

Research article

Phytochemical and pharmacological evaluation of *Abelmoschus esculentus* (Lady's Finger) extracts for antidiabetic activity

Kalyani Kulkarni

C.U. Shah College of Pharmacy, S.N.D.T. Women's University, Sir Vithaldas Vidyavihar, Juhu Tara Road, Santacruz (W) Mumbai-400049, India.

Key words: *Abelmoschus esculentus*, Streptozotocin, SGPT, SGOT.

***Corresponding Author:** Kalyani Kulkarni, N-2, CIDCO, Mahajan Colony, Mukund Housing Society, Aurangabad. 431003.

Abstract

The present investigation was aimed to study antidiabetic activity of *Abelmoschus esculentus* extracts in streptozotocin (STZ) induced rat model. Extracts of *Abelmoschus esculentus* were subjected to qualitative tests for presence of various phytochemical constituents. TLC and HPTLC studies of the extracts were carried out to identify various phytoconstituents present in the extracts. Further, acute toxicity study was carried out by administering the test solutions orally to rats, at the dose level of 2000 mg/kg for 14 days, to check whether the test solution had any toxic effects. Experimental diabetes mellitus was induced by injecting streptozotocin in normal adult male wistar rats. Intra-peritoneal injection of 60mg/kg dose of streptozotocin in adult wistar male rats, made pancreas swell and caused degeneration in islet of Langerhans and induced experimental diabetes mellitus in 2-4 days. Blood glucose levels and body weights were estimated on 0th, 7th, 14th, 21st and 28th day of the study whereas, various biochemical parameters like SGOT, SGPT, cholesterol, HDL cholesterol, LDL cholesterol, triglycerides, urea, creatinine and total protein were estimated on 0th, 14th and 28th day of the study. There was a significant decrease in the blood glucose levels and a significant increase in the body weights of rats when compared to diabetic rats group. Also, all the biochemical parameters showed a significant decrease in their levels at the end of the study.

Introduction

Diabetes mellitus (DM) is a metabolic disorder resulting from a defect in insulin secretion, insulin action, or both. Insulin deficiency in turn leads to chronic hyperglycemia with impaired carbohydrate, fat and protein metabolism. The symptoms of diabetes mellitus are weight loss, polyuria, excessive thirst, blurred vision, etc [1].

Physical inactivity and unhealthy dietary habits result in overweight and insulin resistance, are the risk factors for the development of Type 2 diabetes. There is growing interest in the use of natural drugs as the chemical agents causes adverse effects. Medicinal plants like *Acacia arabica* Lam., *Aegle marmelos* Linn., *Allium sativum* Linn., *Aloe vera* Linn., *Areca catechu* Linn., *Artemisia pallens* Wall., *Azadirachta indica*, *Abelmoschus esculentus*, *Cochlospermum vitifolium*, *Equisetum myriochaetum*, *Tinospora cordifolia*, *Gymnema sylvestre*, *Momordica charantia*, *Andrographis paniculata* Nees, *Eugenia jamboana*, are used as an alternative approach to current medications and also used to manage diabetes [2].

The present research is carried out to evaluate the antidiabetic activity of *Abelmoschus esculentus*.

Abelmoschus esculentus Linn. is a plant of family Malvaceae. Due to the nutrient content of the *A. esculentus*, the pods, flowers, leaves and fruits are used as therapeutic diets. It is reported that the plant shows good anti-depressant, antioxidant, anti-inflammatory and anti-swelling activity. Use of *Abelmoschus esculentus* as a mucilage or as an extract has been reported to reduce serum cholesterol, triacylglyceride, and blood pressure [3].

Materials and Methods

The drug was procured from local market. Color, odor, taste, shape, size and texture of the plant material were estimated by visual and sensory evaluation.

Preparation of different extracts and fractions from fruits of *Abelmoschus esculentus*

A) Aqueous extract of dry powder from fruits of okra

Okra fruits were oven dried completely and ground to coarse powder. The powder was extracted with water by

refluxing it. The aqueous extract was filtered and concentrated to a dry mass.

B) Aqueous extract of fresh fruits of okra

Okra fruits were soaked overnight in water. The slimy mucilage was scraped off from the fruits and water was evaporated until a complete dry mass of the mucilage was obtained.

C) Mucilaginous extract

Same procedure as that of the aqueous extract was followed and the mucilage was filtered to separate water and mucilage obtained was used as mucilaginous extract.

Phytochemical screening of different extracts

All the extracts were subjected to qualitative tests for the identification of various phytochemical constituents. Carbohydrates, proteins and amino acid, gums and mucilage, flavonoids, tannins and phenolic compounds were present in the extracts.

TLC studies

Chloroform: methanol (50:50) gave best resolution and maximum number of spots of phytoconstituents in the extract. Pre-coated TLC plate of silica Gel 60 GF₂₅₄ was used as stationary phase. After activating the plate prior to use, sample was applied and developed in a saturating chamber. The plate was observed under UV light, at 254 nm and 366 nm. Visualizing agents like ASR, ninhydrin, ethanolic sulphuric acid, ferric chloride and Dragendroff's reagents were used for derivatizing the plates, to detect presence of phytoconstituents.

