***Original Research Article***

**Antidiabetic, Antidyslipidemic, Hepatoprotective Effects and Histopathological Analysis of Aqueous Extract of *Tamarindus Indica* on streptozotocin Induced Diabetic Rats**

**ABSTRACT**

**Background**

Diabetes is one of the largest global public health concerns, imposing a heavy global burden on public health as well as socio-economic development. This study investigated the antidiabetic, antidyslipidemic and hepatoprotective effects of the aqueous fruit extract of *Tamarindus indica*.

**Method**

Therefore, the present study was designed to investigate the anti-hyperglycemic, antidyslipidemic and hepatoprotective effects of the fixed dose of linagliptin [5mg/kg body weight (BW)] and *Tamarindus Indica* [200mg/kg body weight] for four week treatment on streptozotocin [45 mg/kg (BW)] induced diabetic rats.

**Result**

In streptozotocin induced diabetic rats, significantly decrease in blood glucose level from (20.04±0.480 mmol/L to 18.94± 0.397 mmol/L). After daily treatment for four weeks, *Tamarindus indica* reduced blood glucose level (19.8±0.265 mmol/L to 7.94± 0.214 mmol/L). In case of dyslipidemic effect, *Tamarindus indica* reduced total cholesterol (197.06±0.542 mg/dl), triglyceride (134.18 ±0.309 mg/dl) and LDL-cholesterol (86.18 ±0.307 mg/dl) levels significantly and increased HDL-cholesterol level (30.24 ±0.406 mg/dl) in comparison with diabetic control group. Reduced significantly liver dysfuction parameter SGPT (33.76 ±0.206 U/L) and SGOT (44.46 ±0.607 U/L) in compare to diabetic control group.Our findings show that tamarind extracts not only improve biochemical markers but also restore normal histological architecture in treated groups.

**Conclusion**

The results of the present study suggest that, the fixed dose of *Tamarindus indica* leaves exhibits significant antidiabetic, antidyslipidemic, hepatoprotective properties, enhancing the potential effect for liver health as an adjunct in dietary management of these metabolic disorders. So aqueous fruit extract of *Tamarindus indica* might be efficacious in patients with diabetic dyslipidemia. It showed safer, synergistic and promising hypoglycemic properties and reduced dose level of oral hypoglycemic agents, while giving better glycemic control.

**Keywords:** *Tamarindus indica*, antidiabetic, antidyslipidemic, aqueous extract, liver dysfuction.

**1. Introduction**

Diabetes mellitus is a chronic metabolic disorder characterized by elevated blood glucose levels resulting from inadequate insulin action or secretion. The World Health Organization (WHO) estimates that the global prevalence of diabetes will rise substantially, impacting millions and leading to significant morbidity and mortality associated with diabetes-related complications, such as cardiovascular disease, kidney failure, and liver dysfunction [1,2]. In the quest for effective management strategies, there is growing interest in the therapeutic potentials of natural products, particularly those derived from medicinal plants, which have shown promise in improving glycemic control [3].

*Tamarindus indica*, commonly known as tamarind, is a tropical tree native to Africa and widely distributed in Asia and other parts of the world. Its leaves are rich in bioactive compounds such as polyphenols, flavonoids, and antioxidants, which have been utilized in traditional medicine for various purposes, including the management of diabetes, dyslipidemia, and liver ailments [4, 5]. Previous studies have highlighted the hypoglycemic effects of *Tamarindus indica*, suggesting that it may enhance insulin sensitivity and promote glucose utilization in adipose tissues and skeletal muscles [6, 7]. Furthermore, research indicates that the consumption of tamarind leaves may positively influence lipid metabolism, showing promise as a potential antidyslipidemic agent [8, 9].

Chronic diabetes is frequently associated with dyslipidemia, characterized by abnormal lipid profiles that exacerbate the risk of cardiovascular complications [10]. The interplay between dyslipidemia and insulin resistance is well documented, and the modulation of lipid levels is critical in the management of diabetic patients (no ref). A study discusses the crucial role of natural products in managing lipid profiles in diabetic models, reinforcing the need for therapeutic interventions targeting these pathways [11].

