Effects of Dietary Whole Oat Powder Supplementation on Biochemical Parameters, Lipid Profile, Liver and Kidney Functions, and Oxidative Stress in Obese Albino Rats

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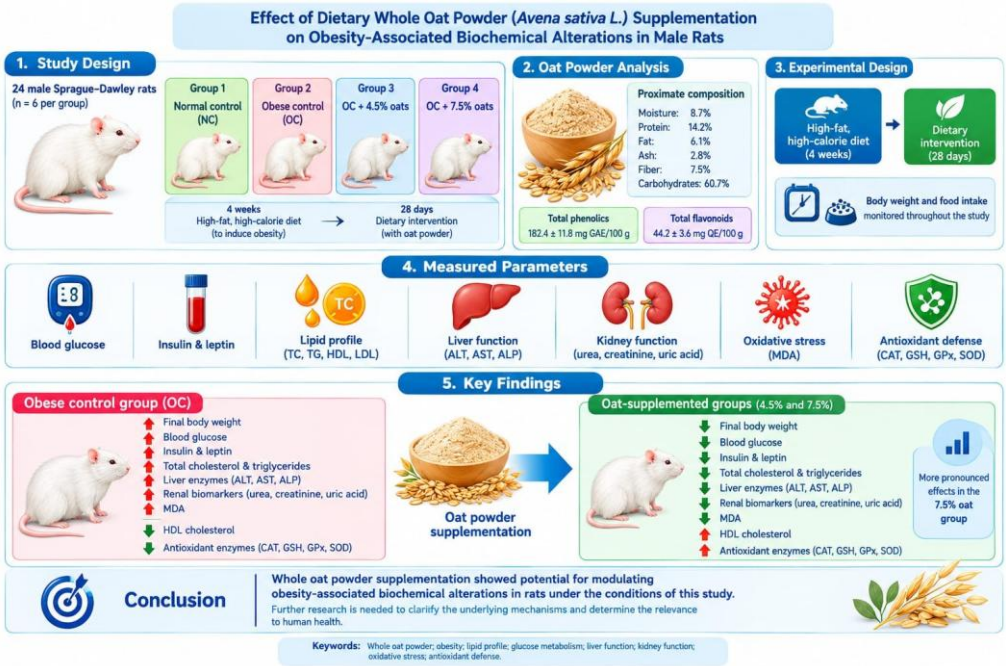
Abstract

This study investigated the effects of dietary whole oat powder (*Avena sativa* L.) supplementation on obesity-associated biochemical alterations in male Sprague–Dawley rats. Twenty-four rats were assigned to four groups (n = 6): a normal control group, an obese control group, and two obese groups receiving diets supplemented with 4.5% or 7.5% whole oat powder. Obesity was induced by feeding a high-fat, high-calorie diet for four weeks, followed by a 28-day dietary intervention. The oat powder was analyzed for proximate composition, total phenolic content, and total flavonoid content. Biochemical assessments included blood glucose, serum insulin and leptin, lipid profile, liver and kidney function biomarkers, and oxidative stress-related parameters. The oat powder contained 182.4 ± 11.8 mg gallic acid equivalents and 44.2 ± 3.6 mg quercetin equivalents of total phenolics and flavonoids, respectively, per 100 g dry weight. Compared with the obese control group, oat-supplemented groups showed lower final body weight, blood glucose, insulin, leptin, total cholesterol, triglycerides, liver enzyme activities, renal biomarkers, and malondialdehyde levels. Conversely, HDL cholesterol and antioxidant defense markers, including catalase, reduced glutathione, glutathione peroxidase, and superoxide dismutase, showed higher values. These changes were generally more pronounced in the 7.5% supplementation group. However, the statistical significance of these differences must be established through appropriate analysis of the experimental data. Overall, whole oat powder supplementation showed potential for modulating obesity-associated biochemical alterations in rats under the conditions of this study. Further research is needed to clarify the underlying mechanisms and determine the relevance of these findings to human health.

Keywords: Whole oat powder; obesity; lipid profile; glucose metabolism; liver function; kidney function; oxidative stress; antioxidant defense.

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Graphical Abstract: Illustrating the Effects of Dietary Whole Oat Powder *(Avena sativa L.)* Supplementation on Obesity-Associated Biochemical Alterations, Lipid Profile, Liver and Kidney Function, and Oxidative Stress in Male Sprague–Dawley Rats.

1. Introduction

Obesity is a complex, chronic disease and a major global public health concern because of its increasing prevalence and association with several noncommunicable diseases. Its development involves complex interactions among genetic, biological, behavioral, environmental, and socioeconomic factors. Obesity is characterized by excessive adiposity that may impair health and increase the risk of metabolic complications, including dyslipidemia, type 2 diabetes, and cardiovascular disease. It is also associated with an increased risk of liver and kidney diseases. Consequently, identifying dietary strategies that may help improve cardiometabolic health has become an important area of nutritional research (World Health Organization [WHO], 2025). Diet plays an important role in the prevention and management of metabolic disorders, and increasing attention has been directed toward whole grains because of their nutritional composition and potential health benefits. Oats (*Avena sativa* L.) are nutritionally valuable cereal grains that contain carbohydrates, proteins, unsaturated fatty acids, dietary fiber, vitamins, minerals, and various bioactive compounds. Their nutritional characteristics distinguish them from several other cereal grains, particularly because of their relatively high content of soluble dietary fiber and their diverse phytochemical constituents. The nutritional and phytochemical composition of oats may vary according to the origin of the grain and the characteristics of its cultivation and processing. Therefore, chemical characterization is important for evaluating the nutritional properties of oat-based ingredients and understanding their potential applications in functional foods (Alemayehu et al., 2023). One of the most important functional components of oats is β-glucan, a soluble dietary fiber that has received considerable attention because of its cholesterol-lowering effects. Oat β-glucan can increase the viscosity of intestinal contents and may influence cholesterol metabolism and the enterohepatic circulation of bile acids. Evidence from systematic reviews and meta-analyses indicates that consuming oats or oat β-glucan can reduce total cholesterol and low-density lipoprotein cholesterol (LDL-C), particularly in individuals with dyslipidemia. However, the magnitude of these effects may vary according to the type of oat product, β-glucan dose, intervention duration, and characteristics of the study population (de Morais Junior et al., 2023; Li et al., 2024).

