Effect of *Solanum lycopersicum* Supplementation on Lipid Profile and Atherogenic Indices in Wistar Rats Fed a High-Fat Diet

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ABSTRACT

This study evaluated the potential of *Solanum lycopersicum* (tomato) powder supplementation in preventing high-fat diet (HFD)-induced metabolic, hepatic, and renal complications. Diets rich in fat, often associated with increased consumption of junk food, are prevalent and contribute to oxidative stress and chronic inflammation. Nutraceuticals with antioxidant properties have been proposed as accessible and cost-effective strategies for mitigating such effects. Twenty-eight Wistar rats were assigned to four dietary groups: standard diet, HFD, HFD supplemented with 3.5% tomato powder, and standard diet supplemented with 3.5% tomato powder. Growth parameters, glycemic control, lipid profile, and markers of liver and kidney function were assessed using blood glucose monitoring, lipid profiling, and enzymatic assays. Results showed that rats fed tomato-supplemented HFD had higher feed intake and weight gain compared to the unsupplemented HFD group. Serum lipid analysis revealed increased cholesterol, triglycerides, and lipoprotein levels in the supplemented groups. Liver enzyme activities (AST and ALT) were significantly elevated in the supplemented standard diet group, indicating possible hepatic stress. Renal function markers, including urea and creatinine, also showed significant alterations, suggesting potential kidney involvement. Atherogenic indices, including Atherogenic Index of Plasma (AIP), Cardiac Risk Index I (CRI-I), and Cardiac Risk Index II (CRI-II), were evaluated. Although tomato supplementation did not cause severe electrolyte imbalance, findings indicate limited benefits in weight control and lipid regulation, with possible adverse effects on liver and kidney function. These results highlight the need for further investigation before recommending tomato powder supplementation in high-fat diets.

Keywords: Cardiovascular risk; Dyslipidemia; Hepatoprotection; Metabolic health; Renoprotection; Tomato supplementation

INTRODUCTION

Obesity and its associated complications have reached epidemic proportions globally, driven largely by the overconsumption of high-fat diets (HFDs) which disrupt energy homeostasis and promote chronic metabolic diseases such as type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD), and various cancers (Steven *et al.*, 2012; Kennedy *et al.*, 2009). In low- and middle-income populations, including Nigeria, the burden of HFD-induced diseases is increasingly prevalent due to nutrition transitions and lifestyle changes. The World Health Organization (WHO) estimates that over 1.1 billion adults worldwide are overweight, with 115 million affected by obesity-related disorders, especially in economically vulnerable regions (WHO, 2015).

Mechanistically, HFDs contribute to dyslipidemia by increasing levels of total cholesterol (TC), triglycerides

(TG), and low-density lipoprotein cholesterol (LDL-C), while simultaneously reducing high-density lipoprotein cholesterol (HDL-C) (Chen *et al*., 2023). This altered lipid profile increases the risk of atherosclerosis and cardiovascular complications. Atherogenic indices—such as Castelli's Risk Index I (TC/HDL-C) and II (LDL-C/HDL-C)—have been employed as predictive markers of cardiovascular risk due to their sensitivity in reflecting the balance between protective and harmful lipids (Kazemi *et al*., 2018).

While pharmacological agents are available to manage lipid abnormalities, their long-term use is often associated with side effects, prompting the search for safer, natural alternatives. *Solanum lycopersicum* (tomato), a nutrient-rich fruit, contains potent antioxidants such as lycopene, vitamin C, flavonoids, and phenolic compounds (Britton *et al*., 2004). Epidemiological evidence suggests that diets high in lycopene can have protective cardiovascular effects and may counteract the deleterious impact of HFDs (Chen *et al*., 2023).

This study, therefore, investigates the effect of *Solanum lycopersicum* supplementation on lipid profile and atherogenic indices in Wistar rats fed a high-fat diet. The primary objective is to determine whether dietary inclusion of *S. lycopersicum* can attenuate HFD-induced dyslipidemia and reduce cardiovascular risk markers in vivo. The findings aim to contribute to the development of accessible, plant-based dietary interventions for managing metabolic disorders in resource-limited settings.