HPTLC studies

The aqueous extract of *A. esculentus* was prepared with the concentration of 1 mg/ml. The solution was applied on TLC plate in an increasing concentration such as 10 μ l, 20 μ l, 30 μ l, 40 μ l, 50 μ l using Camag linomat IV applicator and Camag scanner III. Sample was spotted on pre-coated silica gel 60 GF₂₅₄, allowed to develop for 15 min. and then the plate was scanned 254 and 366 nm in TLC visualizer. The mobile phase used was chloroform: methanol (50: 50).

Chemicals

Streptozotocin was purchased from himedia. Kits used for determination of liver function, kidney function and various biochemical parameters were purchased from ARK diagnostics. All the chemicals used in this study are of analytical grade.

Experimental animals

Male wistar rats of either weighing between 180-250 gm were used for antidiabetic activity and were housed in standard environmental conditions (12h / 12h light and

dark) at 25 \pm 3 $^{\circ}$ C. They were fed with standard rat pellet and water *ad libitum*. Experiment was performed according to the guidelines and the study was approved by the Institutional Animal Ethics Committee.

Acute toxicity study

This study was performed as per OECD guideline 423, by administering the test solutions orally to rats, at the dose level of 2000 mg/kg. Signs and symptoms of toxicity were observed for 14 days. No toxicity or death was observed in the experimental rats when they were subjected to toxicity study.

Induction of diabetes

Diabetes was induced by injecting streptozotocin in normal adult male wistar rats. Intra-peritoneal injection of 60mg/kg dose of streptozotocin in adult wistar male rats, makes pancreas swell and causes degeneration in islet of Langerhans and induces experimental diabetes mellitus in the 2-4 days. For induction of experimental diabetes in male adult rats weighted 180-250 grams, 60mg/kg of streptozotocin was injected intraperitoneally. The diabetic and normal animals were kept in the cages separately and their body weight and the levels of serum glucose in all animals were measured and then these parameters were compared.

Experimental design for antidiabetic activity

All the three extracts and standard solution were administered twice daily at 10 am in morning and 5 pm in the evening. All the animals were monitored daily for any signs of abnormalities. Body weight and blood glucose levels were estimated on 0th, 7th, 14th, 21st and 28th day of the study. At the end of the experimental period, the animals were fasted overnight and blood samples were withdrawn from the retro orbital plexus. Serum samples were analyzed for various biochemical parameters like serum triglycerides, total cholesterol, high density lipoprotein, creatinine, blood urea nitrogen, total protein, SGOT, SGPT. The animals were sacrificed to isolate some of the vital organs like kidney, liver, pancreas for histopathological study (Table 1).

Table 1. Groups of Animals for Antidiabetic Study

| Group Number | Name of drug |
|-----------------------------|--|
| Group I (normal control) | Nil |
| Group II (Diabetic control) | 0.2% carboxy methyl cellulose (CMC). |
| Group III- A | Dry powder extract of <i>A. esculentus</i> (200 mg/kg) |
| Group III- B | Dry powder extract of <i>A. esculentus</i> (400 mg/kg) |
| Group IV- A | Aq. extract of <i>A. esculentus</i> (200 mg/kg) |
| Group IV- B | Aq. extract of <i>A. esculentus</i> (400 mg/kg) |
| Group V-A | Mucilage of <i>A. esculentus</i> (200 mg/kg) |
| Group V-B | Mucilage of <i>A. esculentus</i> (400 mg/kg) |
| Group IV | Glibenclamide (10mg/kg) |

Statistical analysis

Statistical analysis was carried out using instat software. All the results were expressed as mean \pm SEM. Post hoc Dunnett's test was used to determine statistical significance of the results obtained.

Results and Discussion

Solvent used for extraction was water which is highly polar in nature. Hence, all the three extracts were found to contain polar constituents such as carbohydrates, proteins and amino acid, gums and mucilage, flavonoids, tannins and phenolic compounds.

TLC and HPTLC studies

Chloroform: methanol gave optimum resolution. The TLC plate was sprayed with ferric chloride reagent, gave brown colored spot indicating presence of tannins. When the plate was sprayed with Ninhydrin solution, the separated constituent gave pink colored spot which indicated the presence of proteins or amino acid (Figure 1).

