

## Original Research

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Yellow corn; *Zea mays*; diabetes mellitus; streptozotocin; glucose; lipid profile; liver enzymes; renal function.

## Dose-Dependent Effects of Dietary Yellow Corn Powder on Glycemic Control, Liver Enzymes, and Renal Function in Diabetic Rats: A 28-Day Experimental Study.

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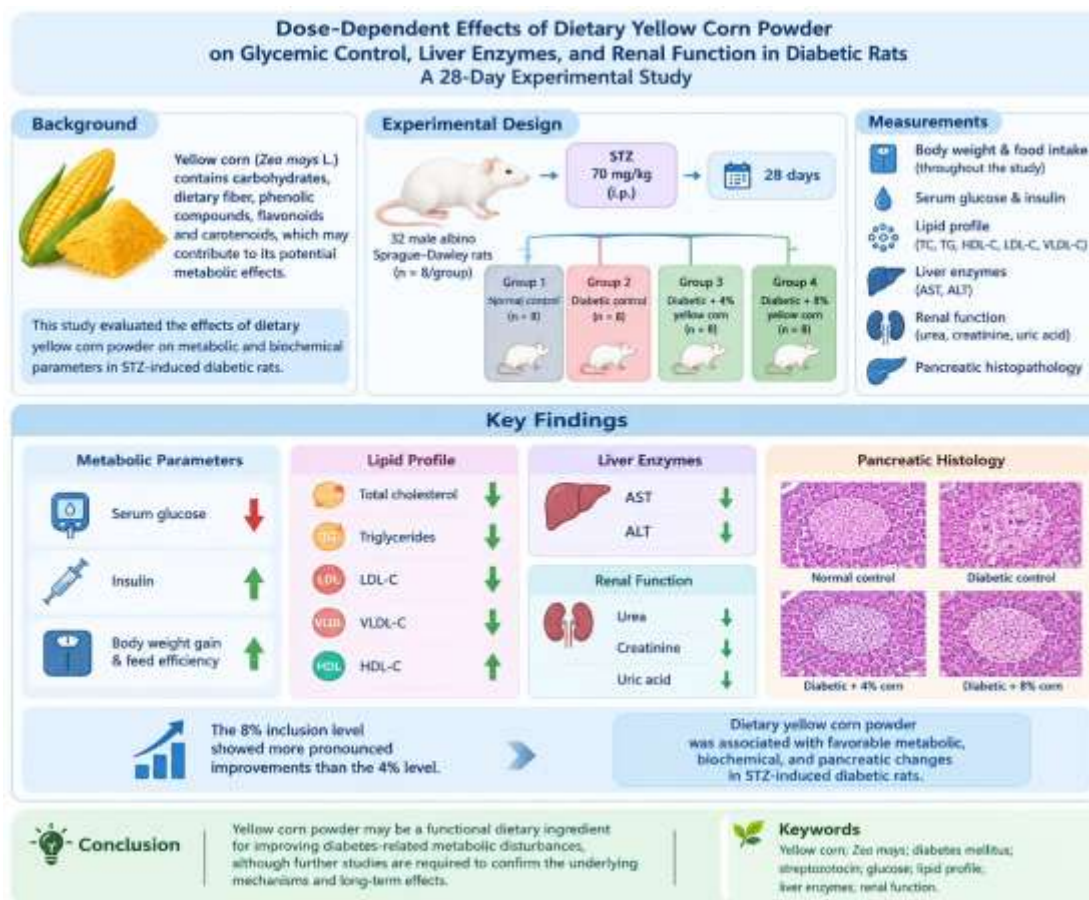
### ABSTRACT:

**Background:** Diabetes mellitus is associated with disturbances in glucose and lipid metabolism and may adversely affect hepatic and renal function. Yellow corn (*Zea mays* L.) contains carbohydrates, dietary fiber, phenolic compounds, flavonoids, and carotenoids that may contribute to its potential metabolic effects. This study evaluated the effects of dietary yellow corn powder at two inclusion levels on selected metabolic and biochemical parameters in streptozotocin-induced diabetic rats.

**Methods:** Thirty-two male albino Sprague–Dawley rats were randomly allocated into four groups (n = 8/group): normal control, diabetic control, and diabetic rats receiving diets containing 4% or 8% yellow corn powder. Diabetes was induced by intraperitoneal administration of streptozotocin at 70 mg/kg body weight. The experimental period lasted 28 days. Body weight and food intake were monitored, and serum glucose, insulin, lipid profile, AST, ALT, urea, creatinine, and uric acid were determined at the end of the experiment. Pancreatic tissues were also examined histopathologically.

**Results:** Compared with the diabetic control group, yellow corn supplementation was associated with improved body weight gain and feed efficiency, reduced serum glucose, and increased insulin concentrations. The supplemented groups also showed lower total cholesterol, triglycerides, LDL-C, VLDL-C, AST, ALT, urea, creatinine, and uric acid levels, together with higher HDL-C concentrations. Pancreatic histology showed relatively better preservation of tissue architecture in supplemented rats. Overall, the 8% inclusion level produced more pronounced improvements than the 4% level.

**Conclusion:** Dietary yellow corn powder was associated with favorable metabolic, biochemical, and pancreatic changes in STZ-induced diabetic rats. These findings support its potential as a functional dietary ingredient for improving diabetes-related metabolic disturbances, although further studies are required to confirm the underlying mechanisms and long-term effects.

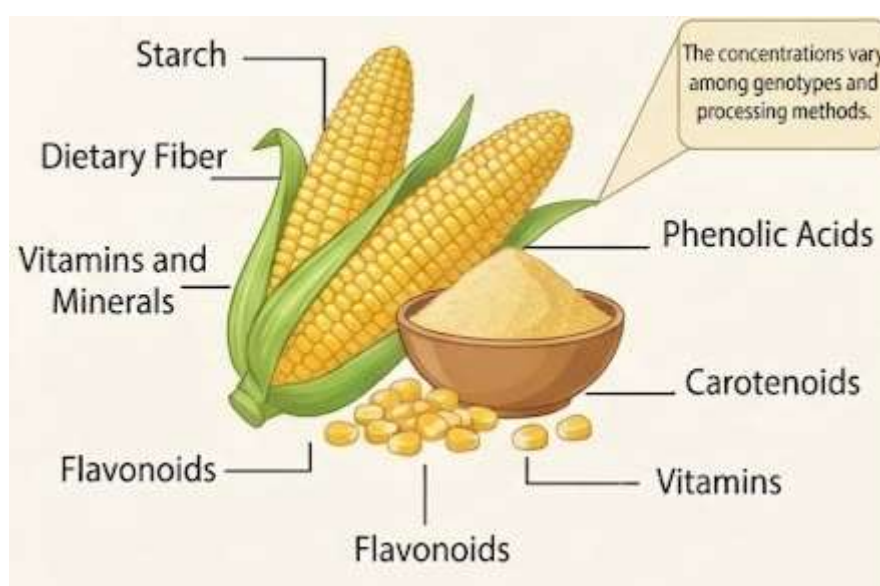


**Graphical Abstract:** Metabolic and Biochemical Benefits of Dietary Yellow Corn Powder in Experimental Type 1 Diabetes: A 28-Day Investigation.

