

## Antidiabetic Activity of Aqueous Leaves Extract of *Sesbania sesban* (L) Merr. in Streptozotocin Induced Diabetic Rats

Ramdas B. Pandhare<sup>1,2\*</sup>, B. Sangameswaran<sup>3</sup>, Popat B. Mohite<sup>1</sup>, Shantaram G. Khanage<sup>1</sup>

1. MES College of Pharmacy, Sonai, Newasa, Ahmednagar, Maharashtra, India

2. Research Scholar Department of Pharmacy, Suresh Gyan Vihar University, Jaipur, Rajasthan, India

3. Department of Pharmacognosy, TIT-Pharmacy, Bhopal, India

### Abstract

The aqueous leaves extract of *Sesbania sesban* (L) Merr. (Family: Fabaceae) was evaluated for its antidiabetic potential on normal and streptozotocin (STZ)-induced diabetic rats. In the chronic model, the aqueous extract was administered to normal and STZ-induced diabetic rats at the doses of 250 and 500 mg/kg body weight (b.w.) p.o. per day for 30 days. The fasting Blood Glucose Levels (BGL), serum insulin level and biochemical data such as glycosylated hemoglobin, Total Cholesterol (TC), Triglycerides (TG), High Density Lipoproteins (HDL) and Low Density Lipoproteins (LDL) were evaluated and all were compared to that of the known anti-diabetic drug glibenclamide (0.25 mg/kg b.w.). The statistical data indicated significant increase in the body weight, liver glycogen, serum insulin and HDL levels and decrease in blood glucose, glycosylated hemoglobin, total cholesterol and serum triglycerides when compared with glibenclamide. Thus the aqueous leaves extract of *Sesbania sesban* had beneficial effects in reducing the elevated blood glucose level and lipid profile of STZ-induced diabetic rats.

*Avicenna J Med Biotech* 2011; 3(1): 37-43

**Keywords:** Diabetes mellitus, Hyperglycemia, *Sesbania sesban*, Streptozotocin

### \* Corresponding author:

Ramdas B. Pandhare,  
M.Pharm., M.E.S. College of  
Pharmacy, Ahmednagar,  
Maharashtra, India

Tel: +91 9881969052

Fax: +91 02427-230948

### E-mail:

ramdaspandhare83@rediff  
mail.com

Received: 24 Jan 2011

Accepted: 15 Mar 2011

### Introduction

*Sesbania sesban* (L) Merr. is a small perennial tree with woody stems, yellow flowers and linear pods belongs to the family Fabaceae. Seed and bark are used as astringent, emmenagogue, in menorrhagia, spleen enlargement and diarrhea. The pods and leaves contain campesterol and beta-sitosterol. Flowers contain cyanidin and delphinidin glucosides. Pollen and pollen tubes contain alpha-ketoglutaric, oxaloacetic and pyruvic acids<sup>(1,2)</sup>. Leaves are used as antihelmintic and also useful in diabetes, colic and skin diseases. Seeds are stimulant, emmenagogue, astringent and also useful in diarrhea<sup>(3)</sup>.

Reports suggest that previous phytochem-

ical investigations of the plant led to the isolation of oleanolic acid, stigmasta-5,24(28)-diene-3-ol-3-0-β-D-galactopyranoside, fatty acids and amino acids<sup>(4)</sup>. Various types of lignins are composed of guaiacyl, syringyl and P-hydroxyphenylpropane building units<sup>(5)</sup> and also anti-tumor principal, kaempferol trisaccharide<sup>(6)</sup>. However, the literature indicates that there is no specific evidence to support the antidiabetic effect of *Sesbania sesban*. The present study investigates the action of aqueous extract of *Sesbania sesban* leaves in the STZ-induced diabetic rats to ascertain the scientific basis for the use of this plant in the treatment of diabetes.

