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Comparative Study of the Lipid and Lipoprotein Profile of Overweight Consumers Versus Non-consumers of Palm Oil at the National Institute of Public Health, Côte d'Ivoire

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Abstract: Palm oil is often not recommended to overweight patients, on the pretext that it provides saturated fat and cardiovascular diseases. This work studied variations in lipid and lipoprotein parameters in overweight consumers versus non-consumers of palm oil who came for visits at the nutrition department of the National Institute of Public Health of Adjamé in Abidjan, Côte d'Ivoire. We included 328 overweight subjects, including 227 palm oil consumers and 101 non-consumers, in a three-month descriptive and analytical cross-sectional, prospective study. The lipid parameters analysed by enzymatic technique were total cholesterol, triglycerides, HDL and LDL cholesterol. The atherogenicity index was also determined. The comparison of proportions was made by the chi square-test (5%). Moderate obesity accounted for 41.6%, overweight 31.2%. Among the patients, 89% consumed palm oil, and 11% did not. In palm oil consumers, 64.2% had normal cholesterol, while 16.1% had hypercholesterolemia. Among non-consumers, 75% had normal cholesterol compared to 25% hypercholesterolemia. The difference was not significant in both groups. Serum triglycerides, HDL, LDL cholesterols, and atherogenicity index varied in the same range as total cholesterol, with no significant difference observable, whatever the form of palm oil consumed. The non-significative variation of lipid and lipoprotein parameters in palm oil consumers and non-consumers, showed that normal consumption of palm oil has no significant effect on weight gain. This consumption is beneficial because of the presence of antioxidants in palm oil, which gives it its health and nutritional benefits.

Keywords: Palm Oil, Cholesterol, Triglyceride, Atherogenicity Index, Dyslipidemia, Overweight

1. Introduction

Palm oil (PO) is a vegetable oil extracted from the pulp of oil palm fruit, which is a monocotyledonous plant from the *Aceraceae* family. It leads industrial oilseeds and occupies only 7% of the agricultural area in oilseeds [1, 2]. It is used in many areas (food, cosmetic, medicinal, etc.) [2, 3]. Like any fluid oil, PO contains almost 100% lipids. These are sources of energy for the functioning body. PO is now the most widely consumed vegetable oil in the world [4, 5]. PO contains 48% of Saturated Fatty Acids (SFA) and 52% of Unsaturated Fatty Acids (UFA), in addition to its richness of unsaponifiable lipids such as antioxidants (vitamin A, E, polyphenols...) [6-8]. However, this oil has become the subject of controversies both for its nutritional and environmental impacts [1, 6, 9]. Some Non-Governmental Organizations (NGO) are strongly denouncing the development of PO, because it is accused of being responsible for massive deforestation, for promoting obesity and the occurrence of cardiovascular pathologies [1, 8-10]. In 2012, an "anti-palm oil" crusade was carried out in France, following the senate's proposal to overtax products made from this oil, because it was accused of promoting obesity and deforestation [6, 11, 12]. Although several studies have highlighted the benefits of consuming PO, this oil is very often the object of attacks for being atherogenic [13-20]. In addition, some patients with metabolic disorders such as type II diabetes, and cardiovascular diseases are advised against consuming PO because it would worsen their pathologies [8, 21, 22]. A need for good management of obesity is now necessary because there are increasingly cases of overweight and obesity in sub-Saharan Africa which are now a public health concern [13, 14, 19, 23]. Even though the effects of PO on the lipid profile of human serum are subject of controversies, some studies have instead focused on the lipid profile of healthy subjects consuming PO [24-27]. In order to understand the impact of PO consumption on lipid metabolism in the human body of patients, especially those with weight problems, the current study involved overweight patients consuming PO, versus non-consumers. The goal of this study was to assess the effects of PO consumption on the obesogenic, lipid and lipoprotein profile of the study patients.