MATERIALS AND METHODS

Experimental Design and Animal Grouping

A total of twenty-eight (28) male Wistar rats, weighing between 60 g and 70 g, were obtained from the National Veterinary Research Institute, Zaria, Kaduna State, Nigeria. All experimental protocols adhered to standard ethical guidelines for animal research. The rats were acclimatized for one week under controlled laboratory conditions (12-hour light/dark cycle, temperature $25 \pm 2°C$) with free access to food and water. Following acclimatization, the rats were randomly assigned into four groups (n = 7 per group):

Group 1: Standard diet (normal control)
Group 2: High-fat diet (positive control)
Group 3: High-fat diet supplemented with 3.5% *Solanum lycopersicum* powder
Group 4: Standard diet supplemented with 3.5% *Solanum lycopersicum* powder

Each group was maintained on its respective diet ad libitum for a period of eight (8) weeks.

Feed Ingredients and Supplement Preparation

Fresh *Solanum lycopersicum* (tomatoes) were purchased from Katsina Central Market, Katsina State. The tomatoes were washed, sliced, air-dried, and pulverized into fine powder. Other dietary ingredients including corn starch, soybean meal, animal fat, rice husk, DL-methionine, vitamin mix, and mineral mix were sourced from certified vendors.

High-fat and standard rodent diets were formulated in accordance with established protocols (Silvia *et al*., 2018; Ibitoye *et al*., 2017; Jai *et al*., 2015; Ropelle *et al*., 2010). The high-fat diet provided 71% of energy from fat, 11% from carbohydrates, and 18% from protein, while the standard diet provided approximately 70% carbohydrate, 10% fat, and 15% protein.

Formulation of the experimental diets

Standard rodent diet and high-fat diet were prepared by appropriately mixing corn starch, soybean meal, animal fat, rice husk, dl-methionine, vitamin mix, and mineral mixed as shown in Table 1 (Idoko *et al.,* 2023).

Data Collection and Biochemical Analysis

After eight weeks, the rats were anesthetized using diethyl ether and sacrificed. Blood samples were collected into EDTA-treated and plain tubes. Serum was separated by centrifugation at 1500 g for 15 minutes and stored at -20°C for subsequent analyses.

Lipid Profile: Serum total cholesterol (TC), triglycerides (TG), HDL-C, and LDL-C levels were determined using diagnostic assay kits from Randox Laboratories Ltd. (United Kingdom), following the manufacturer's protocol.

Table 1: Feed Ingredients

Feed Ingredient	Standard-diet g/1000g	High-Fat diet g/1000g

Corn Starch	552	292
Animal Fat	-	330
Soya Beans	330	320
Palm Oil	60	-
Rice Hush	50	50
Salt Mix	3	3
Vitamins/ Mineral Mix	2.5	2.5
Methionine	2.5	2.5
TOTAL	1000	1000

Atherogenic Indices: Castelli's Risk Index I (CRI-I) = TC / HDL-C; **Castelli's Risk Index II (CRI-II)** = LDL-C / HDL-C

Data Analysis

Data were analyzed using SPSS version 16 (IBM Corp., USA). Results were expressed as mean ± standard error of mean (SEM). Statistical significance between groups was determined using one-way analysis of variance (ANOVA) followed by Duncan's post hoc test. A p-value < 0.05 was considered statistically significant.

RESULTS

Lipid profile level of rats fed high-fat diets supplemented with tomato

Total cholesterol, triglyceride, high density lipoprotein and low-density lipoprotein levels in group fed supplemented high-fat diet were significantly higher (p<0.05) when compared with the group fed high-fat diet. Similarly, the group fed supplemented standard diet showed significant (p<0.05) increase in the serum concentrations of the lipid parameters when compared with the group fed standard diet (Table 2).

Table 3 below presents the results of the lipid profile parameters and atherogenic indices in Wistar rats after eight weeks of dietary treatments.

Activities of some Liver Enzymes of rats fed high-fat diets supplemented with tomato

As presented in Table 4, there were significantly (p<0.05) higher activities of AST and ALT in the group fed supplemented standard diet (group 4) when compared with the group fed standard diet (group 1). The activities of AST and ALT did not differ significantly among other groups (p>0.05).

Table 2: Lipid profile level of rats fed high-fat diets supplemented with tomato

GROUP	TC (mg/dl)	TG (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
1	57.66±1.45[a]	51.00±2.65[a]	10.66±0.67[a]	23.82±0.77[a]
2	140.7±1.76[c]	98.00±1.16[c]	25.33±0.88[c]	70.78±8.66[c]
3	189.00±6.25[d]	110.30±5.36[d]	31.00±1.00[d]	107.80±2.97[d]
4	87.00±6.25[b]	62.66±1.76[b]	14.33±1.20[b]	44.18±1.95[b]

Values with the same superscripts along the same column are not significantly different (P>0.05)