## Material and Methods

### Collection of plant material

The leaves of *Sesbania sesban* were collected during July 2008 from the Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The leaves were identified by Dr. P.G.Diwakar, Joint Director, Botanical Survey of India, Pune. A voucher specimen (KS GSS12) has been kept in herbarium, in Botanical Survey of India, Pune Maharashtra.

### Preparation of test sample

*Sesbania sesban* leaves were cut into small pieces and were allowed to dry in the shade. About 100 g of the dried powdered material was hot extracted at 60°C for 6 hr using 1 L of water. The water extract was filtered and evaporated for dryness under vacuum, which yielded a sticky material (yield: 7.5% w/w)<sup>(7,8)</sup>.

### Preliminary phytochemical screening

The preliminary phytochemical screening of aqueous extract of the *Sesbania sesban* leaves was carried out for qualitative identification of type of phytoconstituents present. The presence of various phytoconstituents viz. steroids and terpenoids (Leibermann Burchard test), alkaloids (Dragendorffs test), tannins and phenolics (Ferric chloride test), flavonoids (Shinoda test), Sugars (Fehling solution test), amino acids (Ninhydrin test), etc. was detected by usual methods prescribed in standard texts<sup>(9,10)</sup>.

### Animals

Healthy adult male albino wistar rats (150-200 g), in house breed at the animal house of M.E.S. College of Pharmacy, Sonai, India were used for the study. Rats were housed in polypropylene cages lined with husk in standard environmental conditions. (temperature 25±2°C; relative humidity 55±10%; and 12:12 light:dark cycle,) The rats were fed on a standard pellet diet (Amrut rat and mice feed, Sangli, India) *ad libitum* and had free access to water. The experiments were performed after approval of the protocol by the Institutional Animal Ethical Committee (IAEC) and were carried out in accordance with the cur-

rent guidelines for the care of laboratory animals.

### Acute toxicity studies

Acute toxicity study was carried out for the *Sesbania sesban* by adapting fixed dose method of CPCSEA, OECD guidelines no 420. Thirty fasted male albino mice were weighed (25-30 g, 10 weeks old), grouped into A, B, C, D, E, and F with five animals each. Group A animals served as control and received distilled water, while groups B, C, D, E and F were orally administered 500, 1000, 1500, 2000, and 2500 mg/kg body weight of SSAE in distilled water, respectively, using orogastric tubes. The animals were observed at 2, 6, 24 and 48 hr after extract administration to detect changes in autonomic or behavioral responses. Mortality was observed for 24 hrs<sup>(11)</sup>.

### Effect of aqueous extract in normoglycemic rats

The rats were divided into four groups of 6 animals (n=6) each. Group I served as control and received distilled water. Group II served as standard control, received glibenclamide (0.25 mg/kg b.w.). Group III and IV received 250 and 500 mg/kg SSAE orally. Blood glucose levels were determined at 0, 1, 2, 3 and 4 hr following treatment by retro-orbital plexus of the eye under mild ether anesthesia.

### Effect of aqueous extract on oral glucose tolerance test in STZ-induced diabetic rats (OGTT)

The rats were divided into five groups of 6 animals (n=6) each. Group I served as control and received distilled water. Group II served as diabetic control and received distilled water. Group III served as positive control, received glibenclamide (0.25 mg/kg b.w.). Group IV and V received 250 and 500 mg/kg SSAE orally. All the animals were given glucose (2 g/kg) 30 min after dosing. Blood samples were collected from the retro-orbital plexus of the eye just prior (0 hr) and 30, 60, 90, and 120 min. After the glucose loading, blood glucose levels were estimated.

### Evaluation of antidiabetic activity

**Induction of diabetes:** Diabetes was induced in rats by single intra peritoneal (*i.p.*) injection

of streptozotocin (STZ, Sigma chemical Co. USA) at a dose 60 mg/kg b.w. freshly dissolved in 0.1 M cold citrate buffer of pH 4.5; 48 hr later blood samples were collected and blood glucose levels were determined to confirm the development of diabetes. Those animals which showed hyperglycemia (blood glucose levels >240 mg/dl) were used in experiment<sup>(12)</sup>.

