RESEARCH PAPER

Evaluation of Anti-diabetic and Organ-Protective Effects of Berberis aristata in Alloxan-Induced Diabetes Rats

Pankaj[1], Dr. Charanjeet Singh[2], Dr Shankar Lal Soni[2], Dr Vandana Sharma[3], Jitendra Saini[4] Vineet Chouhan[4]

[1]Research Scholar, Department of Pharmacology, Arya College of Pharmacy, Kukas, Jaipur, Rajasthan, India.

[2]Professor, Arya College of Pharmacy, Kukas, Jaipur, Rajasthan, India.

[3]Principal, Arya College of Pharmacy, Kukas, Jaipur, Rajasthan, India.

[4]Assistant Professor, Arya College of Pharmacy, Kukas, Jaipur, Rajasthan, India.

Corresponding author: Dr. Charanjeet Singh; Email: charanjeet2004@gmail.com

ABSTRACT

The present study was conducted to evaluate the antidiabetic, antioxidant, and organ-protective effects of the hydroalcoholic extract of *Berberis aristata* DC. stem bark in alloxan-induced diabetic animals. The stem bark was extracted using the Soxhlet method with ethanol and distilled water in a ratio of 70:30 (v/v). The extractive yield was 12.84% w/w. Preliminary phytochemical screening indicated the presence of alkaloids, flavonoids, phenolic compounds, tannins, saponins, glycosides, steroids, and other phytochemical constituents. The antidiabetic activity was evaluated by monitoring body weight, fasting blood glucose, oral glucose tolerance, serum insulin, and lipid profile. Hepatic and renal function parameters, oxidative stress markers, antioxidant enzymes, and histopathological changes were also assessed. The results showed that the diabetic control group exhibited hyperglycaemia, reduced body weight, altered lipid profile, impaired liver and kidney function, and increased oxidative stress. Treatment with the extract improved these abnormalities, with the high-dose group generally showing greater improvement than the low-dose group. Fasting blood glucose decreased to 129.67 mg/dL in the high-dose group by Day 28, compared with 276.17 mg/dL in the diabetic control group. The extract also improved serum insulin, lipid parameters, liver and kidney function markers, and antioxidant status. Histopathological observations showed improvement in hepatic and renal tissue architecture following treatment. These findings suggest that *Berberis aristata* stem bark extract has promising antidiabetic, antioxidant, and organ-protective potential in the experimental model. Further studies are required to establish its active constituents, safety, and therapeutic relevance.

Keywords: *Berberis aristata*, antidiabetic activity, alloxan-induced diabetes, antioxidant activity, hepatoprotective effect, renoprotective effect.

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INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycaemia resulting from impaired insulin secretion, reduced insulin action, or both. The disease affects carbohydrate, lipid, and protein metabolism and may lead to complications involving the liver, kidneys, cardiovascular system, eyes, and nervous system. Prolonged elevation of blood glucose is associated with oxidative stress, inflammation, and progressive tissue damage. Therefore, effective diabetes management requires not only glycaemic control but also attention to the metabolic and organ-related complications associated with the disease.

Medicinal plants have received considerable attention as potential sources of bioactive compounds for the management of metabolic disorders. *Berberis aristata* DC., commonly known as Daruharidra or Indian barberry, belongs to the family Berberidaceae and has a long history of use in traditional medicine. Its roots and stem bark contain several phytoconstituents, particularly isoquinoline alkaloids such as berberine, along with berbamine, palmatine, and other phenolic compounds. These constituents have been investigated for their antidiabetic, antioxidant, and anti-inflammatory properties. Previous studies have also reported the potential of *B. aristata* preparations to influence glucose metabolism and lipid profiles.

Oxidative stress plays an important role in diabetes-associated tissue injury. Excessive production of reactive oxygen species can damage cellular components and reduce the activity of endogenous antioxidant defence systems. This imbalance may contribute to hepatic and renal dysfunction in diabetic conditions. The antioxidant properties of phytoconstituents present in *B. aristata* provide a basis for investigating its possible protective

effects against diabetes-associated oxidative damage. However, the biological activity of a plant extract may vary according to its source, plant part, extraction method, and phytochemical composition. Standardized experimental evaluation is therefore necessary to assess its potential effects.

Alloxan-induced diabetes is an established experimental model used to investigate antidiabetic agents. Alloxan produces pancreatic beta-cell injury, primarily through oxidative mechanisms, resulting in reduced insulin secretion and elevated blood glucose levels. This model allows the evaluation of changes in glucose regulation, body weight, lipid metabolism, biochemical markers of organ function, antioxidant status, and tissue architecture following treatment. Metformin is commonly used as a reference antidiabetic drug in experimental investigations.

The present study was undertaken to evaluate the antidiabetic, antioxidant, and organ-protective effects of the hydroalcoholic extract of *Berberis aristata* DC. stem bark in alloxan-induced diabetic animals. The investigation included extract preparation, preliminary phytochemical screening, assessment of fasting blood glucose and oral glucose tolerance, measurement of serum insulin and lipid parameters, evaluation of hepatic and renal function, and analysis of oxidative stress and antioxidant defence markers. Histopathological examination of liver and kidney tissues was also performed to assess structural changes associated with diabetes and treatment.

The study aimed to determine whether treatment with *B. aristata* extract could improve diabetes-associated metabolic abnormalities and reduce hepatic and renal tissue damage in the experimental model. The findings may contribute to the scientific evaluation of *B. aristata* as a potential source of bioactive constituents for further antidiabetic research. Further investigations, including detailed phytochemical characterization, safety assessment, and well-designed studies, are necessary before therapeutic conclusions can be drawn.

Materials and Methods

Collection and Authentication of Plant Material: The stem bark of *Berberis aristata* DC., belonging to the family Berberidaceae, was used in the present study. The plant material, locally known as Daruharidra, was procured during May 2026 from Shri Ram Herbals & Aromas LLP, Patel Nagar, Jaipur, Rajasthan, India.