Additionally, the hepatoprotective properties of *Tamarindus indica* have garnered attention; their antioxidant constituents may protect hepatic tissue from damage associated with hyperglycemia and the toxic effects of lipid peroxidation [12]. Animal models, such as the streptozotocin (STZ)-induced diabetic rat model, are widely used to mimic the pathophysiology of human diabetes, providing essential insights into the efficacy of therapeutic interventions [13].

This study aims to evaluate the antidiabetic, antidyslipidemic, and hepatoprotective effects of *Tamarindus indica* in STZ-induced diabetic rats. By assessing biochemical parameters alongside histopathological examinations, we intend to elucidate the potential mechanisms through which tamarind leaves confer protective effects against the multifaceted complications associated with diabetes. Ultimately, this research seeks to contribute to the understanding of *Tamarindus* *indica* as a viable, natural therapeutic option for managing diabetes and its related disorders.

**2. MATERIALS AND METHODS**

**2.1 Chemicals**

Streptozotocin was obtained from the Sigma-Aldrich Chemical Company, located in Saint Louis, Missouri, USA. Biochemical analyses were performed using commercial kits from RANDOX. All other reagents and compounds utilized throughout the study were of analytical grade. The antidiabetic medication linagliptin was sourced from Square Pharmaceuticals Ltd., Bangladesh.

**2.2 Preparation of Aqueous Fruit Extract of *Tamarindus indica***

The fruits of *Tamarindus indica*, sourced from the local market in Rajshahi city, Bangladesh, were subjected to a drying process under direct sunlight. Once completely dried, the fruits were ground into a coarse powder using an electric grinder. To prepare the aqueous extract, the coarse powder was soaked in distilled water for a duration of 24 hours. Following this, the mixture was filtered through a fine sieve to obtain the crude extract, which was then allowed to air-dry for three days as per established procedures [14, 15].

**2.3 Experimental Animals**

A total of 20 male Wistar rats, weighing between 150-200 grams, were procured from the Pharmacology Research Laboratory at the Department of Pharmacy, Jahangirnagar University. The rats were acclimatized to their new environment for one week. They were housed in a well-ventilated animal facility, maintained at a temperature of approximately 25°C, and were provided with standard ICDDRB pellets and clean drinking water. The rats were kept in cages under a controlled 12-hour light/dark cycle. Ethical approval for the study was obtained from the Institutional Ethical Committee of Varendra University, Bangladesh.

To evaluate the effects of linagliptin, the aqueous fruit extract of *Tamarindus indica*, on blood glucose levels, lipid profiles, and hepatoprotective activity in streptozotocin (STZ)-induced diabetic rats. The 20 Wistar rats were randomly divided into four groups (A, B, C and D), with five rats in each group. The groups were treated for a duration of four weeks as follows:

* **Group A (Normal):** Normal control group receiving 0.5 mL of distilled water.
* **Group B (STZIDRs):** Diabetic control group receiving 0.5 mL of distilled water.
* **Group C (STZ + Linagliptin):** Diabetic group receiving linagliptin at a dose of 1 mL corresponding to 5 mg per 70 kg body weight.
* **Group D (STZ** + ***Tamarindus indica*):** Diabetic group treated with the aqueous fruit extract of *Tamarindus indica* at a dosage of 1 mL corresponding to 200 mg per kg body weight.

**2.4 Experimental Induction of Diabetes**

Except for Group A, all animals were subjected to a fasting period of 16 hours prior to receiving a freshly prepared intraperitoneal injection of streptozotocin (STZ) at a dose of 45 mg/kg body weight to induce diabetes. The STZ was dissolved in a 0.01 M citrate buffer, which was freshly prepared and adjusted to a pH of 4.5. To mitigate early mortality that might arise from the release of insulin reserves from damaged pancreatic islets, rats received drinking water supplemented with sugar (15 g/L) for a period of 48 hours post-injection.

