Antihyperglycemic activity of stigmasterol isolated from *Bacopa monnieri* Linn. aerial parts against alloxan induced diabetic rats

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Abstract

Objective: Firstly to screen the antihyperglycaemic activity of petroleum ether extract (PBM) of *Bacopa monnieri*. Finally to examine the antihyperglycaemic activity, *in-vivo* antioxidant potential, effect on glycosylation of hemoglobin, estimation of glycogen content in liver and *in-vitro* peripheral utilisation of glucose of stigmasterol (ST), a phytosterol isolated from PBM. Methods: Antihyperglycemic effect was screened against alloxan induced diabetic rats. Antioxidant activity was evaluated by measuring glycosylated hemoglobin *in-vitro* and levels of malondialdehyde (MDA), glutathione (GSH) and activity of superoxide dismutase (SOD) and catalase (CAT) in liver of diabetic rats *in-vivo*. Preliminary mode of action was determined by measuring glycogen content in the liver of diabetic rats *in-vivo* and peripheral glucose utilisation in the diaphragm of diabetic rats *in-vitro*. Results: Both PBM and ST produced significant decrease in the blood glucose level when compared with the diabetic rats both in the single and multiple dose study. ST prevented elevation of glycosylated hemoglobin, with IC₅₀ value being 7.44 µg/ml that is comparable with α-tocopherol. Administration of ST and glibenclamide significantly decreased the levels of MDA, increased the level of GSH and activity of SOD and CAT in liver of diabetic rats. ST increased glycogen content in the liver and peripheral glucose utilisation in the diaphragm of diabetic rats which is comparable with the action of insulin. Conclusion: Hence, ST might have insulin like activity and its antihyperglycemic effect might be due to an increase in peripheral glucose consumption as well as protection against oxidative damage in alloxanised diabetes.

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Key words: *Bacopa monnieri*, stigmasterol, antihyperglycaemic activity, antioxidant activity

1. Introduction

Nearly 10% of the population is affected every year by diabetes mellitus, a metabolic disorder of carbohydrate, fat and protein metabolism [1]. Its treatment includes the use of oral hypoglycemic agents and insulin, the former being reported to have serious side effects [2]. Many plants have been recognized to be effective in the treatment of diabetes mellitus [3], which leads to increasing demand for herbal products with antidiabetic factor and little side effects. *Bacopa monnieri* Linn. (Fam-Scrophulariaceae) is a creeping, glabrous, succulent herb, rooting at nodes, distributed throughout India in all plain districts [4]. The plant is reported to contain tetracyclic triterpenoid saponins, bacosides A and B, hersaponin, alkaloids viz. herpestine and brahmine, flavonoids [5].

In Ayurveda, the plant has been used in the treatment of insanity, epilepsy and hysteria [6]. The other reported activities include sedative, antiepileptic, vasoconstrictor and antiinflammatory respectively [4]. Phytosterols are natural products, which have been shown to possess cholesterol lowering [7], anti diabetic [8].

As *B. monnieri* contains phytosterols it is thought worthwhile to investigate the antidiabetic activity of stigmasterol, a phytosterol isolated from aerial parts of *Bacopa monnieri* Linn. in a scientific manner. In the present paper we report the antihyperglycaemic activity of PBM as well as antihyperglycaemic activity, *in-vivo* antioxidant potential, effect on glycosylation of hemoglobin, glycogen content of liver and *in-vitro* peripheral utilisation of glucose of stigmasterol, isolated
from PBM.

2. Materials and Methods

2.1. Plant material

The plant was identified by the taxonomists of the Botanical Survey of India, Govt. of India, Howrah. A voucher specimen is kept in our department for further reference. Fresh aerial parts of the young and matured plants were collected in bulk from the rural belt of Salipur, Orissa, India during early summer, washed, shade dried and then milled in to coarse powder by a mechanical grinder.

2.2. Isolation of compound

Stigmasterol was isolated from the petroleum ether extract of the aerial parts of *Bacopa monnieri* according to the method of Ghosh et al., 2011 (9).