The plant material was authenticated by the Department of Botany, University of Rajasthan, Jaipur. The authentication certificate was dated 24 May 2026, with Certificate No. BOT/2026/BA/021 and Voucher Specimen No. RUBL/BA/2026/021. The material was cleaned to remove foreign matter, shade-dried, and pulverized into a coarse powder. The powdered material was stored in an airtight container under suitable conditions until extraction.

Preparation of Plant Extract: The hydroalcoholic extract of *Berberis aristata* stem bark was prepared using the Soxhlet extraction method. Approximately 100 g of powdered plant material was placed in a suitable extraction thimble. Ethanol and distilled water in a ratio of 70:30 (v/v) were used as the extraction solvent.

Extraction was carried out for approximately 18 hours. The resulting extract was filtered through Whatman No. 1 filter paper, and the filtrate was concentrated under reduced pressure using a rotary evaporator at approximately 40–45°C. The concentrated extract was collected in a clean container and stored in an airtight amber-coloured glass container at approximately 2–8°C until further use.

Determination of Percentage Yield: The percentage yield of the extract was calculated by comparing the weight of the dried extract with the initial weight of the powdered plant material.

Formula:

Percentage yield (% w/w) = (Weight of dried extract / Weight of powdered plant material) × 100

The reported extract yield was 12.84% w/w.

Preliminary Phytochemical Screening: The prepared extract was subjected to preliminary phytochemical screening to identify the major classes of chemical constituents. Standard qualitative tests were used to examine the presence of alkaloids, flavonoids, phenolic compounds, tannins, saponins, glycosides, carbohydrates, proteins, amino acids, steroids, and triterpenoids.

The observations were recorded according to the colour changes, precipitate formation, or other characteristic reactions obtained during the respective tests.

Experimental Animals and Ethical Considerations: Adult Wistar rats were selected for the experimental investigation. The animals were maintained under standard laboratory conditions, with suitable housing, a regular light–dark cycle, standard pellet diet, and drinking water available as permitted by the experimental protocol. The animals were allowed to acclimatize before the commencement of the study.

All animal procedures were required to follow the applicable institutional and national guidelines for laboratory animal care. Prior approval from the Institutional Animal Ethics Committee (IAEC) was required before conducting the experiments. The official approval number and date should be reported according to the institutional records.

Induction and Confirmation of Diabetes: Experimental diabetes was induced in the selected animals using alloxan monohydrate according to the approved experimental protocol. Following administration, the animals were monitored for general health and signs of hyperglycaemia. Fasting blood glucose was measured after the prescribed post-induction period.

Animals that fulfilled the predefined blood glucose criterion were considered diabetic and included in the subsequent treatment study. The dose, route of administration, fasting conditions, and confirmation criteria were to be followed as specified in the approved experimental protocol.

Experimental Grouping and Treatment: The animals were allocated to five experimental groups:

- **Group I:** Normal control, receiving vehicle.
- **Group II:** Diabetic control, receiving alloxan and vehicle.
- **Group III:** Standard treatment group, receiving the approved standard antidiabetic drug.
- **Group IV:** Diabetic animals treated with a lower dose of *Berberis aristata* extract.
- **Group V:** Diabetic animals treated with a higher dose of *Berberis aristata* extract.

The standard drug, extract doses, number of animals per group, route of administration, and treatment duration should be entered according to the actual laboratory records and approved protocol.

Evaluation of Antidiabetic Activity: The antidiabetic activity of the extract was assessed by monitoring fasting blood glucose, body weight, oral glucose tolerance, serum insulin, and lipid profile. Blood glucose and body weight were recorded at the predetermined study intervals.

Serum biochemical parameters, including total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), total protein, and albumin, were assessed using suitable validated laboratory methods or commercial diagnostic kits.

Assessment of Antioxidant Activity: The antioxidant effect of the extract was evaluated by measuring selected oxidative stress and antioxidant parameters. These included malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT), reduced glutathione (GSH), and glutathione peroxidase (GPx), as applicable to the experimental protocol.

The results were compared among the normal control, diabetic control, standard treatment, and extract-treated groups to determine changes in oxidative stress and antioxidant status.

Assessment of Organ-Protective Activity: Hepatic and renal outcomes were evaluated using complementary biochemical and morphological endpoints. Serum transaminases, alkaline phosphatase, bilirubin and circulating protein concentrations were used as indicators of hepatocellular injury and associated metabolic disturbance; urea, creatinine and uric acid were examined as renal-related indices. Liver and kidney histology provided descriptive evidence of tissue alterations. These endpoints were interpreted together rather than regarding any isolated serum marker as definitive proof of protection.

Hepatic Function: Hepatic function was assessed by measuring serum alanine aminotransferase (ALT/SGPT), aspartate aminotransferase (AST/SGOT), alkaline phosphatase (ALP), total bilirubin, total protein, and albumin. The findings were compared among the experimental groups to evaluate changes associated with diabetes and extract treatment.

Renal Function: Renal function was assessed using biochemical markers such as serum urea and creatinine. Uric acid was included where measured under the study protocol. The values obtained from the treated groups were compared with those of the normal and diabetic control groups.

Histopathological Examination: Liver and kidney tissues were collected at the end of the experimental period according to the approved protocol. The tissues were processed for histopathological examination, including fixation, preparation of tissue sections, and staining with haematoxylin and eosin (H&E), where performed. Microscopic observations were used to assess tissue changes in the diabetic control and treatment groups.

Statistical Analysis: The experimental data were expressed as mean ± standard deviation or mean ± standard error, according to the original data records. Appropriate statistical tests were used to compare the experimental groups. The significance level, statistical test, software, and number of animals analysed should be reported according to the actual statistical analysis performed.

RESULTS AND DISCUSSION

The reported group means are presented below, alongside descriptive comparisons with diabetic controls and the reference-treatment group. Findings are discussed in the context of phytochemical composition, hyperglycaemia-associated metabolic disturbances and oxidative injury. Percentage changes are descriptive calculations from reported mean values; statistical significance and mechanistic causality cannot be inferred without animal-level datasets, group sample sizes and the original analysis plan. The observed trends should therefore be interpreted as preliminary experimental evidence rather than established therapeutic efficacy.