2. Material and Methods

2.1. Study Design and Diet

Overweight patients coming for consultations were recruited, in a three-month descriptive and analytical cross-sectional study.

2.2. Sample Size Calculation

The patient sample size was calculated using the following formula [36]: $n = \frac{\varepsilon^2 X p X q}{I^2}$

n is the minimum sample size; Ɛ is the difference reduced to the agreed risk α; it is 1.96 for a risk of error of 5%; p is the expected percentage of palm oil consumption among overweight patients set to 50%; q is the complement of p (q = 1-p=50%); I is the precision with which we estimated the frequency of palm oil consumption = 7%. After calculation, a minimum sample of 196 patients was required. After the recruitment, a total of 328 participants were selected.

2.3. Dietary Intervention

The experimental test fats were PO which is used as the cooking oil in a typical Ivorian diet [28]. The PO was purchased from local markets. The energy from fat comprised approximately 30% of the total dietary energy. In addition, the intake of dietary cholesterol was controlled to be no more than 300 mg/day [29, 30] following the dietary guidelines from the WHO and the Dietary Reference Intakes which recommend a total fat intake to not exceed 80 g, precisely between 20 and 35% of total calories [31-33].

2.4. Participant Selection

Overweight male and female patients' recruitment were carried out at the Nutrition Department of the NIPH (Adjamé, Côte d'Ivoire). Overweight patients were defined as a patient who's the body mass index (BMI) ≥ 25 kg/m^2. We assured that they met the following inclusion criteria: (1) Age ranged from 18 to 60 years old, (2) No personal or family history of CVD, diabetes, hypertension, hypothyroidism, hyperthyroidism, chronic renal disease, hepatitis, or cancer; (3) Not pregnant or lactating; (4) A fasting blood glucose (FBG) level <6.1 mmol/L; and (5) Do not receive lipid-lowering therapy.

2.5. Data Collection

Before starting the experiment, everyone involved (including researchers and participants) received training. All participants meeting at the Nutrition Department of NIPH the inclusion criteria were requested to submit to a blood collection after their consent during the study period. Throughout the experiments, the researchers asked the participants to answer a questionnaire. Their body weight, blood pressure and fasting serum lipid profile were recorded.

2.6. Physical Examination, Blood Sample Collection, and Parameters Analyzed

Physical examinations were conducted and fasting blood samples were measured. Blood samples were collected after the participants had fasted for at least 12 h and sent to Biochemistry Laboratory (Treichville Teaching Hospital, Abidjan, Côte D'Ivoire) for blood index analysis. Blood samples were collected from the antecubital vein and placed into separation gel tubes before biochemical tests. Serum was collected by centrifugation at 4000 rpm for 4 min before detection. The blood biochemical indices, including serum lipid and lipoprotein profiles (total cholesterol (TC), triglyceride (TG), HDL-Cholesterol, levels in serum), were analysed by enzymatic technique and detected using an automated biochemical analyzer (COBAS C311, ROCHE Diagnostics). Calculation of LDL cholesterol content was made by Friedwald formula: LDL-cholesterol = total cholesterol– (HDL-cholesterol + TG/5) [34]. Normal values of lipid and lipoprotein parameters were followed: Serum TC level < 6.20 mmol/L, LDL-C level < 4.12 mmol/L, HDL-C level > 1.04 mmol/L, and TG level < 2.26 mmol/L, an atherogenicity index normal < 5 [35]. Finally, anthropometric parameters, including weight, height, waist circumference, body mass index, and blood pressure, were measured by the paramedical staff of the nutrition service at the NIPH.

2.7. Informed Consent and Confidentiality

Patients gave their written informed consent for the study and were reassured that the information was collected in strict confidentiality. This study was conducted according to the Declaration of Helsinki and all of the procedures involving human participants were approved by the Ivoirian Ethics Committee for Clinical Research (Approval number: N/Ref: 143/MSHP/CNER-kp of January 18, 2018). Authorization from the Ministry of Health and Public Hygiene to carry out the study in the departments concerned (Letter of March 07, 2018) was obtained.

