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RESEARCH ARTICLE

PROTECTIVE EFFECTS OF Microtermes nigeriensis OIL ON LIPID PROFILE, FASTING BLOOD GLUCOSE AND ATHEROGENIC RISK PREDICTORS IN HYPERCHOLESTEROLEMIC RATS

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Abstract

Background and Objectives: Hypercholesterolemia is a major risk factor for cardiovascular diseases, prompting interest in alternative dietary interventions with lipid-lowering properties. Edible insects are emerge as functional foods due to their rich nutrients and bioactive composition. This study evaluated the protective effects of *Microtermes nigeriensis* oil supplementation on lipid profile, fasting blood glucose, and atherogenic risk indices in hypercholesterolemic Wistar rats.
Methods: Oil was extracted from *M. nigeriensis* using Soxhlet extraction with n-hexane, yielding 19.86%. Thirty male albino rats were divided into five groups: normal control, hypercholesterolemic control, hypercholesterolemic + 5% oil, hypercholesterolemic + 10% oil, and 15% oil only. Hypercholesterolemia was induced using egg yolk-enriched diet for 21 days. Serum lipid profile, fasting blood glucose, body weight, and atherogenic indices were determined using standard methods.
Results: The oil was rich in oleic acid (55.16%) with total unsaturated fatty acids of 62.94%. Supplementation significantly reduced total cholesterol, triglycerides, and LDL-C while improving HDL-C. The 15% oil group showed the greatest effect, reducing total cholesterol by 36.29%, lowering LDL-C to 59.54 mg/L, and increasing HDL-C to 50.56 mg/L. Fasting blood glucose and atherogenic indices also improved significantly.
Conclusion: *Microtermes nigeriensis* oil demonstrated hypolipidemic, glucose-lowering, and anti-atherogenic effects, suggesting potential as a functional dietary intervention against dyslipidemia.
Keywords: Atherogenic index, edible insect oil, functional food, hypercholesterolemia, lipid profile, *Microtermes nigeriensis*.

INTRODUCTION

Hypercholesterolemia is defined by abnormally high levels of cholesterol in the bloodstream, triglycerides, and low-density lipoprotein cholesterol (LDL-C), which predispose individuals to atherosclerosis, coronary heart disease, and stroke[1]. Cardiovascular disease remains the leading cause of mortality worldwide, accounting for approximately 17.9 million deaths annually, with dyslipidemia representing a key modifiable risk factor[2]. Dietary intervention remains one of the most practical approaches to managing hypercholesterolemia. Functional foods rich in monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) have been shown to improve lipid metabolism, reduce LDL oxidation, and decrease cardiovascular risk[3]. Recently, edible insects have emerged as promising sustainable nutritional resources due to their rich protein, lipid, mineral, and antioxidant contents[4].

Microtermes nigeriensis, an edible termite commonly consumed in many African communities, is traditionnally valued for its nutritional richness, especially during the rainy season. Despite its widespread consumption, limited studies have evaluated its extracted oil for lipid-modulating and anti-atherogenic

properties. Previous research has shown that oils obtained from insects such as *H. illucens* and *Tenebrio molitor* can improve serum lipid profiles and reduce oxidative stress, likely due to their beneficial fatty acid content[5]. However, there remains a knowledge gap regarding the cardiometabolic benefits of *M. nigeriensis* oil, particularly in experi-mentally induced hyper-cholesterolemia.

Therefore, this study investigated the fatty acid composition and hypolipidemic effects of *M. nigeriensis* oil supplementation on lipid profile, fasting blood glucose, body weight, and atherogenic risk indices in hypercholesterolemic albino rats.

MATERIALS AND METHODS

Sample collection

Adult winged termites (*M. nigeriensis*) were collected during the rainy season (May–June, 2025) in the early morning hours from residential buildings in Umudike community, Abia State, Nigeria, using traditional light attraction methods at night followed by handpicking. The collected insects were immediately transported in ice-packed containers to the Department of Biochemistry Laboratory, Michael Okpara University of Agriculture, Umudike, for further processing. Selection of *M. nigeriensis* was based on its local edibility, nutritional importance, availability, and high community preference as a commonly accepted and widely consumed delicacy in the area.

