Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 32s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Phytochemical Screening and Antidiabetic Activity of Ethanolic Extract of *Ficus racemosa* bark in Streptozotocin-Induced Diabetic Rats

Anamika kulshrestha[1], Veerendra C. Yeligar[2], Asokan B.R.[*3], Pruthviraj C. Meshram[4], Pramod Ramrao[5], Monisha A[6], Chand Kaur[7], Santa Mandal[8]

[1]Department of Pharmacology, Arya College of Pharmacy, Kukus, Jaipur Pin 302028.

[2]Department of Pharmaceutical Chemistry, D. Y. Patil College of Pharmacy kadamwady Kolhapur-416003.

[*3]Department of Pharmacology TSRMMCH & RC, Irungalur, Trichy, 621105, The Tamilnadu Dr. MGR, Medical University, Chennai.

[4]Maharashtra Institute of Pharmacy (B. Pharm) Chougan Phata, Betala, Bramhapuri, Dist. Chandrapur, Maharashtra 441206.

[5]Department of Pharmacognosy, Ramesh Patil Institute of Pharmacy Khandgaon Bendri tq. Naigaon Dist. Nanded 431709.

[6]Department of Pharmacology, Faculty of Pharmacy, Dr. MGR Educational and Research Institute, Chennai 77.

[7]Department of Pharmacology, Geeta Institute of Pharmacy, Geeta University, 132145.

[8]Faculty of Pharmaceutical Science, Assam down town University, Sankar Madhab Path, Gandhi Nagar, Panikhaiti, Guwahati 781026, Assam, India.

[*]**Corresponding author:**

Asokan B.R.

Department of Pharmacology TSRMMCH & RC, Irungalur, Trichy, 621105, The Tamilnadan Dr. MGR, Medical University, Chennai.

Cite this paper as: Anamika kulshrestha, Veerendra C. Yeligar, Asokan B.R., Pruthviraj C. Meshram, Pramod Ramrao, Monisha A, Chand Kaur, Santa Mandal, (2025) Phytochemical Screening and Antidiabetic Activity of Ethanolic Extract of Ficus racemosa bark in Streptozotocin-Induced Diabetic Rats. *Journal of Neonatal Surgery*, 14 (32s), 2887-2898.

ABSTRACT

Diabetes mellitus is a chronic metabolic disorder marked by persistent high blood glucose due to impaired insulin secretion, action, or both. It is a major global health challenge, with prevalence expected to rise from 537 million in 2021 to over 783 million by 2045. Type 2 diabetes mellitus constitutes over 90% of cases and is strongly associated with lifestyle and genetic factors. It leads to serious complications such as retinopathy, nephropathy, neuropathy, and cardiovascular diseases, which impose significant burdens on healthcare systems and reduce patients' quality of life. Despite various pharmacological treatments, managing diabetes long-term is difficult due to side effects, cost, and the progressive need for combination therapies or insulin. This has sparked interest in alternative therapies, especially plant-based treatments that may offer fewer side effects and additional benefits. Ficus racemosa L., or cluster fig, is traditionally used to treat diabetes and other ailments. Its bark contains bioactive compounds like flavonoids, tannins, saponins, alkaloids, triterpenoids, and glycosides, which have antioxidant, anti-inflammatory, and hypoglycemic properties. However, scientific evidence supporting the antidiabetic effects of its ethanolic bark extract is limited. This study aims to evaluate the phytochemical profile and antidiabetic potential of Ficus racemosa bark ethanolic extract in streptozotocin-induced diabetic rats. Parameters such as fasting blood glucose, serum insulin, lipid profile, liver and kidney function markers, and pancreatic histology will be assessed to examine β-cell protection or regeneration. The results are expected to validate traditional claims and support the use of Ficus racemosa in diabetes management, especially in resource-poor settings.

Keywords: *Ficus racemosa, phytochemical screening, antidiabetic activity, streptozotocin, β-cell regeneration, plant-based medicine*

1. INTRODUCTION

Diabetes mellitus is a complex, chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It is a leading global health issue with a growing prevalence across both developed and developing nations. According to the International Diabetes Federation, the number of individuals living with diabetes reached approximately 537 million in 2021, and this figure is expected to escalate to over 783 million by the year 2045

(Antar et al., 2023). Type 2 diabetes mellitus (T2DM), which accounts for more than 90% of all cases, is largely associated with lifestyle factors such as sedentary behavior, obesity, poor dietary choices, and genetic predisposition. Uncontrolled diabetes leads to a myriad of complications, including retinopathy, nephropathy, neuropathy, cardiovascular diseases, and increased susceptibility to infections, thereby imposing a significant burden on healthcare systems and adversely affecting the quality of life of patients (Antar et al., 2023). Despite the availability of various therapeutic options, the management of diabetes remains a challenge. Current antidiabetic drugs such as biguanides (e.g., metformin), sulfonylureas, insulin analogs, DPP-4 inhibitors, and SGLT2 inhibitors offer effective glycemic control but often fail to provide holistic management of the disease. Long-term use of these medications is frequently associated with undesirable side effects, including gastrointestinal disturbances, hypoglycemia, hepatotoxicity, and weight gain (Schootman et al., 2020). Moreover, the cost of lifelong treatment, especially involving newer drug classes, creates a substantial financial burden, particularly in low- and middle-income countries where access to healthcare may be limited. The progressive nature of diabetes also means that many patients eventually require combination therapy or insulin supplementation as monotherapies become insufficient due to declining pancreatic β-cell function or increasing insulin resistance (Olesen et al., 2021).

These limitations have led to a surge in interest in complementary and alternative medicine (CAM), particularly the use of plant-derived compounds with antidiabetic properties. Natural products are considered to have minimal side effects, lower toxicity, and the potential for long-term use in chronic conditions (Umapathy et al., 2018). Several medicinal plants used in traditional healing systems have shown promising results in experimental models of diabetes. These plants are believed to exert their effects through multiple mechanisms, including enhancement of insulin secretion, improvement of insulin sensitivity, inhibition of carbohydrate-digesting enzymes, and antioxidant activity (Osei et al., 2003). One such plant of significant ethnomedicinal relevance is *Ficus racemosa* L., also known as the cluster fig or 'Gular' in India. This deciduous tree belongs to the Moraceae family and is widely distributed throughout the Indian subcontinent, Southeast Asia, and parts of Australia. Various parts of the tree—bark, leaves, fruits, and latex—have been utilized in traditional systems of medicine such as Ayurveda, Siddha, and Unani for treating diverse ailments (Deep et al., 2013). These include gastrointestinal disorders, wounds, respiratory conditions, urinary infections, and metabolic syndromes including diabetes. The bark, in particular, has been described in ancient Ayurvedic texts for its astringent, antidiarrheal, anti-inflammatory, and antidiabetic properties. Despite these claims, scientific validation of its pharmacological potential remains limited and fragmented (Deepa et al., 2018).

