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Ameliorative Effect of Garlic Oil on Metabolic Changes in Mice Fed with High Fat Diet

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Abstract **Original Research Articles**

High-fat diets (HFDs) are a major risk factor for obesity, dyslipidaemia, and insulin resistance, which contribute to the global burden of metabolic syndrome. Garlic oil, rich in bioactive organosulfur compounds, has been reported to possess antioxidant and lipid-lowering properties. This study investigated the effects of garlic oil on metabolic changes in mice fed with a high-fat diet. Twenty-five mice were randomly divided into five groups of five mice each. Group one (1) was the control group, fed with rat chow only. Group two (2) was fed with a high-fat diet alone without treatment, while Groups 3, 4, and 5 received high-fat diet + garlic oil at doses of 1 mg/kg, 2 mg/kg, and 3 mg/kg, respectively, for four weeks. Body Mass Index (BMI) was calculated weekly for the period of four weeks, and serum from blood samples collected by cardiac puncture was analyzed for lipid profile.

In comparison to the high-fat diet group (Group 2), which exhibited significantly elevated cholesterol (mean: 244.07 mg/dL), triglycerides (mean: 156.63 mg/dL), and low-density lipoprotein (LDL-C) (mean: 175.25 mg/dL), while showing lower high-density lipoprotein (HDL-C) (mean: 26.43 mg/dL), the garlic oil-supplemented groups showed marked improvements. Group 5 (high-fat diet + garlic oil 3 mg/kg) demonstrated the most significant reduction in cholesterol (mean: 138.95 mg/dL), triglycerides (mean: 128.54 mg/dL), and LDL-C (mean: 123.92 mg/dL), alongside the highest increase in HDL-C (mean: 34.82 mg/dL). Groups 3 and 4 also exhibited favorable changes in lipid profiles, with Group 3 showing cholesterol levels of 167.91 mg/dL, triglycerides of 158.00 mg/dL, and LDL-C of 122.40 mg/dL, and Group 4 showing cholesterol levels of 159.03 mg/dL, triglycerides of 142.83 mg/dL, and LDL-C of 135.92 mg/dL.

Regarding BMI, Group 2 showed an increase in BMI (mean: 4.5) over the 5-week period. In contrast, the garlic oil-supplemented groups showed a reduction in BMI, with Group 3 having a final BMI of 3.8, Group 4 at 3.9, and Group 5 showing the most significant decrease with a final BMI of 3.4, demonstrating the effectiveness of garlic oil in mitigating the obesity-related effects of a high-fat diet.

These findings indicate that garlic oil supplementation significantly improves lipid metabolism and reduces obesity-related markers, suggesting its potential as a therapeutic intervention for managing dyslipidemia, obesity, and related metabolic disorders.

Keywords: *Garlic oil, High fat diet, Diabetes mellitus, lipid profile, metabolic syndrome, Obesity*.

INTRODUCTION

High-fat diets (HFDs) have become increasingly prevalent, contributing significantly to the rise in metabolic diseases such as hyperlipidemia, diabetes, arteriosclerosis, and cardiovascular diseases. These conditions are at the core of metabolic syndrome, a multifactorial disorder characterized by obesity, insulin resistance, dyslipidemia, and hypertension. Metabolic syndrome is one of the most pressing public health concerns worldwide, with its prevalence rising in both developed and developing countries. According to the World Health Organization (WHO, 2025), in 2022, 1 in 8 people worldwide were living with obesity. The global prevalence of obesity among adults has more than doubled since 1990, and adolescent obesity has quadrupled during the same period. This increase in obesity and its associated diseases has profound effects on global health systems.

Dietary factors play a crucial role in the development of metabolic diseases, and garlic (Allium sativum L.) has garnered attention for its potential therapeutic effects. For centuries, garlic has been used not only as a spice but also as a traditional medicine due to its perceived ability to prevent and cure various ailments (Kang et al., 2010; Asdaq et al., 2009). The biological activity of garlic, particularly its organosulfur compounds, has been well-documented. Four key organosulfur compounds, which include, diallyl sulfide (DAS), diallyl disulfide (DADS), diallyl trisulfide (DATS), and allylmethyl trisulfide are believed to be the major biological agents responsible for garlic's health benefits (Nicastro et al., 2015).

