Studies on the glycemic and lipidemic effect of *Murraya koenigii* in experimental animals

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**Abstract**

Diabetes is often accompanied by lipid abnormalities, which contribute significantly to cardiovascular morbidity and mortality in diabetic patients. Previously, we have demonstrated potent hypoglycemic activity of lyophilized aqueous extract of *Murraya koenigii* leaves in normal and alloxan induced diabetic rabbits for short duration of 6 h. In this study, we examined the effect of 1 month oral administration of *Murraya koenigii* aqueous leaves extract in normal and STZ induced severe diabetic rats, at the dose of 300 mg/kg bw, on various biochemical parameters, viz., fasting blood glucose (FBG), total cholesterol (TC), HDL-cholesterol (HDL), triglyceride (TG), alkaline phosphatase (ALKP), serum glutamate oxaloacetate and pyruvate transaminases (SGOT and SGPT) and serum creatinine. In case of diabetic animals fasting blood glucose (FBG) levels of treated animals reduced by 48.2% after 30 days treatment with the aqueous leaves extract. A fall of 19.2 and 30.8% in TC and 22.97 and 37.1% in TG levels were also observed in the case of treated normal as well as diabetic rats, respectively. Feeding the extract increased the HDL-cholesterol level by 16 and 29.4% in normal and diabetic rats, respectively, as compared with their initial values.

In the normal rats after 1 month of oral administration of the extract SGOT and SGPT levels were decreased by 21.7 and 25.0%. Serum alkaline phosphatase values of the treated normal animals were also reduced by 33% while negligible change was observed in the normal control animals. In the case of diabetic rats, SGOT and SGPT levels were reduced by 36.7 and 32.2%, respectively, whereas ALKP levels decreased by 39.7% after 1 month oral administration of the extract.

The serum creatinine levels decrease in normal as well as in the diabetic animals by 17.75 and 18.2%, respectively, as compared to initial values. In the diabetic control animals the urinary sugar remains at +4 level but there was a decrease of 75% in urine sugar in the case of treated diabetic rats. This indicates that the aqueous extract of *Murraya koenigii* has favorable effect in bringing down the severity of diabetes.

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**Keywords**: *Murraya koenigii*; Streptozotocin; Antihyperglycemic; Hypolipidemic; SGOT; SGPT; Alkaline phosphatase

1. Introduction

Type II diabetes is the commonest form of diabetes constituting 90% of the diabetic population (King et al., 1998). The countries with the largest number of diabetic patients in the year 2025 will be India, China and United States (Ramchandran et al., 2002). Therefore, it has become necessary to look for novel oral therapeutically effective treatment especially for usage in the developing as well as under-developed countries.

India is a country with a vast reserve of natural resources and a rich history of traditional medicine (Grover and Vats, 2001). Ethnopharmacological surveys indicate that more than 1200 plants are used in traditional medicine for their alleged hypoglycemic activity (Marles and Farnsworth, 1995; Jouad et al., 2001; Grover et al., 2002). The hypoglycemic activity of a large number of these plants/plant products has been evaluated and confirmed in animal models (Gupta et al., 2005a,b; Kesari et al., 2005, 2006; Ruzaidi et al., 2005) as well as in human beings (Jaouhari et al., 1999; Herrera-Arellano et al., 2004; Jayawardena et al., 2005).

Abbreviations: FBG, fasting blood glucose; TC, total cholesterol; TG, triglyceride; LDL, low density lipoprotein; HDL, high density lipoprotein; VLDL, very low density lipoprotein; SGOT, serum glutamate oxaloacetate transaminase; SGPT, serum glutamate pyruvate transaminase; ALKP, alkaline phosphatase; CV, cardiovascular; STZ, streptozotocin; MK, *Murraya koenigii*; bw, body weight