## 1. Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from impaired insulin secretion, impaired insulin action, or both (American Diabetes Association Professional Practice Committee, 2025a). It represents a major global health challenge because prolonged hyperglycemia contributes to chronic complications affecting multiple organs, particularly the kidneys, eyes, nerves, and cardiovascular system (American Diabetes Association Professional Practice Committee, 2025; World Health Organization, 2024b). These complications are associated with interconnected mechanisms, including metabolic disturbances, oxidative stress, inflammation, endothelial dysfunction, and hyperglycemia-related intracellular pathways (Sibony et al., 2024; Zhao & Hu, 2024). Oxidative stress and chronic inflammation are particularly important in the progression of diabetic microvascular and macrovascular complications (Aljehani et al., 2026; Zhao & Hu, 2024). Dietary management is an important component of diabetes care because the amount and quality of dietary carbohydrate influence glycemic responses. Current recommendations emphasize individualized dietary patterns, nutrient quality, appropriate energy intake, and fiber-rich carbohydrate sources (American Diabetes Association Professional Practice Committee, 2025a). Cereal foods are important sources of dietary energy, mainly from carbohydrates, while their fiber and phytochemical composition varies according to cereal species, genotype, processing, and refinement (Evert et al., 2019). Recent evidence suggests that whole-grain consumption may favorably influence some indicators of glycemic control, although these effects depend on the type and amount consumed (Ying et al., 2024). Therefore, the metabolic effects of cereal-based foods should be considered in relation to their overall nutritional composition and quantity rather than their cereal classification alone (Adam et al., 2026; Evert et al., 2019). Yellow corn (*Zea mays* L.) is an important cereal crop and a major source of dietary carbohydrates. In addition to starch, it contains dietary fiber and various bioactive compounds, including carotenoids, phenolic acids, and flavonoids. The concentration and composition of these phytochemicals vary

according to genotype, plant tissue, environmental conditions, and processing methods (Peniche-Pavía et al., 2022; Zhang et al., 2023). Maize flavonoids have received particular attention because of their structural diversity and potential biological activities, while other phytochemicals present in *Z. mays* have been associated with potential antioxidant, anti-inflammatory, and antidiabetic properties (Mahzari et al., 2026; Zhang et al., 2023). However, the presence of bioactive compounds in yellow corn does not establish that yellow corn powder directly lowers blood glucose or protects against diabetes-related organ damage. The physiological effects of a whole food cannot be inferred solely from the biological activities of its isolated phytochemicals and must be evaluated through controlled experimental studies. Accordingly, measurements of blood glucose, insulin-related parameters, oxidative stress, and biochemical indicators of organ function can provide complementary evidence regarding the effects of dietary interventions. Thus, experimental and nutritional evidence provides a rationale for investigating yellow corn powder as a dietary intervention in diabetes, while its specific metabolic and organ-related effects should be established through appropriately controlled animal or human studies (Mashnafi et al., 2026).



**Figure 1:** Composition and main nutritional constituents of yellow corn (*Zea mays* L.).

Aini et al. (2022) investigated corn-flour cookies containing different sugar and fat sources in diabetic rats over four weeks and reported significant effects on blood glucose, malondialdehyde (MDA), hemoglobin, and body-weight-related parameters. However, because the intervention involved formulated cookies containing corn flour together with other ingredients, the observed effects cannot be attributed exclusively to corn flour or directly extrapolated to diets supplemented with defined levels of yellow corn powder. This highlights the need for controlled studies evaluating corn powder incorporated directly into a basal diet at specified inclusion levels. Blood glucose is a primary indicator of altered glucose homeostasis in experimental diabetes; however, glycemic assessment alone does not fully characterize the broader metabolic and organ-related changes associated with diabetes. Therefore, experimental diabetic models are commonly evaluated using complementary metabolic and biochemical parameters, including hepatic and renal markers (Lutz, 2023; Spanou et al., 2023). Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) are commonly used indicators of hepatocellular injury, although they should not be considered direct measures of overall liver function. ALT is relatively more specific to hepatic injury, whereas AST is also present in extrahepatic tissues such as skeletal and cardiac muscle (Kwo et al., 2017; Arif-Tiwari et al., 2023). Accordingly, changes in these enzymes should be interpreted as indicators of hepatic biochemical alterations within the context of other physiological and biochemical findings.

Similarly, serum creatinine and urea are frequently assessed as renal-related biochemical indicators. Although creatinine is widely used in evaluating kidney filtration, its concentration can be influenced by muscle mass, nutritional status, dietary factors, and hydration. Urea may also be affected by protein intake, hydration, and metabolic or catabolic conditions (De Rosa et al., 2023). Thus, these parameters should not be interpreted independently as definitive evidence of renal injury; rather, their combined assessment can provide useful information on renal-related biochemical alterations. Overall, the

combined evaluation of glycemic, hepatic, and renal parameters provides a broader characterization of physiological responses to dietary interventions in diabetic animals (Lutz, 2023; Spanou et al., 2023). The choice of an appropriate experimental model is also critical in diabetes research. Animal models permit controlled investigation of metabolic and physiological responses, although no single model completely reproduces the complexity of human diabetes (Mjery et al., 2026). Rodents are widely used and can develop diabetes through genetic, dietary, chemical, or other approaches, with the resulting phenotype influenced by the animal strain, induction method, and duration and severity of metabolic disturbance (Alkhudhayri, 2026; Lutz, 2023; Spanou et al., 2023). Consequently, findings from diabetic rats should be interpreted within the specific experimental context and not automatically generalized to human diabetes. Despite the nutritional and phytochemical characteristics of maize and preliminary evidence from corn-based interventions, further controlled studies are required to characterize the effects of dietary yellow corn powder at defined inclusion levels. Comparing 4% and 8% inclusion levels may indicate whether biochemical responses differ with the proportion of corn powder incorporated into the diet. However, increasing corn powder may simultaneously alter the diet's carbohydrate, energy, fiber, and other nutrient contents, which should be considered when interpreting the results.

## 2. MATERIALS AND METHODS

### 2.1. Yellow Corn Powder

Yellow corn (*Zea mays* L.) was used as the dietary intervention in the present study. The corn kernels were visually inspected, and visibly damaged kernels and foreign materials were removed before processing. The kernels were then mechanically ground into a fine powder suitable for incorporation into the experimental diets. Maize is a cereal grain that provides starch as well as dietary fiber and a range of micronutrients and phytochemicals, including phenolic compounds, carotenoids, and flavonoids; however, the composition of these constituents can vary according to genotype and processing conditions (Peniche-Pavía et al., 2022; Zhang et al., 2023). The resulting yellow corn powder was placed in clean, airtight containers and stored under appropriate conditions until use.

### 2.2. Experimental Animals and Housing Conditions

Thirty-two white albino Sprague–Dawley rats, with an initial body weight of approximately  $150 \pm 10$  g, were used in the present study. The animals were housed in the Animal House of the Faculty of Home Economics, Menoufia University, Egypt. Experimental animal models are widely used in diabetes research because they permit the investigation of metabolic responses under controlled experimental conditions; however, no single animal model reproduces all aspects of human diabetes (Lutz, 2023). Rodent models are among the most frequently used experimental models for investigating diabetes and its metabolic consequences (Lutz, 2023). The experimental procedures were conducted over a 28-day period in accordance with the conditions specified in the approved animal research protocol. The animals had free access to drinking water and their assigned diets throughout the experimental period, except during periods of fasting required for specific experimental procedures. Body weight, food intake, and general health status were monitored throughout the study.

### 2.3. Induction of Experimental Diabetes

Following the acclimatization period, experimental diabetes mellitus was induced using streptozotocin (STZ). Streptozotocin is widely used to produce experimental diabetes in rodents because of its ability to induce pancreatic  $\beta$ -cell injury and subsequent disturbances in glucose homeostasis (Lutz, 2023). The rats had an initial body weight of approximately  $150 \pm 10$  g. Streptozotocin (Sigma-Aldrich, St. Louis, MO, USA) was administered intraperitoneally at a dose of 70 mg/kg body weight according to the approved experimental protocol. Following STZ administration, blood glucose concentrations were measured to confirm the development of experimental diabetes. Rats that met the predefined criterion for diabetes were included in the diabetic groups, whereas non-diabetic rats were assigned to the normal control group. The severity of the diabetic phenotype in experimental animals can vary according to the animal strain, induction procedure, housing conditions, and duration of the experimental period (Lutz, 2023).

### 2.4. Basal Diet

Throughout the experimental period, the rats were fed a standardized basal diet providing approximately 2850 kcal/kg. The diet consisted of 64.0% carbohydrates, 20.0% crude protein, 4.0% crude fat, 3.5% crude fiber, and 6.0% ash. It also contained 0.50% salt, 1.0% calcium, and 0.60% phosphorus. The vitamin content included 20.0 IU/g vitamin A, 2.20 IU/g vitamin D,

and 70.0 IU/kg vitamin E. The diet also provided trace elements, including cobalt, iodine, manganese, iron, copper, zinc, and selenium. The basal diet was provided to all experimental groups, whereas the designated intervention groups received the specified concentrations of yellow corn powder. Because differences in the inclusion level of a dietary ingredient may alter the overall nutrient composition of an experimental diet, including its carbohydrate, energy, fiber, and other nutrient contents, the composition of the experimental diets should be considered when interpreting differences between treatment groups.

