RESEARCH PAPER

Evaluation of a Standardized Polyherbal Formulation of *Juglans nigra*, *Coriandrum sativum*, and *Mucuna pruriens* for Antidiabetic, Lipid-Modulating, and Hepatoprotective Activity in Streptozotocin-Induced Diabetic Rats.

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ABSTRACT

Objectives: To evaluate the antidiabetic, lipid-modulating, and hepatoprotective potential of a standardized polyherbal extract (PHE) containing *Juglans nigra*, *Coriandrum sativum*, and *Mucuna pruriens* in streptozotocin-induced diabetic rats.

Materials and Methods: Hydroalcoholic extracts of the selected plants were prepared and combined to formulate PHE. Experimental diabetes was induced in rats using streptozotocin (60 mg/kg). Animals were treated with PHE at doses of 250 and 500 mg/kg for 21 days, while glibenclamide (5 mg/kg) served as the standard reference drug. Fasting blood glucose levels were monitored periodically. Biochemical parameters, including total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), serum total protein, and liver enzyme levels (SGOT, SGPT, and ALP), were evaluated.

Results: Diabetic control rats exhibited elevated blood glucose levels, reaching 274.17 mg/dL on day 7. PHE treatment produced a dose-dependent reduction in blood glucose, with the 500 mg/kg dose reducing the level to 180.83 mg/dL after 21 days, compared with 164.17 mg/dL in the glibenclamide-treated group. Serum total protein increased from 4.60 g/dL in diabetic controls to 8.34 g/dL following treatment with the higher PHE dose. PHE also reduced total cholesterol from 296.25 to 201 mg/dL and triglycerides from 229.40 to 156.50 mg/dL, increased HDL levels, and decreased LDL and very-low-density lipoprotein (VLDL) levels. Elevated liver enzyme levels in diabetic controls, including ALP (551 IU/L), SGOT (71.56 IU/L), and SGPT (87.01 IU/L), were reduced following PHE treatment.

Conclusion: The polyherbal extract demonstrated potential antidiabetic, lipid-modulating, and hepatoprotective effects in streptozotocin-induced diabetic rats. These preliminary findings suggest that PHE warrants further investigation as a potential plant-based intervention for diabetes-associated metabolic complications.

Keywords: Antidiabetic activity, Diabetes mellitus, Hepatoprotective activity, Hyperlipidemia, Medicinal plants, Polyherbal extract, Streptozotocin.

How to cite this article: Vipin Kumar Wani. Evaluation of a Standardized Polyherbal Formulation of Juglans nigra, Coriandrum sativum, and Mucuna pruriens for Antidiabetic, Lipid-Modulating, and Hepatoprotective Activity in Streptozotocin-Induced Diabetic Rats.. Int J Drug Deliv Technol. 2026;16(90s):1740-1753. DOI: 10.25258/ijddt.16.90s.175.1.

INTRODUCTION

1.1 Global Burden of Diabetes

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, impaired insulin action, or both. It is associated with disturbances in carbohydrate, lipid, and protein metabolism that can lead to long-term damage and dysfunction of vital organs, including the heart, kidneys, liver, nerves, and eyes [1]. Owing to its increasing prevalence and associated complications, diabetes mellitus represents a major global public health challenge.

Type 2 diabetes mellitus (T2DM) accounts for approximately 90–95% of diabetes cases. According to the International Diabetes Federation,

an estimated 537 million adults were living with diabetes in 2021, and this number was projected to increase to 643 million by 2030 and 783 million by 2045 [2]. The rising prevalence of diabetes is associated with population ageing, urbanization, sedentary lifestyles, unhealthy dietary patterns, and increasing rates of overweight and obesity.

Developing countries, including India, face a substantial and growing burden of diabetes. Changes in dietary habits, reduced physical activity, genetic susceptibility, and increasing obesity contribute to the increasing prevalence of the disease in India [3]. Effective diabetes management therefore requires therapeutic approaches that address hyperglycemia and associated metabolic abnormalities while maintaining an acceptable safety profile.

1.2 Pathophysiology of Type 2 Diabetes Mellitus

The pathophysiology of T2DM involves multiple metabolic abnormalities, particularly insulin resistance in peripheral tissues, including skeletal muscle, adipose tissue, and the liver, together with progressive dysfunction of pancreatic β-cells [4]. During the early stages of insulin resistance, pancreatic β-cells may compensate by increasing insulin secretion. However, progressive β-cell dysfunction can eventually result in inadequate insulin secretion and persistent hyperglycemia.

Oxidative stress and chronic low-grade inflammation are also implicated in diabetes-associated metabolic dysfunction. Excessive production of reactive oxygen species (ROS) can damage cellular components and interfere with insulin-signalling pathways, potentially aggravating glucose dysregulation [5]. Inflammatory mediators, including tumour necrosis factor-α (TNF-α) and interleukin-6 (IL-6), together with activation of nuclear factor-κB (NF-κB) signalling, have also been associated with insulin resistance and metabolic disturbances [6].

Persistent hyperglycemia and altered lipid metabolism contribute to dyslipidemia and increase the risk of cardiovascular disease, nephropathy, neuropathy, and retinopathy [7]. Diabetes may also be associated with hepatic metabolic disturbances and oxidative injury. Consequently, therapeutic strategies that improve glycemic control and lipid metabolism while protecting against associated tissue injury are of considerable research interest.

1.3 Limitations of Conventional Antidiabetic Therapy

The management of diabetes mellitus involves lifestyle modification and pharmacological interventions, including biguanides, sulfonylureas, thiazolidinediones, and insulin. Metformin, glibenclamide, and insulin are examples of agents used in clinical diabetes management, depending on the patient's clinical condition and treatment requirements.

Although these therapies can effectively improve glycemic control, their use may be associated with adverse effects. Sulfonylureas, including glibenclamide, can cause hypoglycemia and weight gain, while metformin may produce gastrointestinal disturbances. Other antidiabetic agents have distinct safety considerations depending on the drug, dosage, patient characteristics, and associated diseases [8]. Furthermore, diabetes is a multifactorial disorder involving interconnected pathways related to glucose regulation, lipid metabolism, inflammation, and oxidative stress.

