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The effects of turmeric, strawberry, and broccoli on dyslipidemia, and hepatic histopathology in male Wistar rats

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ABSTRACT: Dyslipidemia is a major independent risk factor for cardiovascular disease and requires effective management strategies, including dietary modification and the use of medicinal plants. This study aimed to evaluate the effects of turmeric ethanol extract, strawberry juice, and broccoli juice on lipid profile parameters and hepatic histopathology in male Wistar rats with high-fat diet–induced dyslipidemia. Fifteen male Wistar rats aged 6–8 weeks were randomly divided into five groups: negative control receiving standard feed, positive control receiving a high-fat diet, and three treatment groups receiving turmeric ethanol extract, strawberry juice, or broccoli juice. The high-fat diet (60 g/cage/day) was administered for 11 weeks, followed by four weeks of treatment with turmeric ethanol extract (270 mg/kg body weight/day), strawberry juice (9 g/kg body weight/day), or broccoli juice (9 g/kg body weight/day). Administration of turmeric ethanol extract and strawberry juice significantly reduced total cholesterol, low-density lipoprotein, and triglyceride levels, whereas broccoli juice reduced low-density lipoprotein and triglyceride levels without significantly affecting total cholesterol. Histopathological examination of liver tissue demonstrated that turmeric ethanol extract and broccoli juice exerted protective effects against hepatic steatosis and hepatocellular necrosis, while strawberry juice showed no significant hepatoprotective effect. These findings indicate that turmeric ethanol extract and broccoli juice possess both hypolipidemic and hepatoprotective properties, whereas strawberry juice primarily exhibits hypolipidemic activity in male Wistar rats with high-fat diet–induced dyslipidemia.

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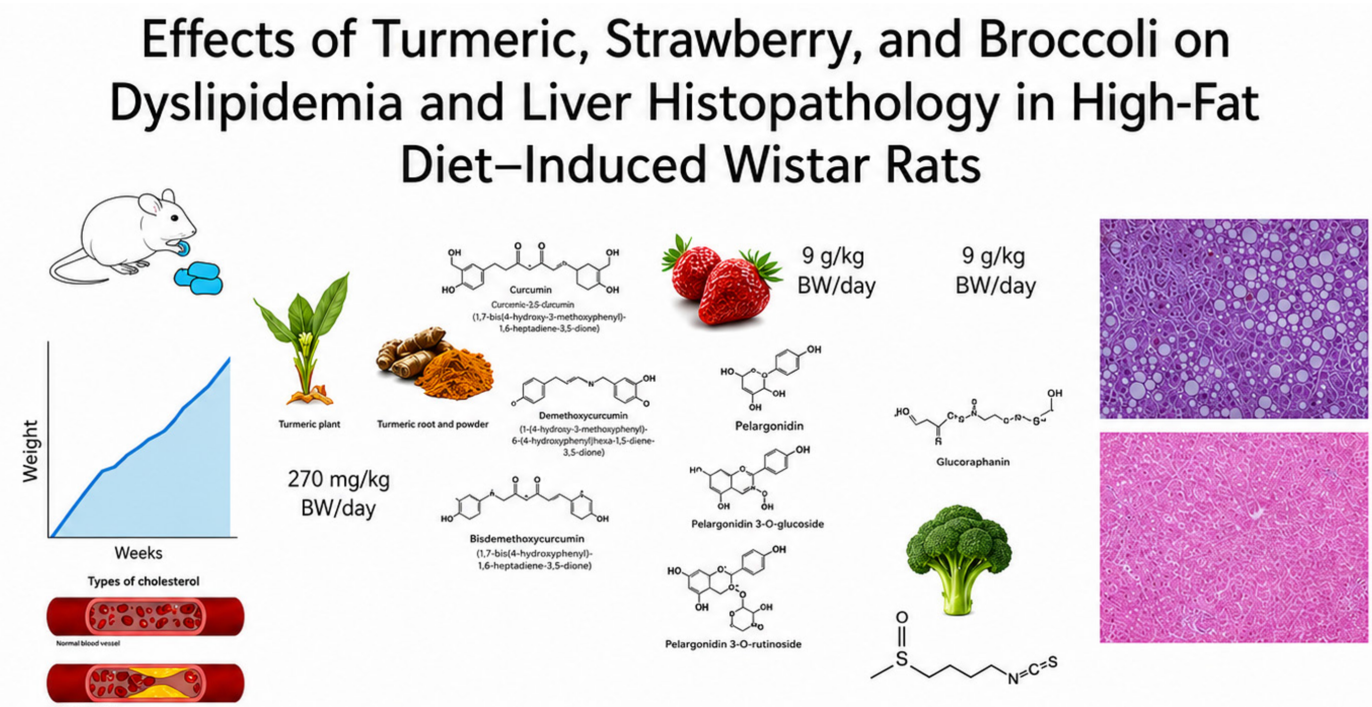
GRAPHICAL ABSTRACT



