[1] Department of Pharmacy, University of Sargodha, Sargodha, Pakistan
[2] Department of Physiology and Pharmacology, University of Agriculture, Faisalabad, Pakistan
[3] King Edward Medical University, Mayo Hospital, Lahore, Pakistan

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EFFECT OF *LODOICEA SECHELLARUM LABILL* (SEA COCONUT) FRUIT ON BLOOD GLUCOSE AND LIPID PROFILE IN TYPE 2 DIABETIC AND NORMAL HUMAN VOLUNTEERS

Muhammad Shoaib Akhtar[1], Saba Khan[2], Sajid Bashir[1], Mariam Salman[3]

Key words: Lodoicea sechellarum Labill*, blood glucose, lipids, diabetes mellitus type 2*

SUMMARY

*Effects of oral administration of sea coconut (*Lodoicea sechellarum Labill*) on blood glucose and lipid profile were studied in normal and diabetic volunteers. Oral treatment with 2, 3 and 4 g of sea coconut and repaglinide (1 mg) decreased blood glucose significantly in normal and diabetic subjects. Furthermore, sea coconut decreased total cholesterol, triglycerides and LDL-cholesterol but increased HDL-cholesterol in both normal subjects and type 2 diabetics. The data showed more than one hypoglycemic and antihyperlipidemic principles in sea coconut that have produced significant changes in blood glucose and lipid levels in normal and diabetic volunteers. These results validated the folkloric uses and earlier studies of treating type 2 diabetics. However, double-blind clinical trials should be conducted to establish the efficacy of this natural drug, while activity directed phytochemical studies are required to isolate active principles from the plant which would help find newer model antidiabetic compound(s) for the treatment of diabetes.*

Corresponding author: Prof. Muhammad Shoaib Akhtar, PhD, Department of Pharmacology, Faculty of Pharmacy, University of Sargodha, Sargodha-40100, Pakistan
E-mail: drmsakhtar@gmail.com

INTRODUCTION

Despite considerable progress in the management of diabetes mellitus by conventional synthetic drugs, research work on natural agents has greatly increased all over the globe. It has become quite clear that the use of herbal products to treat type 2 diabetes mellitus has greatly increased during the past decades (1,2). However, scientific and medical evaluation to assess their efficacy supporting the presumed antidiabetic effect is usually absent or requires further investigation (3). In folk medicine, a large number of medicinal plants are considered efficacious in the treatment of diabetes mellitus (4-6).

Lodoicea sechellarum Labill, commonly known as sea coconut (Naryal Daryai) has been used in folkloric medicine for different medicinal purposes including a remedy for diabetes. In addition, it has been used as a preservative, alexipharmac and tonic (4,7), but scientific studies to evaluate its antidiabetic efficacy have yet been awaited. The hypoglycemic effect of powdered fruit of *Lodoicea sechellarum* was previously studied in normal and alloxan-diabetic

rabbits and its significant hypoglycemic effect was recorded in normal rabbits only (8). Since hypoglycemic/antidiabetic activity of this natural product has not been evaluated in diabetic patients, the present study was designed to investigate its effects on blood glucose levels and lipid profile in both normal and type 2 diabetic subjects, with the intention to rationalize the use of folkloric antidiabetic plants in patients suffering from type 2 diabetes.

MATERIALS AND METHODS

Plant material

The fruit of *Lodoicea sechellarum,* locally known as sea coconut or Naryal Daryai, was procured from local herbal market. They were carefully cleaned to make them free from dust, dried in oven at 40 °C and powdered with an electric grinder. The plant belongs to the family Arecaceae and *L. maldevica* (Poir.) is its synonym. It is reported to reduce sugar in urine in diabetics. It is also useful in cholera, hyperdipsia, edema, diarrhea and colic. It is said to be a good cardiotonic (9).

Drug and chemicals

Tablets of 1 mg of repaglinide (Novonorm^R) and gum tragacanth were purchased from a local medical store. All other chemicals were of analytical grade.

Study subjects

Normal volunteers were selected from family members, relatives and friends. They were apparently healthy and showed normal glucose tolerance and lipid profile. However, diabetic volunteers were enrolled by holding a free camp for diabetic patients at Taunsa. Diabetic volunteers were of both sexes, age range 30-60 years, and were suffering from type 2 diabetes mellitus. Most of them were on different oral hypoglycemic agent(s), and the others were on dietary regimen only.

