



Hypoglycemic Activity of *Ruellia tuberosa* Linn (Acanthaceae) in Normal and Alloxan-Induced Diabetic Rabbits

Durre Shahwar^{a,*}, Saif Ullah^a, Mobasher Ahmad^b, Sami Ullah^a, Naeem Ahmad^a,
Muhammad Akmal Khan^a

^aResearch Lab-II, Department of Chemistry Government College
University Lahore 54000, Pakistan

^bUniversity College of Pharmacy University of the Punjab, Allama Iqbal
Campus Lahore 54000, Pakistan

Abstract

The present study was carried out to determine the hypoglycemic activity of the methanolic extract and solvent fractions (n-hexane and ethyl acetate) of *Ruellia tuberosa* in normal and alloxan-induced diabetic rabbits. Optimum dose of *R. tuberosa* for hypoglycemic activity was determined by oral administration of the methanolic extract (ME) to normal and diabetic rabbits. Diabetes was induced by intra-peritoneal injection of alloxan monohydrate (150 mg/kg). Hypoglycemic effect of n-hexane (HF) and ethyl acetate (EF) fractions was evaluated at a dose of 150 and 100 mg/kg b.w., respectively, in normal and diabetic rabbits. Administration of the optimum dose (500 mg/kg b.w.) of *R. tuberosa* to normal and diabetic rabbits showed significant blood glucose lowering effect. EaF (100 mg/kg) showed the highest anti-diabetic activity with 28.64±0.28% decrease in blood glucose, while HF (150 mg/kg) showed moderate anti-diabetic activity and lowered the blood glucose level around 15.17±0.58%. The results were compared with the standard drug tolbutamide (100 mg/kg). Phytochemical investigation of EF and HF indicated flavonoids and triterpenoids in the extracts, respectively. Antioxidant activity was evaluated by DPPH method and the amount of total phenols was determined by Folin-Ciocalteu method. ME extract and its fractions showed the antioxidant activity in the order of EF>ME>WF>HF. The results were in agreement with the folkloric use of *R. tuberosa* in the treatment of diabetes and related complications.

Keywords: Acanthaceae; Alloxan-monohydrate; Hypoglycemic activity; Optimum dose, *R. tuberosa*.

Received: January 29, 2011; **Accepted:** March 25, 2011

1. Introduction

Ruellia tuberosa L. (Acanthaceae) is a tropical perennial plant. It is widely distributed in south East Asia including Thailand and Laos. In folk medicines, *R. tuberosa* has been used as diuretic, anti-diabetic, antipyretic,

*Corresponding Author: Durre Shahwar; Department of Chemistry,
Government College University Lahore-54000 Pakistan.
Phone: (+92)42-111000010; Fax: (+92)42-9213341
E-mail: drdshahwar@yahoo.com,

analgesic, antihypertensive, thirst quenching and antidotal agent. Recently, it has been introduced as a component of herbal drink in Taiwan [1, 2].

Diabetes mellitus (DM) is a major endocrine disorder that is regarded as hyperglycemia [3]. Asia and Africa are the most viable areas where the disease is feared to raise 2-3 folds [4]. DM is affecting approximately 5% of the world population. Worldwide projections suggest that more than 300 million people will have diabetes by the year 2025 [5]. According to World Ethnobotanical Information of medicinal plants, almost 800 plants are used in the control of DM. However, only few of these plants have been studied [6]. Traditional medicines of plant origin play a vital role in the cure of DM [7]. World Health Organization (WHO) has also recommended the evaluation of traditional plant treatments for diabetes because they are effective, non-toxic, having less or no side effects and are considered good candidates for oral therapy [8]. In this regard, several scientists carried out experimental and clinical trials on medicinal plants and found significant anti-diabetic activity [9-13]. Literature data indicates that some of the flavonoids and triterpenes isolated from medicinal plants have significantly reduced the blood glucose level [14-17].

The objective of this study was to ascertain the scientific basis of the use of *R. tuberosa* in the treatment of diabetes. The present investigation reports the hypoglycemic activity of methanolic extract, n-hexane, ethyl acetate, and water fractions of the crude methanolic extract of *R. tuberosa*. To the best of our knowledge this is the first report of the anti-diabetic activity of this plant.