Parameter	Turmeric	Strawberry	Broccoli
Total Cholesterol	↓	↓	↔
LDL	↓	↓	↓
Triglycerides	↓	↓	↓
HDL	↑ / ↔	↔	↔
Liver Histopathology in High-Fat Diet	Protective effect	Showed no significant hepatoprotective effect	No protective effect

1. INTRODUCTION

Dyslipidemia is a metabolic abnormality that contributes to the onset of atherosclerosis and is implicated in the pathogenesis of non-alcoholic fatty liver disease (NAFLD), coronary artery disease, and stroke. It is characterized by elevated concentrations of total cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides, alongside decreased levels of high-density lipoprotein (HDL) cholesterol (Martin et al. 2022). Metabolic syndrome is characterized by a combination of diabetes mellitus, central obesity, hypertension, elevated triglyceride levels, and reduced HDL cholesterol. Among these, dyslipidemia, reflected in high triglycerides and low HDL cholesterol, represents a critical component that necessitates treatment (Kosmas et al. 2023).

WHO reported in 2008 that adult hypercholesterolemia was most prevalent in Europe (53.7%) and the Americas (47.7%), with lower prevalence observed in Southeast Asia (30.3%) and Africa (23.1%). In the Asia-Pacific region, the prevalence ranged between 9% in Indonesia and 46.9% in the Philippines (Mohamed-Yassin et al. 2021). According to WHO, dyslipidemia in Indonesia is common, with 36% of men and 38.2% of women over 25 years presenting triglyceride levels greater than 160 mg/dL. Supporting this, a smaller study of 1,013 individuals revealed that among particular ethnic groups, the prevalence of dyslipidemia—triglyceride levels above 240 mg/dL—varied between 9% and 25% (Chen et al. 2018).

Management of dyslipidemia can be achieved through lifestyle modification. For individuals with obesity, achieving a body mass index (BMI) within the target range of 20–25 kg/m² is advised, with waist circumference maintained below 94 cm in men and 80 cm in women. Efforts should focus on lowering elevated total cholesterol, LDL cholesterol, and triglyceride levels. Key strategies include adopting dietary modifications and engaging in regular physical activity. Exercise recommendations consist of 150–200 minutes per week of moderate-intensity activity or 75–150 minutes per week of vigorous-intensity activity. The recommended diet emphasizes high-fiber fruits and vegetables, with limited sugar and fat intake (Martin et al. 2022). LDL cholesterol reduction can be achieved with statins, which block HMG-CoA reductase, and with ezetimibe, which prevents cholesterol absorption (Martin et al. 2022). The use of statins is associated with muscle-related side effects such as myalgia, myopathy, and myositis, which may present with or without elevated creatine kinase levels. In more severe cases, these complications can develop into rhabdomyolysis (Ruscica et al. 2022). Thus, alternative strategies for managing dyslipidemia must continue to be explored. As noted earlier, dietary modification—such as increased intake of vegetables and fruits like broccoli and strawberries—plays an important role. Additionally, medicinal plants, including turmeric, offer potential as complementary approaches to dyslipidemia management (Berisha et al. 2025). The objective of this research is to evaluate the impact of turmeric ethanol extract, strawberry juice, and broccoli juice on lipid profiles and to examine their effects on hepatic steatosis and hepatocellular necrosis in high-fat diet–induced male Wistar rats.

2. MATERIALS AND METHODS

Required equipment: rat cages, digital scales, gloves, feeding and drinking containers for rats, wood shavings, oral gavage and 5 mL syringe, cholesterol and triglyceride test strips, cotton and alcohol, 1.5 mL Eppendorf tubes, white tips, parafilm, centrifuge tubes, blender, knife, micropipette, chemistry autoanalyzer, label stickers, measuring glass, filter, 1.5 mL and 2 mL microtubes, –20°C freezer, –80°C freezer, object glass slides, cover glass, and microtome.