Sample processing

Collected termites were sorted manually to remove extraneous materials such as stones and debris, after which the wings and legs were removed. The samples were washed three times with clean tap running water to remove dirt and soil particles. The cleaned termites were blanched in hot water for 60 s, drained and oven-dried at 40°C for 12 h. The dried samples were milled into fine powder using an electric blender (Model BN-2001-62WC, Germany) to particle size <1 mm. The powdered samples were stored in airtight containers at −4°C until analysis.

Oil extraction

Oil extraction was performed using Soxhlet extraction according to Jayanegara *et al.*[6]. About 100 g of powdered termite sample was placed in a cellulose thimble and extracted with n-hexane using a Soxhlet apparatus for 6 h. The solvent was removed by evaporation in an oven at 60°C, and the extracted oil was collected, transferred into dark airtight bottles, and refrigerated until use.

Determination of percentage oil yield

Oil yield was determined gravimetrically after complete solvent evaporation using a water bath at 70°C for 30 min. Percentage oil yield was calculated:

$$\text{Oil yield (\%)} = \frac{\text{Weight of oil extracted}}{\text{Weight of sample used}} \times 100$$

Chemicals, reagents and apparatus

All chemicals and reagents used were of analytical grade and included n-hexane, hydrochloric acid, potassium hydroxide, methanol, n-heptane, sodium hydroxide, sodium chloride, potassium chloride, and distilled water. Lipid profile assay kits for total cholesterol, triacylglycerol, and HDL-cholesterol were obtained from Randox Laboratories. Other reagents were procured from HosLab, Umuahia, Nigeria.

Equipment used included electronic weighing balance (Model SF-400), glucometer (Accu-Chek Active, Roche Diagnostics, Germany), GC-MS system, centrifuge (Model 800B, Tenor, Italy), UV-Visible spectrophotometer (Model 1138), incubator (Triton-DNP-9022-1A), water bath (HH-W420), Gallenkamp oven, refrigerator (LG), Soxhlet apparatus, micro-pipettes, test tubes, and sample bottles.

Determination of fatty acid composition

Fatty acid composition was analyzed. One gram of extracted oil was saponified with 15 mL methanolic KOH at 90°C for 1 h, followed by treatment with 2 mL of 1.4 N HCl for another 1 h. After cooling, 15 mL n-heptane and 200 mL brine were added. Fatty acid methyl esters (FAMEs) obtained were analyzed using gas chromatography–mass spectrometry (GC-MS) with helium as carrier gas. Identification was performed by comparison with authentic FAME standards (Supelco 37 Component FAME Mix, Sigma Chemicals, USA)[7].

Diet formulation

Experimental diets were formulated according to AIN guidelines as modified by Rocha *et al.*[8]. Hyper-cholesterolemic diet was prepared by incorporating 5% egg yolk into standard rat feed. *M. nigeriensis* oil was supplemented into feed at 5%, 10%, and 15% levels for test diets.

Experimental animals

Thirty male albino rats (115–150 g) obtained from the Department of Veterinary Medicine Animal House, Michael Okpara University of Agriculture, Umudike, were used. Animals were housed under standard laboratory conditions (12 h light/dark cycle, room temperature 25±2°C) and acclimatized for 7 days with free access to feed and water ad libitum. Experimental procedures complied with ILAR guidelines for laboratory animal care[9].

Experimental design

Treatment lasted for 21 days. Animals were randomly divided into five groups (n=6):

1. Group A: Normal control.

2. Group B: Hypercholesterolemic control (standard diet + 5% egg yolk + cholesterol).

3. Group C: Standard diet + 5% egg yolk + 5% *M. nigeriensis* oil.

4. Group D: Standard diet + 5% egg yolk + 10% *M. nigeriensis* oil.

5. Group E: Standard diet + 15% *M. nigeriensis* oil only.

Blood collection and serum preparation

At the end of treatment, rats were fasted overnight, anesthetized, and sacrificed by cardiac puncture. Blood samples were collected into plain sample tubes and allowed to clot for 30 min. Samples were centrifuged at 3000 × g for 10 min to obtain serum, which was stored at −20°C until analysis.