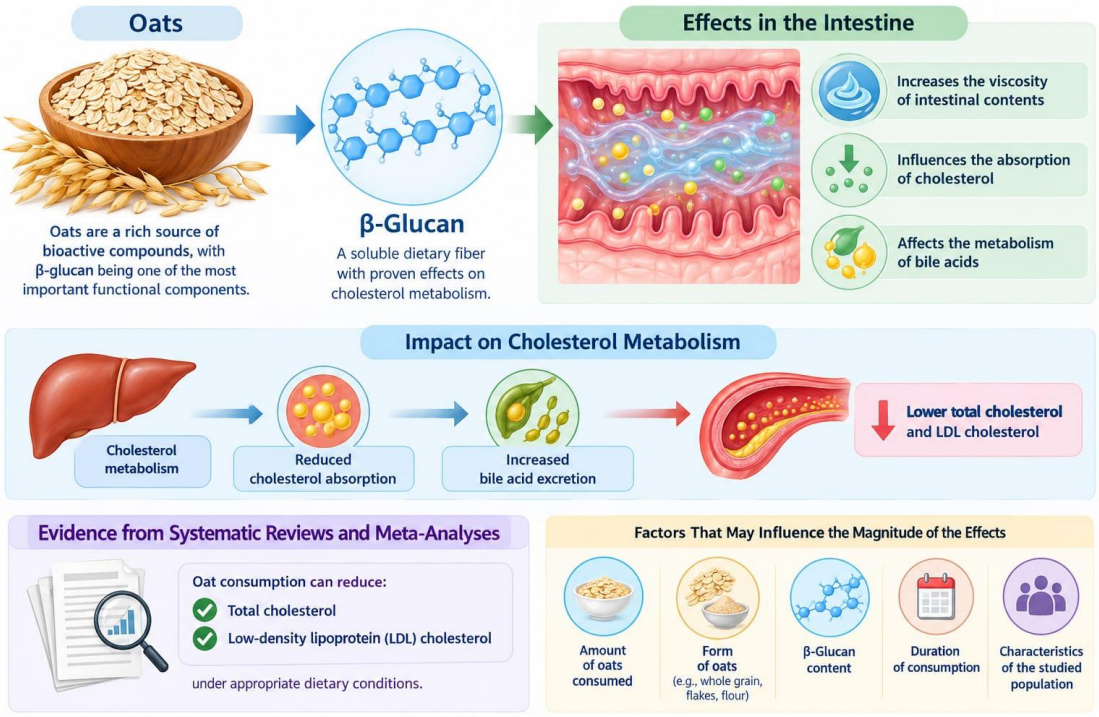


Figure 1. Proposed Mechanisms of Oat β-Glucan in Modulating Cholesterol Metabolism and Factors Influencing Its Cholesterol-Lowering Effects.

In addition to its potential effects on lipid metabolism, oat β-glucan may influence postprandial glucose responses and other aspects of metabolic regulation. A systematic review and meta-analysis of controlled feeding trials found that oat β-glucan reduced postprandial glucose and insulin responses, although the magnitude of these effects depended on factors such as β-glucan dose and molecular weight (Zurbau et al., 2021). These properties make whole oats a relevant dietary ingredient for investigating nutritional strategies targeting obesity-associated metabolic alterations. Beyond their macronutrients and dietary fiber, oats contain several bioactive phytochemicals, including phenolic acids, flavonoids, and avenanthramides. Avenanthramides are distinctive phenolic compounds found in oats and have attracted scientific interest because of their antioxidant and anti-inflammatory activities. These compounds, together

with other oat phenolics, may participate in biological processes related to cellular redox balance and inflammatory responses (Pretorius & Dubery, 2023; Xie et al., 2024). Nevertheless, the concentration and composition of oat phenolics are not uniform across all oat samples. Malunga et al. (2022) demonstrated that genetic and environmental factors can substantially influence the concentrations of phenolic compounds and avenanthramides in oats. Therefore, evaluating the chemical composition and bioactive constituents of a particular oat preparation provides useful information when investigating its potential biological effects. Oxidative stress occurs when the generation of reactive oxygen species exceeds the capacity of antioxidant defense systems to maintain redox balance. In obesity, excessive nutrient availability and disturbances in metabolic regulation may contribute to increased oxidative stress and inflammatory responses. These processes are associated with alterations in glucose metabolism, lipid homeostasis, and tissue function (Martínez-Martínez & Cachofeiro, 2022; Sudar-Milovanovic et al., 2022). The liver plays a central role in glucose and lipid metabolism, whereas the kidneys contribute to the regulation of fluid and electrolyte balance and the elimination of metabolic waste products. Obesity is also associated with an increased risk of kidney disease and metabolic disturbances affecting hepatic function (Verde et al., 2023). Accordingly, biochemical indicators of hepatic and renal function, together with selected oxidative stress markers, can provide complementary information about physiological changes associated with experimental obesity. Studies using experimentally induced obesity in rats have assessed these outcomes together, including liver function markers, antioxidant enzyme activities, and lipid peroxidation indicators (Hamza & Alsolami, 2023). However, these biomarkers must be interpreted collectively and in the context of the experimental model rather than being considered individually as definitive evidence of organ damage or protection. Although the nutritional composition of oats and their potential effects on lipid metabolism have been investigated extensively, further experimental research can help clarify the effects of incorporating whole oat powder into the diets of animals with obesity, particularly when multiple biochemical outcomes are evaluated concurrently. In addition, characterizing the specific oat powder used in an experiment can help establish its proximate composition and quantify selected bioactive constituents, including total phenolic and total flavonoid contents. Integrating these analyses with an animal feeding experiment provides a more comprehensive approach to investigating the relationship between the nutritional properties of oats and their potential metabolic effects (Alemayehu et al., 2023; Malunga et al., 2022). Therefore, the present study was designed to investigate the effects of dietary whole oat powder supplementation at inclusion levels of 4.5% and 7.5% on selected biochemical parameters in obese male albino rats of the Sprague–Dawley strain over a 28-day experimental period. The study included the assessment of blood glucose, lipid profile, liver and kidney function biomarkers, and selected oxidative stress-related parameters. In addition, the chemical composition of the whole oat powder and its selected bioactive constituents, particularly total phenolic and total flavonoid contents, were evaluated. By combining chemical characterization with experimental nutritional assessment, this study aimed to provide further insight into the potential effects of whole oat powder on biochemical alterations associated with obesity.

2. Materials and Methods

2.1. Materials

2.1.1. Plant Material

Whole oat grains (*Avena sativa* L.) were used as the dietary intervention material in the present study. The grains were cleaned to remove visible impurities and foreign materials and then ground into a relatively homogeneous powder. The prepared whole oat powder was incorporated into the experimental diets at inclusion levels of 4.5% and 7.5% (w/w). A representative sample of the powder was retained for chemical characterization, including proximate composition analysis and determination of total phenolic and total flavonoid contents. The powder was stored in clean, airtight containers under appropriate conditions until use.

2.1.2. Experimental Animals

Twenty-four adult male albino rats of the Sprague–Dawley strain, weighing approximately 150 ± 10 g at the beginning of the experiment, were used in this study. The animals were assigned to four experimental groups, with six rats per group (n = 6). The study included a normal control group, an obese control group, and two groups of obese rats receiving dietary whole oat powder at inclusion levels of 4.5% and 7.5%.

2.1.3. Dietary Ingredients and Chemicals

The ingredients used in the preparation of the experimental diets included casein as a protein source, soybean oil, cellulose, sucrose, corn starch, choline chloride, and vitamin and mineral mixtures. The chemical reagents required for the analysis of the oat powder and the biochemical parameters were used according to the analytical procedures and references specified for each determination.

2.2. Preparation of Whole Oat Powder

Whole oat grains were cleaned and ground to obtain a homogeneous powder suitable for incorporation into the experimental diets. The prepared powder was stored in clean, airtight containers under appropriate storage conditions until use. The powder was used directly as a dietary ingredient without solvent extraction or chemical fractionation. A representative sample was retained for the determination of proximate composition, total phenolic content, and total flavonoid content.

2.3. Experimental Animals and Housing Conditions

The rats were allowed to acclimatize to the laboratory environment for one week before the experimental procedures began. During the study, the animals were housed in clean, well-ventilated cages under controlled environmental conditions. The room temperature was maintained at 25 ± 2 ℃, relative humidity at 50–55%, and the light/dark cycle at 12/12 h. Drinking water was provided throughout the experimental period. Animal housing and handling procedures were conducted in accordance with the approved institutional animal-care protocol.