2. Material and methods

2.1. Plant material

The fresh whole plants of *R. tuberosa* were collected from University of Sargodha, Sargodha campus. The plant was identified at

the Department of Botany GC University Lahore where a voucher specimen was deposited (Voucher No. GC.Herb.Bot. 987).

2.2. Preparation and fractionation of the methanolic extract

The plant was cleaned, dried under shade, and the powdered plant material was soaked in methanol for 7 days at room temperature. The methanolic extract (ME) was filtered and evaporated using a rotary evaporator (Laborta 4000-Hedolph). The dried crude extract was dissolved in water and fractionated with n-hexane (HF) and ethyl acetate (EF). The fractions and remaining aqueous layer (WF) were concentrated under reduced pressure. The amounts of solvent fractions for oral administration were calculated from optimum dose (500 mg ME/kg b.w.).

2.3. Preparation of test samples

A weighed portion of each fraction (equivalent to 500 mg ME extract) was suspended in 0.5% aqueous carboxymethyl cellulose (CMC) solution in distilled water prior to oral administration to animals (5 ml/kg b.w.). Animals in control group received only 0.5% CMC suspension in distilled water. Tolbutamide (100 mg/kg b.w.) was used as the reference drug.

2.4. Animals

Adult normal male rabbits (*Oryctolagus cuniculus*) obtained from the animal house, University College of Pharmacy, University of the Punjab (UCP-PU) Allama Iqbal Campus Lahore, were used for the study. All of the rabbits were kept in individual metal cages located in the UCP-PU. The rabbits were allowed for one week to acclimatize in animal house of Pharmacology Department (UCP-PU). The animal experiments were preceded following the internationally accepted ethical guidelines for the care of laboratory animals. The animal house facility was maintained at standard conditions:

Table 1. Anti-diabetic effect produced by the oral administration of different doses of *R. tuberosa* methanol extract in normal and alloxan-induced diabetic rabbits.

Study	Groups	Samples	Dose (mg/kg b. w)	Mean blood glucose		
				concentration±S.E.M. (mg/dL)		% reduction
				0 h (in fasting)	4 h	
I-N	Control	0.5 % CMC	84.9±1.55	84.7±1.17	0.07±1.46	
II-N	ME Ext.	125	89.5±1.48	88.2±1.51	1.45±1.86	
III-N	ME Ext.	250	86.5±1.37	83.4*±1.60	3.62±0.56	
IV-N	ME Ext.	500	89.2±0.64	73.7***±1.17	17.33±1.53	
V-N	ME Ext.	750	86.6±1.59	73.5±1.52	15.14±1.44	
VI-N	ME Ext.	1000	86.9±1.48	73.8±0.86	15.02±0.97	
VII-N	ME Ext.	2000	93.1±1.51	79.9±1.41	14.10±0.44	
VIII-N	Tolbutamide	100	94.5±1.48	76.9±1.18	18.65±1.73	
I-D	Control	0.5 % CMC	275.3±1.96	275.4±2.46	0.02±0.94	
II-D	ME Ext.	125	269.4±1.95	262.6** ±2.21	2.52±0.39	
III-D	ME Ext.	250	268.0±2.33	258.5** ±3.28	3.56±0.60	
IV-D	ME Ext.	500	279.1±1.56	226.0*** ±1.36	19.03±0.68	
V-D	ME Ext.	750	272.9±2.27	226.6±0.94	16.96±0.52	
VI-D	ME Ext.	1000	276.7±2.15	229.0±1.24	17.21±0.80	
VII-D	ME Ext.	2000	273.2±1.32	230.6±1.09	15.59±0.29	
VIII-D	Tolbutamide	100	270.0±0.81	214.5±1.52	20.57±0.56	

ME Ext: Methanol extract; N: normal; D:diabetic; n=6; Values are mean ± S.E.M.; * $p < 0.05$ significant from normal control; ** $p < 0.025$ significant from diabetic control; ***Optimum dose ($p < 0.005$).

temperature (28 ± 2 °C), relative humidity ($50 \pm 5\%$) and a 12 h light/dark cycle. They were fed with standard diet and water ad libitum. Prior the experiments, they were fasted over night but allowed free access to water.