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**Murraya koenigii** (L.) Spreng (family: Rutaceae) is an aromatic pubescent shrub or small tree commonly known as ‘Curry patta’ in India. The plants originated in Tarai regions of Uttar Pradesh, India and now widely found in all parts of India. It adorns every house yard of Southern India and is also cultivated in Sri Lanka, China, Australia and the Pacific islands (Anon., 1962; Joseph and Peter, 1985). The plant is used in Indian system of medicine to treat various ailments (Chopra et al., 1996; Warman, 1999; Kesari et al., 2005). The aromatic leaves, which retain their flavour and other qualities even after drying, are slightly bitter, acrid, cooling, weakly acidic in tastes and are considered as tonic, anthelmintic, analgesic, digestive, appetizing and are widely used in Indian cookery for flavouring food stuffs. The green leaves are used to treat piles, inflammation, itching, fresh cuts, dysentery, vomiting, burses and dropsy. The roots are considered as tonic, anthelminthic, analgesic, digestive, appetizing and are widely used in Indian cookery for flavouring food stuffs. The essential oil of the leaves is reported to possess antimicrobial (Goutam and Purohit, 1974), antifungal (Deshmukh et al., 1986) and pesticidal (Pathak et al., 1997) activities.

**Murraya koenigii** (MK) leaves mixed with fat separated butter fat are used for the treatment of amoebiasis, diabetes and hepatitis in Ayurveda (Pillai, 1958; Bose, 1985; Satyavati et al., 1987). The aqueous extract of the leaves of *Murraya koenigii* produced hypoglycemia in normal and alloxan diabetic dogs (Narayan and Sastry, 1975). Oral feeding of *Murraya koenigii* leaves diet for 60 days to normal rats showed hypoglycemic effect associated with increase in the concentration of hepatic glycogen (Khan et al., 1995). Dietary supplement with curry leaves has been shown to increase lecithin cholesterol acyl transferase activity (Khan et al., 1996). Curry leaves powder supplementation (12 g providing 2.5 g fibre) for a period of 1 month in 30 type II diabetes patients showed reduction in fasting and post-prandial blood sugar levels at 15-day period with no significant changes in serum glycosylated protein levels, glycosylated low density lipoprotein cholesterol fraction, serum lipids, lipoprotein cholesterol levels, uronic acid and total amino acids (Iyer and Mani, 1990). Daily intraperitoneal injection of 80 mg/kg of curry leaf extract to diabetic ob/ob mice for 10 days showed decrease of blood cholesterol and blood glucose levels in them (Xie et al., 2006). Yadav et al. (2002) has reported that feeding different doses of *Murraya koenigii* leaves to diabetic rats play role in control of mild diabetes but in case of moderate, severe and type I diabetes this agent alone is not likely to be useful.

In continuation of our research work with *Murraya koenigii* leaves (Kesari et al., 2005) we have further extended our study for severe diabetic models. The present work deals with the antidiabetic and hypolipidemic action of aqueous extract of *Murraya koenigii* leaves in case of severe diabetic rats.

2. Materials and methods

2.1. Materials

Streptozotocin was purchased from Sigma–Aldrich Co., USA. Serum glucose, TC, HDL-cholesterol, TG, ALKP, SGOT, SGPT and serum creatinine were estimated using commercial kits purchased from Bayer Diagnostics India Ltd. Glucose in urine were estimated by using Uristix of Bayer Diagnostics.

2.2. Preparation of extract

Fresh leaves of *Murraya koenigii* (5 kg) were collected locally and got identified by Botanical Survey of India (Allahabad Branch). The leaves were shade dried and were crushed to moderately coarse powder. The powder was extracted with distilled water using soxhelt at boiling temperature (100 °C) up to 10 h. A dark brown colour extract is obtained. This dark brown extract was cooled and filtered to remove the residue. The extract was concentrated on rotavapour under reduced pressure and then lyophilized to get a powder weighing about 7.5 g (Kesari et al., 2005).

2.3. Animals

Healthy male Wistar albino rats (weighing 180–230 g) were used for the investigation. The animals were housed in standard conditions of temperature (21 ± 2 °C), humidity (55 ± 10%) and a 12 h light–dark cycle. The rats were fed with commercial diet (Pashu aahar, Varanasi) and water *ad libitum*. For experimental purpose the animals were kept fasting overnight but were allowed free access to water.

