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The Effects of Gingerol on Lipid and Protein Profiles in Alloxan-Induced Diabetic Rats

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Abstract: This study investigated the impact of gingerol, the main bioactive phenolic compound in Zingiber officinale, on lipid and protein profiles in alloxan-induced diabetic rats. Diabetes mellitus is associated with profound metabolic disturbances, including dyslipidemia and alterations in serum protein levels, which contribute to the progression of cardiovascular complications.30 Male Wistar rats were divided into therr groups (n = 10 per group) : non-diabetic control, diabetic control, diabetic rats treated with gingerol (2 mg/kg body weight) .Diabetes was induced by a single intraperitoneal injection of alloxan (150 mg/kg). Treatments were administered orally for four weeks. Serum lipid parameters (total cholesterol, triglycerides, HDL-C, LDL-C, VLDL-C) and total protein profile levels(total protein , albumin , globulin , fibrinogen) were analyzed using standard biochemical methods. Histopathological examination of the pancreas was also performed to assess tissue alterations. Results revealed that gingerol supplementation significantly reduced total cholesterol, triglycerides, LDL-C, and VLDL-C while increasing HDL-C compared to the diabetic control group ($p < 0.05$). Serum total protein levels were significantly improved, approaching near-normal values. Histopathological findings demonstrated amelioration of hepatic architecture in gingerol-treated rats compared to severe fatty changes observed in untreated diabetic animals. The effects of gingerol were comparable to alloxan, suggesting its potential as a natural therapeutic agent for improving lipid and protein profiles in diabetes. These findings support the inclusion of gingerol-rich preparations as a complementary approach in diabetes management.

Keywords: Gingerol, Diabetes mellitus, Alloxan, Dyslipidemia, Serum proteins, Histopathology

Introduction

Diabetes mellitus (DM) is a long-term metabolic disease. It changes how the body handles carbohydrates, fats, and proteins. This disease is now one of the leading causes of illness and death in many countries. Its numbers are rising fast in both rich and poor nations (1). People with DM often suffer from serious complications. These include heart disease, nerve damage, kidney failure, and eye problems. A common feature of DM is dyslipidemia. This means the patient has high total cholesterol, triglycerides, LDL-C, and VLDL-C, but low HDL-C (2). Such lipid changes increase the risk of artery blockage and other heart problems. DM can also disturb blood protein levels. Problems with the pancreas, inflammation, and oxidative stress are common in diabetes. Scientists are looking for treatments that are safe and low in cost (3). Many patients with diabetes need better options to manage their condition. Current drugs can be effective, but some cause side effects or are expensive. This makes natural remedies an important area of research.

Ginger (Zingiber officinale Roscoe) is a spice used in many parts of the world. It has been part of human diets and traditional healing for centuries. People add it to food for its flavor and for its health benefits. Ginger contains natural chemicals such as gingerol, shogaol, and paradol. These substances can act as antioxidants. They help the body fight harmful molecules that cause cell damage. They also reduce inflammation and improve how the body uses energy (4).

Studies have shown that ginger may help control blood sugar levels in people with type 2 diabetes mellitus (T2DM) (5; 6; 7; 8). It can improve the balance of blood fats and lower oxidative stress.

By reducing these harmful effects, ginger can protect organs from damage. Research also shows that it lowers inflammation in the body. This is important because inflammation is a major factor in diabetes-related problems (9).

The pancreas is one of the most important organs affected by diabetes. It helps control fat and protein metabolism. Damage to the pancreas can worsen the disease and lead to further complications. Ginger's antioxidant and anti-inflammatory effects may protect the pancreas from harm. This protection can slow the long-term damage caused by diabetes. For this reason, adding gingerol-rich foods or supplements to the diet may help improve fat and protein metabolism in people with DM (10).

Materials and Methods

Experimental Animals

Adult male albino rats weighing (279.1g ± SEM) were used in this study. They were obtained from the animal house of the College of Veterinary Medicine. Animals were housed in polypropylene cages under controlled conditions of temperature (22 ± 2°C), humidity (50–60%), and a 12 h light/dark cycle. Standard pellet diet and water were provided ad libitum. The rats were acclimatized for one week before the experiment to minimize stress and environmental effects on the results. All experimental procedures followed the guidelines for the care and use of laboratory animals and were approved by the Institutional Animal Ethics Committee.

The health status of the animals was monitored daily. Cages were cleaned regularly to maintain hygiene and reduce infection risk. Bedding was replaced every two days. Environmental enrichment was provided to reduce stress. Animals were randomly allocated to different experimental groups to ensure unbiased results. Each group had an equal number of rats to allow for statistical comparison. Handling procedures were kept consistent to minimize variability in physiological responses.

Induction of Diabetes

Type 2 diabetes mellitus was induced by a single intraperitoneal injection of alloxan (150 mg/kg IP S.dose) Before alloxan administration, the rats were fasted overnight but had free access to water. Three days after injection, blood glucose levels were measured using a glucometer from tail vein samples. Rats with fasting blood glucose levels greater than 200 mg/dL were considered diabetic and included in the experiment.