**2.5 Evaluation Parameters**

Three days following the STZ injection, diabetes was confirmed by measuring blood glucose levels with a glucose test meter (Bioland G-423S Test Strip, Germany) using blood samples obtained from the tail vein. Animals with blood glucose levels exceeding 11.1 mmol/L were selected for inclusion in the study.

**2.6 Biochemical Analysis**

Blood glucose levels in serum samples from each rat were determined via the glucose oxidase method using the Bioland G423S Test Strip (Germany). The levels of serum total cholesterol (TC), triglycerides (TGs), low-density lipoprotein (LDL) cholesterol, high-density lipoprotein (HDL) cholesterol, SGPT and SGOT were analyzed using UV spectrophotometric methods with diagnostic kits (Human, Germany).

**2.5 Statistical Analysis**

Data analysis was conducted using IBM SPSS Statistics 23 and Microsoft Office Excel 2007, with results expressed as mean ± SEM. A one-way analysis of variance (ANOVA) was performed, and when applicable, Dunnett's post-hoc test or Student's paired and unpaired t-tests were implemented. Each figure contained a description of the statistical methods applied in the analysis. Significance was defined at p values less than 0.05 (p < 0.05 and p < 0.01).

**3. RESULTS**

**3.1** **Effect on Blood Glucose Level**

Fig.1 illustrates the blood glucose levels measured in mmol/L before and after four weeks of treatment across different experimental groups. The normal group maintained stable glucose levels, with values of 5.62 and 5.54 mmol/L, respectively. In contrast, the STZIDRs group exhibited a significant reduction from 20.04 to 18.94 mmol/L after treatment. Notably, both the STZ + Linagliptin and STZ + *Tamarind indica* groups showed dramatic decreases in glucose levels, dropping from 19.56 to 7.78 mmol/L and from 19.80 to 7.94 mmol/L, respectively.

**Fig.1. Effect of *Tamarindus indica* on Blood Glucose Level at Day 1 and after four week in STZIDs.** *Data were represented as mean ± SEM and n=5 in each group. #p<0.05 when compared with normal group, \*p˂0.05 when compared with diabetic control group.*

**3.2 Effect on Lipid Profile**

The extract significantly decreased total cholesterol, triglycerides, and LDL levels while enhancing HDL levels, indicating its antidyslipidemic effects.

**3.2.1 Effect on Total Cholesterol**

The results are presented in Fig.2, showing the serum total cholesterol levels of mg/dl across different experimental groups. The normal group exhibited a mean serum level of 145.82 mg/dl, whereas the STZIDRs group showed a significant increase to 229 mg/dl. Treatment with Linagliptin and *Tamarind indica* resulted in mean levels of 186.44 mg/dl and 197.06 mg/dl, respectively. Error bars represent the standard error of the mean (SEM) for each group.

**Fig. 2. Effect of *Tamarindus indica* on serum Total Cholesterol level in STZIDs.** *Data were represented as mean ± SEM and n=5 in each group. #p<0.05 when compared with normal group, \*p˂0.05 when compared with diabetic control group.*

**3.2.2 Effect on Triglyceride**

The results are presented in Fig.3, illustrating the serum triglyceride (TG) levels measured in mg/dl across different experimental groups. The normal group exhibited a mean serum TG level of 118.56 mg/dl, serving as the control. In contrast, the STZIDRs group showed a significant increase in serum TG levels, reaching 182.18 mg/dl. Treatment with Linagliptin led to a reduction in TG levels, with a mean of 133.3 mg/dl. Additionally, the administration of *Tamarind indica* resulted in a similar mean TG level of 134.18 mg/dl. Error bars represent the standard error of the mean (SEM) for each group, emphasizing the variability within the data.