2.5. Collection and processing of blood for estimation of glucose

Blood glucose concentration (mg/dL) of overnight fasted animals was determined using standard kit (Randox UK) based on glucose oxidase method using a UV-visible spectrophotometer at 546 nm. Blood samples were collected from the marginal ear vein just prior to and 4 h after dosing. Serum was separated by centrifuging the samples at 5000 rpm for 10 min [18].

2.6. Induction of diabetes

Diabetes was induced in rabbits by intraperitoneal injection of alloxan monohydrate at a dose of 150 mg/kg b.w. dissolved in normal saline [19]. Seven days after injection, the rabbits were confirmed as

diabetic rabbits with blood glucose ≥ 250 mg/dL were selected for the experiments. The results are presented in Table 1.

2.7. Determination of optimum dose

To find out the optimum dose of methanol extract of *R. tuberosa*, eight groups (I-N to VIII-N; N: normal) comprising of six rabbits each were used. The animals were fasted for 8 h before the experiments. Group I-N animals received 0.5% CMC in distilled water and served as control. After collecting the blood samples at zero h, various doses (125, 250, 500, 750, 1000 and 2000 mg/kg b.w.) of the ME extract of *R. tuberosa* were administered orally to the animals of group II-N to VII-N, respectively. Blood samples were collected for the estimation of glucose concentration from the marginal ear vein of the rabbits after 4 h of the drug (ME extract) administration [20]. Results were compared with tolbutamide which was administered orally to animals of group VIII-N (reference) at a dose of 100 mg/kg b.w.

Diabetic animals were similarly divided

Table 2. Effects of methanolic extract, n-hexane, ethyl acetate and water fractions of *R. tuberosa* on blood glucose level in normal and alloxan-induced diabetic rabbits.

Test Samples	Dose (mg/kg b. w)	Mean blood glucose concentration±S.E.M.			Mean blood glucose concentration±S.E.M.		
		(mg/dL) in normal animals			(mg/dL) in diabetic animals		
		0 h	4 h	% reduction	0 h	4 h	% reduction
Control	0.5 %	94.3±0.60	93.8±0.49	0.57±0.53	277.3±1.38	277.2±1.25	0.03±0.53
ME Ext.	CMC	89.2±0.64	73.7±1.17*	17.33±1.53	279.1±1.56	226.0±1.36**	19.03±1.53
HF	500	88.3±0.88	81.5±0.38*	7.58±1.04	274.0±1.71	232.4±2.08**	15.17±0.58
EF	150***	105.1±0.98	87.5±0.84*	16.70±0.73	266.0±1.66	189.8±1.80**	28.64±0.28
WF	100***	89.9±1.34	90.2±0.34	1.04±0.96	269.8±2.70	266.5±1.63	1.20±0.41
Tolbutamide	275***	100.7±4.12	68.3±1.93*	31.70±2.92	289.8±2.20	190.4±1.60**	34.31±0.39
	100						

n = 6; Values are mean±S.E.M; ME Ext: methanol extract; HF: n-hexane fraction, EF: ethyl acetate fraction, WF: water fraction. The doses selected for various fractions are based on their relative amounts present in 500 mg ME extract (500 mg/kg b. w of ME extract is the optimum dose); * $p < 0.005$ significant from normal control; ** $p < 0.005$ significant from diabetic control; *** ≈ 500 mg/kg b. w of ME Extract.

into eight groups (I-D to VIII-D; D: diabetic) of six animals each. Different doses (125, 250, 500, 750, 1000 and 2000 mg/kg b.w.) of ME extract were administered to animals of group II-D to VII-D while group I-D served as control. Tolbutamide was administered to group VIII-D at a dose of 100 mg/kg b.w.

2.8. Hypoglycemic effect of fractions of *R. tuberosa*

Fasted normal rabbits were divided into five groups (IX-N, X-N, XI-N, XII-N and XIII-N; N: normal; six animals in each group). The IX-N group (normal control) received only 0.5% CMC (10 mL/kg b.w.) and served as control. Various fractions (HF, EF and WF) suspended in CMC were administered orally at the dose of 150, 100 and 275 mg/kg b.w. in a volume of 10 mL/kg to the animals of group X-N, XI-N and XII-N, respectively. The doses selected for various fractions are based on their relative amounts present in 500 mg ME; 500 mg/kg b.w. of ME is the optimum dose. Group XIII-N received tolbutamide (100 mg/kg b.w.) as the reference drug suspended in 0.5% CMC.