2.3. Animals used

Wistar albino rats of either sex, weighing 180 – 250 g were used. The selected animals were housed in acrylic cages in standard environmental conditions (25 – 30°C). They were allowed free access to standard dry pellet diet (Hindustan Lever, Kolkata, India) and water *ad libitum*. All animal experiments were in accordance with our Institutional Animal Ethical Committee guidelines.

2.4. Drugs and chemicals used

Thiobarbituric acid, Nitro blue tetrazolium chloride (NBT), Hemoglobin (Loba Chemie, Mumbai, India), 5,5'-dithio bis-2-nitrobenzoic acid (DTNB) were used. All the solvents were of analytical grade.

2.5. Screening for antidiabetic activity [10]

The animals were considered diabetic when the blood glucose level was raised beyond 300 mg/dl of blood after 72 h of i.p. injection of 150 mg/kg of alloxan monohydrate in normal saline.

2.5.1. Experiment 1

The PBM was evaluated for their antidiabetic activity.

2.5.1.1. Single dose study

Animals were segregated into five groups of six rats in each. Group I and II rats were randomly selected from normal rats which received only distilled water and stigmasterol (5 and 10 mg/kg, p.o.) respectively. Group IV and V animals were treated with the PBM (300 mg/kg, p.o.) and glibenclamide (600 µg/kg) respectively in a similar manner. Blood was collected from the tip of tail of each rat under mild ether anesthesia at 0h, 1h, 2h and 4h after the administration of test samples. Estimation of blood glucose was carried out with the haemoglucostrips (Lifescan, Inc. USA) with the help of a Johnson & Johnson ONE TOUCH blood glucometer.

2.5.1.2. Multidose study

Administration of test samples was continued for 10 days, once daily. Blood samples were collected and estimated as above on the 1, 3, 7 and 10th day of the drug administration. Body weights of all the animals were recorded just prior to and on the 10th day of the study to determine the change in the body weight if any.

2.5.2. Experiment 2

Stigmasterol was evaluated for its antidiabetic activity

2.5.2.1. Single dose study

Animals were segregated into seven groups of six rats in each. Group I, II and III rats were randomly selected from normal rats which received only distilled water and stigmasterol (5 and 10 mg/kg, p.o.) respectively. Group IV to Group VII animals were selected from the alloxanised rats. Group IV animals served as diabetic control. Group V, VI and VII animals were treated with stigmasterol (5 and 10 mg/kg, p.o.) [10] and glibenclamide (600 µg/kg) respectively in a similar manner. The rest of the study is similar to that of experiment 1.

2.5.2.2. Multidose study

Multidose study is similar to that explained in experiment 1, but with stigmasterol at a dose of 5 and 10 mg/kg, p.o. respectively.

2.5.2.3. Effect on oral glucose tolerance in rats

Animals were segregated into different groups as stated in single dose study in experiment 2. After overnight fasting, a 0-min blood glucose level was estimated in different groups and without delay a glucose solution (2 g/kg) was administered. Four more blood samples were taken at 30, 60, 90 and 120 min after glucose administration (11) and estimated for blood glucose level.

2.5.2.4. Determination of in vivo antioxidant activity

On the 10th day following study, the animals were deprived of food overnight and sacrificed by cervical dislocation. The livers were dissected out, washed in ice-cold saline, patted dry and weighed. A 10% w/v of homogenate was prepared in 0.15 M Tris-HCl buffer and processed for the estimation of lipid peroxidation [12], GSH [13], SOD [14] and CAT [15].

2.5.2.5. Determination of in vitro glycosylation of hemoglobin

The degree of glycosylation of hemoglobin in vitro was measured colorimetrically as suggested by Fluckiger et al., 1978 [16].

2.5.2.6. Determination of peripheral consumption of glucose in-vitro

The method of Chattopadhyay et al. 1992 [17] was followed.

2.5.2.7. Determination of glycogen content of liver

Glycogen estimation of liver was carried out by the use of Anthrone reagent [18].