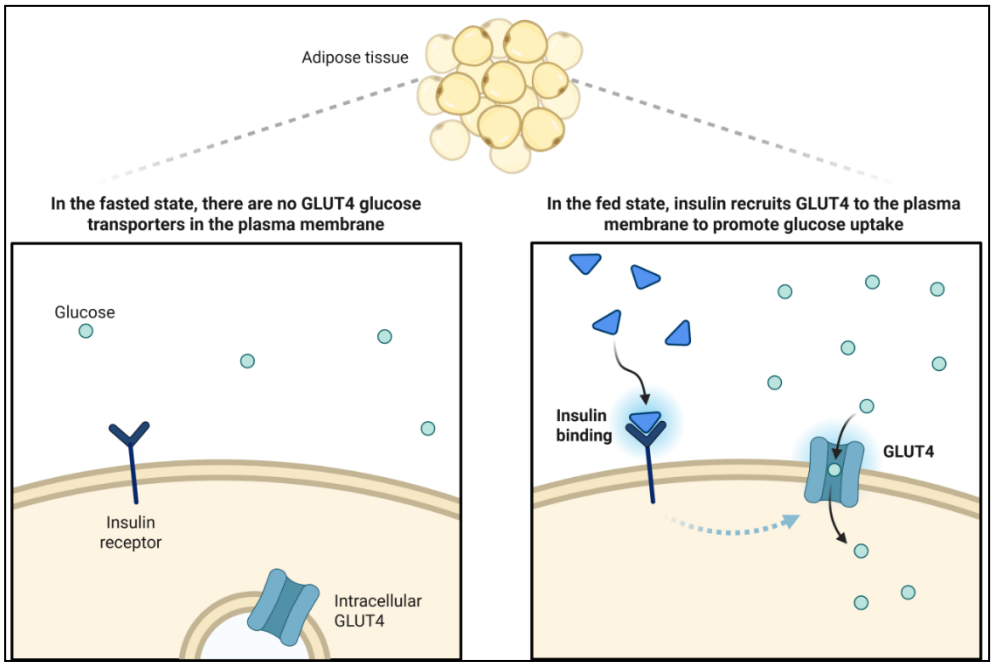

Figure 1: Mechanism of Insulin Action

Preliminary pharmacognostic studies have revealed that *Ficus racemosa* bark is rich in bioactive phytoconstituents such as flavonoids, tannins, saponins, alkaloids, triterpenoids, and glycosides. These compounds are known to possess antioxidant, anti-inflammatory, and hypoglycemic activities, which could theoretically contribute to antidiabetic effects. Flavonoids and phenolic compounds, in particular, have been widely studied for their ability to scavenge free radicals, improve insulin sensitivity, and modulate carbohydrate metabolism (Zanzabil et al., 2023). Furthermore, tannins and saponins have been reported to have insulin-mimetic properties, reduce oxidative stress, and support pancreatic tissue repair. However, the

specific pharmacological contributions of these constituents, particularly in the context of ethanolic extracts of *Ficus racemosa* bark, remain inadequately explored (Shah et al., 2016). The use of streptozotocin (STZ)-induced diabetic rats as an experimental model provides a reliable and widely accepted approach for assessing the efficacy of antidiabetic agents. STZ is a compound that selectively destroys pancreatic β-cells, thereby inducing a diabetic condition that closely mimics the pathology of type 1 and, to some extent, type 2 diabetes. This model allows for the examination of not only the glucose-lowering potential of an extract but also its impact on insulin levels, lipid profile, and histopathological changes in key organs such as the pancreas, liver, and kidneys (Maske et al., 2023).

Given the pharmacological potential and traditional usage of *Ficus racemosa*, there is a compelling need for systematic scientific investigation to validate its antidiabetic activity and identify the phytochemicals responsible for this effect. While some studies have examined the aqueous or methanolic extracts of the plant, there is a paucity of data specifically focusing on ethanolic extracts, which are known to extract a broader spectrum of both polar and nonpolar compounds. Moreover, the majority of existing research has not employed a robust experimental design that includes both biochemical and histological assessments (Pahari et al., 2022). In this context, the present study aims to fill this critical research gap by investigating the phytochemical composition and antidiabetic efficacy of the ethanolic extract of *Ficus racemosa* bark using a validated animal model. The study is designed to carry out a comprehensive phytochemical screening to qualitatively assess the presence of secondary metabolites such as alkaloids, flavonoids, saponins, tannins, glycosides, and terpenoids (Biswas & Mukherjee, 2003). Subsequently, the extract will be administered to STZ-induced diabetic rats to evaluate its effects on key biochemical parameters including fasting blood glucose levels, serum insulin concentration, lipid profile, and markers of hepatic and renal function (Bhargava & Shah, 2021).

The study will also include a detailed histopathological examination of pancreatic tissues to assess the extent of β-cell regeneration or preservation following treatment with the plant extract. These evaluations are crucial for understanding the morphological basis of the extract's pharmacological action and for identifying potential therapeutic mechanisms. Additionally, the findings from this study will contribute to a growing body of literature supporting the integration of plant-based medicines into conventional diabetes management strategies (Kalailingam et al., 2014). Overall, this research aims to provide a scientific foundation for the traditional use of *Ficus racemosa* bark in the treatment of diabetes mellitus. The outcomes are expected to highlight its potential as a natural, multi-targeted antidiabetic agent and to encourage further pharmacological and clinical studies. Given the increasing demand for effective and affordable alternatives to synthetic drugs, especially in underserved populations, validating such ethnomedicinal claims through rigorous experimental research is both timely and essential (Huang et al., 2024).

2. MECHANISMS OF ANTIDIABETIC ACTION FROM PLANT CONSTITUENTS

Plants used in traditional medicine for the treatment of diabetes mellitus contain a wide spectrum of bioactive phytoconstituents. These compounds exert antidiabetic effects through diverse mechanisms that target various physiological and molecular pathways involved in glucose metabolism, insulin signaling, and pancreatic β-cell function. The ethanolic extract of *Ficus racemosa* bark, like many medicinal plants, contains secondary metabolites such as flavonoids, tannins, alkaloids, glycosides, saponins, and terpenoids, which are known to contribute synergistically to its therapeutic potential (Tran et al., 2020).

2.1. Insulin Secretagogue Activity

Phytochemicals found in medicinal plants, particularly flavonoids and alkaloids, have been shown to possess insulin secretagogue activity, which is crucial for managing type 2 diabetes in its early stages. These compounds mimic the action of sulfonylureas by targeting the ATP-sensitive potassium channels on pancreatic β-cell membranes. Their interaction leads to the depolarization of these membranes, resulting in the opening of voltage-dependent calcium channels. The subsequent influx of calcium ions triggers the exocytosis of insulin-containing granules from the β-cells, thereby increasing circulating insulin levels and promoting glucose uptake by peripheral tissues (Alam et al., 2022). In the context of *Ficus racemosa*, previous phytochemical investigations have indicated the presence of flavonoid-rich fractions that may contribute to this mechanism. These compounds not only stimulate insulin release but may also enhance the sensitivity of β-cells to glucose, providing a dual effect (Rahman et al., 2022). This property is especially beneficial in patients with partially functioning pancreatic cells, as it helps delay disease progression and reduces dependency on external insulin or complex drug regimens. Moreover, plant-based secretagogues are considered to have fewer side effects compared to synthetic drugs, making them promising candidates for long-term diabetes management. Future studies should explore the dose-dependency and receptor-mediated effects of these phytochemicals (Singh et al., 2022).