2.8. Statistical Analysis

Data were analysed using IBM SPSS Statistics, Version 19.0 (IBM Corporation; 95 Armonk, New York) to determine significant differences between the two groups. Gaussian distribution data were expressed as means ± SDs. The comparison of proportions was made by the chi square-test and statistical significance was set at $p < 0.05$.

3. Results

3.1. Convenient Consumption of PO

Among PO consumers, 64.75% consumed both forms (refined and unrefined oil), while 17.62% consumed respectively refined (40 patients) and crude form (40 patients). The very frequent consumption of PO represented 52.6% since childhood.

3.2. Variations of Lipid and Lipoprotein Parameters

Table 1. *Comparison of lipid and lipoprotein parameters of PO consumers versus non-consumers.*

Blood Lipids Parameters		Consumption of PO (n=227)		No consumption of PO (n=101)		p value
		n	%	n	%	
	Lowered	45	19.7%	--	--	
Total cholesterolemia	Normal	146	64.2%	76	75.0%	0.13
	High	36	16.1%	25	25.0%	
	Lowered	7	2.9	--	--	
Triglyceridemia	Normal	210	92.7	88	87.5	0.314
	High	10	4.4	13	12.5	
	Lowered	83	36.5	44	43.8	
HDL-cholesterol	Normal	144	63.5	57	56.3	0.593
	High	--	--	--	--	
	Lowered	--	--	--	--	
LDL-cholesterol	Normal	195	86.1	76	75.0	0.265
	High	32	13.9	25	25.0	
	Lowered	--	--	--	--	
Atherogenicity Index	Normal	119	52.6	44	43.8	0.601
	High	108	47.6	57	56.3	

n, number of patients; p-value (≤ 0.05) is statistically significant

Cholesterolemia was normal at 64.2% among PO consumers compared to 75% among non-consumers (Table 1). 16.1% of consumers had hypercholesterolemia against 25% in non-consumers. The difference was not significant. In patients consuming PO, triglyceridemia was normal at 92.7% compared to 87.5% in non-consumers and raised to 4.4% in consumers compared to 12.5% in non-consumers. The difference was not significant.

HDL cholesterol levels were normal in 63.5% of PO consumers compared to 56.3% in non-consumers. The difference was not significant. The serum LDL-cholesterol level was normal in 86.1% of PO consumers compared to 75.0% in non-consumers. It was high in 13.9% of cases among consumers compared to 25% among non-consumers. The difference was not significant. The atherogenicity index (CT / HDL) was normal in 52.6% of patients consuming PO against 43.8% in non-consumers and abnormal in 47.4% of cases in consumers compared to 56, 3% among non-consumers. The difference was not significant.

Cholesterolemia (A) was normal at 88.9% among consumers of the raw form versus 63.2% among consumers of the refined form and 63.3% among those who consumed both forms (Figure 1). 19.3% of the consumers of the two forms had hypercholesterolemia against 5.3% of the consumers of the refined form. The difference was not significant ($p = 0.217$).

Patients consuming only red PO had normal triglyceridemia (B) in 88.9% of cases, compared to 100% in consumers of the refined form and 92.7% in consumers of both forms. 10% of consumers of the red form had high triglyceridemia compared to 4.6% of consumers of both forms. The difference was not significant ($p = 0.385$).

In patients who consumed only the red form of PO, 11.1% had lowered serum HDL cholesterol (C) level, compared to 57.9% of consumers in the refined form and 67.9% of two forms. 80% of the consumers of the red form had a lowered HDL-cholesterol level compared to 42.1% for the consumers of the refined form and 32.1% for the consumers of the two forms. The difference was not significant ($p = 0.10$).

