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METABOLIC AND PANCREATIC HISTOPATHOLOGICAL RESPONSES TO DIETARY BAOBAB (*ADANSONIA DIGITATA L.)* POWDER AT GRADED INCLUSION LEVELS IN STREPTOZOTOCIN-INDUCED DIABETIC RATS

Manal Almatrafi

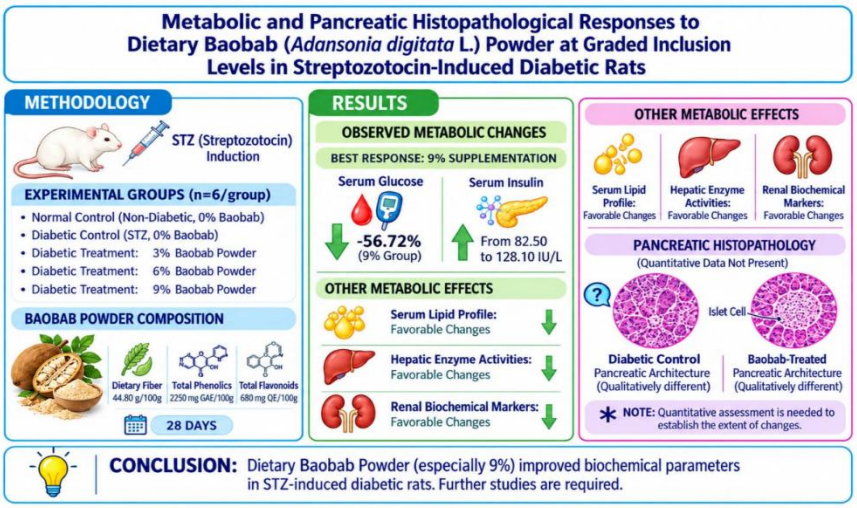
Department of Food Science and Nutrition, College of Sciences, Taif University, P.O. Box 11099, Taif 21944, Saudi Arabia, msmatrafi@tu.edu.sa

ABSTRACT

Background: Baobab (*Adansonia digitata* L.) fruit is a valuable source of dietary fiber and biologically active compounds that could contribute to the regulation of metabolic functions. **Objective:** The present investigation aimed to examine the influence of baobab fruit powder incorporation into the diet on selected metabolic indices and pancreatic tissue morphology in rats with streptozotocin (STZ)-induced diabetes. **Methods:** A total of 30 male Sprague–Dawley rats were randomly distributed into five experimental groups, comprising six animals each. The groups included a healthy control, an untreated diabetic control, and three diabetic groups receiving basal diets containing 3%, 6%, or 9% baobab fruit powder over a 28-day experimental period. The chemical composition of the powder was characterized by determining its proximate constituents, total phenolic compounds, and total flavonoids. Throughout the experiment, growth-related parameters, serum glucose and insulin, lipid profile, liver enzyme activities, kidney function indicators, and pancreatic histological features were assessed. **Results:** The analysis demonstrated that baobab fruit powder provided substantial dietary fiber (44.80 g/100 g), together with total phenolic compounds of 2,250 mg gallic acid equivalents/100 g and total flavonoids of 680 mg quercetin equivalents/100 g. Dietary administration of baobab powder resulted in lower circulating glucose concentrations and increased serum insulin levels relative to the untreated diabetic group. The most pronounced reduction in blood glucose was recorded in rats receiving 9% baobab powder, reaching 56.72%. In addition, serum insulin concentration increased from 82.50 to 128.10 IU/L. Improvements were additionally noted in lipid profile measurements, hepatic enzyme activities, and biochemical indicators of renal function. Histological observations of pancreatic tissues indicated variations in tissue structure across the experimental groups, although further quantitative investigations are necessary to characterize these alterations accurately. **Conclusion:** Incorporating baobab fruit powder into the diets of STZ-diabetic rats, especially at a concentration of 9%, was associated with beneficial alterations in several biochemical and metabolic indicators. Nevertheless, additional investigations are necessary to clarify the biological mechanisms involved, establish its long-term safety, and evaluate whether these experimental findings can be translated into potential human health benefits.

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KEYWORDS: *Adansonia digitata* L.; baobab fruit powder; experimental diabetes; streptozotocin; blood glucose regulation; lipid metabolism; kidney function; pancreatic tissue morphology.



Graphical Abstract: "Metabolic and Pancreatic Histopathological Responses to Dietary Baobab (Adansonia digitata L.) Powder in STZ-Induced Diabetic Rats"

1- INTRODUCTION

Diabetes mellitus is a multifactorial metabolic disease characterized by chronic hyperglycemia arising from insufficient insulin secretion, impaired insulin sensitivity, or both. Its increasing global prevalence represents a major public health concern, with the World Health Organization reporting a rise in the number of affected individuals from approximately 200 million in 1990 to 830 million in 2022 (WHO, 2024). Persistent hyperglycemia is associated with progressive vascular damage and complications involving the cardiovascular system, kidneys, and eyes (Aljehani et al., 2026). In addition to disturbed glucose homeostasis, diabetes is frequently accompanied by dyslipidemia, oxidative stress, and impaired organ function. Excessive production of reactive oxygen species (ROS), together with weakened antioxidant defenses, may aggravate cellular damage, interfere with insulin signaling, and contribute to pancreatic, hepatic, and renal dysfunction (Weinberg Sibony et al., 2024). Streptozotocin (STZ)-induced diabetes is a commonly employed experimental model for investigating diabetic metabolic abnormalities and pancreatic injury. STZ produces diabetes primarily through pancreatic β-cell damage, resulting in reduced insulin availability and elevated blood glucose concentrations. However, the severity of these alterations is influenced by animal strain, dosage, administration protocol, and individual susceptibility (Ghasemi & Jeddi, 2023). Accordingly, combining biochemical measurements with histopathological examination provides a more comprehensive evaluation of diabetes-related metabolic and structural changes. Growing interest in plant-based nutritional interventions has encouraged investigations into dietary ingredients containing fiber and biologically active phytochemicals. Nevertheless, their physiological effects depend on plant species, botanical components, processing methods, and administered concentrations (Dogara & Al-Zahrani, 2024; Silva et al., 2023). Among these resources, African baobab (*Adansonia digitata* L.), a member of the Malvaceae family, has attracted attention because of its nutritional composition and phytochemical diversity. Its fruit contains dietary fiber, vitamin C, minerals, phenolic compounds, flavonoids, tannins, and proanthocyanidins (Ahmed et al., 2024; Mahzari et al., 2026; Abduljawad et al., 2026). Previous investigations have highlighted the potential biological relevance of baobab constituents. Adam et al. (2026) reviewed evidence concerning the antioxidant properties and possible glycemic regulatory effects of *A. digitata*, particularly in relation to its fiber and polyphenolic content. Similarly, Alzahrani et al. (2025) reported antioxidant activity associated with phytochemicals identified in baobab fruit pulp, whereas Mashnafi et al. (2025) discussed the phytochemical composition and pharmacological properties of different baobab plant parts. However, antioxidant activity demonstrated in laboratory assays does not necessarily establish equivalent physiological benefits in living organisms. Moreover, findings obtained from extracts, leaves, bark, or isolated compounds cannot be directly extrapolated to whole-fruit dietary powder (Abd Elmeged et al., 2024; Wasihun et al., 2023). Despite these findings, evidence regarding the effects of graded dietary baobab fruit powder supplementation on glucose regulation, lipid metabolism, hepatic and renal function, and pancreatic morphology in experimental diabetes remains limited. Therefore, the present study investigated the effects of incorporating 3%, 6%, and 9% *A. digitata* fruit powder into the diets of STZ-induced diabetic male Sprague–Dawley rats over 28 days. Biochemical parameters, including blood glucose, lipid profile, and liver and kidney function markers, together with pancreatic histopathological alterations, were evaluated to characterize the responses associated with different dietary inclusion levels and provide further experimental evidence regarding the nutritional potential of baobab fruit powder in diabetes management.