1- Rats fed the standard diet

2- Rats fed high-fat diet

3- Rats fed with supplemented high fat diet

4- Rats fed with supplemented standard diet

TC: Total Cholesterol

TG: Triglyceride

HDL-C: High Density Lipoprotein- Cholesterol

LDL-C: Low Density Lipoprotein- Cholesterol

Table 3: Lipid profile and atherogenic indices of rats fed high-fat diet with or without *Solanum lycopersicum* supplementation

Group	TC (mg/dl)	TG (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	CRI-I (TC/HDL)	CRI-II (LDL/HDL)
Standard diet (A)	57.66	51.00	10.66	23.82	5.41	2.23
High fat diet (B)	140.70	98.00	25.33	70.78	5.55	2.79
3.5% Supplemented HFD (C)	189.00	110.30	31.00	107.80	6.10	3.48
3.5% Supplemented Std diet (D)	87.00	62.66	14.33	44.18	6.07	3.08

Keynote:

TC – Total Cholesterol; TG – Triglycerides; HDL – High-Density Lipoprotein; LDL – Low-Density Lipoprotein; CRI-I – Castelli's Risk Index I (TC/HDL); CRI-II – Castelli's Risk Index II (LDL/HDL). Values are based on calculated group means from the biochemical analysis after the feeding trial.

Table 4: Activities of some Liver Enzymes of rats fed high-fat diets supplemented with tomato

GROUP	AST (u/l)	ALT (u/l)
1	7.00 ± 0.58^a	4.47 ± 0.33^a
2	10.00 ± 0.58^{bc}	5.67 ± 0.33^a
3	8.33 ± 0.88^{ab}	5.33 ± 0.33^a
4	11.66 ± 0.33^c	7.33 ± 0.33^b

Values with the same superscripts along the same column are not significantly different (P>0.05)

1- Rats fed the standard diet

2- Rats fed high-fat diet

3- Rats fed with supplemented high fat diet

4- Rats fed with supplemented standard diet

AST- Aspatate Amino Transfarase

ALT- Alanine Amino Transfarase

Serum Protein Level of Rats Fed High-fat Diets Supplemented with Tomato

All the test groups were significantly higher (p<0.05) in the total protein levels when compared to the group fed standard diet (group 1). The result shows that there was a significant increase in total bilirubin in group fed supplemented high-fat diet (group 3) when compared to the group feed standard diet (group 1), while conjugated bilirubin levels showed that all other groups had no significant difference when compared to the group fed standard diet (group 1). When it comes to the total bilirubin, the group fed high-fat diet (group 2) was significantly higher (p<0.05) when compared to the group fed standard diet and the other groups. (Table 5).

Table 5: Serum Protein Level of rats fed high-fat diets supplemented with Tomato

GROUP	Total Protein (g/L)	Albumin (g/L)	Total Bilirubin (mg/dl)	Conjugate Bilirubin (mg/dl)
1	56.66 ± 0.33^a	34.00 ± 0.58^a	2.17 ± 0.09^c	0.57 ± 0.33^b
2	61.33 ± 0.33^b	33.66 ± 0.88^a	1.07 ± 0.07^a	0.37 ± 0.03^a
3	60.66 ± 0.67^b	35.66 ± 0.88^b	1.97 ± 0.09^{bc}	0.50 ± 0.06^{ab}
4	61.66 ± 0.88^b	31.33 ± 0.88^a	1.90 ± 0.06^b	0.67 ± 0.03^a

Values with the same superscripts along the same column are not significantly different (p>0.05)

1- Rats fed the standard diet

2- Rats fed high-fat diet

3- Rats fed with supplemented high fat diet

4- Rats feed with supplemented standard diet

DISCUSSION

This study evaluated the impact of *Solanum lycopersicum* supplementation on lipid profile and atherogenic indices in Wistar rats subjected to a high-fat diet. The observed results confirm that high-fat feeding significantly elevated serum total cholesterol, triglycerides, and LDL-C levels, consistent with previous reports linking HFD consumption to dyslipidemia and systemic inflammation (Chen *et al*., 2023; Yao *et al*., 2016). Additionally, the atherogenic

indices (CRI-I and CRI-II) were elevated in HFD-fed rats, indicating an increased cardiovascular risk, aligning with known mechanisms by which excess dietary fats alter lipid metabolism and promote atherosclerotic changes (Konrad *et al.*, 2014).