2.4. Induction of Experimental Obesity

Experimental obesity was induced in the designated groups by feeding the rats a high-fat caloric diet (HFCD) for four weeks before the dietary intervention. The normal control group received the basal diet and did not undergo the obesity-induction procedure. Body weight was monitored during the induction period to assess changes associated with high-fat feeding. At the end of this period, the animals assigned to the obese groups were allocated to the obese control group or to the groups receiving whole oat powder supplementation.

2.5. Experimental Design and Dietary Treatment

The experiment consisted of an obesity-induction phase followed by a dietary intervention phase. During the first phase, six rats received the basal diet and served as the normal control group, whereas the remaining 18 rats received the HFCD for four weeks to induce obesity. During the second phase, the obese rats were divided among three experimental groups, each containing six animals. The dietary treatments were as follows:

- **Group 1 (G1), normal control:** Non-obese rats receiving the basal diet without whole oat powder supplementation.
- **Group 2 (G2), obese control:** Obese rats receiving the HFCD without whole oat powder supplementation.
- **Group 3 (G3), 4.5% whole oat powder:** Obese rats receiving the HFCD supplemented with 4.5% whole oat powder.
- **Group 4 (G4), 7.5% whole oat powder:** Obese rats receiving the HFCD supplemented with 7.5% whole oat powder.

The dietary intervention continued for 28 consecutive days. Whole oat powder was incorporated into the designated diets at the specified inclusion levels, expressed as a percentage of the total diet weight (w/w).

Body weight was recorded at the beginning of the experiment, following the obesity-induction phase, where applicable, and at the end of the dietary intervention. Body-weight gain was determined from the difference between the final body weight and the body weight recorded at the beginning of the relevant measurement period. The calculation of percentage body-weight gain should follow a consistent formula based on the corresponding initial body weight for that period.

2.6. Preparation of the Experimental Diets

The basal diet was prepared according to the formulation described by Reeves et al. (1993). The formulation consisted of 14% protein, 5% soybean oil, 3.5% mineral mixture, 1% vitamin mixture, 5% fiber, 10% sucrose, and 0.25% choline chloride. Corn starch was added to make up the remaining proportion to 100%.

The high-fat caloric diet was prepared according to the procedure described by Bhatt et al. (2006). The diet supplied approximately 59% of total dietary energy from fat sources, including sheep fat and soybean oil, 21% from carbohydrates, and 20% from protein. The HFCD was used during the obesity-induction phase and was continued in the obese control group during the dietary intervention. In the treatment groups, whole oat powder was incorporated into the HFCD at levels of 4.5% and 7.5% (w/w).

The diet ingredients were mixed thoroughly to ensure homogeneous distribution of the components. The prepared diets were packed in closed bags and stored under refrigeration at 5 °C until use.

2.7. Proximate Chemical Analysis of Whole Oat Powder

The whole oat powder was analyzed to determine its proximate composition, including moisture, crude protein, crude fat, crude fiber, ash, and carbohydrate content. Moisture content was determined by drying the sample to a constant weight, crude protein by the Kjeldahl method, crude fat by solvent extraction, ash by incineration, and crude fiber by the applicable gravimetric procedure. The analyses were based on the relevant methods described in the *Official Methods of Analysis of AOAC International* (Latimer, 2016).

Carbohydrate content was calculated according to the procedure used for the sample analysis. The calculation method and the treatment of dietary fiber in the carbohydrate value should be clearly specified. Results were expressed on a dry-weight basis where applicable.

2.8. Determination of Total Phenolic and Total Flavonoid Contents

Total phenolic content was determined using the Folin–Ciocalteu colorimetric method, based on the procedure described by Singleton and Rossi (1965). Gallic acid was used as the calibration standard, and the results were expressed as milligrams of gallic acid equivalents per 100 g of dry sample (mg GAE/100 g DW).

Total flavonoid content was determined using the aluminum chloride colorimetric method, based on the procedure described by Zhishen et al. (1999). The results were expressed as milligrams of quercetin equivalents per 100 g of dry sample (mg QE/100 g DW). The extraction and analytical conditions followed the procedures applied in the laboratory.

2.9. Blood Collection and Serum Preparation

At the end of the 28-day dietary intervention, blood samples were collected following an overnight fasting period. Blood collection was performed under appropriate anesthesia according to the approved experimental protocol. The samples were transferred into clean, labeled tubes and allowed to clot before centrifugation at 3,000 × g for 10 min at 4 °C. The separated serum was transferred into labeled tubes and stored at −20 °C until biochemical analysis. Animal handling, blood collection, and euthanasia were conducted according to the approved institutional animal-care protocol.

2.10. Biochemical Analyses

Biochemical analyses were conducted to evaluate changes in glucose regulation, lipid metabolism, liver and kidney function biomarkers, and oxidative stress-related parameters. The analytical methods used for the measurements were based on the references specified for the respective determinations.

2.10.1. Blood Glucose

Glucose concentration was determined using an enzymatic colorimetric method based on glucose oxidase, according to Trinder (1969). The results were expressed in mg/dL.

2.10.2. Serum Lipid Profile

Serum total cholesterol (TC), triglycerides (TG), total lipids (TL), and high-density lipoprotein cholesterol (HDL-C) were determined using the respective analytical methods described by Zollner and Kirsch (1962), Vassault et al. (1986), Hostmark et al. (1991), and Young (2001), as applicable to the individual parameters.

Low-density lipoprotein cholesterol (LDL-C) was estimated using the Friedewald equation (Friedewald et al., 1972), where applicable. Very-low-density lipoprotein cholesterol (VLDL-C) was calculated from triglyceride concentration when the calculation method was used in the experimental analysis. Lipid concentrations were expressed in mg/dL.

2.10.3. Liver Function Biomarkers

Liver function-related biochemical parameters were assessed by determining serum aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) activities. AST and ALT activities were determined using the methods described by Reitman and Frankel (1957), where applicable. ALP activity was determined

according to Roy (1970). The results were expressed in U/L.

2.10.4. Kidney Function Biomarkers

Kidney function-related parameters were evaluated by determining serum urea, creatinine, and uric acid concentrations. These parameters were measured using the respective analytical procedures applied in the laboratory. The results were expressed in mg/dL.

2.10.5. Insulin and Leptin

Serum insulin concentration was determined using the method specified for the assay employed in the study. Serum leptin concentration was determined using the corresponding analytical procedure. The methods and references cited for these determinations should correspond to the assays actually performed in the laboratory.

2.10.6. Oxidative Stress and Antioxidant Defense Markers

Serum malondialdehyde (MDA) was determined as a marker of lipid peroxidation using the thiobarbituric acid reaction, according to Ohkawa et al. (1979). Reduced glutathione (GSH) concentration was determined according to Beutler et al. (1963).

Superoxide dismutase (SOD) activity was determined according to Marklund and Marklund (1974). Catalase (CAT) activity was assessed according to Aebi (1984), where this method was used. Glutathione peroxidase (GPx) activity was determined according to the specific analytical procedure used in the laboratory. The measured concentrations and enzyme activities were expressed in the units specified for the corresponding assays.

2.11. Statistical Analysis

Experimental data were expressed as mean ± standard deviation (SD). Differences among the four experimental groups were analyzed using one-way analysis of variance (ANOVA). When the overall analysis indicated a statistically significant difference, Tukey's honestly significant difference test was used for multiple comparisons, where applicable (Tukey, 1949). Statistical analyses were performed using SPSS software for Windows, version 22.0. Differences were considered statistically significant at $p < 0.05$.