Similarly, the overnight fasted alloxan-induced diabetic rabbits were divided into

five groups (IX-D, X-D, XI-D, XII-D and XIII-D; D: diabetic) of six rabbits each. Group IX-D (diabetic control) received vehicle (0.5% CMC). Doses of 150, 100 and 275 mg/kg b.w. of HF, EF and WF, respectively, were given orally to group X-D, XI-D and XII-D. Group XIII-D received tolbutamide as the reference drug (100 mg/kg b.w.) suspended in vehicle (10 mL/kg b.w.).

2.9. Toxicity evaluation in rabbits

The methanol extract was tested for its acute toxicity (if any) in rabbits. To study the acute toxicity, six groups of animals (3 animals in each group) were taken. Different doses (100, 500, 1000, 3000, and 5000 mg/kg b.w.) of the extract were orally administered to the overnight starved rabbits of group T1-T5. The control group (T6) was given only CMC. After the administration of extract, the rabbits were observed for gross behavioral, neurological, autonomic and toxic effects continuously for 2 h and then at 6 h interval up to three days and daily up to two weeks.

2.10. Phytochemical studies

Phytochemical study of the various solvent fractions was carried out to determine the

Table 3. Antioxidant activity and total phenolic content of extract/fractions of *R. tuberosa*.

Samples	DPPH• scavenging assay		Total phenolics (mg GAE/g)**
	% Inhibition (at 100 µg/mL)	IC ₅₀ (µg/mL)*	
ME ext	41.6±1.13.	233.5±3.39	544.49±14.28
HF	30.9±3.81	1956.6±26.94	188.04±11.28
EF	64.8±0.53	51.0±3.22	763.46±12.77
WF	18.5±4.17	513.3±25.04	385.82±9.64
BHT	76.2±0.41	11.2±0.53	-

Values are mean±S.E.M, ME: methanol, HF: n-hexane fraction, EF: ethyl acetate fraction, WF: water fraction and BHT: butylated hydroxytoluene.;*The antioxidant activity was evaluated as the concentration of the test sample required to decrease the absorbance at 517 nm be 50 %in comparison to the control response.; ** Total phenolic content is expressed as gallic acid equivalents (GAE; mg gallic acid/g of extract).

presence of alkaloids, flavonoids, triterpenoids, sterols and phenolics.

2.11. Antioxidant activity

Antioxidant activity of the extract/fractions was analyzed using DPPH assay [1]. 2.0 mL of DPPH (0.2 mg/mL in methanol) was mixed with 1.0 mL sample solution (0.5 mg/mL in methanol). Reduction in the concentration of free radicals was monitored at 517 nm using UV-Visible spectrophotometer. Absorbance of blank sample containing 1.0 mL of methanol and 2.0 mL DPPH solution was also measured. Percent inhibition was calculated by the following formula:

$$\text{Inhibition\%} = [(A_B - A_A) / A_B] \times 100$$

Where A_B = Absorbance of blank sample

A_A = Absorbance of fraction (test sample)

Standard antioxidant butylated hydroxytoluene (BHT) was tested and used as reference. The sample solutions having >50 % inhibition were diluted in series to get concentration 0.1-1.0 mg/mL and the percentage of inhibition was calculated. A plot of inhibition% of DPPH against concentration of the various fractions of *R. tuberosa* was used to determine IC₅₀ values.

2.12. Determination of total phenols

Total phenols were determined by the method of Djeridane [21]. Equal to 0.1 mL of each test sample (0.5 mg/mL) was mixed with 0.1 mL of Folin-Ciocalteu reagent. After 1 min, 2.8 mL of 10% sodium bicarbonate solution was added and the mixture was allowed to stand for 30 min. Absorbance was

measured at 725 nm spectrophotometrically. Gallic acid (0.05-0.5 mg/mL) was used to establish standard calibration curve. The mean of three readings was used and the total phenolic contents were expressed as milligrams of gallic acid equivalent/g dry weight of the extract. The coefficient of determination was $R^2 = 0.9946$.