Required materials: turmeric ethanol extract, broccoli, strawberries, standard feed, high-fat feed, distilled water, Carboxy Methyl Cellulose (CMC), ketamine, xylazine, Diagnostics Cholesterol and Triglycerides reagent, 75% ethanol, Hematoxylin-Eosin (HE) stain, 10% neutral buffered formalin, 40–100% alcohol, Entellan, toluene, paraffin, and xylol.

The experiment involved 18 male Wistar rats (*Rattus norvegicus*), aged 6–8 weeks with an average body weight of around 200 g, obtained from PT. Bio Farma, Bandung. The animals were randomly assigned to five groups of three rats each: a negative control group (standard diet), a positive control group (high-fat diet), a turmeric ethanol extract group, a strawberry juice group, and a broccoli juice group.

The study was a true experimental laboratory design using a completely randomized design (CRD), with ethical clearance obtained from the Ethics Committee of the Faculty of Medicine, Maranatha Christian University, Bandung (Approval No. 108/KEP/IV/2023).

The rats were acclimatized to the laboratory environment for 7 days and provided with standard feed at a rate of 60 g/cage/day and distilled water for drinking. Subsequently, the rats were induced with high-fat feed (HFF) at 60 g/cage/day for 11 weeks, except for the negative control group, which continued to receive standard feed and distilled water.

Following the induction period, the rats were treated according to their respective groups for 4 weeks with the following dosages: turmeric ethanol extract at 270 mg/kg BW/day, strawberry juice at 9 g/kg body weight (BW)/day, broccoli juice at 9 g/kg BW/day.

Post-treatment, rat blood samples were collected to measure lipid parameters, including total cholesterol, LDL, HDL, and triglycerides. The animals were then humanely sacrificed, and liver tissues were harvested for both Hematoxylin-Eosin-based histopathological assessment.

3. RESULTS

The results of the Total-Cholesterol levels in different groups after 11 weeks of high-fat feed induction and 4 weeks of treatment are presented in Table 1 and Figure 1.

The mean total cholesterol level in the positive control group was 78.98 mg/dL, significantly higher than that of the negative control group at 34.10 mg/dL, confirming that a high-fat diet elevated total cholesterol in male Wistar rats. Administration of turmeric ethanol extract (42.70 mg/dL), strawberry juice (39.90 mg/dL), and broccoli juice (56.63 mg/dL) significantly reduced total cholesterol levels in high-fat diet–induced rats ($p < 0.05$).

Table 1
Total-cholesterol levels in different treatment groups (mg/dL).

Treatment group	Average total-cholesterol levels	Standard deviation	*P value*
Negative control	34.10	5.58	0.000
Positive control	78.98	6.32	
Turmeric ethanol extract	42.70	5.97	
Strawberry juice	39.90	6.69	
Broccoli juice	56.63	10.28	

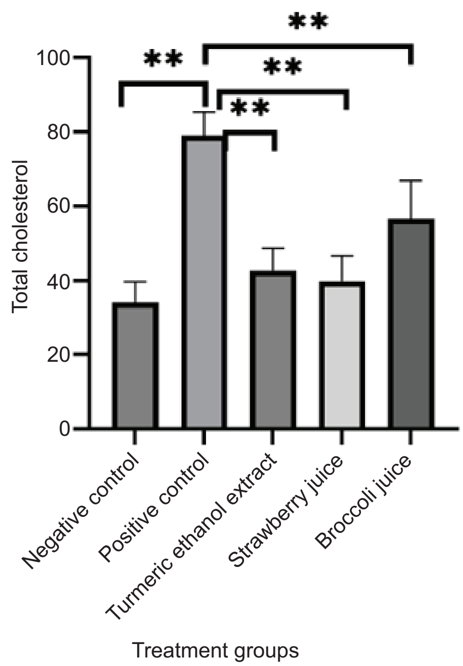


Figure 1. Bar chart total-cholesterol levels in different treatment groups (mg/dL)

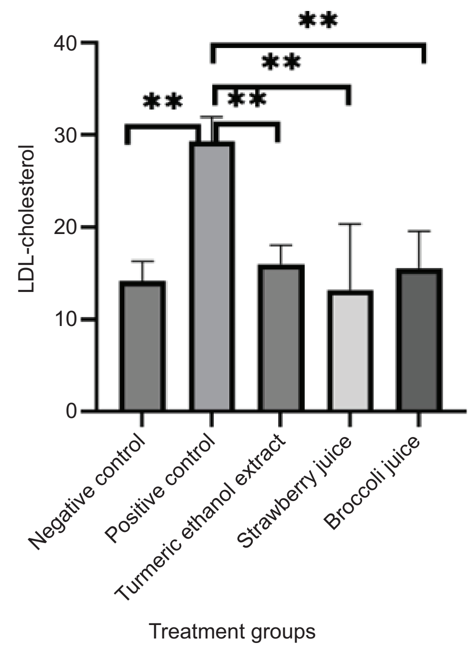


Figure 2. Bar chart LDL-cholesterol levels in different treatment groups (mg/dL).