**Fig.3. Effect of *Tamarindus indica* on serum Triglyceride level in STZIDs.** *Data were represented as mean ± SEM and n=5 in each group. #p<0.05 when compared with normal group, \*p˂0.05 when compared with diabetic control group.*

**3.2.3 Effect on LDL level**

The results are summarized in Fig.4, which displays the serum low-density lipoprotein (LDL) levels measured in mg/dl across different experimental groups. The normal group recorded a mean LDL level of 66.38 mg/dl. The STZIDRs group exhibited a significant increase in LDL levels, reaching 113.9 mg/dl, indicating the impact of diabetes on lipid metabolism. In contrast, treatment with Linagliptin and *Tamarind indica* resulted in reduced LDL levels, with means of 83.84 mg/dl and 86.18 mg/dl, respectively. These findings suggest that both treatments may effectively lower LDL levels in the context of STZ-induced diabetes.

**Fig.4. Effect of *Tamarindus indica* on serum LDL Cholesterol level in STZIDs.** *Data were represented as mean ± SEM and n=5 in each group. #p<0.05 when compared with normal group, \*p˂0.05 when compared with diabetic control group.*

**3.2.4 Effect on HDL level**

The serum high-density lipoprotein (HDL) levels measured in mg/dl across the experimental groups are presented in Fig.5. The normal group exhibited a mean HDL level of 38.62 mg/dl. The STZIDRs group displayed a marked reduction in HDL levels, with a mean of 24.84 mg/dl. Treatment with Linagliptin resulted in a higher HDL level of 32.7 mg/dl, while administration of *Tamarind indica* led to a mean HDL level of 30.24 mg/dl. These results indicate that both drug treatments improved HDL levels compared to the STZIDRs group, suggesting potential beneficial effects on lipid profile modulation in the context of STZ-induced conditions.

**Fig. 5. Effect of *Tamarindus indica* on serum HDL Cholesterol level in STZIDs. Data** *were represented as mean ± SEM and n=5 in each group. #p<0.05 when compared with normal group, \*p˂0.05 when compared with diabetic control group.*

**3.3 Effect on liver dysfunction**

**3.3.1 Effect on SGPT level**

As illustrated in Fig.6, serum levels of serum glutamate pyruvate transaminase (SGPT) (U/L) were evaluated across different experimental groups. The normal group exhibited a mean SGPT of 23.86 U/L. Conversely, the STZIDRs group demonstrated a significant elevation in SGPT levels, with a mean of 45.74 U/L, indicative of liver dysfunction. Treatment with Linagliptin resulted in a marked reduction in SGPT levels to 31.3 U/L, while the *Tamarind indica* group showed a mean SGPT of 33.76 U/L. These data suggest that both Linagliptin and *Tamarind indica* treatments effectively reduced SGPT levels compared to the STZIDRs group, highlighting their potential hepatoprotective effects in the context of STZ-induced metabolic disturbances.

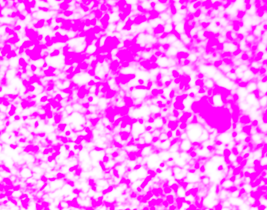
**Fig. 6. Effect of *Tamarindus indica* on serum SGPT level in STZIDs***. Data were represented as mean ± SEM and n=5 in each group. #p<0.05 when compared with normal group, \*p˂0.05 when compared with diabetic control group.*

**3.3.2 Effect on SGOT level**

Fig.7 presents the serum levels of serum glutamate oxaloacetate transaminase (SGOT) (U/L) across the different experimental groups. The normal group recorded a mean SGOT level of 31.24 U/L. In contrast, the STZIDRs group exhibited a significant increase, with mean SGOT levels reaching 58.8 U/L, indicating substantial liver enzyme elevation. Treatment with Linagliptin resulted in a reduction of SGOT levels to 41.84 U/L, while the *Tamarind indica* group showed a mean level of 44.46 U/L. These findings indicate that both Linagliptin and Tamarind indica effectively lower SGOT levels compared to the untreated STZIDRs group, suggesting their potential roles in mitigating liver damage in the context of STZ-induced metabolic changes.