2.13. Statistical analysis

All the data was expressed as mean±SEM for six rabbits in each group. The significance of blood glucose reduction produced by the ME extract and its various fractions was determined by applying student's unpaired 't' test [18].

3. Results

Methodology of Kato [22] was adopted for the hypoglycemic activity of various fractions with slight modification in time pattern for blood glucose level determination. Test samples (ME extract, HF, EF and WF of *R. tuberosa* and tolbutamide) were given immediately after the collection of initial blood samples. The blood glucose levels of normal and diabetic animals were determined at 0 h and 4 h after the oral administration of various fractions of *R. tuberosa* [18].

ME extract of *R. tuberosa* was fractionated to obtain HF, EF and WF in 26.44%, 16.38% and 55.12% yields, respectively. Phytochemical studies of HF and EF indicated the presence of triterpenoids and flavonoids, respectively. WF showed the presence of polyphenols.

3.1. Acute toxicity study

The ME extract of *R. tuberosa* was subjected to acute toxicity study up to a dose of 5000 mg/kg b.w. which indicated non-toxic nature of the extract. No gross behavioral changes were observed at any of the doses selected until the end of the study period.

3.2. Hypoglycemic study

3.2.1. Determination of optimum dose of *R. tuberosa*

The effects of ME extract *R. tuberosa* on blood glucose level of fasting normal and alloxan-induced diabetic rabbits is shown in Table 1. Optimum activity was observed at 500 mg/kg b.w. level in normal animals. Minimum dose (125 mg/kg b.w.) did not show any blood glucose lowering activity. Fasting blood glucose (FBG) decreased to 73.7±1.2 mg/dL ($p<0.05$) after 4 h of the drug (500 mg/kg b.w.) administration from an initial value of 89.2±0.64 mg/dL. A dose-dependent effect was observed on FBG upto a dose of 500 mg/kg b.w. Tolbutamide (100 mg/kg b.w.) caused a marked decrease in FBG (glucose concentration from 94.5±1.5 to 76.9±1.2 mg/dL; 18.65±1.73% decrease) in the animals.

A dose-dependent effect was also observed in diabetic animals upto a dose of 500 mg/kg b.w. which decreased the glucose concentration to 226.0±1.4 mg/dL from an initial level of 279.1±1.6 mg/dL (19.03±0.68% reduction; $p<0.005$). Tolbutamide showed a significant anti-diabetic activity at a dose of 100 mg/kg b.w. in alloxan-induced diabetic rabbits.

3.2.2. Effect of *R. tuberosa* fractions on blood glucose level

The effect of *R. tuberosa* solvent fractions on the blood glucose level of normal and alloxan-induced diabetic rabbits is shown in Table 2.

Normal control group showed no

statistically significant hypoglycemic activity ($p>0.2$ at 4 h). EF and HF of *R. tuberosa* produced a significant hypoglycemia in normal rabbits. EF and HF significantly decreased the blood glucose level at 4th h (16.70±0.73% and 7.58±1.04%) respectively in normal animals which is comparable with the standard drug tolbutamide.

The results of the effect of *R. tuberosa* fractions on blood glucose of alloxan-induced diabetic rabbits are shown in Table 2. The HF showed moderate reduction of blood glucose level to 15.17±0.58 % after 4 h in diabetic rabbits while the effect of EF (100 mg/kg b.w.) is higher with reduction in blood glucose level of 28.64±0.28% after 4 h of drug administration. WF showed no blood glucose lowering activity ($p>0.1$) in normal as well as alloxan-induced diabetic animals.

3.3. Antioxidant activity

Table 3 describes the results of antioxidant activity of ME extract and various solvent fractions of *R. tuberosa*. IC₅₀ values ranged from 51.0±3.2 to 1956.6±26.9 µg/mL. Highest DPPH radical scavenging activity was observed in EF with lowest IC₅₀ 51.0 µg/mL followed by ME extract (IC₅₀: 233.5±3.4 µg/mL). Higher antioxidant activity of EF than ME can be attributed to the increase in the concentration of active components through condensation effects during the solvent-solvent partitioning processes [1].