The results of the LDL-Cholesterol levels in different groups after 11 weeks of high-fat feed induction and 4 weeks of treatment are presented in Table 2 and Figure 2.

In the positive control group, the mean LDL-cholesterol was 29.30 mg/dL, markedly higher than the 14.17 mg/dL observed in the negative control group, indicating that a high-fat diet induced LDL elevation in Wistar rats. Treatment with turmeric ethanol extract (16.02 mg/dL), strawberry juice (13.22 mg/dL), and broccoli juice (15.56 mg/dL) significantly lowered LDL-cholesterol compared to untreated high-fat diet–fed rats ($p < 0.05$).

The results of the Triglyceride levels in different groups after 11 weeks of high-fat feed induction and 4 weeks of treatment are presented in Table 3 and Figure 3.

Triglycerides were elevated in the positive control group (153.25 mg/dL) compared to the negative control (46.43 mg/dL), confirming the effect of a high-fat diet. Administration of turmeric ethanol extract (76.62 mg/dL), strawberry juice (71.72 mg/dL), and broccoli juice (89.62 mg/dL) significantly lowered triglyceride levels in high-fat diet–fed Wistar rats ($p < 0.05$).

Table 2

LDL-cholesterol levels in different treatment groups (mg/dL).

Treatment group	Average LDL-cholesterol levels	Standard deviation	*P value*
Negative control	14.17	2.13	0.004
Positive control	29.30	2.66	
Turmeric ethanol extract	16.02	2.03	
Strawberry juice	13.22	7.13	
Broccoli juice	15.56	3.99	

Table 3

Triglyceride levels in different treatment groups (mg/dL).

Treatment group	Average triglyceride levels	Standard deviation	*P value*
Negative control	46.43	3.63	0.000
Positive control	153.25	39.50	
Turmeric ethanol extract	76.62	11.16	
Strawberry juice	71.72	26.99	
Broccoli juice	89.62	17.70	

The results of the HDL-Cholesterol levels in different groups after 11 weeks of high-fat feed induction and 4 weeks of treatment are presented in Table 4 and Figure 4.

The HDL-cholesterol level in the positive control group was 14.58 mg/dL, which was not significantly different from the HDL-cholesterol level in the negative control group, which was 17.41 mg/dL. This indicates that administering a high-fat diet to male Wistar rats had no effect on HDL cholesterol levels.

An overview of liver histopathology in male Wistar rats is presented in Figure 5, and the percentage of fat degeneration is presented in Table 5 and Figure 6. Percentage of necrosis

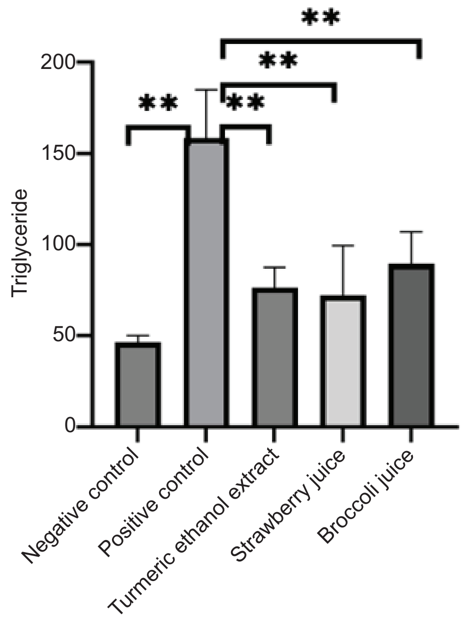


Figure 3. Bar chart triglyceride levels in different treatment groups (mg/dL).

Table 4
HDL-cholesterol levels in different treatment groups (mg/dL).

Treatment group	Average HDL-cholesterol levels	Standard deviation	*P value*
Negative control	17.41	1.40	0.397
Positive control	14.58	2.07	
Turmeric ethanol extract	18.12	2.39	
Strawberry juice	16.94	3.54	
Broccoli juice	16.1	0.48	

in liver histopathological features across different treatment groups is presented in Table 6 and Figure 7.

