INFORMATICS JOURNALS

Research Article

Journal of Natural Remedies
DOI: 10.18311/jnr/2026/55133

eISSN: 2320-3358 | Vol 26(6), 2026 | pp. 1647-1653

In Vivo Evaluation of Antidiabetic Activity of *Erythroxylum coca* in Rats

Ravindra Mishra*, Pradeep Prajapati and Vinay Jain

Shriram College of Pharmacy, Banmore, Morena - 476444, Madhya Pradesh, India; ravindra.mishra1412@gmail.com

Abstract

Background: Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycemia and associated microvascular and macrovascular complications. Despite the availability of conventional therapies, limitations such as side effects and reduced long-term efficacy necessitate exploring alternative treatments. Medicinal plants rich in bioactive phytoconstituents have gained attention for their potential antidiabetic effects. **Aim:** The present study aimed to evaluate the *in vivo* antidiabetic activity of the ethanolic extract of *Erythroxylum coca* leaves in streptozotocin (STZ)-induced diabetic rats. **Methods:** Diabetes was induced in Wistar albino rats using STZ (55 mg/kg, i.p.). Animals were divided into six groups: normal control, diabetic control, extract-treated groups (100, 200, and 400 mg/kg), and standard drug (metformin, 250 mg/kg). Treatments were administered orally for 28 days. Biochemical parameters, including fasting blood glucose, insulin, HbA1c, and lipid profile, were evaluated. Oxidative stress markers (SOD, CAT, GSH, MDA) and histopathological analysis of pancreas, liver, and kidney were also performed. **Results:** The extract demonstrated significant dose-dependent antidiabetic activity. At 400 mg/kg, fasting blood glucose was reduced by approximately 64% ($p < 0.01$), a reduction comparable to that of metformin. Significant improvements were observed in glucose tolerance, serum insulin levels, and HbA1c. Lipid abnormalities were corrected, with reductions in total cholesterol, triglycerides, and LDL, and increases in HDL levels. Oxidative stress was attenuated by reduced MDA levels and increased antioxidant enzyme activities. Histopathological findings revealed restoration of pancreatic β-cell architecture and protection of liver and kidney tissues. **Conclusion:** The ethanolic extract of *E. coca* exhibits potent antidiabetic activity mediated through antioxidant, β-cell protective, and metabolic regulatory mechanisms. These findings suggest its potential as a natural therapeutic agent for diabetes management, warranting further mechanistic and clinical investigations.

Major Findings: The ethanolic extract of *E. coca* significantly improved glycemic control in streptozotocin-induced diabetic rats in a dose-dependent manner. Treatment reduced fasting blood glucose, HbA1c, lipid abnormalities, and oxidative stress while enhancing insulin levels and glucose tolerance. The 400 mg/kg dose showed effects comparable to metformin and demonstrated marked protection of pancreatic tissue architecture.

Keywords: Antioxidant, Diabetes Mellitus, *Erythroxylum coca*, Herbal Medicine, Hypoglycemic Activity, Streptozotocin

(Article Chronicle: Article Received on: 01.03.2026; Revised on: 11.05.2026; Accepted on: 01.06.2026)

1. Introduction

Diabetes Mellitus (DM) is a chronic metabolic disorder characterised by persistent hyperglycemia due to defects in insulin secretion, insulin action, or both. The International Diabetes Federation reported that 537 million adults were affected worldwide in 2021. India represents a major global burden of type 2 diabetes mellitus (T2DM)[1].

Prolonged hyperglycemia leads to microvascular and macrovascular complications through oxidative stress, advanced glycation end products, and endothelial dysfunction[2,3]. Conventional therapies such as insulin, metformin, and sulfonylureas are effective but often associated with adverse effects and limited long-term efficacy[4]. Medicinal plants containing flavonoids, alkaloids, phenolics, and glycosides exhibit antidiabetic activity by improving insulin sensitivity,

*Author for correspondence

enhancing insulin secretion, and reducing oxidative stress[5,6]. *Erythroxylum coca* possesses diverse bioactive compounds with reported antioxidant and metabolic regulatory effects[7,8]. The present study aimed to scientifically evaluate the antidiabetic potential of *E. coca* leaf extract using an STZ-induced diabetic rat model[9]. "Despite the ethnopharmacological relevance of *E. coca*, systematic *in vivo* evaluation of its antidiabetic potential remains limited. Furthermore, its role in modulating oxidative stress-mediated β-cell dysfunction has not been adequately explored."

