Original Research Article

Physico-chemical characterization of palm kernel oil extracted from the seeds of two varieties of oil palm (*Elaeis guineensis* Jacq.) for a possible use in feed or food

Abstract

Oils (oil D and oil T) extracted from the seeds of two varieties (respectively Dura and Tenera) of oil palm (*Elaeis guineensis* Jacq.) by the Soxhlet method were deployed for physico-chemical analysis in order to assess the quality of oil suitable for alternative in animal oil in feed or food. The results obtained show that he values for the physical parameters (Oil yield, density and percentage of impurities) of both oils were similar and fell in those of the standards of Codex Alimentarius 2015. However, for the chemical parameters (Acid value, percentage of free fatty acids, peroxide value, saponification value and ester value), the values obtained for oil D were the highest, but for both oils, the values were above those recommended by the standards of Codex Alimentarius 2015, excepted the Saponification values and the Ester values which were below these standards. The determination of fatty acids composition by Gas Chromatography showed that these oils were not significantly different. Indeed, the totals saturated fatty acids were in amounts of 87.92% ± 0.17 and 87.53% ± 0.24, while the totals unsaturated fatty acids were in amounts of 12.08% ± 0.02 and 12.47% ± 0.02 respectively for oil D and oil T. The predominant fatty acid was lauric acid in amounts of 36.87% and 37.84% respectively for oil D and oil T.

Thus, these palm kernel oils could be used as ingredients and preservatives in feed due to their content in lauric acid which is known to possess antimicrobial properties and also to their content in unsaturated fatty acids (oleic and linoleic acids) which is an indicator of oil quality. However, oil T seems to be more suitable for alternative in animal oil in feed due to its percentage of free fatty acid which is less than that of oil D.

Keywords: Variety Dura, variety Tenera, palm seeds, palm kernel oil, physical parameters, chemical parameters, fatty acids.

1. Introduction

The gradual removal of animal oils in animal feed required the exploitation of vegetable oils as alternatives. Indeed, the quality of ingredients in animal feed can affect the quality of the milk and meat of the animal and then can impact consumer's health. As it is known, vegetable oils are an important source of nutrients (presence of essential fatty acids, fat-soluble vitamins, polyphenols, phytosterols) which give them a special role in the diets of populations [1]. They are extracted from oleaginous plants, which have most of the time, traditionally been used for seasoning and preserving the sanitary quality of foods through the oils they produce [2]. In addition to the preservation of food quality, vegetable oils are used in pharmaceutical, cosmetic and oil industry fields [3]. Among the vegetable oils, there is palm kernel oil derived from the kernel of the fruit of oil palm (*Elaeis guineensis* Jacq.). The kernel of the fruit is the most important quantity of residues obtained after extraction of palm oil from the pulp of the fruit of oil palm [4]. Thus, from the fruit of oil palm, at least two types of oils can be extracted.

Many researches have been made on palm oil. Indeed, according to [5, 6] the palm oil is the vegetable oil more consumed in the world. Its refining results in derived products such as palm olein (rich in oleic acid) and palm stearin (rich in saturated fatty acids) [7, 8]. Red palm oil and olein palm are widely used in African dishes as well as in those of South American and Asian. In other countries, the most consumed refining product is palm stearin [5]. Red palm oil and palm olein are rich in saturated fatty acids (SFAs), which is about 50% of the total fatty acids. The monounsaturated Fatty Acids (MUFAs) and Polyunsaturated Fatty Acids (PUFAs) represent respectively 40% and 10% of the total fatty acids [9, 10, and 11]. During the last decades, the link between nutrition and health has been the subject of

many debates. Indeed, the effects of a diet rich in saturated fatty acids, such as palmitic acid, have been the subject of several directives dietary measures to reduce cardiovascular diseases [12, 13]. According to World Health organization, the consummation of saturated fatty acids such as palmitic acid and myristic acid increases the risk of occurrence of cardiovascular diseases [14].