2.2. β-Cell Regeneration and Protection

One of the most significant complications of chronic hyperglycemia in diabetes mellitus is the progressive loss of functional pancreatic β-cells due to oxidative stress and inflammatory damage. Plant-derived compounds, particularly flavonoids and tannins, have demonstrated potent cytoprotective effects on pancreatic tissue, helping to preserve or even regenerate β-cell architecture (Hosseini et al., 2015). These phytochemicals act as antioxidants by scavenging reactive oxygen species (ROS)

and reducing oxidative stress biomarkers such as malondialdehyde (MDA). Simultaneously, they upregulate the activity of endogenous antioxidant enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase (GPx), which fortify the cell's defenses against oxidative damage (Lee & Jun, 2014). Histopathological studies in diabetic animal models treated with plant extracts rich in these compounds have shown preserved islet morphology and even regeneration of islet cells, which supports their use as β-cell protectants. In the case of *Ficus racemosa*, its bark extract has shown promise in preliminary studies for maintaining the structural integrity of pancreatic tissues (Wang & Wang, 2017). This regenerative potential not only improves insulin secretion over time but may also help reverse the underlying pathology of diabetes. Therefore, such phytochemicals could play a crucial role in delaying insulin dependency and improving long-term glycemic control in diabetic patients (Passino et al., 2024).

2.3. Improvement of Peripheral Insulin Sensitivity

Insulin resistance, especially in skeletal muscle, liver, and adipose tissue, is a defining feature of type 2 diabetes and contributes significantly to chronic hyperglycemia. Certain phytoconstituents, particularly polyphenols and saponins, improve insulin sensitivity by modulating key proteins and signaling pathways involved in glucose uptake and metabolism. One of the most notable mechanisms involves the upregulation of glucose transporter-4 (GLUT-4) in skeletal muscle and adipose tissue, facilitating enhanced glucose entry into cells in response to insulin (Johnson et al., 2016). Additionally, many of these compounds activate AMP-activated protein kinase (AMPK), a critical energy-sensing enzyme that promotes glucose uptake and fatty acid oxidation while inhibiting hepatic gluconeogenesis. Activation of the AMPK pathway not only enhances insulin sensitivity but also improves overall energy metabolism, contributing to better glycemic control. Saponins and flavonoids may also exert effects on adiponectin levels, an insulin-sensitizing adipokine, further enhancing this effect (Gilijamse et al., 2020). Plant extracts from *Ficus racemosa* have demonstrated potential in modulating these metabolic pathways, possibly due to their phytochemical complexity. Improving insulin sensitivity is especially vital in the early and intermediate stages of type 2 diabetes to delay the onset of complications and reduce the requirement for high-dose pharmacological therapy (Ryan et al., 2020).

2.4. Inhibition of Intestinal Glucose Absorption

One effective mechanism for reducing postprandial hyperglycemia is the inhibition of carbohydrate-digesting enzymes in the gastrointestinal tract, specifically α-amylase and α-glucosidase. These enzymes play a central role in breaking down complex carbohydrates into glucose, which is then rapidly absorbed into the bloodstream. Phytochemicals such as tannins and flavonoids present in medicinal plants, including *Ficus racemosa*, can inhibit the activity of these enzymes, thereby slowing the rate of carbohydrate digestion and glucose absorption (Li et al., 2022). This enzymatic inhibition mimics the pharmacological action of drugs like acarbose, which are clinically used to blunt postprandial blood glucose spikes. However, plant-based inhibitors may offer this benefit with fewer gastrointestinal side effects. By reducing the glycemic load of meals, these compounds help smoothen blood glucose fluctuations, improve overall glycemic control, and reduce oxidative stress that accompanies postprandial glucose surges (Hasaninezhad et al., 2020). Moreover, the delay in glucose absorption also reduces the stimulus for excessive insulin secretion, thereby mitigating insulin resistance over time. Regular intake of such plant-based enzyme inhibitors may also contribute to appetite regulation and improved satiety, indirectly aiding in weight management—another crucial aspect of diabetes control. This makes the inhibition of intestinal glucose absorption a key therapeutic strategy in managing type 2 diabetes (Gong et al., 2020).

3. MATERIALS AND METHODS

3.1. Plant Collection and Authentication

The bark of *Ficus racemosa* L. was collected in the month of March 2024 from the rural areas surrounding Meerut district, Uttar Pradesh, India. The plant material was botanically verified and authenticated at the Department of Botany, Chaudhary Charan Singh University (CCSU), Meerut. The authentication was performed by Dr. Anil Kumar (Botanist) and Dr. Suresh Chandra (Taxonomist), both faculty members of the Department of Botany, CCSU. The botanical identity was confirmed based on macroscopic and microscopic characteristics, and comparison with standard herbarium specimens. A voucher specimen was submitted and preserved in the university herbarium under Authentication No: CCSU/BOT/2024/FR-07 for future reference. Following authentication, the collected bark was washed thoroughly with running tap water to eliminate surface impurities, shade-dried for 10–15 days at room temperature (25–30°C), and coarsely powdered using a mechanical grinder. The powdered material was stored in an airtight container in a cool and dry place until further use. The authentication procedure ensured the scientific accuracy, traceability, and reproducibility essential for the phytochemical and pharmacological evaluation of the plant material.

3.2. Preparation of Ethanolic Extract

The coarse powder of *Ficus racemosa* bark obtained after authentication was subjected to extraction using the Soxhlet apparatus. Approximately 250 grams of dried bark powder were packed into a thimble and extracted continuously using 95% ethanol as the solvent. The extraction process was carried out for 8–10 hours until the solvent in the siphon tube appeared colorless, indicating the exhaustion of phytoconstituents. Ethanol was selected due to its efficiency in extracting a broad

range of polar and non-polar bioactive compounds including flavonoids, tannins, alkaloids, saponins, and glycosides. After completion of the extraction, the ethanolic solution was concentrated under reduced pressure using a rotary evaporator at 40–45°C to remove excess solvent and obtain a semi-solid crude extract. The extract was further dried in a desiccator over anhydrous silica gel until a constant weight was achieved (Pradeep Kumar & Sachin, 2013). The yield of the extract was calculated using the formula:

% Yield = (Weight of extract / Weight of plant material used) × 100

The percentage yield of the ethanolic extract was found to be approximately **12.4% w/w**. The dried extract was stored in an airtight container at 4°C for further phytochemical screening and pharmacological evaluation.

3.3. Phytochemical Screening

Preliminary phytochemical screening of the ethanolic extract of *Ficus racemosa* bark was conducted to qualitatively identify the presence of major secondary metabolites. Standard procedures were employed as described in established phytochemical manuals.

- **Alkaloids**: Detected using Mayer's and Dragendorff's reagents. Formation of a cream-colored precipitate (Mayer's) or orange-brown precipitate (Dragendorff's) indicated the presence of alkaloids.
- **Flavonoids**: Identified by the alkaline reagent test. The addition of sodium hydroxide solution produced an intense yellow color, which turned colorless upon addition of dilute hydrochloric acid, confirming flavonoids.
- **Saponins**: Determined using the froth test. A persistent froth lasting more than 15 minutes after vigorous shaking with water indicated the presence of saponins.
- **Tannins**: Confirmed by adding ferric chloride ($FeCl_3$) solution. A dark green or blue-black coloration indicated the presence of hydrolyzable or condensed tannins, respectively.
- **Glycosides**: Detected using Keller-Killiani test. A reddish-brown color at the junction and bluish-green color in the upper layer indicated cardiac glycosides.
- **Terpenoids**: Identified by Salkowski's test. The formation of a reddish-brown interface upon mixing the extract with chloroform and concentrated sulfuric acid confirmed the presence of terpenoids.