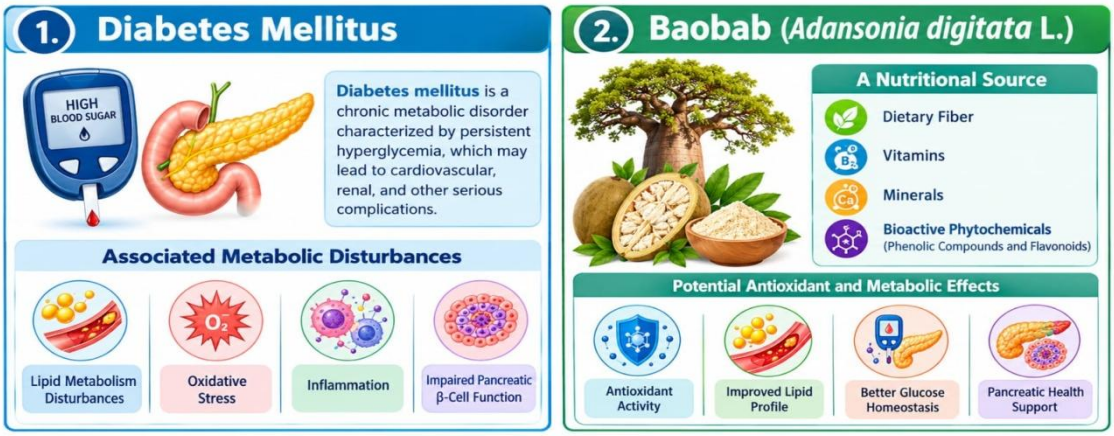


Figure 1. Nutritional and Protective Role of Baobab (*Adansonia digitata* L.) against Diabetes Mellitus-Induced Complications

2. MATERIALS AND METHODS: -

2.1. Plant Material and Preparation of Baobab Powder

2.1. Preparation of Baobab Fruit Powder

Baobab (*Adansonia digitata* L.) fruit was used as the source material for dietary supplementation. The collected material was carefully examined, and foreign particles and deteriorated portions were discarded. The acceptable

material was subsequently dried under appropriate conditions and milled to obtain a homogeneous fine powder. The resulting powder was transferred into airtight, clean containers and kept under suitable storage conditions until its incorporation into the experimental diets. Three dietary concentrations (3%, 6%, and 9%) were selected to investigate the effects of different baobab supplementation levels on metabolic indices and pancreatic histological characteristics.

2.2. Chemicals and Biochemical Reagents

Streptozotocin (STZ) was employed to establish experimental diabetes in the designated animals. Biochemical determinations were carried out using suitable analytical reagents and commercial diagnostic kits, as applicable, following the corresponding laboratory protocols and manufacturers' recommendations. The investigated variables included blood glucose, serum lipid indices, hepatic and renal biochemical markers, and oxidative stress-associated parameters.

2.3. Experimental Animals and Housing Conditions

The experiment involved 30 male albino Sprague–Dawley rats weighing 150 ± 10 g at the beginning of the study. Animals were maintained under controlled laboratory conditions with alternating 12-h light and 12-h dark periods. Drinking water and the respective experimental diets were available throughout the study. General health status and clinical manifestations were monitored during the experimental period. Animal-related procedures and reporting were conducted with reference to the ARRIVE 2.0 guidelines (Percie du Sert et al., 2020).

2.4. Induction of Experimental Diabetes

Diabetes was experimentally established in the designated groups through STZ administration according to the protocol adopted in this investigation. Following treatment, blood glucose was measured to verify the induction of hyperglycemia. Animals exhibiting fasting glucose concentrations above 250 mg/dL were considered diabetic and assigned to the corresponding experimental groups. The healthy control animals received neither STZ nor baobab supplementation and remained on the basal diet. Diabetic animals underwent STZ treatment before receiving their respective dietary interventions. The use of STZ as an experimental diabetogenic agent is well established in laboratory animal research (Akbarzadeh et al., 2007).

2.5. Formulation of the Basal Diet

The basal diet was formulated using the following ingredient proportions: 10% protein source, 10% corn oil, 0.2% choline chloride, 5% cellulose, 1% vitamin mixture, 4% mineral mixture, and 69.8% corn starch. The combined ingredients accounted for 100% of the dietary formulation. Although standardized rodent dietary formulations have been described by Reeves et al. (1993), the present formulation was based on the actual proportions specified in the experimental protocol and was not considered an AIN-93 diet.

2.6. Experimental Design

The feeding trial extended over 28 days and comprised five experimental groups, each containing six animals (n = 6):

- **Group I (NC):** Healthy rats receiving the basal diet.
- **Group II (DC):** STZ-diabetic rats maintained on the basal diet.
- **Group III (DC + BP3%):** Diabetic rats receiving the basal diet supplemented with 3% baobab powder.
- **Group IV (DC + BP6%):** Diabetic rats receiving the basal diet supplemented with 6% baobab powder.
- **Group V (DC + BP9%):** Diabetic rats receiving the basal diet supplemented with 9% baobab powder.

The control groups served as reference groups for evaluating diabetes-associated alterations and the potential effects of dietary supplementation. The three baobab concentrations were included to examine the responses associated with increasing dietary inclusion levels. Experimental reporting followed the relevant ARRIVE 2.0 recommendations (Percie du Sert et al., 2020).

2.7. Preparation of Experimental Diets

Dietary formulations were obtained by incorporating the appropriate quantity of baobab powder into the basal diet to achieve final inclusion levels of 3%, 6%, and 9%. Each formulation was thoroughly mixed to ensure an even distribution of the powdered material. The resulting diets were supplied to the corresponding animal groups throughout the 28-day feeding period.

2.8. Assessment of Body Weight and Food Consumption

Body weight was recorded individually at predetermined intervals, while food consumption was monitored throughout the experiment. The following indices were calculated:

Body weight gain (BWG):

BWG (g) = Final body weight (g) − Initial body weight (g)

Body weight gain percentage (BWG%):

BWG (%) = [BWG (g) / Initial body weight (g)] × 100

Feed efficiency ratio (FER):

FER = Body weight gain (g) / Total food intake (g)

Initial and final body weights were designated IBW and FBW, respectively.

2.9. Blood Sampling and Serum Separation

At the completion of the experimental feeding period, blood specimens were obtained for biochemical investigations. Following coagulation, the samples were centrifuged to obtain serum. The separated serum was transferred into properly identified tubes and preserved under appropriate conditions until subsequent

biochemical determinations. Particular care was taken during sample handling to reduce hemolysis and minimize pre-analytical errors.

2.10. Biochemical Investigations

Serum biochemical analyses covered glycemic status, lipid metabolism, hepatic and renal function, and selected oxidative stress-related parameters. Individual measurements were performed using the corresponding laboratory analytical procedures or commercial assay kits.

2.10.1. Blood Glucose Concentration

Glucose concentration was quantified using an enzymatic colorimetric procedure employing glucose oxidase and a chromogenic oxygen acceptor. The analytical principle followed the method reported by Trinder (1969). Results were expressed as mg/dL.

2.10.2. Serum Lipid Profile

Serum lipid status was evaluated through the determination of total cholesterol (TC), triglycerides (TG), and high-density lipoprotein cholesterol (HDL-C). TC was measured using the enzymatic procedure described by Allain et al. (1974), whereas TG concentrations were determined according to the enzymatic colorimetric method of Fossati and Prencipe (1982). HDL-C was assessed using the laboratory separation procedure followed by cholesterol determination, with the analytical approach described by Lopes-Virella et al. (1977) serving as a methodological reference. Low-density lipoprotein cholesterol (LDL-C) was calculated using the Friedewald equation when its application criteria were met (Friedewald et al., 1972). Very-low-density lipoprotein cholesterol (VLDL-C) was calculated only when specified in the experimental analytical protocol.

2.10.3. Hepatic Function Parameters

Hepatic biochemical status was assessed by measuring serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities. Their determination was based on the colorimetric procedure described by Reitman and Frankel (1957), where applicable. Additional measurements included serum total protein and albumin when specified among the investigated variables. The biuret-based protein assay was described by Gornall et al. (1949), while the bromocresol green method for albumin determination was reported by Doumas et al. (1971).