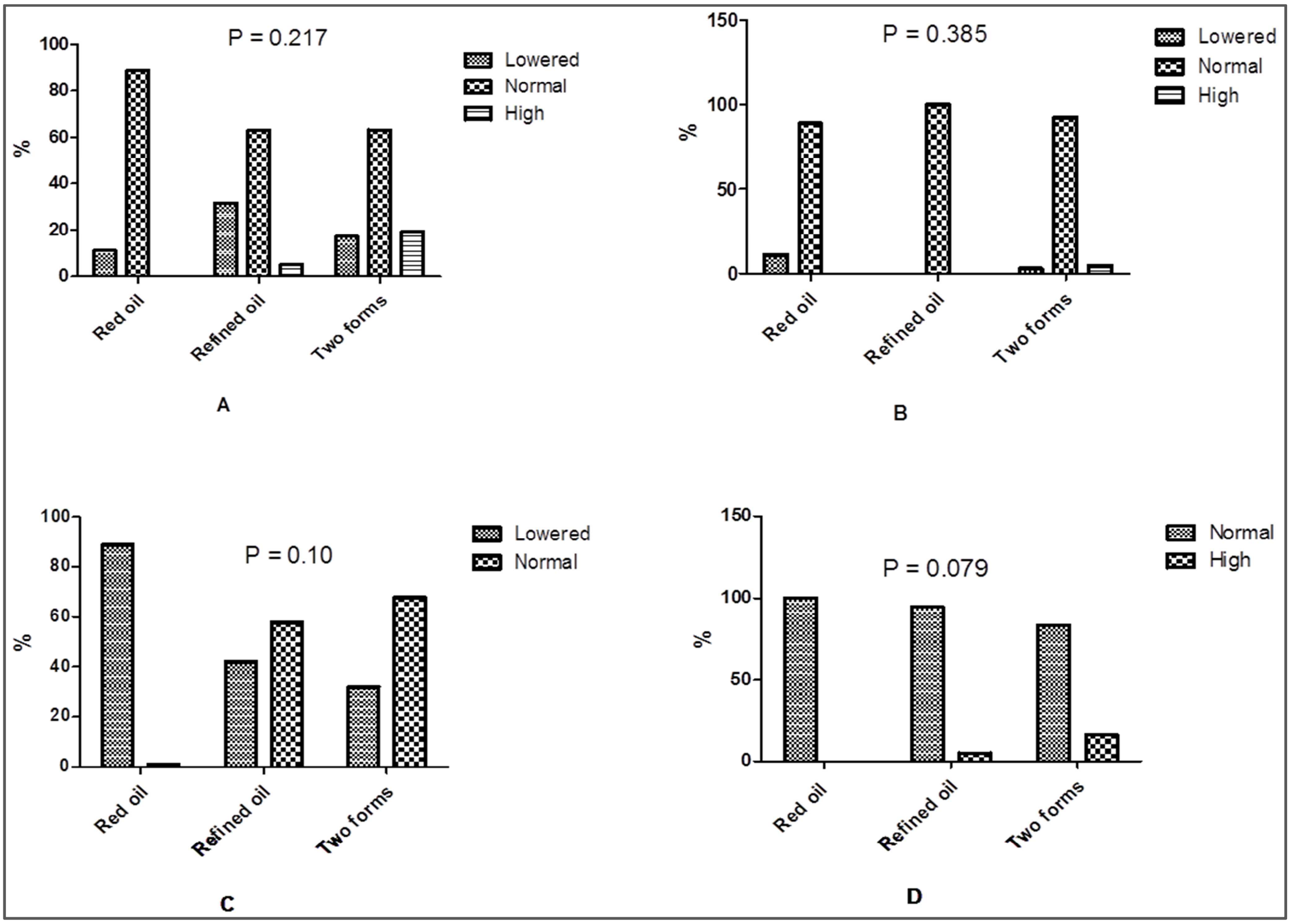

Figure 1. *Comparison of lipid parameters according to the form of PO consumption.*

In patients consuming only the red form of PO, 100% had normal LDL cholesterol (D) level, compared to 94.7% for consumers of the refined form and 83.5% for consumers of both forms. 16.5% of the consumers of both forms had a high LDL-cholesterol level compared to 5.3% in the consumers of the refined form. The difference was not significant (0.079).