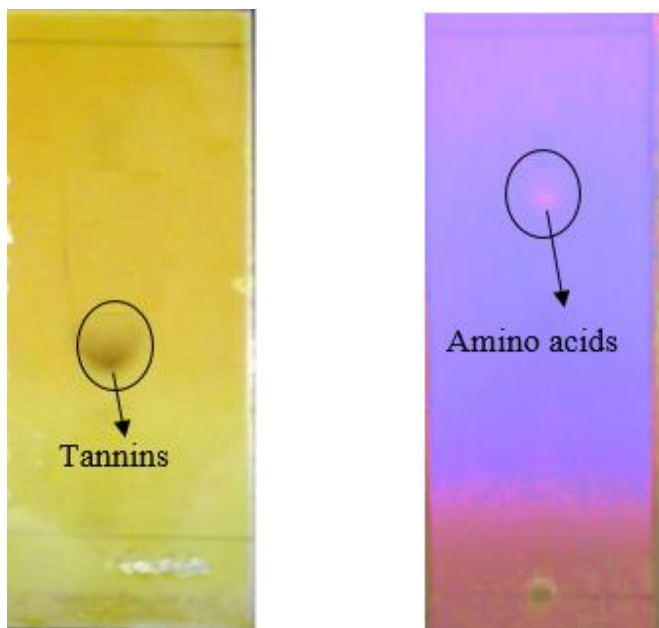


Figure 1. TLC Plate Sprayed With Spraying Reagents:
A: ferric chloride solution
B: ninhydrin solution

HPTLC study

The plate was developed with the mobile phase chloroform: methanol (50:50) for 20 min. After chromatographic development, the TLC plate was scanned over the wavelength of 254 and 366 nm. Four distinct, well separated spots were observed on the plate with Rf values of 0.19, 0.24, 0.47, 0.70 (Figure 2, 3, 4).

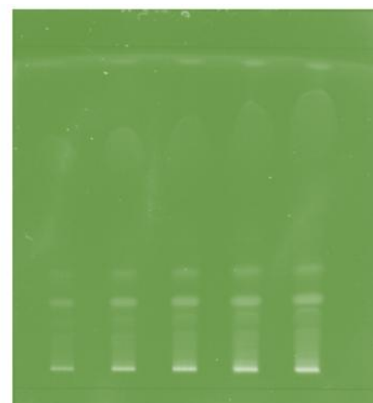


Figure 2. Video image of TLC plate of extract of dry *Abelmoschus esculentus* powder at 254 nm.

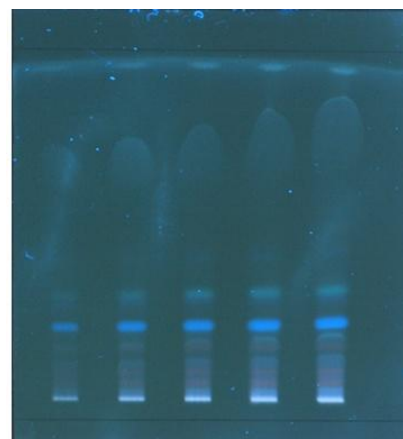


Figure 3. Video image of TLC plate of extract of dry *Abelmoschus esculentus* powder at 366 nm.

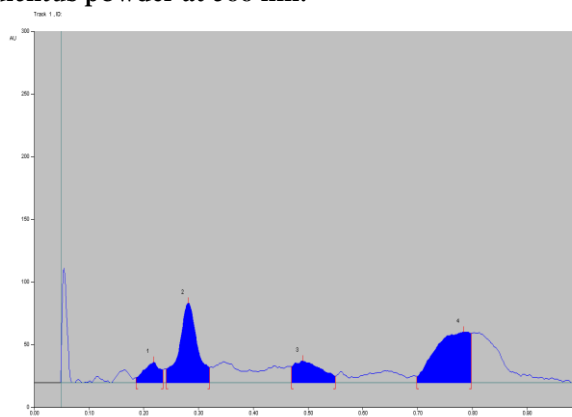


Figure 4. HPTLC chromatogram of aqueous extract obtain from dry *Abelmoschus esculentus* powder.

Evaluation of antidiabetic activity of *Abelmoschus esculentus* extracts

Body weight and blood glucose levels of rats were studied to determine the effectiveness of *Abelmoschus esculentus* extracts.

There was a sudden increase in body weight on 28th day of the study with the dose of 400 mg/kg. Rats treated with aqueous extract showed maximum activity (Table 2).

Blood glucose levels of all the three extract treated groups animals were not as low as the normal control group

animals. But there was statistically significant decrease in the blood glucose levels at the end of the study. All the three extracts showed decrease in the blood glucose levels, at the dose level of 400 mg/kg as compared to the dose level of 200 mg/kg. Extract of dry powder of *A.esculentus* showed maximum activity as compared to the other two extracts (Table 3).

Effect of extracts on various Biochemical parameters

Biochemical parameters such as SGPT, SGOT, total cholesterol, HDL, creatinine, triglyceride, urea and total protein levels were studied to determine the potency of *Abelmoschus esculentus* extracts.