These findings indicate a broad spectrum of bioactive constituents in the extract.

3.4. Experimental Animals

Healthy adult Wistar albino rats of either sex, weighing between 150–200 grams, were used for the study. The animals were procured from a certified animal breeding facility and housed in clean polypropylene cages under standard laboratory conditions: a 12-hour light/dark cycle, temperature of 22 ± 2°C, and relative humidity of 50–60%. The rats were acclimatized to the laboratory environment for one week before initiating the experimental procedures. They were provided with a standard pellet diet and water ad libitum throughout the study. All experimental protocols involving animals were conducted in strict accordance with the guidelines of the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA), Government of India. Ethical clearance was obtained from the Institutional Animal Ethics Committee (IAEC) of Chaudhary Charan Singh University, Meerut, Uttar Pradesh. The study protocol was approved under IAEC approval number CCSU/IAEC/2024/PH-12. Efforts were made to minimize animal suffering and to use the minimum number of animals required to obtain scientifically valid results. The housing, handling, and all experimental procedures adhered to ethical standards to ensure humane treatment and welfare of the laboratory animals.

3.5. Induction of Diabetes

Diabetes mellitus was experimentally induced in overnight-fasted Wistar albino rats by a single intraperitoneal (i.p.) injection of Streptozotocin (STZ). STZ was freshly prepared in a cold citrate buffer (0.1 M, pH 4.5) at a dosage of 50 mg/kg body weight and administered within 15 minutes of preparation to ensure chemical stability. The injection was performed under mild anesthesia to minimize discomfort (Akbarzadeh et al., 2007). Following STZ administration, the rats were provided with 5% glucose solution in their drinking water for the next 24 hours to prevent initial hypoglycemic shock due to sudden insulin release from damaged pancreatic β-cells. After 72 hours, fasting blood glucose (FBG) levels were measured using a glucometer by tail vein puncture. Rats with FBG levels exceeding 250 mg/dL were considered diabetic and selected for further study (M. A. Ali & Mustafa, 2023). The STZ model is widely recognized for its ability to induce selective cytotoxicity in pancreatic β-cells, thus mimicking insulin-deficient diabetes. This model reliably reproduces hyperglycemia and related metabolic disturbances, making it suitable for evaluating the antidiabetic potential of therapeutic agents. All procedures were performed in compliance with ethical guidelines and under the supervision of a qualified veterinarian (Saadane et al., 2020).

3.6. Experimental Design

The study was designed to evaluate the antidiabetic efficacy of the ethanolic extract of *Ficus racemosa* bark in streptozotocin-

induced diabetic rats. A total of 30 Wistar albino rats were randomly divided into five groups (n = 6 per group) as follows:

- **Group I (Normal Control):** Received vehicle (distilled water) only and served as a baseline.
- **Group II (Diabetic Control):** Received STZ (50 mg/kg, i.p.) but no treatment.
- **Group III (Standard Drug):** Diabetic rats treated with **metformin** at a dose of **100 mg/kg body weight/day** orally.
- **Group IV (Low Dose Extract):** Diabetic rats treated with *Ficus racemosa* ethanolic extract at **200 mg/kg body weight/day** orally.
- **Group V (High Dose Extract):** Diabetic rats treated with *Ficus racemosa* ethanolic extract at **400 mg/kg body weight/day** orally.

The treatment duration was 21 consecutive days, during which animals were monitored regularly for body weight, fasting blood glucose levels, and behavioral changes. At the end of the experimental period, blood samples were collected for biochemical analysis, and pancreatic tissues were harvested for histopathological examination. This design allowed comparative evaluation of dose-dependent efficacy against a standard antidiabetic drug.

3.7. Biochemical Analysis

Biochemical analysis was conducted to assess the therapeutic effects of the ethanolic extract of *Ficus racemosa* bark in STZ-induced diabetic rats. Fasting blood glucose (FBG) levels were measured on days 0, 7, 14, and 21 using a glucometer following overnight fasting. Body weight was recorded weekly to monitor changes associated with diabetes and treatment response. At the end of the 21-day treatment period, blood samples were collected from the retro-orbital plexus under mild anesthesia and centrifuged at 3000 rpm for 15 minutes to obtain serum. Serum insulin levels were estimated using a standard ELISA kit. Lipid profile parameters, including total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL), were measured using commercially available biochemical assay kits (Veerapur et al., 2012). In addition, liver function was assessed by estimating serum glutamate oxaloacetate transaminase (SGOT) and serum glutamate pyruvate transaminase (SGPT), while renal function was evaluated by measuring serum creatinine levels. All tests were performed according to the manufacturers' protocols using semi-automated or fully automated biochemical analyzers. These analyses provided comprehensive data on the extract's effect on glycemic control, lipid metabolism, and organ function (. & Mishra, 2019; Abeeleh et al., 2009).

3.8. Histopathological Examination

At the end of the treatment period, animals were euthanized, and the pancreas was carefully excised, rinsed with normal saline, and immediately fixed in 10% neutral-buffered formalin for 24–48 hours. The fixed tissues were then processed using standard histological procedures, including dehydration in graded alcohol series, clearing in xylene, and embedding in paraffin wax. Thin sections (5 µm) were cut using a microtome and mounted on glass slides. The sections were stained with hematoxylin and eosin (H&E) and examined under a light microscope to assess histopathological changes in the pancreatic tissue (S. Ali, Ekbbal, et al., 2023; Shamim et al., 2025a). Particular attention was given to the structure and morphology of the islets of Langerhans, cellular integrity, β-cell population, and evidence of necrosis, inflammation, or regeneration. The histological findings from the treated groups were compared with those of the normal and diabetic control groups to evaluate the protective or regenerative effects of the Ficus racemosa extract on pancreatic β-cells. Photomicrographs were taken for documentation and analysis. This examination helped to correlate the biochemical findings with structural changes and provided insight into the potential mechanisms of antidiabetic action of the plant extract (S. Ali, Ali, et al., 2023; Ekbbal et al., 2024; Shamim et al., 2025b).

4. RESULTS

4.1 Phytochemical Constituents

The preliminary phytochemical screening of the ethanolic extract of *Ficus racemosa* bark confirmed the presence of several key bioactive constituents. These secondary metabolites are associated with various pharmacological effects, especially antidiabetic, antioxidant, and anti-inflammatory properties. The results indicated a rich phytochemical profile, supporting the ethnomedicinal use of this plant. The presence of flavonoids and tannins suggests potential antioxidant and β-cell protective activities, while alkaloids and glycosides are known for their insulin-mimetic and glucose-lowering effects. Saponins and terpenoids also play roles in improving insulin sensitivity and modulating lipid metabolism. The findings are presented in the table below:

Table 1: Qualitative Phytochemical Screening of Ethanolic Extract of *Ficus racemosa* Bark

Phytochemical Class	Test Result	Pharmacological Significance
Alkaloids	+	Stimulates insulin secretion, reduces blood glucose
Flavonoids	+++	Antioxidant, protects β-cells, improves insulin action
Saponins	++	Enhances insulin sensitivity, lowers cholesterol
Tannins	++	Enzyme inhibition (α-amylase), reduces glucose absorption
Glycosides	+	Cardiotonic effects, improves glucose metabolism
Terpenoids	+	Anti-inflammatory, supports metabolic regulation

Note: (+) Present; (++) Moderately present; (+++) Abundantly present

These results justify further pharmacological evaluation of the extract.