Microscopic analysis of liver tissue demonstrated marked fat degeneration in the positive control group (47.25%), which was significantly greater than that in the negative control (5.27%). These results confirm the role of a high-fat diet in promoting hepatic fat accumulation in Wistar rats. Administration of turmeric ethanol extract (26.54%) and broccoli juice (29.81%) significantly ameliorated fat degeneration ($p < 0.05$), whereas strawberry juice (41.20%) failed to show a statistically significant improvement ($p > 0.05$).

Liver histological analysis revealed that the proportion of hepatocyte necrosis in the positive control group reached 51.55%, which was significantly higher compared to 15.08% in the negative control group. Treatment with ethanol extract of turmeric (22.86%) and broccoli juice (34.23%) significantly decreased the percentage of necrotic hepatocytes ($p < 0.05$) in male Wistar rats fed a high-fat diet, while strawberry juice (37.45%) showed no significant effect ($p > 0.05$).

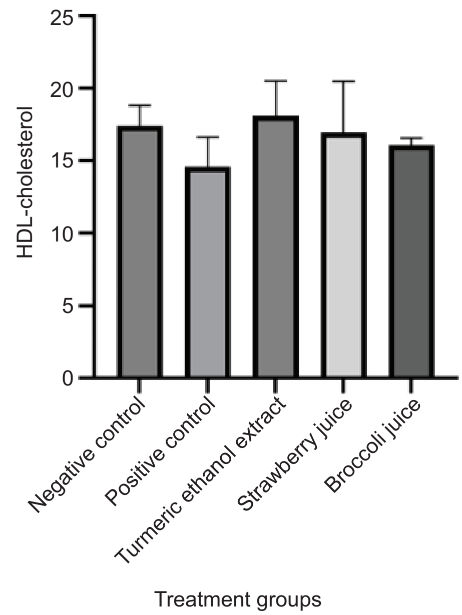


Figure 4. Bar chart HDL-cholesterol levels in different treatment groups (mg/dL).

4. DISCUSSION

The administration of a high-fat diet in this study led to an increase in total cholesterol levels, LDL-cholesterol levels, triglyceride levels, as well as causing hepatic steatosis and hepatocellular necrosis. The high-fat diet used in this study contained 37% fat. This indicates that dietary patterns influence total cholesterol, LDL-cholesterol, triglycerides, and can even cause fatty liver. The results of the study showed that the administration of turmeric ethanol extract reduced Total-Cholesterol (42.70 + 5.97 mg/dL), LDL-Cholesterol (16.02 + 2.03 mg/dL), and Triglyceride (76.62 ± 11.16 mg/dL) levels in rats fed a high-fat diet compared with positive control (Total-Cholesterol 78.98 + 6.32 mg/dL, LDL-Cholesterol 29.30 + 2.66 mg/dL, and Triglyceride 153.25 ± 39.50 mg/dL). The ethanol turmeric extract also attenuates hepatic steatosis (26.54 + 5.37%) and reduces hepatic cell necrosis (22.86 + 1.45%) in male Wistar rats with dyslipidemia compared to hepatic steatosis (47.25 + 3.59%) and hepatic cell necrosis (51.55 + 4.09%) at positive control

The ethanol extract of turmeric, primarily through its active constituent curcumin, exhibits hypolipidemic and hepatoprotective effects via several mechanisms. It reduces cholesterol levels by inhibiting intestinal absorption through blockade of