Extract Yield and Preliminary Phytochemical Screening: Extraction of 100 g of powdered stem bark yielded 12.84 g of dried hydroalcoholic extract, corresponding to a 12.84% (w/w) recovery (Table 1).

$$\text{Percentage Yield (\% w/w)} = \frac{\text{Weight of dried extract obtained (g)}}{\text{Weight of powdered drug used (g)}} \times 100$$

$$= \frac{12.84}{100} \times 100 = 12.84\%\ w/w$$

Table 1: Extractive Yield of Hydroalcoholic Extract of Berberis aristata Stem Bark

Parameter	Observation
Plant material	*Berberis aristata* DC. stem bark
Powdered drug taken	100 g
Extraction method	Soxhlet extraction
Extraction solvent	Hydroalcoholic
Ethanol : distilled water	70:30 (v/v)
Extraction duration	Approximately 18 h
Concentration temperature	40–45°C
Weight of dried extract obtained	12.84 g
Percentage extractive yield	12.84% w/w
Storage	Amber-coloured airtight container
Storage temperature	2–8°C

Preliminary Phytochemical Screening: Qualitative assays indicated alkaloids, flavonoids, phenolics, tannins, saponins, glycosides and other tested classes (Tables 2–3).

Table 2: Preliminary Phytochemical Screening of Hydroalcoholic Extract of Berberis aristata

S. No.	Phytochemical constituent	Test performed	Observation	Inference
1	Alkaloids	Mayer's test	Creamish precipitate	+
		Dragendorff's test	Orange-red precipitate	+
		Wagner's test	Reddish-brown precipitate	+
2	Flavonoids	Shinoda test	Pinkish-red colour	+
		Alkaline reagent test	Yellow colour, diminished after acidification	+
3	Phenolic compounds	Ferric chloride test	Bluish-green colour	+
4	Tannins	Ferric chloride test	Blue-green colour	+
5	Saponins	Froth test	Persistent froth	+
6	Glycosides	Keller–Killiani test	Characteristic colour reaction	+
7	Carbohydrates	Molisch's test	Violet ring	+
		Fehling's test	Brick-red precipitate	+
8	Proteins	Biuret test	Violet colour	+
9	Amino acids	Ninhydrin test	Blue-violet colour	+
10	Steroids	Liebermann–Burchard test	Characteristic colour development	+
11	Triterpenoids	Salkowski test	Reddish-brown colour	+

Key: + = Present; − = Absent/Not detected.

Table 3: Summary of Phytochemical Profile of Berberis aristata Extract

Phytochemical group	Result
Alkaloids	+
Flavonoids	+
Phenolic compounds	+
Tannins	+
Saponins	+
Glycosides	+
Carbohydrates	+
Proteins	+
Amino acids	+
Steroids	+
Triterpenoids	+

Effect on Body Weight: The diabetic control group declined from 199.50 g at baseline to 164.17 g on Day 28, whereas normal controls increased from 198.33 to 212.33 g (Table 4). At Day 28, mean weight was 197.17 g with low-dose extract and 202.17 g with high-dose extract, compared with 200.50 g in the standard-treatment group.



Table 4: Effect of Berberis aristata Extract on Body Weight of Experimental Animals

Group	Treatment	Day 0 (g)	Day 7 (g)	Day 14 (g)	Day 21 (g)	Day 28 (g)
I	Normal control	198.33 ± 2.16	201.17 ± 2.32	204.83 ± 2.42	208.17 ± 2.39	212.33 ± 2.47
II	Diabetic control	199.50 ± 2.28	185.83 ± 2.51	177.17 ± 2.64	170.33 ± 2.55	164.17 ± 2.73
III	Standard treatment	200.17 ± 2.35	187.00 ± 2.42	190.83 ± 2.31	195.17 ± 2.27	200.50 ± 2.34
IV	*B. aristata* low dose	198.83 ± 2.17	186.50 ± 2.36	188.67 ± 2.44	192.83 ± 2.39	197.17 ± 2.46
V	*B. aristata* high dose	199.17 ± 2.26	186.67 ± 2.31	191.50 ± 2.38	197.00 ± 2.42	202.17 ± 2.51

Effect on Blood Glucose Level: Diabetic controls showed a progressive rise in fasting glucose from 248.50 to 276.17 mg/dL across 28 days. In contrast, mean Day-28 values were 151.83 mg/dL and 129.67 mg/dL in the low- and high-dose extract groups, respectively, compared with 118.50 mg/dL in the standard-treatment group (Table 5). Relative to their own Day-0 means, the extract groups showed approximately 39.19% and 48.30% reductions, respectively.

Table 5: Effect of Berberis aristata Extract on Fasting Blood Glucose Level

Group	Treatment	Day 0 (mg/dL)	Day 7 (mg/dL)	Day 14 (mg/dL)	Day 21 (mg/dL)	Day 28 (mg/dL)
I	Normal control	92.17 ± 2.14	93.00 ± 2.08	91.83 ± 2.16	92.50 ± 2.11	93.33 ± 2.19
II	Diabetic control	248.50 ± 5.72	256.67 ± 5.91	264.17 ± 6.08	270.33 ± 6.21	276.17 ± 6.35
III	Standard treatment	251.33 ± 5.84	216.17 ± 5.36	178.83 ± 4.72	142.67 ± 4.18	118.50 ± 3.64
IV	*B. aristata* low dose	249.67 ± 5.61	228.83 ± 5.42	205.17 ± 5.01	177.33 ± 4.63	151.83 ± 4.27
V	*B. aristata* high dose	250.83 ± 5.76	220.17 ± 5.24	188.50 ± 4.78	155.17 ± 4.35	129.67 ± 3.91

Formula: Percentage reduction from baseline = [(Day 0 fasting blood glucose − Day 28 fasting blood glucose) / Day 0 fasting blood glucose] × 100. This applies to groups with a reduction and should not be confused with percent difference relative to diabetic control. Calculations should be checked against the numerical entries: for the standard group, (251.33 − 118.50) / 251.33 × 100 = 52.85%.