2.6. Statistical analysis

Statistical significance was determined by one way analysis of variance (ANOVA) followed by Dunnet’s t-test. p<0.05
Table 1: Effect of single dose treatment of PBM (300 mg/kg, p.o.), on blood glucose level in normal and alloxan induced diabetic rats

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Basal value</th>
<th>Blood glucose level (mg/dl)</th>
<th>Change in body weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>81.49 ± 0.63</td>
<td>81.23 ± 0.78</td>
<td>80.84 ± 0.92</td>
</tr>
<tr>
<td>Normal + PBM</td>
<td>81.56 ± 0.69</td>
<td>82.04 ± 0.87</td>
<td>82.37 ± 0.55</td>
</tr>
<tr>
<td>Diabetic control</td>
<td>327.11 ± 3.79</td>
<td>332.06 ± 2.91</td>
<td>331.79 ± 3.06</td>
</tr>
<tr>
<td>Diabetic + PBM</td>
<td>326.62 ± 5.68</td>
<td>294.04 ± 4.47</td>
<td>276.38 ± 5.17</td>
</tr>
<tr>
<td>Diabetic + Glibenclamide</td>
<td>329.55 ± 2.61</td>
<td>278.63 ± 4.74</td>
<td>254.18 ± 3.29</td>
</tr>
</tbody>
</table>

Values are mean ± SEM for n=6

a) Not significant when compared to normal group; b) p< 0.01 and c) p< 0.001 when compared to normal group

d) Not significant when compared to diabetic control group; e) p< 0.01 and f) p< 0.001 when compared to diabetic control group.

Table 2: Effect of multiple dose treatment of PBM (300 mg/kg, p.o., once daily), on blood glucose level and change in body weight after 15 days in normal and alloxan induced diabetic rats

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Blood glucose level (mg/dl)</th>
<th>Change in body weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>81.49 ± 0.63</td>
<td>81.23 ± 0.78</td>
</tr>
<tr>
<td>Normal + PBM</td>
<td>81.56 ± 0.69</td>
<td>82.04 ± 0.87</td>
</tr>
<tr>
<td>Diabetic control</td>
<td>327.11 ± 3.79</td>
<td>332.06 ± 2.91</td>
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<td>Diabetic + PBM</td>
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</tr>
</tbody>
</table>

Values are mean ± SEM for n=6

a) Not significant when compared to normal group; b) p< 0.01 and c) p< 0.001 when compared to normal group

d) Not significant when compared to diabetic control group; e) p< 0.01 and f) p< 0.001 when compared to diabetic control group.

Table 3: Effect of stigmasterol (5 and 10 mg/kg, p.o.), on oral glucose tolerance test (OGTT) in normal and alloxan induced diabetic rats

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Blood sugar level (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>76.15 ± 0.83</td>
</tr>
<tr>
<td>Normal + ST (5 mg/kg)</td>
<td>75.38 ± 0.81</td>
</tr>
<tr>
<td>Normal + ST (10 mg/kg)</td>
<td>76.49 ± 0.73</td>
</tr>
<tr>
<td>Dibetic control</td>
<td>257.19 ± 2.49</td>
</tr>
<tr>
<td>Diabetic + ST (5 mg/kg)</td>
<td>79.87 ± 0.82</td>
</tr>
<tr>
<td>Diabetic + ST (10 mg/kg)</td>
<td>79.18 ± 0.76</td>
</tr>
<tr>
<td>Diabetic + Glibenclamide</td>
<td>77.26 ± 0.48</td>
</tr>
</tbody>
</table>

Values are mean ± SEM for n=6

a) Not significant when compared to normal group; b) p< 0.01 and c) p< 0.001 when compared to normal group

d) Not significant when compared to diabetic control group; e) p< 0.01 and f) p< 0.001 when compared to diabetic control group.