Biochemical assays

Fasting blood glucose was determined using Accu-Chek Active glucometer (Roche Diagnostics, Germany). Serum lipid parameters including total cholesterol, triglycerides, HDL-cholesterol, and LDL-

cholesterol were analyzed using enzymatic colorimetric methods with Randox commercial kits. LDL-cholesterol was calculated using the Friedewald equation[10].

Determination of atherogenic indices

Atherogenic risk indices were calculated as follows[11]:

$$\text{Cardiac Risk Ratio (CRR)} = \frac{TC}{HDL - C}$$

$$\text{Atherogenic Coefficient (AC)} = \frac{TC - HDL - C}{HDL - C}$$

$$\text{Atherogenic Index (AI)} = \frac{LDL - C}{HDL - C}$$

Statistical analysis

Data were expressed as mean±standard deviation (SD). Statistical analysis was performed using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test for post hoc comparisons using SPSS version 16.0. Differences were considered statistically significant at $p<0.05$.

RESULTS AND DISCUSSION

Table 1 shows that the percentage oil yield of the *M. nigeriensis* after extraction with hexane was 19.86 %.The fatty acid composition shown in Table1 indicated four dominant fatty acids: oleic acid (monounsaturated) at 55.16%, palmitic acid (saturated) at 28.06%, stearic acid (saturated) at 8.12% and linoleic acid (polyunsaturated) at6.96%. The *M. nigeriensis* oil has shown a good ratio (1.69) of TUFA/TSFA, indicating higher degree of unsaturation than the saturated fatty acid. Figure 1 presents the mean weekly feed intake across the different treatment groups, showing a significant difference ($p<0.05$) in the positive control group, which received a standard diet with egg yolk only (HC), when compared with the normal control (NC) and other experimental groups. The results also indicated that animals fed the diet supplemented with 5% *M. nigeriensis* oil consumed a lower but significant amounts of feed. However, the percentage feed intake did not differ significantly ($p>0.05$) from that of the group fed the unsupplemented control diet.

Table 2 shows that no mortality or observable signs of toxicity were recorded throughout the experimental period, indicating that supplementation with *M. nigeriensis* oil was well tolerated by the animals. All experimental rats remained healthy and were available for final assessment.

Table 1: Fatty acid composition and degree of saturation of *M. nigeriensis* oil sample.

Formula	Identification	Composition (%)
C12:0	Lauric acid	0.25±0.06
C14:0	Myristic acid	0.73±0.03
C16:0	Palmitic acid	28.06±0.12
C16:1	Palmitoleic	0.82±0.02
C18:0	Stearic acid	8.12±0.29
C18:1	Oleic acid	55.16±0.58
C18:2	Linoleic acid	6.96±0.14
Degree of saturation	**Full name**	**Composition (%)**
MUFA	Monounsaturated fatty acid	55.98
PUFA	Polyunsaturated fatty acid	6.96
TUFA	Total unsaturated fatty acid	62.94
TSFA	Total saturated fatty acid	37.04
TUFA/TSFA	-----	1.69

Values are expressed as mean±standard deviation (SD) of duplicate determinations; MUFA, PUFA, TUFA, and TSFA represent monounsaturated, polyunsaturated, total unsaturated, and total saturated fatty acids respectively, while fatty acid composition was determined using GC–MS following AOAC.

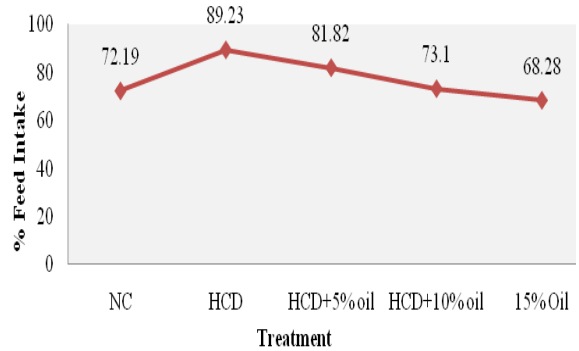

Figure 1: Mean weekly feed intake in different treatment groups.