$$\text{Percentage reduction} = \frac{\text{FBG}_{Day\,0} - \text{FBG}_{Day\,28}}{\text{FBG}_{Day\,0}} \times 100$$

Table 6: Percentage Reduction in Blood Glucose

Group	Day 0 FBG (mg/dL)	Day 28 FBG (mg/dL)	Reduction (%)
I – Normal control	92.17	93.33	—
II – Diabetic control	248.50	276.17	—
III – Standard	251.33	118.50	52.84
IV – Low dose	249.67	151.83	39.19
V – High dose	250.83	129.67	48.30

Effect on Oral Glucose Tolerance Test (OGTT): After the glucose challenge, all groups showed increased glucose concentrations at 30 minutes, followed by a decline towards 120 minutes (Table 7 and Figure 2). Diabetic controls remained markedly hyperglycaemic at 120 minutes (287.17 mg/dL). The corresponding mean values

were 162.33 mg/dL for low-dose extract and 136.17 mg/dL for high-dose extract, compared with 119.67 mg/dL for standard treatment.

Table 7: Effect of Berberis aristata Extract on Oral Glucose Tolerance

Group	Treatment	0 min (mg/dL)	30 min (mg/dL)	60 min (mg/dL)	90 min (mg/dL)	120 min (mg/dL)
I	Normal control	92.17 ± 2.14	137.33 ± 3.26	119.17 ± 2.91	103.83 ± 2.53	94.50 ± 2.22
II	Diabetic control	248.50 ± 5.72	326.67 ± 7.14	318.17 ± 6.83	301.33 ± 6.42	287.17 ± 6.18
III	Standard treatment	118.50 ± 3.64	184.83 ± 4.82	158.33 ± 4.27	135.17 ± 3.76	119.67 ± 3.42
IV	*B. aristata* low dose	151.83 ± 4.27	226.17 ± 5.31	208.50 ± 5.02	184.83 ± 4.61	162.33 ± 4.35
V	*B. aristata* high dose	129.67 ± 3.91	205.33 ± 5.08	179.67 ± 4.54	151.83 ± 4.13	136.17 ± 3.72

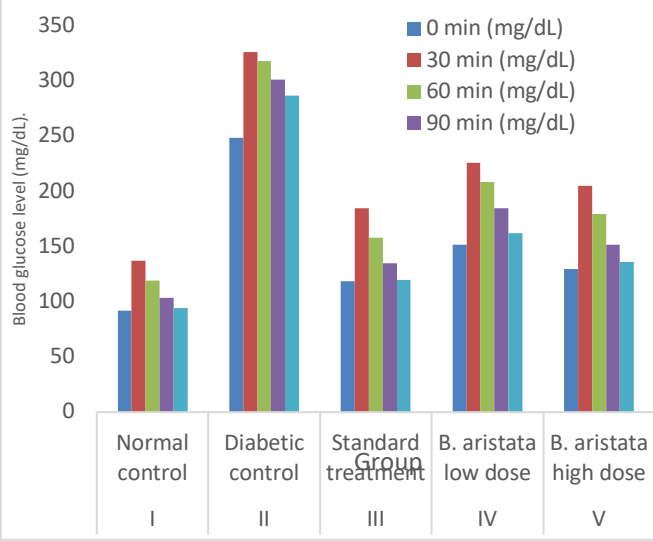


Figure 2: Effect of Berberis aristata extract on oral glucose tolerance in experimentally diabetic rats.

Effect on Serum Insulin: Mean serum insulin was 6.38 µIU/mL in diabetic controls versus 15.42 µIU/mL in normal controls (Table 8). The low- and high-dose extract groups had means of 9.84 and 12.31 µIU/mL, corresponding to increases of approximately 54.23% and 92.79% relative to diabetic controls (Table 9).

Table 8: Effect of Berberis aristata Extract on Serum Insulin Level

Group	Treatment	Serum Insulin (µIU/mL)
I	Normal control	15.42 ± 0.68
II	Diabetic control	6.38 ± 0.41
III	Standard treatment	13.86 ± 0.59
IV	*B. aristata* low dose	9.84 ± 0.47
V	*B. aristata* high dose	12.31 ± 0.53

Table 9: Percentage Improvement in Serum Insulin

Group	Serum Insulin (µIU/mL)	Change vs. Diabetic Control
Diabetic control	6.38 ± 0.41	—
Standard treatment	13.86 ± 0.59	117.24%
B. aristata low dose	9.84 ± 0.47	54.23%
B. aristata high dose	12.31 ± 0.53	92.79%

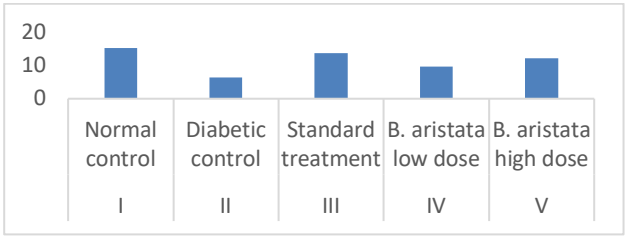


Figure 3: Effect of Berberis aristata extract on serum insulin levels in experimentally diabetic rats.

Effect on Lipid Profile: Relative to diabetic controls, both extract groups had lower mean total cholesterol, triglycerides and LDL-C and higher HDL-C (Tables 10–11; Figure 4). High-dose extract reduced the reported total cholesterol mean from 142.67 to 99.24 mg/dL, triglycerides from 126.83 to 86.53 mg/dL and LDL-C from 76.54 to 41.38 mg/dL, while HDL-C increased from 24.31 to 34.27 mg/dL.