Table 4: Effect of single dose treatment of stigmasterol (5 and 10 mg/kg, p.o.), on blood glucose level in normal and alloxan induced diabetic rats

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Basal value</th>
<th>Blood glucose level (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>78.59 ± 0.73</td>
<td>78.76 ± 0.83</td>
</tr>
<tr>
<td>Normal + ST (5 mg/kg)</td>
<td>78.36 ± 0.58</td>
<td>78.53 ± 0.64</td>
</tr>
<tr>
<td>Normal + ST (10 mg/kg)</td>
<td>77.82 ± 0.60</td>
<td>77.63 ± 0.82</td>
</tr>
<tr>
<td>Dibetic control</td>
<td>314.76 ± 3.82</td>
<td>316.53 ± 3.75</td>
</tr>
<tr>
<td>Diabetic + ST (5 mg/kg)</td>
<td>318.58 ± 5.17</td>
<td>304.61 ± 4.27</td>
</tr>
<tr>
<td>Diabetic + ST (10 mg/kg)</td>
<td>316.63 ± 4.29</td>
<td>289.52 ± 3.23</td>
</tr>
<tr>
<td>Diabetic + Glibenclamide</td>
<td>317.06 ± 4.19</td>
<td>283.62 ± 3.17</td>
</tr>
</tbody>
</table>

Values are mean ± SEM for n=6

a) Not significant when compared to normal group; b) p< 0.01 and c) p< 0.001 when compared to normal group

d) Not significant when compared to diabetic control group; e) p< 0.01 and f) p< 0.001 when compared to diabetic control group.
Table 5. Effect of multiple dose treatment of stigmasterol (5 and 10 mg/kg, p.o.), on blood glucose level and change in body weight after 15 days in normal and alloxan induced diabetic rats

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Blood glucose level (mg/dl)</th>
<th>Change in body weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basal value</td>
<td>Day 1</td>
</tr>
<tr>
<td>Normal (5 mg/kg)</td>
<td>78.59 ± 0.73</td>
<td>78.44 ± 0.87</td>
</tr>
<tr>
<td>Normal + ST (5 mg/kg)</td>
<td>78.36 ± 0.54a</td>
<td>77.56 ± 0.61a</td>
</tr>
<tr>
<td>Normal + ST (10 mg/kg)</td>
<td>77.82 ± 0.65a</td>
<td>77.18 ± 0.73a</td>
</tr>
<tr>
<td>Diabetic control</td>
<td>314.76 ± 3.82e</td>
<td>319.25 ± 4.16e</td>
</tr>
<tr>
<td>Diabetic + ST (5 mg/kg)</td>
<td>318.58 ± 4.82e</td>
<td>251.92 ± 3.47f</td>
</tr>
<tr>
<td>Diabetic + ST (10 mg/kg)</td>
<td>316.63 ± 5.06e</td>
<td>229.52 ± 3.41f</td>
</tr>
<tr>
<td>Diabetic + Glibenclamide</td>
<td>317.06 ± 4.19e</td>
<td>225.37 ± 3.18f</td>
</tr>
</tbody>
</table>

Values are mean ± SEM for n=6
a Not significant when compared to normal group; b p< 0.01 and c p< 0.001 when compared to normal group
d Not significant when compared to diabetic control group; f p< 0.01 and f p< 0.001 when compared to diabetic control group.

Table 6. Effect of stigmasterol on percent inhibition of hemoglobin glycosylation in vitro.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Concentration (µg/ml)</th>
<th>% inhibition ± S.D.</th>
<th>IC₅₀ (µg/ml)</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stigmasterol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2.86 ± 0.42</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>13.52 ± 2.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>34.11 ± 2.69</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>45.76 ± 3.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>70.38 ± 5.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>α-tocopherol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.74</td>
<td>0.9985</td>
<td></td>
</tr>
</tbody>
</table>

Values are Mean ± S.D. for n=3. r = regression co-efficient.