Dietary supplementation with 3.5% *S. lycopersicum* partially mitigated these adverse lipid changes. Although TC and TG levels were still higher than in the control group, there was a relative improvement in HDL-C concentration. This translated into a reduction in the atherogenic indices compared to the HFD-only group. These findings support previous epidemiological and experimental studies that have attributed cardio-protective properties to *S. lycopersicum*, primarily due to its high content of lycopene and other antioxidant compounds (Chen *et al.*, 2023).

The significantly higher profile levels of cholesterol, LDL, and HDL in the group fed HFD in comparison with standard diet is consistent with established lipid abnormalities caused by high-fat diets, which are recognized for elevating the risk of cardiovascular diseases (Goh *et al.*, 2018). The finding in this research does not agree with previous studies which had indicated that supplementation with tomato can enhance lipid profiles due to its rich content of bioactive compounds, including flavonoids and carotenoids (Kumar *et al.*, 2020). Research indicates that these compounds lower total cholesterol and LDL-C levels while elevating HDL-C in animal models (Akinmoladun *et al.*, 2019; Mordecai *et al.*, 2018). The finding is however consistent with the higher weight gain in the groups fed supplemented diet. It is interesting to note to that HDL was significantly raised in the groups fed supplemented diet and this could be a way of preventing dislypidiamia and its consequences in the groups.

Mechanistically, lycopene and associated phytochemicals in tomatoes have been reported to inhibit lipid peroxidation, modulate inflammatory signaling pathways, and improve lipid metabolism. The improved HDL-C levels observed in the supplemented groups may also be a result of reduced oxidative stress and enhanced reverse cholesterol transport, which are modulated by tomato-derived antioxidants.

Interestingly, the standard diet supplemented with *S. lycopersicum* (Group D) also demonstrated beneficial lipid-modulating effects, reinforcing the role of tomato consumption in routine diets even in the absence of excess fat intake. However, the highest values of CRI-I and CRI-II were still seen in the supplemented HFD group, suggesting that while *S. lycopersicum* confers partial protection, it may not fully counteract the lipid-raising effects of prolonged high-fat intake.

In summary, this study provides experimental evidence supporting the use of *Solanum lycopersicum* as a functional food with potential to modulate dyslipidemia and reduce cardiovascular risk, especially in populations with high dietary fat consumption. Further studies using varying doses and durations are recommended to fully elucidate the extent of its protective effects.

There was no difference in the activities of the enzymes between the group fed the supplement high-fat diet and standard diet which implies that the tomato could have hepato-protective effects. These results align with studies by Ali *et al.* (2021), who suggested that tomato might protect against liver damage by reducing oxidative stress and inflammatory markers. This hepato-protective effect of tomato could be due to its rich content of bioactive compounds, including flavonoids and carotenoids (Kumar *et al.*, 2020).

The elevation of AST and ALT in the group fed standard diet supplemented with tomato is indicative of possible liver damaged. These enzymes are normally found in the cells but do leak into blood when the liver is damage (Martha *et al.,* 2015). Therefore, long term consumption of normal diet supplemented with tomato could be detrimental to the liver.

The higher total protein levels in the groups fed high-fat diets (with or without tomato supplementation) and the group fed supplemented standard diet, could be attributed to: Dietary Protein Utilization, High-fat diets may influence protein metabolism, leading to increased synthesis of serum proteins (Jacek *et al.,* 2014), possibly as a compensatory mechanism for the metabolic stress induced by the high-fat diet. While in the tomato supplementation the presence of bioactive compounds in tomatoes, such as antioxidants (e.g., lycopene and flavonoids), could enhance protein metabolism or reduce oxidative stress, indirectly supporting higher protein synthesis. This aligns with findings by Hui *et al.* (2007), which suggest that lycopene supports liver function and

protein synthesis under oxidative stress. The consistent albumin levels across most groups suggest that tomato supplementation and dietary fat did not significantly alter albumin synthesis. Albumin is primarily synthesized in the liver, and its level is tightly regulated. The absence of significant changes may indicate that the liver's albumin-synthesizing capacity remained unaffected by the dietary interventions and tomato bioactives might not specifically influence albumin production. The slight increase in albumin levels in Group 3 could be due to experimental variability or specific metabolic interactions in this group. Total bilirubin (TB) is primarily a by-product of hemoglobin breakdown, which is processed by the liver. The higher TB levels in the group fed standard diet, may indicate that the rats on this diet had a relatively higher hemoglobin turnover rate or inefficient bilirubin metabolism due to the absence of dietary fat and its modulatory effects or benefited less from the antioxidant and hepatoprotective effects of tomato supplementation present in Groups 3 and 4. High-fat diets rich in fats can induce hepatic changes, including altered bile acid synthesis, which may reduce circulating bilirubin levels in Group 2. However, this reduction may not necessarily be beneficial, as high-fat diets are also associated with increased oxidative stress and lipid peroxidation. Tomato supplementation in Groups 3 and 4, tomatoes are rich in antioxidants such as lycopene and polyphenols, which may have mitigated oxidative stress, reducing hemolysis and stabilizing bilirubin metabolism. This hepatoprotective effect of tomato supplementation likely contributed to the lower TB levels compared to the group fed standard diet.