Table 10: Effect of Berberis aristata Extract on Lipid Profile

Group	Treatment	Total Cholesterol (mg/dL)	Triglycerides (mg/dL)	LDL-C (mg/dL)	HDL-C (mg/dL)
I	Normal control	78.42 ± 2.31	68.17 ± 2.14	25.63 ± 1.52	39.18 ± 1.36
II	Diabetic control	142.67 ± 4.28	126.83 ± 3.91	76.54 ± 3.27	24.31 ± 1.18
III	Standard treatment	91.36 ± 2.74	78.42 ± 2.53	34.87 ± 1.84	36.52 ± 1.27
IV	*B. aristata* low dose	113.58 ± 3.26	99.17 ± 3.08	51.26 ± 2.43	30.14 ± 1.22
V	*B. aristata* high dose	99.24 ± 2.89	86.53 ± 2.71	41.38 ± 2.06	34.27 ± 1.25

Table 11: Percentage Change in Lipid Parameters Compared with Diabetic Control

Treatment	TC Reduction (%)	TG Reduction (%)	LDL-C Reduction (%)	HDL-C Increase (%)
Standard treatment	35.94	38.17	54.44	50.23
B. aristata low dose	20.40	21.82	33.03	23.98
B. aristata high dose	30.46	31.79	45.95	40.97

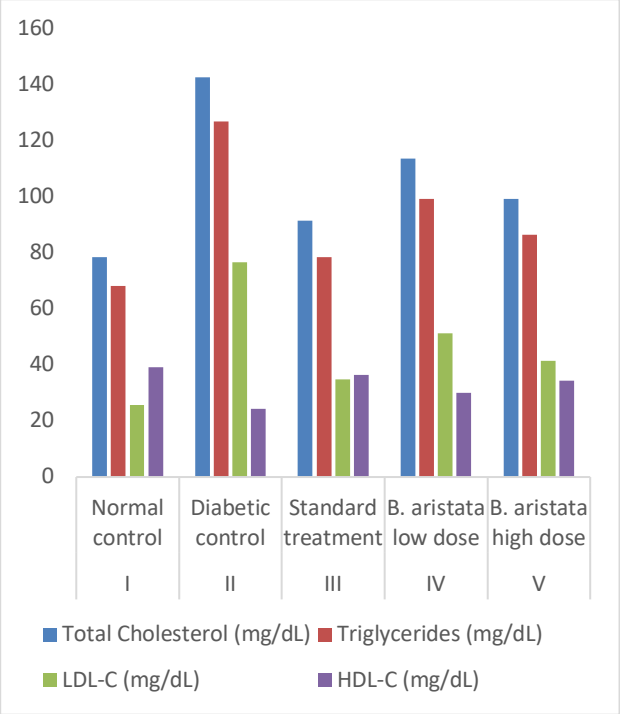


Figure 4: Effect of Berberis aristata extract on serum lipid profile in experimentally diabetic rats.

Effect on Liver Function Parameters: Diabetic controls exhibited higher ALT, AST, ALP and bilirubin and lower total protein and albumin than normal controls (Table 12). With high-dose extract, the reported ALT mean was 43.26 U/L versus 68.54 U/L in diabetic controls, AST was 53.47 versus 82.67 U/L, and bilirubin was 0.88 versus 1.38 mg/dL. Serum albumin also increased from 3.18 to 3.87 g/dL.

Table 12: Effect of Berberis aristata Extract on Liver Function Parameters

Group	Treatment	ALT/SGPT (U/L)	AST/SGOT (U/L)	ALP (U/L)	Total Bilirubin (mg/dL)	Total Protein (g/dL)	Albumin (g/dL)
I	Normal control	32.18 ± 1.42	38.26 ± 1.57	86.42 ± 2.84	0.62 ± 0.04	7.18 ± 0.12	4.21 ± 0.09
II	Diabetic control	68.54 ± 2.73	82.67 ± 3.16	128.36 ± 4.27	1.38 ± 0.08	5.84 ± 0.15	3.18 ± 0.11
III	Standard treatment	38.47 ± 1.68	46.32 ± 1.82	94.17 ± 3.12	0.76 ± 0.05	6.92 ± 0.13	4.02 ± 0.08
IV	*B. aristata* low dose	52.83 ± 2.21	64.18 ± 2.67	113.24 ± 3.84	1.06 ± 0.07	6.31 ± 0.14	3.62 ± 0.10
V	*B. aristata* high dose	43.26 ± 1.93	53.47 ± 2.14	101.38 ± 3.46	0.88 ± 0.06	6.68 ± 0.12	3.87 ± 0.09

Table 13: Percentage Improvement of Liver Parameters Compared with Diabetic Control

Treatment	ALT Reduction (%)	AST Reduction (%)	ALP Reduction (%)	Bilirubin Reduction (%)	Total Protein Improvement (%)	Albumin Improvement (%)
Standard treatment	43.86	43.96	26.66	44.93	18.84	26.42
B. aristata low dose	22.92	22.37	11.77	23.19	8.05	13.84
B. aristata high dose	36.90	35.31	21.00	36.23	14.38	21.70

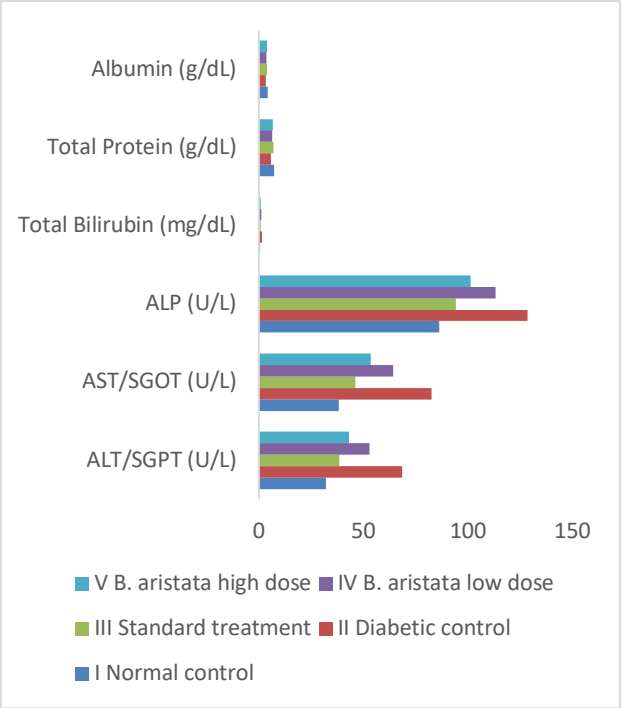


Figure 5: Effect of Berberis aristata extract on liver function parameters in experimentally diabetic rats.