4.2 Effect on FBG and Body Weight

The effect of *Ficus racemosa* ethanolic extract on fasting blood glucose (FBG) and body weight was evaluated over a 21-day treatment period. In STZ-induced diabetic rats (Group II), a significant increase in FBG levels was observed, accompanied by progressive weight loss. Treatment with both low (200 mg/kg) and high (400 mg/kg) doses of the extract (Groups IV and V) resulted in a significant, dose-dependent reduction in FBG levels compared to the diabetic control group. The high-dose group showed glucose-lowering effects comparable to the standard drug (metformin, Group III). Furthermore, treated rats exhibited partial restoration of body weight, suggesting improved metabolic balance and glycemic control. The data are presented below.

Table 2: Effect of *Ficus racemosa* Extract on FBG and Body Weight in Rats

Group	FBG (mg/dL) Day 0	Day 21	Body Weight (g) Initial	Final
Normal Control (I)	90 ± 5	95 ± 4	180 ± 6	195 ± 7
Diabetic Control (II)	280 ± 10	310 ± 15	178 ± 5	150 ± 6
Standard Drug (III)	275 ± 12	120 ± 8	182 ± 7	188 ± 5
Low Dose Extract (IV)	278 ± 9	155 ± 10	179 ± 6	182 ± 4
High Dose Extract (V)	281 ± 11	125 ± 7	180 ± 5	190 ± 6

Values expressed as Mean ± SEM (n = 6); significant at $p < 0.05$ compared to diabetic control.

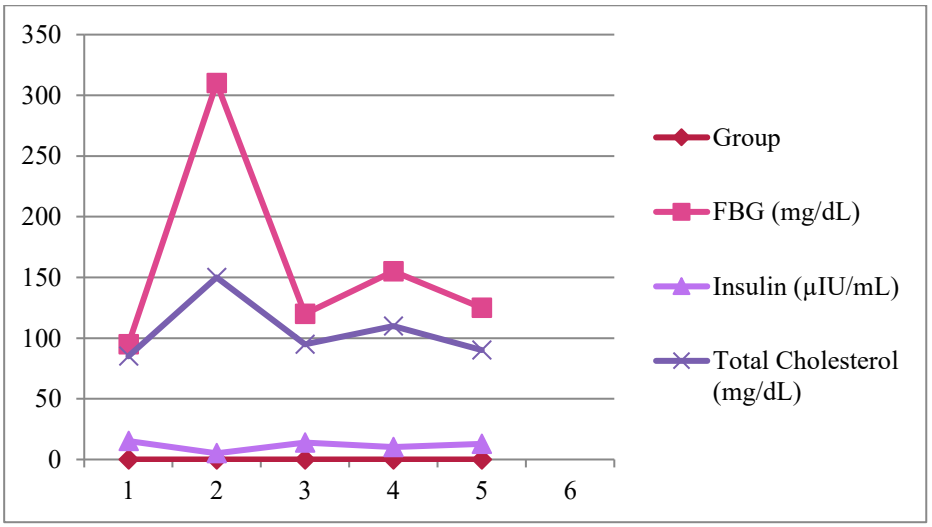

Figure 2: Effect of *Ficus racemosa* Extract on FBG and Body Weight in Rats

4.3 Effect on Serum Insulin and Lipids

The ethanolic extract of *Ficus racemosa* bark significantly improved serum insulin levels and lipid profiles in STZ-induced diabetic rats. The diabetic control group (Group II) showed a marked reduction in insulin levels and a deranged lipid profile, characterized by elevated total cholesterol (TC), triglycerides (TG), and low-density lipoprotein (LDL), along with decreased high-density lipoprotein (HDL). Treatment with *Ficus racemosa* extract, especially at the high dose (400 mg/kg), significantly increased insulin levels and restored lipid parameters toward normal ranges. The results were comparable to those of the standard drug (metformin), indicating the extract's potential role in improving both glycemic and lipid metabolism.

Table 3: Effect of *Ficus racemosa* Extract on Serum Insulin and Lipid Profile

Group	Insulin (µIU/mL)	TC (mg/dL)	TG (mg/dL)	LDL (mg/dL)	HDL (mg/dL)
Normal Control (I)	15.2 ± 0.8	85 ± 5	78 ± 4	40 ± 3	42 ± 2
Diabetic Control (II)	5.1 ± 0.6	150 ± 10	160 ± 8	98 ± 7	25 ± 2
Standard Drug (III)	13.8 ± 0.7	95 ± 6	88 ± 5	48 ± 3	40 ± 2
Low Dose (IV)	10.2 ± 0.6	110 ± 7	102 ± 6	60 ± 4	34 ± 3
High Dose (V)	13.0 ± 0.8	90 ± 5	84 ± 4	46 ± 3	39 ± 2

Values expressed as Mean ± SEM (n = 6); $p < 0.05$ vs. diabetic control.

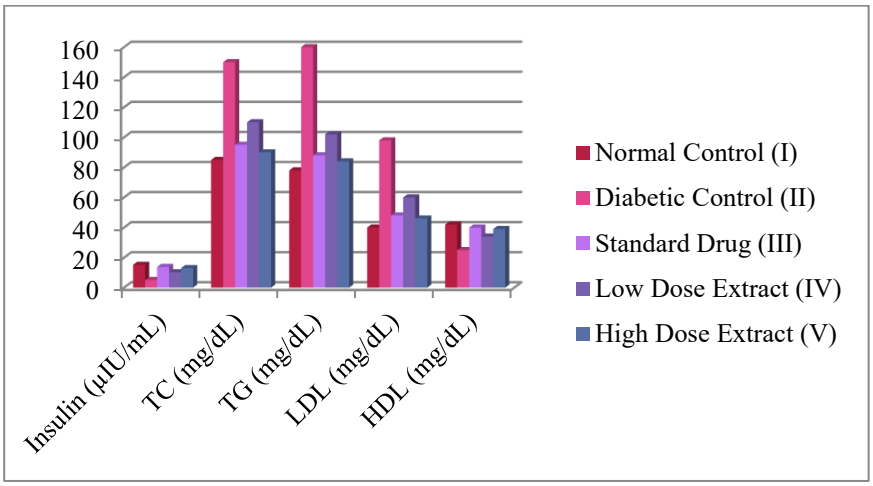

Figure 3: Effect of *Ficus racemosa* Extract on Serum Insulin and Lipid Profile

4.4 Histopathological Observations

Histopathological examination of pancreatic tissues revealed distinct morphological differences across the treatment groups. The **normal control group (Group I)** showed healthy islets of Langerhans with normal β-cell architecture and no signs of inflammation or necrosis. In contrast, the **diabetic control group (Group II)** exhibited severe β-cell destruction, islet shrinkage, and infiltration of inflammatory cells—hallmarks of STZ-induced pancreatic damage. The **standard drug group (Group III)** displayed near-normal islet architecture with minimal degeneration, reflecting the protective effect of metformin. Notably, rats treated with the ethanolic extract of *Ficus racemosa* demonstrated dose-dependent restoration of islet structure. The **low-dose group (Group IV)** showed moderate cellular recovery, while the **high-dose group (Group V)** revealed significant regeneration of β-cells, increased islet size, and reduced necrosis. These findings support the hypothesis that *Ficus racemosa* bark extract possesses pancreatic protective and regenerative potential.