## 2.5. Experimental Design

A total of 32 Sprague–Dawley rats, with an initial body weight of  $150 \pm 10$  g, were randomly allocated into four experimental groups, with eight rats per group. The experimental period lasted 28 days. The use of separate normal and diabetic control groups allows the effects associated with the diabetic state to be distinguished from responses associated with dietary supplementation.

- **Group 1 – Normal control group:** Eight non-diabetic rats received the basal diet without yellow corn powder supplementation.
- **Group 2 – Diabetic control group:** Eight diabetic rats received the basal diet without yellow corn powder supplementation.
- **Group 3 – 4% yellow corn powder group:** Eight diabetic rats received the basal diet supplemented with 4% yellow corn powder.
- **Group 4 – 8% yellow corn powder group:** Eight diabetic rats received the basal diet supplemented with 8% yellow corn powder.

Body weight and food intake were monitored throughout the experimental period. At the end of the 28-day experimental period, blood samples were collected for determination of serum glucose, ALT, AST, urea, creatinine, uric acid, and lipid profile parameters. The experimental design was intended to evaluate whether incorporation of yellow corn powder into the diet was associated with differences in biochemical responses in diabetic rats and whether these responses varied according to the inclusion level.

## 2.6. Monitoring of Body Weight and Food Intake

Body weight and food intake were monitored throughout the 28-day experimental period. Initial and final body weights were recorded, and food consumption was determined according to the laboratory's established recording procedure.

Body weight gain (BWG), body weight gain percentage (BWG%), and feed efficiency ratio (FER) were calculated from the original recorded measurements as follows:

### Body weight gain (g):

$$\text{BWG} = \text{Final body weight} - \text{Initial body weight}$$

### Body weight gain percentage (%):

$$\text{BWG\%} = [(\text{Final body weight} - \text{Initial body weight}) / \text{Initial body weight}] \times 100$$

### Feed efficiency ratio (FER):

$$\text{FER} = \text{Body weight gain (g)} / \text{Food intake (g)}$$

These indices were used to characterize changes in body weight and the relationship between food consumption and body weight gain.

## 2.7. Blood Collection and Serum Preparation

At the end of the 28-day experimental period, blood samples were collected according to the procedure specified in the approved experimental protocol. If fasting was performed before blood collection, the duration of fasting and the availability of drinking water during the fasting period were recorded. Blood samples intended for serum biochemical analysis were allowed to clot and were subsequently centrifuged according to the laboratory's established procedure. The separated serum

was transferred into appropriately labeled tubes and stored under suitable conditions until analysis. Serum was used for the determination of glucose, liver enzyme activities, renal biochemical parameters, and lipid profile components.

## 2.8. Biochemical Analyses

The biochemical analyses were selected to provide information regarding glucose homeostasis as well as selected hepatic, renal, and lipid-related biochemical responses. Such a multidimensional assessment is useful in experimental diabetes because animal models may exhibit metabolic disturbances extending beyond hyperglycemia alone (Lutz, 2023). All biochemical measurements were performed using the analytical procedures and commercial diagnostic kits available in the laboratory. Where applicable, analyses were conducted according to the manufacturers' instructions.

### 2.8.1. Blood Glucose

Serum glucose concentration was determined using an enzymatic colorimetric method based on the glucose oxidase peroxidase (GOD–POD) principle. The method is based on the enzymatic oxidation of glucose and subsequent color development, which is measured spectrophotometrically (Trinder, 1969). The glucose concentration was expressed as mg/dL. Trinder (1969) described the oxidase peroxidase colorimetric approach for glucose determination, which has subsequently been widely used in clinical and experimental biochemical analysis.

### 2.8.2. Liver Enzymes

Serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities were determined using a colorimetric method based on the procedure described by Reitman and Frankel (1957). The method is based on the measurement of the products generated by transaminase activity through colorimetric detection (Reitman & Frankel, 1957). The activities of ALT and AST were expressed as U/L. ALT and AST are commonly used biochemical indicators of hepatocellular injury; however, their interpretation should consider the fact that they are not direct measures of total hepatic function (Kwo et al., 2017). Therefore, the results of ALT and AST in the present study were interpreted as indicators of hepatic biochemical alterations rather than as independent measures of overall liver function.

### 2.8.3. Renal Biochemical Parameters

Renal biochemical status was evaluated by determining serum urea, creatinine, and uric acid concentrations. These parameters are commonly used in experimental studies to characterize biochemical changes associated with renal function.

**Serum urea:** Serum urea concentration was determined using the enzymatic colorimetric procedure specified for the diagnostic assay used in the laboratory. The method is based on enzymatic hydrolysis of urea and subsequent colorimetric detection of the reaction products.

**Serum creatinine:** Serum creatinine concentration was determined using the colorimetric procedure specified for the diagnostic assay used in the laboratory. In Jaffé-based procedures, creatinine reacts with alkaline picrate to form a colored complex, the intensity of which is related to the creatinine concentration.

**Serum uric acid:** Serum uric acid concentration was determined using an enzymatic colorimetric procedure based on the uricase–peroxidase reaction. In this type of assay, uric acid is oxidized enzymatically, and the resulting hydrogen peroxide participates in a chromogenic reaction. Serum creatinine and urea should be interpreted in the context of other physiological and experimental variables because their concentrations may be influenced by factors other than renal filtration alone, including nutritional status, hydration, and muscle mass (De Rosa et al., 2023).

### 2.8.4. Lipid Profile

The serum lipid profile included total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C).

**Total cholesterol:** Serum total cholesterol concentration was determined using an enzymatic colorimetric method based on cholesterol esterase, cholesterol oxidase, and peroxidase reactions, according to Allain et al. (1974). In this method, cholesterol esters are hydrolyzed to free cholesterol, which is subsequently oxidized, generating hydrogen peroxide that

participates in a color-producing reaction. The resulting chromogen was measured spectrophotometrically, and the concentration was expressed as mg/dL (Allain et al., 1974).

**Triglycerides:** Serum triglyceride concentration was determined using an enzymatic colorimetric method according to Fossati and Prencipe (1982). In this method, triglycerides are hydrolyzed by lipase, and the resulting glycerol undergoes subsequent enzymatic reactions that generate hydrogen peroxide. The hydrogen peroxide is then measured colorimetrically in the presence of peroxidase (Fossati & Prencipe, 1982). The concentration was expressed as mg/dL.

**HDL-C:** Serum HDL-C concentration was determined following precipitation of non-HDL lipoproteins, followed by enzymatic determination of cholesterol in the resulting supernatant, according to the method described by Warnick et al. (1982). The concentration of HDL-C was expressed as mg/dL.

**LDL-C:** Serum LDL-C was either determined directly using an enzymatic colorimetric assay or calculated from the measured TC, HDL-C, and TG concentrations, depending on the analytical procedure used in the laboratory. When calculated using the Friedewald equation, LDL-C was estimated as follows:

$$\text{LDL-C (mg/dL)} = \text{TC} - \text{HDL-C} - (\text{TG}/5)$$

The Friedewald equation was originally developed for estimating LDL-C from measurements of total cholesterol, HDL-C, and triglycerides without preparative ultracentrifugation (Friedewald et al., 1972). The equation should be applied only when its analytical assumptions are satisfied, including appropriate triglyceride concentrations.

## 2.9. Statistical Analysis

All data are presented as mean  $\pm$  standard deviation (SD). Statistical analysis was performed using one-way analysis of variance (ANOVA) for a completely randomized design. Significant differences among group means were determined using Duncan's multiple range test at  $p < 0.05$  (Duncan, 1955).