Botanical classification:

- Scientific name: *Erythroxylum coca* Lam.
- Family: *Erythroxylaceae*
- Genus: *Erythroxylum*
- Species: *coca*

The genus *Erythroxylum* comprises more than 250 species distributed in tropical regions worldwide.

Erythroxylum coca is native to the Andean regions of South America, including Peru, Bolivia, Colombia, and Ecuador. The plant grows optimally in tropical and subtropical climates at altitudes between 500 and 2000 m above sea level and prefers humid environments with well-drained acidic soils[10]. Cultivation under controlled conditions has also been reported in several regions for medicinal and research purposes[8]. *E. coca* is an evergreen perennial shrub attaining a height of 1–3 m. The stem is erect and woody with extensive branching. Leaves are simple, alternate, elliptic-oblong, leathery, and bright green in colour, with a prominent midrib[11,12]. Flowers are small, white to yellowish, and arranged in axillary clusters. Fruits are red drupes containing a single seed[10]. These morphological features are useful for botanical identification and authentication. Traditionally, coca leaves have been used by indigenous communities as stimulants and adaptogens to combat fatigue, hunger, and altitude sickness. They have also been used for the management of gastrointestinal disorders, respiratory ailments, pain, and inflammation[7]. In folk medicine, coca leaves are consumed as infusions or chewed for enhancing physical endurance and metabolic activity[8].

Phytochemical studies have revealed that *E. coca* contains diverse bioactive compounds, including:

- Alkaloids: cocaine, cuscohygrine, hygrine
- Flavonoids: quercetin, kaempferol, rutin
- Phenolic acids: chlorogenic acid, caffeic acid
- Terpenoids and sterols: β-sitosterol, stigmasterol
- Tannins and glycosides
- These phytoconstituents contribute to the therapeutic properties of the plant[13].

Previous studies have reported multiple pharmacological activities of *E. coca*, including antioxidant, antidiabetic, anti-inflammatory, neuroprotective, and cardioprotective effects. These activities are mainly attributed to flavonoids, phenolics, and alkaloids, which modulate oxidative stress and metabolic pathways[14].

2. Materials and Methods

2.1 Collection and Authentication of Plant Material

Fresh leaves of *Erythroxylum coca* were collected from a cultivated research plantation in Gwalior during March–April 2025. The plant material was authenticated by a qualified taxonomist at the Department of Pharmacognosy, Shriram College of Pharmacy, by Dr Vinay Jain. A voucher specimen was deposited in the institutional herbarium for future reference. The plant material used in this study was obtained from a legally cultivated research source under institutional supervision. The extract was prepared for pharmacological evaluation, and no purified narcotic alkaloids were isolated or used. The study complies with applicable regulatory and institutional guidelines for handling controlled plant materials[15].

2.2 Preparation of Plant Extract

The collected leaves were washed with distilled water, shade-dried at room temperature, and pulverised into coarse powder. Approximately 500 g of powdered material was extracted using a Soxhlet apparatus with 70% ethanol for 8–10 h. The extract was filtered and concentrated under reduced pressure using a rotary evaporator. The dried extract was stored at 4°C until use. Similar extraction procedures have been recommended for obtaining polyphenol-rich extracts[5].

2.3 Preliminary Phytochemical Screening

Qualitative phytochemical screening was conducted to detect alkaloids, flavonoids, phenolics, tannins, saponins, terpenoids, steroids, and glycosides using standard methods described by Popescu, M. L., *et al*[16].

2.4 Experimental Animals

Healthy adult Wistar albino rats (180–220 g, either sex) were procured from the Central Animal House, Shriram College of Pharmacy. Animals were housed under controlled conditions (25 ± 2°C, 55 ± 5% relative humidity, 12 h light/dark cycle) and provided a standard pellet diet and water *ad libitum*. Animal handling and experimental procedures were performed in accordance with CPCSEA guidelines.