Table 2. *Comparison of the atherogenicity index (AI) of overweight patients according to the form of palm oil consumption.*

		Normal AI	Abnormal AI	p
Red oil	n	153	74	
	%	66.7	33.3	
Refined oil	n	119	108	0.802
	%	52.6	47.4	
Both forms	n	121	106	
	%	53.2	46.8	

n, number of patients; p-value (≤ 0.05) is statistically significant

In patients consuming only red PO, 66.7% had a normal atherogenicity index, compared to 47.4% in consumers of the refined form and 53.2% in consumers of both forms. The atherogenicity index was abnormal in 33.3% of the red form consumers compared to 52.6% of the refined form consumers and 46.8% of both forms' consumers. The difference was not significant (Table 2).

4. Discussion

In many chronic diseases, such as obesity, cardiovascular diseases, and diabetes, PO has been regarded as the key risk factors because of its richness in SFA. Previous studies have shown that the consumption of diet with PO may affect the blood lipid and lipoprotein profiles [21, 22, 37]. In order to elucidate the effect of consumption of diet with PO on the obesity, we have studied the serum lipid and lipoprotein profiles during PO consumption versus no consumption in these overweight subjects. Overall, we have not observed significant difference ($p > 0.05$) of BMI and serum lipid and lipoprotein profiles among these two groups, and these results indicate that the palm oil's consumption may not affect the body weight and lipid parameters in human.

4.1. Body Mass Index (BMI) and Age of Overweight

A moderate obesity was found in 41.6% of patients while 31.2% were overweight. Regarding the overweight age, 58.5% of patients had been overweight for more than 5 years and 41.6% for less than 5 years. These results confirm the studies of Bohué et al. [38] who indicated that moderate consumption of PO does not lead to a significant increase in body mass in young rats. Similarly, the study of Sun et al. [25] showed that in a dietary crossover trial, palm olein and olive oil had no recognisably different effects on body fatness in a healthy Chinese population.

4.2. Breakdown of the Study Population by Practice of PO Consumption

Patient's consumers of PO represented 69% compared to 31% who did not. Our results corroborate other research findings according to which palm oil is the most widely consumed vegetable oil in the world [2, 3]. This consumption is mainly in the two forms (raw form and refined form) in 64.75% of cases. These different results show that PO occupies not only the first place in the world in terms of production [5, 9], but also the main source of fat in the African diet, particularly in West Africa [6, 19]. It is frequently consumed in 52.6% in the population and it started since childhood. Regarding non-consumers of PO, 88.2% had an outage period of less than 5 years.

4.3. Comparison of the Lipid and Lipoprotein Profile of Patients Consuming Versus Non-consuming PO

In PO consumers, 64.2% had normal cholesterol and 16.1% had hypercholesterolemia. In non-consumers, cholesterolemia also varied in the same trend, with normal cholesterolemia in 75% and hypercholesterolemia in 25%. This cholesterolemia also varied in the same proportion concerning the form of consumption of palm oil. This level of total cholesterol varied in non-consumers with a normal total cholesterolemia of 75% and high of 25% (Table 1). There was no significant difference between the total cholesterol values, both in consuming subjects and in non-consumers of PO, regardless of the form and frequency of consumption of this oil (Figure 1A). These results are like those of Sundram [20] who had shown that PO had a cholesterol-lowering effect on healthy volunteers on a PO diet. Likewise, studies by Lecerf [39] have shown that a diet rich in palm olein led to a reduction in total cholesterol of 19% compared to a diet rich in coconuts. The study by Bohué et al. [38] found that moderate consumption of PO over a 28-day period did not cause a significant increase in total cholesterol content in rats. Some researchers [40-42] have claimed that considering that 70% of the palmitic acid in PO is in the sn-1 and sn-3 positions, PO may be less cholesterol lowering than fat animal.