#### **Chronic treatment model**

The rats were divided into five groups of 6 animals (n=6) each as below:

Group I- Normal control (received distilled water 10 ml/kg b.w., p.o.)

Group II- Diabetic control untreated (received distilled water 10 ml/kg b.w., p.o.)

Group III- Diabetic treated with standard drug glibenclamide (0.25 mg/kg/day, p.o.)

Group IV- Diabetic treated with SSAE (250 mg/kg/day, p.o.)

Group V- Diabetic treated with SSAE (500 mg/kg/day, p.o.)

For 30 days blood glucose levels and body weights were measured on 1<sup>st</sup>, 10<sup>th</sup>, 20<sup>th</sup> and 30<sup>th</sup> day of the study. Finally on day 30, blood was collected to estimate various parameters<sup>(13)</sup>.

#### **Estimation of plasma glucose, body weight and lipid profile**

Every week, following overnight fasting (16 hr fasting with free access to water), the blood samples were withdrawn from the animals by retro-orbital puncture under light ether anesthesia.

The plasma glucose estimation was done by the glucose oxidase/peroxidase (GOD/POD)<sup>(14)</sup> method using a standard kit obtained from Span Diagnostics, India. Body weight of all experimental animals was recorded using a digital weighing scale. The TG, TC and HDL levels were estimated<sup>(15)</sup> using standard kits obtained from Span Diagnostics, India

VLDL = TG/5

LDL = TC - (HDL + VLDL)<sup>(16-18)</sup>

#### **Estimation of serum insulin**

Serum insulin concentration was determined by radioimmunoassay kit done spectrophotometrically using standard kits (RIA kit

provided by BRIT, BARC, India), The kit included human insulin as standard and 125I-labelled human insulin antibody, which cross-reacts similarly with rat insulin.

#### **Estimation of glycated hemoglobin**

After 30 days experimental period, the 12hr fasted rats were sacrificed by cervical decapitation, blood was withdrawn by retro orbital puncture under light ether anesthesia and the glycated hemoglobin was estimated<sup>(19)</sup>.

#### **Estimation of liver glycogen**

After 30 days experimental period, the 12hr fasted rats were sacrificed by cervical decapitation. The liver tissue (1 g) was collected, placed in a centrifuge tube containing 2 ml of KOH (300 g/L) after washing with saline water and heated for 20 min with occasional shaking. To this, a saturated solution of sodium sulphate (0.2 ml) was added and mixed thoroughly. The glycogen was precipitated by the addition of ethanol (5 ml).

The precipitate was removed and dissolved in 10 ml of water. One ml of this solution was added to 1 ml of HCl (1.2 mol/l) and boiled for 2 hr. After 2 hr, the solutions were neutralized by NaOH (0.5 mol/l) using phenol red as indicator. The neutralized solution was diluted to 5 ml and transferred to a calorimeter tube and read at 620 nm after adjusting the calorimeter with the reagent blank. The glycogen content was expressed as mg/g of liver tissue<sup>(20,21)</sup>.

#### **Statistical analysis**

The results were expressed as mean± S.E.M. Statistical difference was tested by using one-way analysis of variance (ANOVA) followed by Dunnett's multiple comparison test. A difference in the mean p value <0.05 was considered as statistically significant.

## **Results**

#### **Preliminary phytochemical screening**

Preliminary phytochemical screening revealed the presence of triterpenoids, carbohydrates, vitamins, amino acids, proteins, tannins, saponin glycosides and steroids.

**Acute toxicity study**

In the LD<sub>50</sub> value determination, we observed that the SSAE was safe to use in animals and showed no mortality on 2500 mg/kg b.w. Therefore 2500 mg/kg dose was considered as a safe dose, 1/5th (500 mg/kg b.w.) and 1/10th (250 mg/kg b. mg/kg b.w.) of that was selected for all *in vivo* experiments as maximal dose.