2.4. Induction of diabetes and blood sample collection in rats

A freshly prepared solution of streptozotocin (45 mg/kg bw) in 0.1 M citrate buffer, pH 4.5 was injected intraperitoneally to overnight fasted rats. After 3 days, blood was collected in vials from the tail vein of overnight fasted rats and was allowed to clot to separate serum. It is then centrifuged at 4000 rpm for 10 min to obtain clear serum. FBG level was estimated and PPG was checked regularly up to stable hyperglycemia, usually 1 week after streptozotocin injection. Animals having marked hyperglycemia (FBG > 250 mg/dl) were selected for the study (Gupta et al., 2005a).

2.5. Biochemical parameters

Glucose, TC, HDL-cholesterol and TG levels in blood serum were measured spectrophotometrically by prescribed methods. LDL cholesterol was calculated from the above measurement by using Friedwald formula (Friedwald et al., 1972) and VLDL cholesterol by formula TG/5. ALKP, SGOT, SGPT and Creatinine were estimated in blood serum. Urine sugar was detected by reagent-based uristrix from Bayer. Total haemoglobin was estimated in blood by Drabkin reagent. Body weight was estimated gravimetrically.

2.6. Experimental design

It has already been found that the most effective dose was 300 mg/kg (Kesari et al., 2005), therefore this dose was taken for
evaluation in the case of severe diabetic animals. The experiment was carried on four groups (I, II, III and IV) of six rats each:

- Group I: normal control.
- Group II: normal treated with 300 mg/kg of extract.
- Group III: diabetic control.
- Group IV: diabetic treated with 300 mg/kg of extract.

Control rats (groups I and III) received orally vehicle (distilled water) only while groups II and IV received the 300 mg/kg of extract orally, suspended in distilled water. All biochemical parameters were estimated at the beginning and after 30 days of experiment.

2.7. Toxicity studies

Four groups of rats of both sex (six animals per group) were administered orally a single dose of either 5, 10 or 15 times of effective dose of aqueous extract of Murraya koenigii leaves. The rats were observed for gross behavioural, neurologic, autonomic, and toxic effect continuously. Food consumption, faeces and urine were also examined at 2 h and then at 6 h intervals for 24 h.

2.8. Statistical analysis

The data are expressed as mean ± standard deviation (S.D.). Statistical comparisons were performed by one-way analysis of variance (ANOVA) followed by Duncan’s multiple range test (DMRT). The results were considered statistically significant if the P values were 0.05 or less.

3. Results

3.1. Serum glucose levels

Fasting blood glucose levels of normal healthy rats are in normal range (Table 1). No marked change was observed in FBG of treated normal animals. In case of diabetic animals fasting blood glucose levels of treated animals reduced by 48.2% in 30 days treatment with the aqueous leaves extract. The FBG of control diabetic rats continued to rise during the experiment period.

3.2. Serum total cholesterol and HDL-cholesterol level

Treatment with the extract decreased the total cholesterol level. A fall of 19.2 and 30.8% was observed in the case of treated normal and diabetic rats, respectively, as compared with their initial values (Table 1). Feeding the extract increased the HDL-cholesterol level by 16 and 29.4% in normal and diabetic rats, respectively, as compared with their initial values (Table 1).

3.3. Serum triglyceride, LDL and VLDL levels

There was a fall in triglyceride, LDL and VLDL levels of the extract fed normal as well as diabetic rats. In case of normal and diabetic rats the TG and VLDL levels were reduced by 22.97 and 37.1%, respectively (Tables 1 and 2). In the animals treated with the extract for 30 days there was a decrease in LDL level in both normal and diabetic animals by 45.2 and 56.3%, respectively.

3.4. Liver function tests (SGOT, SGPT and ALKP) and serum creatinine

In the normal rats after 1 month extract SGOT level was decreased by 21.7% with respect to initial values. Similarly SGPT level was reduced by 25% and there was no marked reduction in untreated control group of animals (Table 3). ALKP values of the extract treated normal animals were reduced by 33% (Table 3) while negligible change was observed in the normal control animals. In the case of diabetic rats, SGOT and SGPT levels were reduced by 36.7 and 32.2%, respectively, with respect to initial value. The reduction was more in diabetic animals than in the normal animals. ALKP was decreased by 39.7% in treated diabetic animals when compared with their initial values. The serum creatinine levels decreases in normal as well as in the diabetic animals by 17.75 and 18.2%, respectively, as compared to initial values. The values were in the normal range.