In fact, most palmitic acids in animal fats adopt the sn-2 position, which could improve their absorption [43]. This analysis proves the stabilizing effect that PO has which shows its ability to lower cholesterol level [17, 20, 25]. Indeed, the tocotrienols contained in PO could inhibit the activity of the enzyme HMG CoA reductase and thus, regulate the serum total cholesterol level [20, 39, 44].

Obesity is a metabolic disease characterized by an excess of white adipose tissue resulting from an excess of energy stored in adipocytes as TAGs; In addition, it is well known that dietary lipids associated with metabolic defects are the cause of many health conditions such as obesity, cardiovascular, neurodegenerative defects, and cancer [1, 5]. In PO consumers, triglyceridemia was normal in 92.7% of cases and high in 4.4% of cases. In non-consumers, triglyceridemia also varied in the same proportion with a normal value at 87.5% and a high value at 12.5%. The difference was not significant. In non-consumers, triglyceridemia was normal in 85.4% of cases and high in 12.5% of cases (Table 1). Regarding the form of consumption of PO, patients who consumed both forms and the refined form only had triglyceridemia which varied in the trend, with no significant difference (Figure 1B). These results are also consistent with those of Bohué et al. [38] who have shown that refined PO does not cause a significant increase in serum triglyceride levels in rats fed palm fortified foods. Sundram [20] and Fattore et al. [21] had shown that the consumption of PO did not influence the serum triglyceride level. It also should be noted that the plasma triglyceride content in humans is not modified by a diet rich in lipids but rather by a diet rich in carbohydrates where there is a sharp increase in this [44, 45].

Low plasma levels of HDL-cholesterol (HDL-C) have been consistently associated with an increased risk of atherosclerotic cardiovascular diseases (CVD), and it is considered to be an anti-atherogenic lipoprotein [46, 47]. Patients with normal HDL-cholesterol level represented 63.5% among palm oil consumers compared to 56.3% among non-consumers (Table 1). Whether or not PO was consumed did not significantly affect HDL-cholesterol levels. Patients who consumed PO in both forms had a normal HDL cholesterol level of 67.9% and those who consumed the refined form only had a normal rate of 57.9% (Figure 1C). HDL plays a primary role in all stages of reverse cholesterol transport (RCT): (1) cholesterol efflux, where these lipoproteins remove excess cholesterol from cells; (2) lipoprotein remodeling, where HDL undergo structural modifications with possible impact on their function; and (3) RCT is believed to be a primary atheroprotective property of HDL and its major protein, apolipoprotein A-I (apoA-I). HDL and apoA-I have been shown to promote the efflux of excess cholesterol from macrophage-derived foam cells via the cholesterol transporters, ATP-binding cassette transporter A1 (ABCA1), ABCG1, and scavenger receptor class B, type I (SR-BI), and then transport it back to the liver for excretion into bile and eventually into the feces [46, 47]. Other studies have also reported the beneficial effects of PO on the lipid profile of rats, more specifically on the elevation of HDL cholesterol [41], likewise the beneficial effect of phytosterol-rich fraction (PRF) obtained from palm fatty acid distillate (PFAD) in the treatment of dyslipidemia rats reported by Ahmadi et al. [48]. Evidence suggests that consumption of PO is a protective factor against cardiovascular diseases.