The study of [15] showed an increase in cardiovascular risk associated with cooking oil palm consumption. However, the study of [16] showed that harmful effects of palm oil (red or olein) on whole body and hepatic health were not worse than that of olive oil (Considered good for health). Thus, the results of the studies of the effects of this oil on human health are ambivalent. However, in animal feed, the results of the study of the effects of feeding palm oil residue on the productive and economical performances of broiler chickens showed an improvement in performances with 7% of palm oil residue incorporation in the diets [17]. These authors showed also that, the use of 7% palm oil residue in diet results in 17% reduction of the cost production of broiler chicks when compared to the production cost of the control birds. In addition to the palm oil residue, the palm kernel cake which is one of the solid residues that are produced after extraction of oil from palm kernel process [18, 19] has been shown especially suitable for feeding ruminants because of its relatively important fibers content [4]. Currently, palm kernel cake is majorly commercialized as ingredients of beef and dairy feed [20, 21]. Concerning the palm kernel oil, it is used in folk medicine for the treatment of skin irritations and mycosis. It is also used for seasoning the dishes and as food preservative. Thus, it could also be used as preservative in feed. This palm kernel oil is an appreciable source of saturated fatty acids but contains also monounsaturated and polyunsaturated fatty acids [22]. It has been shown that, at the temperature of 40 °C, it can be stored for 6 months [23]. However, despite these uses, most of the studies on palm kernel oil didn't indicate the type of variety of fruits of oil palm from which this palm kernel oil is extracted.

Thus, in this study, the physico-chemical properties of palm kernel oil derived from the kernel of the fruits of two varieties (Dura and Tenera) of oil palm were characterized for further contribution for the search of alternative in animal oil used in feed.

2. Material and methods

2. 1. Material

The biological material used is palm kernel oil extracted from the kernel of the fruits of two varieties (Dura and Tenera) of oil palm *(Elaeis guineensis* Jacq.). These two varieties (Figure 1) are the ones which are produced and consumed in Côte d'Ivoire. For this research, the fruits of these varieties of oil palm were bought on the markets in Abidjan (Côte d'Ivoire).

2. 2. Methods

2. 2. 1. Oil extraction

Oil extraction was carried out by using the Soxhlet method with hexane as solvent which gives best oil yield with solid sample according to [24]. For this extraction, the fruits of oil palm were dried under sunlight for one week and then the kernel of these fruits was removed. The kernel obtained was ground and a quantity of 10 grams of sample were weighed and placed in a cellulose extraction cartridge. The cartridge was plugged with cotton wool and then placed in the Soxhlet extractor containing 100 ml of n-hexane. A magnetic stirrer in the round bottom flask was used to mix up the sample with the solvent thoroughly.

During this process, the round bottom flask was heated in the beaker filled with water and the solvent was evaporated and moved to the condenser where the steam was converted into liquids which then drip back into the round bottom flask. The solvent-oil

mixture in the round bottom flask was collected at the end of the extraction process. The flask containing a mixture of sample, solvent and oil were separated at the end of the extraction process. A filter paper was used to separate the residue from the solvent-oil mixture before it was dried in the oven overnight at 60 °C. Then, the powder was being weighed for the determination of the percentage of oil yield.

The oil was recovered by evaporating off the solvent using rotary evaporator where it was heated at 70 °C until the solvent finally evaporated and leaving behind the extracted oil. All experiments were conducted in triplicate. The oil obtained was stored at 4° C until analysis.

The total fat content (FA) is given by the following formula**:**

FA (Total fat content) = P2 – P1

Oil yield = (FA/P0) X 100

$$\text{Oil yield} = \frac{P2 - P1}{P0} \times 100$$

Where: P0: mass (g) of the test sample; P1: mass (g) of the empty flask and P2: mass (g) of the flask and the total fat extracted

2. 2. 2. Physico-chemical characterization

2. 2. 2. 1. Relative density at 20° C Determination

The relative density is the ratio of the mass of a given volume of the oil at 20 °C to the mass of an equal volume of distilled water at 20 °C. Thus, a flask empty was weighed (P1) and filled with distilled water at the laboratory at 20 °C.

This flask containing the distilled water was then weighed (P2). After that, the flask was emptied and filled with the oil and then weighed at the same temperature (P3) [25].