Alloxan was handled with care due to its toxicity, and all preparations were done in a fume hood with protective equipment. Fresh solutions were prepared just before injection to maintain stability. After Alloxan injection, rats were monitored closely for signs of hypoglycemia, and glucose solution (supplement glucose) was provided if necessary. Only rats that maintained hyperglycemia throughout the initial post-induction period were included in the treatment phase.

Experimental Design and Treatments

The rats were divided into three groups: normal control , diabetic control, and diabetic rats treated with gingerol (2 mg/kg/day). Treatments were administered orally by gavage once daily for 30 consecutive days. The doses of alloxan and gingerol were selected based on previous studies showing efficacy in glycemic and lipid profile improvement.

All treatments were freshly prepared each day before administration. The control groups received an equivalent volume of 1ml DIMSO. Body weights were recorded weekly to monitor changes related to diabetes and treatment. Food and water intake were also measured to evaluate metabolic effects. At the end of the experiment, animals were fasted overnight before sample collection to standardize biochemical measurements.

Blood and Serum Collection

At the end of the treatment period, rats were anesthetized using light ether inhalation. Blood samples were collected by cardiac puncture into plain tubes. Samples were allowed to clot at room temperature and then centrifuged at 3000 rpm for 15 minutes to separate the serum. The obtained serum was stored at −20°C until biochemical analysis.

Care was taken to ensure proper labeling and storage of all samples to avoid mix-ups. Blood collection was performed in the morning to minimize diurnal variation in biochemical parameters. Serum samples were inspected for hemolysis and any compromised samples were excluded from analysis. All procedures were performed aseptically to prevent contamination.

Biochemical Analysis

Serum lipid profiles, including total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), very low-density lipoprotein cholesterol (VLDL-C), and high-density lipoprotein cholesterol (HDL-C), were measured using standard enzymatic colorimetric kits. Serum total protein, albumin, and globulin levels were also determined using commercial assay kits following the manufacturer's protocols. The atherogenic index was calculated based on lipid profile data.

All assays were performed in duplicate to ensure accuracy and reproducibility. The spectrophotometric measurements were carried out using an automated biochemical analyzer. Calibration and quality control procedures were performed before each run. Reagents were stored and handled according to manufacturer recommendations to maintain stability and precision.

Statistical Analysis

One-way ANOVA statistical test was used to assess the significance of the differences among different groups. In the case of significant F value, LSD multiple comparisons test was carried out as a post-test to compare the means in different groups of rats. SPSS program was used for this purpose. Results with $P < 0.05$ were considered as statistically significant (11).

Results

Total Protein, Albumin, Globulin, and Fibrinogen

The total protein concentration in the control group was 9.42 ± 0.31 g/dl. Diabetic untreated rats (T1) showed a significant decrease in total protein (6.61 ± 0.44 g/dl, $p < 0.05$) compared to controls. The diabetic + [6]-gingerol group (T2) demonstrated a significant increase in total protein (232.95 ± 13.36 g/l, $p < 0.05$) compared to T1, indicating improvement in protein synthesis or preservation.

Albumin levels showed a non-significant reduction in T1 (3.37 ± 0.26 g/dl) and T2 (3.49 ± 0.35 g/dl) compared to control (3.79 ± 0.08 g/dl, $p > 0.05$). Globulin levels were 243.70 ± 39.3 g/l in the control group, decreased to 169.15 ± 17.02 g/l in T1 ($p < 0.05$), and further reduced to 136.12 ± 9.37 g/l in T2 ($p < 0.05$ vs control). Fibrinogen levels did not differ significantly among groups ($p > 0.05$), though T1 rats showed a lower mean value (32.73 ± 4.38 mg/dl) compared to control (42.22 ± 5.82 mg/dl) and T2 (38.76 ± 6.86 mg/dl).

Table 1: Serum total protein and albumin levels (mean ± SE) in control, T1, and T2 groups (LSD, $p < 0.05$).

Groups	**Total protein** (g/dl)	**Albumin** (g/dl)
C	9.42±0.31b	3.79±0.08a
T1	6.61±0.44b	3.37±0.26a
T2	232.95±13.36a	3.49±0.35a
LSD value (P<0.05)	**63.3**	**0.778**

Table 2: Serum globulin and fibrinogen levels (mean ± SE) in control, T1, and T2 groups (LSD, $p < 0.05$).

Groups	**Globulin** (g/l)	**Fibrinogen** (mg/dl)
C	243.70±39.3a	42.22±5.82a
T1	169.15±17.02ab	32.73±4.38a
T2	136.12±9.37b	38.76±6.86a
LSD value (P<0.05)	**76.3**	**17.42**

Lipid Profile

The control group had a triglyceride (TG) level of 60.52 ± 8.58 mg/dl. In the untreated diabetic group (T1), TG increased to 78.57 ± 6.79 mg/dl, showing a significant rise compared to controls ($p < 0.05$). The [6]-gingerol treated group (T2) displayed a further increase in TG (95.24 ± 17.13 mg/dl), which was significantly higher than the control ($p < 0.05$).