3.4. Total Phenols

Total phenolic contents of the crude ME extract and solvent fractions of *R. tuberosa* are shown in Table 3. The total phenolic content varied in different fractions and ranged from 188.04±11.28 to 763.46±12.77 mg GAE/g of dry extract. EF showed the highest amount of total phenol (763.46±12.77) followed by ME extract (544.49±14.28) as shown in Table 3.

4. Discussion

Diabetes mellitus (DM) is probably the world's largest growing metabolic disease

which has been identified as a heterogeneous disease [23]. Diabetic complications have been controlled world wide by the use of traditional plant medicines. Drugs which are obtained from natural sources corresponded to 78 % of new drugs approved by Food and Drug Administration (FDA) between 1983 & 1994 [24]. Furthermore, the limitations of currently available pharmacological agents for control of hypoglycemia have stimulated research on novel anti-diabetic agents with different mechanism of action [25]. The present study is a preliminary intent to validate the use of *R. tuberosa* to control DM. Our results revealed that *R. tuberosa* has significant blood glucose lowering effect in normal and alloxan-induced diabetic rabbits. Among the extract/fractions of *R. tuberosa*, ME extract (500 mg/kg b.w.), EF (100 mg/kg b.w.) showed a significant hypoglycemic effect, while HF (150 mg/kg b.w.) exhibited moderate activity after 4 h of the administration. In the present work normal and alloxan-induced diabetic rabbits were used. HF exhibited $7.58 \pm 1.04\%$ reduction of blood glucose level in normal, while $15.17 \pm 0.58\%$ reduction in diabetic animals. Similarly EF showed 16.70 ± 0.73 and $28.64 \pm 0.28\%$ blood glucose reduction in normal and alloxan-induced diabetic rabbits, respectively. The results showed that HF and EF can effectively control diabetic conditions. Alloxan causes hyperglycemia by destroying pancreatic β -cells selectively, mediated by the generation of cytotoxic free radicals [26, 27]. Furthermore, diabetes-induced oxidative stress due to increased reactive oxygen species enhances complications in diabetes [28]. Therefore, it has been suggested that a variety of antioxidants may prevent diabetic complications. Traditional use of *R. tuberosa* in herbal drink is attributed to its antioxidant activity. The results of antioxidant activity of the extract and solvent fractions of *R. tuberosa* demonstrated strong antioxidant activity in the EF with IC₅₀ 51.0 ± 3.22

$\mu\text{g/mL}$, which is in agreement with the literature [1].

Flavonoids constitute one of the well known and wide spread groups of phenolics in higher plants [29]. Several flavonoids; apigenin, luteolin, 3, 5-diglucoside, apigenin 7-O-glucuronide, apigenin glucoside, apigenin rutinoside, luteolin glucoside, pedalitin, flavone glycoside, cirsimaritin, cirsimarin, cirsiol 4'-glucoside, sorbifolin and pedalitin are reported in *R. tuberosa* [2, 30, 31]. Among possible mechanisms to lower blood glucose level, *R. tuberosa* might act by quenching of free radicals in the body and to improve the metabolic disorder which can be attributed to the presence of flavonoids in the EF. Thus, it can be proposed that the flavonoids of *R. tuberosa* play a vital role in the reduction of blood glucose level both in normal as well as in diabetic rabbits.

HF of *R. tuberosa* exhibited reduction in blood glucose level after 4 h of the drug administration. Phytochemical analysis of the n-hexane fraction indicated the presence of sitosterols which has been reported to have anti-diabetic effect and work like sulphonyl urea medicine [32-34]. The hypoglycemic effect of the ME extract could possibly be related to its composition. Thus the significant anti-diabetic effect of *R. tuberosa* may be due to the presence of more than one hypoglycemic principle and their synergetic properties.

5. Conclusion

In conclusion, we have demonstrated that the methanolic extract and solvent fractions (ethyl acetate and n-hexane) of *R. tuberosa* possess significant blood glucose lowering effect both in normoglycemic and in alloxan-induced diabetic rabbits. The present results suggest the validity of the clinical use of *R. tuberosa* in the control of diabetes mellitus. However, further comprehensive chemical and pharmacological investigations are required to isolate and evaluate the

hypoglycemic effects of the active components from *R. tuberosa*.