The density was determined using the following formula:

D = P3 –P1 / P2 –P1

P1: mass of empty flask,

P2: mass of flask containing the distilled water

P3: mass of flask containing oil

2. 2. 2. 2. Viscosity value determination

The viscosity of each sample of the oils was measured according to [26]. The oil sample was placed into a glass U-tube. The sample was drawn through the tube using suction until it reached the starting position indicated on the tube side. The suction was then released, allowing the sample to flow back through the tube under gravity. The resistance of the oil flowing under gravity through the capillary tube measured the oils kinematic viscosity. The Kinematic viscosity is the product of the measured flow time and the calibration constant of the viscometer. The viscosity is reported in centistokes (cSt), equivalent to mm^2/s in SI unit, and is calculated from the time it takes oil to flow from the starting point to the stopping point using a calibration constant supplied for each tube. An average of independent three measurements of viscosity test at temperatures of 40 ºC and 100 ºC for each sample was reported.The viscosity index oil was then calculated from its viscosities at 40 and 100 ºC. The procedure for the calculation is given in ASTM Method D 2270-74 for calculating viscosity Index from kinematic Viscosity at 40 and 100 ºC.

Viscosity index (VI):

$$VI = \frac{L - U}{L - H} X\ 100$$

Where:

L= Kinematic viscosity at 40 ºC of an oil of 0 viscosity index having the same kinematic viscosity at 100 ºC as the oil whose viscosity index is to be calculated.

U = Kinematic viscosity at 40 ºC of the oil whose viscosity index is to be determined;

H = Kinematic viscosity at 40 ºC of an oil of 100 viscosity index, and having the same kinematic viscosity at 100 ºC as the oil whose viscosity index is to be calculated.

Basic values for L and H for kinematic viscosity at 40 – 100 ºC can be found in standard viscosity index tables.

2. 2. 2. 3. Acid value and free fatty acid determination

This parameter indicates the degree of unsaturation and oxidative condition of the oil. Its determination was done by dissolving a quantity of 5 g of oil in about 100 ml of the mixture of equal parts ethanol and diethyl ether previously neutralized in a 250 ml conical flask. The solution obtained was titrated with stirring, with an ethanolic solution of 0.1 N potassium hydroxide, until the phenolphthalein in the conic flask has remained pink for at least 10 seconds [27].

The Acid value is given by the relation: AV = (V × 56.1 × N) / W [mg KOH / g].

Where:

56.1 = molar mass of the KOH

V = Volume of KOH solution in mL

N = Normality of KOH solution

W = Weight of sample in g

% FFA = AV/1.99

2. 2. 2. 4. Iodine value determination

The iodine index is a measure of the degree of unsaturation in oil and could be used to quantify the amount of double bonds present in the oil which reflects the susceptibility of oil to oxidation. Iodine index was determined according to [28]. For this determination, a quantity of 0.4 g of the sample was weighed into a conical flask and 20 mL of carbon tetrachloride was added to dissolve the oil. Then 25 mL of Dam's reagent was added to the flask using a safety pipette in fume chamber. Stopper was then inserted and the content of the flask was vigorously swirled. The flask was then placed in the dark for 2 hours 30 minutes. At the end of this period, 20 mL of 10% aqueous potassium iodide and 125 mL of water were added using a measuring cylinder.

The content was titrated with 0.1M sodium thiosulphate solution until the yellow color almost disappeared. Few drops of 1% starch indicator was added and the titration continued by adding thiosulphate drop wise until blue coloration disappeared after vigorous shaking. The same procedure was used for blank test and other samples.

The Iodine value (IV) is given by the expression:

IV = 12.69 C (V1 – V2) / M

Where:

The value of 126.91 is related to the atomic mass of iodine; C= Concentration of sodium

V1= Volume of sodium thiosulphate (Na_2S2O_3) solution used to titrate the blank,

V2 = Volume of sodium thiosulphate solution used to titrate the sample.

M = Mass of the sample

2. 2. 2. 5. Saponification value determination

The saponification value represents the number of milligrams of potassium hydroxide per gram of oil (mg KOH g-1). The [29] method was used. The determination was done by putting 2 g of oil into a 250 ml Erlenmeyer flask. A quantity of 25 mL of the alcoholic potassium hydroxide solution was added into the flask. A blank determination was conducted along with the sample. The sample flasks was connected to the blank flask with air condensers, kept on the water bath, boiled gently but steadily until saponification is complete, as indicated by absence of any oily matter and appearance of clear solution. Clarity was achieved in one hour of boiling. After the flask and condenser have cooled somewhat wash down the inside of the condenser with about 10 ml of hot ethyl alcohol neutral to phenolphthalein. The excess of potassium hydroxide was titrated with 0.5N hydrochloric acid, using about 1.0 ml phenolphthalein indicator.

