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Lipid Profile Alterations in Rats Fed Oxidized Palm Oil Diets

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Abstract **Original Research Articles**

This study investigated the effects of oxidized palm oil diets on lipid profile parameters; total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) in Wistar rats. Twenty (20) male albino Wistar rats were randomly assigned to four groups (n = 5): control, fresh palm oil diet (FPO), photo-oxidized palm oil diet (PPO), and thermo-oxidized palm oil diet (TPO). After the period of administration, animals were sacrificed under urethane anesthesia, and blood samples were collected via cardiac puncture for serum biochemical analysis. The results showed that total cholesterol levels showed no significant differences among groups. However, triglyceride concentrations were significantly elevated ($p < 0.05$) in the PPO and TPO groups compared with the control. HDL levels were significantly reduced ($p < 0.05$), while LDL levels were significantly increased ($p < 0.05$) in both PPO- and TPO-fed rats relative to the control. In conclusion, these findings indicate that consumption of oxidized palm oil adversely alters lipid profile, potentially increasing the risk of cardiovascular disease and contributing to tissue damage.

Keywords: Palm oil, FPO TPO, PPO, Cholesterol, triglyceride, HDL, LDL.

INTRODUCTION

The increasing global demand for edible oils has led to a widespread reliance on palm oil due to its high yield and versatility in food processing (Sundram *et al*., 2003). However, palm oil, like other vegetable oils, is susceptible to oxidation, a process accelerated by heat, light, and air exposure during processing, storage, and cooking (Choe & Min, 2006). Oxidation leads to the formation of various deleterious compounds, including hydroperoxides, aldehydes, and free radicals, which can significantly alter the oil's nutritional quality and introduce potential health risks (Choe & Min, 2006; Shahidi & Zhong, 2005).

Lipid profile, encompassing parameters such as total cholesterol, triglycerides, low-density lipoprotein, and high-density lipoprotein, is an important indicator of cardiovascular health. Dyslipidemia, characterised by an imbalance in these lipid parameters, is a risk factor for atherosclerosis, and other metabolic disorders (Grundy, 2004). While the impact of fresh, unoxidized palm oil on lipid profiles has been a subject of ongoing debate, with some studies suggesting beneficial effects due to its balanced fatty acid composition (Hayes *et al*., 1995), the consumption of oxidised oils presents a distinct and concerning health challenge (Osim *et al*., 1996; Choe & Min, 2007).

In vivo and in vitro scientific studies have suggested that oxidised lipids may induce oxidative stress, inflammation, and cellular damage, potentially contributing to various pathologies (Staprans *et al*., 2005; Uchida, 2003). Specifically, the consumption of oxidised fats has been linked to alterations in hepatic lipid metabolism, impaired lipoprotein synthesis and catabolism, and increased oxidation of LDL, further aggravating atherogenic processes (Osim *et al*., 1996; Staprans *et al*., 1994; Kanner, 2007). Given the widespread consumption of palm oil, often in forms that may have undergone some degree of oxidation, it is imperative to investigate the specific effects of oxidised palm oil, specifically photo-oxidised palm oil (PPO) and thermo-oxidised palm oil (TPO), on lipid profiles.

This study examined the changes in the lipid profile of rats fed diets containing oxidised palm oil. By systematically analyzing key lipid parameters (high-density lipoprotein, low-density lipoprotein, triglycerides, and total cholesterol), this research aims to elucidate the potential dyslipidemic effects associated with the consumption of oxidized palm oil. The findings from this study will contribute to a better understanding of the health implications of oxidised dietary fats and provide valuable insights for public health recommendations regarding the processing and consumption of edible oils.

MATERIALS AND METHODS

Animal Care

Twenty (20) healthy adult male Wistar rats, weighing 140–160 g, were utilized in this study. The animals were housed under standard laboratory conditions (29 ± 2 °C; relative humidity 40–55%) with ad libitum access to water and standard rat chow. All procedures were conducted following the Guidelines for the Care and Use of Laboratory Animals in Biomedical Research (National Research Council, 1985). The animals were acclimatized for 14 days before the commencement of the experiment.