2.10.4. Renal Function Parameters

Biochemical indicators associated with renal function included serum urea, creatinine, and uric acid, depending on the parameters actually measured. Appropriate laboratory assays or commercial diagnostic kits were used for their determination. Relevant methodological references included the urea assay described by Fawcett and Scott (1960) and the creatinine determination procedure reported by Bartels et al. (1972).

2.10.5. Oxidative Stress-Related Parameters

The oxidative stress profile was investigated through selected indicators of lipid peroxidation and enzymatic antioxidant defense, namely malondialdehyde (MDA), superoxide dismutase (SOD), and glutathione peroxidase (GPx), where included in the experimental analyses. MDA was considered an indicator of lipid peroxidation. When the thiobarbituric acid-reactive substances (TBARS) assay was employed, the procedure followed the method of Ohkawa et al. (1979). SOD activity was evaluated as an indicator of enzymatic antioxidant capacity. When based on inhibition of pyrogallol autoxidation, the determination followed the principle described by Marklund and Marklund (1974). GPx activity was assessed as an additional measure of antioxidant defense. The classical analytical procedure described by Paglia and Valentine (1967) was used as a methodological reference for glutathione peroxidase determination. These measurements were considered collectively to provide information about lipid peroxidation and antioxidant enzyme activity. Interpretation of the results took into account the actual analytical procedures, biological samples, assay conditions, and units employed.

2.11. Pancreatic Histopathological Examination

Following completion of the experimental period, pancreatic specimens were obtained after euthanasia in accordance with the approved animal protocol. The pancreas was carefully dissected and prepared for microscopic histopathological assessment. Tissue examination focused on identifying morphological alterations potentially associated with STZ-induced diabetes and dietary baobab supplementation. Histological observations were considered in conjunction with biochemical findings to provide complementary information regarding pancreatic structure and metabolic alterations.

2.12. Statistical Analysis

Experimental results were presented as mean ± standard deviation (SD), with six animals per group ($n = 6$). Differences among the five experimental groups were evaluated using one-way analysis of variance (ANOVA). Duncan's multiple range procedure was subsequently applied for pairwise comparisons of group means. Statistical differences were considered significant at $P < 0.05$, following the statistical principles described by Snedecor and Cochran (1989).

2.13. Ethical Approval

The animal experimentation protocol received approval from the Research Ethics Committee of Al-Baha University, Saudi Arabia (Approval No. 47119677; 17 May 2026). All experimental procedures involving animals were performed in accordance with the approved ethical protocol and applicable principles governing the responsible use of laboratory animals. Reporting of the experimental procedures was guided by the ARRIVE 2.0 recommendations (Percie du Sert et al., 2020).

3.RESULTS AND DISCUSSION

3.1.Chemical Results

Nutritional composition, total phenolic content, and total flavonoid content of baobab (*Adansonia digitata* L.) fruit powder.

The compositional analysis of baobab (*Adansonia digitata* L.) fruit powder revealed considerable variation in the proportions of its major constituents. Dietary fiber was the predominant component, with a concentration of 44.80 g/100 g, representing the largest proportion of the reported compositional parameters. Carbohydrates constituted the second-largest component, with a content of 38.20 g/100 g. Together, dietary fiber and carbohydrates accounted for 83.00 g/100 g of the powder, indicating that these components collectively represented the majority of its reported composition. The moisture content was 8.50 g/100 g, reflecting the proportion of water present in the sample. Total ash accounted for 5.30 g/100 g and represented the inorganic residue remaining after the complete combustion of the organic material. Crude protein and crude fat were present at comparatively lower concentrations of 2.60 and 0.60 g/100 g, respectively. Among the measured compositional constituents, crude fat was the least abundant, followed by crude protein. These results demonstrate that dietary fiber and carbohydrates were the principal components of the baobab fruit powder, whereas ash, protein, and fat contributed smaller proportions to its overall composition. In addition to its compositional characteristics, the baobab fruit powder contained measurable amounts of phenolic and flavonoid compounds. The total phenolic content (TPC) was 2,250.00 mg gallic acid equivalents (GAE)/100 g, whereas the total flavonoid content (TFC) reached 680.00 mg quercetin equivalents (QE)/100 g.

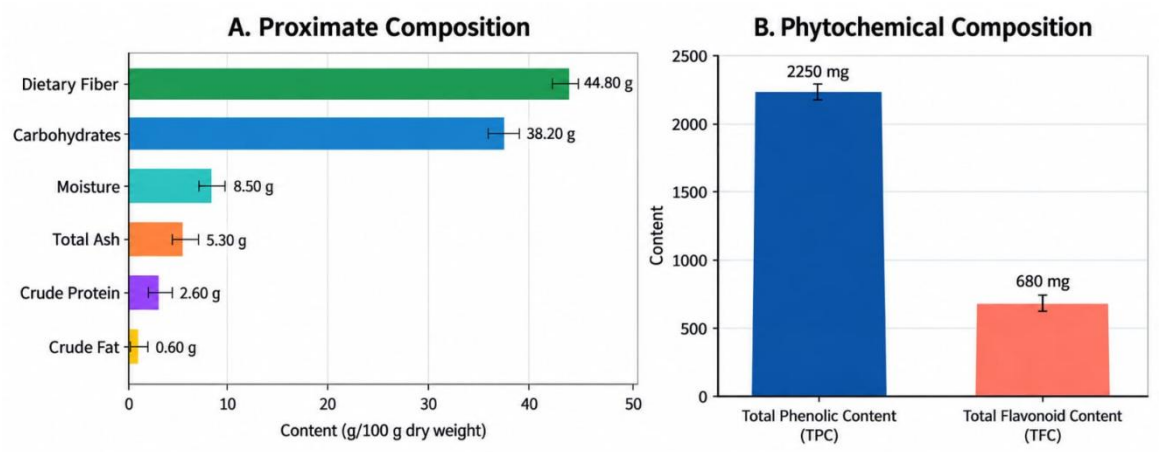


Figure 2. Nutritional composition, total phenolic content (TPC), and total flavonoid content (TFC) of baobab (*Adansonia digitata* L.) fruit powder. Nutritional components are expressed as g/100 g of sample, whereas TPC and TFC are expressed as mg gallic acid equivalents (GAE)/100 g dry weight (DW) and mg quercetin equivalents (QE)/100 g DW, respectively. Carbohydrate content was calculated by difference. Abbreviations: GAE, gallic acid equivalents; QE, quercetin equivalents; DW, dry weight.

3.2.Biochemial Results

Effects of dietary supplementation with baobab *(Adansonia digitata L.)* fruit powder at different inclusion levels on Body Weight, Body Weight Gain, Food Intake, and Feed Efficiency Ratio.

At the beginning of the study, the experimental groups exhibited relatively uniform body weights, with mean values ranging from 204.15 to 206.25 g, indicating the absence of significant baseline differences. Following the 28-day feeding trial, the diabetic control rats attained a final body weight of 247.90 g, which was slightly lower than that of the normal control animals (248.50 g). Greater final body weights were recorded following dietary incorporation of baobab fruit powder, with values of 261.20, 263.80, and 272.40 g in the 3%, 6%, and 9% supplementation groups, respectively. Although the two lower supplementation levels produced comparable intermediate responses, the highest dietary concentration resulted in the greatest final body weight, with a significant difference compared with the remaining groups ($p < 0.05$). The changes in body weight gain (BWG) were consistent with the final body weight findings. The percentage of weight gain was 20.75% in diabetic control rats and 21.72% in normal control animals. In comparison, dietary baobab supplementation increased BWG to 26.73%, 28.18%, and 32.07% at inclusion levels of 3%, 6%, and 9%, respectively. No significant difference was detected between the 3% and 6% groups, whereas the 9% group demonstrated the highest percentage of weight gain and was significantly different from the other experimental groups ($p < 0.05$). These observations suggest that increasing the proportion of baobab powder in the diet was associated with progressively greater body weight gain. Regarding daily food consumption, the lowest recorded value was observed in the diabetic control group (20.85 g/rat/day), while the highest was found in animals receiving 9% baobab powder (22.60 g/rat/day). Food intake values in the normal control, 3%, and 6% supplementation groups were 21.10, 21.90, and 22.15 g/rat/day, respectively. Although these measurements showed a gradual numerical increase with baobab supplementation, the absence of reported variability estimates and statistical testing prevents confirmation of significant differences among the groups. Feed efficiency ratio (FER) also increased in

association with dietary baobab inclusion. The normal and diabetic control groups exhibited FER values of 0.052 and 0.050, respectively. Supplementation at 3% and 6% resulted in higher values of 0.061 and 0.064, respectively, while the maximum value (0.071) was observed in the 9% group. Statistical comparisons indicated no significant difference between the two intermediate supplementation groups. However, the 9% group demonstrated significantly greater feed efficiency than all other experimental groups ($p < 0.05$). Overall, the findings indicate that dietary supplementation with baobab fruit powder, particularly at the 9% level, was associated with improved body weight development and feed utilization in STZ-induced diabetic rats.