## 2.10. Ethical Approval

The experimental protocol was approved by the Institutional Research Ethics Committee of Al-Baha University, Saudi Arabia (Approval No. 47119677; May 17, 2026).

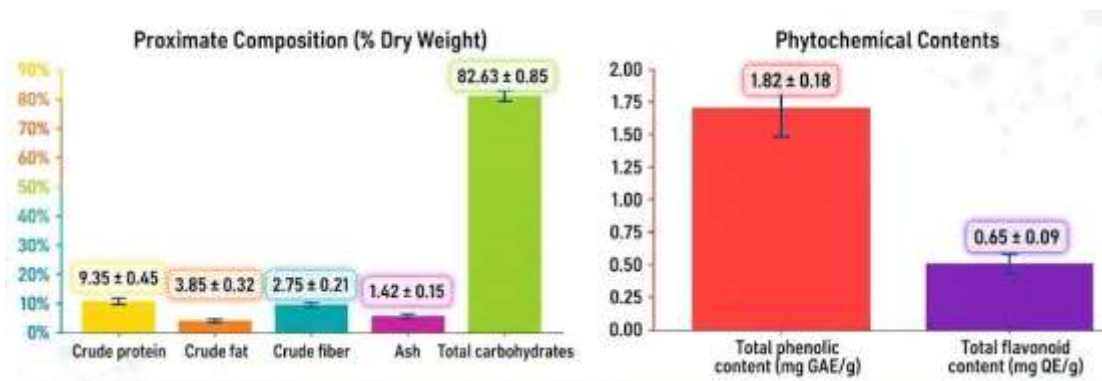
## 3. RESULTS

### 3.1. Chemical Results

#### Chemical Composition and Phytochemical Contents of Yellow Corn Powder on a Dry-Weight Basis

Figure 2 illustrates the chemical composition and major phytochemical constituents of the yellow corn powder on a dry-weight basis. The results demonstrate that carbohydrates constituted the predominant component of the sample, reaching  $82.63 \pm 0.85\%$ . This relatively high carbohydrate proportion indicates that carbohydrates account for the majority of the dry matter of yellow corn powder. Crude protein represented the second most abundant component, with a value of  $9.35 \pm 0.45\%$ , indicating a measurable contribution of protein to the overall nutritional composition of the sample. The crude fat content was  $3.85 \pm 0.32\%$ , while crude fiber accounted for  $2.75 \pm 0.21\%$  of the dry matter. Although these components occurred at considerably lower levels than carbohydrates, both contribute to the overall nutritional characteristics of the corn powder. The ash content was  $1.42 \pm 0.15\%$ , representing the inorganic fraction remaining after combustion and providing an indirect indication of the mineral fraction of the sample. The sum of the reported proximate components accounted for approximately 100% of the chemical composition, confirming the internal consistency of the compositional data. In addition to its major chemical constituents, the yellow corn powder contained detectable levels of phenolic and flavonoid compounds. The total phenolic content was  $1.82 \pm 0.18$  mg GAE/g dry sample, whereas the total flavonoid content was  $0.65 \pm 0.09$  mg QE/g dry sample. The higher value observed for total phenolic content compared with total flavonoid content indicates that phenolic compounds, as quantified by the respective analytical assays, contributed more substantially to the measured phytochemical fraction than flavonoid compounds. However, these values represent total phenolic and flavonoid contents determined using equivalent-based assays and should not be interpreted as the concentrations of individual phenolic or flavonoid compounds. Overall, the composition shown in Figure 2 indicates that yellow corn powder is characterized by a carbohydrate-dominated chemical profile, accompanied by moderate levels of protein and smaller proportions of fat, fiber,

and ash. The detection of phenolic and flavonoid constituents further demonstrates the presence of measurable phytochemical components in the sample. The reported values are expressed as mean  $\pm$  standard deviation from three independent determinations ( $n = 3$ ), providing an indication of the analytical variability among the measurements.



**Figure 2.** Proximate composition (% dry weight) and major phytochemical contents of yellow corn powder. Data are presented as mean  $\pm$  standard deviation (SD) based on triplicate measurements.

- **Left panel:** Proximate composition, including crude protein, crude fat, crude fiber, ash, and total carbohydrate contents.
- **Right panel:** Phytochemical composition, expressed as total phenolic content (mg GAE/g extract) and total flavonoid content (mg QE/g extract).

## 3.2. Biochemical Results

### Effects of dietary yellow corn powder supplementation on body weight and feeding-related parameters in diabetic rats

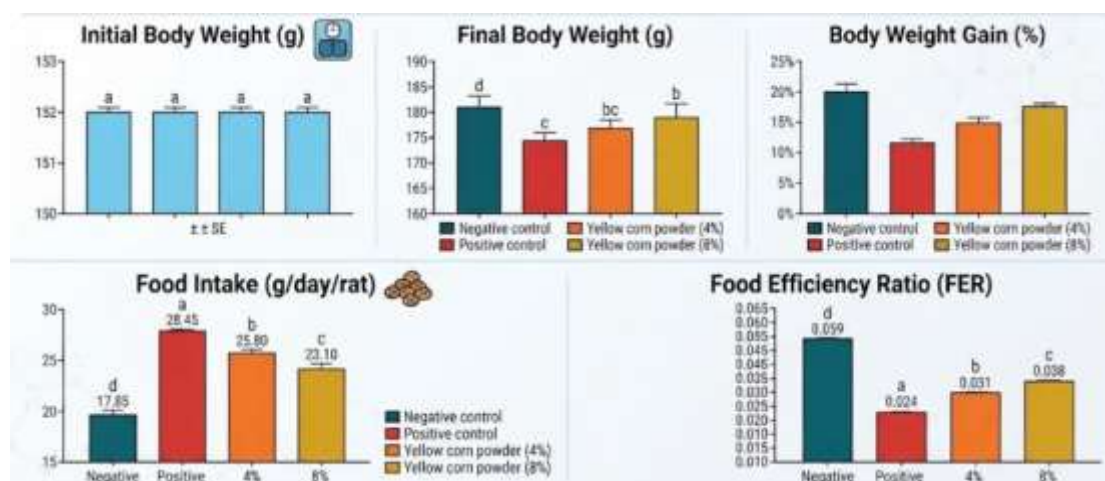
Figure 3 presents the effects of dietary supplementation with yellow corn powder at concentrations of 4% and 8% on body weight and feeding-related parameters in diabetic rats. The initial body weights were comparable among all experimental groups, ranging from 150.9 to 151.2 g, with no statistically significant differences observed between groups ( $P > 0.05$ ). This similarity in baseline body weight indicates that the experimental groups were adequately comparable at the beginning of the feeding period. At the end of the experimental period, the negative control group exhibited the highest final body weight, reaching  $181.4 \pm 1.62$  g, whereas the positive control group recorded a lower final body weight of  $169.2 \pm 1.95$  g. Dietary supplementation with yellow corn powder resulted in intermediate final body weights, with values of  $173.8 \pm 1.84$  g and  $177.5 \pm 1.68$  g in rats receiving 4% and 8% yellow corn powder, respectively. The superscript lettering indicates that these differences were statistically significant ( $P < 0.05$ ). Notably, the group receiving 8% yellow corn powder showed a higher final body weight than the 4% supplementation group and approached the value observed in the negative control group.

A similar pattern was observed for body weight gain. The negative control group recorded the highest body weight gain (19.97%), followed by the 8% yellow corn powder group (17.55%), the 4% supplementation group (15.02%), and the positive control group (12.13%). Thus, supplementation with yellow corn powder was associated with a progressive increase in body weight gain as the dietary inclusion level increased from 4% to 8%. The greater body weight gain observed in the supplemented groups, particularly at the 8% level, suggests that dietary yellow corn powder may have contributed to improved weight maintenance in the diabetic rats under the conditions of the present experiment.

Food intake showed an inverse pattern relative to body weight gain. The positive control group exhibited the highest food intake, averaging  $28.45 \pm 0.38$  g/day/rat, followed by the 4% yellow corn powder group ( $25.80 \pm 0.34$  g/day/rat) and the 8% group ( $23.10 \pm 0.30$  g/day/rat). The negative control group recorded the lowest food intake at  $17.85 \pm 0.28$  g/day/rat. The significant differences among groups ( $P < 0.05$ ) indicate that dietary supplementation with yellow corn powder was accompanied by a reduction in daily food consumption compared with the positive control group, with the reduction being more pronounced at the 8% inclusion level.