Procurement of Fresh Palm Oil

A ten litres of fresh palm oil was procured directly from a palm oil mill in Ukpenu, Ekpoma, Esan West Local Government Area, Edo State, Nigeria, and immediately stored in a black container. The container was kept in a cool, dry room, protected from sunlight and heat.

Preparation of Thermo and Photo-oxidised Palm Oil

Photo-oxidized palm oil was produced by subjecting fresh palm oil to direct sunlight exposure for 5 hours per day over 20 days, simulating typical market conditions. The procedure was adapted from Beshel *et al*. (2018) with minor modifications.

Thermo-oxidized palm oil was prepared by subjecting a separate portion of fresh palm oil to five cycles of heating for 10 minutes each. After every heating cycle, the oil was allowed to cool before reheating at 190 °C. This process was designed to replicate the thermal conditions commonly employed in frying foods such as akara and yam.

Formulation of Palm Oil Diets (Fresh Palm Oil, Photo-oxidised and Thermo-oxidised Palm Oil Diets)

The palm oil diets (fresh, photo-oxidized, and thermo-oxidized) were formulated following the methods of Beshel *et al*., (2014) and Ikhajiangbe *et al*., (2025). Each formulation consisted of 15 g of palm oil thoroughly mixed with 85 g of rat chow to produce a 15% palm oil diet, reflecting the typical composition of a traditional Black African diet as reported by Umoh (1972).

Experimental Protocol

The animals were randomly assigned into four (4) groups of five (5) rats each:

Group 1 (Control): Received standard rat chow without palm oil supplementation.

Group 2 (FPO): Fed a diet containing 15% fresh palm oil.

Group 3 (PPO): Fed a diet containing 15% photo-oxidized palm oil.

Group 4 (TPO): Fed a diet containing 15% thermo-oxidized palm oil.

The period of administration lasted for 30 days.

Collection of Blood

Twenty-four hours (day 31) after the last administration, the animals were sacrificed under urethane anesthesia and blood samples were collected through cardiac puncture and the blood dispensed into containers.

Biochemical Analysis

The blood in EDTA bottle was centrifuge at 3000 rpm for 10 minutes to obtain the serum. Serum concentration of total cholesterol, triglycerides, and high-density lipoprotein concentrations were determined using commercial kits while low density lipoprotein was calculated based on standard formula.

Method of Determination of Peroxide Values (PV) of the Different Forms of Palm Oil

$$PV = \frac{S \times N \times 103}{W}$$

Where S = Sulphur

N = Nitrogen

W = Weight

$$\text{SAMPLE FPO} = \frac{2.9 \times 0.025 \times 103}{1} = 7.467$$

$$\text{SAMPLE PPO} = \frac{5.5 \times 0.025 \times 103}{1} = 14.162$$

$$\text{SAMPLE TPO} = \frac{7.6 \times 0.025 \times 103}{1} = 19.570$$

Statistical Analysis

Data were presented as mean ± standard error of the mean (SEM). Statistical analyses were performed using GraphPad Prism software, version 8.02 (GraphPad Software, San Diego, CA, USA). One-way analysis of variance (ANOVA) was employed to compare group means; thereafter, Tukey's multiple comparison post hoc test. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