Testing procedure

History of each patient was recorded and diagnosis confirmed with proper laboratory tests and symptoms. They were motivated to give consent for the trial and approval was obtained from the institutional ethics committee. Normal volunteers were randomly divided into 4 groups (A, B, C and D) of six subjects. Group A included untreated control subjects administered 30 mL of 2% gum tragacanth aqueous solution only, whereas groups B, C and D were treated orally with 2, 3 and 4 g of powdered sea coconut suspended in 30 mL of gum solution, respectively. Diabetic volunteers were also divided into 4 groups (E, F, G and H) of six subjects. Group E served as treated-control subjects administered repaglinide tablet (1 mg) once daily orally with 30 mL gum solution. Diabetic volunteers from groups F, G and H were treated orally with 2, 3, and 4 g of powdered sea coconut in 30 mL of gum solution, respectively. Fasting blood glucose levels were determined and then a standard breakfast including 2 toasts, 2 eggs and a cup of tea without sugar was served. Subsequently, 2-h postprandial blood glucose was determined using the latest glucometer on post-treatment days 0, 1, 8, 15 and 21 of continuous once daily oral intake of powdered sea coconut in the prescribed dosage.

Collection of blood samples

Blood samples were obtained before (fasting) and 2 hours after breakfast. Lipid profile parameters including total cholesterol, triglycerides, high density lipoprotein cholesterol (HDL-cholesterol) and low density lipoprotein cholesterol (LDL- cholesterol) were determined with the respective reagent kits (Randox, UK).

Statistical analysis

Data were expressed as standard error of means (mean ± SEM) (10). The level of significance of between-group differences was determined by ANOVA. A 95% level of confidence (P<0.05) was accepted for all comparisons.

Table 1. **Mean fasting blood glucose levels (mg/dL ± SEM) on various days before and after oral administration of 2, 3 and 4 g of powdered *Lodoicea sechellarum* fruit and repaglinide 1.0 mg once daily given with 2% gum tragacanth aqueous solution in normal and type 2 diabetic subjects**

Time (day)	Normal subjects					Diabetic subjects		
	Group A Gum, 2% sol.	Group B Powdered *Lodoicea sechellarum* 2 g	Group C Powdered *Lodoicea sechellarum* 3 g	Group D Powdered *Lodoicea sechellarum* 4 g	Group E Repaglinide 1 tbl.	Group F Powdered *Lodoicea sechellarum* 2 g	Group G Powdered *Lodoicea sechellarum* 3 g	Group H Powdered *Lodoicea sechellarum* 4 g
0	90.5±2.6	92.5±3.6	91.3±3.8	99.7±2.5	177.0±4.8	211.7±13.1	226.3±16.4	228.8±13.3
1	91.8±4.2^{NS}	91.0±2.8^{NS}	90.8±2.3^{NS}	89.3±3.5^{NS}	120.3±6.4^{NS}	213.8±9.4^{NS}	198.8±16.8^{NS}	200.2±10.7^{NS}
8	92.0±3.1^{NS}	85.2±3.1*	81.3±2.5*	73.5±2.2**	119.3±5.5**	210.8±9.6^{NS}	129.7±16.1*	168.7±16.0**
15	91.3±4.0^{NS}	81.2±3.1*	75.2±2.3**	69.0±6.9**	100.3±3.4**	206.7±9.3^{NS}	124.0±11.3*	110.2±12.3**
21	81.8±3.1^{NS}	80.8±2.9*	71.0±2.5**	62.7±1.8**	97.3±4.2**	200.2±8.6^{NS}	111.3±12.3**	95.3±9.4**

^{NS}non-significant (P>0.05) difference from day 0 level; *significant decrease as compared to day 0 level (P<0.05); **highly significant decrease as compared to day 0 level (P<0.001); number of volunteers in each group=6

Table 2. **Mean 2-h postprandial blood glucose levels (mg/dL ± SEM) on various days before and after oral administration of 2, 3 and 4 g of powdered *Lodoicea sechellarum* fruit and repaglinide 1.0 mg once daily given with 2% gum tragacanth aqueous solution in normal and type 2 diabetic subjects**