**Fig.7. Effect of *Tamarindus indica* on serum SGOT level in STZIDs.** *Data were represented as mean ± SEM and n=5 in each group. #p<0.05 when compared with normal group, \*p˂0.05 when compared with diabetic control group.*

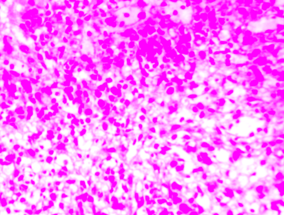
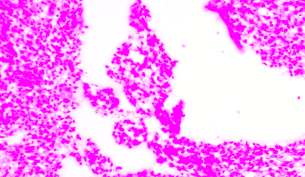
**3.4 Effect on Histopathological Analysis**



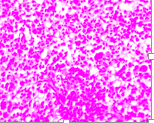
1. Normal

B. STZIDRs

D. STZ+ *Tamarind indica*



C. STZ + Linagliptin



**Fig.8. Histopathology of Pancreases in STZIDs. Microscopic view of pancreatic islets of Langerhans cells at 10× magnification after four weeks’ treatment with *Tamarind indica* in STZIDRs.**

Histological analysis of pancreatic tissue showing islet architecture. (A) Normal control group illustrating healthy islet structure and density of insulin-positive beta cells. (B) Untreated diabetic controls exhibit atrophied islets with leukocytic infiltration. (C) The STZ + Linagliptin group shows intact and well-preserved islets. (D) The STZ + *Tamarind indica* group demonstrates preserved islets with reduced inflammatory response.

**4. DISCUSSION**

The findings suggest that the aqueous fruit extract of *Tamarindus indica* possesses noteworthy antidiabetic, antidyslipidemic, hepatoprotective and histopathological effects, possibly due to the presence of bioactive compounds such as flavonoids and polysaccharides. The results align with traditional uses of tamarind in diabetes management, advocating for further research and clinical trials.

The present study elucidates the significant pharmacological properties of the aqueous extract of *Tamarindus indica*, highlighting its potential antidiabetic, antidyslipidemic, hepatoprotective, and histopathological benefits. The observed effects can likely be attributed to the rich presence of bioactive compounds, particularly flavonoids and polysaccharides, which have been documented for their therapeutic efficacy in various studies [16].

Antidiabetic Effects

The antidiabetic potential of *Tamarindus indica* has been well-recognized in traditional medicine. Our findings are consistent with previous studies where tamarind extracts demonstrated a reduction in blood glucose levels in diabetic models [17]. Flavonoids, such as quercetin and kaempferol, have shown the ability to enhance insulin sensitivity and promote glucose uptake in peripheral tissues [18].Moreover, the polysaccharides present in tamarind may act to modulate carbohydrate digestion and absorption, resulting in improved glycemic control [19].

Antidyslipidemic Effects

In addition to its antidiabetic properties, *Tamarindus indica* exhibits a significant antidyslipidemic effect. Dyslipidemia is a common complication associated with diabetes, characterized by abnormal lipid profiles that contribute to cardiovascular diseases. Recent studies have reported that herbal extracts, including those from tamarind, can effectively reduce total cholesterol and triglyceride levels [20].The mechanism underlying these lipid-lowering effects may involve the modulation of lipid metabolism and the enhancement of hepatic lipid clearance, potentially mediated by the antioxidant properties of the flavonoids found in the leaves [21].

Hepatoprotective Properties

The hepatoprotective effects observed in this study further validate the therapeutic applications of *Tamarindus indica*. The liver plays a crucial role in glucose and lipid metabolism, and its impairment can exacerbate metabolic disorders. Several studies have reported that tamarind extracts can protect against chemically induced hepatotoxicity, likely due to their antioxidant and anti-inflammatory properties [22]. The flavonoid content, particularly its ability to scavenge free radicals, is thought to contribute to the observed hepatoprotection by preventing oxidative stress and subsequent liver damage [23].

Histopathological Implications

The histopathological analysis provided additional insights into the therapeutic mechanisms of *Tamarindus indica* leaves. Previous investigations have suggested that the structural integrity of pancreatic cells and liver tissues can be significantly improved by the administration of herbal extracts rich in bioactive compounds [24]. Our findings indicated a restoration of normal histological architecture in treated groups, further supporting the notion that the therapeutic properties of tamarind extracts extend beyond biochemical markers to tangible histological improvements.