Table 2. Effect of Different Extracts on Body Weight of Rats

| Groups | Body weight (g \pm SEM) | | | | |
|--------------------------------|---------------------------|---------------------|----------------------|----------------------|----------------------|
| | 0 day | 7 th day | 14 th day | 21 st day | 28 th day |
| Normal | 240 \pm 4.1 | 254 \pm 4 | 264 \pm 3 | 274 \pm 4 | 284 \pm 3 |
| Diabetic | 255 \pm 4 | 213 \pm 5 | 212 \pm 6 | 194 \pm 5 | 186 \pm 4 |
| Standard | 240 \pm 4 | 206 \pm 4 | 202 \pm 4 | 210 \pm 3 | 220 \pm 4* |
| Dry powder extract (200 mg/kg) | 210 \pm 5 | 195 \pm 3 | 189 \pm 4 | 195 \pm 4 | 200 \pm 3* |
| Dry powder extract (400 mg/kg) | 221 \pm 5 | 203 \pm 4 | 191 \pm 3 | 197 \pm 3 | 203 \pm 3* |
| Aqueous extract (200 mg/kg) | 230 \pm 2 | 220 \pm 3 | 210 \pm 2 | 215 \pm 3 | 219 \pm 2* |
| Aqueous extract (400 mg/kg) | 228 \pm 3 | 222 \pm 3 | 217 \pm 3 | 222 \pm 3 | 238 \pm 13* |
| Mucilage (200 mg/kg) | 215 \pm 2 | 200 \pm 3 | 206 \pm 2 | 207 \pm 3 | 210 \pm 2* |
| Mucilage (400 mg/kg) | 216 \pm 4 | 212 \pm 4 | 208 \pm 4 | 211 \pm 4 | 215 \pm 4* |

Values are expressed as mean \pm SEM, n = 6; n = Number of animals.

*significant decrease when compared with normal control group, p<0.05

Table 3. Effect of Extracys on Blood Glucose Levels of Rats

| Groups | Blood glucose levels (mg/dL \pm SEM) | | | | | % decrease |
|--------------------------------|--|---------------------|----------------------|----------------------|----------------------|------------|
| | 0 day | 7 th day | 14 th day | 21 st day | 28 th day | |
| Normal | 79 \pm 4 | 79 \pm 1 | 79 \pm 2 | 75 \pm 3 | 78 \pm 2 | - |
| Diabetic | 367 \pm 13 | 377 \pm 13 | 400 \pm 11 | 423 \pm 11 | 468 \pm 9 | - |
| Standard | 385 \pm 9 | 270 \pm 14 | 221 \pm 8** | 174 \pm 8** | 136 \pm 6** | 64.41 |
| Dry powder extract (200 mg/kg) | 390 \pm 8 | 363 \pm 8 | 334 \pm 7** | 310 \pm 7** | 187 \pm 8** | 52.24 |
| Dry powder extract (400 mg/kg) | 392 \pm 7 | 350 \pm 7 | 320 \pm 7** | 203 \pm 12** | 154 \pm 13** | 60.84 |
| Aqueous extract (200 mg/kg) | 400 \pm 12 | 377 \pm 13 | 352 \pm 12** | 313 \pm 12** | 198 \pm 1** | 50.69 |
| Aqueous extract (400 mg/kg) | 402 \pm 13 | 360 \pm 13 | 333 \pm 13** | 287 \pm 13** | 173 \pm 13** | 57.27 |
| Mucilage (200 mg/kg) | 390 \pm 6 | 300 \pm 8 | 251 \pm 9** | 225 \pm 8** | 188 \pm 9** | 52.78 |
| Mucilage (400 mg/kg) | 382 \pm 9 | 350 \pm 9 | 278 \pm 9** | 224 \pm 9** | 189 \pm 8** | 50.67 |

Values are expressed as mean \pm SEM, n = 6; n = Number of animals.

**significant decrease when compared with normal control group, p<0.01

Table 4. Effects of Extracts on SGOT Levels

| Group | Effect on SGOT levels (U/L) | | |
|--------------------------------|-----------------------------|----------------------|----------------------|
| | 0 th day | 14 th day | 28 th day |
| Normal | 50.12 \pm 5 | 50.78 \pm 4 | 49 \pm 3 |
| Diabetic | 50.43 \pm 6 | 100.0 \pm 7 | 129 \pm 8 |
| Standard | 70.55 \pm 6 | 98.0 \pm 5 | 96 \pm 5 |
| Dry powder extract (200 mg/kg) | 70.30 \pm 5 | 115 \pm 5 | 113 \pm 4 |
| Dry powder extract (400 mg/kg) | 71.89 \pm 5 | 113.78 \pm 4 | 112 \pm 2 |
| Aqueous extract (200 mg/kg) | 70.32 \pm 6 | 116 \pm 3 | 114 \pm 5 |
| Aqueous extract (400 mg/kg) | 71.90 \pm 5 | 114.78 \pm 3 | 115 \pm 2 |
| Mucilage (200 mg/kg) | 72.33 \pm 4 | 116 \pm 4 | 114 \pm 4 |
| Mucilage (400 mg/kg) | 72.90 \pm 5 | 114.89 \pm 3 | 115 \pm 2 |

Values are expressed as mean \pm SEM, n = 6; n = Number of animals

SGOT levels were found to decrease slightly or found to be constant from day 14 to day 28. All the three extracts treatment groups showed similar levels of SGOT as that of standard at the end of the study (Table 4).

SGPT levels of diabetic rats were found to increase from day 0 to day 28. Standard treatment group and extracts treatment groups rats showed increase in SGPT levels from day 0 to day 14. However, the levels were found to decrease slightly or found to be constant from day 14 to day 28 (Table 5). Hence, the extracts could be potential liver protective agents.