The food efficiency ratio (FER) further reflected differences in the relationship between food intake and body weight gain. The negative control group showed the highest FER ( $0.059 \pm 0.002$ ), whereas the positive control group had the lowest value ( $0.024 \pm 0.002$ ). Rats receiving 4% and 8% yellow corn powder showed intermediate FER values of  $0.031 \pm 0.002$  and  $0.038 \pm 0.002$ , respectively. The progressive increase in FER with increasing yellow corn powder supplementation suggests that the supplemented groups achieved greater body weight gain relative to their food intake than the positive control group. The 8% supplementation level produced a higher FER than the 4% level, indicating a more favorable feed utilization pattern under the conditions of the study.

Taken together, the findings illustrated in Figure 3 show that dietary yellow corn powder was associated with improvements in final body weight, body weight gain, and food efficiency, together with a reduction in food intake compared with the positive diabetic control group. These effects were more evident at the 8% inclusion level. Nevertheless, the observed differences should be interpreted in the context of the experimental design and the measured parameters, and they do not by themselves establish a specific physiological mechanism for the observed changes.



**Figure 3.** Effects of dietary yellow corn powder supplementation on body weight and feeding-related parameters in diabetic rats.

### 3.3. Biochemical Results

#### Effects of dietary yellow corn powder supplementation on serum glucose and insulin concentrations in diabetic rats.

Figure 4 illustrates the effects of dietary supplementation with yellow corn powder at 4% and 8% inclusion levels on serum glucose and insulin concentrations in diabetic rats. A clear difference was observed between the negative and positive control groups, indicating a marked alteration in glucose and insulin status in the diabetic animals. The negative control group exhibited the lowest serum glucose concentration, with a value of  $90.00 \pm 2.00$  mg/dL, whereas the positive control group showed a substantially higher glucose concentration of  $200.00 \pm 4.50$  mg/dL. This difference was statistically significant ( $P < 0.05$ ), as indicated by the different superscript letters.

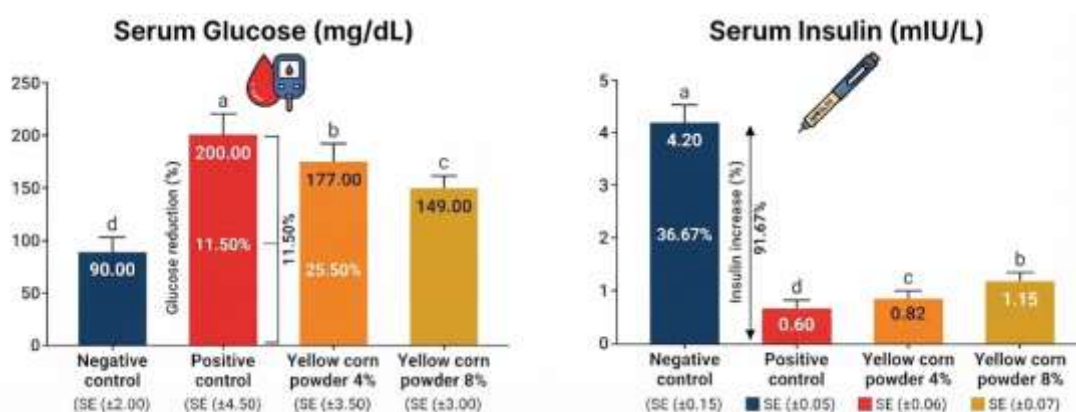
Dietary supplementation with yellow corn powder was associated with a progressive reduction in serum glucose concentration compared with the positive diabetic control group. Rats receiving 4% yellow corn powder showed a serum glucose concentration of  $177.00 \pm 3.50$  mg/dL, corresponding to an 11.50% reduction relative to the positive control group. Increasing the supplementation level to 8% resulted in a further decline in serum glucose to  $149.00 \pm 3.00$  mg/dL, representing a 25.50% reduction compared with the diabetic control. The different statistical groupings indicate that both supplementation levels produced significant differences in serum glucose concentrations, with the 8% treatment producing a greater reduction than the 4% treatment ( $P < 0.05$ ).

An opposite trend was observed for serum insulin concentrations. The negative control group recorded the highest insulin concentration at  $4.20 \pm 0.15$  mIU/L, whereas the positive control group exhibited the lowest concentration, reaching only

$0.60 \pm 0.05$  mIU/L. This marked reduction in circulating insulin in the positive control group was accompanied by the elevated serum glucose concentration observed in the same animals. Following dietary supplementation with yellow corn powder, serum insulin concentrations increased in a dose-related manner. The 4% supplementation group showed an insulin concentration of  $0.82 \pm 0.06$  mIU/L, corresponding to a 36.67% increase relative to the positive control group. At the 8% supplementation level, serum insulin increased further to  $1.15 \pm 0.07$  mIU/L, representing a 91.67% increase compared with the positive diabetic control.

The simultaneous decrease in serum glucose and increase in serum insulin observed with increasing levels of yellow corn powder indicate a favorable shift in the measured glucose–insulin profile of the diabetic rats. The response was more pronounced in the group receiving 8% yellow corn powder, which exhibited both the lowest serum glucose concentration among the diabetic treatment groups and the highest serum insulin concentration. These findings suggest that the level of yellow corn powder incorporated into the diet influenced the measured metabolic parameters in a concentration-dependent manner under the conditions of the present experiment.

Overall, Figure 4 demonstrates that dietary supplementation with yellow corn powder, particularly at the 8% level, was associated with an improvement in serum glucose and insulin concentrations compared with the positive diabetic control group. However, these findings describe associations between dietary treatment and the measured biochemical parameters and should not, by themselves, be interpreted as evidence of a specific mechanism of action. Further biochemical and physiological investigations would be required to determine the mechanisms underlying these changes.



**Figure 4.** Effects of dietary yellow corn powder supplementation on serum glucose and insulin concentrations in diabetic rats.

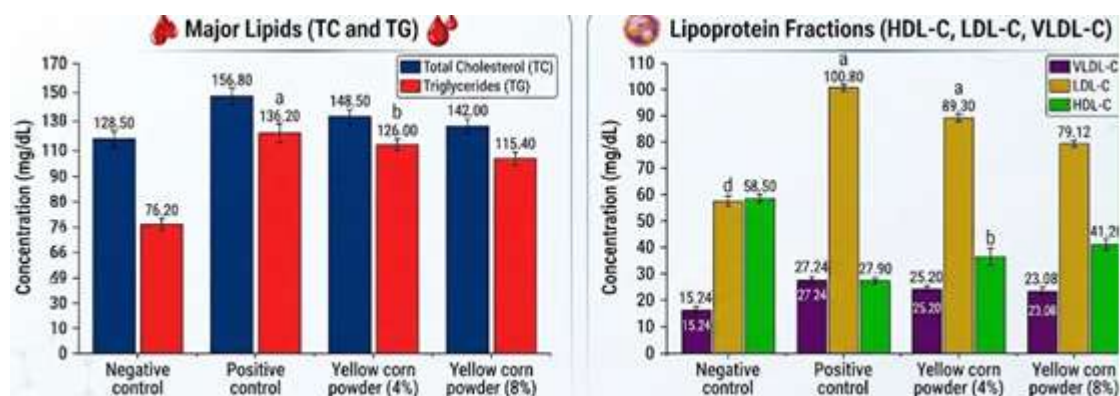
## Effects of Dietary Yellow Corn Powder Supplementation on the Serum Lipid Profile of Diabetic Rats.