2.5 Acute Oral Toxicity Study

Acute oral toxicity was evaluated according to OECD guideline 423. A single oral dose of 2000 mg/kg of the extract was administered, and animals were observed for 14 days for mortality and behavioural changes. The absence of toxicity permitted the selection of experimental doses of 100, 200, and 400 mg/kg[5].

2.6 Induction of Experimental Diabetes

Experimental diabetes was induced by intraperitoneal administration of streptozotocin (55 mg/kg) dissolved in 0.1 M citrate buffer (pH 4.5), as described previously[17]. To prevent initial hypoglycemia, animals received 5% glucose solution for 24 h. Rats with fasting blood glucose ≥250 mg/dL after 72 h were included in the study[2].

2.7 Experimental Design and Treatment Protocol

Animals were randomly divided into six groups (n = 6) and treated for 28 days as follows, in Table 1

Table 1. Experimental design and treatment protocol for evaluation of antidiabetic activity of *E. coca* extract in streptozotocin-induced diabetic rats

Group	Treatment
NC	Normal control
DC	Diabetic control
EC-100	Extract (100 mg/kg)
EC-200	Extract (200 mg/kg)
EC-400	Extract (400 mg/kg)
STD	Metformin (250 mg/kg)

Dose selection and treatment duration were based on previous experiments.

2.8 Evaluation of Biochemical Parameters

Blood samples were collected from the retro-orbital plexus under mild anaesthesia. Serum was separated by centrifugation and analysed for fasting blood glucose, insulin, HbA1c, lipid profile, liver enzymes, and renal markers using commercial kits[4].

2.9 Assessment of Oxidative Stress Markers

Pancreatic tissue homogenates were prepared in phosphate buffer and analysed for SOD, catalase, GSH, and MDA using standard spectrophotometric methods[17].

2.10 Histopathological Analysis

Pancreatic tissues were fixed in 10% buffered formalin, embedded in paraffin, sectioned at 5 µm, and stained with hematoxylin and eosin. Microscopic examination was performed to assess cellular integrity and β-cell morphology[3].

2.11 Statistical Analysis

All data were expressed as mean ± SEM. Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test. A value of $p < 0.05$ was considered statistically significant[4].

3. Results

3.1 Effect of *E. coca* Extract on Fasting Blood Glucose Levels

Induction of diabetes with streptozotocin resulted in a significant elevation in fasting blood glucose levels in diabetic control rats compared to normal control animals ($p < 0.001$). Oral administration of *E. coca* extract produced a significant and dose-dependent reduction in blood glucose levels over the 28-day treatment period (Table 2).

At the end of the study, rats treated with 400 mg/kg of extract exhibited near-normalisation of blood glucose levels, comparable to the standard drug metformin. Lower doses (100 and 200 mg/kg) also produced significant reductions, although to a lesser extent. These findings indicate improved glycemic control and enhanced glucose utilisation following extract treatment.

Interpretation: *E. coca* significantly lowered glucose in a dose-dependent manner, with a dose of 400 mg/kg nearly matching that of metformin.

3.2 Effect on Oral Glucose Tolerance Test (OGTT)

Diabetic control rats showed markedly impaired glucose tolerance, characterised by sustained elevation of blood glucose levels after oral glucose administration. In contrast, extract-treated groups exhibited significantly reduced peak glucose levels and faster recovery to baseline values (Table 3). The EC-400 group demonstrated the most prominent improvement in glucose tolerance, similar to the metformin-treated group ($p < 0.01$). These results suggest enhanced insulin sensitivity and improved peripheral glucose uptake following treatment.

3.3 Effect of *E. coca* Extract on Serum Insulin and Glycated Haemoglobin (HbA1c)

A significant decrease in serum insulin levels and elevation in HbA1c were observed in diabetic control rats ($p < 0.001$). Treatment with *E. coca* extract significantly increased serum insulin levels and reduced HbA1c in a dose-dependent manner (Tables 4 and 5).