3.5. Body weight and urine sugar levels

There was a gradual increase in body weight in the normal controls while the diabetic controls continued to lose weight. However, treated diabetic group gained 19.2% weight as compared to diabetic control and the bodyweights of diabetic treated animals were towards normal range. In the normal untreated

### Table 1

<table>
<thead>
<tr>
<th>Experimental groups</th>
<th>Before treatment (mg/dl)</th>
<th>After treatment (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FBG</td>
<td>TC</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group I)</td>
<td>82.5</td>
<td>66.2</td>
</tr>
<tr>
<td>Treated (group II)</td>
<td>76.8</td>
<td>72.1</td>
</tr>
<tr>
<td>Diabetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group III)</td>
<td>292.2</td>
<td>106.2</td>
</tr>
<tr>
<td>Treated (group IV)</td>
<td>288.6</td>
<td>110.6</td>
</tr>
</tbody>
</table>

* P < 0.01 as compared to initial value.
** P < 0.001 as compared to initial value.
Table 2
Effect of administration of feeding the aqueous extract of *Murraya koenigii* leaves on low density lipoprotein and very low density lipoprotein in normal and diabetic rats for 1 month

<table>
<thead>
<tr>
<th>Experimental groups</th>
<th>Before treatment</th>
<th>After treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LDL (mg/dl)</td>
<td>VLDL (mg/dl)</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group I)</td>
<td>40.0 ± 4.2</td>
<td>17.6 ± 3.2</td>
</tr>
<tr>
<td>Treated (group II)</td>
<td>49.1 ± 4.4</td>
<td>19.3 ± 4.6</td>
</tr>
<tr>
<td>Diabetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group III)</td>
<td>101.2 ± 5.2</td>
<td>32.9 ± 5.1</td>
</tr>
<tr>
<td>Treated (group IV)</td>
<td>98.8 ± 5.1</td>
<td>31.3 ± 4.2</td>
</tr>
</tbody>
</table>

* P < 0.001 as compared to initial value.

Table 3
Effect of administration of feeding the aqueous extract of *Murraya koenigii* leaves on SGOT, SGPT, ALKP and serum cretanine (CRTN) in normal and diabetic rats for 1 month

<table>
<thead>
<tr>
<th>Experimental groups</th>
<th>Before treatment</th>
<th>After treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SGOT (U/l)</td>
<td>SGPT (U/l)</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group I)</td>
<td>66.7 ± 3.2</td>
<td>29.2 ± 1.4</td>
</tr>
<tr>
<td>Treated (group II)</td>
<td>73.7 ± 2.8</td>
<td>27.9 ± 1.2</td>
</tr>
<tr>
<td>Diabetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group III)</td>
<td>108.2 ± 8.0</td>
<td>59.8 ± 3.8</td>
</tr>
<tr>
<td>Treated (group IV)</td>
<td>114.8 ± 7.6</td>
<td>66.7 ± 5.4</td>
</tr>
</tbody>
</table>

* P < 0.01 as compared to initial value.

3.6. Total and glycosylated haemoglobin levels

In the control healthy animals there was negligible change in the total haemoglobin levels at the end of experiment. In the animals treated with the extract for 1 month there was increase in total haemoglobin in both normal and diabetic animals by about 14.1 and 11.3%, respectively (Table 5). In the case of glycohaemoglobin there was a drop of 21% in normal treated animals while in diabetic treated animals a fall of 30% was observed.