Figure 5 illustrates the effects of dietary yellow corn powder supplementation on the serum lipid profile of diabetic rats. The diabetic positive-control group showed a significantly adverse lipid profile compared with the negative-control group ( $P < 0.05$ ), as evidenced by higher serum concentrations of total cholesterol, triglycerides, LDL-C, and VLDL-C, together with a marked reduction in HDL-C. The mean concentrations of total cholesterol, triglycerides, LDL-C, and VLDL-C in the positive-control group were  $156.80 \pm 1.60$ ,  $136.20 \pm 1.15$ ,  $100.80 \pm 1.10$ , and  $27.24 \pm 0.23$  mg/dL, respectively, whereas HDL-C was  $27.90 \pm 0.75$  mg/dL.

Dietary supplementation with yellow corn powder resulted in significant improvements in the serum lipid profile compared with the positive-control group ( $P < 0.05$ ). Rats receiving 4% yellow corn powder showed lower concentrations of total cholesterol, triglycerides, LDL-C, and VLDL-C, accompanied by an increase in HDL-C to  $35.40 \pm 0.68$  mg/dL. These changes were more evident in rats receiving 8% yellow corn powder, in which total cholesterol, triglycerides, LDL-C, and VLDL-C decreased to  $142.00 \pm 1.22$ ,  $115.40 \pm 0.82$ ,  $79.12 \pm 0.85$ , and  $23.08 \pm 0.16$  mg/dL, respectively, while HDL-C increased to  $41.20 \pm 0.60$  mg/dL.

Overall, the figure demonstrates a dose-related improvement in the serum lipid profile with increasing levels of yellow corn powder supplementation. The 8% supplementation level produced the most favorable lipid profile among the diabetic

groups, with values approaching those observed in the negative-control group. These findings suggest that dietary yellow corn powder supplementation was associated with an improvement in lipid abnormalities in diabetic rats, with the greater effect observed at the 8% supplementation level.



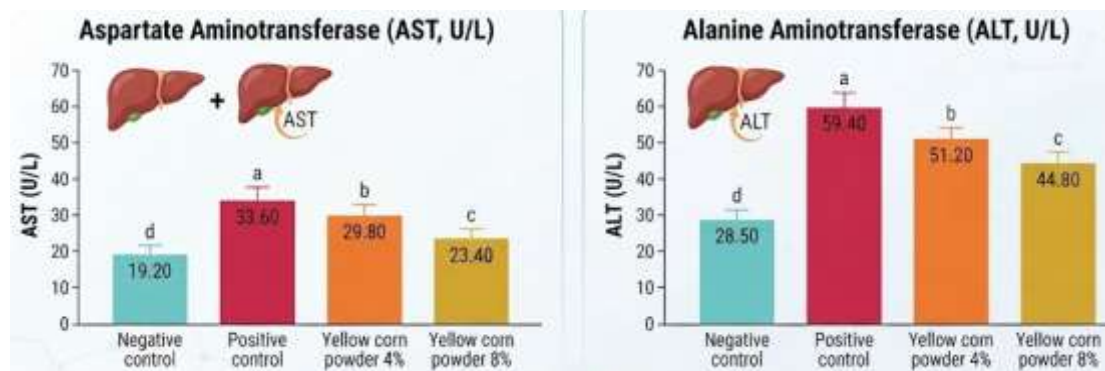
**Figure 5.** Effects of Dietary Yellow Corn Powder Supplementation on the Serum Lipid Profile of Diabetic Rats

## Effects of Dietary Yellow Corn Powder Supplementation on Serum Liver Function Markers in Diabetic Rats

Figure 6 presents the effects of dietary yellow corn powder supplementation on serum liver function markers, as assessed by the activities of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) in diabetic rats. Significant differences were observed among the experimental groups for both enzymes ( $P < 0.05$ ). The negative-control group exhibited the lowest AST and ALT activities, with values of  $19.20 \pm 0.45$  and  $28.50 \pm 0.38$  U/L, respectively. In contrast, the positive-control group showed a marked elevation in both liver enzyme activities, reaching  $33.60 \pm 0.82$  U/L for AST and  $59.40 \pm 0.95$  U/L for ALT. These findings indicate a clear difference in the measured liver function markers between the non-diabetic control animals and the diabetic positive-control group.

Dietary supplementation with yellow corn powder was associated with a significant reduction in serum AST activity compared with the positive-control group ( $P < 0.05$ ). In rats receiving 4% yellow corn powder, AST activity decreased from  $33.60 \pm 0.82$  U/L in the positive-control group to  $29.80 \pm 0.70$  U/L. A greater reduction was observed at the 8% supplementation level, where AST activity declined further to  $23.40 \pm 0.51$  U/L. Thus, the AST values showed a progressive decrease as the level of yellow corn powder supplementation increased from 4% to 8%, with the 8% group approaching the value recorded for the negative-control group.

A similar pattern was observed for serum ALT activity. The positive-control group recorded the highest ALT activity at  $59.40 \pm 0.95$  U/L, whereas supplementation with 4% yellow corn powder reduced ALT activity to  $51.20 \pm 0.81$  U/L. Increasing the supplementation level to 8% resulted in a further decrease to  $44.80 \pm 0.72$  U/L. Although ALT activity remained higher than that of the negative-control group, which recorded  $28.50 \pm 0.38$  U/L, the reduction observed with the 8% supplementation level was greater than that observed with the 4% level. Overall, Figure 6 demonstrates that diabetic rats in the positive-control group had the highest serum AST and ALT activities, while dietary supplementation with yellow corn powder was associated with a progressive reduction in both liver enzyme markers. The 8% supplementation level produced the most pronounced improvement among the supplemented groups, resulting in AST and ALT values that were closer to those observed in the negative-control group. Taken together, these findings suggest that increasing the dietary level of yellow corn powder was associated with a favorable change in the measured serum liver function markers of diabetic rats. However, the observed changes in AST and ALT should be interpreted as biochemical findings and should not, by themselves, be considered definitive evidence of improved hepatic function without complementary histopathological or additional biochemical assessments.



**Figure 6.** Effects of Dietary Yellow Corn Powder Supplementation on Serum Liver Function Markers in Diabetic Rats.

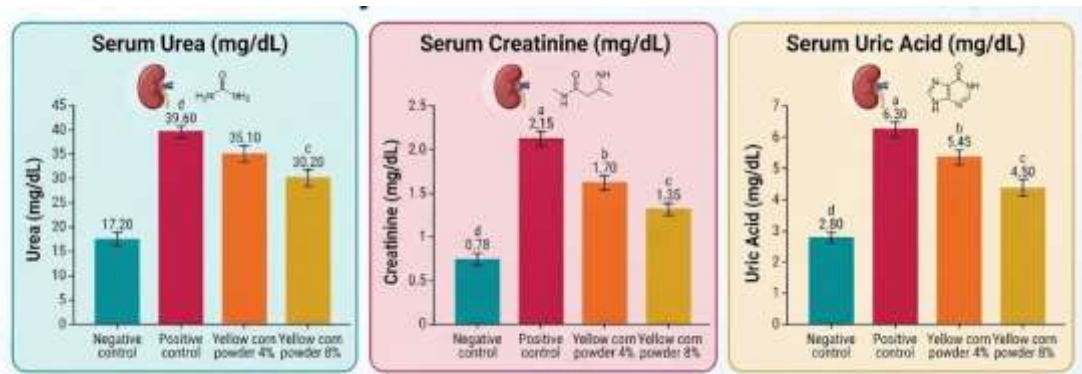
## Effects of Dietary Yellow Corn Powder Supplementation on Serum Kidney Function Markers in Diabetic Rats

Figure 7 illustrates the effects of dietary yellow corn powder supplementation on serum kidney function markers, including urea, creatinine, and uric acid, in diabetic rats. Significant differences were observed among the experimental groups for all measured parameters ( $P < 0.05$ ). The negative-control group exhibited the lowest serum concentrations of urea, creatinine, and uric acid, with values of  $17.20 \pm 0.35$ ,  $0.78 \pm 0.02$ , and  $2.80 \pm 0.07$  mg/dL, respectively. In contrast, the diabetic positive-control group showed marked elevations in all three parameters, reaching  $39.60 \pm 0.75$  mg/dL for urea,  $2.15 \pm 0.07$  mg/dL for creatinine, and  $6.30 \pm 0.18$  mg/dL for uric acid. Dietary supplementation with yellow corn powder was associated with a significant reduction in serum urea concentration compared with the positive-control group ( $P < 0.05$ ). Urea decreased from  $39.60 \pm 0.75$  mg/dL in the positive-control group to  $35.10 \pm 0.62$  mg/dL in rats receiving 4% yellow corn powder. A further reduction was observed in the 8% supplementation group, where the serum urea concentration decreased to  $30.20 \pm 0.55$  mg/dL. Although the value remained higher than that of the negative-control group, the 8% supplementation level produced a greater reduction than the 4% level.