Effect on Kidney Function Parameters: Relative to normal controls, diabetic controls showed raised urea (68.47 mg/dL), creatinine (1.46 mg/dL) and uric acid (4.63 mg/dL), suggesting renal-related biochemical disturbance in this model (Table 14). High-dose extract was associated with lower values of 44.17, 0.96 and 3.28 mg/dL, respectively; intermediate values were reported for low-dose extract.

Table 14: Effect of Berberis aristata Extract on Kidney Function Parameters

Group	Treatment	Serum Urea (mg/dL)	Serum Creatinine (mg/dL)	Uric Acid (mg/dL)
I	Normal control	34.26 ± 1.38	0.72 ± 0.04	2.84 ± 0.16
II	Diabetic control	68.47 ± 2.54	1.46 ± 0.08	4.63 ± 0.23
III	Standard treatment	39.18 ± 1.57	0.83 ± 0.05	3.06 ± 0.18
IV	*B. aristata* low dose	52.36 ± 2.11	1.13 ± 0.07	3.72 ± 0.21
V	*B. aristata* high dose	44.17 ± 1.74	0.96 ± 0.06	3.28 ± 0.19

Table 15: Percentage Reduction in Renal Parameters Compared with Diabetic Control

Treatment	Urea Reduction (%)	Creatinine Reduction (%)	Uric Acid Reduction (%)
Standard treatment	42.78	43.15	33.91
B. aristata low dose	23.53	22.60	19.65
B. aristata high dose	35.49	34.25	29.16

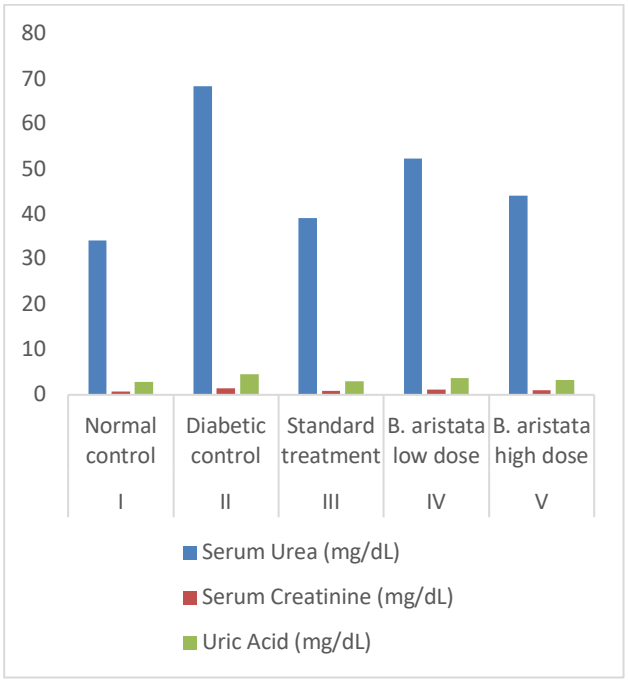


Figure 6: Effect of Berberis aristata extract on kidney function parameters in experimentally diabetic rats.

Effect on Oxidative Stress and Antioxidant Parameters: The diabetic control group had higher MDA (5.96

nmol/mL) and lower SOD, CAT, GSH and GPx than normal controls, indicating an adverse oxidative-stress profile (Table 16). High-dose extract was associated with MDA of 3.67 nmol/mL, SOD of 7.18 U/mL, CAT of 4.68 U/mL, GSH of 6.67 µmol/L and GPx of 5.21 U/mL.

Table 16: Effect of Berberis aristata Extract on Oxidative Stress and Antioxidant Parameters

Group	Treatment	MDA (nmol/mL)	SOD (U/mL)	CAT (U/mL)	GSH (µmol/L)	GPx (U/mL)
I	Normal control	2.84 ± 0.12	8.62 ± 0.31	5.74 ± 0.24	7.83 ± 0.28	6.18 ± 0.25
II	Diabetic control	5.96 ± 0.21	4.37 ± 0.22	2.81 ± 0.17	4.26 ± 0.21	3.12 ± 0.18
III	Standard treatment	3.18 ± 0.14	7.91 ± 0.29	5.21 ± 0.22	7.14 ± 0.26	5.76 ± 0.23
IV	*B. aristata* low dose	4.43 ± 0.18	6.02 ± 0.26	3.94 ± 0.20	5.86 ± 0.24	4.51 ± 0.21
V	*B. aristata* high dose	3.67 ± 0.16	7.18 ± 0.28	4.68 ± 0.21	6.67 ± 0.25	5.21 ± 0.22

Table 17: Percentage Improvement in Oxidative-Stress Parameters

Treatment	MDA Reduction (%)	SOD Improvement (%)	CAT Improvement (%)	GSH Improvement (%)	GPx Improvement (%)
Standard treatment	46.64	81.01	85.41	67.61	84.62
B. aristata low dose	25.67	37.76	40.21	37.56	44.55
B. aristata high dose	38.42	64.30	66.55	56.57	67.00

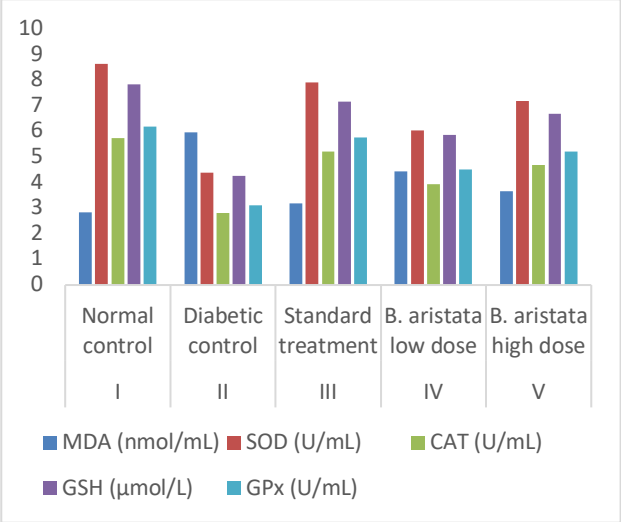


Figure 7: Effect of Berberis aristata extract on oxidative stress and antioxidant parameters in experimentally diabetic rats.