Table 4
Effect of administration of feeding the aqueous extract of *Murraya koenigii* leaves on body weight and urine sugar in normal and diabetic rats for 1 month

<table>
<thead>
<tr>
<th>Experimental groups</th>
<th>Urine sugar</th>
<th>Body weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before treatment</td>
<td>After treatment</td>
</tr>
<tr>
<td>Normal control</td>
<td>Nil</td>
<td>192.0 ± 8.6</td>
</tr>
<tr>
<td>Normal treated</td>
<td>Nil</td>
<td>198.6 ± 7.8</td>
</tr>
<tr>
<td>Diabetic control</td>
<td>+4</td>
<td>206.5 ± 8.8</td>
</tr>
<tr>
<td>Diabetic treated</td>
<td>+4*</td>
<td>185.2 ± 6.4</td>
</tr>
</tbody>
</table>

* P < 0.01 as compared to initial value.

Table 5
Effect of administration of feeding the aqueous extract of *Murraya koenigii* leaves on haemoglobin and glycosylated haemoglobin in normal and diabetic rats for 1 month

<table>
<thead>
<tr>
<th>Experimental groups</th>
<th>Before treatment</th>
<th>After treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Hb %</td>
<td>gly-Hb %</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group I)</td>
<td>13.2 ± 1.6</td>
<td>7.3 ± 0.6</td>
</tr>
<tr>
<td>Treated (group II)</td>
<td>12.8 ± 2.1</td>
<td>6.9 ± 0.8*</td>
</tr>
<tr>
<td>Diabetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (group III)</td>
<td>12.6 ± 1.8</td>
<td>10.6 ± 1.2</td>
</tr>
<tr>
<td>Treated (group IV)</td>
<td>12.4 ± 1.6</td>
<td>10.2 ± 1.4*</td>
</tr>
</tbody>
</table>

* P < 0.01 as compared to initial value.

3.7. Toxicity studies

Experiment was carried out on normal healthy rats. The behaviour of the treated rats appeared normal. No toxic effect was reported up to 10 and 15 times of effective dose of the aqueous extract and there were no deaths in any of these groups.

4. Discussion

Our previous investigation (Kesari et al., 2005) have shown the maximum fall of 14.68% in normal and 27.96% in mild diabetic after 4 h of oral administration of 300 mg/kg of MK aqueous extract. The same dose also showed a marked improve-
ment in glucose tolerance of 46.25% in sub-diabetic and 38.5% in mild diabetic rabbits in glucose tolerance test after 2 h (Kesari et al., 2005), confirming the ethnomedical use of *Murraya koenigii* in diabetes. In the present study, we investigated whether the *Murraya koenigii* extract has any effect on lipids profile, in addition to its antihyperglycemic action, in STZ-diabetic rats.

The continuous treatment for 30 days with the aqueous extract caused a significant decrease in the blood glucose levels of diabetic rats but no such effect was observed in the normal treated rats. This is an interesting observation, as the continuous use of the extract or the accidental overdose of this drug will not result in hypoglycemic shock. In this way this drug will be better than insulin or sulfonylurea drugs, which causes severe hypoglycemia when taken in excessive doses (Ferner, 1988).

Since lipid abnormalities accompanying with premature atherosclerosis is the major cause of cardiovascular diseases in diabetic patients therefore ideal treatment for diabetes, in addition to glycemic control, should have a favorable effect on lipid profile. CV diseases are listed as the cause of death in 65% people suffering from diabetes (Geiss et al., 1995). The dose of 300 mg/kg of the aqueous extract not only lowered the TC, TG, VLDL and LDL levels but also enhanced the cardio protective lipid HDL by 16 and 29.4% in normal and diabetic rats, respectively, after 30 days of treatment. Several studies have shown that an increase in HDL-cholesterol is associated with a decrease in coronary risk (Harrison et al., 2003) and most of the drugs that decrease total cholesterol also decrease HDL-cholesterol (Wilson, 1990). In the present study the extract not only decrease the total cholesterol but also enhances the HDL-cholesterol significantly.

High levels of TC and more importantly LDL cholesterol are major coronary risk factors (NCEPEP, 1994; Temme et al., 2002). Administration of leaves extract to diabetic rats for 30 days lowered TC and LDL cholesterol by 30.8 and 56.3%, respectively. This is an important finding of this experiment as diabetes is associated with coronary complications, which is the major cause of morbidity and deaths in diabetic subjects (Huse et al., 1988; Baynes, 1991).