These considerations have encouraged research into complementary therapeutic approaches, including medicinal plant-derived preparations. However, plant-based products also require appropriate evaluation of their efficacy, toxicity, chemical composition, and batch-to-batch consistency before their therapeutic potential can be established.

1.4 Role of Medicinal Plants in Diabetes Management

Medicinal plants have long been used in traditional healthcare systems, including Ayurveda, Siddha, and Unani medicine, for the management of various metabolic disorders. Their potential role in diabetes research has attracted scientific interest because plant extracts contain diverse phytochemicals that may influence several biological pathways [9].

Phytochemical groups investigated for potential antidiabetic activity include flavonoids, alkaloids, tannins, terpenoids, and other phenolic compounds. Depending on their chemical structures and biological properties, these constituents may influence glucose metabolism through mechanisms such as modulation of insulin secretion, enhancement of peripheral glucose uptake, inhibition of carbohydrate-digesting enzymes, reduction of oxidative stress, and protection against cellular injury [10].

Experimental studies of medicinal plants have reported a range of antihyperglycemic and metabolic effects, although the strength of evidence varies among individual plants, extracts, and experimental models [11]. The identification, standardization, and pharmacological evaluation of

plant-derived preparations are therefore important steps in investigating their potential applications in diabetes management.

1.5 Therapeutic Potential of Polyherbal Formulations

Polyherbal formulations combine extracts or preparations from two or more medicinal plants. Such combinations are investigated because their constituents may influence different biological targets and potentially produce complementary pharmacological effects. In diabetes research, a polyherbal preparation may be evaluated for its effects on blood glucose regulation, lipid metabolism, and oxidative stress-related outcomes.

The therapeutic activity of a polyherbal formulation depends on factors such as the identity and quality of the constituent plants, extraction procedures, proportions of the extracts, chemical composition, dose, and interactions among their constituents [12]. Although combining medicinal plants may offer a broader range of biological activities, synergistic effects, improved bioavailability, and reduced toxicity should not be assumed without experimental evidence.

Standardization is particularly important because differences in plant sources, processing methods, and phytochemical content can influence the reproducibility of herbal preparations. Accordingly, systematic preparation and pharmacological evaluation are necessary to establish the efficacy and safety profile of polyherbal formulations [13].

1.6 Selected Medicinal Plants for the Polyherbal Formulation

The present study investigates a polyherbal extract (PHE) comprising *Coriandrum sativum*, *Mucuna pruriens*, and *Juglans nigra*. These plants were selected based on their reported phytochemical constituents and potential pharmacological properties relevant to metabolic disorders.

1.6.1 *Coriandrum sativum*

Coriandrum sativum L., commonly known as coriander, is an aromatic plant widely used as a culinary ingredient and in traditional medicine. Various parts of the plant contain phenolic compounds, flavonoids, and other phytochemicals that have been investigated for antioxidant and metabolic effects. Experimental studies have reported antihyperglycemic and hypolipidemic activities associated with coriander preparations [14].

Coriander extracts have also been investigated for their potential effects on carbohydrate metabolism, postprandial glucose regulation, and the activity of enzymes involved in carbohydrate digestion [15]. However, these effects may vary according to the plant part, extraction solvent, chemical composition, and experimental conditions. Further evaluation of standardized extracts is necessary to establish their contribution to the activity of a combined formulation.

1.6.2 *Mucuna pruriens*

Mucuna pruriens (L.) DC. is a tropical leguminous plant with a diverse phytochemical composition. Its seeds are particularly known for containing L-3,4-dihydroxyphenylalanine (L-DOPA), along with other constituents whose concentrations may vary with the source and processing of the plant material [16].

Although *Mucuna pruriens* has been extensively investigated for its neurological pharmacological properties, its phytochemical constituents have also attracted interest in research concerning antioxidant activity and metabolic regulation. Such properties provide a rationale for further investigation of selected preparations in experimental models of metabolic disorders [17]. Nevertheless, its specific contribution to the antidiabetic activity of the present polyherbal formulation requires direct experimental confirmation.

1.6.3 *Juglans nigra*

Juglans nigra L., commonly known as black walnut, belongs to the family Juglandaceae. Different parts of the plant contain phenolic compounds and other secondary metabolites that have been investigated for antioxidant and biological activities. Juglone, a naphthoquinone associated with the genus *Juglans*, is among the compounds studied for its biological properties [18].

The antioxidant and metabolic properties reported for walnut-related preparations provide a basis for investigating *Juglans nigra* in a polyherbal formulation intended for diabetes-associated metabolic abnormalities. However, the phytochemical composition and pharmacological effects of black walnut preparations may differ according to the plant part and extraction method. Its role in the present formulation therefore requires evaluation using the specific extract prepared for the study [19].

1.7 Rationale and Objective of the Present Study

Diabetes mellitus is associated with interconnected disturbances in glucose regulation, lipid metabolism, and oxidative balance. Investigating plant-derived formulations that may influence more than one of these outcomes is therefore a relevant area of pharmacological research. However, the activity of a combined extract cannot be inferred solely from reports concerning its individual plant constituents.

The present study was designed to prepare and evaluate a polyherbal extract containing *Coriandrum sativum*, *Mucuna pruriens*, and *Juglans nigra*. The extract was prepared by combining the individual hydroalcoholic extracts in a 1:1:1 ratio and was subjected to preliminary phytochemical evaluation. Its pharmacological effects were investigated in streptozotocin (STZ)-induced diabetic rats.

The primary objective was to evaluate the effect of the polyherbal extract at doses of 250 and 500 mg/kg body weight on blood glucose levels. Additional outcomes included lipid profile parameters, serum total protein, and liver enzyme levels, with glibenclamide serving as the reference drug. The study aimed to generate experimental evidence regarding the antidiabetic and lipid-modulating potential of the formulation and to investigate biochemical indicators relevant to hepatic function in STZ-induced diabetic rats.