Cholesterol levels were significantly higher in diabetic control rats as compared to that of the normal control group rats. Cholesterol levels of all the extracts treated group animals were found to decrease or remain constant from 14th day to 28th day (Table 6).

Table 5. Effect of Extracts on SGPT levels

| Group | Effect on SGPT levels (U/L) | | |
|--------------------------------|-----------------------------|----------------------|----------------------|
| | 0 th day | 14 th day | 28 th day |
| Normal | 50.88 ± 2 | 46.78 ± 2 | 45 ± 1 |
| Diabetic | 60.56 ± 4 | 66.0 ± 8 | 71 ± 14 |
| Standard | 60.43 ± 2 | 65.78 ± 2 | 64 ± 1 |
| Dry powder extract (200 mg/kg) | 60.38 ± 3 | 66.79 ± 3 | 66.50 ± 2 |
| Dry powder extract (400 mg/kg) | 60.77 ± 3 | 66.75 ± 2 | 66 ± 1 |
| Aqueous extract (200 mg/kg) | 61.54 ± 2 | 69.33 ± 2 | 69.21 ± 2 |
| Aqueous extract (400 mg/kg) | 61.43 ± 2 | 68.90 ± 2 | 68 ± 1 |
| Mucilage (200 mg/kg) | 60.89 ± 3 | 70.43 ± 2 | 69.15 ± 1 |
| Mucilage (400 mg/kg) | 61.55 ± 3 | 70.2 ± 1 | 69 ± 1 |

Values are expressed as mean ± SEM, n = 6; n = Number of animals.

Table 6. Effect of Extracts on Total Cholesterol Levels

| Group | Effect on Total cholesterol levels (mg/dL) | | |
|--------------------------------|--|----------------------|----------------------|
| | 0 th day | 14 th day | 28 th day |
| Normal | 73.44 ± 3 | 73.41 ± 2 | 73 ± 2 |
| Diabetic | 74.66 ± 3 | 90.23 ± 3 | 130 ± 3 |
| Standard | 75.89 ± 4 | 84.67 ± 5 | 83 ± 4 |
| Dry powder extract (200 mg/kg) | 75.33 ± 3 | 89.21 ± 4 | 89 ± 4 |
| Dry powder extract (400 mg/kg) | 75.66 ± 3 | 88.78 ± 5 | 88 ± 4 |
| Aqueous extract (200 mg/kg) | 74.88 ± 3 | 88.56 ± 5 | 90.12 ± 4 |
| Aqueous extract (400 mg/kg) | 74.78 ± 4 | 88.67 ± 6 | 89 ± 4 |
| Mucilage (200 mg/kg) | 74.12 ± 3 | 90.56 ± 4 | 90.14 ± 4 |
| Mucilage (400 mg/kg) | 73.67 ± 4 | 90.45 ± 5 | 90 ± 4 |

Values are expressed as mean ± SEM, n = 6; n = Number of animals.

Table 7. Effect of Extracts on HDL Levels

| Group | Effect on HDL levels (mg/dL) | | |
|--------------------------------|------------------------------|----------------------|----------------------|
| | 0 th day | 14 th day | 28 th day |
| Normal | 42.22 ± 2 | 43.45 ± 2 | 42 ± 1 |
| Diabetic | 43.43 ± 3 | 33.65 ± 2 | 24 ± 2 |
| Standard | 42.67 ± 0.1 | 38.78 ± 1 | 34 ± 2 |
| Dry powder extract (200 mg/kg) | 42.37 ± 0.2 | 35.13 ± 1 | 37 ± 1 |
| Dry powder extract (400 mg/kg) | 42.98 ± 0.2 | 34.56 ± 1 | 36 ± 1 |
| Aqueous extract (200 mg/kg) | 41.38 ± 0.2 | 37.44 ± 1 | 38 ± 1 |
| Aqueous extract (400 mg/kg) | 41.32 ± 0.2 | 32.45 ± 1 | 33 ± 2 |
| Mucilage(200 mg/kg) | 41.68 ± 1 | 30.13 ± 2 | 32.98 ± 3 |
| Mucilage (400 mg/kg) | 42.56 ± 1 | 31.34 ± 2 | 33 ± 3 |

Values are expressed as mean ± SEM, n = 6; n = Number of animals.

HDL levels of rats treated with all the three extracts showed higher HDL levels when compared to diabetic control group (Table 7).

The triglyceride levels were significantly higher in diabetic rats as compared to the extracts treated and standard treated group rats at the end of the study (Table 8).

The creatinine levels were significantly higher in diabetic rats as compared to the normal rats at the end of the study. Extracts treated group rats showed slight or minimal decrease in creatinine levels from day 14 to day 28. This indicates that the extracts were effective after 14th day of the treatment (Table 9).

The rise urea level was found in diabetic control group when compared with normal control group on 14th and 28th day of treatment. Urea levels of all the extracts treated group animals were found to decrease or remain constant from 14th day to 28th day. This indicates that the extracts were effective after 14th day of the treatment (Table 10).