Time (day)	Normal subjects					Diabetic subjects		
	Group A Gum, 2% sol.	Group B Powdered *Lodoicea sechellarum* 2 g	Group C Powdered *Lodoicea sechellarum* 3 g	Group D Powdered *Lodoicea sechellarum* 4 g	Group E Repaglinide 1 tbl 1	Group F Powdered *Lodoicea sechellarum* 2 g	Group G Powdered *Lodoicea sechellarum* 3 g	Group H Powdered *Lodoicea sechellarum* 4 g
0	150.5±4.9	151.5±2.0	174.8±6.7	173.0±9.7	290.0±10.7	280.5±13.2	289.7±9.4	278.3±6.1
1	161.2±5.5^{NS}	153.5±3.2^{NS}	168.2±5.0^{NS}	163.0±8.5*	211.7±7.8*	226.2±10.9^{NS}	269.3±5.7^{NS}	248.5±4.9*
8	153.5±5.7^{NS}	143.7±2.5*	149.2±6.1*	142.8±6.3**	196.0±9.7**	223.5±9.7^{NS}	236.7±6.0*	218.8±9.5**
15	159.8±4.7^{NS}	139.3±3.8*	131.8±3.4**	127.8±3.2**	145.0±3.5**	182.7±9.8*	165.0±7.4**	141.5±8.4**
21	145.8±4.7^{NS}	126.2±3.6*	129.0±2.5**	117.2±2.7**	114.5±3.8**	180.3±8.2*	130.0±8.3**	128.7±6.6**

^{NS}non-significant (P>0.05) difference from day 0 level; *significant decrease as compared to day 0 level (P<0.05); **highly significant decrease as compared to day 0 level (P<0.001); number of volunteers in each observation=6

Table 3. **Mean total blood lipid levels (mg/dL ± SEM) on various days before and after oral administration of 2, 3 and 4 g/kg of powdered *Lodoicea sechellarum* fruit and repaglinide 1.0 mg once daily given with 2% gum tragacanth aqueous solution in normal volunteers and type 2 diabetic subjects**

Time (day)	Normal subjects					Diabetic subjects		
	Group A Gum, 2% sol.	Group B Powdered *Lodoicea sechellarum* 2 g	Group C Powdered *Lodoicea sechellarum* 3 g	Group D Powdered *Lodoicea sechellarum* 4 g	Group E Repaglinide tbl. 1	Group F Powdered *Lodoicea sechellarum* 2 g	Group G Powdered *Lodoicea sechellarum* 3 g	Group H Powdered *Lodoicea sechellarum* 4 g
0	170.5±4.9	181.5±2.0	174.8±7.7	173.0±9.7	210.0±8.7	220.5±11.2	259.7±9.4	258.3±6.1
1	171.2±5.5^{NS}	183.5±3.2^{NS}	178.2±4.9^{NS}	173.0±8.5^{NS}	211.7±7.8^{NS}	226.2±10.9^{NS}	259.3±5.7^{NS}	248.5±5.9*
8	173.5±5.7^{NS}	179.7±2.5^{NS}	169.2±6.1^{NS}	162.8±6.3^{NS}	216.0±9.7^{NS}	223.5±12.1^{NS}	246.7±6.0^{NS}	238.8±7.5*
15	169.8±4.7^{NS}	169.3±4.8*	161.8±3.4*	152.8±5.2*	215.0±7.5^{NS}	212.7±11.8^{NS}	225.0±7.4*	231.5±6.4*
21	165.8±4.7^{NS}	166.2±5.6*	159.0±4.5*	141.2±4.7**	194.5±6.8^{NS}	212.3±10.2^{NS}	220.0±8.3*	218.7±6.6**

^{NS}non-significant (P>0.05) difference from day 0 level; *significant decrease as compared to day 0 level (P<0.05); **highly significant decrease as compared to day 0 level (P<0.001); number of volunteers in each group=6

RESULTS

As expected, there was a non-significant effect (P>0.05) on fasting blood glucose levels in the control group receiving gum solution only. However, oral intake of 2, 3 and 4 g of powdered *Lodoicea sechellarum* (sea coconut) fruit produced a significant (P<0.05 or P<0.001) decrease in fasting blood glucose on days 8, 15 and 21 as compared to day 0 in both normal and diabetic groups (groups B, C, D and groups F, G and H, respectively). A similar decrease was also observed in group E of diabetic human subjects on days 8, 15 and 21 after oral treatment with repaglinide 1 mg tablet once daily (Table 1).