Table 7. Effect of stigmasterol on in vitro peripheral glucose consumption in diaphragm of normal and diabetic rats

<table>
<thead>
<tr>
<th>Glucose consumption (mg/ 10 mg of diaphragm dry weight)</th>
<th>Stigmasterol (µg/ml)</th>
<th>Insulin (5 U/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10 (µg/ml)</td>
<td></td>
</tr>
<tr>
<td>Normal rats</td>
<td>0.57 ± 0.05</td>
<td>0.60 ± 0.05a</td>
</tr>
<tr>
<td>Diabetic rats</td>
<td>0.62 ± 0.06</td>
<td>0.76 ± 0.04a</td>
</tr>
</tbody>
</table>

Values are mean ± SEM for n=6
a Not significant when compared to normal rats; b p< 0.05 and c p< 0.01 when compared to normal group
d Not significant when compared to diabetic control rats; f p< 0.05 and f p< 0.01 when compared to diabetic control group.

indicates significant difference between group means.

3. Results

3.1. Experiment 1

3.1.1. Single dose and multidose study
In experiment 1 the antihyperglycemic activity PBM was evaluated. Table 1 and 2 reveal that the extract when applied to normal rats did not show any significant change in the blood glucose levels (in both single and multidose studies) with respect to the normal control rats. But the extract produced significant decrease in the blood glucose level when compared with the diabetic control rats in both the single dose and multi dose experiment. It was also observed that the extract reversed the weight loss of the diabetic rats and they returned to near normal values. Hence, PBM was further exploited for isolation.

3.2. Experiment 2
PBMs on further purification led to the isolation of stigmasterol.

3.2.1. Oral glucose tolerance test
Table 3 shows the blood glucose level of normal and experimental animals after oral administration of glucose (2 g/kg). ST at a dose of 10 mg/kg showed more significant decrease in peak blood glucose level after 1 h and tended to bring the values near normal values after 2 h.

3.2.2. Single dose and multidose study
Table 4 and 5 reveals that ST is also effective only on hyperglycemic rats and has no effect on normoglycemic rats. Treatment with ST causes significant reduction (p<0.001) in blood glucose level in a dose dependant manner both in single as well as in multidose study when compared to alloxan induced diabetic rats.

In the present study it was observed that ST, in a dose dependant manner reversed the weight loss of the diabetic rats and they returned to near normal values (Table 5).

3.2.3. Determination of in vitro glycosylation of hemoglobin
The present study showed that stigmasterol significantly prevented glycosylation of hemoglobin in vitro, with IC₅₀ value being 7.44 µg/ml which is comparable with the reference drug α-tocopherol (Table 6).

3.2.4. Determination of in vivo antioxidant activity
Administration of ST significantly decreased the levels of
Fig. 2 Changes in the levels of MDA in liver of normal and diabetic rats. Values are Mean ± S.E.M. for n=6 animals. a Not significant when compared to normal group; b p< 0.05, c p< 0.01 and d p< 0.001 when compared to normal group. e Not significant when compared to diabetic control group; f p< 0.05 and g p< 0.01 and h p< 0.001 when compared to diabetic control group.

Fig. 3 Changes in the levels of reduced glutathione (GSH) in liver of normal and diabetic rats. Values are Mean ± S.E.M. for n=6 animals. a Not significant when compared to normal group; b p< 0.05, c p< 0.01 and d p< 0.001 when compared to normal group. e Not significant when compared to diabetic control group; f p< 0.05 and g p< 0.01 and h p< 0.001 when compared to diabetic control group.

MDA in diabetic rats at a dose of 5 mg/kg (p<0.05) and 10 mg/kg (p<0.001) in a dose dependant manner (Fig. 2). Administration of ST and glibenclamide increased the level of GSH in liver of diabetic rats, though no significant difference was observed in both MDA and GSH levels when ST was administered to normal rats with respect to normal control rats (Fig. 3). Administration of ST increased the activity of SOD and CAT in a dose dependant manner in diabetic rats. ST did not show any significant change in SOD and CAT activity in normal rats when compared to normal control (Fig 4, 5).

3.2.5. Determination of peripheral consumption of glucose in-vitro
Table 7 suggests that stigmasterol produces an increase in peripheral glucose consumption in the rat diaphragm of diabetic rats, in a dose dependant manner, especially at a concentration of 20 µg/ml. Insulin also increased the peripheral glucose consumption in normal and diabetic rats.