2.12. Ethical Considerations

All animal procedures were conducted in accordance with the approved institutional animal-care protocol and applicable ethical requirements. The study was approved by the Institutional Research Ethics Committee of Al-Baha University, Saudi Arabia (Approval No. 47119677; dated 17 May 2026).

3.RESULTS

3.1 . Composition and phytochemical profile of whole oat powder (*Avena sativa* L.).

Figure 2 illustrates the nutritional composition and phytochemical characteristics of whole oat powder (*Avena sativa* L.) based on the experimental findings of this study. The proximate analysis revealed that total carbohydrates constituted the major measured component, with a concentration of 67.65 ± 0.82 g/100 g dry weight. The crude protein content reached 12.85 ± 0.31 g/100 g dry weight, followed by crude fiber at 10.40 ± 0.35 g/100 g dry weight. The crude fat content was 6.95 ± 0.18 g/100 g dry weight, whereas ash represented the smallest proportion among the reported proximate components, amounting to 2.15 ± 0.06 g/100 g dry weight. These findings describe the distribution of the principal nutritional constituents in the analyzed oat powder. The phytochemical analysis further demonstrated the presence of measurable amounts of total phenolic and flavonoid compounds. The total phenolic content was 182.4 ± 11.8 mg gallic acid equivalents (GAE)/100 g dry weight, while the total flavonoid content was 44.2 ± 3.6 mg quercetin equivalents (QE)/100 g dry weight.

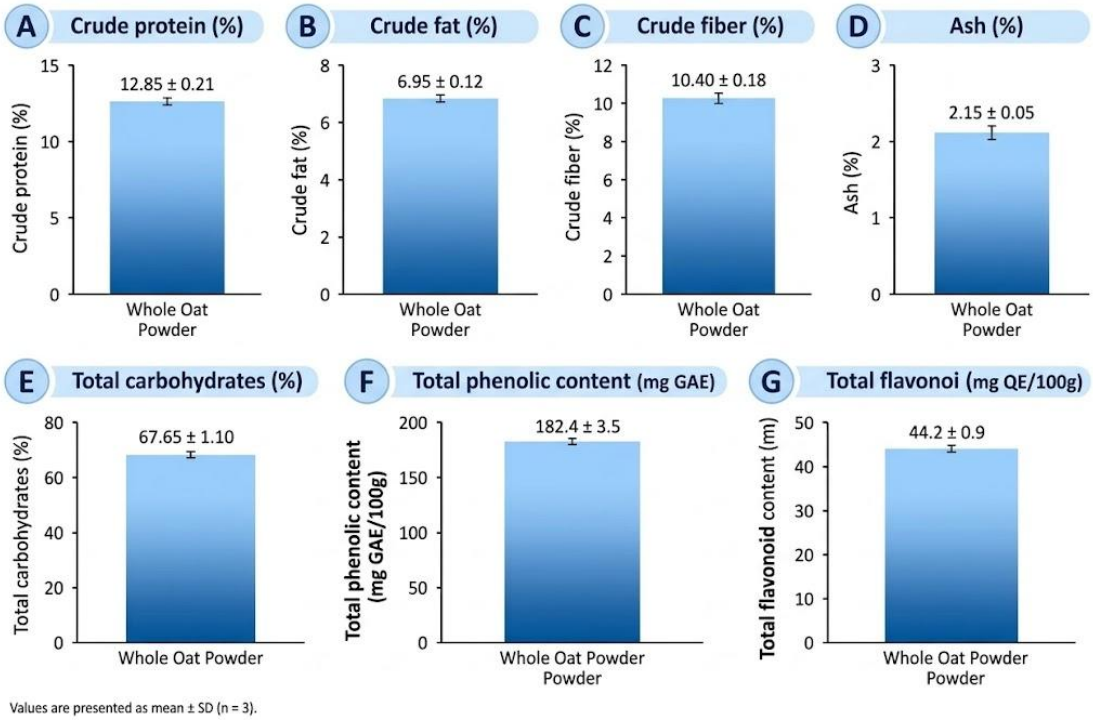


Figure 2. Composition and phytochemical profile of whole oat powder (*Avena sativa* L.). All values are expressed as mean ± standard deviation (SD).
Abbreviations: DW, dry weight; GAE, gallic acid equivalents; QE, quercetin equivalents.

3.2. Biological evaluation

Effects of Dietary Whole Oat Powder Supplementation on Body Weight and Body-Weight Gain in Obese Rats

Figure 3 presents body-weight measurements recorded at the different experimental stages. The initial body weights were similar across the experimental groups, ranging from 151.90 to 152.50 g. Following the four-week obesity-induction phase, the rats assigned to the obese groups had body weights ranging from 237.60 to 238.40 g.

At the end of the 28-day dietary intervention, the final body weight was 288.70 ± 4.05 g in the obese control group, compared with 270.40 ± 3.50 g and 255.30 ± 3.40 g in the groups receiving 4.5% and 7.5% whole oat powder, respectively. The corresponding body-weight gains during the intervention period were 50.30 ± 2.90 g in the obese control group, 32.80 ± 2.45 g in the 4.5% supplementation group, and 17.20 ± 2.10 g in the 7.5% supplementation group.

When percentage body-weight gain was calculated relative to body weight at the beginning of the dietary intervention, the ratios derived from the group means were approximately 21.10%, 13.80%, and 7.22% for G2, G3, and G4, respectively. These values indicate progressively lower numerical body-weight gains across the obese control, 4.5% oat, and 7.5% oat groups. The normal control group gained 40.40 g between the beginning and end of the overall study period; however, this value represents a different measurement interval and should not be directly compared with the four-week intervention gains in the obese groups.

The statistical significance of differences in final body weight and body-weight change should be determined using the appropriate analysis of the individual-animal data. Claims of significant differences or a statistically significant group-by-time effect should be included only after verification of the corresponding statistical results.

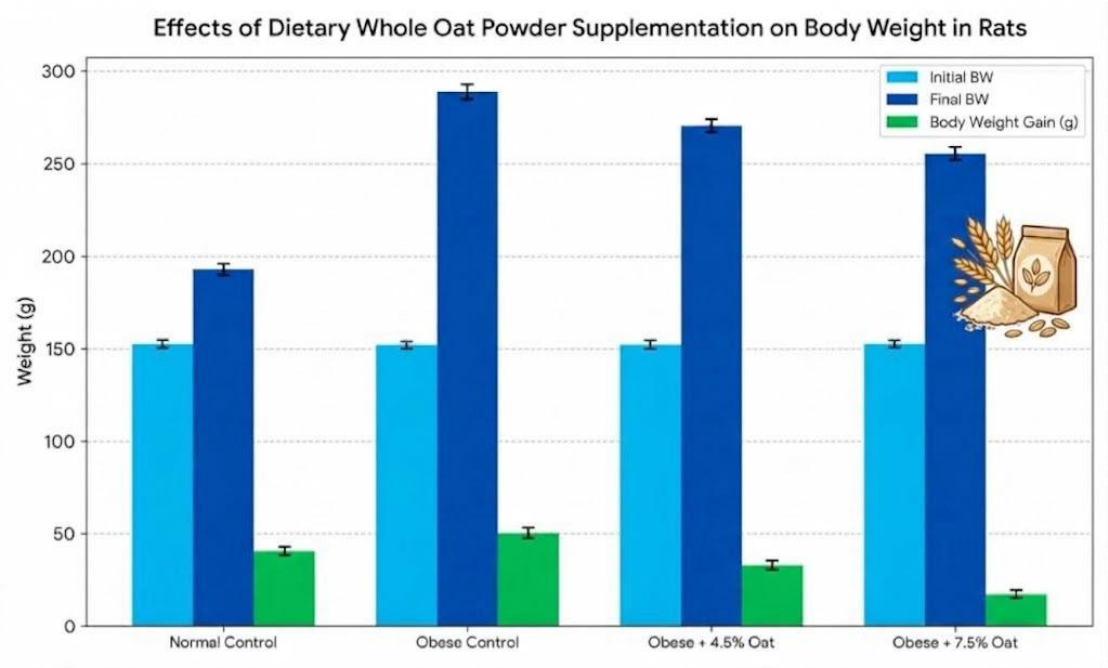


Figure 3. Effects of dietary whole oat powder supplementation on body weight and body weight gain in obese rats.