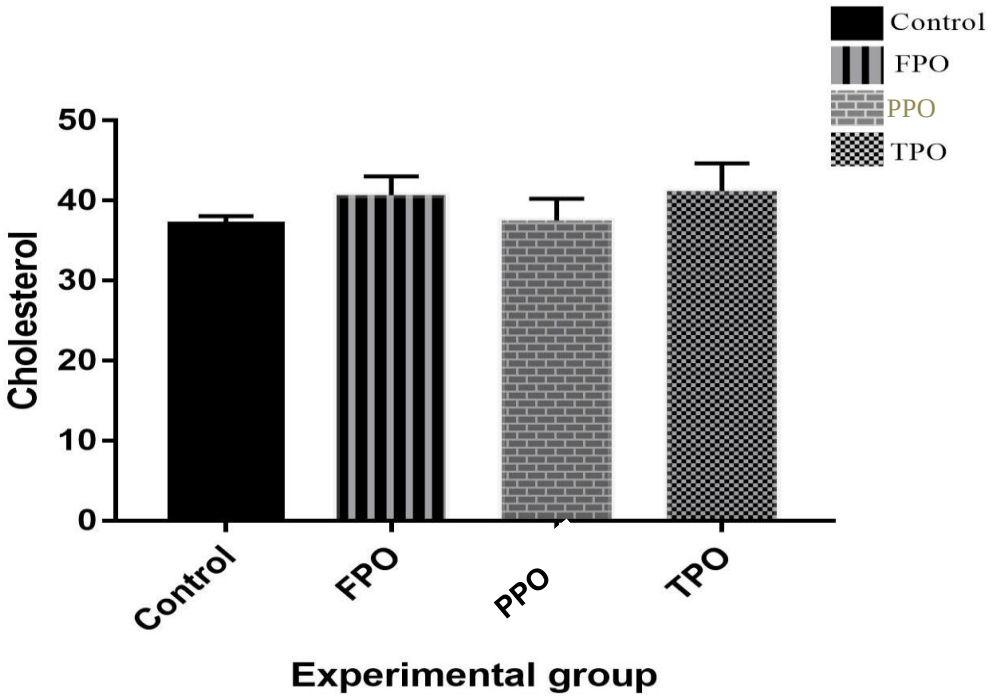
TABLE 1: THE RESULTS OF PEROXIDE VALUES OF THE DIFFERENT FORMS OF PALM OIL

Samples	*Peroxide Value (mEq O_2/kg)*
TPO	19.570
PPO	14.162
FPO	7.467

Accepted peroxide values for edible oils are between 10-20mEq O_2/kg (Connell, 1975).

Figure 1: Comparison of Cholesterol Levels in Animals Treated With the Different Forms of Palm Oil

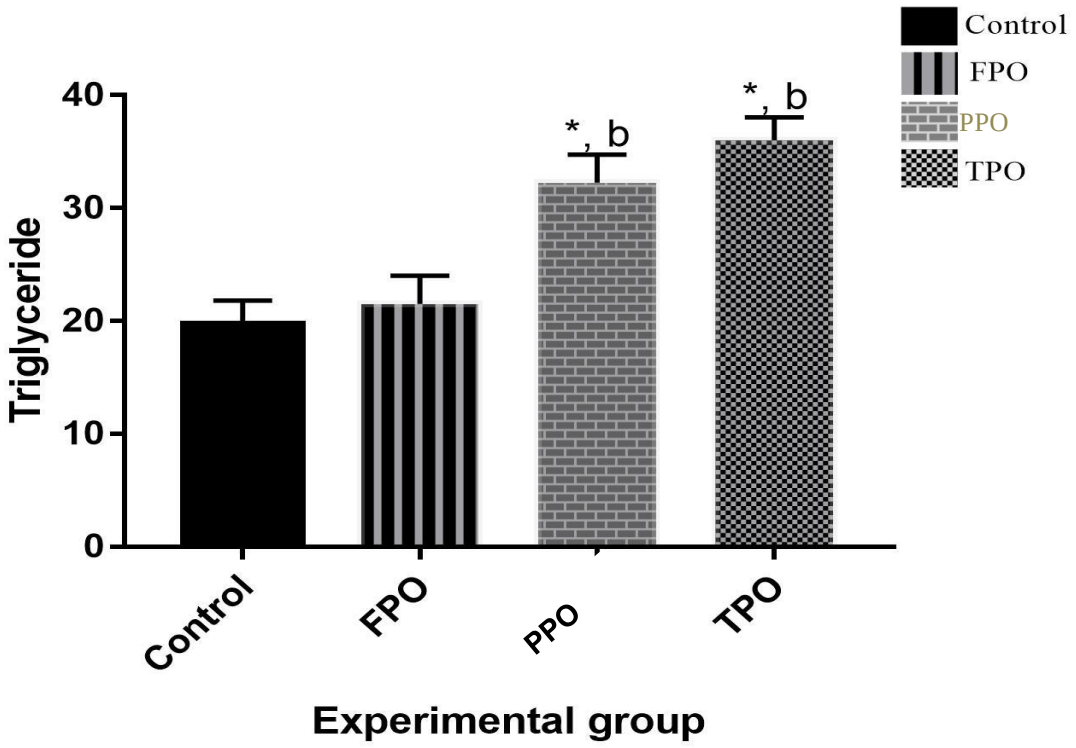
Figure 1 presents the results of cholesterol levels in the different groups. The mean value of cholesterol level was 37.00±1.08, 40.67±2.33, 37.50±2.72, and 41.20±3.43 for the control, FPO-diet fed, photo-oxidised palm oil, and TPO-diet fed groups respectively. There was no significant difference between the experimental groups.