**Effect of aqueous extract in normoglycemic rats**

The results from the study clearly indicated that there was no significant effect observed on normoglycemic rats when treated with the single dose of *Sesbania sesban* aqueous extract (Table 1).

**Effect of aqueous extract on oral glucose tolerance test in STZ-induced diabetic rats (OGTT)**

The results from the study clearly indicated that the aqueous extract of *Sesbania sesban* leaves at 250 and 500 mg/kg reduced the blood glucose level (hyperglycemia due to glucose load 2 g/kg *p.o.*) significantly and glibenclamide (0.25 mg/kg) after 60 min of oral administration, when compared to diabetic control (Table 2).

**Hypoglycemic effect of the aqueous extract**

The results from the study clearly indicated that the aqueous extract exhibited significant hypoglycemic activity in STZ-induced diabetic rats, whilst there was no significant effect observed on normoglycemic rats. However, at the end of 30 days of treatment, there was a 70.12 %, 64.96% and 68.09% ( $p < 0.01$ ) decrease of serum glucose levels with the glibenclamide and aqueous extract (250 and 500 mg/kg) respectively when compared with diabetic control after 30 days (Table 3).

**Changes in body weight**

At the end of 30 days treatment, the body weight of normal rats, aqueous extract and standard drug treated group increased significantly; whereas body weight of diabetic control group decreased (Table 4).

**Changes of serum insulin, liver glycogen and glycosylated hemoglobin**

After 30 days treatment period it was observed that animals treated with aqueous extract showed a significant increase in the serum insulin level, liver glycogen level and decrease in glycosylated hemoglobin level as

Table 1. Effect of aqueous extract of *Sesbania sesban* leaves in normoglycemic rats

Group treatment (n=6)	Fasting plasma glucose level (mg/dl) at (hrs)				
	0	1	2	3	4
I Normal	95.00±0.73	94.16±0.65	92.50±1.05	91.83±1.07	91.33±0.49
II Glibenclamide	95.16±0.70	92.50±0.67	89.16 ±0.47*	88.50±0.67*	85.33±0.95**
III Aqueous extract	95.66±1.05	94.16±0.60	90.00±0.57	89.33±0.33	88.50±0.42*
IV Aqueous extract	94.83±1.01	93.83±0.79	90.66±0.91	89.83±0.70	88.62±0.42*

\*  $p < 0.05$ , \*\* $p < 0.01$ , Values are mean±SEM, n=6, when compared with normal by using one way ANOVA followed by Dunnet's multiple comparison test

Table 2. Effect of aqueous extract of *Sesbania sesban* leaves on OGTT in stz-induced diabetic rats

Group treatment (n=6)	Fasting plasma glucose level (mg/dl) at (hrs)				
	0	1	2	3	4
I Normal	95.00±0.73	123.17±2.72	134.83±1.35	144.83±1.35	154.83±1.35
II Diabetic control	259.17±1.16	269.50±0.95	279.50 ±0.95	289.50±0.95	297.83±0.83
III Positive control	255.17±1.01	265.17±1.01*	275.17±1.01*	285.17±1.01*	265.00±1.15**
IV Aqueous extract	259.67±1.02	266.33±1.30	276.33±1.30	286.33±1.30	274.67±1.17*
V Aqueous extract	258.50±2.04	265.17±1.13*	275.37±1.13*	285.47±1.13*	265.17±1.13**

\*  $p < 0.05$ , \*\* $p < 0.01$ , Values are mean±SEM, n=6, when compared with diabetic control by using one way ANOVA followed by Dunnet's multiple comparison test

compared to serum insulin levels in normal groups (Table 5).