3.3.Biochemical Analysis

- **Serum Lipid Profile**

Effects of dietary whole oat powder supplementation on the lipid profile of obese rats.

As shown in Figure 4, the obese control group exhibited an unfavorable lipid profile compared with the normal control group. Total cholesterol increased from 81.20 ± 2.30 to 148.90 ± 4.50 mg/dL, while triglyceride concentrations rose from 85.60 ± 3.00 to 162.10 ± 4.80 mg/dL. Total lipid levels also increased from 358.40 ± 9.10 to 528.30 ± 11.50 mg/dL. In addition, the obese control group showed a reduction in HDL-C concentration, from 44.10 ± 1.60 to 24.60 ± 1.40 mg/dL, accompanied by increases in LDL-C and VLDL-C concentrations to 91.20 ± 3.40 and 32.40 ± 0.95 mg/dL, respectively. Dietary supplementation with whole oat powder was associated with improvements in the measured lipid parameters compared with the obese control group. At the 4.5% supplementation level, total cholesterol and triglyceride concentrations decreased to 122.30 ± 3.80 and 131.40 ± 4.10 mg/dL, respectively, while total lipids declined to 471.60 ± 9.80 mg/dL. HDL-C increased to 31.50 ± 1.50 mg/dL, whereas LDL-C and VLDL-C decreased to 63.80 ± 2.60 and 26.20 ± 0.82 mg/dL, respectively.

More pronounced numerical changes were observed in rats receiving 7.5% whole oat powder. Total cholesterol, triglycerides, and total lipids decreased to 104.50 ± 3.10, 111.20 ± 3.50, and 426.80 ± 8.90 mg/dL, respectively. Meanwhile, HDL-C increased to 37.40 ± 1.70 mg/dL, and LDL-C and VLDL-C declined to 44.10 ± 2.20 and 22.20 ± 0.70 mg/dL, respectively.

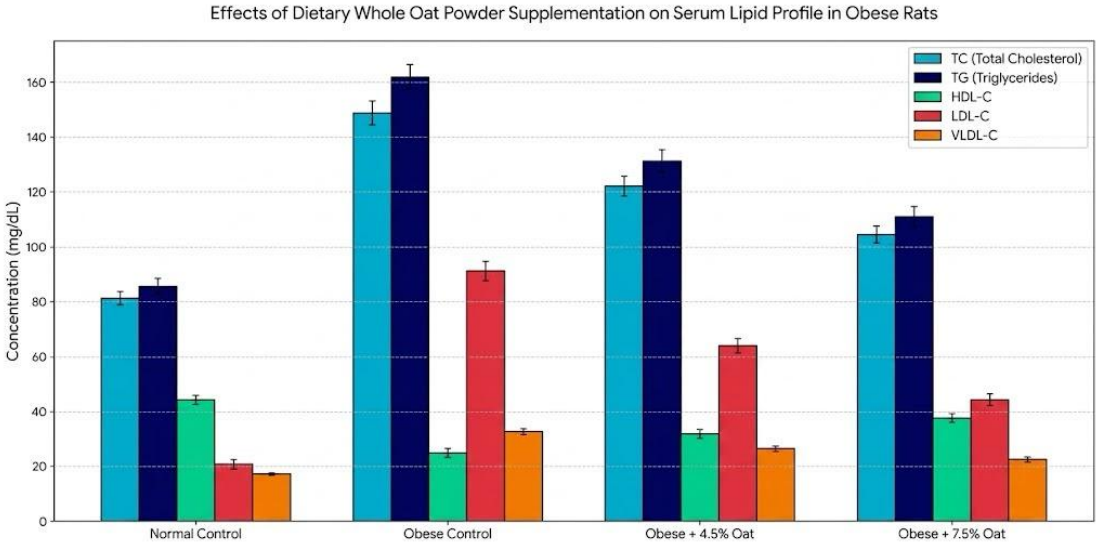


Figure 4. Effects of dietary whole oat powder supplementation on the lipid profile of obese rats.

- **Liver Function**

Effects of dietary whole oat powder supplementation on serum liver enzyme activities in obese rats.

Figure 5 illustrates the changes in serum aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) activities among the experimental groups. The obese control group exhibited higher activities of all three enzymes than the normal control group. AST activity increased from 82.50 ± 1.90 U/L in the normal control group to 154.20 ± 3.20 U/L in the obese control group. Likewise, ALT activity rose from 41.20 ± 1.40 to 89.30 ± 2.60 U/L, while ALP activity increased from 108.40 ± 3.00 to 182.10 ± 3.90 U/L. These findings demonstrate differences in the measured serum enzyme activities between the normal and obese control groups.

Dietary supplementation with whole oat powder was associated with reductions in serum liver enzyme activities compared with the obese control group. In rats receiving a diet supplemented with 4.5% whole oat powder, AST activity decreased to 122.80 ± 2.70 U/L, representing a numerical reduction of approximately 20.4% relative to the obese control group. ALT activity declined to 68.90 ± 2.10 U/L, corresponding to a reduction of approximately 22.8%, whereas ALP activity decreased to 150.50 ± 3.40 U/L, representing a reduction of approximately 17.4%.

More pronounced reductions were observed in rats fed a diet containing 7.5% whole oat powder. AST activity reached 99.40 ± 2.30 U/L, approximately 35.5% lower than that of the obese control group. ALT activity decreased to 54.20 ± 1.70 U/L, corresponding to a reduction of approximately 39.3%, while ALP activity declined to 130.10 ± 3.10 U/L, representing a reduction of approximately 28.6%. Thus, the group receiving 7.5% whole oat powder exhibited lower activities of all three measured enzymes than the group receiving 4.5% supplementation.

A comparison between the two oat-supplemented groups indicates that the higher supplementation level was associated with additional reductions in AST, ALT, and ALP activities. These changes suggest that dietary whole oat powder may influence biochemical markers associated with liver function in obese rats.