The calculation of the saponification index was done using the following formula:

Saponification value (SV) = 56.1 (B-S) N / W

Where: B = Volume in mL of standard hydrochloric acid required for the blank.

S = Volume in ml of standard hydrochloric acid required for the sample.

N = Normality of the standard hydrochloric acid.

W = Weight in g of the oil.

2. 2. 2. 6. Ester value determination

The ester value (EV) is given by the following formula:

EV = SV – AV

Where: SV = Saponification value; AV = Acid value.

2. 2. 2. 7. Peroxide value

The Peroxide value was determined according [30]. A quantity of 12 mL of chloroform and 18 mL of acetic acid was added to 5g of oil contained in an Erlenmeyer flask. To this solution obtained, 1 ml of potassium iodide KI (0.5 in 1ml of distilled water) was added. The solution was shaken for 1 minute and protected from light for 5 minutes and then 75ml of distilled water was added to it and the whole was shaken vigorously in the presence of starch pies. The titration was done with 0.01N sodium thiosulfate ($Na2S_2O_3$) to the appearance of the transparent color. A blank test (without oil) was also carried out.

PV: The peroxide value is expressed in milliequivalent gram of active oxygen per kilogram of fat. The peroxide value (PV) is given by the following formula:

PV = (N × (V1 – V0) × 1000)/P

Where: V0: Volume of Sodium thiosulfate (mL) solution for the blank test.

V1: Volume of Sodium thiosulfate (mL) solution used; N: Sodium thiosulfate solution normality (0,01N) and P: Sample test (g).

2. 2. 2. 8. Determination of insoluble impurities

The insoluble impurities were determined according to the method of [31]. A quantity of 2 g of the oil sample was weighed into a 250 mL conical flask and 20 mL of 1:1 solvent mixture (petroleum ether + diethyl ether) was added. The flask was then shaken vigorously and allowed to stand for 30 minutes at 30 °C. The liquid was then filtered through a dried and weighed Whatman number 1 filter paper. The filter paper was carefully washed with 10 mL of the solvent mixture. The filter paper was then dried to a constant weight in an oven at 103 °C.

The increase in weight represented the weight of impurities and was expressed as a percentage of the initial sample as follows:

% of insoluble impurities = (A/W) X 100

Where:

A = increase in the weight of filter paper

W = weight of sample

2. 2. 3. Determination of Fatty Acids Composition by Gas Chromatography

The analysis started by the conversion of the oil into fatty acid methyl ester (FAME). This esterification was conducted following the procedure described by [32]. For this esterification, 100 mg of oil sample was placed into a screw cap glass tube. A quantity of 1.5 mL of NaOH in methanol (0.5 N) was added into the tube and then nitrogen was blown for 15 seconds to the tube. The tube was covered tightly, vortexed, heated in a water bath for 5 minutes at 87 °C and then cooled. The mixture was stirred for about 10 minutes. In this stage, fatty acids were converted to fatty acid methyl esters (FAMEs). After reaction, solution was centrifuged to separate the layers. Sample of FAME was diluted with cyclohexene and prepared for Gas Chromatography analyses.

Then, series of standard mixtures were prepared from AOCS Low Erucic Rapeseed Oil (Sigma-Aldrich) with analytical grade cyclohexane (Sigma-Aldrich) in concentration of solution from 1.5 – 10 mg/mL. FAMEs from external standard or FAMEs resulted from sample derivatization were injected separately into Gas Chromatograph (Perkin Elmer Clarus 500, Shelton, USA) which was fitted with a flame-ionization detector (FID) and a polar capillary column of BPX70 (0.32 mm internal diameter, 30 m length and 0.25 μm film thickness; SGE International Pty, Ltd., Victoria, Australia).