Numerous studies have reported that garlic possesses various biological activities, including hypolipidemic, hypocholesterolemic, and antioxidant effects (Asdaq et al., 2015; Kang et al., 2010, Sanjay, 2002). Given these properties, garlic oil has been suggested as a potential dietary intervention for improving lipid profiles, reducing atherosclerosis risk, and combating cardiovascular disease (Chao et al., 2018). Several biological mechanisms have been proposed to explain these effects, including inhibition of lipid synthesis, enhancement of antioxidant defenses, and modulation of cholesterol biosynthesis (Yu-Yan, 2001). Furthermore, studies have indicated that water-soluble organosulfur compounds like S-allyl cysteine (SAC) and diallyl disulfide (DADS), particularly in aged garlic extracts and garlic oil, are potent inhibitors of cholesterol synthesis (Liu and Yeh, 2002).

Garlic's protective effects on cardiovascular health are attributed to its ability to reduce lipid accumulation in the arterial walls and suppress lipogenic enzyme activities. Recent evidence suggests that garlic-derived organosulfur compounds exert their lipid-lowering effects by enhancing the activity of liver enzymes involved in lipid metabolism, such as lecithin-cholesterol acyltransferase (LCAT) and acyl-CoA:cholesterol acyltransferase (ACAT), leading to improved cholesterol efflux and lipid profile regulation (Li et al., 2022). Additionally, garlic is rich in antioxidants that protect the body from oxidative damage by scavenging free radicals, thereby potentially reducing the risk of chronic diseases (Asdaq et al., 2015; Cheng et al., 2018).

Garlic has also been shown to improve cardiovascular parameters, such as microcirculation, and reduce carotid artery intima-media thickness, which are critical factors in reducing cardiovascular disease (Imaizumi et al., 2022). Additionally, garlic can lower blood lipids, decrease systolic and diastolic blood pressure, and improve high-density lipoprotein (HDL) levels (Varshney et al., 2016). These effects contribute to its potential in reducing the risk of cardiovascular diseases, especially those induced by high-fat diets. Furthermore, dietary factors, particularly saturated fats and cholesterol, significantly alter liver metabolic processes, affect lipid metabolism, and impact the biosynthesis of fatty acids and lipoproteins, which are associated with diseases like atherosclerosis and diabetes (Gonzalez, 2008; Fan, 2003).

The increasing prevalence of obesity and type 2 diabetes has been largely attributed to the rising consumption of saturated fats, which contribute to both obesity and an increased incidence of cardiovascular diseases such as stroke and heart attack (Jibran et al., 2020). In response to these growing health challenges, numerous studies are exploring natural food-based interventions to mitigate the effects of a high-fat diet. Garlic oil, with its readily available and affordable bioactive components, presents a promising option.

The aim of this study was to investigate the effects of garlic oil on metabolic changes in mice fed a high-fat diet. The findings from this study are of significant importance, as they may encourage the use of natural remedies such as garlic oil as an alternative approach to preventing obesity, diabetes, and cardiovascular diseases caused by high-fat diets. This research will also provide valuable insights and literature for future studies in the field.

MATERIALS AND METHODS

Experimental Animals

Twenty five (n=25) healthy mice bred in the animal's house, Benue state university Makurdi were purchased and were used for the study.

The animals were maintained in a room temperature with 12 hours light, 12 hours dark cycle and were allowed free access to standard feed and water at *libitum* in the Animal's House in College of Health Sciences, Benue state university Makurdi

Garlic Oil

Garlic Oil capsule, (3mg) per capsule, manufactured by Sirio Pharma Co., ltd no. 83, Taishan road (West), Shantou, China was procured from a registered pharmacy (Rovi Pharmacy), High level, Makurdi, Benue state, Nigeria.

Diet Composition

The HFD was formulated based on previous method described by Licholai et al. (2018), with modifications according to the procedure outlined by Abi et al. (2020). The composition included 60% normal chow diet (growers feed), 25% tallow, and 15% soya oil. The fat component consisted of 60% saturated fat and 40% unsaturated fat.

Experimental Design

The research animals were allowed to acclimatize for the period of two weeks. After acclimatization the weight of each animal was taken prior to administration and application of treatment, the body mass index was calculated from the readings. All animals were fed with normal diet throughout the period of acclimatization. Twenty five (25) healthy mice were randomly divided into five (5) groups of five (5) in each group and housed in a well-ventilated plastic cage, in the animal's house of College of Health Sciences, Benue State University, Makurdi. The experiment lasted for forty four (44) days with fourteen (14) days of acclimatization inclusive.

Animal Grouping

Group 1: Control group, they were fed with standard feed (rat chow) and water at *libitum*

Group 2: Fed on high fat diet only as diabetic model

Group 3: Fed on high fat diet and treated with 1 mg / kg of garlic oil.