2. MATERIALS AND METHODS

2.1 Plant Materials and Authentication

Coriandrum sativum stalk powder and *Mucuna pruriens* seed powder were collected from the forest region of Sipat, Bilaspur, Chhattisgarh, India. *Juglans nigra* plant material was procured from an online source. The plant materials were submitted for taxonomic authentication to the Department of Botany, Guru Ghasidas Vishwavidyalaya (GGV), Bilaspur, Chhattisgarh, India. The authentication specimen was deposited under voucher number Bot/GGV/2023/60. The collected plant materials were shade-dried, coarsely powdered, and used for the preparation of the polyherbal extract (PHE).

2.2 Preparation of Hydroalcoholic Extracts

The powdered plant materials were extracted separately using a hydroalcoholic solvent consisting of ethanol and distilled water in a ratio of 70:30 (v/v). Approximately 500 g of each powdered plant material was subjected to extraction using a Soxhlet apparatus for 6–8 hours. The resulting extracts were filtered through Whatman No. 1 filter paper and concentrated under reduced pressure using a rotary evaporator. The concentrated extracts were further dried to obtain the respective crude extracts. The percentage yield of each extract was calculated, and the dried extracts were stored in airtight containers at 4°C until further use.

$$\text{Extract yield (\%)} = \frac{\text{Weight of dried extract (g)}}{\text{Weight of powdered plant material (g)}} \times 100$$

2.3 Preparation of Polyherbal Extract (PHE)

The dried hydroalcoholic extracts of *Coriandrum sativum*, *Mucuna pruriens*, and *Juglans nigra* were mixed in equal proportions (1:1:1, w/w) to prepare the polyherbal extract. The extracts were thoroughly blended using a mortar and pestle to obtain a homogeneous mixture. The prepared PHE was stored in an airtight container under suitable storage conditions until further phytochemical and pharmacological evaluation.

2.4 Preliminary Phytochemical Screening

Preliminary qualitative phytochemical screening of the PHE was performed to identify the presence of major classes of phytoconstituents, including alkaloids, flavonoids, tannins, phenolic compounds, saponins, glycosides, terpenoids, and steroids. Standard qualitative procedures were employed, including Mayer's test for alkaloids, the Shinoda test for flavonoids, the ferric chloride test for phenolic compounds, the foam test for saponins, and the Keller–Killiani test for cardiac glycosides. The appearance of characteristic colour changes, foam, or precipitates was interpreted according to the respective test procedures.

2.5 Experimental Animals and Housing Conditions

Adult Wistar albino rats of both sexes, weighing 100–200 g, were used for the experimental study. The animals were maintained under controlled laboratory conditions at a temperature of 22–25°C, with a 12-hour light/dark cycle. Standard laboratory feed and drinking water were provided *ad libitum*. The animals were acclimatized to the laboratory conditions before the commencement of the experiment.

All animal handling and experimental procedures were conducted in accordance with applicable institutional ethical guidelines and the approval granted by the relevant Institutional Animal Ethics Committee (IAEC), where applicable. The details of the ethical approval should be provided in the final manuscript. Reagents, consumables, and laboratory equipment were obtained from the School of Pharmacy, Chouksey Engineering

College, Bilaspur, Chhattisgarh, India, or other relevant sources, as applicable.

2.6 Induction of Experimental Diabetes

Experimental diabetes was induced in overnight-fasted Wistar albino rats by a single intraperitoneal injection of streptozotocin (STZ) at a dose of 50 mg/kg body weight. STZ was freshly dissolved in citrate buffer (pH 4.5) immediately before administration. After 72 hours, fasting blood glucose levels were measured using a digital glucometer. Animals exhibiting fasting blood glucose levels greater than 250 mg/dL were considered diabetic and selected for subsequent pharmacological evaluation.

2.7 Experimental Design and Treatment Groups

The experimental animals were randomly allocated to five groups, with six animals in each group (n = 6).

- **Group I: Normal control** — animals receiving the vehicle only.
- **Group II: Diabetic control** — STZ-induced diabetic animals receiving the vehicle.
- **Group III: PHE low-dose group** — diabetic animals receiving PHE at 250 mg/kg body weight.
- **Group IV: PHE high-dose group** — diabetic animals receiving PHE at 500 mg/kg body weight.
- **Group V: Standard treatment group** — diabetic animals receiving glibenclamide at 5 mg/kg body weight.

The assigned treatments were administered orally once daily for 21 consecutive days. The vehicle composition and administration volume should be specified according to the actual experimental protocol.

2.8 Determination of Blood Glucose Levels

Fasting blood glucose levels were measured on days 0, 7, 14, and 21 of the treatment period. Blood samples were collected from the tail vein and analysed using a digital glucometer. The antihyperglycemic activity of PHE was evaluated by comparing blood glucose levels in the PHE-treated groups with those in the diabetic control and standard treatment groups.

2.9 Measurement of Body Weight

The body weight of each experimental animal was recorded at the beginning of the treatment period and at weekly intervals thereafter. Changes in body weight during the 21-day treatment period were assessed to monitor the animals' general metabolic status and the effects associated with treatment.

2.10 Statistical Analysis

Experimental data were expressed as mean ± standard deviation (SD), with six animals per group (n = 6). Statistical analysis was performed using two-way analysis of variance (ANOVA), followed by Bonferroni's multiple-comparison post hoc test. GraphPad Prism, version 5.0, was used for statistical analysis. A p value of less than 0.05 was considered statistically significant.

Comparisons were made between the normal control group, STZ-induced diabetic control group, PHE-treated groups, and glibenclamide-treated group, as appropriate. The statistical significance symbols and corresponding comparison groups should be defined consistently in the legends of the respective tables and figures.