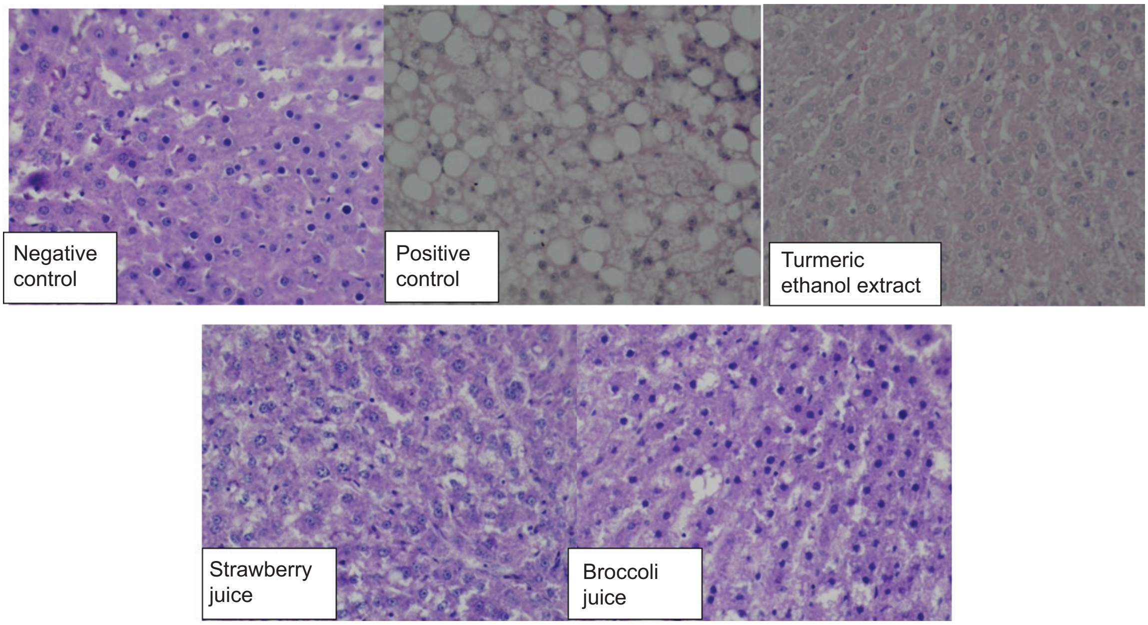


Figure 5. Histopathology of the liver of male Wistar rats.

Table 5
Percentage of fat degeneration hepatic histopathology in various treatment groups (%).

Treatment group	Percentage of fat degeneration	Standard deviation	*P value*
Negative control	5.57	5.92	0.000
Positive control	47.25	3.59	
Turmeric ethanol extract	26.54	5.37	
Strawberry juice	41.20	4.32	
Broccoli juice	29.81	8.30	

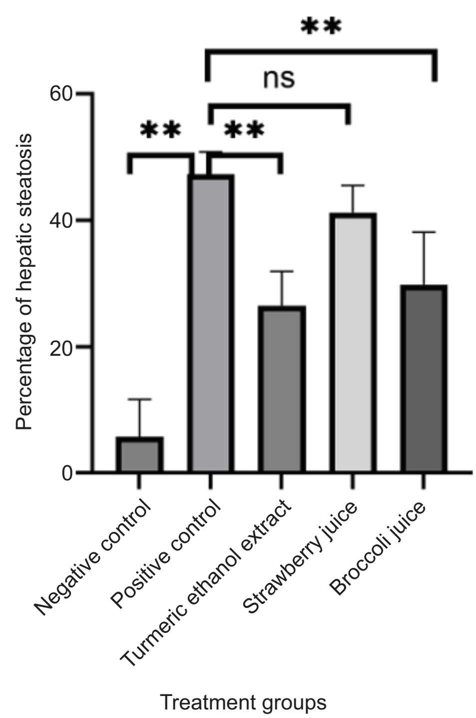


Figure 6. Percentage of fat degeneration hepatic histopathology in various treatment groups (%).

the NPC1L1 transporter and by suppressing hepatic cholesterol synthesis via downregulation of HMG-CoA reductase. Furthermore, activation of the AMP-activated protein kinase (AMPK) pathway plays a pivotal role in lipid metabolism regulation, while enhancing PPAR-α expression, which promotes fatty acid β-oxidation and prevents hepatic lipid accumulation (Ruiz de Porras et al. 2023). In addition to its effects on lipid metabolism, the ethanol extract of turmeric exerts anti-inflammatory actions through the gut–liver axis. By enhancing intestinal barrier integrity and upregulating tight junction proteins, it reduces lipopolysaccharide (LPS) translocation, leading to suppression of the NF-κB signaling pathway in the liver and thereby decreasing hepatic inflammation and steatosis (Buonomo et al. 2019). Moreover, turmeric extract modulates immune responses by inhibiting the polarization of macrophages toward the pro-inflammatory phenotype, reducing the production of pro-inflammatory cytokines including IL-1β and TNF-α, while enhancing PPAR-γ activity, which collectively protects hepatocytes against necrosis (Peng et al. 2021). The hepatoprotective effects are further supported by the strong antioxidant capacity of curcumin (Akram et al. 2021). Experimental studies in HepG2 cells have also shown that ethanol extract of turmeric can directly inhibit triglyceride

Table 6
Percentage of necrosis in liver histopathological features across different treatment groups (%).