Group 4: Fed on high fat diet and treated with 2 mg / kg of garlic oil.

Group 5: Fed on high fat diet and treated with 3 mg / kg of garlic oil.

Garlic oil gotten in 3mg per capsule, Mohamed *et al*., (2021).

Sample Collection

After the treatment days had elapsed, the animals were fasted for 12 hours prior to the time (day) of sacrifice (Rebekah, 2023). The animals were anesthetized using chloroform vapor and blood sample was collected by cardiac puncture in to sterile sample bottles, using 10ml syringes. The serum was finally subjected to biochemical analysis for lipid profile.

Ethical consideration

Ethical approval was obtained from the Animal Ethical Committee, of Benue State University. All animals were handled in accordance with the guidelines for animal research as detailed in the NIH Guidelines for the Care and Use of Laboratory Animals (NIH Publication 1985).

Statistical Analysis

Data are expressed as mean ± standard error of the mean (SEM). Statistical differences among groups were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's post-hoc test. A p-value < .05 was considered statistically significant. GraphPad Prism (version 9.0) was used for all analyses.

RESULTS

1. Effect of Garlic Oil on Cholesterol: The results from Figure 1 demonstrate that the model group (Group 2) fed a high-fat diet had significantly higher levels of cholesterol compared to the control group (Group 1) and the groups fed with garlic oil. However, there was no significant difference in cholesterol levels between the control group and the groups receiving low (1 mg/kg) or moderate (2 mg/kg) doses of garlic oil. The group receiving the high dose of garlic oil (3 mg/kg) (Group 5) showed a significant decrease in cholesterol levels compared to both the control group and the high-fat diet group (Group 2), highlighting the dose-dependent effect of garlic oil in reducing cholesterol levels ($p < 0.05$).

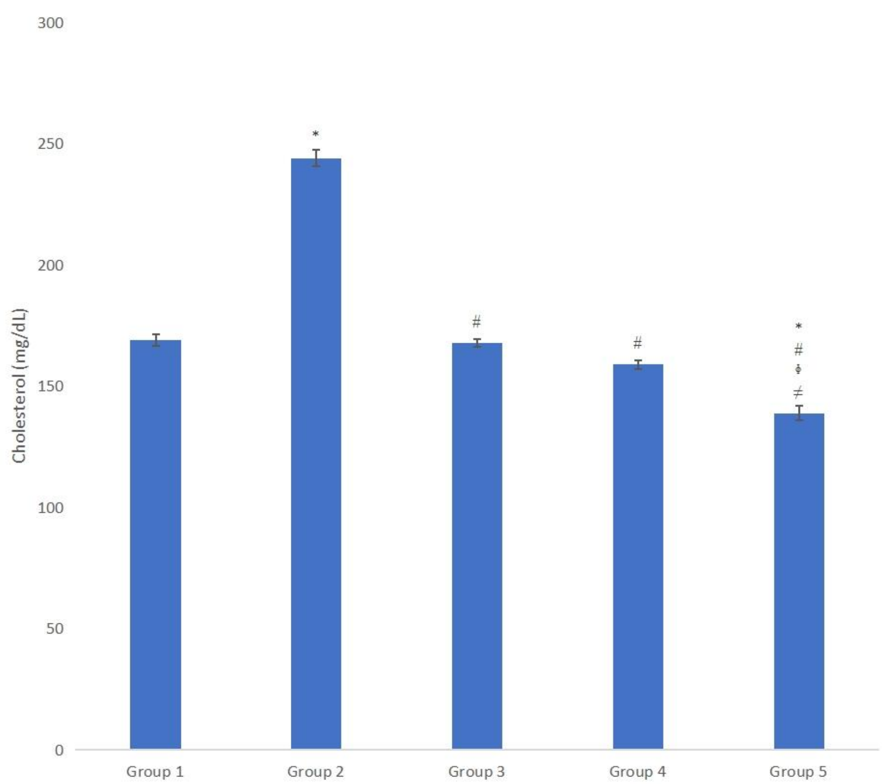

Figure 1: Cholesterol Level

N = 3, values expressed as mean ± SEM, * = significant relative to Group 1 at $P < 0.05$, # = significant relative to Group 2 at $P < 0.05$, ϕ = significant relative to Group 3 at $P < 0.05$, ǂ = significant relative to Group 4 at $P < 0.05$.