III. Results

3.1 Standardization and Phytochemical Characterization of the Polyherbal Extract

Standardization of crude plant materials is an essential prerequisite for ensuring the quality, purity, and reproducibility of herbal formulations. In the present study, the medicinal plants Coriandrum sativum, Mucuna pruriens, and Juglans nigra were subjected to pharmacognostic, phytochemical, and chromatographic analysis prior to formulation development.

Organoleptic and Microscopic Evaluation

The powdered plant materials were evaluated for their organoleptic characteristics including color, odor, taste, and texture. The samples exhibited characteristic morphological features consistent with the authentic plant materials described in pharmacognostic references.

Powder microscopy revealed the presence of several diagnostic features such as calcium oxalate crystals, lignified fibers, tracheids, starch granules, vessel elements, and parenchymatous tissues. These microscopic features confirmed the botanical authenticity of the selected plants and ensured the absence of adulteration or contamination.

Microscopic authentication remains an important tool in herbal drug standardization, as structural features remain intact even after grinding and drying processes.

3.2 Preliminary Phytochemical Screening

Preliminary phytochemical screening was carried out to identify the major classes of bioactive compounds present in the selected plants.

Table 1. Qualitative Phytochemical Constituents

of Selected Plants

S. No.	Chemical Component	Presence
1.	Proteins	-
2.	Lipids	-
3.	Alkaloids	+
4.	Glycosides	+
5.	Sterols	+
6.	Triterpenes	+
7.	Tannins/Flavonoids	++
8.	Saponins	+
9.	Steroids	-

The results indicated that the plants contain abundant flavonoids, tannins, glycosides, and alkaloids, which are known to exhibit strong antioxidant, anti-inflammatory, and antidiabetic activities.

Flavonoids have been reported to improve glucose metabolism through multiple mechanisms including enhancement of insulin secretion, protection of pancreatic β-cells, and inhibition of carbohydrate-digesting enzymes.

Similarly, tannins and phenolic compounds are known to reduce oxidative stress associated with hyperglycemia and prevent diabetes-related complications.

3.3 Successive Solvent Extraction and Phytochemical Distribution

Extraction of the plant materials was performed using solvents of increasing polarity in order to isolate phytoconstituents with varying solubility characteristics.

Table 2. Distribution of Phytoconstituents in Different Solvent Extracts

Plant Constituents	Extractive Solvents			
	Petroleum Ether	Chloroform	Methanol	Water
Steroides	+	+	-	-
Flavonoides	-	-	+	-
Alkaloides	-	+	+	+
Carohydrades	-	-	+	+
Proteins	-	-	+	-
Tannins	-	-	+	+
Glycosides	-	+	+	+
Saponins	-	-	-	+
Triterpenes	-	-	-	-
Fixed Oil	+	-	-	-
Coumarines	-	-	+	-

Among the solvents used, methanol extract showed the highest diversity of phytoconstituents, indicating that polar solvents are particularly effective for extracting biologically active compounds such as flavonoids, phenolics, and glycosides.

These phytochemicals are widely recognized for their role in glucose homeostasis, lipid metabolism, and protection against oxidative stress, which are key factors in diabetes management.

3.4 Thin Layer Chromatography (TLC) Profiling

Thin layer chromatography was used to establish a chemical fingerprint profile of the plant extracts.

Distinct bands were observed under ultraviolet light at 254 nm and 365 nm, indicating the presence of multiple phytoconstituents.

Coriandrum sativum

TLC analysis revealed several fluorescent bands corresponding to flavonoid glycosides and phenolic compounds. These phytochemicals are reported to exhibit strong antioxidant and antihyperglycemic properties.

Mucuna pruriens

TLC profiling confirmed the presence of L-DOPA, a major bioactive compound in the seeds of Mucuna pruriens. Although primarily known for neurological applications, L-DOPA and associated phenolic compounds have also demonstrated antioxidant and metabolic regulatory effects.

Juglans nigra

Extracts of Juglans nigra showed chromatographic bands corresponding to flavonols and naphthoquinones such as juglone. These compounds have been reported to possess antioxidant, anti-inflammatory, and glucose-modulating properties.

The TLC fingerprint confirmed the presence of diverse bioactive compounds that may collectively contribute to the therapeutic activity of the polyherbal formulation.

3.5 Anti-Diabetic Studies

Experimental diabetes was induced in rats using Streptozotocin (STZ, 60 mg/kg) in combination with a high-fat diet (HFD). STZ selectively damages pancreatic β-cells, resulting in insulin deficiency and persistent hyperglycemia, thereby mimicking features of Type 2 Diabetes Mellitus. The antidiabetic potential of the polyherbal extract (PHE) composed of Juglans nigra, Coriandrum sativum, and Mucuna pruriens was evaluated by assessing serum glucose, total protein, lipid profile, lipoprotein fractions, and hepatic enzyme levels. The results were compared with the standard antidiabetic drug Glibenclamide.

3.5.1 Effect on Serum Glucose

Serum glucose levels of normal and experimental animals are presented in Table 3 At day 0, all experimental groups showed comparable baseline glucose levels. Following induction of diabetes with STZ and HFD, the diabetic control group exhibited a marked increase in serum glucose levels, reaching 274.17 mg/dL on the 7th day, confirming successful induction of hyperglycemia.

Table 3. Effects of PHE on Serum Glucose of Control and Experimental Animals

STZ (60 mg/kg) in high fat diet rats induced marked hyperglycemia 274 mg/dL in diabetic control. Treatment with PHE at 500 mg/kg significantly reduced serum glucose to 239 mg/dL over the treatment period compared to diabetic controls, showing dose-dependent effect. The lower dose (250 mg/kg) also effected improvement but less markedly; glibenclamide (standard) showed similar or better effects at its dose.