Recent studies suggest that TG itself is independently related to coronary heart disease (Bainton et al., 1992; El-Hazmi and Warsy, 2001) and most of the antihypercholesterolemic drugs do not decrease TG levels but MK extract lowered it by 37.1% after 30 days of treatment.

Its strong effect on diabetic hypertriglyceridemia could be through its control of hyperglycemia. This is in agreement with the fact that (a) the level of glycemic control is the major determinant of very low density lipoprotein and triglyceride concentrations (Markku, 1995) and (b) improved glycemic control following sulfonylurea therapy decreases level of serum VLDL and total triglyceride (Huupponen et al., 1984; Hughes et al., 1985; Taskinen et al., 1986).

Generally total haemoglobin level is much below the normal level in diabetic subjects (Chandalia and Krishnaswamy, 2002). Administration of aqueous MK leaves not only reversed the total haemoglobin levels in STZ-diabetic rats but also improves the total haemoglobin levels of normal rats. Other parameters of diabetes such as body weight were also affected on treatment with MK. Treatment with MK inhibits the reduction in bodyweight by diabetes as the treatment altered the bodyweights of diabetic animals towards normalcy.

Administration of aqueous MK leaves improved the liver function by decreasing the serum SGPT, SGOT and ALKP levels in both normal as well as in diabetic rats. The increase of SGOT and SGPT will increase the incidence of heart and liver diseases. SGOT is an enzyme found primarily in the cells of the liver, heart, skeletal muscles, kidneys, pancreas and to a lesser extent, in red blood cells. Its serum concentration is in proportion to the amount of cellular leakage or damage. It is released into serum in larger quantities when any one of these tissues is damaged. Its increased levels are usually associated with heart attacks or liver disease. MK leaves extract decreased the SGOT level, which is an indication of the protective effect on liver and heart.

The significance of SGPT, an enzyme found primarily in the liver, is far greater. Its enhanced release into the bloodstream is the result of liver abnormality. It therefore serves as a fairly specific indicator of liver status and its elevated levels in serum indicate liver damage. Increased levels of ALKP indicates bone disease, liver disease or bile tract blockage. MK leaves extract reduced the ALKP levels too indicating its protective effect over liver and improvement in liver functional efficiency.

As far as the mechanism of action of the MK extract is concerned Vinuthan et al. (2005) have suggested, on the basis of insulin measurements, that the hypoglycemic effect of MK aqueous extract may be mediated through stimulating and/or secretion from β cells of pancreatic islet of langerhans.

The aqueous extract of *Murraya koenigii* leaves contains a range of active pharmacological agents, which include carbazole alkaloids, flavonoids and tannins (Guptha and Nigam, 1971; Chakraborty et al., 1978; Wang et al., 2003). These principles are known to be bioactive for the management of diabetes (Oliver-Bever, 1986; Shammas, 1987; Rheumann and Zaman, 1989). It is known that certain alkaloids and flavonoids exhibit hypoglycemic activity (Pathak et al., 1991; Ahmad et al., 2000) and are also known for their ability of beta cell regeneration of pancreas (Chakravarti et al., 1980, 1981). Tannins have also shown to decrease blood sugar in experimental animal models (Gray and Flatt, 1998; Suba et al., 2004). Thus, the significant antidiabetic effect of aqueous extract of MK leaves may be due to the presence of more than one antihyperglycemic principle and/or their synergistic effects.

In summary, the aqueous extract exhibited strong hypolipidemic activity in addition to hypoglycemic action in diabetic animals. This has clinical implications, that the relatively non-toxic *Murraya koenigii* extract, if used as a hypoglycemic agent, may also reverse dyslipidemia associated with diabetes, and prevent the CV complications which are very prevalent in diabetic patients. The present investigation has also opened avenues for further research especially with reference to the development of potent phytomedicine for diabetes mellitus from *Murraya koenigii* leaves (patent filed Watal et al., 2003).
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References