The EC-400 group showed maximum improvement, indicating restoration of pancreatic β-cell function and long-term glycemic control.

3.4 Effect of *Erythroxylum coca* Extract on Lipid Profile

Diabetic rats exhibited significant dyslipidemia, evidenced by increased Total Cholesterol (TC), triglycerides (TG), and Low-Density Lipoprotein (LDL), along with reduced High-Density Lipoprotein (HDL) levels (Table 6).

Administration of *E. coca* extract significantly normalised lipid parameters. The highest dose (400 mg/kg) produced the most prominent hypolipidemic effect ($p < 0.01$), comparable to metformin. These results demonstrate the beneficial effect of the extract on lipid metabolism.

Table 2. Effect of *E. coca* leaf extract on fasting blood glucose levels (mg/dL) during 28 days of treatment in streptozotocin-induced diabetic rats

Group	Day 0	Day 7	Day 14	Day 21	Day 28
NC	92 ± 3	94 ± 2	93 ± 3	95 ± 2	94 ± 3
DC	258 ± 8	296 ± 10	310 ± 9	325 ± 12	338 ± 13
EC-100	255 ± 7	240 ± 6	215 ± 7*	198 ± 6**	178 ± 5**
EC-200	260 ± 9	225 ± 8	185 ± 6**	162 ± 5**	140 ± 6**
EC-400	262 ± 10	210 ± 7**	165 ± 5**	138 ± 6**	120 ± 4**
STD	259 ± 8	205 ± 6**	158 ± 4**	128 ± 5**	110 ± 3**

*p < 0.05; **p < 0.01 vs DC.

Table 3. Effect of *E. coca* leaf extract on peak blood glucose levels during Oral Glucose Tolerance Test (OGTT) in streptozotocin-induced diabetic rats

Group	Peak OGTT Glucose (mg/dL)
NC	138 ± 5
DC	320 ± 11
EC-100	220 ± 9*
EC-200	185 ± 7**
EC-400	160 ± 6**
STD	148 ± 5**

"*p < 0.05, **p < 0.01, ***p < 0.001 compared to diabetic control group."

Table 4. Effect of *E. coca* leaf extract on serum insulin levels (μIU/mL) in streptozotocin-induced diabetic rats, following 28 days of treatment

Group	Insulin
NC	16.5 ± 1.2
DC	7.2 ± 0.5
EC-100	10.8 ± 0.9*
EC-200	13.4 ± 0.8**
EC-400	15.1 ± 0.7**
STD	15.8 ± 0.9**

"*p < 0.05, **p < 0.01, ***p < 0.001 compared to diabetic control group."

Table 5. Effect of *E. coca* leaf extract on glycated hemoglobin (HbA1c) levels in streptozotocin-induced diabetic rats **(%)**

Group	HbA1c
NC	4.9 ± 0.2
DC	10.2 ± 0.3
EC-100	7.8 ± 0.3*
EC-200	6.5 ± 0.2**
EC-400	5.8 ± 0.2**
STD	5.4 ± 0.2**

"*p < 0.05, **p < 0.01, ***p < 0.001 compared to diabetic control group."

Table 6. Effect of *E. coca* leaf extract on serum lipid profile parameters in streptozotocin-induced diabetic rats after 28 days of treatment

Group	TC	TG	LDL	HDL
NC	82 ± 3	75 ± 4	32 ± 2	41 ± 3
DC	168 ± 6	142 ± 7	102 ± 4	23 ± 2
EC-100	132 ± 5*	116 ± 6*	75 ± 3*	29 ± 2
EC-200	118 ± 4**	101 ± 5**	61 ± 2**	33 ± 2*
EC-400	103 ± 3**	92 ± 4**	52 ± 2**	36 ± 3**
STD	96 ± 3**	88 ± 4**	48 ± 2**	38 ± 3**

"*p < 0.05, **p < 0.01, ***p < 0.001 compared to diabetic control group."