A comparable pattern was observed for serum creatinine. The positive-control group recorded the highest creatinine concentration at  $2.15 \pm 0.07$  mg/dL, whereas supplementation with 4% yellow corn powder reduced this value to  $1.70 \pm 0.05$  mg/dL. Increasing the supplementation level to 8% resulted in a further decrease to  $1.35 \pm 0.04$  mg/dL. Thus, creatinine concentrations progressively declined with increasing levels of yellow corn powder supplementation, with the 8% group showing a value closer to that of the negative-control group ( $0.78 \pm 0.02$  mg/dL).

Serum uric acid showed a similar response across the experimental groups. The highest concentration was recorded in the positive-control group at  $6.30 \pm 0.18$  mg/dL. Supplementation with 4% yellow corn powder reduced the uric acid concentration to  $5.45 \pm 0.15$  mg/dL, while the 8% supplementation level resulted in a further reduction to  $4.50 \pm 0.13$  mg/dL. The value observed in the 8% group was therefore closer to that of the negative-control group, which recorded  $2.80 \pm 0.07$  mg/dL.

Overall, Figure 7 demonstrates a consistent pattern of improvement in the measured serum kidney function markers following yellow corn powder supplementation. Increasing the dietary supplementation level from 4% to 8% was accompanied by progressive reductions in serum urea, creatinine, and uric acid concentrations. Among the diabetic groups, the 8% yellow corn powder treatment produced the most pronounced changes in all three parameters, although the measured values did not completely return to those observed in the negative-control group. These findings indicate that dietary yellow corn powder supplementation was associated with a favorable change in serum biochemical markers related to kidney function in diabetic rats, with the greater response observed at the 8% supplementation level.



**Figure 7.** Effects of Dietary Yellow Corn Powder Supplementation on Serum Kidney Function Markers in Diabetic Rats.

### 3.4. Histopathological Results

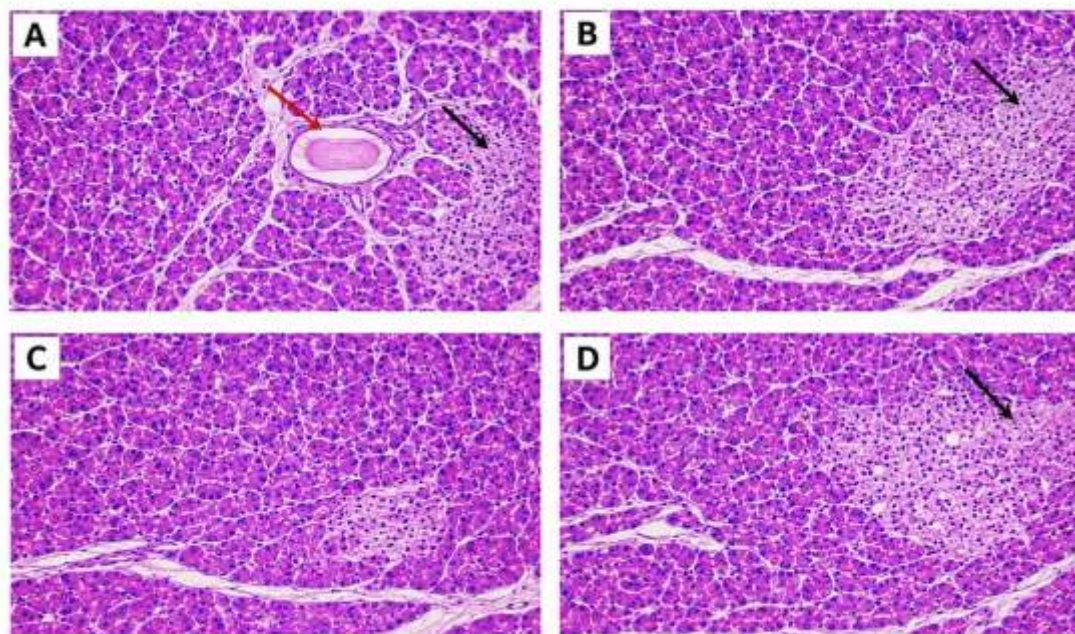
Histopathological examination of pancreatic tissue revealed distinct differences in the pancreatic architecture among the experimental groups (Figure 8).

Group 1 (A) – Control (–Ve): The pancreatic tissue exhibited a well-preserved and essentially normal histological architecture. The exocrine component was composed of closely arranged pancreatic acini with relatively uniform cellular morphology and intact nuclei. The islets of Langerhans were clearly distinguishable from the surrounding exocrine tissue and showed a preserved cellular arrangement without obvious degenerative changes. The overall organization of the pancreatic parenchyma appeared normal, with no apparent pathological alterations.

Group 2 (B) – Control (+Ve): The pancreatic tissue showed noticeable histopathological alterations compared with the normal architecture observed in Group 1. The pancreatic parenchyma was generally maintained; however, the islets of Langerhans exhibited areas of cellular vacuolation, indicating degenerative changes. In addition, dilation of the pancreatic duct was observed, as indicated by the arrow. These alterations suggest that diabetes induction was associated with structural changes involving both the endocrine component and ductal structures of the pancreas.

Group 3 (C) – Yellow corn powder 4%: The pancreatic tissue showed a largely preserved histological architecture compared with the diabetic control group. The pancreatic acini maintained a relatively organized appearance, while the islets of Langerhans remained identifiable within the surrounding exocrine tissue. No prominent inflammatory or necrotic changes were apparent in the examined section. The findings indicated partial preservation of the pancreatic tissue architecture following dietary supplementation with 4% yellow corn powder.

Group 4 (D) – Yellow corn powder 8%: The pancreatic tissue demonstrated generally well-preserved architecture, with relatively organized pancreatic acini and identifiable islets of Langerhans. Focal vacuolar changes were observed in some cells within the islets of Langerhans, as indicated by the arrow. These changes appeared limited in distribution, while the surrounding pancreatic parenchyma retained a relatively normal organization. Overall, the 8% yellow corn powder group showed substantial preservation of pancreatic architecture compared with the diabetic control group. Overall, the histopathological findings demonstrated normal pancreatic morphology in the non-diabetic control group, whereas the diabetic control group exhibited more evident structural alterations, particularly islet cell vacuolation and pancreatic duct dilation. In contrast, dietary supplementation with yellow corn powder at 4% and 8% was associated with relatively preserved pancreatic architecture, with fewer apparent pathological alterations compared with the diabetic control group. The preservation appeared more evident in the 8% supplementation group.



**Figure 8.** Histopathological changes in pancreatic tissue of experimental rats. (A) Normal control group showing normal pancreatic architecture. (B) Diabetic control group showing islet cell vacuolation and pancreatic duct dilation. (C) Diabetic rats supplemented with 4% yellow corn powder showing relatively preserved pancreatic architecture. (D) Diabetic rats supplemented with 8% yellow corn powder showing preserved pancreatic architecture with focal islet cell vacuolation.