2. Effect of Garlic Oil on Triglycerides

In Figure 2, triglyceride levels were significantly elevated in the high-fat diet group (Group 2) and the group receiving the low dose of garlic oil (1 mg/kg, Group 3) compared to the control group (Group 1). In contrast, the groups receiving moderate (2 mg/kg) and high (3 mg/kg) doses of garlic oil had significantly lower triglyceride levels compared to the model group. These results confirm that garlic oil reduces triglyceride levels, with higher doses showing stronger effects ($p < 0.05$).

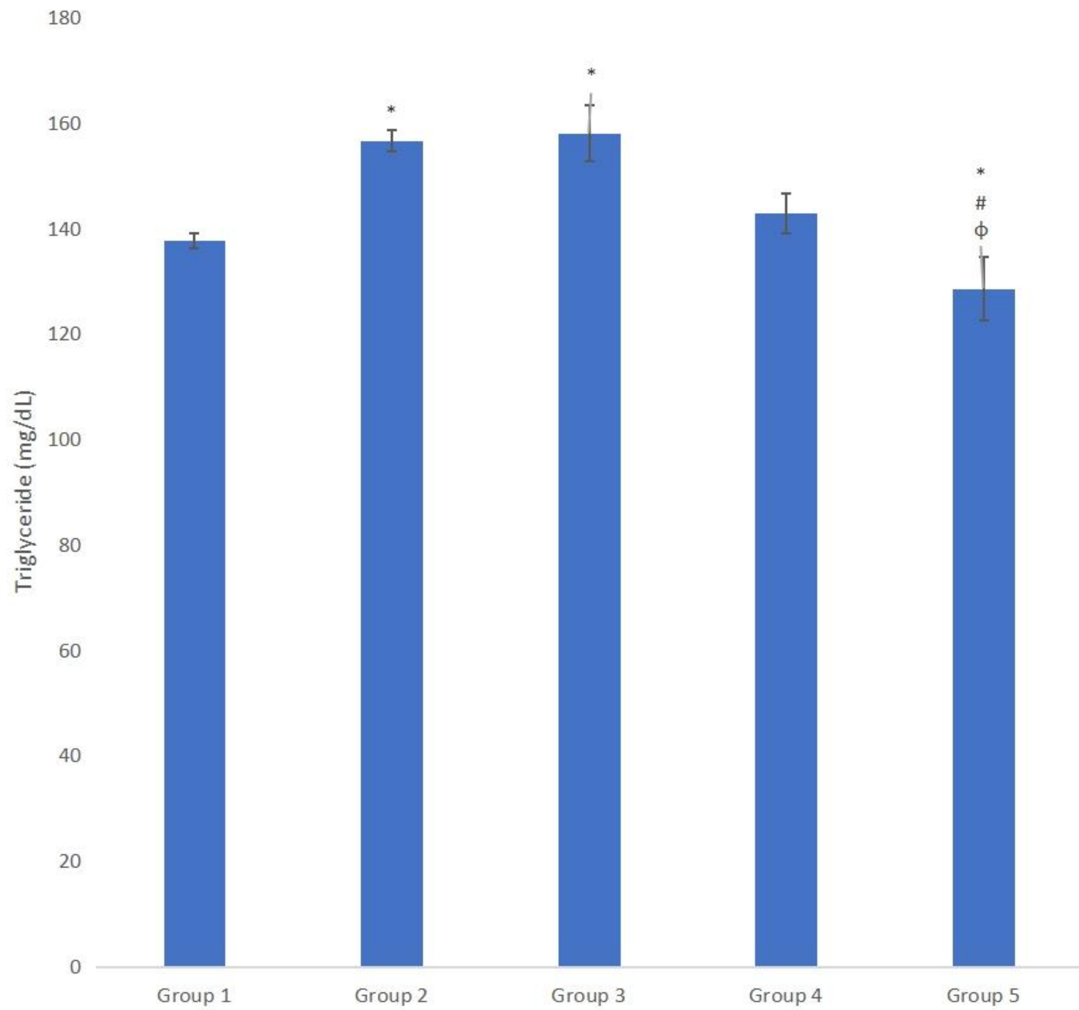

Figure 2: Triglyceride Level

N = 3, values expressed as mean ± SEM, * = significant relative to Group 1 at P < 0.05, # = significant relative to Group 2 at P < 0.05, ϕ = significant relative to Group 3 at P < 0.05, ɨ = significant relative to Group 4 at P < 0.05.

3. Effect of Garlic Oil on High-Density Lipoprotein Cholesterol (HDL-C)

The result showed that, HDL-C levels were significantly higher in the control group (Group 1) and the groups receiving garlic oil (Groups 3, 4, and 5) compared to the high-fat diet group (Group 2), which showed significantly lower HDL-C levels. The results suggest that garlic oil supplementation may enhance HDL-C levels, supporting its potential role in improving cardiovascular health ($p < 0.05$).