Parameters	Groups / Days	NORMAL (5% CMC)	CONTROL [STZ 60 (mg/kg) + HFD]	TREATMENT 1 (PHE 250 mg/kg)	TREATMENT 2 (PHE 500 mg/kg)	STANDARD (GLB 5 mg/kg)
Serum glucose level (mg/dL)	0 day	123 ± 3.35	123.83 ± 4.17	124.50 ± 2.07	125.17 ± 2.48	124.83 ± 3.06
	3rd day	124.33 ± 4.80	239.50 ± 5.24 c	239.50 ± 5.24 c	239.67 ± 5.50 c	239.17 ± 5.04 c
	7th day	124.50 ± 4.76	274.17 ± 4.62 c	234.50 ± 3.08 cfi	216.33 ± 1.75 cfi	206.33 ± 1.75 cfi
	14th day	123.83 ± 6.43	264.33 ± 2.66 c	214.67 ± 2.88 cfi	192.33 ± 3.50 cf h	184.00 ± 3.41 cfi
	21st day	121.67 ± 2.58	238.50 ± 3.37 c	194.33 ± 3.33 cfi	180.83 ± 3.06 cfi	164.17 ± 3.06 cfi

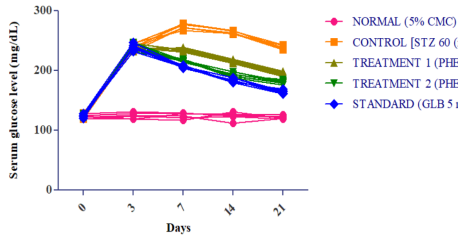


Figure 1. Graphical presentation of Effects of PHE on Serum Glucose of Control and Experimental Animals

Treatment with the polyherbal extract resulted in a progressive reduction in serum glucose levels throughout the study period. Animals treated with PHE (250 mg/kg) showed a moderate decrease in glucose levels, reaching 194.33 mg/dL by day 21, whereas animals treated with PHE (500 mg/kg) demonstrated a more pronounced reduction to 180.83 mg/dL. The standard drug glibenclamide produced the greatest reduction in glucose levels (164.17 mg/dL on day 21). The observed antihyperglycemic effect of PHE was therefore dose-dependent, with the higher dose exhibiting stronger activity.

The glucose-lowering effect of the polyherbal extract may be attributed to multiple mechanisms including:

- stimulation of pancreatic insulin secretion
- enhancement of peripheral glucose uptake
- inhibition of intestinal glucose absorption
- protection of pancreatic β-cells through

antioxidant activity

Phytoconstituents such as flavonoids and phenolic compounds present in the formulation are known to exhibit insulin-mimetic and antioxidant properties that improve glucose metabolism.

3.5.2 Effect on Serum Total Protein

The effect of PHE on serum total protein levels is summarized in Table 4 Diabetic control animals exhibited a significant reduction in serum protein levels (4.60 g/dL) compared with the normal control group (8.53 g/dL), indicating impaired protein metabolism under diabetic conditions.

Table 4. Effects of PHE on Total Protein of Control and Experimental Animals

Group	Total Protein (g/dl)
NORMAL (5% CMC)	8.53 ± 0.51
CONTROL [STZ 60 (mg/kg) + HFD]	4.60 ± 0.43^{c}
TREATMENT 1 (PHE 250 mg/kg)	6.82 ± 0.25^{cf}
TREATMENT 2 (PHE 500 mg/kg)	8.34 ± 0.29^{f}
STANDARD (GLB 5 mg/kg)	7.24 ± 0.5^{cfi}

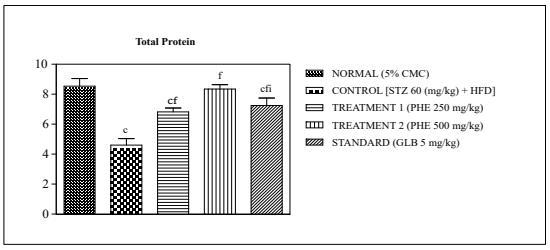


Figure 2. Graphical presentation of Effects of PHE on Total Protein of Control and Experimental Animals

Treatment with the polyherbal extract significantly restored serum protein levels. Animals receiving PHE (250 mg/kg) showed moderate improvement (6.82 g/dL), while those treated with PHE (500 mg/kg) demonstrated a substantial recovery (8.34 g/dL), approaching normal levels.

The standard drug glibenclamide also improved protein levels (7.24 g/dL). Restoration of serum protein levels suggests that the polyherbal extract may improve protein metabolism and reduce protein catabolism associated with diabetic conditions.

3.5.3 Effect on Lipid Profile

Diabetes is frequently associated with dyslipidemia characterized by elevated levels of cholesterol and triglycerides. The effects of PHE on lipid parameters are shown in Table 5.

Table 5. Effects of PHE on Cholesterol, Triglyceride and Phospholipids of Control and experimental Animals

Group	Cholesterol (mg/dl)	Triglycerides (mg/dl)	Phospholipids (mg/dl)
NORMAL (5% CMC)	202.0 ± 1.97	141.20 ± 2.20	84.38 ± 1.68
CONTROL [STZ 60 (mg/kg) + HFD]	296.25 ± 4.58^{c}	229.40 ± 2.76^{c}	122.30 ± 4.65^{c}
TREATMENT 1 (PHE 250 mg/kg)	221.30 ± 4.99^{cfi}	205.0 ± 3.67^{cfi}	101.20 ± 3.63^{cfi}
TREATMENT 2 (PHE 500 mg/kg)	201.0 ± 1.63^{f}	156.50 ± 3.08^{cfi}	93.11 ± 2.27^{bf}
STANDARD (GLB 5 mg/kg)	202.40 ± 3.96^{f}	194.10 ± 4.00^{cf}	87.86 ± 6.43^{f}

Induction of diabetes resulted in a significant elevation of lipid parameters in the diabetic control group, including:

- total cholesterol: 296.25 mg/dL
- triglycerides: 229.40 mg/dL
- phospholipids: 122.30 mg/dL

Treatment with PHE significantly reduced these lipid abnormalities. The higher dose (500 mg/kg) reduced cholesterol to 201 mg/dL, triglycerides to 156.50 mg/dL, and phospholipids to 93.11 mg/dL. These effects were comparable to those observed with glibenclamide treatment.