Values are expressed as Mean ± SEM, n=5.

Figure 2: Comparison of Triglycerides (TG) Levels in Animals Treated With the Different Forms of Palm Oil

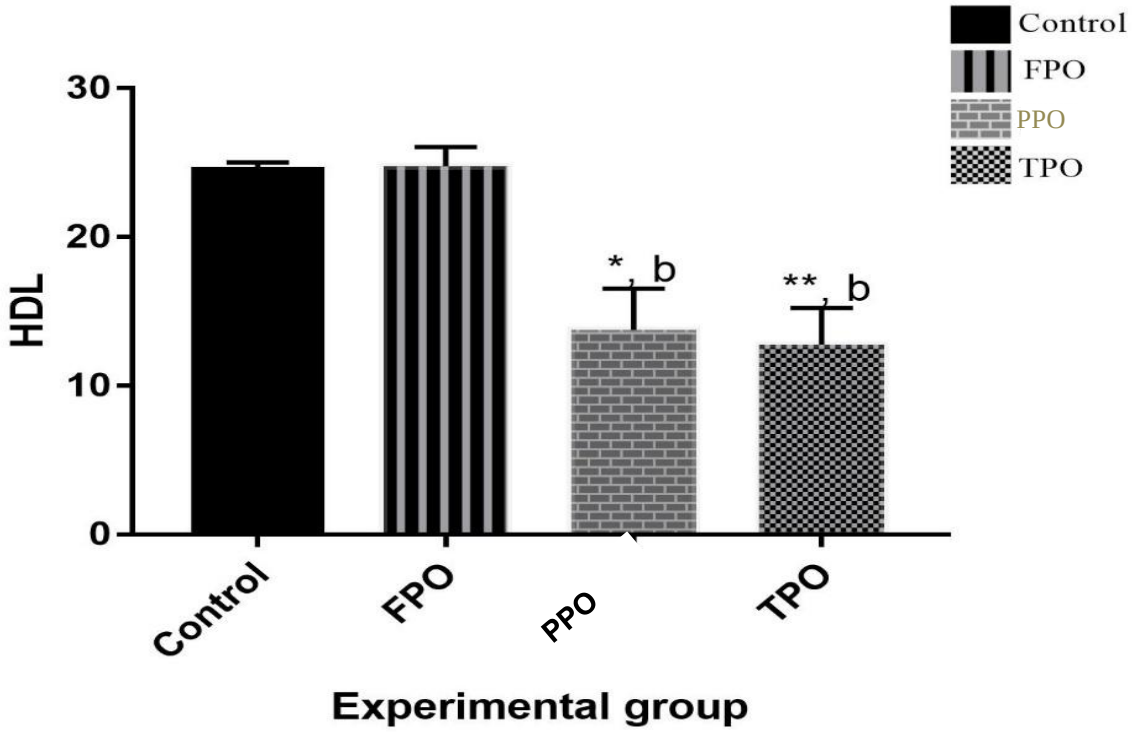
Figure 2 presents the levels of triglyceride. The mean value of triglyceride level was 19.75±2.06, 21.5±2.53, 32.25±2.50, and 36.00±2.04 for the control, FPO, PPO, and TPO-diets fed groups respectively. Triglyceride levels increased significantly ($p<0.05$) in the TPO and PPO groups, respectively, compared with control group. Furthermore, it was also significantly increased ($p<0.01$) in the TPO and PPO groups, respectively, compared with the FPO group.