Treatment group	Percentage of liver cell necrosis	Standard deviation	*P value*
Negative control	15.08	4.15	0.008
Positive control	51.55	4.09	
Turmeric ethanol extract	22.86	1.45	
Strawberry juice	37.45	3.23	
Broccoli juice	34.23	19.93	

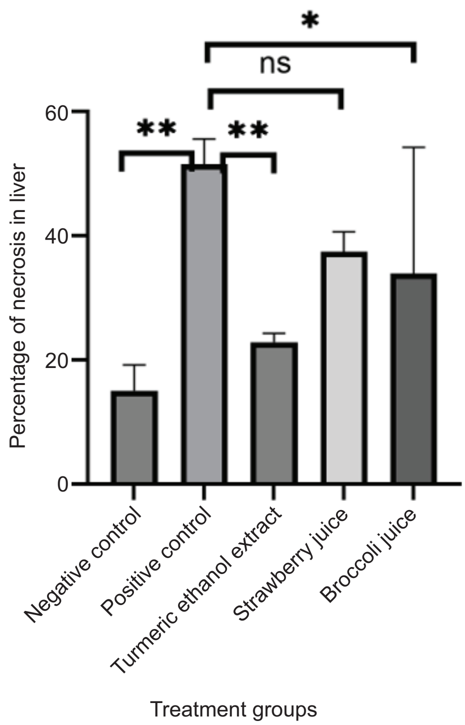


Figure 7. Percentage of necrosis in liver hepatic histopathology in various treatment groups (%).

synthesis by approximately 70% and cholesterol synthesis by about 66%, demonstrating potent lipid-lowering activity that may surpass that of curcumin alone (Thomes et al. 2023). These mechanisms explain the ability of ethanol extract of turmeric to lower serum total cholesterol, LDL cholesterol, and triglyceride levels, as well as to attenuate hepatic steatosis and hepatocellular necrosis in dyslipidemia models.

The administration of strawberry juice reduced Total-Cholesterol (39.90 + 6.69 mg/dL), LDL-Cholesterol (13.22 + 7.13 mg/dL) and Triglyceride (71.72 ± 26.99 mg/dL) levels in rats fed a high-fat diet compared with positive control (Total-Cholesterol 78.98 + 6.32 mg/dL, LDL-Cholesterol 29.30 + 2.66 mg/dL, and Triglyceride 153.25 ± 39.50 mg/dL); however, no significant effect was observed on HDL cholesterol levels. Furthermore, in this study, strawberry juice administration did not reduce the percentage of hepatic steatosis nor decrease the number of hepatocytes undergoing necrosis in male Wistar rats with high-fat diet–induced dyslipidemia. These findings suggest that the hypolipidemic effect of strawberry juice is primarily mediated via modulation of circulating lipid profiles, while its hepatoprotective activity appears limited under the present experimental conditions.

In contrast, previous studies have demonstrated broader protective effects of strawberry or berry preparations. For instance, strawberry supplementation in diabetic rats (STZ-induced) exhibited both antihyperlipidemic and antioxidant effects, along with improved liver histology (Mallhi et al. 2023). Methanolic extracts of strawberries activated AMPK in HepG2 hepatocytes, thereby reducing cholesterol and triglyceride synthesis (Forbes-Hernández et al. 2017). Additionally, functional beverages based on strawberry and blueberry prevented hepatic triglyceride accumulation and upregulated fatty acid oxidation genes, attenuating steatosis in obese rats (Sotelo-González et al. 2023). Collectively, these studies indicate that the absence of hepatic histopathology improvement in the present experiment may be related to differences in bioactive compound concentration, method of administration, treatment duration, or the severity of diet-induced liver damage. Clearly, further research is needed to optimize dosing and regimen of strawberry-derived bioactives.

The administration of broccoli juice reduced LDL-Cholesterol (15.56 + 3.99 mg/dL) and Triglyceride (89.62 ± 17.70 mg/dL) levels in rats fed a high-fat diet compared with positive control (LDL-Cholesterol 29.30 + 2.66 mg/dL, and Triglyceride 153.25 ± 39.50 mg/dL) but did not reduced Total-Cholesterol (56.63 + 10.28) compared with positive control (78.98 + 6.32 mg/dL), and no significant effect was observed on HDL cholesterol in a high-fat diet–induced dyslipidemia model using male Wistar rats. Moreover, broccoli juice administration attenuated hepatic steatosis and decreased the number of hepatocytes undergoing necrosis in this experimental model. These findings indicate that broccoli juice exerts both hypolipidemic and hepatoprotective effects, which are likely attributed to its high content of glucosinolates, sulforaphane, and other antioxidant phytochemicals.