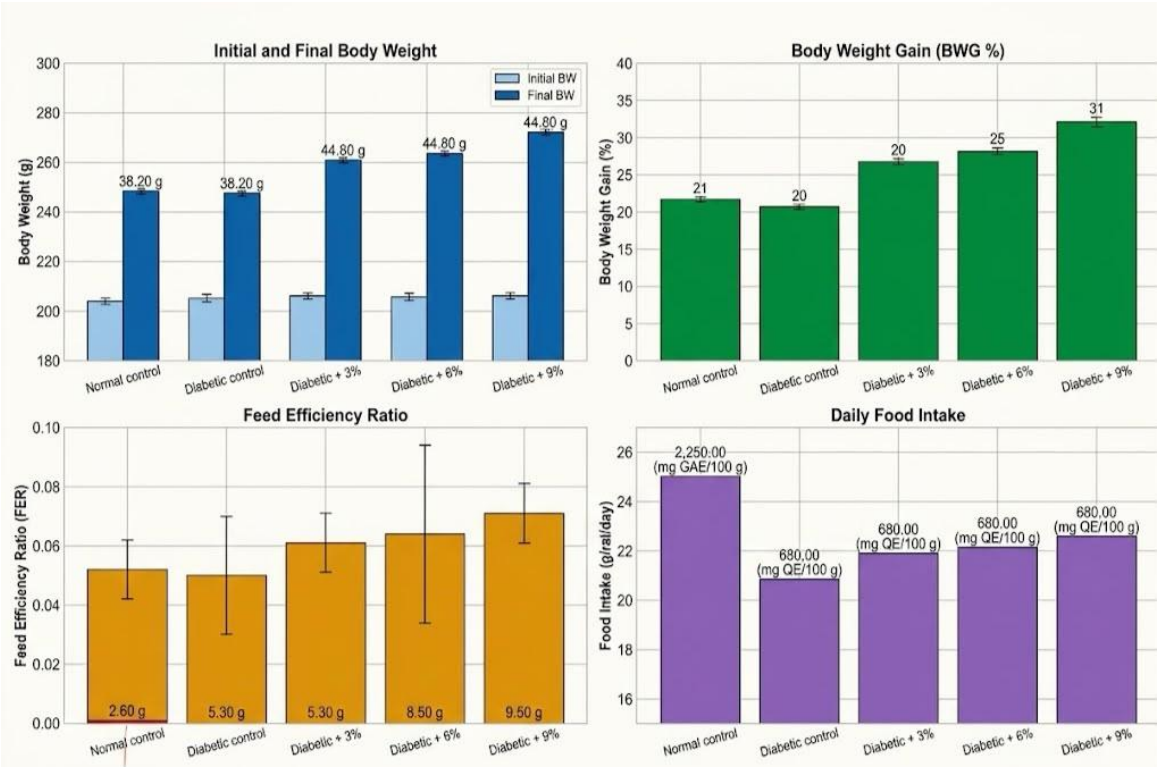


Figure 3. Effects of baobab (*Adansonia digitata* L.) fruit powder supplementation (3%, 6%, and 9%) on growth performance in streptozotocin (STZ)-induced diabetic rats. (A) Initial and final body weight; (B) body weight gain (BWG); (C) feed efficiency ratio (FER); and (D) daily food intake (FI). Data are expressed as mean ± SD, where available. Different superscript letters indicate significant differences ($p < 0.05$). Food intake is presented without variability data

3.3.Biochemial Results

Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at different inclusion levels on serum lipid profiles in streptozotocin-induced diabetic rats.

The biochemical assessment of serum lipids revealed considerable differences between healthy and diabetic control rats. Compared with the normal control group, diabetic animals exhibited a less favorable lipid profile, characterized by elevated total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and very-low-density lipoprotein cholesterol (VLDL-C). The corresponding concentrations in diabetic controls were 218.40, 182.10, 160.18, and 36.42 mg/dL, respectively, whereas the normal control animals showed substantially lower values of 122.50, 82.40, 44.72, and 16.48 mg/dL, respectively. Conversely, HDL-C concentration was markedly reduced in diabetic rats, declining from 61.30 mg/dL in healthy controls to 21.80 mg/dL. Dietary incorporation of baobab fruit powder was accompanied by favorable changes in serum lipid concentrations relative to the untreated diabetic group. At the 3% supplementation level, TC, TG, LDL-C, and VLDL-C concentrations declined to 172.30, 145.20, 103.76, and 29.04 mg/dL, respectively. Meanwhile, HDL-C increased to 39.50 mg/dL. A comparable response was observed in rats receiving 6% baobab powder, in which the respective concentrations of TC, TG, LDL-C, and VLDL-C were 174.10, 158.80, 100.54, and 31.76 mg/dL, while HDL-C reached 41.80 mg/dL. Based on the statistical superscripts, no significant differences were identified between the 3% and 6% supplementation groups for the investigated lipid variables. More pronounced alterations were evident in animals fed the diet containing 9% baobab powder. In this group, serum TC, TG, LDL-C, and VLDL-C concentrations decreased to 147.80, 116.50, 72.10, and 23.30 mg/dL, respectively. In contrast, HDL-C increased to 52.40 mg/dL. Statistical comparisons indicated significant differences between this group and the two lower supplementation groups. Nevertheless, the lipid profile did not completely return to the levels recorded in the normal control animals. Taken together, these results demonstrate that baobab fruit powder supplementation was associated with an improved serum lipid profile in STZ-induced diabetic rats, as reflected by reductions in atherogenic lipid fractions and an increase in HDL-C. Among the tested dietary

concentrations, the 9% inclusion level produced the most pronounced changes. These observations suggest that baobab fruit powder may have potential as a dietary component influencing lipid metabolism under experimental diabetic conditions. However, further investigations are necessary to clarify the physiological mechanisms responsible for these changes.