Table 4: Histopathological Changes in Pancreatic Tissues Across Groups

Group	Islet Structure	β-cell Integrity	Inflammation	Regeneration Evidence
Normal Control (I)	Normal, well-defined	Intact	Absent	Not applicable
Diabetic Control (II)	Shrunken, damaged	Severely degenerated	Prominent	Absent

Standard Drug (III)	Near normal	Largely preserved	Mild	Evident
Low Dose Extract (IV)	Moderately preserved	Partial restoration	Mild	Moderate
High Dose Extract (V)	Well-preserved, enlarged	Regenerating β-cells	Minimal	Marked

Note: Observations based on H&E staining under light microscopy (40×).

4.5 Statistical Analysis

All experimental data were expressed as Mean ± Standard Error of Mean (SEM) for each group (n = 6). Statistical analysis was performed using one-way analysis of variance (ANOVA) to determine the overall significance among groups. When ANOVA showed significant differences ($p < 0.05$), intergroup comparisons were carried out using Tukey's post hoc test to identify specific group differences. The software used for analysis was GraphPad Prism (version 9.0). A p-value less than 0.05 ($p < 0.05$) was considered statistically significant, while $p < 0.01$ and $p < 0.001$ were considered highly and very highly significant, respectively. All comparisons were made between treated groups and the diabetic control group unless otherwise specified. This statistical approach ensured accurate interpretation of the treatment effects of Ficus racemosa extract on various biochemical and histological parameters.

5. DISCUSSION

The findings of this study provide strong evidence supporting the antidiabetic activity of the ethanolic extract of *Ficus racemosa* bark in STZ-induced diabetic rats. Phytochemical analysis confirmed the presence of flavonoids, tannins, saponins, alkaloids, and terpenoids, and glycosides secondary metabolites known for their therapeutic potential. Among these, flavonoids and tannins are potent antioxidants that scavenge free radicals and protect pancreatic β-cells from oxidative damage, a key pathological event in diabetes mellitus. Saponins and alkaloids are reported to possess insulin-mimetic effects or promote insulin secretion from residual β-cells. The extract-treated groups showed a dose-dependent reduction in fasting blood glucose (FBG) levels, with the 400 mg/kg dose producing effects nearly equivalent to those of metformin. Improvement in serum insulin levels in extract-treated groups further supports the hypothesis that *Ficus racemosa* may enhance endogenous insulin secretion or facilitate β-cell regeneration, as also evidenced by histopathological recovery of islet cell structure.

Table 5: Comparative Analysis of FBG, Insulin, and TC across Groups

Group	FBG (mg/dL)	Insulin (µIU/mL)	TC (mg/dL)
Normal Control (I)	95 ± 4	15.2 ± 0.8	85 ± 5
Diabetic Control (II)	310 ± 15	5.1 ± 0.6	150 ± 10
Metformin (III)	120 ± 8	13.8 ± 0.7	95 ± 6
Extract 200 mg/kg (IV)	155 ± 10	10.2 ± 0.6	110 ± 7
Extract 400 mg/kg (V)	125 ± 7	13.0 ± 0.8	90 ± 5

Values are Mean ± SEM; significant at $p < 0.05$ compared to diabetic control.

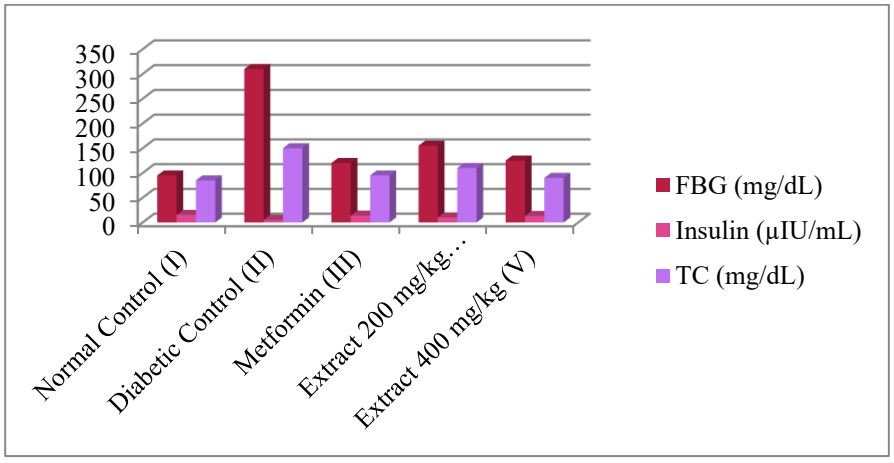

Figure 4: Comparative Analysis of FBG, Insulin, and TC across Groups

Comparison with metformin, a standard antidiabetic drug, revealed that the plant extract demonstrated comparable efficacy in controlling hyperglycemia and improving metabolic parameters. While metformin is primarily an insulin sensitizer acting through AMP-activated protein kinase (AMPK) pathways, *Ficus racemosa* appears to exert broader therapeutic effects, including antioxidant, insulinogenic, and lipid-lowering actions. This multifactorial mechanism could be particularly useful in managing the complex pathophysiology of type 2 diabetes. Lipid profile normalization was also observed, with reductions in total cholesterol (TC), triglycerides (TG), and low-density lipoprotein (LDL), and an increase in high-density lipoprotein (HDL) levels. This suggests that the extract not only exerts glycemic control but also mitigates the risk of diabetic dyslipidemia and cardiovascular complications, possibly through inhibition of lipid peroxidation and improved hepatic lipid metabolism. Furthermore, the use of *Ficus racemosa* in Ayurvedic medicine for treating "Madhumeha" aligns with the outcomes of this research. The ability of the extract to target multiple mechanisms—such as oxidative stress, insulin deficiency, β-cell damage, and lipid abnormalities—reaffirms its value in traditional medicine and highlights its promise as a complementary therapeutic agent for diabetes management.

6. CONCLUSION

The findings of this study provide substantial scientific support for the traditional use of Ficus racemosa bark as an antidiabetic agent. The ethanolic extract of Ficus racemosa bark demonstrated significant hypoglycemic activity in streptozotocin-induced diabetic rats, as evidenced by marked reductions in fasting blood glucose levels and improvements in serum insulin concentrations. Phytochemical screening revealed the presence of key bioactive compounds, including flavonoids, tannins, saponins, alkaloids, triterpenoids, and glycosides, which are known for their antioxidant, anti-inflammatory, and glucose-lowering properties. These phytoconstituents likely act synergistically to exert multifaceted benefits, such as enhancing insulin secretion, improving insulin sensitivity, protecting pancreatic β-cells, and inhibiting intestinal glucose absorption. The extract also favorably modulated lipid profiles and preserved hepatic and renal function, indicating its potential to address not only hyperglycemia but also diabetes-associated metabolic disturbances and organ damage. Histopathological analysis further confirmed the protective and regenerative effects of the extract on pancreatic tissue, supporting its role in β-cell preservation. Importantly, the study highlights the value of plant-based therapies as safer, more accessible alternatives or adjuncts to conventional antidiabetic drugs, particularly in resource-limited settings where the burden of diabetes is rapidly increasing. However, while these results are promising, further research is needed to isolate and characterize the specific active constituents, clarify their mechanisms of action, and establish the long-term safety and efficacy of Ficus racemosa bark extract through rigorous clinical trials. Overall, this research lays a strong foundation for the development of novel, affordable, and effective plant-based interventions for diabetes management, and underscores the importance of integrating ethnomedicinal knowledge with modern pharmacological research.

