complications.

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