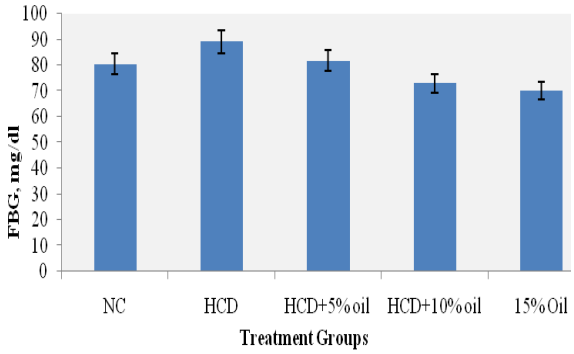

Figure 2: Fasting blood glucose (FBG) levels in different treatment groups.

A transient reduction in body weight was observed in Groups 3, 4, and 5 during the first week of treatment, after which gradual weekly weight gain occurred across all groups. The positive control group (Group 2) exhibited a significantly higher ($p<0.05$) mean weekly body weight gain compared with the normal control and groups fed cholesterol-based diets supplemented with *M. nigeriensis* oil. No significant difference ($p>0.05$) was observed among rats fed 5% and 10% oil-supplemented cholesterol diets with respect to body weight gain.

Table 2: Body weight changes in rats fed *M. nigeriensis* oil supplemented feed.

Treatment	Body weight (g)		
	Initial	Final	Change (%)
Normal control	133.17±4.89	159.4±5.3	26.3 (16.45) [a]
Positive control (EY)	120.6±3.12	145.9±8.2	25.3 (17.34) [b]
EY+5% MNO	127.7±0.36	151.1±3.7	23.4 (15.48)[ab]
EY+10% MNO	113.8±2.12	132.4±8.3	18.6 (14.06) [a]
15% MNO only	139.18±6.41	162.2±2.1	23.02 (14.19) [a]

Values are expressed as mean±standard deviation (SD), and different superscript letters within the same column indicate statistically significant differences at $p<0.05$; MNO=*M. nigeriensis* oil and EY=egg yolk.

Table 3: Serum lipid profile (mg/L) of rats fed *M. nigeriensis* oil supplemented feed.

Group	TC	HDL-C	LDL-C	TAG
Normal control	142.52±0.51[a]	48.49±0.04[a]	66.92±0.04[a]	135.54±0.12[a]
Positive control (HCD)	166.26±2.10[b]	36.45±0.15[b]	97.85±4.20[b]	159.82±0.01b
HCD+5% MNO	154.31±0.84[c]	40.45±1.06[c]	85.32±3.01[c]	142.68±2.14[c]
HCD+ 10% MNO	149.79±2.04[ac]	45.16±4.51[ad]	75.14±0.88[d]	144.45±3.01[c]
15%MNO only	138.31±4.12[d]	50.56±3.02[a]	59.54±2.42[e]	141.07±1.18[c]

Values are mean±standard deviation. Values with different alphabets in column are statistically significant ($p<0.05$). MN=*M. nigeriensis*. EY= Egg York.

Although the normal control group recorded the highest percentage weight gain (16.45%) relative to Groups C (15.48%), D (14.06%), and E (14.19%), these differences were not statistically significant ($p>0.05$), except in the positive control group, which showed a comparatively greater increase in body weight. Values are expressed as mean±standard deviation (SD), and different superscript letters within the same column indicate statistically significant differences at $p<0.05$; MNO=*M. nigeriensis* oil and EY=egg yolk. Figure 2 shows that fasting blood glucose (FBG) levels were significantly elevated in the high-cholesterol control group compared with the normal control group, indicating the metabolic effect of the cholesterol-enriched diet. A progressive reduction in FBG levels was observed in Groups C–E following dietary supplementation with *M. nigeriensis* oil at different concentrations. Although the treated groups exhibited lower glucose levels relative to the positive control, no statistically significant difference ($p>0.05$) was observed among Groups C, D, and E. Notably, rats fed the 15% *M. nigeriensis* oil-supplemented diet recorded the lowest fasting blood glucose level among all treatment groups, suggesting a possible dose-dependent glucose-lowering effect of the oil.