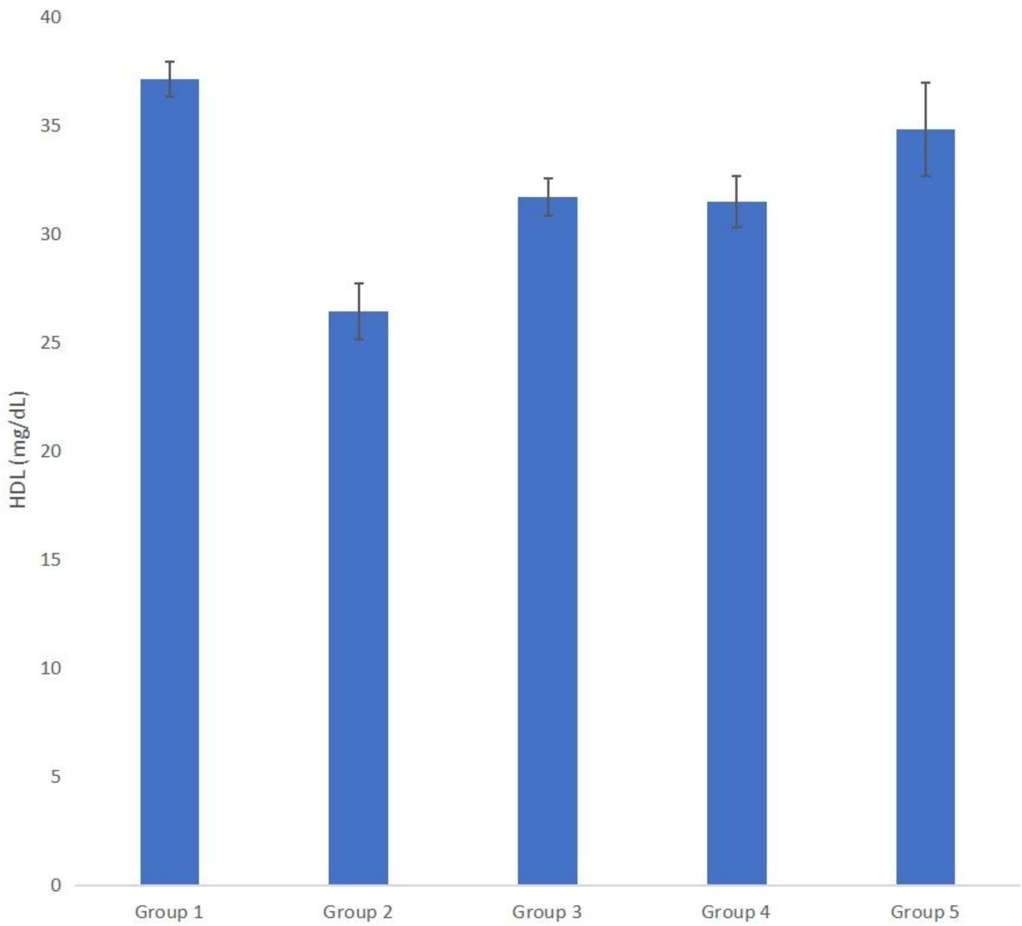

Figure 3: HDL Level

N = 3, values expressed as mean ± SEM, * = significant relative to Group 1 at $P < 0.05$, # = significant relative to Group 2 at $P < 0.05$.

4. Effect of Garlic Oil on Low-Density Lipoprotein Cholesterol (LDL-C)

In Figure 4, the model group (Group 2) fed with a high-fat diet exhibited significantly higher levels of LDL-C compared to the control group (Group 1) and all groups receiving garlic oil, regardless of dose. However, the groups receiving garlic oil (Groups 3, 4, and 5) had significantly higher LDL-C levels compared to the control group (Group 1), though they were lower than the model group ($p < 0.05$).