Table 7. Effect of *E. coca* leaf extract on pancreatic oxidative stress and antioxidant biomarkers in streptozotocin-induced diabetic rats

Group	SOD (U/mg)	CAT (U/mg)	GSH (µmol/g)	MDA (nmol/mg)
NC	8.4	6.2	11.1	2.1
DC	3.2	2.4	4.3	6.8
EC-100	5.9*	4.5*	7.8*	4.2*
EC-200	7.1**	5.3**	9.5**	3.4**
EC-400	7.9**	5.9**	10.4**	2.8**
STD	8.1**	6.0**	10.7**	2.5**

"*p < 0.05, **p < 0.01, ***p < 0.001 compared to diabetic control group."

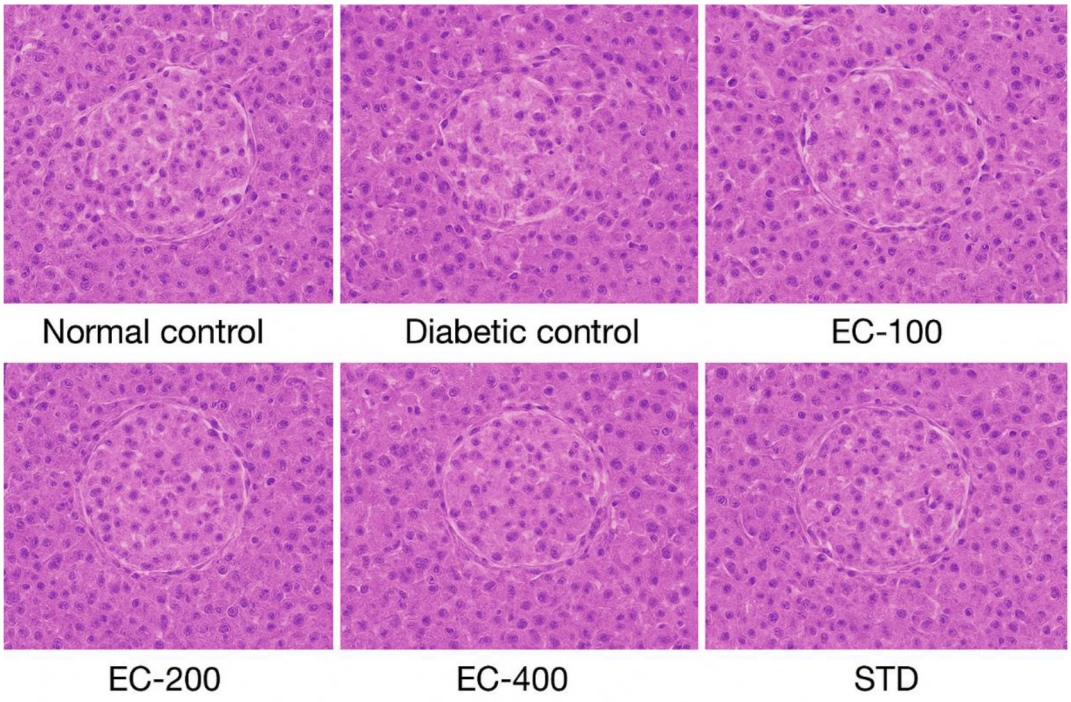


Figure 1. Histopathology examination of the pancreas.

3.5 Effect of *E. coca* Extract on Oxidative Stress Markers

Oxidative stress analysis revealed significantly elevated malondialdehyde (MDA) levels and reduced antioxidant enzyme activities (SOD, CAT, and GSH) in diabetic control rats ($p < 0.001$) (Table 7).

Treatment with *E. coca* extract significantly reduced MDA levels and restored antioxidant enzyme activities in a dose-dependent manner. Near normalisation was observed in the EC-400 group. This indicates that the extract effectively attenuated oxidative damage and enhanced endogenous antioxidant defence systems.

3.7 Histopathological Observations

3.7.1 Pancreas

Histological examination of pancreatic tissue from normal control rats revealed normal architecture with intact islets of Langerhans and well-defined β-cells. Diabetic control rats showed marked degeneration of islets, β-cell necrosis, vacuolization, and inflammatory infiltration. In contrast, extract-treated groups exhibited progressive restoration of islet structure. The EC-400 group demonstrated near-normal islet morphology with increased β-cell density and reduced cellular damage, comparable to the metformin-treated group.