### Lipid profile

Lipid profile of animals treated with aqueous extract showed significant reductions ( $p < 0.01$ ) of 19.06% and 25.70% CHL (cholesterol), 50.34% and 60.44% LDL, 15.79% and 13.53% VLDL (Very Low density lipoproteins) and 27.84% and 32.21% TG after treatment with aqueous extract of *Sesbania sesban* leaves (250 and 500 mg/kg), respectively when compared with diabetic control rats. Also there was a significant ( $p < 0.05$ ) increase of HDL in the treated diabetic rats. In case of untreated diabetic rats, there was a fall in HDL level (Table 6).

### Discussion

The present study was undertaken to evaluate the antidiabetic activity of aqueous leaves extract of *Sesbania sesban* (L) Merr. in normal, glucose-loaded hyperglycemic and STZ-induced diabetic rats. There was no lethality or no toxic reactions were found with the selected doses until the end of study period. The results of the study have shown that the aqueous extract of leaves at dose 500 mg/kg has a marked hypoglycemic activity by improvement of the glucose tolerance test in normoglycemic rats and by lowering the blood glucose levels in STZ-induced diabetic rats. The results of the study have shown a significant ( $p < 0.01$ ) difference between the initial and

Table 3. Effect of aqueous extract of *Sesbania sesban* leaves on serum glucose level

Group treatment (n=6)	Fasting plasma glucose level (mg/dl)			
	1 <sup>st</sup> day	10 <sup>th</sup> day	20 <sup>th</sup> day	30 <sup>th</sup> day
I Normal control	94.50±2.07	94.33±2.10	96.33±1.89	95.16±2.02
II Diabetic control	255.00±1.18	286.67±1.22	312.67±4.58	387.67±2.83
III Diabetic + glibenclamide (0.25 mg/kg)	255.67±1.33	265.67±1.33**	210.67±2.84**	115.83±1.53**
IV Diabetic + aqueous extract (250 mg/kg)	255.83±0.79	275.83±0.79**	235.83±0.79**	135.83±0.79**
V Diabetic + aqueous extract (500 mg/kg)	256.33±2.65	268.67±1.02**	223.67±2.01**	123.67±2.01**

\*  $p < 0.05$ , \*\* $p < 0.01$ , Values are mean±SEM, n=6, when compared with diabetic control by using one way ANOVA followed by Dunnett's multiple comparison test

Table 4. Effect of aqueous extract of *Sesbania sesban* leaves on body weight in stz-induced diabetic rats

Group treatment (n=6)	Changes in body weight (g) at (days)			
	0	10	20	30
I Normal	155.67±0.76	166.33±0.91	172.00±0.91	185.33±0.87
II Diabetic control	158.17±0.70	153.50±0.56	148.67±0.66	139.00±0.77
III Positive control	158.00±0.77	161.50±1.05**	163.33±0.80**	168.33±1.35**
IV Aqueous extract	163.33±5.04	166.83±0.94**	168.50±0.34**	175.17±1.37**
V Aqueous extract	158.67±0.49	165.33±1.70**	167.33±0.55**	173.50±1.14**

\*  $p < 0.05$ , \*\* $p < 0.01$ , Values are mean±SEM, n=6, when compared with normal by using one way ANOVA followed by Dunnett's multiple comparison test

Table 5. Effect of aqueous extract of *Sesbania sesban* leaves on serum parameters after 30 days

Group treatment (n=6)	Serum insulin $\mu\text{U/ml}$	Glycosylated hemoglobin mg/g Hb	Liver glycogen mg/g
II Diabetic control	7.13±0.31	0.58±0.009	7.16±0.60
III Diabetic + glibenclamide (0.25 mg/kg)	16.66±0.33**	0.25±0.007**	13.00±0.25**
IV Diabetic + aqueous extract (250 mg/kg)	13.33±0.33**	0.27±0.006**	11.41±0.37**
V Diabetic + aqueous extract (500 mg/kg)	15.33±0.33**	0.31±0.004**	12.58±0.23**