The 2-h postprandial blood glucose levels in normal and diabetic subjects clearly pointed to a significant (P<0.05 or P<0.001) decrease in blood glucose levels on days 8, 15 and 21 in normal B, C and D groups and in F, G and H diabetic groups treated with 2, 3 and 4 g of powdered sea coconut (Table 2).

Table 4. **Mean blood triglyceride levels (mg/dL ± SEM) on various days before and after oral administration of 2, 3 and 4 g of powdered *Lodoicea sechellarum* fruit and repaglinide 1.0 mg once daily given with 2% gum tragacanth aqueous solution in normal volunteers and type 2 diabetic subjects**

	Normal subjects					Diabetic subjects		
Time (day)	Group A Gum, 2% sol.	Group B Powdered *Lodoicea sechellarum* 2 g	Group C Powdered *Lodoicea sechellarum* 3 g	Group D Powdered *Lodoicea sechellarum* 4 g	Group E Repaglinide tbl. 1	Group F Powdered *Lodoicea sechellarum* 2 g	Group G Powdered *Lodoicea sechellarum* 3 g	Group H Powdered *Lodoicea sechellarum* 4 g
0	136.3±2.4	156.7±12.5	146.3±6.7	148.5±5.8	174.8±5.1	180.3±9.8	193.2±6.8	186.8±6.9
1	136.7±2.6^{NS}	156.5±11.1^{NS}	145.0±6.1^{NS}	151.5±5.4^{NS}	174.3±3.2^{NS}	181.3±10.4^{NS}	190.5±8.1^{NS}	190.0±7.0*
8	129.3±3.2^{NS}	140.2±11.0*	143.3±3.2^{NS}	139.8±5.4*	168.3±6.8^{NS}	170.5±9.0*	180.2±5.9*	177.3±6.3**
15	124.7±4.9^{NS}	125.5±12.7*	134.5±2.7*	131.8±5.3**	164.0±4.0^{NS}	159.0±8.9**	176.2±4.2**	162.0±6.3**
21	119.3±5.6^{NS}	122.3±10.9*	129.2±4.7*	126.7±6.2**	159.2±4.3^{NS}	157.5±8.4**	167.5±4.9**	166.2±4.9**

^{NS}non-significant (P>0.05) difference from day 0 level; *significant decrease as compared to day 0 level (P<0.05); **highly significant decrease as compared to day 0 level (P<0.001); number of volunteers in each group=6

Table 5. **Mean blood LDL-cholesterol levels (mg/dL ± SEM) on various days before and after oral administration of 2, 3 and 4 g of powdered *Lodoicea sechellarum* fruit and repaglinide 1.0 mg once daily given with 2% gum tragacanth aqueous solution in normal and type 2 diabetic subjects**

	Normal subjects					Diabetic subjects		
Time (day)	Group A Gum, 2% sol.	Group B Powdered *Lodoicea sechellarum* 2 g	Group C Powdered *Lodoicea sechellarum* 3 g	Group D Powdered *Lodoicea sechellarum* 4 g	Group E Repaglinide tbl. 1	Group F Powdered *Lodoicea sechellarum* 2 g	Group G Powdered *Lodoicea sechellarum* 3 g	Group H Powdered *Lodoicea sechellarum* 4 g
0	99.4±6.8	105.8±4.6	100.9±6.6	101.8±11.7	129.5±7.9	141.6±16.6	178.9±10.4	162.3±6.9
1	96.5±6.6^{NS}	107.7±5.0^{NS}	103.5±6.9^{NS}	100.7±10.5^{NS}	130.1±8.6^{NS}	146.4±11.3^{NS}	175.6±6.0^{NS}	161.0±7.2^{NS}
8	98.0±6.2^{NS}	103.3±4.0^{NS}	95.3±6.3^{NS}	97.7±5.4*	134.5±9.4^{NS}	141.4±12.0^{NS}	163.4±4.4*	147.0±9.6*
15	95.9±4.7^{NS}	94.8±5.0*	86.3±3.1*	92.1±3.6*	131.9±5.5^{NS}	129.2±11.9^{NS}	151.6±7.8*	137.1±8.4**
21	92.1±4.2^{NS}	91.7±4.4*	81.7±2.4*	79.3±3.7**	109.8±6.3^{NS}	128.5±10.0^{NS}	133.0±6.8**	121.9±9.2**