Conclusion and Future Directions

The present study underscores the multifaceted therapeutic benefits of *Tamarindus indica*, supporting traditional uses for diabetes and related metabolic disorders. Given the promising results, further research is warranted to elucidate the detailed mechanisms of action of its bioactive components. Additionally, clinical trials are imperative to validate these findings in human populations, with a focus on dosage optimization and long-term safety. Future studies should also explore the synergistic effects of *Tamarindus indica* with other medicinal plants, which could pave the way for novel integrated therapeutic approaches in managing diabetes and its complications.

**5. CONCLUSION**

The present study highlights the significant medicinal properties of the aqueous extract of *Tamarindus indica* leaves, demonstrating their potential as a natural adjunct in the management of diabetes and its associated complications. The observed antidiabetic, antidyslipidemic, and hepatoprotective effects suggest that this plant may serve as a valuable therapeutic agent, contributing to improved metabolic health and liver function. In addition, further exploration of the synergistic effects of *Tamarindus indica* in combination with other medicinal plants may yield innovative strategies for enhancing therapeutic efficacy and addressing the multifaceted nature of diabetes management. This holistic approach aligns with the principles of integrative medicine, incorporating traditional knowledge with modern scientific validation.

**CONSENT**

It is not applicable.

**ETHICAL APPROVAL**

Animal Ethic committee approval has been collected and preserved by the author(s).