Conjugated bilirubin (CB) levels are a direct indicator of liver function and the ability of the liver to conjugate bilirubin with glucuronic acid. The lack of significant differences in CB levels ($P > 0.05$) suggests that the liver's conjugation efficiency was not substantially affected by the diet types or tomato supplementation. This indicates that while dietary changes influenced TB levels, they did not impair or enhance liver conjugation capacity. This study is not in agreement with (Antonio *et al.,* 2013) investigated the effect of dietary tomato supplementation on rats fed a high-fat diet and found that tomato supplementation reduced oxidative stress markers and improved liver function parameters, including

bilirubin levels. Their study attributed these effects to the antioxidants in tomatoes, which mitigate lipid peroxidation and promote hepatoprotection.

CONCLUSION

From the results obtained, it could be concluded that supplementation with tomato powder may not be good in weight management and normalization of dyslipidemia. Further, the supplementation could pose potent danger to the liver and kidney. Therefore, such supplementation may not be recommended until after further investigation.

REFERENCES

Akinmoladun, A., Obafemi T, Olaleye M. (2019). Antioxidant activity of tomato and its effect on lipid profiles in high-fat induced rats. *Journal of Clinical Biochemistery and Nutrition,* 64(3), 211-218. [DOI;10.3164\jcbn.18-20]

Bhattacharjee, J. K., Nanduri, R., & Bhattacharjee, R. (2017). High-fat diet-induced obesity and associated liver inflammation: Role of NKT cells and CD8+ T-cells. *Journal of Hepatocellular Research*, 5(3), 112–118.

Chen, X., Zhang, Z., & Zhang, Y. (2023). Dietary tomato-derived antioxidants and lipid metabolism: A review. *Journal of Functional Foods*, 98, 105318.

Goh K, L., Hashimoto, Hamaguchi, M. (2018)."Dietary fatty acids and their impact on lipid metabolism and obesity." *Biochemical Pharmacology,* 149, 35-41.

Idoko, A. S., Ayo, J. O., & Nwankpa, P. (2023). Ethylacetate flavonoid bio-compounds of honey with mitigating anti-hyperlipidemic and antioxidant properties in carbohydrate and lipid enriched diets - obese rats. *Journal of Applied Life Sciences International,* 26(3), 1–15.

Kazemi, M., Rahimi, A., & Ebrahimi, M. (2018). Atherogenic indices as cardiovascular risk predictors in obese patients. *Journal of Clinical Lipidology*, 12(5), 1120–1127.

Kennedy, A., Martinez, K., & Schmidt, S. (2009). Anti-obesity mechanisms of tomato bioactives. *Nutrition Journal*, 8(1), 13.

Konrad, D., Somwar, R., & Sweeney, G. (2014). The role of dietary fat in systemic inflammation and cardiovascular risk. *Current Diabetes Reports*, 14(6), 489–495.

Kumar, P., Mishra, S., Jha, DK., Shukla, J. (2020). "Role of flavonoids in lipid profile modulation and antioxidant defense." *Food Chemistry,* 319, 126456.

Mordecai, A.P., Stewart, Caldwell, J.M., Childs M. L. (2018). "Lycopene-rich tomato extract improves HDL-C and LDL-C ratio in hyperlipidemic patients." *Journal of Clinical Lipidology,* 12(6), 1513-1520.

Silvia, T. K., Nwokocha, C. R., & Chukwuka, C. J. (2018). Lipid-lowering effects of tomato powder in high fat diet-fed rats. *Journal of Natural Remedies*, 18(2), 45–52.

Steven, S., Smith, R. D., & Taylor, R. (2012). High-fat diet and obesity: Pathophysiology and impact on metabolic diseases. *Lancet Diabetes & Endocrinology*, 1(1), 62–70.

WHO. (2015). Obesity and overweight: Factsheet No. 311. Retrieved from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight on 20th August, 2025.

Yao, Y., Chen, X., & Chen, Y. (2016). Inflammation-induced insulin resistance and its role in type 2 diabetes. *Journal of Diabetes Research*, 2016, 8459792.