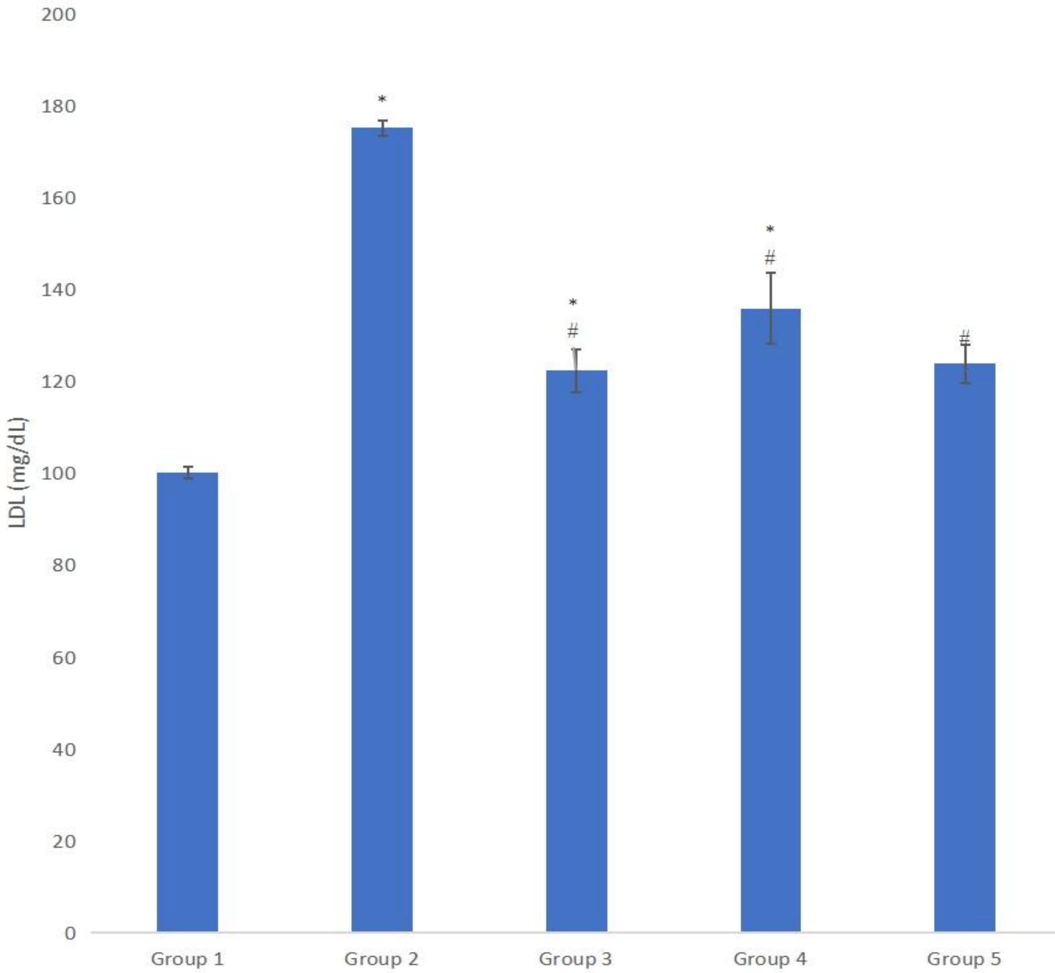

Figure 4: LDL Level

N = 3, values expressed as mean ± SEM, * = significant relative to Group 1 at P < 0.05, # = significant relative to Group 2 at P < 0.05.

5. Effect of Garlic Oil on Body Mass Index in Mice fed with High Fat Diet

Result showed that, the model group (group 2) showed significant ($p<0.05$) increase in body Mass Index when compared with control group (group 1) and groups fed with garlic oil and high fat diet concurrently.