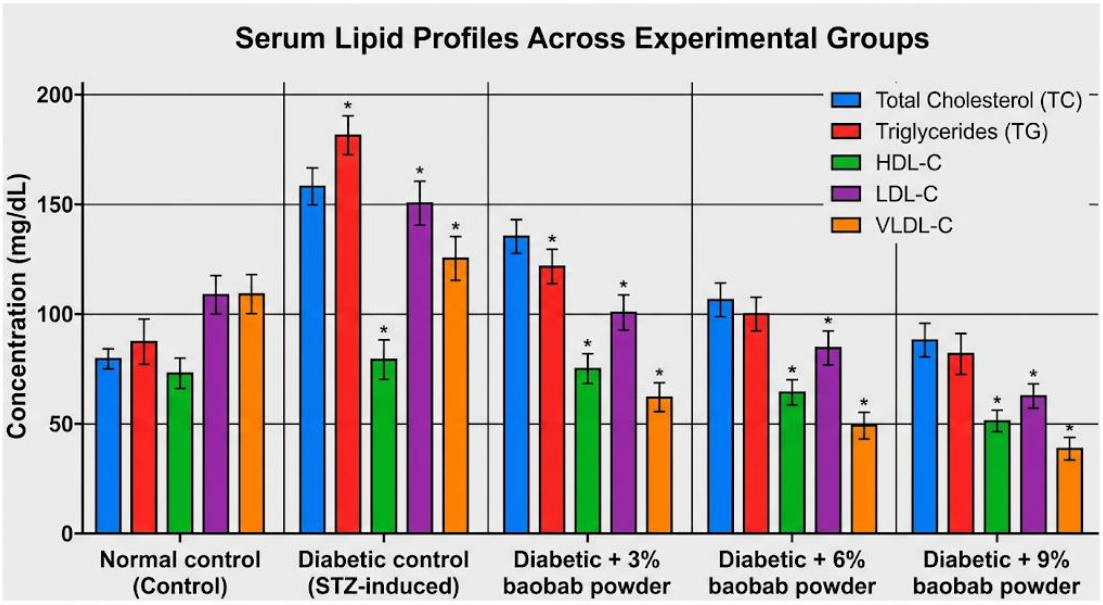


Figure 5. Serum glucose and insulin concentrations in streptozotocin (STZ)-induced diabetic rats receiving dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder. Results are expressed as mean ± standard deviation (SD). Different letters indicate statistically significant differences among experimental groups ($p < 0.05$). Abbreviations: NC, normal control; DC, diabetic control; GLU, serum glucose; INS, serum insulin; STZ, streptozotocin.

Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at different inclusion levels on serum glucose and insulin concentrations in streptozotocin (STZ)-induced diabetic rats.

A clear distinction in serum glucose and insulin levels was observed between the normal and diabetic control groups. Rats in the diabetic control group showed a pronounced increase in serum glucose, reaching 260.80 mg/dL, whereas the corresponding value in the normal control group was 94.20 mg/dL. Conversely, serum insulin was markedly reduced in diabetic control rats (82.50 IU/L) compared with normal controls (142.80 IU/L), reflecting the disruption of glucose–insulin homeostasis induced by the experimental diabetic condition. Baobab fruit powder supplementation was associated with a reduction in serum glucose levels across all treated groups compared with the diabetic control. In rats receiving 3% and 6% baobab powder, serum glucose decreased to 136.40 and 140.10 mg/dL, representing reductions of 48.49% and 47.09%, respectively, relative to the diabetic control. The identical statistical superscript assigned to these two groups indicates that their glucose concentrations were not significantly different at the specified significance level ($p < 0.05$). A more pronounced response was recorded in the 9% baobab group, where serum glucose reached 114.60 mg/dL, corresponding to a 56.72% decrease relative to the diabetic control. This concentration was significantly lower than those observed in the 3% and 6% groups, although it remained above the value recorded in normal controls. Serum insulin concentrations showed a progressive increase with increasing dietary baobab powder inclusion. Specifically, insulin levels increased from 82.50 IU/L in the diabetic control group to 96.30, 108.40, and 128.10 IU/L in the 3%, 6%, and 9% baobab groups, respectively. Based on the reported statistical superscripts, significant differences were detected among these supplemented groups ($p < 0.05$). Thus, the highest insulin concentration among the baobab-treated diabetic groups was observed at the 9% inclusion level, although it did not reach the normal control value of 142.80 IU/L. Overall, baobab fruit powder supplementation was associated with improved serum glucose and insulin profiles in STZ-induced diabetic rats. The 9% inclusion level produced the most marked response, yielding the greatest reduction in serum glucose and the largest increase in serum insulin among the tested supplementation levels. However, neither parameter was fully restored to the corresponding level in normal control rats. These findings indicate a potential beneficial effect of dietary baobab powder on glucose insulin regulation under the conditions of this experiment. Further studies are needed to clarify the mechanisms responsible for these responses and to assess their implications for broader metabolic regulation.

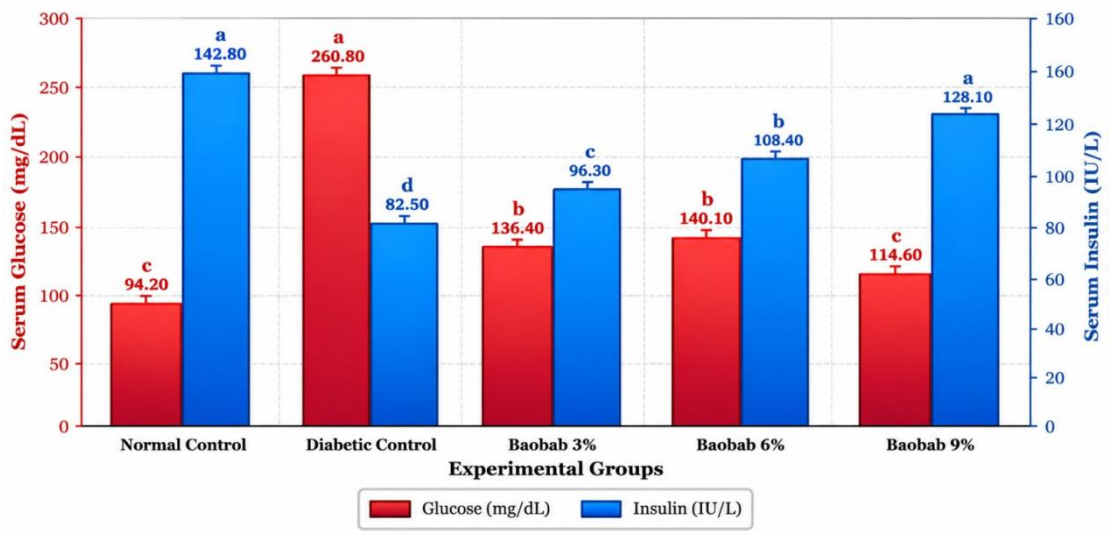


Figure 6. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at different inclusion levels on serum lipid parameters in streptozotocin (STZ)-induced diabetic rats: (A) total cholesterol (TC), (B) triglycerides (TG), (C) total lipids (TL), (D) high-density lipoprotein cholesterol (HDL-C), (E) low-density lipoprotein cholesterol (LDL-C), and (F) very-low-density lipoprotein cholesterol (VLDL-C). Data are presented as mean ± standard deviation (SD) (n = 6). Within each panel, bars bearing different superscript letters indicate statistically significant differences, as determined by Duncan's multiple range test ($P < 0.05$). Abbreviations: NC, normal control; DC, diabetic control; STZ, streptozotocin.

Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at different inclusion levels on serum lipid parameters in streptozotocin-induced diabetic rats.