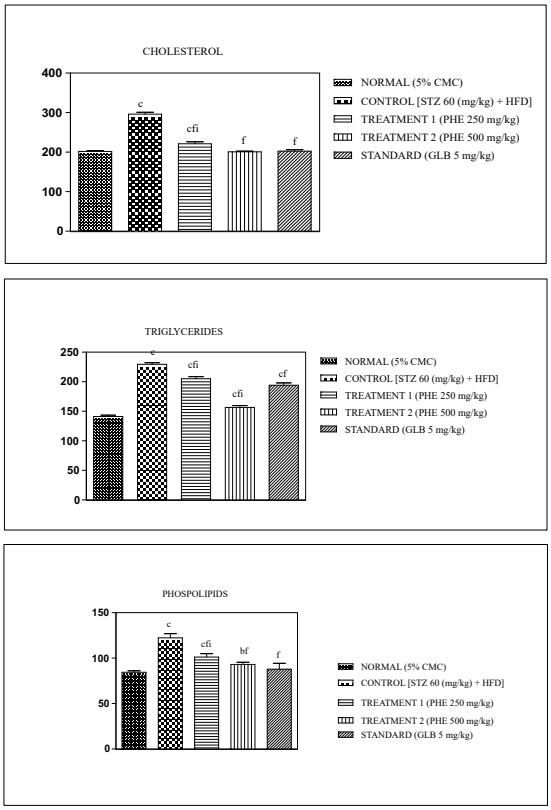


Figure 3. Effects of PHE on Cholesterol, Triglyceride and Phospholipids of Control and experimental Animals

The improvement in lipid profile indicates that the polyherbal extract possesses hypolipidemic activity, which may reduce the risk of cardiovascular complications commonly associated with diabetes.

3.5.4 Effect on Lipoprotein Fractions

The influence of the polyherbal extract on lipoprotein fractions is presented in Table 6 Diabetic control animals showed significant dyslipoproteinemia characterized by:

- decreased HDL levels (82.28 mg/dL)
- increased LDL levels (143.20 mg/dL)
- elevated VLDL levels (43.74 mg/dL)

Treatment with PHE significantly improved these parameters. The higher dose (500 mg/kg) increased HDL to 91.58 mg/dL while reducing LDL and VLDL to 111.30 mg/dL and 29.04 mg/dL, respectively. These results indicate that PHE effectively restored lipoprotein balance toward normal values.

Table 6. Effects of PHE on HDL, LDL and VLDL of Control and experimental Animals

Groups of Animals	HDL (mg/dl)	LDL (mg/dl)	VLDL (mg/dl)
NORMAL (5% CMC)	89.07 ± 3.43	110.70 ± 2.69	29.28 ± 1.70
CONTROL [STZ 60 (mg/kg) + HFD]	82.28 ± 3.72^{b}	143.20 ± 3.56^{c}	43.74 ± 3.30^{c}
TREATMENT 1 (PHE 250 mg/kg)	89.56 ± 4.07^{eh}	135.20 ± 3.29^{cfi}	41.71 ± 3.82^{c}
TREATMENT 2 (PHE 500 mg/kg)	91.58 ± 2.34^{fi}	111.30 ± 2.49 ^{fi}	29.04 ± 2.69 ^{fi}
STANDARD (GLB 5 mg/kg)	81.60 ± 2.05^{b}	123.10 ± 2.72^{cf}	39.41 ± 2.98^{c}

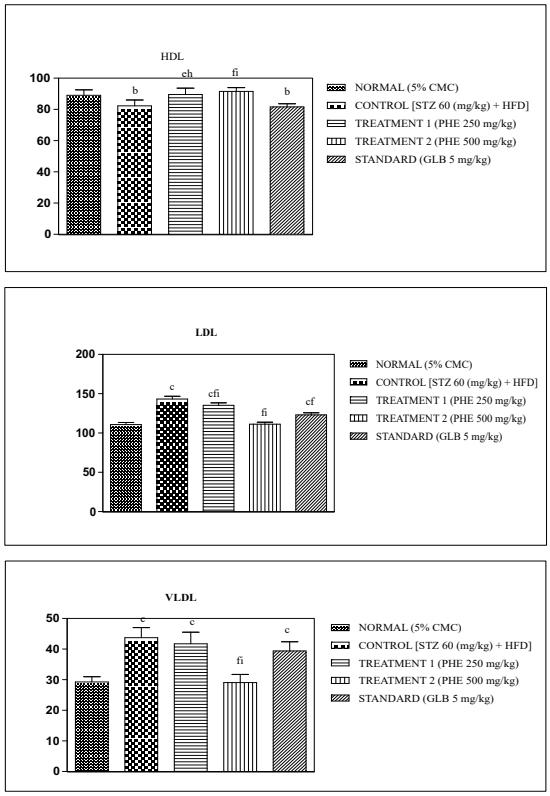


Figure 4.Effects of PHE on HDL, LDL and VLDL of Control and experimental Animals

The improvement in lipoprotein profile suggests that the polyherbal formulation may reduce the risk of atherosclerosis and other cardiovascular complications associated with diabetes.

3.5.5 Effect on Liver Enzymes

The effects of PHE on hepatic enzymes are shown in Table 7 Diabetic control animals exhibited significantly elevated levels of hepatic enzymes, indicating liver damage caused by hyperglycemia-induced oxidative stress..