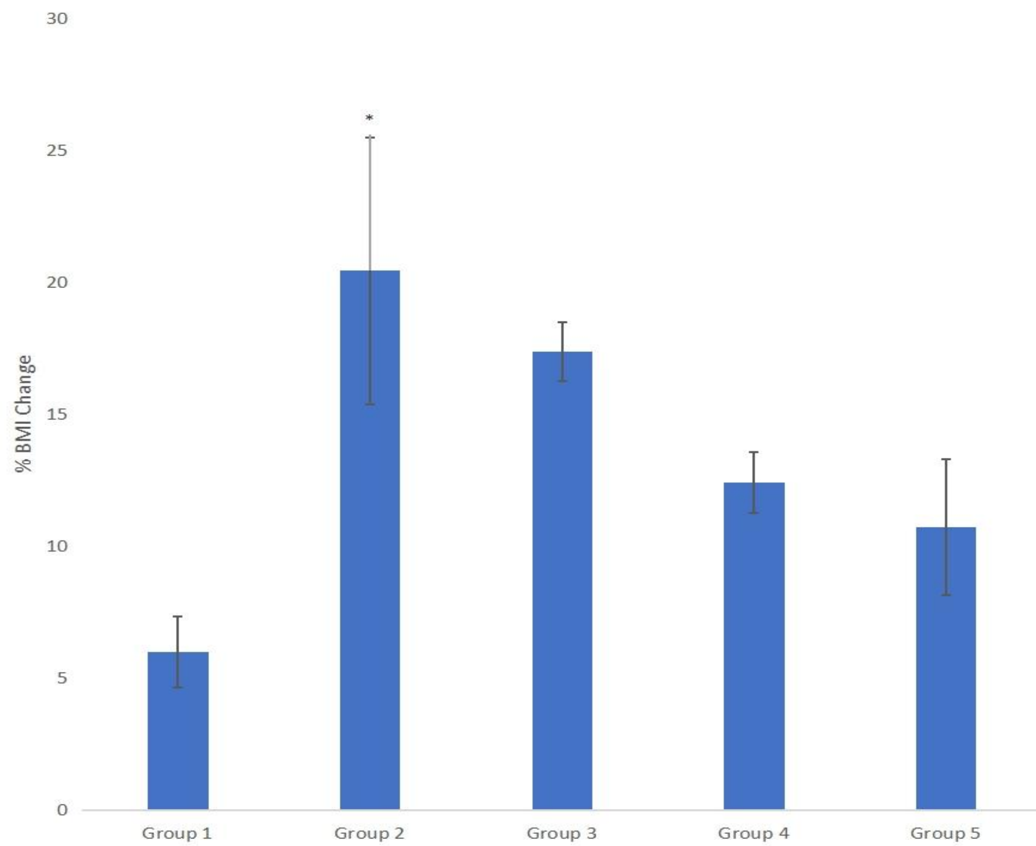

Figure 5: Percentage BMI Change

N = 3, values expressed as mean ± SEM, * = significant relative to Group 1 at P < 0.05.

RAW DATA FOR LIPID PROFILE

GROUP	CHOLESTEROL	TRIGLYCERIDE	HIGH DENSITY LIPOPROTIEN	LOW DENSITY LIPOPROTEIN
GROUP 1	164.54	153.44	35.7	98.15
	170.24	156.61	37.2	100.32
	172.34	155.03	38.45	102.46
GROUP2	240.34	160.48	28.8	175.45
	241.13	153.44	24.4	178.05
	250.74	155.96	26.1	172.25
GROUP3	170.21	168.25	33.4	113.16
	165.32	150.23	30.5	125.58
	168.2	155.52	31.24	128.45
GROUP4	155.83	140.13	30.7	125.66
	159.57	138.15	29.9	131.12
	161.7	150.2	33.8	150.99
GROUP5	144.54	125.5	30.8	125.5
	138.17	140	35.5	130.13
	134.15	120.12	38.15	116.12

RAW DATA FOR BODY MASS INDEX

	WEEK1	WEEK2	WEEK3	WEEK4	WEEK5
GROUP1	2.9	3.2	3.1	3.1	3.05
	2.9	3.2	3.2	3.1	3.15
	3.1	3.3	3.3	3.6	3.25
GROUP2	3.9	4.6	4.5	4.5	4.5
	3.6	3.9	4.1	4.3	4.7
	3.9	4.6	4.2	4.4	4.5
GROUP3	3.3	3.5	3.6	3.8	3.8
	3.3	3.5	3.5	3.9	3.9
	3.2	3.4	3.6	3.8	3.8
GROUP4	3.5	3.6	3.7	3.8	3.9
	3.6	3.6	3.6	3.8	4.0
	3.4	3.4	3.6	3.7	3.9
GROUP5	2.8	3.0	2.7	2.9	3.1
	3.3	3.7	3.5	3.5	3.8
	3.2	3.4	3.6	3.4	3.4

DISCUSSION

The findings from this study clearly demonstrate that a high-fat diet (HFD) alone (Group 2) led to significant alterations in lipid metabolism, including increased levels of cholesterol, triglycerides, low-density lipoprotein (LDL-C), and body mass index (BMI), while decreasing the levels of high-density lipoprotein (HDL-C). These alterations are consistent with the detrimental metabolic effects commonly observed in obesity and dyslipidemia. In contrast, supplementation with garlic oil (Groups 3, 4, and 5) resulted in a marked improvement in these lipid parameters. Specifically, garlic oil administration significantly reduced cholesterol, triglycerides, and LDL-C levels while simultaneously increasing HDL-C levels. These results align with previous research highlighting garlic's potential to positively influence lipid profiles and mitigate obesity-related biomarkers (Chao et al., 2018; Varshney et al., 2021).