The serum lipid profile differed considerably between the normal and diabetic control groups. Compared with normal rats, diabetic control animals exhibited substantially elevated levels of total cholesterol (TC), triglycerides (TG), total lipids (TL), low-density lipoprotein cholesterol (LDL-C), and very-low-density lipoprotein cholesterol (VLDL-C). TC increased from 68.45 mg/dL in normal controls to 239.70 mg/dL in diabetic rats, while TG rose from 89.15 to 274.35 mg/dL. Likewise, TL increased from 312.50 to 618.40 mg/dL. The concentrations of LDL-C and VLDL-C also showed marked increases, rising from 20.85 and 17.83 mg/dL in the normal group to 86.70 and 54.87 mg/dL in the diabetic control group, respectively. In contrast, HDL-C was considerably lower in diabetic rats (11.80 mg/dL) than in normal controls (42.15 mg/dL). Incorporating baobab fruit powder into the diet was associated with a reduction in the elevated serum lipid concentrations observed in diabetic rats. At the 3% supplementation level, TC, TG, and TL decreased to 156.20, 185.40, and 524.10 mg/dL, respectively. In the group receiving 6% baobab powder, the corresponding values were 154.95, 183.80, and 388.60 mg/dL. Statistical comparisons based on the reported superscript letters showed that TC and TG did not differ significantly between the 3% and 6% groups. In contrast, TL was significantly lower in the 6% group, indicating a more pronounced response at this supplementation level. The greatest reductions in these three parameters were recorded in rats fed 9% baobab powder, with TC, TG, and TL values of 94.30, 128.50, and 321.40 mg/dL, respectively. These concentrations were significantly lower than those observed in both the 3% and 6% groups. However, they remained significantly different from the corresponding values in normal control rats. Comparable changes were noted in LDL-C and VLDL-C following baobab supplementation. LDL-C concentrations declined from 86.70 mg/dL in diabetic controls to 58.25, 49.60, and 29.40 mg/dL in the groups receiving 3%, 6%, and 9% baobab powder, respectively. Similarly, VLDL-C decreased from 54.87 mg/dL in the diabetic control group to 37.08, 36.76, and 25.70 mg/dL across the respective supplementation groups. According to the reported statistical groupings, no significant difference was detected in VLDL-C between the 3% and 6% groups, whereas the 9% group had significantly lower levels than either of these treatments. Overall, the 9% supplementation level was associated with the most substantial decreases in both LDL-C and VLDL-C among the baobab-treated groups. Unlike the other lipid fractions, HDL-C increased with increasing dietary inclusion of baobab fruit powder. Its concentration rose from 11.80 mg/dL in diabetic controls to 19.65 mg/dL in the 3% group, 24.80 mg/dL in the 6% group, and 28.10 mg/dL in the 9% group. The different superscript letters indicate statistically significant differences among these groups. Although the highest HDL-C concentration among the supplemented diabetic groups was recorded at the 9% inclusion level, it remained below the value observed in normal controls (42.15 mg/dL). Taken together, the findings suggest that dietary baobab fruit powder supplementation was associated with an improvement in the serum lipid profile of streptozotocin-induced diabetic rats. This response was characterized by decreases in TC, TG, TL, LDL-C, and VLDL-C, accompanied by an increase in HDL-C. Among the inclusion levels investigated, 9% baobab powder produced the most pronounced overall changes in the measured lipid parameters. Nevertheless, the lipid profile was not completely restored to the levels observed in the normal control group. Further research is warranted to

investigate the mechanisms potentially responsible for these changes and to establish the broader metabolic effects of baobab fruit powder supplementation.

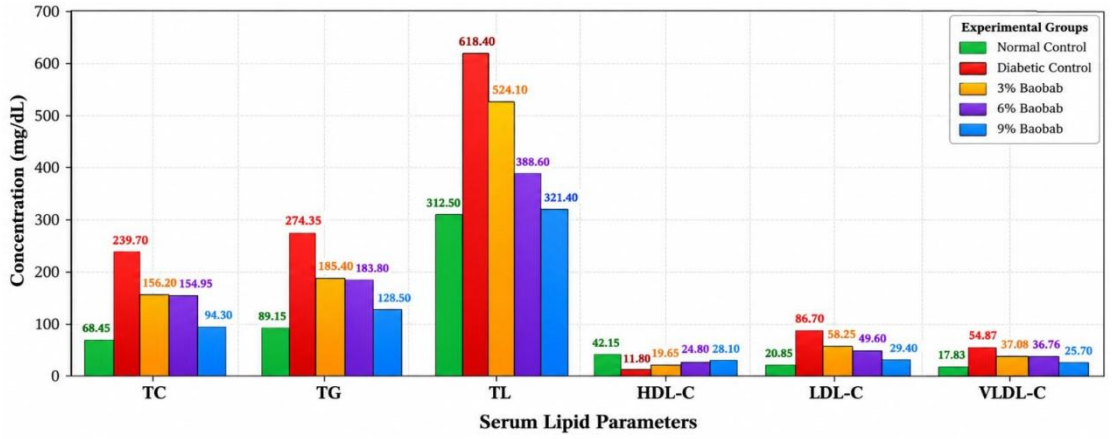


Figure 6. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at different inclusion levels on serum lipid parameters in streptozotocin (STZ)-induced diabetic rats: (A) total cholesterol (TC), (B) triglycerides (TG), (C) total lipids (TL), (D) high-density lipoprotein cholesterol (HDL-C), (E) low-density lipoprotein cholesterol (LDL-C), and (F) very-low-density lipoprotein cholesterol (VLDL-C). Data are presented as mean ± standard deviation (SD) (n = 6). Within each panel, bars bearing different superscript letters indicate statistically significant differences, as determined by Duncan's multiple range test ($P < 0.05$). Abbreviations: NC, normal control; DC, diabetic control; STZ, streptozotocin.

Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at different inclusion levels on serum hepatic enzyme activities in streptozotocin-induced diabetic rats.

A marked difference in serum hepatic enzyme activities was evident between the normal and diabetic control groups. In streptozotocin-induced diabetic rats, the activities of aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) increased to 218.45, 188.60, and 168.90 U/mL, respectively. By comparison, the normal control group exhibited considerably lower activities, with corresponding values of 98.20, 76.50, and 62.10 U/mL. These findings reflect substantial changes in circulating hepatic enzyme activities following the induction of diabetes. Supplementation with baobab fruit powder was accompanied by a progressive decline in the activities of all three enzymes relative to the diabetic control group. In rats fed a diet containing 3% baobab powder, AST, ALT, and ALP activities decreased to 162.30, 156.40, and 145.20 U/mL, respectively. A further reduction was observed at the 6% inclusion level, where the respective enzyme activities reached 138.60, 122.10, and 114.80 U/mL. According to the reported superscript letters, both supplementation groups differed significantly from the diabetic control group, and significant differences were also detected between the 3% and 6% groups ($p < 0.05$). The greatest decreases in hepatic enzyme activities were recorded in the group receiving 9% baobab powder. AST activity fell to 112.50 U/mL, whereas ALT and ALP activities declined to 92.70 and 88.40 U/mL, respectively. These values were significantly lower than those measured in the 3% and 6% supplementation groups, as indicated by the reported statistical comparisons ($p < 0.05$). Despite this improvement, the activities of AST, ALT, and ALP remained significantly above those of the normal control group, suggesting that baobab supplementation did not completely restore these parameters to their normal levels.

Overall, dietary inclusion of baobab fruit powder was associated with lower serum AST, ALT, and ALP activities in streptozotocin-induced diabetic rats. The most pronounced changes were observed at the 9% inclusion level, followed by the 6% and 3% levels. These findings suggest a potentially beneficial association between baobab supplementation and biochemical indicators of hepatic status. However, changes in serum enzyme activities alone cannot establish the extent of liver protection or explain the biological mechanisms involved. Additional biochemical assessments, together with histopathological examination of liver tissue, are therefore necessary to provide further evidence and clarify the nature of these effects.

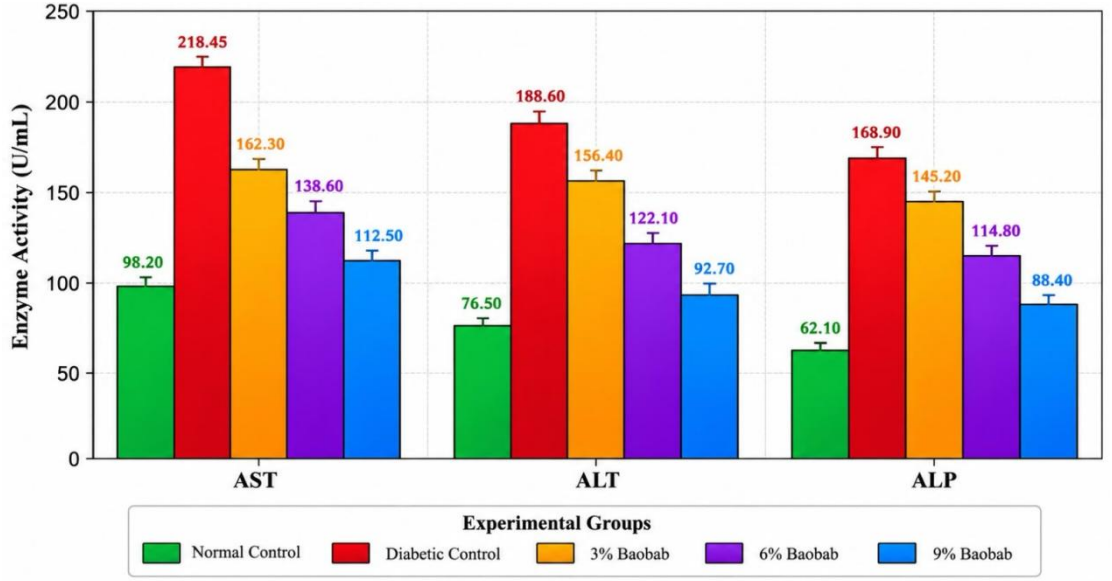


Figure 7. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at graded inclusion levels on serum hepatic enzyme activities in streptozotocin (STZ)-induced diabetic rats: (A) aspartate aminotransferase (AST), (B) alanine aminotransferase (ALT), and (C) alkaline phosphatase (ALP). Results are expressed as mean ± standard deviation (SD) (n = 6). Within each panel, different superscript letters denote statistically significant differences among groups, as determined by Duncan's multiple range test ($P < 0.05$). Abbreviations: NC, normal control; DC, diabetic control; STZ, streptozotocin; AST, aspartate aminotransferase; ALT, alanine aminotransferase; ALP, alkaline phosphatase.