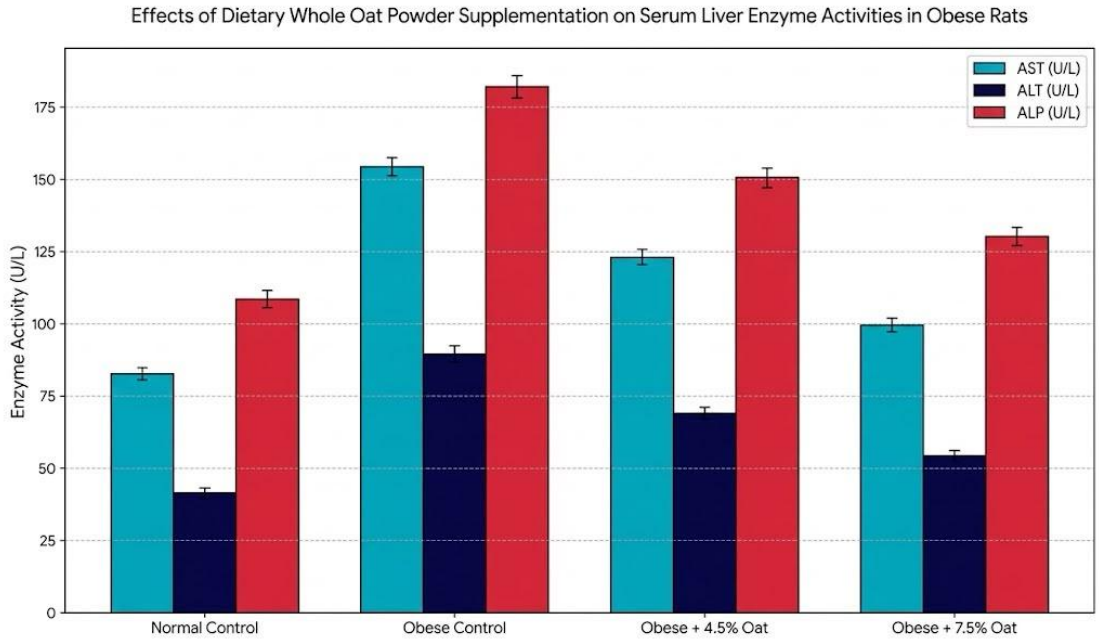


Figure 5. Effects of dietary whole oat powder supplementation on serum liver enzyme activities in obese rats.

- **Renal Function Biomarkers**

Effects of dietary whole oat powder supplementation on selected renal function biomarkers in obese rats

Figure 6 illustrates the changes in urea, creatinine, and uric acid levels among the experimental groups. The obese control group (G2) exhibited higher levels of all three biomarkers than the normal control group (G1). Urea levels increased from 24.80 ± 1.90 mg/dL in the normal control group to 46.50 ± 3.10 mg/dL in the obese control group. Similarly, creatinine levels increased from 0.45 ± 0.04 to 0.79 ± 0.07 mg/dL, while uric acid levels rose from 2.70 ± 0.25 to 4.90 ± 0.38 mg/dL.

Dietary supplementation with whole oat powder was associated with lower levels of these biomarkers compared with the obese control group. In rats receiving 4.5% whole oat powder (G3), urea, creatinine, and uric acid levels decreased to 35.10 ± 2.60 mg/dL, 0.65 ± 0.06 mg/dL, and 4.00 ± 0.32 mg/dL, respectively. Greater numerical reductions were observed in rats receiving 7.5% whole oat powder (G4), with corresponding values of 29.20 ± 2.30 mg/dL for urea, 0.56 ± 0.05 mg/dL for creatinine, and 3.30 ± 0.28 mg/dL for uric acid.

Overall, the results show that the groups supplemented with whole oat powder had lower measured levels of urea, creatinine, and uric acid than the obese control group. The lowest values for all three biomarkers were observed in the group receiving 7.5% whole oat powder.

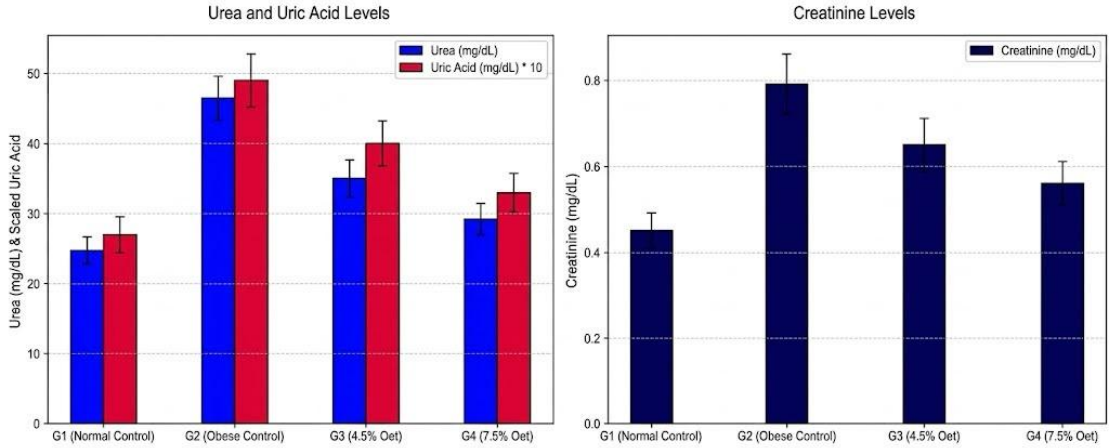


Figure 6. Effects of dietary whole oat powder supplementation on selected renal function biomarkers in obese rats.

- **blood glucose and pancreatic enzyme activities**

Effects of dietary whole oat powder supplementation on blood glucose and serum insulin and leptin concentrations in obese rats.

Figure 7 presents the changes in blood glucose levels and serum insulin and leptin concentrations across the experimental groups. The obese control group exhibited higher values for all three parameters than the normal control group. Blood glucose increased from 89.60 ± 2.10 mg/dL in the normal control group to 164.20 ± 3.90 mg/dL in the obese control group. Similarly, serum insulin concentration increased from 7.90 ± 0.40 to 17.80 ± 0.70 µIU/mL, while serum leptin concentration rose from 2.90 ± 0.22 to 8.60 ± 0.38 ng/mL. Dietary supplementation with whole oat powder was associated with lower blood glucose levels and serum insulin and leptin concentrations compared with the obese control group. In rats receiving 4.5% whole oat powder, blood glucose decreased to 134.50 ± 3.30 mg/dL, serum insulin declined to 13.80 ± 0.55 µIU/mL, and serum leptin decreased to 6.80 ± 0.32 ng/mL. These values indicate numerical reductions 18.1%, 22.5%, and 20.9%, respectively, relative to the obese control group. More pronounced changes were observed in rats receiving 7.5% whole oat powder. Blood glucose decreased to 109.80 ± 2.70 mg/dL, representing a reduction of approximately 33.1% compared with the obese control group. Serum insulin and leptin concentrations also declined to 10.40 ± 0.48 µIU/mL and 5.30 ± 0.28 ng/mL, corresponding to reductions of approximately 41.6% and 38.4%, respectively. Overall, the results show that the group receiving 7.5% whole oat powder had lower blood glucose, insulin, and leptin values than the group receiving 4.5% supplementation. This pattern suggests a potential association between dietary oat inclusion and improvements in the measured metabolic parameters in obese rats.