The observed results are consistent with previous studies reporting that cruciferous vegetables, particularly broccoli and sulforaphane, modulate lipid metabolism, reduce oxidative stress, and protect hepatocytes from diet-induced injury. Sulforaphane has been shown to activate nuclear factor erythroid 2–related factor 2 (Nrf2), thereby enhancing the expression of antioxidant and detoxification enzymes, reducing hepatic lipid peroxidation, and attenuating inflammation (Houghton, Fassett, and Coombes 2016). Similar hepatoprotective and hypolipidemic effects have also been demonstrated with other antioxidant-rich plant extracts, such as turmeric, pomegranate, and blueberry, which improve lipid profiles and ameliorate hepatic steatosis through the suppression of oxidative stress and inflammatory signaling pathways (Służały, Paśko, and Galanty 2024). Therefore, broccoli juice supplementation may represent a promising dietary strategy not only for improving lipid profiles but also for preventing liver injury associated with high-fat diet–induced dyslipidemia.

Dyslipidemia pose significant health risks due to their strong association with metabolic and cardiovascular disorders. Lipid are vital for energy storage (Du and Qin 2023). However, when present in excessive amounts, they disrupt metabolic homeostasis and lead to severe complications (Linţa et al. 2024). Dyslipidemia significantly contributes to the development of atherosclerosis, a condition characterized by fatty deposits accumulating on arterial walls, reducing blood flow (Wazir et al. 2023). This blockage can result in coronary artery disease (CAD), wherein restricted blood supply to the heart leads to angina or heart attacks (Lu et al. 2022). Additionally, dyslipidemia are associated with an increased risk of ischemic stroke. Increased cholesterol levels can lead to hepatic fat accumulation, triggering the development of non-alcoholic fatty liver disease (NAFLD), which may further progress into more severe conditions such as NASH, liver fibrosis, cirrhosis, or hepatocellular carcinoma (Alloubani, Nimer, and Samara 2020). Furthermore, dyslipidemia exacerbate insulin resistance, which amplifies liver fat deposition and metabolic dysfunction. As a central element of metabolic syndrome, hypertriglyceridemia is linked to a combination of conditions that significantly raise the likelihood of developing type 2 diabetes, cardiovascular disease, and stroke. This syndrome is commonly associated with central obesity, high blood pressure, elevated fasting glucose, and reduced HDL cholesterol levels (Klop, Elte, and Cabezas 2013).

Reducing the health threats linked to dyslipidemia requires proper management, which includes adopting a balanced diet featuring natural triglyceride-lowering foods such as strawberries and broccoli, staying physically active, and seeking medical treatment if necessary. Pharmacological options like fibrates, along with herbal remedies such as turmeric, have shown promise in reducing triglyceride levels and preventing associated complications.

5. CONCLUSION

The administration of turmeric ethanol extract and strawberry juice reduced Total-Cholesterol, LDL-Cholesterol, and Triglyceride levels in rats fed a high-fat diet While, the administration of broccoli juice reduced LDL-Cholesterol and Triglyceride levels in rats fed a high-fat diet but did not reduced Total-Cholesterol in a high-fat diet–induced dyslipidemia model using male Wistar rats.

The ethanol turmeric extract and broccoli juice attenuates hepatic steatosis and reduces hepatic cell necrosis in male Wistar rats with dyslipidemia. While, Strawberry juice administration did not reduce the percentage of hepatic steatosis nor decrease the number of hepatocytes undergoing necrosis in male Wistar rats with high-fat diet–induced dyslipidemia.

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MANDATORY DISCLOSURE ON USE OF ARTIFICIAL INTELLIGENCE

The authors declare that: AI-assisted tools were used as follows: ChatGPT, for the purpose of assisting with language editing. All references have been manually verified for accuracy and relevance.

AUTHOR CONTRIBUTIONS

Diana Krisanti Jasaputra: Research concept and design. Collection and/or assembly od data, annalysis and interpretation, writing, critical revision, and final approval of the article. Penny Setyawati Martioso: collection and/or assembly of data, analysis, and interpretation, writing, and final approval of the article. Shirley Tanuwireja: and Julia Windi Gunadi: writing critical revision and final approval of the article. Elza Stiana Rusfaidah. Filana Finacia Ardhinata. Laura Gabriela Hidajat, Reynard Saputra Tungerapan. Ivana Indriati Sutrisno: Collection and/or assembly od data, annalysis and interpretation, writing, critical revision.

CONFLICT OF INTEREST

The authors declared no conflict of interest.

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