Table 3 presents the serum lipid profile of experimental rats at the end of the study period. The hypercholesterolemic control group (HC) showed a significant increase ($p<0.05$) in total cholesterol (TC) compared with the normal control (NC) and all treated groups, confirming successful induction of hypercholesterolemia using the egg yolk-enriched diet. Supplementation with *M. nigeriensis* oil in Groups C, D, and E resulted in a dose-related reduction in TC, with percentage decreases of 22.1%, 33.42%, and 36.29%, respectively. Similarly, triglyceride (TG) levels were reduced by 17.79%, 20.28%, and 22.01% across the respective treatment groups. However, changes in HDL-C were not statistically significant ($p>0.05$) in Groups C and D when compared with both the positive and normal controls, except in Group E (15% *M. nigeriensis* oil), which showed a significant increase in HDL-C levels ($p<0.05$). LDL-C levels were reduced by 24.3% in the group receiving 5% oil supplementation, although no statistically significant reductions were observed in Groups C and D relative to the positive control. Overall, improvements in lipid parameters were more pronounced with increasing dietary inclusion of *M. nigeriensis* oil, suggesting a dose-dependent hypolipidemic effect.

Table 4 shows that the atherogenic risk index, expressed as the LDL-C/HDL-C ratio, was lower in *M. nigeriensis* oil-treated groups compared with the egg yolk-induced high-cholesterol control group. Although the LDL-C/HDL-C ratio in the EY + 5% MNO and EY + 10% MNO groups did not differ significantly ($p>0.05$), a marked improvement in the negative atherogenic index was observed in the group that fed 15% MNO without egg yolk induction. Furthermore, dietary supplementation with varying concentrations of MNO significantly improved the positive atherogenic risk predictor index (HDL-C/TC) when compared with the positive control group.

Table 4: Atherogenic risk predictor indices in rats fed Mn-oil supplemented feed.

Group	Positive index (HDL-C/TC	Negative Index LDL-C/HDL-C
Normal control	0.34±0.11[a]	1.38±0.12[a]
Positive control (HCD)	0.21±0.15[b]	2.68±0.28[b]
HCD+ 5% MNO	0.26±0.08[c]	2.10±0.06[b]
HCD+ 10% MNO	0.31±0.14[ad]	1.65±0.21[b]
15% MNO only	0.37±0.02[e]	1..07±0.07[c]

Values are expressed as mean±standard deviation (SD), and different superscript letters within the same column indicate statistically significant differences at $p<0.05$; MNO=*M. nigeriensis* oil and HCD=hypercholesterolemic diet.

The most pronounced cardioprotective effect was recorded in Group E, which received 15% MNO supplementation alone, indicating superior modulation of lipid-related cardiovascular risk markers at higher inclusion levels of the oil. The oil yield of 19.86% obtained from *M. nigeriensis* indicates a moderate lipid recovery when compared with higher-yielding edible insect species such as *H. illucens*, which has been reported to possess substantially higher extractable lipid fractions, highlighting species-dependent variability in insect lipid content and extraction efficiency. However, the dominance of oleic acid (55.16%) and the TUFA/TSFA ratio of 1.69 strongly indicate a cardioprotective lipid profile, since MUFA-rich oils have consistently been associated with improved plasma lipid regulation, including LDL-C reduction and HDL-C elevation, as well as reduced atherogenesis[12-14]. This finding is consistent with earlier reports on edible termites that emphasize their richness in unsaturated fatty acids and potential as functional lipid sources[15] and it further extends those observations by demonstrating *in vivo* hypolipidemic efficacy in a cholesterol-induced animal model.

The feed intake pattern observed in the hyper-cholesterolemic control group suggests that egg yolk enrichment may alter metabolic signaling and dietary preference, consistent with high-fat diet studies reporting dysregulation of satiety pathways and altered hypothalamic appetite control[16,17]. However, the absence of significant appetite suppression in MNO-treated groups indicates that *M. nigeriensis* oil is well tolerated, aligning with insect oil supplementation studies that reported minimal effects on feed acceptability and palatability[4]. In contrast to some high-fat feeding models that show reduced intake due to metabolic stress, the present findings demonstrate relatively stable consumption patterns under MNO supplementation, suggesting metabolic adaptation without adverse feeding suppression.