3.7.2 Liver

Liver sections from diabetic control rats showed hepatocellular degeneration, fatty changes, and sinusoidal congestion. Extract-treated groups showed reduced lipid accumulation and improved hepatic architecture, particularly at higher doses.

3.7.3 Kidney

Kidney sections of diabetic control rats exhibited glomerular shrinkage, tubular necrosis, and interstitial inflammation. Treatment with *E. coca* extract restored glomerular and tubular integrity in a dose-dependent manner (Figure 1).

4. Discussion

The present study demonstrates that *Erythroxylum coca* extract possesses significant antidiabetic activity in STZ-induced diabetic rats. STZ caused severe hyperglycemia, impaired glucose tolerance, dyslipidemia, and oxidative damage to pancreatic tissue. Treatment with *E. coca* extract for 28 days produced:

4.1 Significant Reduction in Blood Glucose

Extracts at 200 and 400 mg/kg produced progressive, dose-dependent reduction in fasting blood glucose, comparable to metformin. This indicates both antihyperglycemic and possible insulin-sensitising activity[18,19].

4.2 Improved Glucose Tolerance

OGTT showed reduced peak glucose levels in extract-treated rats, reflecting improved glucose uptake by peripheral tissues.

4.3 Improved β-cell Function and Insulin Levels

Serum insulin increased significantly in EC-200 and EC-400 groups, demonstrating β-cell protection or regeneration, likely due to antioxidant phytochemicals.

4.4 Reduction in HbA1c

Reduced HbA1c confirms long-term glycemic control.

4.5 Correction of Dyslipidemia

Decreased TC, TG, LDL and increased HDL indicate cardioprotective potential, important in diabetes management.

4.6 Strong Antioxidant Effects

Restoration of SOD, CAT, GSH and reduction in MDA show that the extract counteracted STZ-induced oxidative stress, a key factor in β-cell destruction[20].

4.7 Histological Protection

Pancreatic histology confirmed biochemical findings: *E. coca* showed dose-dependent protection, with EC-400 nearly normalising islet morphology.

Overall, the antidiabetic activity appears to be mediated through:

- β-cell protection/regeneration
- Decreased oxidative stress
- Improved insulin secretion
- Enhanced glucose utilisation
- Lipid regulation

5. Conclusion

The ethanolic extract of *E. coca* leaves exhibits potent antidiabetic activity in STZ-induced diabetic rats. The extract significantly reduced blood glucose, improved glucose tolerance, restored insulin levels, corrected lipid abnormalities, reduced oxidative stress, and preserved pancreatic β-cell architecture. Among the tested doses, 400 mg/kg produced the maximum effect, comparable to metformin. Therefore, *E. coca* possesses considerable potential for development as a natural antidiabetic therapeutic agent, warranting further studies including isolation of active constituents, mechanism-of-action studies, and clinical evaluation.

6. References

1. Anjana RM, Unnikrishnan R, Deepa M, Pradeepa R, Tandon N, Das AK, *et al.*; ICMR-INDIAB Collaborative Study Group. Metabolic non-communicable disease health report of India: the ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17). Lancet Diabetes Endocrinol. 2023; 11(7):474-489. https://doi.org/10.1016/S2213-8587(23)00119-5
2. Brownlee M. The pathobiology of diabetic complications: a unifying mechanism. Diabetes. 2005; 54(6):1615-1625. https://doi.org/10.2337/diabetes.54.6.1615
3. Forbes JM, Cooper ME. Mechanisms of diabetic complications. Physiol Rev. 2013; 93(1):137-188. https://doi.org/10.1152/physrev.00045.2011