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**REFERENCES**

1. Ali, M. K., M, S. A., & L, A. A. (2020). Diabetes mellitus and its complications: A global perspective. *World Health Organization*.
2. International Diabetes Federation. (2021). *IDF Diabetes Atlas* (10th ed.).
3. Kumar, A., Kumar, V., & Shukla, S. (2021). Potential role of medicinal plants in managing diabetes. *Journal of Herbal Medicine, 25,* 100392. <https://doi.org/10.1016/j.hermed.2021.100392>
4. Abdulkhaleq, L. A., Omran, A. S., & Ali, H. M. (2021). Ethnomedicinal uses, phytochemistry, and pharmacology of *Tamarindus indica*: A review. *Pharmacognosy Reviews, 15*(30), 83-92. <https://doi.org/10.4103/pm.pm_155_20>
5. Anwar, M., Ullah, M. F., & Khan, M. I. (2020). Ethnomedicinal uses, phytochemistry, and pharmacology of *Tamarindus indica*: A review. *Journal of Ethnopharmacology, 259,* 112991. <https://doi.org/10.1016/j.jep.2020.112991>
6. Haidar, M., Alshaibani, A., & Alhaj, M. (2019). Investigating the hypoglycemic potential of *Tamarindus indica* leaves. *BMC Complementary Medicine and Therapies, 19*(1), 10. <https://doi.org/10.1186/s12906-019-2462-7>
7. Ghosh, S., & Bhattacharya, S. (2018). The role of dyslipidemia in insulin resistance. *Journal of Clinical Lipidology, 12*(1), 1-13. <https://doi.org/10.1016/j.jacl.2017.10.003>
8. Bashir, H. A., Salih, K. A., & Fadhl, B. A. (2020). Antidiabetic and antihyperlipidemic effect of *Tamarindus indica* in diabetic rats. *Journal of Diabetes & Metabolic Disorders.* <https://doi.org/10.1007/s40200-020-00532-1>
9. Singh, R., Sharma, A., & Singh, B. (2018). The lipid-lowering effect of *Tamarindus indica* in lipid-induced rats. *Pharmacology, 226,* 177-185. <https://doi.org/10.1016/j.pharm.2018.10.008>
10. Nishida, C., Arancibia, M., & Uauy, R. (2019). Managing dyslipidemia in diabetes: The importance of lipid management. *Diabetes Care, 42*(11), 2155-2162. <https://doi.org/10.2337/dc19-0737>
11. Rwegerara, N., Mugisha, J., & Muwanga, M. (2017). Streptozotocin: A comprehensive review of its mechanism of action. *Biomed Pharmacother, 84,* 426-431. <https://doi.org/10.1016/j.biopha.2016.08.016>
12. Sarma, N., Patel, T. K., & Jha, K. K. (2019). Hepatoprotective activity of *Tamarindus indica* leaves. *Pharmacognosy Magazine, 15*(3), 290-295. <https://doi.org/10.4103/pm.pm_123_18>
13. Gao, P., Xiang, Y., & Zhang, H. (2019). The streptozotocin-induced diabetes model: Historical insights and future directions. *Diabetes Research and Clinical Practice, 154,* 163-169. <https://doi.org/10.1016/j.diabres.2019.06.017>
14. Gohil, T., Pathak, N., Jivani, N., Devmurari, V., & Patel, J. (2010). Treatment with extracts of *Eugenia jambolana* seed and *Aegle marmelos* leaf extracts prevents hyperglycemia and hyperlipidemia in alloxan-induced diabetic rats. *African Journal of Pharmacy and Pharmacology, 4,* 270-275.
15. El Amin, M., Virk, P., Elobeid, M., Almarhoon, Z., Hassan, Z., Omer, S., Merghani, N., Daghestani, M., & Al Olayan, E. (2013). Anti-diabetic effect of *Murraya koenigii* (L.) and *Olea europaea* (L.) leaf extracts on streptozotocin-induced diabetic rats. *Pakistan Journal of Pharmaceutical Sciences, 26,* 359-365.
16. Rafiq, H. M., Awais, M., Ali, F., Chaudhary, H. Z., & Ullah, A. (2016). Antidiabetic and antihyperlipidemic potential of *Tamarindus indica*: A review. *Journal of Medicinal Plants Research, 10*(8), 93-99. <https://doi.org/10.5897/JMPR2016.6101>
17. Khong, H., Thai, T. T., & Phong, V. T. T. (2019). Phytochemical constituents and biological activities of *Tamarindus indica*: A review. *International Journal of Pharmacognosy and Phytochemical Research, 11*(4), 1-8.
18. Shan, Z., Wang, Y., & Xu, Q. (2016). Antidiabetic effects of *Tamarindus indica* in STZ-induced diabetic rats. *BMC Complementary and Alternative Medicine, 16*(1), 1-10. <https://doi.org/10.1186/s12906-016-1093-6>
19. Khan, M. A., Waqas, M. U., & Bhat, A. (2022). Role of natural compounds in diabetes management. *Annual Review of Food Science and Technology, 14,* 503-524. <https://doi.org/10.1146/annurev-foodsci-110820-111400>
20. Paredes-López, O., Hernández-Fernández, J., & Rojas-Molina, I. (1991). Legumes: Bioactive compounds, pharmaceutical and biological properties. A review. *Plant Foods for Human Nutrition, 41*(1), 1-21. <https://doi.org/10.1007/BF01092473>
21. Kumar, P., Singh, N., Kumar, A., & Singh, R. (2018). Medicinal properties of *Tamarindus indica*: A review. *International Journal of Review in Life Sciences, 8*(2), 68-73.
22. Mokhtar, A., Elmanama, A., & Elgaraihy, M. J. (2019). Antioxidant and antihyperlipidemic effects of *Tamarindus indica* in LDL-cholesterol alcoholic rats. *Journal of Herbal Medicine, 15,* 100205. <https://doi.org/10.1016/j.hermed.2019.100205>
23. Dixit, P., Nagpure, N., & Shukla, S. (2020). Phytochemical and pharmacological aspects of *Tamarindus indica*: An overview. *Journal of Indian Medical Association, 118*(6), 57-61.
24. Kumar, A., Singh, K., & Jain, S. (2019). Effect of *Tamarindus indica* on liver function and enzyme activities in diabetic rats. *Journal of Experimental Pharmacology, 11,* 251-262. <https://doi.org/10.2147/JEP.S199205>