^{NS}non-significant (P>0.05) difference from day 0 level; *significant decrease as compared to day 0 level (P<0.05); **highly significant decrease as compared to day 0 level (P<0.001); number of volunteers in each group=6

Table 6. **Mean blood HDL-cholesterol levels (mg/dL ± SEM) on various days before and after oral administration of 2, 3 and 4 g of powdered *Lodoicea sechellarum* fruit and repaglinide 1.0 mg once daily given with 2% gum tragacanth aqueous solution in normal and type 2 diabetic subjects**

	Normal subjects					Diabetic subjects		
Time (day)	Group A Gum, 2% sol.	Group B Powdered *Lodoicea sechellarum* 2 g	Group C Powdered *Lodoicea sechellarum* 3 g	Group D Powdered *Lodoicea sechellarum* 4 g	Group E Repaglinide tbl. 1	Group F Powdered *Lodoicea sechellarum* 2 g	Group G Powdered *Lodoicea sechellarum* 3 g	Group H Powdered *Lodoicea sechellarum* 4 g
0	47.2±2.9	44.3±3.1	44.7±2.8	41.5±2.2	45.5±3.5	42.8±2.5	42.2±2.0	48.7±2.6
1	47.3±2.7^{NS}	44.5±3.4^{NS}	45.6±3.1^{NS}	42.0±2.7^{NS}	46.7±2.8^{NS}	43.5±2.1^{NS}	46.2±2.1^{NS}	49.5±2.6^{NS}
8	47.7±1.4^{NS}	48.3±2.2^{NS}	45.2±1.7^{NS}	57.2±3.3*	47.8±2.8^{NS}	48.0±3.0^{NS}	48.0±2.2^{NS}	56.3±2.8*
15	49.0±1.3^{NS}	49.3±2.4^{NS}	48.7±3.0^{NS}	68.3±2.7**	50.3±3.4^{NS}	52.3±4.0*	56.7±3.1*	61.2±3.1**
21	49.8±2.8^{NS}	54.0±2.0*	58.5±3.0*	72.5±3.3**	52.8±2.2^{NS}	56.3±3.3*	63.5±2.4**	73.2±2.8**

^{NS}non-significant decrease as compared to day 0 level (P>0.05); *significant decrease as compared to day 0 level (P<0.05); **highly significant decrease as compared to day 0 level (P<0.001); number of animal in each group=6

Table 3 shows a significant (P<0.05 or P<0.001) decrease in total cholesterol levels in normal and diabetic subjects on days 15 and 21 after treatment with 2, 3 and 4 g of sea coconut. In addition, triglyceride levels in normal and diabetic subjects are shown in Table 4. On days 8, 15 and 21, a significant (P<0.05 or P<0.001) decrease in triglyceride levels was observed in normal B, C and D groups as well as in diabetic F, G and H groups. Table 5 shows that LDL-cholesterol level was also decreased (P<0.05 or P<0.001) in groups B, C and D as compared to day 0. However, HDL-cholesterol levels increased significantly on days 15 and 21 (P<0.05 or P<0.001) in normal and diabetic subjects on different oral test doses of sea coconut (Table 6).

DISCUSSION

The results of the present study are in agreement with Akhtar (6,11) and Mossihuzzaman *et al*. (12), who have also reported significant reduction in blood glucose levels with some other plants. Also, Ahmad *et*

al. (13) have reported similar effect of flavonoids isolated from *Cuminum nigrum* seeds on blood sugar levels and serum lipids in alloxan-diabetic rabbits.

Lipid profile is a direct measure of blood components: total lipids, triglycerides, total cholesterol, LDL-cholesterol and HDL-cholesterol. Factors including diabetes and diet influence the lipid profile (14). The results shown in Table 3 are in accordance with those of He *et al*. (15). Sea coconut is known to contain higher fiber and high fiber diets have been reported to be effective in achieving cholesterol control in diabetics. In the majority of individuals with diabetes it can be best done with a diet that is low in fat and high in carbohydrates (16).