Values are expressed as Mean ± SEM, n=5.
* = p< 0.05 compared with control
[b] = p<0.01 compared with FPO

Figure 3: Comparison of HDL-C Levels in Animals Treated With the Different Forms of Palm Oil

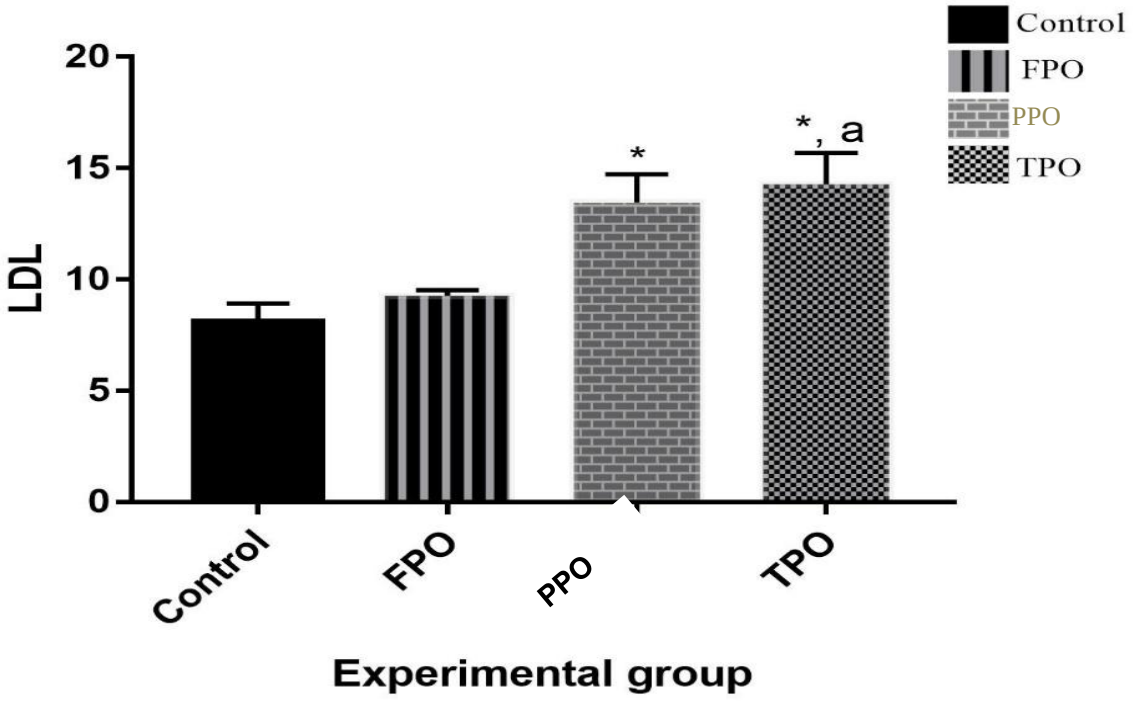
Figure 3 presents the result of HDL levels. The mean value of high-density lipoprotein level was 24.50±0.5, 24.75±1.32, 13.75±2.78 and 12.75± 2.50 for the control, FPO, PPO and TPO-diets fed groups, respectively. HDL levels decreased significantly in PPO ($p<0.05$) and TPO ($p<0.01$) groups respectively, when compared with control group. It was significantly decreased ($p<0.01$) in the PPO and TPO groups, respectively compared with the FPO group.



Values are expressed as Mean ± SEM, n=5.
* = p< 0.05 compared with control
[b] = p<0.01 compared with TPO

Figure 4: Comparison of LDL-C Levels in Animals Treated with the Different Forms of Palm Oil

Figure 4 presents the result of LDL. The mean value for low-density lipoprotein level was 8.10±0.83, 9.28±0.25, 13.45±1.27 and 14.28±1.42, for the control, FPO, PPO, and TPO-diets fed groups, respectively. Statistically, LDL levels were significantly increased ($p<0.05$) in PPO and TPO groups respectively, compared with control group. also, Low-density lipoprotein level decreased significantly ($p<0.05$) in the TPO group compared with the FPO group.



Values are expressed as Mean ± SEM, n=5.
* = $p < 0.05$ compared with control
[a] = $p<0.01$ compared with FPO

DISCUSSION

The present study evaluated the impact of oxidised palm oil diet consumption; specifically thermo-oxidised palm oil (TPO) and photo-oxidised palm oil (PPO), on lipid profiles in rats. The results of the peroxide value (PV) showed that the degree of oxidative rancidity was affected by both photo and thermo-oxidation. The peroxide value is an indicator of oil degradation, measuring the quantity of peroxides produced in cooking oil during oxidation. The more often the oil is reheated or subjected to sunlight, the greater the peroxide index. However, in comparison to earlier findings, soya oil exhibited a higher peroxide value when repeatedly heated under identical frying conditions (Leong *et al*., 2010).