The changes observed in cholesterol and BMI levels in the high-fat diet group (Group 2) that did not receive garlic oil were notably contrasting with garlic oil treatment. This observation supports findings from Yeh (2001), who demonstrated that garlic oil, due to its sulfur-containing compounds, plays a role in reducing cholesterol. The reduction in lipid levels, particularly LDL-C, is consistent with studies by Nicastro et al. (2018) and Liu et al. (2020), which emphasize garlic oil's beneficial effect on cholesterol in both animal models and human subjects. Moreover, the significant reduction in triglyceride levels across all garlic oil-treated groups corroborates results from Yanhui et al. (2022), who similarly observed the triglyceride-lowering effect of garlic oil in animal studies. These findings suggest that garlic oil supplementation can offer protective benefits against high-fat diet-induced lipid disturbances.

Garlic oil administration also led to a significant reduction in triglyceride levels in the treated groups. This is in agreement with Yanhui et al. (2022), who reported that garlic oil reduces triglycerides in animals, suggesting a protective effect against lipid accumulation and cardiovascular disease. In our study, the HFD group (Group 2), which did not receive garlic oil, had elevated triglyceride levels, which further potrays the lipid-lowering potential of garlic oil when added to a high-fat diet. This finding also aligns with research by Jiang et al. (2020), which demonstrated similar lipid-lowering effects of garlic oil supplementation in animal models of hyperlipidemia.

Regarding HDL-C, the results indicated that garlic oil increased HDL-C levels in all treatment groups. The highest dose of garlic oil (3 mg/kg, Group 5) showed the most significant increase in HDL-C levels, supporting the findings of Yue et al. (2018), who reported that garlic oil elevates HDL-C, often considered the "good" cholesterol. In contrast, the model group, which was fed a high-fat diet without garlic oil, exhibited significantly reduced HDL-C levels, corroborating the work of Damke (2006), who found that saturated fat decreases HDL-C levels. This further highlights the potential of garlic oil to counteract the harmful effects of a high-fat diet on cholesterol levels.

Garlic oil administration led to a significant reduction in LDL-C levels in the treated groups, confirming its potential to lower "bad" cholesterol. This result is consistent with the findings of Yue et al. (2018), who demonstrated that garlic oil reduces LDL-C levels in both animals and humans. The reduction of LDL-C levels observed in this study underscores the cardiovascular protective effects of garlic oil, as elevated LDL-C is a well-established risk factor for the development of atherosclerosis and cardiovascular diseases.

The significant reduction in body mass index (BMI) observed in the garlic oil-treated groups further emphasizes the beneficial effects of garlic oil on obesity. The reduction in BMI is likely due to the combined effects of garlic oil on lipid metabolism and adiposity regulation. This finding supports previous research by Fateme et al. (2022), who reported that garlic oil supplementation helps decrease body weight and adiposity in animal models of obesity. The role of garlic oil in reducing adiposity could be attributed to its ability to modulate fat cell metabolism and promote fat oxidation, as highlighted in studies by Wu et al. (2017) and Makarov et al. (2020), who found that garlic oil could reduce fat accumulation by increasing the activity of lipolytic enzymes.

These results collectively demonstrate that garlic oil has the potential to improve lipid profiles, reduce adiposity, and mitigate the negative metabolic effects of a high-fat diet. Our findings align with previous studies suggesting that garlic oil, particularly due to its sulfur compounds, can be an effective intervention for managing dyslipidemia, obesity, and related conditions. This is important, considering the global rise in obesity and cardiovascular diseases. Given the promising results observed in this study, garlic oil supplementation could be considered a beneficial addition to dietary interventions aimed at combating metabolic disorders.

CONCLUSION

In conclusion, this study shows that garlic oil supplementation significantly reduces cholesterol, triglycerides, LDL-C, and BMI, while it increases HDL-C levels in mice fed a high-fat diet. These findings support the hypothesis that garlic oil possesses anti-lipidemic and anti-obesity properties. The results are consistent with the studies of Chao et al. (2018), Varshney et al. (2021), and Yue et al. (2018). Garlic oil may therefore be an effective natural remedy for preventing obesity, dyslipidemia, and cardiovascular diseases. However, further studies with longer durations are required to fully assess the long-term effects of garlic oil on metabolic changes and its potential for clinical applications. Future clinical trials should explore the optimal dosage, the mechanisms of action, and the effects of garlic oil supplementation in human populations with metabolic disorders, to better understand its therapeutic potential and establish concrete recommendations for its use in healthcare.

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