The results presented in Table 4 are in line with Pedersen *et al*. (17). High fiber diet lowered triglycerides in diabetic subjects below 100 mg/dL. Triglyceride levels above 400 mg/dL could be treated first with non-pharmacological approaches including weight loss, low fat diet, avoidance of excess alcohol and regular aerobic exercise (18).

Table 5 shows that LDL-cholesterol level decreased in groups B, C and D as compared to day 0. A similar trend was observed in diabetic groups F, G and H. The results of the present study are in accordance with the finding of Grundy (19) who reports that lower LDL-cholesterol was associated with diets very low in saturated fat or very low in total fat. Lorgeril (18) reports on lower LDL-cholesterol level to be associated with low fat diet, avoidance of excess alcohol and regular exercise.

Virtually, HDL-cholesterol levels in normal and diabetic subjects (Table 6) were found to have increased significantly on days 15 and 21 ($P<0.05$ or $P<0.001$) in normal and diabetic subjects on various doses of sea coconut. Mand *et al*. (20), Mathur *et al*. (21) and Akhtar *et al*. (22) observed similar findings after administration of *Emblica officinalis* fruits.

The results of the present study given in Table 1 are in accordance with the findings of Akhtar *et al*. (23) and Akhtar and Ali (24), who observed that C*uminum nigrum* (kala-zera) seeds in doses of 1, 2, 3 and 4 g/kg produced a significant hypoglycemic effect in normal and diabetic rabbits. Similarly, Frati-Munari *et al*. (25), Akhtar (26), Akhtar and Akhtar (27), and Saleh (28) have reported that certain plants produce low blood glucose and insulin responses in type 1 and type 2 diabetic patients.

Obviously, oral hypoglycemic drugs are of no value in the treatment of patients with severe diabetes of any type, as their islets have already lost all potential to secrete insulin. Therefore, till today the search for more effective and safer antidiabetic agents has continued to be an area of active research. The present study in humans supported the results previously obtained in rabbits (8). It is, therefore, conceivable that hypoglycemic principles in sea coconut act by stimulating insulin release from β-cells of normal individuals and type 2 diabetics. It appears that the fruit contains more than one active principle that act not only indirectly by initiating insulin release but also by a direct insulin-like effect. The data discussed also support the concept according to which oral administration of sea coconut fruits in appropriate doses in mild and moderate type 2 diabetic patients would be sufficiently effective to control their blood glucose levels. However, in severe diabetes patients, the plant drug may have to be supplemented with any of oral sulphonylureas or insulin.

Several factors including diabetes are well known to influence the lipid profile (14). The present study revealed that *Lodoicea sechellarum* (sea coconut) fruit also possesses antihyperlipidemic active principles/constituents, which would make the plant product an ideal drug or may become a source of novel compound(s) that may ultimately provide some curative agent for the treatment of diabetes mellitus and hyperlipidemia. However, further comprehensive phytochemical studies and pharmacological evaluations are required to evaluate and pinpoint the hypoglycemic principle(s) and to study the mechanism of hypoglycemic action. Simultaneously, chronic toxicity studies in laboratory animals must also be carried out to find its ultimate safety for prolonged use in humans. From these studies it has become obvious that the medicinal plant *Lodoicea sechellarum* (sea coconut) fruit possesses useful and interesting

hypoglycemic active principles/constituents that might provide an ideal drug or novel compound for the treatment of diabetes mellitus.