\* $p < 0.05$ , \*\* $p < 0.01$ , Values are mean±SEM, n=6, when compared with diabetic control by using one way ANOVA followed by Dunnett's multiple comparison test

Table 6. Effect of aqueous extract of *Sesbania sesban* leaves on serum lipid profile after 30 days

Group	Cholesterol	LDL	HDL	VLDL	Triglycerides
Normal control	66.16±0.83	22.83±0.87	11.00±0.36	17.33±0.66	66.50±0.76
Diabetic control	95.33±0.71	97.33±0.49	9.83±0.30	22.16±0.30	114.33±1.47
Diabetic+glibenclamide (0.25 mg/kg)	69.66±0.66**	36.00±0.73**	13.83±0.47**	18.16±0.30**	76.50±0.76**
Diabetic+aqueous extract (250 mg/kg)	77.16±0.60**	48.33±0.42**	13.83±0.40**	18.66±0.21**	82.50±0.99**
Diabetic+aqueousextract (500 mg/kg)	70.83±0.60**	38.50±0.76**	14.83±0.30**	19.16±0.16**	77.50±0.84**

\*p<0.05, \*\*p<0.01, Values are mean±SEM, n=6, when compared with diabetic control by using one way ANOVA followed by Dunnette's multiple comparison test

final fasting plasma glucose levels of aqueous leaves extract of *Sesbania sesban* and glibenclamide treated groups (Table 3). Induction of diabetes by STZ leads to loss of body weight due to increased muscle wasting and loss of tissue proteins<sup>(14,15)</sup>. The results obtained with the aqueous extract treatment in chronic diabetic model further clarified the antidiabetic effect of the extract. After 30 days of aqueous extract treatment, gain in body weight was observed in diabetic rats and the results were comparable with that of the standard drug glibenclamide.

Aqueous extract of *Sesbania sesban* showed significant increase in serum insulin level. A marked decrease in triglycerides, total cholesterol, LDL and VLDL was observed, while increase in HDL cholesterol has been observed in aqueous leaves extract treated diabetic rats, which suggest that HDL is inversely related to the total body cholesterol (Table 4)<sup>(19)</sup>. The possible mechanism of antidiabetic action of aqueous extract may be by increasing the pancreatic secretion of insulin from the existing beta cells, by its release from the bound form.

Animals treated with aqueous extract indicated a significant decrease in the glycosylated hemoglobin level which could be due to an improvement in insulin secretion, whereas glycosylated hemoglobin level increased significant in untreated diabetic control group, which confirm the antidiabetic action of the extract<sup>(22)</sup>. The significant increase was observed in glycogen levels of the aqueous leaves extract treated diabetic rats. The extract did not produce any significant effects on normal animals (Table 6).

## Conclusion

In conclusion, it can be stated that the aqueous leaves extract of *Sesbania sesban* has beneficial effects in reducing the elevated blood glucose level and lipid profile of STZ-induced diabetic rats, but has no effect on normal rats. Thus justifying the claim made by ayurvedic classics.

## Acknowledgement

The authors sincerely thank to Principal, Dr. V.K. Deshmukh M.E.S. College of Pharmacy, Prashant Patil Gadakh Secretary, Mula Education Society, Sonai and Department of Pharmacy, Suresh Gyan Vihar University, Jaipur, Rajasthan, India for encouragement and availing of the laboratory facilities during the course of investigation.

## References

- Aslan M, Orhan DD, Orhan N, Sezik E, Yesilada E. In vivo antidiabetic and antioxidant potential of *Helichrysum plicatum* ssp. *plicatum* capitulum in Streptozotocin-induced-diabetic rats. *J Ethnopharmacol* 2007;109(1):54-59.
- Khare CP. *Indian Medicinal Plants-An Illustrated Dictionary*. Berlin: Springer-Verlag; 2007.
- Yusuf M, Chowdhury JU, Wahab MA, Begum J. *Medicinal Plants of Bangladesh*, BCSIR. Dhaka, Bangladesh: Bangladesh Council of Scientific and Industrial Research; 1994.
- Chapman & Hall. *Dictionary of Natural Products*. London: Taylor and Francis. 2002.
- Gupta AK, Grasdalen H. Nmr studies of composition and side-chain arrangement in *Sesbania aegyptiaca* seed galactomannan. *Carbohydrate Res* 1989; 81:239-244.
- Upadhyaya JS, Singh SP. Chromatographic studies of oxidation products of lignin from *Sesbania sesban*. *Cellul Chem Technol* 1991;25:219-226.