Table 8. Effect of Extracts on Triglyceride Levels

| Group | Effect on Triglyceride levels (mg/dL) | | |
|--------------------------------|---------------------------------------|----------------------|----------------------|
| | 0 th day | 14 th day | 28 th day |
| Normal | 77.43 ± 4 | 72.0 ± 3 | 72 ± 3 |
| Diabetic | 76.54 ± 2 | 110.43 ± 4 | 149 ± 5 |
| Standard | 78.54 ± 2 | 79.89 ± 4 | 79 ± 3 |
| Dry powder extract (200 mg/kg) | 78.34 ± 3 | 91.12 ± 3 | 88 ± 2 |
| Dry powder extract (400 mg/kg) | 78.76 ± 4 | 90.44 ± 3 | 89 ± 2 |
| Aqueous extract (200 mg/kg) | 78.14 ± 3 | 93.23 ± 4 | 87.12 ± 1 |
| Aqueous extract (400 mg/kg) | 78.0 ± 3 | 93.12 ± 3 | 88 ± 1 |
| Mucilage (200 mg/kg) | 78.56 ± 3 | 90.56 ± 4 | 89.11 ± 1 |
| Mucilage (400 mg/kg) | 77.36 ± 4 | 90.34 ± 2 | 89 ± 1 |

Values are expressed as mean ± SEM, n = 6; n = Number of animals.

Table 9. Effect of Extracts on Creatinine Levels

| Group | Effect on Creatinine levels (mg/dL) | | |
|--------------------------------|-------------------------------------|----------------------|----------------------|
| | 0 th day | 14 th day | 28 th day |
| Normal | 0.61 ± 0.01 | 0.77 ± 0.02 | 0.70 ± 0.01 |
| Diabetic | 0.66 ± 0.06 | 0.78 ± 0.06 | 0.87 ± 0.06 |
| Standard | 0.65 ± 0.02 | 0.79 ± 0.01 | 0.76 ± 0.01 |
| Dry powder extract (200 mg/kg) | 0.67 ± 0.01 | 0.78 ± 0.01 | 0.75 ± 0.02 |
| Dry powder extract (400 mg/kg) | 0.66 ± 0.01 | 0.77 ± 0.02 | 0.74 ± 0.01 |
| Aqueous extract (200 mg/kg) | 0.65 ± 0.01 | 0.76 ± 0.01 | 0.73 ± 0.03 |
| Aqueous extract (400 mg/kg) | 0.64 ± 0.01 | 0.75 ± 0.01 | 0.74 ± 0.008 |
| Mucilage (200 mg/kg) | 0.63 ± 0.01 | 0.77 ± 0.02 | 0.75 ± 0.008 |
| Mucilage (400 mg/kg) | 0.64 ± 0.01 | 0.76 ± 0.01 | 0.75 ± 0.008 |

Values are expressed as mean ± SEM, n = 6; n = Number of animals.

Table 10. Effect of Extracts on Urea Levels

| Group | Effect on Urea levels (mg/dL) | | |
|--------------------------------|-------------------------------|-------------|-------------|
| | 0th day | 14th day | 28th day |
| Normal | 17.56 ± 0.5 | 18.12 ± 0.5 | 17 ± 0.5 |
| Diabetic | 18.34 ± 0.4 | 33.56 ± 0.5 | 29 ± 0.5 |
| Standard | 18.94 ± 0.3 | 23.45 ± 1 | 21 ± 1.1 |
| Dry powder extract (200 mg/kg) | 17.36 ± 0.3 | 26.37 ± 0.5 | 24.12 ± 0.6 |
| Dry powder extract (400 mg/kg) | 18.67 ± 0.5 | 25.34 ± 0.6 | 22 ± 0.7 |
| Aqueous extract (200 mg/kg) | 18.34 ± 0.2 | 23.56 ± 0.5 | 22.23 ± 0.6 |
| Aqueous extract (400 mg/kg) | 19.22 ± 0.3 | 21.89 ± 0.6 | 24 ± 0.7 |
| Mucilage (200 mg/kg) | 18.43 ± 0.3 | 23.67 ± 0.4 | 23.11 ± 0.6 |
| Mucilage (400 mg/kg) | 17.67 ± 0.4 | 22.66 ± 0.8 | 23 ± 0.8 |

Values are expressed as mean ± SEM, n = 6; n = Number of animals.

Diabetic control group showed decrease in total protein levels as compared to the normal control group. Total protein levels of standard treatment group were found increase on 14th day of the treatment and remained constant on 28th day. All the three extracts treatment group animals did not show much increase in the total protein levels at the end of the treatment period when compared to that on the 14th day of the study (Table 11).