Effects of dietary supplementation with baobab *(Adansonia digitata L.)* fruit powder at different inclusion levels on serum renal function parameters in streptozotocin-induced diabetic rats.

The assessment of renal function-related biochemical parameters revealed notable differences between the normal and diabetic control groups. Diabetic control rats showed elevated concentrations of uric acid, creatinine, and urea, reaching 35.87, 1.63, and 7.70 mg/dL, respectively. In comparison, the normal control group recorded substantially lower values of 21.71, 0.74, and 2.94 mg/dL, respectively. These changes indicate disturbances in the measured biochemical markers associated with renal function in streptozotocin-induced diabetic rats. Dietary incorporation of baobab (*Adansonia digitata* L.) fruit powder was accompanied by a decrease in all three parameters relative to the diabetic control group. At the 3% supplementation level, uric acid, creatinine, and urea concentrations declined to 30.69, 1.37, and 6.14 mg/dL, respectively. A more substantial reduction was observed in rats receiving 6% baobab powder, in which the corresponding values decreased to 26.78, 1.22, and 4.74 mg/dL.

The most marked response occurred in the group supplemented with 9% baobab powder. In this group, uric acid concentration decreased to 23.22 mg/dL, while creatinine and urea levels reached 1.13 and 4.02 mg/dL, respectively. Relative to the diabetic control group, these values corresponded to reductions of approximately 35.27%, 30.67%, and 47.79%, respectively. Accordingly, the 9% supplementation group exhibited the lowest concentrations of all three parameters among the baobab-treated diabetic groups. Nevertheless, uric acid, creatinine, and urea levels remained higher than those recorded in normal control rats, indicating that supplementation did not completely restore these biochemical markers to their normal values under the conditions of the present study. Taken together, these results demonstrate an association between baobab fruit powder supplementation and reduced serum concentrations of uric acid, creatinine, and urea in streptozotocin-induced diabetic rats. Among the dietary inclusion levels examined, the 9% treatment was associated with the greatest reductions, followed by the 6% and 3% treatments. Such changes may reflect an improvement in biochemical indicators related to renal function. However, these findings alone are insufficient to confirm a direct protective effect on renal tissue or establish the physiological mechanisms responsible for the observed responses. Further investigations involving renal histopathological examination and additional kidney function biomarkers are needed to provide a more comprehensive evaluation of the potential renal effects of baobab fruit powder.

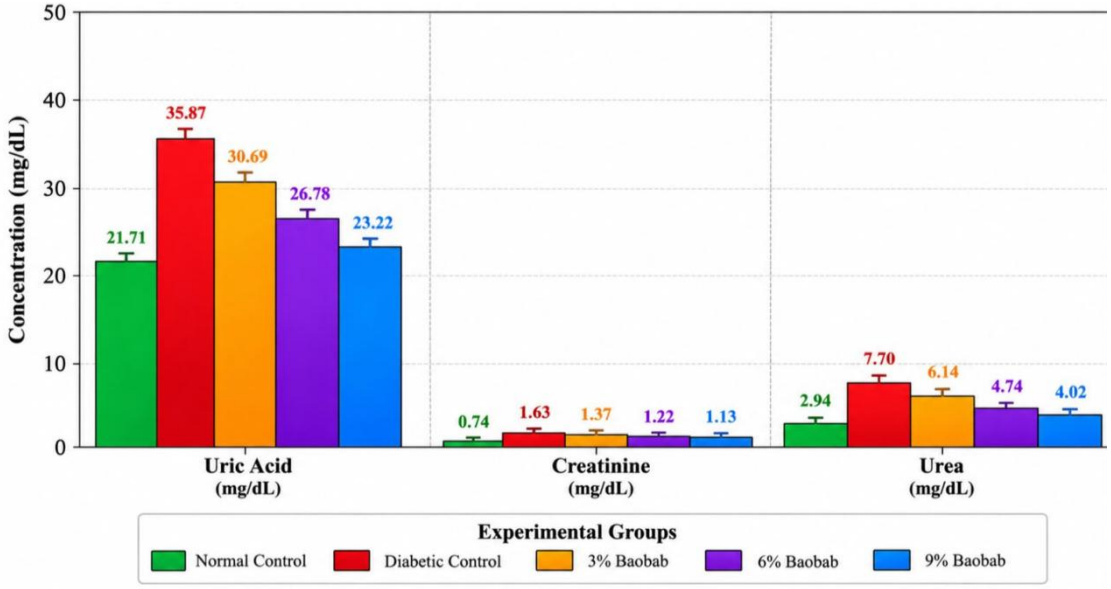


Figure 8. Effects of dietary supplementation with baobab (*Adansonia digitata* L.) fruit powder at different inclusion levels on serum renal function parameters in streptozotocin (STZ)-induced diabetic rats: (A) uric acid, (B) creatinine, and (C) urea. Data are expressed as mean ± standard deviation (SD) (*n* = 6). Abbreviations: NC, normal control; DC, diabetic control; STZ, streptozotocin.

3.4. Histopathological findings

Figure 9. Histological appearance of pancreatic tissue in normal and streptozotocin (STZ)-induced diabetic rats fed diets supplemented with baobab (*Adansonia digitata* L.) fruit powder. Pancreatic tissue sections were examined to evaluate the histological architecture of the pancreas in five experimental groups: the negative control group (normal, non-diabetic rats), the positive control group (STZ-induced diabetic rats without baobab supplementation), and three diabetic groups fed basal diets containing 3%, 6%, or 9% baobab fruit powder. **Panel A (negative control group)** demonstrates relatively intact pancreatic architecture, with a clearly distinguishable islet of Langerhans surrounded by well-organized exocrine acinar tissue. The islet displays a regular outline and a recognizable arrangement of its cellular components, consistent with preserved pancreatic morphology in the examined section. **Panel B (positive control group)** reveals noticeable histological alterations in the exocrine pancreatic tissue, including widened intercellular spaces and regions suggestive of cytoplasmic vacuolation, as indicated by the arrows. These observations may be associated with STZ-induced diabetes. However, their pathological relevance requires confirmation through examination of additional tissue sections and consideration of potential processing artifacts. **Panel C (3% baobab supplementation group)** shows an islet of Langerhans with variable cellular morphology, including differences in cell distribution and staining intensity. Further histological assessment is necessary to characterize these changes and determine whether they represent structural alterations relative to the diabetic control group. **Panel D (6% baobab supplementation group)** presents a recognizable islet of Langerhans located adjacent to a prominent connective tissue septum. The surrounding exocrine acinar tissue appears relatively well organized in the illustrated section. Nevertheless, the presence of connective tissue alone is insufficient to establish fibrosis in the absence of additional supporting histological findings. **Panel E (9% baobab supplementation group)** displays a relatively distinct islet of Langerhans with an identifiable cellular arrangement, together with comparatively preserved architecture of the surrounding acinar tissue. This morphological appearance may suggest better maintenance of pancreatic tissue organization than that observed in certain other examined sections. However, a definitive improvement attributable to treatment cannot be concluded from representative photomicrographs alone and requires systematic evaluation of samples from all experimental animals. Overall, the photomicrographs demonstrate variations in pancreatic histological features among the five experimental groups. The negative control group serves as a reference for normal pancreatic architecture, while the positive control group illustrates morphological changes observed under STZ-induced diabetic conditions. Comparison of the baobab-supplemented groups with the diabetic control group provides a basis for evaluating the possible association between baobab intake and the preservation of pancreatic islet and exocrine tissue structure. Confirmation of any dose-dependent response requires blinded histopathological scoring and, where applicable, quantitative assessment of islet morphology and insulin immunostaining.