7. El-Sayed NH. A rare kaempferol trisaccharide anti-tumor promoter from *Sesbania sesban*. *Pharmazie* 1991;46(9):679-680.
8. Jain SR. Hypoglycemic principal in the *Musa sapientum* and its isolation. *Planta Med* 1968;16(1):43-47.
9. Latha M, Pari L. Effect of an aqueous extract of *Scoparia dulcis* on blood glucose, plasma insulin and some polyol pathway enzymes in experimental rat diabetes. *Braz J Med Biol Res* 2004;37(4):577-586.
10. Kokate CK. *Practical Pharmacognosy*. 4th ed. New Delhi: Vallabh Prakashan; 1994.
11. Khandelwal KR. *Practical Pharmacognosy Techniques and Experiments*. 15th ed. Pune: Nirali Prakashany; 2000.
12. Organization for economic co-operation and development. OECD Guidelines. Guidance document on acute oral toxicity testing (2001) series on testing and assessment no. 24. OECD environment, health and safety publications. Paris, January 2007.
13. Chakrabarti S, Biswas TK, Seal T, Rokeya B, Ali L, Azad Khan AK, et al. 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* 2005;97(1):117-122.
14. Trinder P. Determination of glucose in blood using glucose oxidase with an alternative oxygen acceptor. *Ann Clin Biochem* 1969;6:24-27.
15. Yadav JP, Saini S, Kalia AN, Dangi AS. Hypoglycemic and hypolipidemic activity of ethanolic extract of *Salvadora oleoides* in normal and alloxan-induced diabetic rats. *Indian J Pharmacol* 2008;40(1):23-27.
16. Alayash AI, el-Hassan AM, Omer R, Bonaventura J. Glycosylated hemoglobin: an indicator of long-term blood glucose in domestic sheep and goats. *Comp Biochem Physiol A* 1988;90:229-231.
17. Burstein M, Scholnick HR, Morfin R. Rapid method for the isolation of lipoproteins from human serum by precipitation with polyanions. *J Lipid Res* 1970;11:583-595.
18. Friedwald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low density lipoprotein-cholesterol in plasma without the use of the preparative ultracentrifuge. *Clin Chem* 1972;18:499-502.
19. Sadasivam S, Manickam A. *Methods in Biochemistry*. 2nd ed. New Delhi: New Age International Pvt. Ltd.; 1996.
20. Seifter S, Dayton S, Novic B, Muntwyler E. The estimation of glycogen with anthrone reagent. *Arch Biochem* 1950;25:191-200.
21. Swanston-Flat SK, Day C, Bailey CJ, Flatt PR. Traditional plant treatment for diabetes: studies in normal and streptozotocin diabetic mice. *Diabetologia* 1990;33(8):462-464.
22. Chatterjee MN, Shinde R. *Textbook of Medical Biochemistry*. 5th ed. New Delhi: Jaypee Brothers Medical Publishers; 2002.
23. Reshma SP, Sushma AM. Hypolipidemic activity of *Acorus calamus* L. in rat. *Fitoterapia* 2002;73:451-455.
24. Hall PM, Cook JGH, Sheldon J, Rutherford SM, Gould BJ. Glycosylated hemoglobin and glycosylated plasma proteins in the diagnosis of diabetes mellitus and impaired glucose tolerance. *Diabetes Care* 1984;7(2):147-150.