In PO consuming patients, the serum LDL cholesterol level was normal in 86.1% of cases and increased in 13.9% of them. Among non-consumers 75% had a normal rate against 25% which was high (Table 1). Regarding the form of consumption, the LDL cholesterol level was normal in almost the same proportions, namely 100%; 94.7% and 83.5% respectively for the red, refined form and the two forms (Figure 1D). The difference was not significant. LDL cholesterol transports cholesterol from the liver to peripheral tissues for use and even storage, explaining its role in atherosclerosis. Studies carried out in the world and in Côte d'Ivoire have highlighted the powerful antioxidant properties of PO due to its high content of phenolic acids and vitamin E; the latter causes inhibition of the oxidation of LDL cholesterol [25, 26, 49-52].

In palm oil consumers, AI was normal in 52.6% of patients compared to 43.8% in non-consumers. The form of consumption varied in the same range, with no significant difference (Table 2). The atherogenicity of a diet is linked to the degree of saturation of the fatty acids located in position sn-2 of the triglycerides [40, 43]. The balanced lipid profile of PO consumers is probably a consequence of the fact that in this oil, 85% of FAs in the sn-2 position are UFAs; SFAs mainly in position sn-1 and sn-3 are ultimately less bio-available [15, 40-43]. Salinas et al reported that the supplementation with refined, bleached and deodorized red PO diminishes the TC, improving the ratio TC/HDL-C [53]. The presence of a monounsaturated fatty acid (oleic acid) and the high concentrations of micronutrients (α tocopherol and retinol) in red PO, influence favorably the lipid profile of rats with induced hyperlipidemia as reported by these authors [53].

4.4. Correlation Between Consumption of PO and Variation of Lipid and Lipoprotein Parameters

Finally, there was no significant difference between consumption, form of PO consumption, and changes of lipid and lipoprotein parameters (Table 1 and Figure 1). Thus, we can postulate as described by several studies [54-56] that consumption of PO and the form of consumption (refined, crude or both forms) have no effect on variations of lipid and lipoprotein parameters. A study of albino Wistar rats showed that a diet enriched with PO did not cause any significant variation in HDL cholesterol, however, a significant reduction in serum triglycerides, total cholesterol and LDL cholesterol compared to the control diet was recorded [44]. Previous studies do not demonstrate a negative role of native PO in health, which is a complex alimentary matrix with palmitic acid, and also contains other FAs, mainly oleic acid, along with antioxidant compounds, which may have compensatory effects [3, 27]. In addition, PO is known to be rich in carotenoids, tocopherols, tocotrienols and polyphenols, which confer to this oil their biological properties, as reported by several studies [51, 52, 57], as well as in our recent review study on the health benefits of consuming palm oil [58].

Our study highlights the beneficial effects of PO consumption in human nutrition; therefore, it would be free of the atherogenic effect of which it is accused and should be consumed without any doubt.

5. Conclusion

This study shows that consumption of PO as well as the form of consumption had no significant variation on serum levels of lipid and lipoprotein parameters, likewise on the atherogenicity index in overweight patients. Thus, we can state that the abnormalities of lipid and lipoprotein parameters are unrelated to the consumption of palm oil. On the contrary, this consumption is beneficial because of the presence of antioxidants in PO, which gives it its health and nutritional benefits. More study should be done, considering factors, including dietary diversity, genetic aspects, and the susceptibility of each person.

Abbreviations

PO, Pam Oil; SFA, Saturated Fatty Acids; UFA, Unsaturated Fatty Acids; FAs, Fatty Acids; WHO, World Health Organization; NIPH, National Institute of Public Health; CVD, Cardiovascular Disease; TC, Total Cholesterol; TG, Triglyceride.

Data Availability

The numerical data used to support the findings of this study are available from the corresponding author upon request.

Author's Contribution

All authors designed the review. M. A. A., A-B. L. B. and A. A. A. contributed to the writing of the manuscript. M. A. A., E. K. F. and A. A. A. contributed especially to the statistical analysis. M. A. A., K. P and E. K. F. performed the bibliographic data sections. C-C. M., A. J. R, A-T. O. and T. G. read and approved the final document.

Conflict of Interest

The authors declare no conflict of interest.

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