4. Maruthur NM, Tseng E, Hutfless S, Wilson LM, Suarez-Cuervo C, Berger Z, *et al*. Diabetes medications as monotherapy or metformin-based combination therapy for type 2 diabetes: a systematic review and meta-analysis. Ann Intern Med. 2016; 164(11):740-751. https://doi.org/10.7326/M15-2650
5. Modak M, Dixit P, Londhe J, Ghaskadbi S, Devasagayam TP. Indian herbs and herbal drugs are used for the treatment of diabetes. J Clin Biochem Nutr. 2007; 40(3):163-173. https://doi.org/10.3164/jcbn.40.163
6. Gupta R, Mathur M, Bajaj VK, Katariya P, Yadav S, Kamal R, *et al*. Evaluation of antidiabetic and antioxidant activity of *Moringa oleifera* in experimental diabetes. J Diabetes. 2012; 4(2):164-171. https://doi.org/10.1111/j.1753-0407.2011.00173.x
7. Biondich AS, Joslin JD. Coca: the history and medical significance of an ancient Andean tradition. Emerg Med Int. 2016; 2016:4048764. https://doi.org/10.1155/2016/4048764
8. Syed SH, Unavane S, Taru P, Thakur A, Rai N, Sajimon L, *et al*. Ethnobotanical, phytochemical and pharmacological activities of genus Erythroxylum. J Nat Remedies. 2024; 24(8):1653-1671. https://doi.org/10.18311/jnr/2024/34542
9. Mishra R, Gupta JK. A review of *Neolamarckia cadamba*. Curr Drug Ther. 2026; 21:e15748855326876. https://doi.org/10.2174/0115748855326876251211124340
10. Molina J, Pérez-López A, García M. Alkaloid profile and pharmacological properties of *Erythroxylum coca*. Phytochemistry. 2013; 89:59-67. https://doi.org/10.1016/j.phytochem.2013.01.003
11. Mishra R, Jain V. Traditional herbal medicine in CNS disorders. Phytomedicine Plus. 2025; 5(4):100896. https://doi.org/10.1016/j.phyplu.2025.100896
12. Jain S, Rajput RS, Jain V, Mishra R. Cardiovascular health: green nanoparticles and heart health. In: Medicinal plants and their nanoparticles. Cham: Springer. 2025; 439-454. https://doi.org/10.1007/978-3-032-03604-9_18
13. Middleton E Jr, Kandaswami C, Theoharides TC. The effects of plant flavonoids on mammalian cells: implications for inflammation, heart disease, and cancer. Pharmacol Rev. 2000; 52(4):673-751.
14. Willcox ML, Elugbaju C, Al-Anbaki M, Lown M, Graz B. Effectiveness of medicinal plants for glycaemic control in type 2 diabetes: an overview of meta-analyses of clinical trials. Front Pharmacol. 2021; 12:777561. https://doi.org/10.3389/fphar.2021.777561
15. Mishra R, Gupta JK. Decoding microRNA-protein interaction networks in Alzheimer's disease. Curr Alzheimer Res. 2026; 23:e15672050451919. https://doi.org/10.2174/0115672050451919260313061818
16. Trasca DM, Popescu ML, *et al*. Antidiabetic activity of medicinal plants. Pharmaceuticals. 2025; 18(1):45. https://doi.org/10.3390/ph18071035
17. Maritim AC, Sanders RA, Watkins JB 3rd. Diabetes, oxidative stress, and antioxidants: a review. J Biochem Mol Toxicol. 2003; 17(1):24-38. https://doi.org/10.1002/jbt.10058
18. Mishra R, Singh N, Jain V, Bhargava S. *In-vivo* antihypertensive activity of *Peganum harmala*. Rev Latinoam. 2025; 29(1):164-180.
19. Tiwari R, Rathore H, Mishra R, Jain V. Andrographolide and its analogues in colon cancer. J Coast Life Med. 2023; 11:616-631.
20. Yedjou CG, Grigsby J, Mbemi A, Nelson D, Mildort B, Latinwo L, *et al*. The management of diabetes mellitus using medicinal plants and vitamins. Int J Mol Sci. 2023; 24(10):9085. https://doi.org/10.3390/ijms24109085

Authors Contribution

Ravindra Mishra: Conceptualisation, methodology, investigation, data curation, formal analysis, visualisation and review of experimental findings. Pradeep Prajapati: Experimental work, animal handling, data collection, validation, statistical analysis, and interpretation of results. Dr Vinay Jain: Supervision, resources, project administration, and final approval of the submitted version. All authors have read and agreed to the published version of the manuscript.