## 4. DISCUSSION

The present study investigated the effects of dietary yellow corn powder at 4% and 8% inclusion levels on metabolic, biochemical, and pancreatic outcomes in streptozotocin (STZ)-induced diabetic rats over a 28-day intervention period. Overall, yellow corn supplementation was associated with favorable changes in body weight, glycemic status, serum lipid profile, serum aminotransferase activities, renal biochemical markers, and pancreatic morphology. In general, the 8% inclusion level produced more pronounced changes than the 4% level. Yellow corn powder used in the present study was characterized by a high carbohydrate content (82.63%), followed by protein (9.35%), fat (3.85%), fiber (2.75%), and ash (1.42%). Detectable levels of total phenolics and flavonoids were also observed. These findings are broadly consistent with the nutritional and phytochemical characteristics reported for maize. Recent investigations have demonstrated considerable variation in the phenolic and antioxidant profiles of yellow maize varieties. Zhang et al. (2025), for example, identified multiple phenolic derivatives and observed substantial variation in total phenolic content, total flavonoid content, and antioxidant capacity among 93 yellow maize varieties. Similarly, Cai et al. (2024) reported considerable variation in carotenoid and phenolic composition among different corn cultivars, with lutein and zeaxanthin being prominent carotenoids in yellow corn. However, phytochemical composition varies substantially among cultivars and plant tissues; therefore, the concentrations detected in the present yellow corn powder should not be assumed to be equivalent to those reported for other maize varieties. The presence of total phenolics and flavonoids in the present corn powder suggests that maize contains potentially bioactive phytochemicals. Nevertheless, total phenolic and total flavonoid assays provide aggregate measurements and do not identify individual compounds or establish their absorption, metabolism, or bioavailability. Therefore, the metabolic effects observed in the present study cannot be attributed to a specific phenolic, flavonoid, or carotenoid component. The diabetic control rats showed lower final body weight and body weight gain than the normal control rats despite their higher food intake. This pattern is compatible with metabolic disturbances associated with STZ-induced diabetes, in which impaired glucose utilization and alterations in carbohydrate and protein metabolism may contribute to body-weight loss. Ghasemi and Jeddi (2023) emphasized that STZ is widely used to induce experimental diabetes in rats and

that the resulting metabolic phenotype can vary according to STZ dose, administration conditions, animal characteristics, and other experimental factors. Yellow corn supplementation partially improved body weight gain, with the 8% group showing a greater response than the 4% group. At the same time, food intake decreased progressively with increasing corn inclusion. The improvement in body weight despite lower food intake may suggest more favorable nutrient utilization or improved metabolic status; however, energy expenditure, nutrient digestibility, and nitrogen balance were not measured in the present study. Therefore, this interpretation remains speculative. Similar effects of corn-based dietary interventions on body weight and metabolic parameters have been reported in diabetic rats, although differences in dietary formulation and the presence of other ingredients limit direct comparison with the present study (Aini et al., 2022; Abd Elmeged, et al 2026). The diabetic control group showed marked hyperglycemia and reduced serum insulin concentrations compared with the normal control group, confirming the metabolic effects of STZ administration in the present experimental model. Yellow corn supplementation significantly reduced serum glucose concentrations and increased insulin concentrations, with greater changes observed at the 8% inclusion level. These findings are generally consistent with previous evidence suggesting that corn-based foods may influence glycemic status. (Alzahrani et al., 2026) reported improvements in blood glucose, body-weight-related parameters, and malondialdehyde concentrations in diabetic rats fed corn-flour-based cookies for four weeks. However, their intervention involved cookies containing additional ingredients, including sugar and fat sources, and therefore cannot be considered directly equivalent to the yellow corn powder intervention used in the present study. Cereal grains contain dietary fiber and various bioactive compounds that have been investigated for their potential roles in glucose metabolism, oxidative stress, and advanced glycation. (Dong et al., (2024) reviewed evidence indicating that cereal polyphenols may interfere with the formation of advanced glycation end products and may influence biological pathways associated with oxidative stress and type 2 diabetes. Nevertheless, the present study did not assess insulin sensitivity, glucose absorption,  $\beta$ -cell mass, advanced glycation end products, or molecular signaling pathways. Therefore, the observed improvement in glucose and insulin concentrations should not be interpreted as evidence of a specific underlying mechanism. The diabetic control group showed an unfavorable lipid profile, characterized by increased total cholesterol, triglycerides, LDL-C, and VLDL-C and reduced HDL-C. Yellow corn supplementation improved these abnormalities, with the 8% treatment producing the most pronounced changes. These findings are partly supported by (Abbas et al.,2025 : Ali et al 2026), who investigated resistant starch derived from corn and rice in STZ-induced diabetic rats and reported significant reductions in plasma total lipid and cholesterol concentrations following resistant-starch supplementation. However, the intervention used resistant starch rather than whole yellow corn powder, and therefore the findings provide supportive rather than direct evidence for the present results. The lipid-lowering effects observed in the current study may be related to the combined nutritional characteristics of yellow corn, including dietary fiber and potentially bioactive compounds. However, resistant starch, individual phenolic compounds, phytosterols, and specific carotenoids were not quantified in the present study. Consequently, the contribution of any individual corn component to the observed lipid changes cannot be established. Serum AST and ALT activities were significantly elevated in the diabetic control group and were reduced following yellow corn supplementation. The 8% group showed greater reductions, with values approaching those observed in the normal control group. These findings are compatible with the occurrence of hepatic biochemical disturbances in experimental diabetes. The phenolic and carotenoid constituents reported in yellow maize provide a possible biological context for these observations because such compounds have been investigated for antioxidant and metabolic activities (Mohammed Nour et al., 2025; Zhang et al., 2025). However, this interpretation should remain cautious because the present study did not directly measure hepatic oxidative stress, individual phytochemicals, or hepatic molecular pathways. Importantly, AST and ALT are biochemical indicators of hepatocellular injury and should not be interpreted as comprehensive measures of liver function. Because liver histopathology, bilirubin, albumin, and hepatic oxidative-stress markers were not assessed, the present findings are more appropriately interpreted as an improvement in serum aminotransferase activities rather than definitive evidence of hepatic protection. The diabetic control group showed significantly increased serum urea, creatinine, and uric acid concentrations. Yellow corn supplementation reduced all three markers, with greater improvements observed in the 8% group. These findings are compatible with favorable changes in renal biochemical status in the supplemented groups. Experimental STZ-induced diabetes has been associated with alterations in renal biochemical parameters, although the magnitude and pattern of these changes may depend on the experimental model and severity of diabetes. The reduction in renal biochemical markers may partly reflect the improved glycemic status observed in the supplemented groups. However, serum urea, creatinine, and uric acid concentrations can be affected by factors other than renal filtration, including dietary intake, hydration status, protein metabolism, and muscle mass. Therefore, the present findings provide evidence of favorable

changes in renal biochemical status but do not establish renal protection. Future studies should include urinary albumin excretion, creatinine clearance or other validated filtration measures, together with renal histopathological assessment, to provide stronger evidence regarding renal effects.

Histopathological examination showed relatively preserved pancreatic architecture in the normal control group, whereas the diabetic control group exhibited islet-cell vacuolation and pancreatic duct dilation. The 4% and 8% yellow corn groups showed better preservation of pancreatic architecture, with identifiable islets and fewer apparent pathological alterations than the diabetic control group. These morphological findings were broadly consistent with the observed reduction in serum glucose and increase in insulin concentrations following yellow corn supplementation. However, the histological assessment in the present study was descriptive and did not include quantitative measurements of islet area,  $\beta$ -cell mass, apoptosis, or insulin immunostaining. Thus, the findings suggest relative preservation of pancreatic morphology rather than definitive evidence of  $\beta$ -cell regeneration or restoration. Further studies incorporating quantitative histomorphometry and  $\beta$ -cell-specific immunohistochemical markers would be necessary to determine whether yellow corn supplementation exerts a direct protective effect on pancreatic  $\beta$ -cells.

## 5. CONCLUSION

The present study showed that dietary yellow corn powder was associated with favorable improvements in several metabolic and biochemical parameters in streptozotocin-induced diabetic rats. Supplementation reduced serum glucose, total cholesterol, triglycerides, LDL-C, AST, ALT, urea, creatinine, and uric acid, while increasing serum insulin and HDL-C levels. Improvements in body weight and pancreatic architecture were also observed, particularly at the 8% inclusion level. Overall, the 8% treatment produced more pronounced improvements than the 4% treatment, suggesting potential value of yellow corn powder as a dietary component for improving diabetes-related metabolic disturbances. Further studies are needed to confirm these effects and clarify the underlying mechanisms.

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