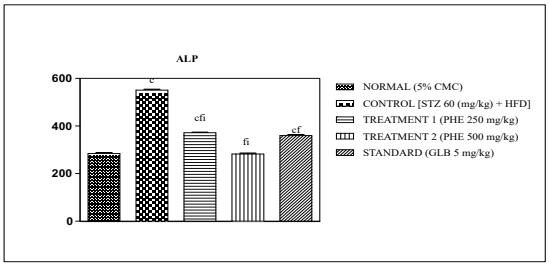
Table 7. Effects of PHE on ALP, SGOT and SGPT of Control and Experimental Animals

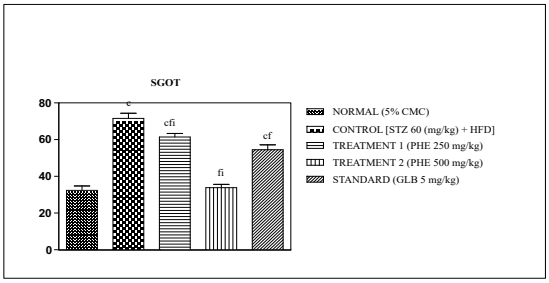
Groups of Animals	ALP (IU/L)	SGOT (IU/L)	SGPT (IU/L)
NORMAL (5% CMC)	284.10 ± 4.08	32.39 ± 2.38	41.45 ± 1.60
CONTROL [STZ 60 (mg/kg) + HFD]	551.0 ± 3.36 ^{c}	71.56 ± 2.77 ^{c}	87.01 ± 2.33 ^{c}
TREATMENT 1 (PHE 250 mg/kg)	371.80 ± 1.76 ^{cfi}	61.40 ± 1.97 ^{cfi}	72.34 ± 1.80 ^{cfh}
TREATMENT 2 (PHE 500 mg/kg)	282.20 ± 3.36 ^{fi}	33.83 ± 1.78 ^{fi}	40.58 ± 1.21 ^{fi}
STANDARD (GLB 5 mg/kg)	359.80 ± 4.60 ^{cf}	54.50 ± 2.64 ^{cf}	67.73 ± 2.78 ^{cf}

The observed enzyme levels in diabetic rats were:

- ALP: 551 IU/L
- SGOT: 71.56 IU/L
- SGPT: 87.01 IU/L

Treatment with PHE significantly reduced these enzyme levels. The higher dose (500 mg/kg) reduced ALP to 282.20 IU/L, SGOT to 33.83 IU/L, and SGPT to 40.58 IU/L, values that were comparable to the normal control group.





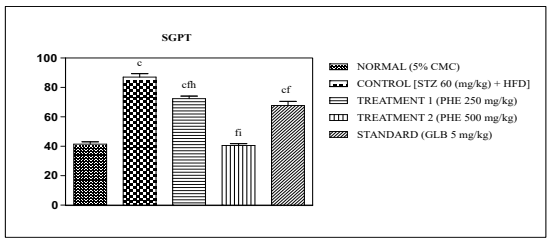


Figure 5. Effects of PHE on ALP, SGOT and SGPT of Control and Experimental Animals

These findings suggest that the polyherbal extract possesses hepatoprotective properties, likely due to the antioxidant activity of its phytochemical constituents.

The present study demonstrates that the polyherbal extract composed of Juglans nigra, Coriandrum sativum, and Mucuna pruriens exhibits significant antihyperglycemic, hypolipidemic, and hepatoprotective activities in STZ-induced diabetic rats.

The formulation not only reduced blood glucose levels but also improved multiple biochemical parameters including:

- serum protein levels
- lipid profile
- lipoprotein balance
- hepatic enzyme markers

The observed pharmacological effects were dose-dependent, with the higher dose (500 mg/kg) producing results comparable to the standard drug Glibenclamide.

The therapeutic activity of the formulation may be attributed to the synergistic action of its bioactive phytoconstituents. Phenolic compounds and flavonoids present in the plants possess antioxidant properties that protect pancreatic β-cells and improve insulin sensitivity. Additionally, compounds such as L-DOPA from Mucuna pruriens and juglone from Juglans nigra may contribute to metabolic regulation and reduction of oxidative stress.

Overall, the findings indicate that the developed polyherbal formulation has promising potential as an alternative or complementary therapeutic approach for the management of diabetes and its associated metabolic complications. However, further studies focusing on the isolation of active constituents, elucidation of molecular mechanisms, and long-term safety evaluation are necessary to validate its clinical applicability.

4. DISCUSSION

The present study evaluated the antidiabetic potential of a polyherbal extract (PHE) comprising hydroalcoholic extracts of *Juglans nigra*, *Coriandrum sativum*, and *Mucuna pruriens* in streptozotocin (STZ)-induced diabetic rats. The investigation assessed changes in blood glucose, serum total protein, lipid parameters, lipoprotein fractions, and selected hepatic enzyme activities.

Overall, the findings suggest that PHE, particularly at 500 mg/kg, was associated with improvements in several biochemical parameters altered in diabetic animals.

Preliminary phytochemical screening indicated the presence of alkaloids, glycosides, sterols, tannins/flavonoids, and saponins. These findings provide an initial indication of the chemical diversity of the selected plant materials. However, qualitative phytochemical tests do not establish the concentrations of individual compounds or demonstrate which constituents are responsible for the observed pharmacological effects. Quantitative phytochemical analysis and validated chemical fingerprinting would therefore strengthen the standardization of the formulation.

TLC profiling provided preliminary information about the chromatographic characteristics of the plant extracts. The observed bands suggest the presence of multiple separable constituents. Nevertheless, assigning individual bands to specific compounds, including L-DOPA or juglone, requires comparison with authentic reference standards and appropriate analytical confirmation. Such confirmation would also improve the suitability of the chromatographic profile for quality-control purposes.

The antihyperglycemic findings showed that blood glucose decreased progressively in the PHE-treated groups during the 21-day experimental period. On day 21, glucose concentrations were 194.33 ± 3.33 mg/dL in the PHE 250 mg/kg group and 180.83 ± 3.06 mg/dL in the PHE 500 mg/kg group, compared with 238.50 ± 3.37 mg/dL in the diabetic control group. The glibenclamide-treated group showed a glucose concentration of 164.17 ± 3.06 mg/dL. These results indicate a greater glucose-lowering response at the higher PHE dose, although the final glucose concentration remained lower in the reference-drug group. The findings support further investigation of the antihyperglycemic potential of PHE in this experimental model.