REFERENCES

[1] S., & Mishra, A. N. (2019). Evaluation of alloxan on induction of diabetes in albino rats. *International Journal of Basic & Clinical Pharmacology*. https://doi.org/10.18203/2319-2003.ijbcp20195290

[2] Abeeleh, M. A., Ismail, Z. B., Alzaben, K. R., Abu-Halaweh, S. A., Al-Essa, M. K., Abuabeeleh, J., & Alsmady, M. M. (2009). Induction of diabetes mellitus in rats using intraperitoneal streptozotocin: A comparison between 2 strains of rats. *European Journal of Scientific Research*.

[3] Akbarzadeh, A., Norouzian, D., Mehrabi, M. R., Jamshidi, S., Farhangi, A., Allah Verdi, A., Mofidian, S. M. A., & Lame Rad, B. (2007). Induction of diabetes by Streptozotocin in rats. *Indian Journal of Clinical Biochemistry*. https://doi.org/10.1007/BF02913315

[4] Alam, S., Sarker, M. M. R., Sultana, T. N., Chowdhury, M. N. R., Rashid, M. A., Chaity, N. I., Zhao, C., Xiao, J., Hafez, E. E., Khan, S. A., & Mohamed, I. N. (2022). Antidiabetic Phytochemicals From Medicinal Plants: Prospective Candidates for New Drug Discovery and Development. In *Frontiers in Endocrinology*. https://doi.org/10.3389/fendo.2022.800714

[5] Ali, M. A., & Mustafa, N. G. (2023). Biochemical Profiles of Different Approaches Applied to Induction of Diabetes in Rats. *Egyptian Journal of Veterinary Science(Egypt)*. https://doi.org/10.21608/EJVS.2023.194510.1445

[6] Ali, S., Ali, S. A., Kondrapu, P., Tripathi, N., Kumar, P. B., Prasad, P. D., & Tonape, M. M. (2023). A Brief Review Of Pathophysiology And Management Of Different Types Of Arthritis. *European Chemical Bulletin*, *12*(12), 199–230. https://doi.org/10.48047/ecb/2023.12.si12.016

[7] Ali, S., Ekbbal, R., Salar, S., Yasheshwar, N., Ali, S. A., Jaiswal, A. K., Singh, M., Yadav, D. K., Kumar, S., & Gaurav, N. (2023). Quality Standards and Pharmacological Interventions of Natural Oils: Current Scenario and Future Perspectives. In *ACS Omega*. https://doi.org/10.1021/acsomega.3c05241

[8] Antar, S. A., Ashour, N. A., Sharaky, M., Khattab, M., Ashour, N. A., Zaid, R. T., Roh, E. J., Elkamhawy, A., & Al-Karmalawy, A. A. (2023). Diabetes mellitus: Classification, mediators, and complications; A gate to

identify potential targets for the development of new effective treatments. In *Biomedicine and Pharmacotherapy*. https://doi.org/10.1016/j.biopha.2023.115734

[9] Bhargava, S., & Shah, M. B. (2021). Evaluation of efficacy of Bombax ceiba extract and its major constituent, mangiferin in streptozotocin (STZ)-induced diabetic rats. *Journal of Complementary and Integrative Medicine*. https://doi.org/10.1515/jcim-2020-0027

[10] Biswas, T. K., & Mukherjee, B. (2003). Plant Medicines of Indian Origin for Wound Healing Activity: A Review. *The International Journal of Lower Extremity Wounds*. https://doi.org/10.1177/1534734603002001006

[11] Deep, P., Singh, K. A., Ansari, M. T., & Raghav, P. (2013). Pharmacological potentials of Ficus racemosa - a review. In *International Journal of Pharmaceutical Sciences Review and Research*.

[12] Deepa, P., Sowndhararajan, K., Kim, S., & Park, S. J. (2018). A role of Ficus species in the management of diabetes mellitus: A review. In *Journal of Ethnopharmacology*. https://doi.org/10.1016/j.jep.2017.12.045

[13] Ekbbal, R., Jaiswal, A. K., Aggarwal, M., Singh, M., Ali, S., Ali, S. A., & Gautam, G. (2024). Indian Medicinal Plants for the Management of Endometriosis: A Comprehensive Review on their phytopharmacology. In *Natural Resources for Human Health*. https://doi.org/10.53365/nrfhh/174668

[14] Gilijamse, P. W., Hartstra, A. V., Levin, E., Wortelboer, K., Serlie, M. J., Ackermans, M. T., Herrema, H., Nederveen, A. J., Imangaliyev, S., Aalvink, S., Sommer, M., Levels, H., Stroes, E. S. G., Groen, A. K., Kemper, M., de Vos, W. M., Nieuwdorp, M., & Prodan, A. (2020). Treatment with Anaerobutyricum soehngenii: a pilot study of safety and dose–response effects on glucose metabolism in human subjects with metabolic syndrome. *Npj Biofilms and Microbiomes*. https://doi.org/10.1038/s41522-020-0127-0

[15] Gong, L., Feng, D., Wang, T., Ren, Y., Liu, Y., & Wang, J. (2020). Inhibitors of α-amylase and α-glucosidase: Potential linkage for whole cereal foods on prevention of hyperglycemia. In *Food Science and Nutrition*. https://doi.org/10.1002/fsn3.1987

[16] Hasaninezhad, F., Tavaf, Z., Panahi, F., Nourisefat, M., Khalafi-Nezhad, A., & Yousefi, R. (2020). The assessment of antidiabetic properties of novel synthetic curcumin analogues: α-amylase and α-glucosidase as the target enzymes. *Journal of Diabetes and Metabolic Disorders*. https://doi.org/10.1007/s40200-020-00685-z

[17] Hosseini, A., Shafee-Nick, R., & Ghorbani, A. (2015). Pancreatic beta cell protection/regeneration with phytotherapy. *Brazilian Journal of Pharmaceutical Sciences*. https://doi.org/10.1590/S1984-82502015000100001

[18] Huang, X., Arjsri, P., Srisawad, K., Yodkeeree, S., & Dejkriengkraikul, P. (2024). Exploring the Anticancer Potential of Traditional Thai Medicinal Plants: A Focus on Dracaena loureiri and Its Effects on Non-Small-Cell Lung Cancer. *Plants*. https://doi.org/10.3390/plants13020290

[19] Johnson, M. L., Distelmaier, K., Lanza, I. R., Irving, B. A., Robinson, M. M., Konopka, A. R., Shulman, G. I., & Nair, K. S. (2016). Mechanism by which caloric restriction improves insulin sensitivity in sedentary obese adults. *Diabetes*. https://doi.org/10.2337/db15-0675