6. Acknowledgements

The authors wish to thank the Principal, Prof. Dr. Mohammad Jamshaid (University College of Pharmacy, University of the Punjab Lahore) for providing animal house facility along with other necessary laboratory facilities and Dr. Zaheer-ud-Din Khan (Department of Botany, GC University Lahore) for the identification of plant material. We are also very grateful to “Higher Education Commission Islamabad” who financially supported this work.

References

- [1] Fu-An C, An-Bang W, Pochuen S, Daih-Huang K, Chi-Ying H. Evaluation of the antioxidant activity of *Ruellia tuberosa*. *Food Chem* 2006; 97: 654-60.
- [2] Chwan-Fwu L, Yu-Ling H, Lee-Ying C, Shuenn-Jyi S, Chien-Chih C. Bioactive flavonoids from *Ruellia tuberosa*. *J Chinese Med* 2006; 17: 103-9.
- [3] Chandra A, Singh RK, Singh VK, Tewari L, Mahdi AA. Antioxidative potential of herbal hypoglycemic agents in diabetes: an overview. *SFRR-India Bulletin* 2004; 3: 24-6.
- [4] Shabeer J, Srivastava RS, Singh SK. Antidiabetic and antioxidant effect of various fractions of *Phyllanthus simplex* in alloxan diabetic rats. *J Ethnopharmacol* 2009; 124: 34-8.
- [5] Anders G, Niels CH, Stig KP. The changing world demography of type 2 diabetes. *Diabetes Metabol Res Rev* 2002; 19: 3-7.
- [6] Alarcon-Aguilara FJ, Roman-Ramos R, Perez-Gutierrez S, Aguilar-Contreras A, Contreras-Weber CC, Flores-Saenz. L. Study of the anti-hyperglycemic effect of plants used as antidiabetics. *J Ethnopharmacol* 1998; 61: 101-10.
- [7] Ahmed I, Adeghate E, Cummings E, Sharma AK, Singh J. Beneficial effects and mechanism of action of *Momordica charantia* juice in the treatment of streptozotocin-induced diabetes mellitus in rat. *Molecular Cell Biochem* 2004; 261: 63-70.
- [8] Caroline D. Invited commentary: traditional plant treatments for diabetes mellitus: pharmaceutical foods. *Brit J Nutr* 1998; 80: 5-6.
- [9] Rao BK, Kesavulu MM, Grri RAC. Antidiabetic and hypolipidemic effects of *Momordica cymbalaua* hook fruit power in alloxan diabetic rats. *J Ethnopharmacol* 1999; 67: 103-9.
- [10] Marles RJ, Franswoth NR. Antidiabetic plants and their active constituents. *Phytomedicine* 1995; 2: 137-89.
- [11] Kesari AN, Gupta RK, Singh SK, Diwakar S, Watal G. Hypoglycemic and antihyperglycemic activity of *Aegle marmalos* seed extracts in normal and diabetic rats. *J Ethnopharmacol* 2006; 107: 374-9.
- [12] Kesari AN, Kesari S, Singh .K, Gupta RK, Watal G. Studies on the glyceemic and lipidemic effect of *Murraya koenigii* in experimental animals. *J Ethnopharmacol* 2007; 112: 305-11.
- [13] Mankil J, Moonsoo P, Hyun CL, Yoon-Ho K, Eun SK, Sang KK. Antidiabetic agents from medicinal plants. *Curr Med Chem* 2006; 13: 1203-18.
- [14] Korec R, Heinz SK, Zoukas R. Effect of neoflavonoides coutareagenin, one of the anti-diabetic substances of *Hintonialatiflora* on streptozotocin-induced diabetes mellitus in rats. *Arzneimittel-Forsch* 2000; 50: 122-8.
- [15] Prez RM, Cervantes H, Zavala MA, Sanchez J, Perez S, Pere C. Isolation and hypoglycemic activity of 5, 7, 3'-trihydroxy-3, 6, 4'-trimethoxy flavone from *Brickellia veronicaefolia*. *Phytomedicine* 2000; 7: 25-9.
- [16] Tommasi DN, Simone DF, Cirino G, Cicala C, Pizza C. Hypoglycemic Effects of sesquiterpene glycosides and polyhydroxylated triterpenoids of *Eriobotrya japonica*. *Planta Medica* 1991; 57: 414-6.
- [17] Prez GRM, Varagas SR. Triterpenes from *Agarista mexicana* as poterntial antidiabeitic agents. *Phytother Res* 2002; 16: 55-8.
- [18] Sushruta K, Satyanarayana S, Srinivas N, Sekhar RJ. Evaluation of the blood-glucose reducing effects of aqueous extracts of the selected Umbelliferous fruits used in culinary practices. *Trop J Pharm Res* 2006; 5: 613-7.
- [19] Patrick EE, Item A, Eyong UE, Godwin EE. The Antidiabetic efficacy of combined extracts from two continental plants: *Azadirachta indica* (A. Juss) (Neem) and *Vernonia amygdalina* (Del.) (African Bitter Leaf). *Am J Biochem Biotech* 2008; 4: 239-44.
- [20] Babu V, Gangadevi T, Subramoniam A. Anti-hyperglycaemic activity of *Cassia kleinii* leaf extract in glucose fed normal rats and alloxan-induced diabetic rats. *Indian J Pharmacol* 2002; 34: 409-15.
- [21] Djeridane A, Yousfi M, Nadjemi B, Boutassouna D, Stocker P, Vidal N. Antioxidant activity of some Algerian medicinal plants extracts