The mechanisms underlying the observed glucose-lowering effect were not directly investigated. Antioxidant activity, effects on insulin secretion, peripheral glucose utilization, and carbohydrate absorption are possible areas for future investigation; however, these mechanisms cannot be confirmed from the current biochemical results alone. Measurements of insulin, pancreatic histology, oxidative-stress biomarkers, and relevant metabolic pathways would help clarify the pharmacological basis of the observed response.

The lipid-profile findings also suggested improvement following PHE administration. In the diabetic control group, total cholesterol, triglycerides, and phospholipids were 296.25 ± 4.58, 229.40 ± 2.76, and 122.30 ± 4.65 mg/dL, respectively. Treatment with PHE at 500 mg/kg reduced these values to 201.00 ± 1.63, 156.50 ± 3.08, and 93.11 ± 2.27 mg/dL, respectively. These findings indicate that the higher PHE dose was associated with reductions in the measured lipid parameters.

Changes in lipoprotein fractions provided additional evidence of a potentially favourable effect on lipid metabolism. At 500 mg/kg, PHE was associated with an increase in HDL from 82.28 ± 3.72 to 91.58 ± 2.34 mg/dL and reductions in LDL from 143.20 ± 3.56 to 111.30 ± 2.49 mg/dL and VLDL from 43.74 ± 3.30 to 29.04 ± 2.69 mg/dL, relative to the diabetic control group. Although these changes suggest improvement in the measured lipoprotein profile, the underlying mechanisms and the clinical significance of these changes require further investigation.

Serum total protein also improved following PHE treatment. The concentration increased from 4.60 ± 0.43 g/dL in the diabetic control group to 6.82 ± 0.25 g/dL and 8.34 ± 0.29 g/dL in the PHE 250 and 500 mg/kg groups, respectively. The value at the higher dose approached the normal control value of 8.53 ± 0.51 g/dL. This finding suggests an association between PHE treatment and improvement in serum total protein levels. Further assessment of protein metabolism, renal function, and other relevant biochemical parameters would be necessary to explain this observation.

The hepatic enzyme results showed that PHE treatment was associated with reductions in ALP, AST/SGOT, and ALT/SGPT activities relative to the diabetic control group. At 500 mg/kg, the respective values were 282.20 ± 3.36, 33.83 ± 1.78, and 40.58 ± 1.21 IU/L, which were close to the corresponding normal control values. These results suggest an improvement in selected biochemical indicators of hepatic status. However, enzyme measurements alone are insufficient to establish hepatoprotection, and additional evidence, including liver histopathology and relevant oxidative-stress markers, would strengthen this interpretation.

The findings should be interpreted in light of the experimental design and the limitations of the available data. The study used an STZ-induced diabetic rat model, and the results should not be generalized directly to human diabetes or treated as definitive evidence of efficacy in type 2 diabetes mellitus. In addition, the precise contribution of

each plant extract, the potential interaction among constituents, and the long-term safety of the combined extract remain to be established.

In summary, the results indicate that PHE, particularly at 500 mg/kg, was associated with improvements in blood glucose, lipid parameters, serum total protein, and selected hepatic enzyme activities in STZ-induced diabetic rats. Further studies involving quantitative chemical standardization, mechanistic evaluation, histopathological assessment, and systematic toxicity testing are required to establish the reproducibility, safety, and therapeutic relevance of these findings.

5. CONCLUSION

The present study evaluated a polyherbal extract comprising *Coriandrum sativum*, *Mucuna pruriens*, and *Juglans nigra* in streptozotocin-induced diabetic rats. Preliminary phytochemical screening and TLC profiling provided initial information about the chemical characteristics of the selected plant materials.

The reported pharmacological findings indicate that PHE was associated with reductions in blood glucose, total cholesterol, triglycerides, phospholipids, LDL, VLDL, and selected hepatic enzyme activities, together with an increase in serum total protein. The higher dose of 500 mg/kg generally produced greater improvements than the 250 mg/kg dose, while glibenclamide produced a greater reduction in final blood glucose.

These findings suggest that the polyherbal extract has potential antihyperglycemic and lipid-modulating activity in this experimental model. The observed changes in hepatic enzyme activities may also indicate improvement in selected biochemical indicators of hepatic status. Nevertheless, the results do not establish the underlying mechanisms, confirm a hepatoprotective effect independently, or demonstrate clinical efficacy.

Further investigations should focus on quantitative standardization of the extracts, confirmation of individual phytoconstituents using validated analytical methods, mechanistic studies, histopathological evaluation, and comprehensive safety assessment. Additional preclinical research followed by appropriately designed clinical studies would be necessary before the formulation could be considered for therapeutic use in humans.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the management and faculty of the School of Pharmacy, Chouksey Engineering College, Bilaspur, Chhattisgarh, and SLT, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisgarh, for their support and for providing facilities relevant to the research. The authors also acknowledge the assistance and encouragement of colleagues who contributed to the research activities.

AUTHOR CONTRIBUTIONS

The following contributions should be retained only where they accurately reflect each author's actual work.

Contribution	Vipin Kumar Wani	Ritesh Jain	Shekhar Verma
Conceptualization	✓		
Methodology	✓	✓	
Software			
Validation			
Formal analysis	✓		✓
Investigation	✓	✓	✓
Resources	✓	✓	
Data curation		✓	
Writing – original draft	✓		
Writing – review and editing	✓	✓	✓
Visualization		✓	
Supervision			✓
Project administration	✓		
Funding acquisition			

All authors contributed to the study in accordance with their respective roles. Vipin Kumar Wani prepared the initial manuscript draft. Ritesh Jain and Shekhar Verma contributed to the research and manuscript review as applicable. All authors reviewed and approved the final manuscript.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

FUNDING

The authors declare that this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

ETHICAL STATEMENT

The animal experimental protocol was approved by the Institutional Animal Ethics Committee (IAEC) of [verified institution name], Bilaspur, Chhattisgarh, India. All procedures were conducted in accordance with the applicable guidelines for the care and use of laboratory animals.

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