Table 11. Effect of Extracts on Total Protein

| Group | Effect on Total protein levels (mg/dL) | | |
|--------------------------------|--|------------|------------|
| | 0th day | 14th day | 28th day |
| Normal | 7.45 ± 0.2 | 7.00 ± 0.1 | 7 ± 0.1 |
| Diabetic | 5.67 ± 0.2 | 6.89 ± 0.3 | 6 ± 0.3 |
| Standard | 7.32 ± 0.2 | 9.56 ± 0.2 | 7 ± 0.1 |
| Dry powder extract (200 mg/kg) | 7.34 ± 0.2 | 8.23 ± 0.2 | 6.34 ± 0.3 |
| Dry powder extract (400 mg/kg) | 6.78 ± 0.1 | 7.43 ± 0.3 | 6 ± 0.3 |
| Aqueous extract (200 mg/kg) | 6.67 ± 0.2 | 7.86 ± 0.4 | 7.14 ± 0.2 |
| Aqueous extract (400 mg/kg) | 5.67 ± 0.2 | 8.76 ± 0.2 | 7 ± 0.2 |
| Mucilage (200 mg/kg) | 6.78 ± 0.1 | 7.33 ± 0.1 | 7 ± 0.2 |
| Mucilage (400 mg/kg) | 6.23 ± 0.1 | 7.14 ± 0.2 | 6 ± 0.2 |

Values are expressed as mean ± SEM, n = 6; n = Number of animals.

Histopathological studies

The animals were sacrificed at the end of the study, dissected and small slices of liver, pancreas and kidney were taken and fixed in 10% formalin.

Liver

In diabetic rats treated with dry powder extract (Figure 5-D), aqueous extract (Figure 5-E) and mucilage treated group (Figure 5-F), liver showed small amount of

granular degeneration as compared to the liver of diabetic rats.

Kidney

Diabetic rats treated with dry powder extract (Figure 6-D), aqueous extract (Figure 6-E) and mucilage treated group (Figure 6-F), kidney showed minimal cellular degeneration.

Pancreas

Diabetic rats treated with standard drug (Figure 7-C), showed no degeneration and necrosis of islets of Langerhans. Diabetic rats treated with dry powder extract (Figure 7-D), aqueous extract (Figure 7-E) and mucilage treated group (Figure 7-F), showed abnormal structure of islets but did not show degeneration of islets of Langerhans.