REFERENCES

1. Day C. Traditional plant treatments for diabetes mellitus. Pharmaceutical foods. Br J Nutr 1998;80:5-7.
2. Grover JK, Yadav S, Vats V. Medicinal plants of India with anti-diabetic potential. J Ethnopharmacol 2002;81:81-100.
3. Baily CJ, Day C. Traditional plant medicines as treatment for diabetes. Diabetes Care 1989;12:553-563.
4. Nadkarni AK. Indian Materia medica, Vol. II. Bombay: Popular Book Depot, 1954.
5. Said M. Hamdard pharmacopoeia of eastern medicine. Karachi, Pakistan: Time Press, 1969; p. 379.
6. Akhtar MS. Hypoglycaemic activities of some indigenous medicinal plants traditionally used as antidiabetic drug. J Pak Med Assoc. 1992;42:271-277.
7. Satyavati GV, Raina MK, Sharma M. Medicinal plants of India, Vol. 1. New Delhi, India: Indian Council of Medical Research, 1976; pp. 48-51.
8. Akhtar MS, Khan QM, Khaliq T. Pharmacological screening of hypoglycaemic activity of *Asparagus racemosus* (roots) and *Lodoicea sechellarum* fruits in rabbits. J Pharm (University of Punjab, Lahore) 1987;8:63-70.
9. Parajapati ND, Kumar U. Agro's Dictionary of medicinal plants. Jodhpur, India: Agrobios, 2005; p. 196.
10. Steel RGD, Torrie JH, Dickey DA. Principles and procedures of statistics. A biometrical approach, 3rd ed. New York: McGraw Hill Publishing Company, 1997.
11. Akhtar, M.S. Trials of *Momordica charantia* powder in patients with maturity-onset diabetes. A preliminary report. J Pak Med Assoc 1982;32:106-107.
12. Mossihuzzaman M, Nahar N, Ali L. Hypoglycaemic effects of three plants from Eastern Himalayan belt. Diabetes Res 1994;26:127-138.
13. Ahmad M, Akhtar MS, Malik T, Gilani AH. Hypoglycaemic action of the flavonoid fraction of *Cuminum nigrum* seeds. Phytother Res 1999;13:1-4.
14. Robert S. Diabetes self management. New York: RA Rapaport Publishing Company, 2002.
15. He J, Klag MJ, Whelton PK, Mo JP, Chen JY, Qian MC, Mo PS, He GQ. Oat bran intake selectively lowers serum LDL-C concentration of hypercholesterolemic men. Am J Clin Nutr 1995;61:366-372.
16. Vessby B, Karlstron b, Ohroal M, Jarvi A, Anderson A, Basil S. Diet, nutrition and diabetes mellitus Ups Med Sci 2000;105:151-160.
17. Pederson O, Hermenson K, Palmvig B, Pederson SE, Sondergaard K. Dietary treatment of diabetes recommendations in 1990s. Ugesker Laeger 1992;154:910-916.
18. Lorgeril W. The medical consequences of high level of triglycerides. Exp Clin Endocrinol Diabetes 1999;106:1-6.
19. Grundy SM. Dietary influence on serum lipids and cholesterol. J Lipid Res 1998;31:1149-1172.

20. Mand JK, Soni GL, Gupta PP, Singh R. Effect of amla *(Emblica officinalis)* on the development of atherosclerosis on hypercholesterolaemic rabbits. Department of Biochemistry, Punjab Agricultural University, Ludhiana J Res Edu 1991;10:1-7.

21. Mathur R, Sharma A, Dixit VP, Varma M. Hypolipidemic effect of fruit juice of *Emblica officinalis* in cholesterol-fed rabbits. J Ethnopharmacol 1996;50:61-68.

22. Akhtar MS, Ramzan A, Ali A, Ahmad M. Effect of *Emblica officinalis* (amla) fruit on blood glucose and lipid profile of normal and type-2 diabetic human volunteers. Phytother Res 2009 (under consideration).

23. Akhtar MS, Akhtar MA, Yaqub M. Effect of *Momordica charantia* on blood glucose level of normal and alloxan diabetic rabbits. Planta Medica 1981;42:205-212.

24. Akhtar MS, Ali MR. Study of hypoglycemic activity of *Cuminum nigrum* seeds in normal and alloxan-diabetic rabbits. Planta Medica 1985;51:81-85.

25. Frati-Munari AC, Gordillo BE, Altamirano P, Ariza CR. Hypoglycemic effect of *Opuntia streptacantha,* Lemaire in NIDDM. Diabetes Care 1988;11:63-66.

26. Akhtar MS. Efficacy of some indigenous medicinal plants in diabetic patients. Proceedings of the 2nd Annual National Symposium on Health Care and Social Development. The Age Khan University, Karachi, 1995; pp. 232-236.

27. Akhtar MS, Akhtar P. Hypoglycemic effect of dried *Pongamia pinnata* (sukhchain) flower in normal volunteers and non-insulin dependent diabetes mellitus patients. Hamdard Medicus 1999;XLII(2):33-36.

28. Saleh MA. Treatment of diabetes (Marz-e-Sugar Ka Aalaj). Personal communication, 1991.