Histopathological Evaluation: Tissue observations were considered alongside serum biochemistry to assess whether the direction of organ-related changes was morphologically plausible. Descriptions in Tables 18–19 indicate comparatively preserved structure in treated groups.

Histopathological Evaluation of Liver: The normal control liver was described as having preserved architecture, whereas the diabetic control showed hepatocellular degeneration and structural alteration (Table 18). Extract-treated groups showed partial to marked restoration, with fewer residual abnormalities reported in the high-dose group. These observations support the direction of serum-marker changes.

Table 18: Histopathological Findings of Liver

Group	Treatment	Histopathological observation	Overall hepatic protection
I	Normal control	Preserved hepatic architecture; normal hepatocellular arrangement	Normal
II	Diabetic control	Hepatocellular degeneration and marked structural alterations	Severe alteration
III	Standard treatment	Substantial preservation of hepatic architecture with reduced degeneration	+++
IV	*B. aristata* low dose	Partial restoration with mild-to-moderate residual alterations	++
V	*B. aristata* high dose	Marked restoration of hepatic architecture with minimal degenerative changes	+++

Semi-quantitative interpretation: (−) = absent; (+) = mild; (++) = moderate; (+++) = marked protection.

Histopathological Evaluation of Kidney: The diabetic control group was described as exhibiting glomerular and tubular abnormalities, while the extract-treated groups showed improved preservation of these structures (Table 19).

Table 19: Histopathological Findings of Kidney

Group	Treatment	Histopathological observation	Overall renal protection
I	Normal control	Preserved glomerular and tubular architecture	Normal
II	Diabetic control	Glomerular and tubular alterations with disturbed renal architecture	alteration
III	Standard treatment	Substantial preservation of glomerular and tubular structures	+++
IV	*B. aristata* low dose	Partial improvement with residual structural alterations	++
V	*B. aristata* high dose	Marked improvement in glomerular and tubular architecture	+++

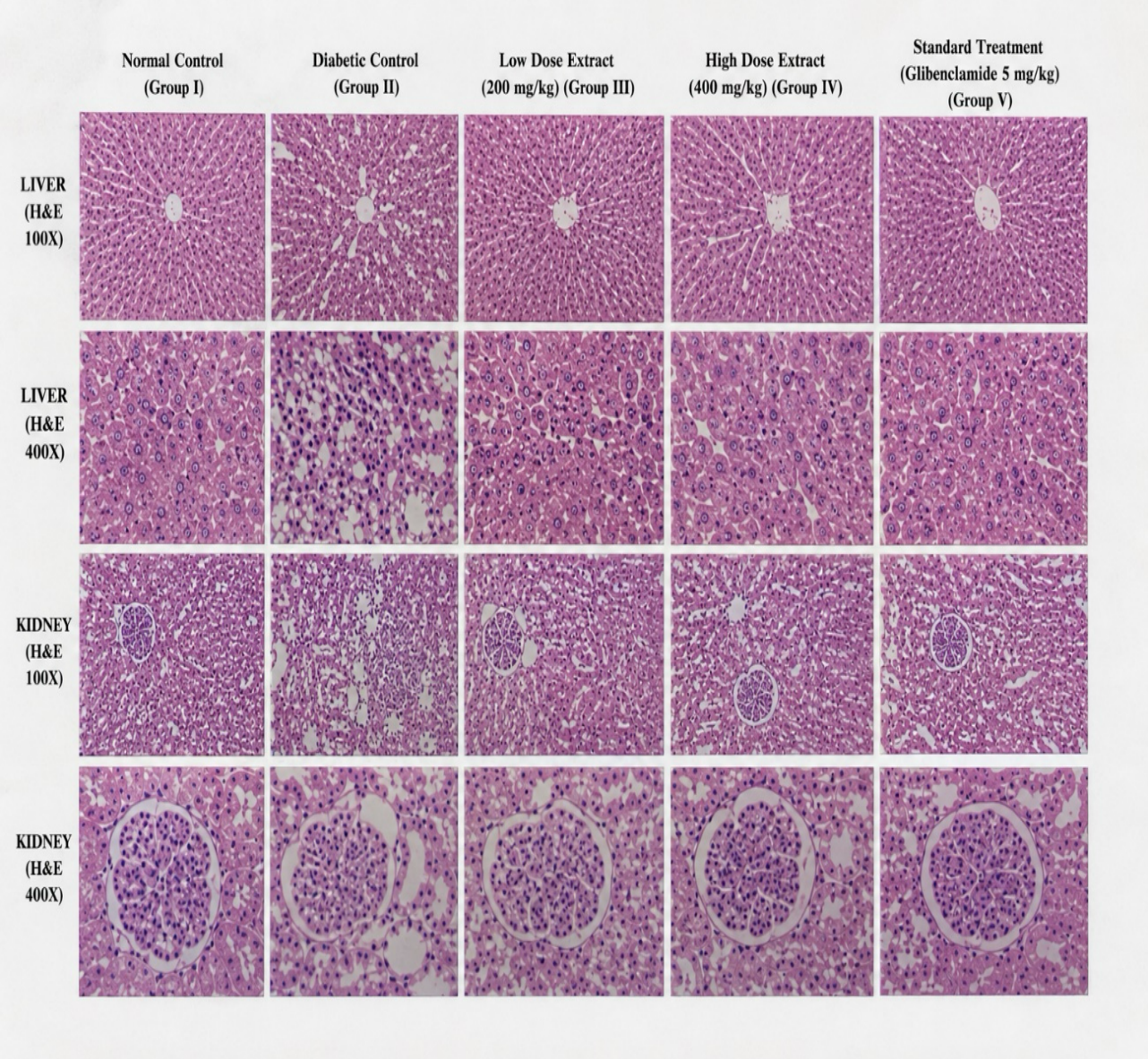


Figure 8: Representative photomicrographs showing the effect of Berberis aristata extract on hepatic and renal architecture in experimentally diabetic rats.