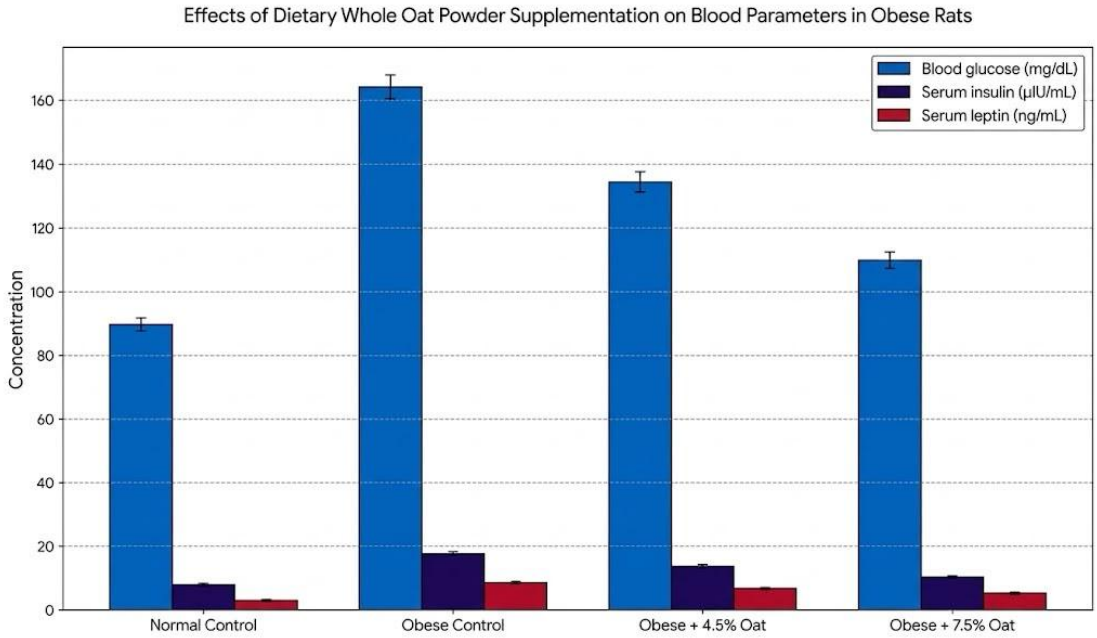


Figure 7. Effects of dietary whole oat powder supplementation on blood glucose and serum insulin and leptin concentrations in obese rats.

- **Antioxidant Markers**

Effects of dietary whole oat powder supplementation on serum malondialdehyde levels and selected antioxidant defense markers in obese rats

Figure 8 illustrates the changes in serum malondialdehyde (MDA) levels and selected antioxidant defense markers, including catalase (CAT), reduced glutathione (GSH), glutathione peroxidase (GPx), and superoxide dismutase (SOD), among the experimental groups. The obese control group (G2) exhibited a higher MDA level than the normal control group (G1), increasing from 1.95 ± 0.10 to 4.65 ± 0.18 nmol/mL. In contrast, the activities of the antioxidant enzymes and the GSH level were lower in the obese control group. CAT activity decreased from 44.20 ± 1.40 to 17.50 ± 0.85 U/mL, GSH concentration declined from 5.40 ± 0.19 to 2.25 ± 0.14 µmol/L, GPx activity decreased from 64.10 ± 1.60 to 29.80 ± 1.10 U/mL, and SOD activity declined from 188.40 ± 4.50 to 102.10 ± 3.40 U/mL.

Dietary supplementation with whole oat powder was associated with lower MDA levels and higher antioxidant defense marker values compared with the obese control group. In rats receiving 4.5% whole oat powder (G3), the MDA level decreased to 3.45 ± 0.15 nmol/mL, while CAT activity, GSH concentration, GPx activity, and SOD activity increased to 28.90 ± 1.05 U/mL, 3.55 ± 0.15 µmol/L, 44.20 ± 1.35 U/mL, and 138.90 ± 3.70 U/mL, respectively.

More pronounced numerical changes were observed in rats receiving 7.5% whole oat powder (G4). The MDA level decreased further to 2.75 ± 0.13 nmol/mL, whereas CAT activity increased to 36.20 ± 1.15 U/mL, GSH concentration to 4.35 ± 0.16 µmol/L, GPx activity to 53.90 ± 1.25 U/mL, and SOD activity to 163.50 ± 3.90 U/mL. Thus, the 7.5% supplementation group showed lower MDA levels and higher values for all measured antioxidant defense markers than the 4.5% supplementation group.

Overall, these findings indicate that dietary whole oat powder supplementation was associated with a reduction in the lipid peroxidation marker MDA and increases in selected antioxidant defense markers in obese rats. The observed pattern was more pronounced at the 7.5% supplementation level.

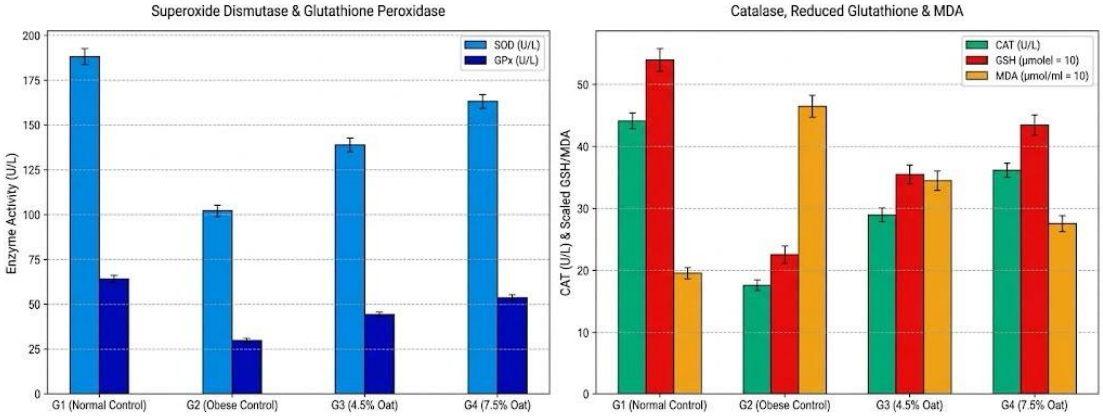


Figure 8. Effects of dietary whole oat powder supplementation on serum malondialdehyde levels and selected antioxidant defense markers in obese rats

4- Discussion

The present study investigated the effects of dietary whole oat powder (*Avena sativa* L.) supplementation at two inclusion levels (4.5% and 7.5%) on body weight, glucose and hormone-related parameters, lipid profile, liver and kidney function biomarkers, and oxidative stress-related measures in obese male Sprague–Dawley rats. Overall, the observed patterns