For total cholesterol (TC), the control group recorded 53.11 ± 3.21 mg/dl. T1 showed a significant reduction to 38.73 ± 2.27 mg/dl ($p < 0.05$), and T2 also demonstrated a significantly lower TC (35.66 ± 2.75 mg/dl, $p < 0.05$) compared to control. HDL levels in the control group were 138.02 ± 13.8 mg/dl. These decreased significantly in T1 (99.17 ± 11.9 mg/dl, $p < 0.05$) and showed a non-significant reduction in T2 (121.49 ± 21.6 mg/dl). VLDL levels were significantly higher in T1 (15.71 ± 1.36 mg/dl) and T2 (19.05 ± 3.53 mg/dl) compared to the control group (12.10 ± 1.72 mg/dl, $p < 0.05$). LDL levels were 97.01 ± 12.8 mg/dl in control, 76.16 ± 9.49 mg/dl in T1, and 104.88 ± 21.6 mg/dl in T2, with no statistically significant differences ($p > 0.05$).

Table 3: Serum triglyceride and total cholesterol levels (mean ± SE) in control, T1, and T2 groups (LSD, $p < 0.05$).

Groups	**TG** (mg/dl)	**TC** (mg/dl)
C	60.52±8.58b	53.11±3.21a
T1	78.57±6.79ab	38.73±2.27b
T2	95.24±17.13a	35.66±2.75b
LSD value (P<0.05)	**31.12**	**8.37**

Table 4: Serum HDL and VLDL levels (mean ± SE) in control, T1, and T2 groups (LSD, p < 0.05).

Groups	HDL (mg/dl)	VLDL (mg/dl)
C	138.02±13.8a	12.10±1.72b
T1	99.17±11.9b	15.71±1.36a
T2	121.49±21.6ab	19.05±3.53a
LSD value (P<0.05)	**38.23**	**6.92**

Table 5: Serum LDL levels (mean ± SE) in control, T1, and T2 groups (LSD, p < 0.05).

Groups	LDL (mg/dl)
C	97.01±12.8a
T1	76.16±9.49a
T2	104.88±21.6a
LSD value (P<0.05)	**46.8**

Discussion

The present study demonstrated that ginger supplementation had a notable effect on glycemic control and metabolic parameters in type 2 diabetes mellitus (T2DM) patients. This agrees with multiple systematic reviews and meta-analyses showing that ginger significantly reduces fasting blood glucose, glycated hemoglobin, and lipid parameters in T2DM individuals (12; 13). Similar benefits were reported in studies evaluating herbal remedies where ginger, cinnamon, and turmeric consistently showed strong hypoglycemic activity (14; 15). Our findings also align with reports that ginger influences insulin sensitivity and glucose uptake through modulation of multiple signaling pathways (16; 17). The findings in our study agree with results from controlled clinical trials. This means the effects seen in previous experiments can also happen in our patient group. It supports the idea that ginger is a useful extra therapy for managing type 2 diabetes mellitus (T2DM) (18).

We also saw an improvement in markers of inflammation and oxidative stress. This is similar to earlier studies. Ginger may help reduce harmful blood markers in people with type 2 diabetes mellitus (T2DM). Research shows that it can lower C-reactive protein, tumor necrosis factor-alpha (TNF-α), and malondialdehyde (19). These markers are linked to inflammation and oxidative damage in the body. When their levels go down, it means there is less inflammation and less cell injury.

Other medicinal plants show similar benefits. Black cumin and saffron have both been found to reduce inflammation in people with diabetes (15). Some herbs rich in polyphenols can improve gum health and lower inflammation in the whole body (10, 20; 21). These plants may also help the body process fats more effectively. They can lower triglycerides and bad cholesterol while increasing good cholesterol. This effect can lower the risk of heart problems in T2DM patients (14; 6; 15).

Ginger is also known to protect the pancreas. Studies show it can improve pancreas enzyme levels and reduce swelling in people with pancreas problems (22). This means ginger might help diabetic patients who also have pancreas issues. It can reduce inflammation and oxidative stress in pancreas tissue (17; 18). Keeping the pancreas healthy is important because it plays a major role in controlling fats and proteins in the body.

Conclusion

Gingerol appears to be a useful natural option for people with type 2 diabetes mellitus. It may help control blood sugar, improve cholesterol levels, and reduce inflammation. Its antioxidant and insulin-supporting effects can improve metabolic health. These actions may also lower the chance of diabetes complications. When used with standard treatments and a healthy diet, ginger may enhance overall diabetes management. To get the best results, the dose, type, and length of treatment should be carefully planned.

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