Body weight gain was highest in the hyper-cholesterolemic control group, confirming lipid accumulation and impaired lipid utilization characteristic of cholesterol-enriched diets, as previously documented in high-fat diet models[18,19]. In comparison, the reduced weight gain observed in MNO-treated groups suggests improved lipid oxidation and energy utilization, consistent with reports that MUFA-rich diets enhance mitochondrial fatty acid oxidation and reduce adiposity[20]. This indicates a protective metabolic effect of the oil against diet-induced weight gain.

The observed reduction in fasting blood glucose among MNO-treated rats suggests improved glucose homeostasis, potentially mediated through enhanced insulin sensitivity and improved membrane lipid composition influenced by unsaturated fatty acids[21,22]. Similar glucose-lowering effects have been reported in MUFA-based dietary interventions, although the magnitude observed in the present study may reflect combined bioactive effects of insect-derived lipid fractions and unsaturated fatty acid composition.

Serum lipid analysis revealed a clear dose-dependent hypolipidemic effect of MNO, with the 15% supplementation group showing the most pronounced improvement, including a 36.29% reduction in total cholesterol, reduced LDL-C (59.54 mg/L), and elevated HDL-C (50.56 mg/L). These findings are comparable to MUFA-enriched dietary studies reporting 20–35% reductions in TC and LDL-C[23,24], suggesting that *M. nigeriensis* oil demonstrates competitive lipid-lowering potential. However, the relatively marked increase in HDL-C compared with some plant-derived lipid interventions suggests a potentially enhanced effect on reverse cholesterol transport and HDL functionality.

Mechanistically, the lipid-lowering activity may be attributed to inhibition of intestinal cholesterol absorption, increased hepatic LDL receptor expression, modulation of HMG-CoA reductase activity, and enhancement of reverse cholesterol transport pathways, mechanisms commonly associated with MUFA-rich dietary fats and bioactive lipid fractions[24]. The combined influence of bioactive lipid components in insect oil may further potentiate these effects beyond those observed in conventional plant oils.

Finally, the atherogenic indices demonstrated significant cardiovascular risk reduction, particularly in the 15% MNO group, where the positive index (HDL-C/TC=0.37) improved and the negative index (LDL-C/HDL-C=1.07) decreased markedly. These findings indicate improved lipid balance and reduced atherogenic potential, consistent with epidemiological and clinical evidence linking lower LDL/HDL ratios with reduced coronary heart disease risk[25,26]. Compared with previous dietary lipid intervention studies, the magnitude of improvement observed suggests that *M. nigeriensis* oil may exert comparable or potentially superior cardiometabolic benefits under experimental high cholesterol conditions, although further mechanistic, dose-optimization, and long-term studies are required to fully validate its therapeutic potential.

This study fills an important gap by providing the first evidence that *M. nigeriensis* oil possesses lipid-lowering and anti-atherogenic effects in experimentally induced hypercholesterolemia. Previous studies have mainly concentrated on the nutritional composition of edible insects, with limited attention given to their potential therapeutic applications in cardiovascular health.

Limitations of the study

The limitations of this study include the use of an experimental rat model, which may not fully reflect human physiology; a relatively short duration that may not capture long-term effects; possible use of limited dosage levels without a full dose–response evaluation; and restricted mechanistic insight since the study focused mainly on biochemical parameters without detailed molecular or histopathological confirmation.

CONCLUSION

M. nigeriensis oil possesses significant hypolipidemic and anti-atherogenic properties in hyper-cholesterolemic rats. Its high oleic acid and total unsaturated fatty acid content likely contributed to reductions in total cholesterol, triglycerides, LDL-C, and improved HDL-C levels. Dietary supplementation with MNO may represent a promising functional food strategy for

managing hypercholesterolemia and reducing cardio-vascular risk.

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AUTHOR'S CONTRIBUTION

Alaebo PO: conceptualization, supervision. **Obasi VN:** experimental procedures. **Ogbonna AO:** data collection, laboratory analysis. **Anyadike NN:** data analysis, writing original draft. **Odo VC:** data analysis, writing original draft. **Onuoha UN:** data analysis. **Muoneke BS:** data interpretation. **Njoku B:** data interpretation. All authors reviewed and approved the final version of the manuscript.

DATA AVAILABILITY

The associated author can provide the empirical data used to support the study's conclusions upon request.

CONFLICT OF INTEREST

There are no conflicts of interest in regard to this project.

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