[20] Kalailingam, P., Kannaian, B., Tamilmani, E., & Kaliaperumal, R. (2014). Efficacy of natural diosgenin on cardiovascular risk, insulin secretion, and beta cells in streptozotocin (STZ)-induced diabetic rats. *Phytomedicine*. https://doi.org/10.1016/j.phymed.2014.04.005

[21] Lee, Y. S., & Jun, H. S. (2014). Anti-diabetic actions of glucagon-like peptide-1 on pancreatic beta-cells. In *Metabolism: Clinical and Experimental*. https://doi.org/10.1016/j.metabol.2013.09.010

[22] Li, X., Bai, Y., Jin, Z., & Svensson, B. (2022). Food-derived non-phenolic α-amylase and α-glucosidase inhibitors for controlling starch digestion rate and guiding diabetes-friendly recipes. In *LWT*. https://doi.org/10.1016/j.lwt.2021.112455

[23] Maske, P. P., Kumbhar, P. S., Wali, A. G., Disouza, J. I., & Sharma, M. (2023). Antioxidant, Antidiabetic and Lipid Profiling of Spermadicyton Suaveolens in Streptozotocin (STZ) Induced Diabetic Rats. *Brazilian Journal of Pharmaceutical Sciences*. https://doi.org/10.1590/s2175-97902023e21820

[24] Olesen, S. S., Hagn-Meincke, R., Drewes, A. M., Steinkohl, E., & Frøkjaer, J. B. (2021). Pancreatic atrophy and exocrine insufficiency associate with the presence of diabetes in chronic pancreatitis patients, but additional mediators are operative. *Scandinavian Journal of Gastroenterology*. https://doi.org/10.1080/00365521.2020.1867891

[25] Osei, K., Schuster, D. P., Amoah, A. G. B., & Owusu, S. K. (2003). Pathogenesis of type 1 and type 2 diabetes mellitus in sub-saharan Africa: Implications for transitional populations. *European Journal of Preventive Cardiology*. https://doi.org/10.1177/174182670301000203

[26] Pahari, N., Majumdar, S., Karati, D., & Mazumder, R. (2022). Exploring the pharmacognostic properties and pharmacological activities of phytocompounds present in Ficus racemosa linn.: A concise review. In *Pharmacological Research - Modern Chinese Medicine*. https://doi.org/10.1016/j.prmcm.2022.100137

[27] Passino, R., Finneran, M. C., Hafner, H., Feng, Q., Huffman, L. D., Zhao, X. F., Johnson, C. N., Kawaguchi, R., Oses-Prieto, J. A., Burlingame, A. L., Geschwind, D. H., Benowitz, L. I., & Giger, R. J. (2024). Neutrophil-inflicted vasculature damage suppresses immune-mediated optic nerve regeneration. *Cell Reports*. https://doi.org/10.1016/j.celrep.2024.113931

[28] Pradeep Kumar, C., & Sachin, J. (2013). Extraction and isolation of bioactive compounds from Ficus racemosa bark and Cissampelos pareira root by chromatographic techniques. *International Journal of Pharmaceutical Sciences Review and Research*.

[29] Rahman, M. M., Dhar, P. S., Sumaia, Anika, F., Ahmed, L., Islam, M. R., Sultana, N. A., Cavalu, S., Pop, O., & Rauf, A. (2022). Exploring the plant-derived bioactive substances as antidiabetic agent: An extensive review. In *Biomedicine and Pharmacotherapy*. https://doi.org/10.1016/j.biopha.2022.113217

[30] Ryan, B. J., Schleh, M. W., Ahn, C., Ludzki, A. C., Gillen, J. B., Varshney, P., Van Pelt, D. W., Pitchford, L. M., Chenevert, T. L., Gioscia-Ryan, R. A., Howton, S. M., Rode, T., Hummel, S. L., Burant, C. F., Little, J. P., & Horowitz, J. F. (2020). Moderate-Intensity Exercise and High-Intensity Interval Training Affect Insulin Sensitivity Similarly in Obese Adults. *Journal of Clinical Endocrinology and Metabolism*. https://doi.org/10.1210/clinem/dgaa345

[31] Saadane, A., Lessieur, E. M., Du, Y., Liu, H., & Kern, T. S. (2020). Successful induction of diabetes in mice demonstrates no gender difference in development of early diabetic retinopathy. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0238727

[32] Schootman, M., Jeffe, D. B., Ratnapradipa, K. L., Eberth, J. M., & Davidson, N. O. (2020). Increased 30-Day Mortality Risk in Patients With Diabetes Mellitus After Colon Cancer Surgery: A Mediation Analysis. *Diseases of the Colon and Rectum*. https://doi.org/10.1097/DCR.0000000000001586

[33] Shah, S. K., Garg, G., Jhade, D., & Pandey, H. (2016). Ficus racemosa Linn: Its potentials food security and rural medicinal management. In *Journal of Pharmaceutical Sciences and Research*.

[34] Shamim, Ali, S., Ali, T., Sharma, H., Kishor, B. N., & Jha, S. K. (2025a). Recent Advances in Monodisperse Gold Nanoparticle Delivery, Synthesis, and Emerging Applications in Cancer Therapy. *Plasmonics*, *0123456789*. https://doi.org/10.1007/s11468-024-02732-4

[35] Shamim, Ali, S., Ali, T., Sharma, H., Kishor, B. N., & Jha, S. K. (2025b). Recent Advances in Monodisperse Gold Nanoparticle Delivery, Synthesis, and Emerging Applications in Cancer Therapy. *Plasmonics*, *20*(1). https://doi.org/10.1007/s11468-024-02732-4

[36] Singh, S., Bansal, A., Singh, V., Chopra, T., & Poddar, J. (2022). Flavonoids, alkaloids and terpenoids: a new hope for the treatment of diabetes mellitus. In *Journal of Diabetes and Metabolic Disorders*. https://doi.org/10.1007/s40200-021-00943-8

[37] Tran, N., Pham, B., & Le, L. (2020). Bioactive compounds in anti-diabetic plants: From herbal medicine to modern drug discovery. In *Biology*. https://doi.org/10.3390/biology9090252

[38] Umapathy, D., Dornadula, S., Rajagopalan, A., Murthy, N., Mariappanadar, V., Kesavan, R., & Kunka Mohanram, R. (2018). Potential of circulatory procalcitonin as a biomarker reflecting inflammation among South Indian diabetic foot ulcers. *Journal of Vascular Surgery*. https://doi.org/10.1016/j.jvs.2017.02.060

[39] Veerapur, V. P., Prabhakar, K. R., Thippeswamy, B. S., Bansal, P., Srinivasan, K. K., & Unnikrishnan, M. K. (2012). Antidiabetic effect of Ficus racemosa Linn. stem bark in high-fat diet and low-dose streptozotocin-induced type 2 diabetic rats: A mechanistic study. *Food Chemistry*. https://doi.org/10.1016/j.foodchem.2011.10.052

[40] Wang, J., & Wang, H. (2017). Oxidative stress in pancreatic beta cell regeneration. In *Oxidative Medicine and Cellular Longevity*. https://doi.org/10.1155/2017/1930261

[41] Zanzabil, K. Z., Hossain, M. S., & Hasan, M. K. (2023). Diabetes Mellitus Management: An Extensive Review of 37 Medicinal Plants. In *Diabetology*. https://doi.org/10.3390/diabetology4020019