Antidiabetic and Organ-Protective Effects: Across the recorded outcomes, the extract-treated groups displayed a broadly consistent pattern of lower fasting glucose, improved circulating insulin and lipid markers, improved liver- and kidney-related biochemistry and a more favourable oxidative-stress profile (Table 20). The high-dose group generally showed larger descriptive changes than the low-dose group, while the reference treatment often produced the largest response.

Table 20: Effect of Berberis aristata Extract in Experimental Diabetes

Parameter	Diabetic control	Low-dose extract	High-dose extract	Overall interpretation
Fasting blood glucose	↑↑	↓	↓↓	Improved glycaemic control
Oral glucose tolerance	Impaired	Moderate improvement	Greater improvement	Improved glucose handling
Serum insulin	↓↓	↑	↑↑	Improved insulin status
Body weight	Decreased/impaired gain	Moderate improvement	Greater improvement	Attenuation of weight loss
Total cholesterol	↑↑	↓	↓↓	Improved lipid profile
Triglycerides	↑↑	↓	↓↓	Improved lipid profile
LDL-C	↑↑	↓	↓↓	Improved lipid profile
HDL-C	↓↓	↑	↑↑	Improved lipid profile
ALT/SGPT	↑↑	↓	↓↓	Improved hepatic function
AST/SGOT	↑↑	↓	↓↓	Improved hepatic function
ALP	Altered/↑	Improved	Greater improvement	Improved hepatic function
Total bilirubin	↑↑	↓	↓↓	Improved hepatic function
Total protein	↓	↑	↑↑	Improved hepatic synthetic status
Albumin	↓	↑	↑↑	Improved hepatic synthetic status
Serum urea	↑↑	↓	↓↓	Improved renal function
Serum creatinine	↑↑	↓	↓↓	Improved renal function
MDA	↑↑	↓	↓↓	Reduced oxidative stress
SOD	↓↓	↑	↑↑	Improved antioxidant defence
CAT	↓↓	↑	↑↑	Improved antioxidant defence
GSH	↓↓	↑	↑↑	Improved antioxidant defence
GPx	↓↓	↑	↑↑	Improved antioxidant defence
Liver architecture	Altered	Partial restoration	Marked restoration	Hepatic protection
Kidney architecture	Altered	Partial improvement	Marked improvement	Renal protection

↑ = increase; ↓ = decrease; single/double symbols indicate relative magnitude of change. This table summarizes the direction of the findings rather than replacing the numerical biochemical tables.

Summary

The present study was conducted to evaluate the antidiabetic, antioxidant, and organ-protective effects of the hydroalcoholic extract of *Berberis aristata* DC. stem bark in alloxan-induced diabetic animals.

The stem bark was extracted by the Soxhlet method using ethanol and distilled water in a ratio of 70:30 (v/v) for approximately 18 hours. The extraction of 100 g of powdered plant material yielded 12.84 g of dried extract, corresponding to 12.84% w/w. Preliminary phytochemical screening indicated the presence of alkaloids, flavonoids, phenolic compounds, tannins, saponins, glycosides, carbohydrates, proteins, amino acids, steroids, and triterpenoids.

The diabetic control group showed increased fasting blood glucose, reduced body weight, decreased serum insulin, altered lipid profile, impaired liver and kidney function, and increased oxidative stress. Treatment with *Berberis aristata* extract improved these parameters, with the high-

dose group generally showing a greater response than the low-dose group.

By Day 28, fasting blood glucose decreased to 151.83 mg/dL in the low-dose group and 129.67 mg/dL in the high-dose group, compared with 276.17 mg/dL in the diabetic control group. The high-dose group also showed improvement in body weight, reaching 202.17 g, and serum insulin, reaching 12.31 ± 0.53 µIU/mL.

The extract improved lipid metabolism by reducing total cholesterol, triglycerides, and low-density lipoprotein cholesterol while increasing high-density lipoprotein cholesterol. Improvement was also observed in liver function parameters, including alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, bilirubin, total protein, and albumin.

Renal function markers also improved following treatment. In the high-dose group, serum urea decreased to 44.17 ± 1.74 mg/dL and creatinine to 0.96 ± 0.06 mg/dL. The extract reduced malondialdehyde levels and improved antioxidant defence markers, including superoxide dismutase, catalase, reduced glutathione, and glutathione peroxidase, as reported in the study.

Histopathological observations indicated improvement in liver and kidney tissue architecture in the treated animals, particularly in the high-dose group. Overall, the findings suggest that the extract has promising antidiabetic, antioxidant, and organ-protective potential in the experimental model.

Conclusion

In this reported alloxan-induced diabetic rat experiment, hydroalcoholic Berberis aristata DC. stem-bark extract was associated with improvements in mean glycaemic, metabolic, hepatic, renal and oxidative-stress indicators compared with diabetic controls. The high-dose group generally showed a larger descriptive response than the low-dose group; several endpoints nonetheless remained less favourable than in standard-treated animals. These findings support further preclinical investigation but do not demonstrate human therapeutic efficacy, independent organ-protective mechanisms or statistical significance in the absence of complete animal-level records.

The extract improved glycaemic control, serum insulin levels, body-weight changes, and lipid profile. It also improved biochemical markers of liver and kidney function and reduced oxidative stress. The histopathological observations supported the biochemical findings by showing improvement in hepatic and renal tissue architecture following treatment.

The high-dose extract generally produced greater improvement than the low-dose extract, although the standard treatment showed a stronger overall response for several parameters. These findings provide preliminary evidence supporting further investigation of *Berberis aristata* stem bark as a potential source of bioactive compounds for managing diabetes-associated metabolic and organ changes.

Further studies are required to identify and quantify the active constituents, establish the safety profile, investigate the mechanisms of action, and confirm the observed effects using standardized experimental procedures. The present findings are limited to the animal model and do not establish clinical efficacy in humans.

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