- containing phenolic compounds. *Food Chem* 2006; 97: 654-60.
- [22] Kato A, Miura T. Hypoglycemic activity of Polygonati rhizome in normal and diabetic mice. *Biol Pharm Bull* 1993; 16: 1118-20.
- [23] Baily CJ, Flatt PR. Antidiabetic drugs, new developments. *Indian Biotech* 1986; 6: 139-42.
- [24] Shahwar D, Ullah S, Ahmad N, Ullah S, Khan MA. Antibacterial and antioxidant activities of two Asteracious species growing in Pakistan. *Asian J Chem* 2010; 22: 3246-54.
- [25] Reddy VS, Sahay RK, Bhadada SK, Agrawal JK, Agrawal NK. Newer oral antidiabetic agents. *J Indian Acad Clinical Med* 2000; 1: 245-51.
- [26] Gandy SE, Buse MG, Crouch RKJ. Protective role of superoxide dismutase against diabetogenic drugs. *J Clin Invest* 1982; 70: 650-8.
- [27] Papaccio G, Pisanti FA, Frascatore S. Acetyl-homocystein-thiolactone-induced increase of superoxide dismutase counteracts the effect of subdiabetogenic doses of streptozotocin. *Diabetes* 1986; 35: 470-4.
- [28] Baynes JW, Thorpe SR. Role of oxidative stress in diabetic complications: a new perspective on an old paradigm. *Diabetes* 1999; 1: 1-9.
- [29] Czinner E, Hagyma'si K, Bla'zovics A, Ke'ry A', Szoke E', Lemberkovics E'. In vitro antioxidant properties of *Helichrysum arenarium* (L.) Moench. *J Ethnopharmacol* 2000; 73: 437-43.
- [30] Nair AGR, Subramanian SS. Apigenin glycosides from *Thumbergia fragrans* and *Ruellia tuberosa*. *Curr Sci* 1974; 43: 480.
- [31] Wagner H, Danninger H, Iyengar MA, Seligmann O, Farkas L, Subramanian SS, Nair AGR. Isolation of apigenin-7- β -D-glucuronide from *Ruellia tuberosa* and its synthesis. *Chemische Berichte* 1971; 104: 2681-7.
- [32] Pathak D, Pathak K, Singla AK. Flavonoids as medicinal agents-recent advances. *Fitoterapia* 1991; 62: 371-89.
- [33] Ahmad M, Akhtar MS, Malik T, Gilani, AH. Hypoglycemic action of flavonoid fraction of *Cuminum nigrum* seeds. *Phytother Res* 2000; 14: 103-6.
- [34] Suba V, Murugensan T, Rao BK, Ghosh L, Pal M, Mandal SC, Saha BP. Anti-diabetic potential of *Barleria lupulina* extract in rats. *Fitoterapia* 2004; 75: 1-4.