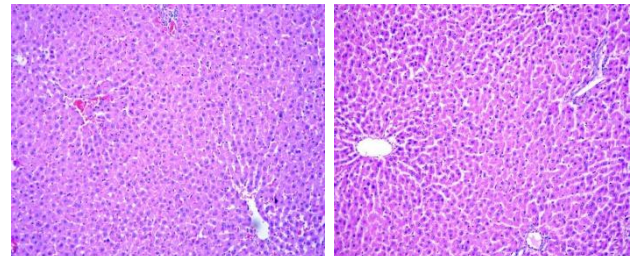


Figure 5-A

Figure 5-B

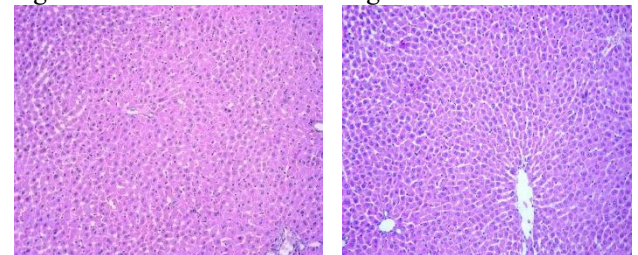


Figure 5-C

Figure 5-D

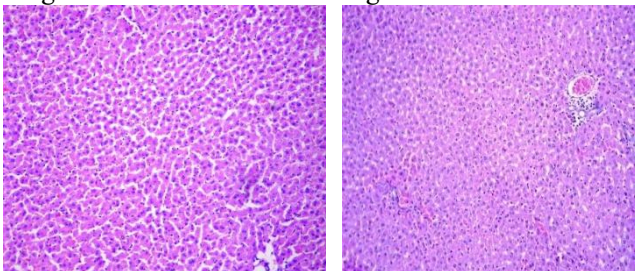


Figure 5-E

Figure 5-F

Figure 5. Representative Photomicrographs of Liver for Antidiabetic Model

5-A: Normal rat

5-B: Diabetic control rat

5-C: Diabetic rat treated with standard

5-D: Diabetic rat treated with dry powder extract

5-E: Diabetic rat treated with aqueous extract

5-F: Diabetic rat treated with mucilage

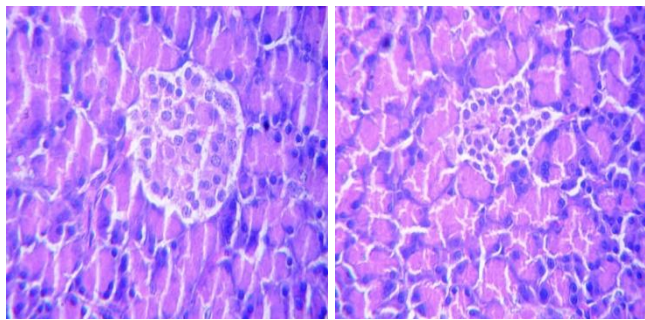


Figure 6-A

Figure 6-B

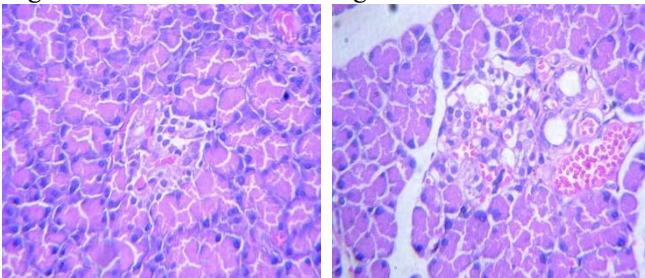


Figure 6-C

Figure 6-D

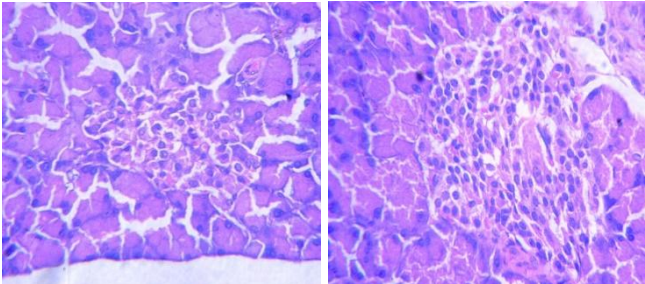


Figure 6-E

Figure 6-F

Figure 6. Representative Photomicrographs of Kidney for Antidiabetic Model

6-A: Normal rat

6-B: Diabetic control rat

6-C: Diabetic rat treated with standard

6-D: Diabetic rat treated with dry powder extract

6-E: Diabetic rat treated with aqueous extract

6-F: Diabetic rat treated with mucilage

Conclusion

It can be concluded that the extracts have good hypoglycemic activity. The hypoglycemic activity of all the extracts was comparable to that of diabetic rats treated with standard drug (Glibenclamide), hence, the extracts can be used as potential hypoglycemic agent. The diabetic rats treated with the extracts showed statistically significant decrease in body weight ($p < 0.05$). This signifies that the extracts have impact on the body weight gain. Animals treated with the extracts caused statistically significant decrease in the activity of liver markers (SGOT and SGPT), cholesterol levels, triglyceride and HDCL levels after day 14 when compared to diabetic control group. Improved urea and serum creatinine levels in diabetic rats treated with extracts showed that the extracts are nephroprotective. The histopathological study showed no abnormalities in the vital

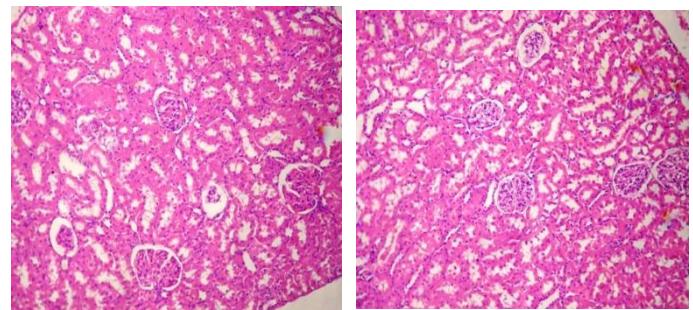


Figure 7-A

Figure 7-B

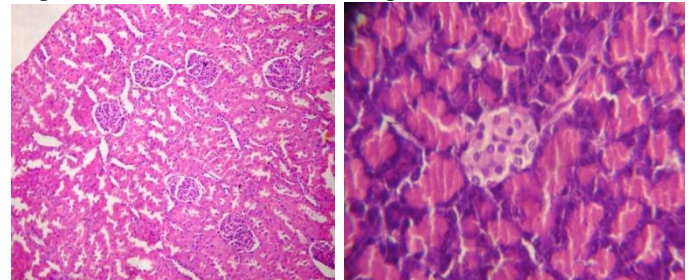


Figure 7-C

Figure 7-D

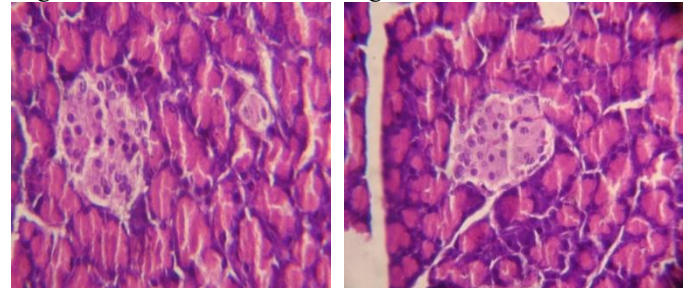


Figure 7-E

Figure 7-F

Figure 7. Representative Photomicrographs of Pancreas for Antidiabetic Model

7-A: Normal rat

7-B: Diabetic control rat

7-C: Diabetic rat treated with standard

7-D: Diabetic rat treated with dry powder extract

7-E: Diabetic rat treated with aqueous extract

7-F: Diabetic rat treated with mucilage

organs i.e. liver, kidney and pancreas. Among all the three extracts, extract obtained from dry powder of *Abelmoschus esculentus* showed better activity to decrease the blood glucose level. Therefore, it can be concluded that the extracts may be considered as promising candidates for the treatment of diabetic conditions.

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