An elevated peroxide value suggests decreased chemical stability of the oil. According to Naghshineh *et al*. (2010), a greater concentration of saturated fatty acids enhances the chemical stability of oils.

The findings of the study revealed that there was no significant difference in total cholesterol levels across the treated groups compared with the control group. This finding agrees with some previous reports suggesting that total cholesterol alone may not be sensitive enough to detect early alterations in lipid metabolism, especially when compensatory mechanisms such as increased hepatic cholesterol clearance or altered synthesis, may balance serum levels (Kritchevsky *et al*., 2000; Alphonse & Jones, 2016). This also points out the importance of evaluating other lipid profile parameters such as HDL and LDL for a more accurate assessment of cardiovascular risk.

Additionally, hepatic cholesterol metabolism involves processes such as biosynthesis, uptake, export, and esterification. Disruptions in these processes can contribute to diseases like cholesterol gallstone disease (CGD) without necessarily altering total serum cholesterol levels (Chenghao *et al*., 2024). Therefore, relying solely on total cholesterol measurements may overlook early metabolic changes. A comprehensive assessment, including evaluations of LDL, HDL and triglyceride levels, and markers of hepatic function, provides a more accurate picture of lipid metabolism and associated risks.

Triglyceride levels in both the TPO and PPO-diets fed groups showed a significant increase ($p<0.05$) compared to controls. This observation is consistent with findings that thermally and photo-oxidised oils can impair hepatic lipid metabolism, leading to the accumulation of triglycerides in the plasma (Osim *et al*., 1996; Staprans *et al*., 1996). Oxidised lipids may interfere with the normal β-oxidation of fatty acids and impair very low-density lipoprotein (VLDL) clearance, resulting in hypertriglyceridemia. Elevated triglycerides are an established

risk factor for metabolic syndrome and atherosclerosis, contributing to endothelial dysfunction and inflammation.

A remarkable reduction in HDL, levels was observed in both oxidised palm oil diet fed groups, more pronounced in the TPO group ($p<0.01$) than the PPO group ($p<0.05$). HDL plays an important role in reverse cholesterol transport and exerts antioxidant and anti-inflammatory effects. A reduction in HDL-C may compromise its protective functions, thereby increasing cardiovascular risk. Oxidised lipids have been shown to impair the synthesis of apolipoprotein A-I (apoA-I), which is the main component of HDL, and reduce HDL maturation (Kanner, 2007). Additionally, lipid peroxidation products may accelerate HDL catabolism, further lowering serum levels.

Conversely, LDL-C levels were significantly elevated in both the TPO and PPO-diet fed groups ($p<0.05$). Elevated LDL-C is a hallmark of atherogenic dyslipidemia, particularly concerning due to its susceptibility to oxidative modification. Oxidised LDL is taken up by macrophages to form foam cells, a key event in the development of atherosclerotic plaques. Diets rich in oxidised fats have been shown to promote hepatic production and secretion of LDL particles while simultaneously reducing their clearance (Staprans *et al*., 1994). This dysregulation may be attributed to the hepatic oxidative stress induced by lipid peroxidation products.

While both TPO and PPO diets adversely affected the lipid profile, the TPO group showed more pronounced changes, particularly in HDL-C reduction. This suggests that thermal oxidation may produce more reactive and biologically damaging compounds than photo-oxidation, possibly due to the formation of high-temperature aldehydes, ketones, and polymeric triglycerides (Choe & Min, 2006). These compounds are known to exert cytotoxic and pro-inflammatory effects, disrupting lipid homeostasis more severely.

CONCLUSION

This study demonstrates that the consumption of oxidised palm oil, whether thermally or photo-oxidised, leads to detrimental alterations in lipid profile, particularly marked by hypertriglyceridemia, reduced HDL-C, and elevated LDL-C levels.

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CONFLICT OF INTEREST

All authors declare that they have no conflicts of interest.

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