suggest that whole oat powder supplementation may influence several metabolic disturbances associated with diet-induced obesity. The changes appeared generally more pronounced in the group receiving 7.5% oat powder. Nevertheless, these findings should be interpreted in accordance with the statistical results of the experiment, and numerical differences should not be described as statistically significant unless confirmed by the appropriate analyses (Percie du Sert et al., 2020). The lower final body weights observed in the oat-supplemented groups, relative to the obese control group, suggest a potential beneficial effect of dietary oat inclusion on body-weight regulation under the experimental conditions. Oats contain soluble and insoluble dietary fibres, including β-glucan, which may influence gastrointestinal function, nutrient absorption, and postprandial physiological responses. However, the contribution of these mechanisms to the body-weight changes observed in the present experiment remains uncertain because food intake, energy intake, and the β-glucan content of the oat powder were not reported as measured outcomes. Furthermore, clinical evidence concerning lipid-related benefits of oats cannot independently establish an anti-obesity effect in rats (de Morais Junior et al., 2023; Li et al., 2024). Accordingly, the lower body weight observed in the present study should be interpreted as a potentially favourable experimental outcome rather than definitive evidence of a specific anti-obesity mechanism. Future experiments should measure daily food consumption and energy intake and characterize the dietary fibre composition of the supplemented powder to determine whether changes in body weight are associated with differences in energy intake, dietary energy density, or other physiological processes. The observed reductions in blood glucose, serum insulin, and leptin in the oat-supplemented groups suggest that oat inclusion may have influenced metabolic parameters associated with obesity. However, these measurements alone are insufficient to demonstrate improved insulin sensitivity or identify the underlying physiological pathway. Although oat β-glucan has been investigated for its potential influence on postprandial glucose responses, the magnitude of its effects depends on the dose, physicochemical characteristics, food matrix, and experimental conditions. The European Food Safety Authority's assessment highlighted uncertainty regarding the consistency of glycaemic effects under the specific conditions evaluated (EFSA Panel, 2025). Because β-glucan was not quantified in the oat powder used in the present study, its specific contribution cannot be established. Moreover, if glucose was measured at a single time point, the results should not be interpreted as direct evidence of improved glucose tolerance. Glucose-tolerance testing and an appropriate assessment of insulin sensitivity would provide stronger evidence for such conclusions. The reduction in circulating leptin may be associated with differences in body weight, adipose tissue mass, or energy balance. Nevertheless, without measurements of body composition, adipose tissue mass, or relevant endocrine pathways, it is not possible to determine the principal factor responsible for the observed changes. Thus, the glucose, insulin, and leptin findings should be regarded as indicators of potentially altered metabolic status rather than definitive evidence of a particular mechanism. An important finding of this study was the generally more favourable lipid profile observed in the oat-supplemented groups, including lower total cholesterol and triglyceride concentrations and higher HDL cholesterol values, compared with the obese control group. These observations are relevant because oat-based dietary interventions have been investigated extensively for their effects on blood lipid concentrations. A systematic review and meta-analysis by de Morais Junior et al. (2023) evaluated the separate effects of whole oats and isolated β-glucan on lipid profiles. Similarly, Yu et al. (2022) reported reductions in total cholesterol and LDL cholesterol following β-glucan supplementation in hypercholesterolemic adults. More recently, Li et al. (2024), in a systematic review and meta-analysis of 17 randomized controlled trials involving 1,731 participants with dyslipidaemia, reported evidence supporting reductions in total cholesterol and LDL cholesterol, whereas the pooled effects on triglycerides and HDL cholesterol were limited. Collectively, these findings support the potential lipid-modulating properties of oats, while indicating that the effects vary according to the lipid parameter, intervention, and study population. One proposed explanation for the cholesterol-lowering effects of oats is the capacity of soluble β-glucan to increase intestinal viscosity and influence bile acid metabolism and enterohepatic circulation. The European Food Safety Authority concluded that oat β-glucan consumption can contribute to lowering blood cholesterol when consumed under the conditions specified in its scientific assessment (EFSA Panel on Dietetic Products, Nutrition and Allergies, 2010). However, this mechanism was not directly investigated in the present experiment. Furthermore, because the β-glucan content of the supplemented powder was not determined, the observed changes cannot be attributed specifically to this component. The higher HDL cholesterol values and lower triglyceride concentrations observed in the present study should also be interpreted cautiously because human meta-analyses have not consistently demonstrated improvements in these parameters following oat or β-glucan interventions (Li et al., 2024; Yu et al., 2022). Differences between the present animal model and human studies may reflect variation in dietary composition, intervention duration, dose, and lipid metabolism. In addition, LDL cholesterol and very-low-density lipoprotein cholesterol values should be checked against the analytical or calculation method used. If these fractions were estimated using equations developed for human samples, their validity in rat serum should be established rather than assumed. The lower activities of liver-associated enzymes observed in the oat-supplemented groups may indicate a more favourable biochemical profile under the experimental conditions. Nevertheless, serum enzyme activities alone do not establish that liver tissue was protected from structural injury or that hepatic steatosis was reduced. Oats contain phenolic compounds, including avenanthramides, which have been investigated for their antioxidant and anti-inflammatory properties across experimental systems (Xie et al., 2024). These findings provide a biological rationale for investigating whether oat-derived compounds contribute to changes in metabolic and oxidative-stress-related outcomes. However, the present study measured total phenolic and flavonoid contents rather than individual compounds and did not directly assess inflammatory signalling, hepatic lipid accumulation, or the activity of specific molecular pathways. Consequently, the contribution of avenanthramides or other individual phytochemicals cannot be inferred from the current findings. A more definitive evaluation would require complementary evidence, including liver histopathology, hepatic triglyceride measurements, and, where appropriate, inflammatory or molecular

markers. Accordingly, the present results support a possible improvement in liver-associated biochemical markers, but stronger evidence is required before concluding that whole oat powder prevents or reverses liver injury.

The lower concentrations of renal function biomarkers in the oat-supplemented groups may suggest a more favourable biochemical profile in the treated animals. Nevertheless, serum renal biomarkers can be influenced by multiple physiological and analytical factors, and their interpretation depends on the specific analyte, assay, and experimental context. Without complementary measurements, such as urinalysis, renal histopathology, or additional validated functional assessments where appropriate, it is not possible to conclude that oat supplementation directly improved kidney function or prevented renal injury. Therefore, these findings should be interpreted as changes in renal-associated biochemical markers rather than definitive evidence of a renoprotective effect. The lower malondialdehyde (MDA) levels and higher values of antioxidant defence markers, including catalase, reduced glutathione, glutathione peroxidase, and superoxide dismutase, suggest that oat supplementation may have been associated with a more favourable oxidative-stress profile. MDA is commonly used as an indicator of lipid peroxidation, whereas the measured antioxidant enzymes and glutathione are components of cellular antioxidant defence. Considered together, these markers provide complementary information about oxidative damage and antioxidant capacity. The phenolic composition of oats offers a plausible basis for investigating this association. Xie et al. (2024) reviewed the biological properties of oat avenanthramides and described evidence of antioxidant and anti-inflammatory activity across experimental systems. Nevertheless, total phenolic and flavonoid measurements do not identify the individual compounds responsible for the observed pattern. Furthermore, antioxidant activity demonstrated in chemical or in vitro systems does not necessarily establish equivalent effects in living animals, where absorption, metabolism, tissue distribution, and interactions among dietary components may influence biological responses.

It is also important to distinguish an association between oat supplementation and antioxidant markers from evidence of a specific antioxidant mechanism. The current results do not establish whether the changes arose from direct radical-scavenging activity, altered endogenous antioxidant regulation, reduced lipid peroxidation, or secondary effects associated with changes in body weight and metabolism. Measuring individual oat phenolics, relevant signalling pathways, and additional oxidative-damage markers would help clarify these possibilities. Thus, the findings provide a basis for further investigation of the relationship between whole oat powder supplementation and oxidative-stress status in diet-induced obesity. The present findings suggest that dietary whole oat powder, particularly at the 7.5% inclusion level, may be associated with favourable changes in selected metabolic, lipid-related, liver-associated, renal-associated, and oxidative-stress-related parameters in obese male Sprague–Dawley rats. However, the apparent dose-related pattern should be confirmed statistically, and the absence of direct measurements of food intake, β-glucan content, tissue pathology, and specific molecular mechanisms limits causal interpretation. Future studies should incorporate comprehensive dietary characterization, appropriate metabolic testing, organ histopathology, and validated statistical analyses to establish the reproducibility, magnitude, and biological significance of these observations. The results should therefore be interpreted as preliminary evidence from an animal model rather than direct evidence of clinical efficacy in humans.

6. Conclusion

The findings suggest that dietary whole oat powder supplementation may help improve several obesity-associated biochemical alterations in male Sprague–Dawley rats, including glucose metabolism, lipid profile, liver and kidney function biomarkers, and oxidative stress-related parameters. The 7.5% supplementation group generally showed more favourable numerical changes than the 4.5% group. However, these findings require confirmation through appropriate statistical analysis. Further studies are needed to clarify the underlying mechanisms, assess long-term effects, and determine the potential relevance of these findings to human health.

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