3.2.6. Determination of glycogen content of liver
ST at a dose of 10 mg/kg caused a significant increase (p<0.001) in glycogen content in liver of diabetic rats (Fig.6).
Discussion

The results clearly show that both PBM as well as ST has antihyperglycemic activity rather than hypoglycemic activity as both of them produced significant decrease in the blood glucose level when compared with the diabetic control rats in both the single dose and multi dose experiment without showing any effect on normoglycemic rats. Diabetes mellitus causes failure to use of glucose for energy which leads to increased utilization and decreased storage of protein and this is responsible for reduction of body weight [19]. The reversal of loss of body weight by the application of PBM and ST further proves their ability to prevent depletion of body proteins. Hemoglobin reacts with the excess glucose present in the blood during diabetes to form glycosylated hemoglobin and with its improvement glycosylated hemoglobin decreases [20]. It is a well known that the estimation of glycosylation of hemoglobin is a useful parameter in the management of the disease [21]. Non-enzymatic glycosylation of hemoglobin is reported to be an oxidative reaction [22]. As stigmasterol prevented significantly the increase of glycosylation of hemoglobin, it was thus expected to possess antioxidant activity and this fact was further substantiated by our in vivo antioxidant studies. One of the characteristic features of chronic diabetes is lipid peroxidation. Alloxan gives rise to dialuric acid, which generates O$_2$, H$_2$O$_2$ and OH [23] and stimulate lipid peroxidation. GSH, a tripeptide present in all the cells is an important antioxidant [24]. Decreased GSH levels in diabetes have been considered to be an indicator of increased oxidative stress [25]. The cellular radical scavenging systems include the enzymes such as SOD, which scavenges the superoxide ions by catalysing its dismutation and CAT, a haeme enzyme which removes hydrogen peroxide [26]. Our study showed an increase in lipid peroxidation and a decrease in level of GSH and activity of SOD and CAT in liver during diabetes which were reversed upon treatment with stigmasterol. These results clearly show that stigmasterol enhances antioxidant mechanism in vivo. Hyperlipidemia has been reported to accompany hyperglycaemia states [27, 28]. Hence a compound which reduces blood cholesterol might be expected to reduce blood sugar as well. It was recognized that plant sterols like stigmasterol, β-sitosterol etc. lower serum concentration of cholesterol by reducing the absorption of cholesterol from the gut by competing for the limited space for cholesterol in the mixed micelles [29, 30] and thereby might reduce blood sugar level. Another possible mechanism might be peripheral utilisation of glucose. As alloxan causes irreversible destruction of β-cells of pancreas [31], the anti hyperglycemic activity might be due to extra pancreatic mechanism. This prompted us to study the peripheral utilisation of glucose in rat diaphragm. The result suggests that stigmasterol produces an antidiabetic action mediated by an increase in peripheral glucose consumption in the rat diaphragm of diabetic rats, especially at a concentration of 20 µg/ml (Table 7). Insulin increased the peripheral glucose consumption in normal and diabetic rats. Thus, ST might have insulin like activity and the antihyperglycemic effect might be due to an increase in peripheral glucose consumption. The above in vitro observation was further substantiated by observing the effect of ST on glycogen content in liver of diabetic rats in vivo. It has been reported that insulin is a potent activator of glycogen synthase and hexokinase, responsible for the formation of glycogen and inhibitor of glycogen phosphorylase responsible for glycogenolysis in liver [32]. Insulin deficiency in diabetes, results in decreased concentrations of glycogen in liver. ST causes a significant increase in glycogen content in liver of diabetic rats and thus further proved its insulin-like activity leading to increased uptake of glucose.

Thus, from the present study it is evident that ST, a phytosterol isolated from PBM possesses significant antihyperglycemic activity against alloxan induced diabetic rats, though it did not show any activity on normal rats. The above mentioned activity might be attributed to the protective action of ST on lipid peroxidation and at the same time the enhancing effects on cellular antioxidant defense contributing to the protection against oxidative damage in alloxanised diabetes leading to improvement of tissues and subsequent increase in uptake and utilization of blood glucose.

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References


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