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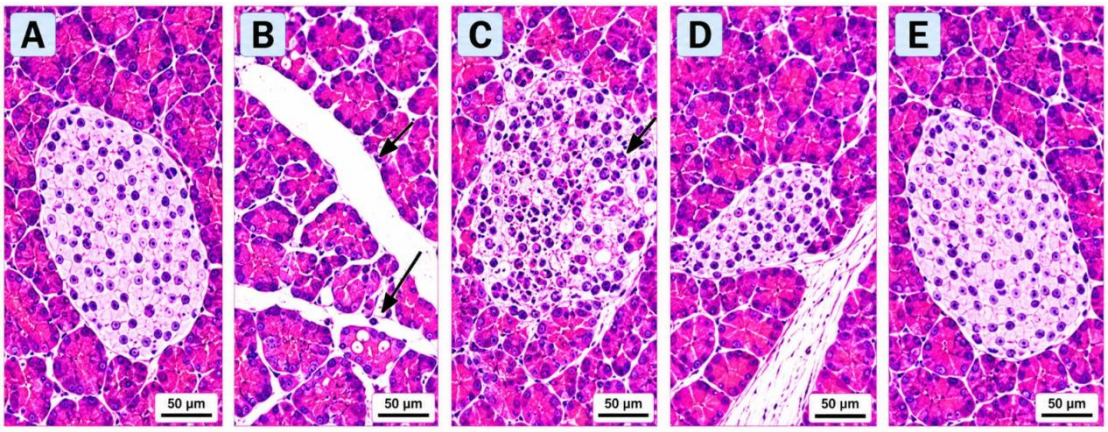


Figure 9. Representative photomicrographs of pancreatic tissue from five experimental groups: (A) negative control (normal, non-diabetic rats); (B) positive control (STZ-induced diabetic rats without supplementation); (C) diabetic rats receiving 3% baobab (Adansonia digitata L.) fruit powder; (D) diabetic rats receiving 6% baobab fruit powder; and (E) diabetic rats receiving 9% baobab fruit powder. The images show the islets of Langerhans and surrounding exocrine pancreatic tissue. Arrows indicate areas of apparent tissue alteration in panels B and C. Scale bars = 50 µm.

4. DISCUSSION

This study examined the effects of dietary *Adansonia digitata* L. fruit powder on biochemical parameters and pancreatic histopathology in streptozotocin (STZ)-induced diabetic rats. Baobab powder contained 44.80 g/100 g dietary fiber, 2250 mg gallic acid equivalents (GAE)/100 g total phenolics, and 680 mg quercetin equivalents (QE)/100 g total flavonoids, highlighting its nutritional value and potential biological relevance. Previous studies have identified dietary fiber and bioactive phytochemicals in baobab that may contribute to metabolic regulation and antioxidant activity (Mjery et al., 2026; Dogara & Al-Zahrani, 2024). Nevertheless, their presence alone does not explain the mechanisms responsible for the effects observed in this study. STZ administration increased serum glucose from 93.20 mg/dL in normal rats to 264.80 mg/dL in diabetic controls, consistent with pancreatic β-cell damage (Ghasemi & Jeddi, 2023). Baobab supplementation at 3%, 6%, and 9% was associated with glucose concentrations of 136.40, 140.10, and 114.60 mg/dL, respectively, with the greatest reduction (56.72%) occurring in the 9% group. Serum insulin also increased from 82.50 IU/L in diabetic controls to 128.10 IU/L in the 9% group, approaching the normal control value (142.80 IU/L). These findings are consistent with previous experimental investigations of baobab-derived preparations (Mohammed et al., 2021; Alkhudhayri et al., 2026). However, the response was not strictly dose-dependent, and serum insulin measurements alone cannot establish improved β-cell function.

Diabetic control rats showed an altered lipid profile, characterized by increased TC, TG, LDL-C, and VLDL-C and decreased HDL-C. Treatment with 9% baobab powder was associated with lower TC (94.30 versus 245.80 mg/dL) and TG (128.50 versus 274.35 mg/dL), while HDL-C increased from 11.80 to 28.10 mg/dL. These changes may be related to improved glycemic status and the nutritional composition of baobab. Similar lipid-related responses have been reported following administration of baobab fruit preparations (Mohammed et al., 2021), although the mechanisms involved remain unclear. The diabetic control group also exhibited elevated AST, ALT, and ALP activities compared with normal controls. In the 9% supplementation group, these activities decreased to 112.50, 92.70, and 88.40 U/mL, respectively, compared with 218.45, 188.60, and 168.90 U/mL in diabetic controls. This pattern suggests an improvement in the measured hepatic biochemical profile. Oxidative stress and inflammation are recognized contributors to diabetes-related organ dysfunction (Weinberg Sibony et al., 2024); however, reduced enzyme activities alone are insufficient to establish hepatoprotection. Similarly, STZ-induced diabetes was associated with elevated uric acid, creatinine, and urea concentrations. Supplementation with 9% baobab powder reduced these values from 35.87 to 23.22 mg/dL, 1.63 to 1.13 mg/dL, and 7.70 to 4.02 mg/dL, respectively, indicating a partial improvement in renal biochemical markers. Diabetes-related renal disturbances may involve metabolic dysfunction, oxidative stress, and inflammation (Weinberg Sibony et al., 2024). Nevertheless, further functional and histopathological assessments are needed to determine whether these changes reflect actual renal protection. Pancreatic histopathological examination complemented the biochemical assessments. Although STZ-induced diabetes is associated with β-cell injury and impaired insulin secretion (Ghasemi & Jeddi, 2023), and previous studies have investigated pancreatic responses to baobab preparations in diabetic rats (Mohammed et al., 2021), the present findings do not provide sufficient quantitative evidence to confirm β-cell regeneration or pancreatic tissue protection. Such conclusions require standardized histological scoring and detailed microscopic evaluation.

Overall, baobab supplementation, particularly at the 9% level, was associated with favorable numerical changes in glycemic, lipid, hepatic, and renal biochemical parameters. These responses may be related to the fiber and phytochemical content of baobab (Mahzari et al., 2026; Dogara & Al-Zahrani, 2024). However, the underlying mechanisms remain undetermined, and antioxidant effects in vivo cannot be confirmed without direct oxidative stress measurements. The study's limitations include the small sample size (six rats per group), short duration

(28 days), incomplete statistical information, and limited quantitative histopathological evidence. Moreover, findings from STZ-induced diabetic rats cannot be directly extrapolated to humans. Further research using larger groups, longer treatment periods, comprehensive histopathological assessments, and oxidative stress measurements is therefore warranted.

5. CONCLUSION

Dietary supplementation with *Adansonia digitata* L. fruit powder was associated with favorable changes in glycemic status, serum lipid profile, hepatic enzyme activities, and renal biochemical markers in STZ-induced diabetic male Sprague–Dawley rats. Among the tested inclusion levels, 9% baobab powder produced the lowest reported glucose concentration and generally the most favorable numerical changes in several biochemical parameters. Pancreatic histopathology also revealed differences among the experimental groups, although β-cell preservation or regeneration cannot be confirmed without further quantitative evidence. These findings support additional investigation of baobab powder as a potential dietary component in experimental diabetes research. Further studies are needed to clarify its mechanisms of action, determine the optimal inclusion level, assess long-term safety, and evaluate its relevance to human health.

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