Injector and detector temperatures were set at 270 °C and 280 °C, respectively. The Gas Chromatography oven program was as follows: 130 °C (hold 2 min), to 170 °C at 6.5 °C/min (hold 5 min), to 215 °C at 2.75 °C/min (hold 12 min), to 230 °C at 30 °C/min (hold 30 min). Helium and nitrogen of ultrahigh purity grade were used as carrier gases at flow rates of 11.07 and 31.24 mL/min. The fatty acid identification was determined by comparing retention time of the peaks with that of standards. The total percentage of saturated and unsaturated fatty acids was calculated by summing up the relative percentage of saturated and unsaturated fatty acids, respectively. The unsaturated and saturated fatty acids ratio was calculated by taking the total percentage of unsaturated fatty acids over the total percentage of saturated fatty acids.

2. 2. 4. Statistical analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 16. Quantitative Data were presented as means ±SD. The independent sample- ANOVA with Post-hoc (LSD) test was used to analyze mean difference. Probability values (P) of less than 0.05 were regarded as statistically significant.

3. Results

The results of the analysis of the physicochemical properties of oil extracted from the variety Dura (oil D) and that extracted from the variety Tenera (oil T) are presented in Table 1. It is noted that there was no significant difference in all the physical parameters analyzed except the viscosity index (Table 1). Indeed, the analysis of the fat contents did not show significant difference between the total oil extracted from the variety Dura that extracted from the variety Tenera ($P>0.05$).

The same observation was noted on the oil yields obtained for these two varieties ($P>0.05$). No significant difference was also observed between the density of oil D and oil T ($P>0.05$). These parameters values fell in those of [33]. In opposite to these physical properties, the viscosity index of the two varieties were significantly different ($P<0.05$). Indeed, the viscosity index of oil D was significantly lower than that of oil T. For the percentage of insoluble impurities, no significant difference was observed between oil D and oil T ($P>0.05$). No significant difference was also observed between these percentages of impurities and that recommended by [33] which is 0.05%. In addition to the physical properties, the analysis for chemical properties (Table 1) indicated that there was significant difference ($p<0.05$) in all the parameters analyzed except the Iodine value. Indeed, significant differences were recorded for the Acid values and the percentages of free fatty acids of oil D and oil T ($P<0.05$). The Acid value of oil D was significantly higher than that of oil T. The percentage of free fatty acids for oil D was also significantly higher than that of oil T. However, these two parameters were significantly high comparing to those recommended by [33]. Concerning the Saponification values, that of oil D was significantly higher than that of oil T ($P<0.05$). However, the Saponification values of both oils were below that recommended by [33] which range between 230-254 mg KOH/g oil. A significant difference was also noted between the Peroxide value of oil D and that of oil T ($P<0.05$). However, that of oil T was around that recommended by [33] which is 15.0 meq/kg fat. As most of the

chemical parameters analyzed, the Ester value of oil D was significantly higher than that of oil T ($P<0.05$).

However, the Ester values of both oils were below that recommended by [33] which range 220-244 mg KOH/g fat. Among these chemical parameters, only the determination of Iodine value didn't show a significant difference between oil D and oil T ($P>0.05$).However, these Iodine values were around the minimum limit recommended by [33] which is 14.1 g I_2/100 g fat.

In addition to these physico-chemical parameters, the fatty acids composition of the two types of oil was determined. These fatty acids identification was made by comparing the retention time of the peaks with that of standards (Table 2, Figure 2). The results of methyl ester fatty acids analysis of oil D and oil T samples are presented respectively in Tables 3 and 4 and Figures 3 and 4. The fatty acids composition is presented in Table 5. It was noted that, oil D and oil T consist of nine types of fatty acids which are caproic acid, caprylic acid, capric acid, dodecanoic acid, myristic acid, palmitic acid, stearic acid, oleic acid and linoleic acid (Table 5). The analysis of the levels of these fatty acids didn't show any significance difference between oil D and oil T ($P>0.05$). Indeed, as it is noted in Figure 5, the totals saturated fatty acids (SFAs), were 87.92% ± 0.17 and 87.53% ± 0.24 of total FAMEs while the totals unsaturated fatty acids (USFAs) were 12.08% ± 0.02 and 12.47% ± 0.02 of total FAMEs respectively for oil D and oil T. Among the unsaturated fatty acids, the levels of monounsaturated fatty acids (MUFAs) were 9.30% and 10.09% and those of polyunsaturated fatty acids (PUFAs) were 2.78% and 2.38% respectively for oil D and oil T (Table 5). These unsaturated fatty acids were all cis fatty acids. The unsaturated and saturated fatty acids ratio was around 0.14 for the two types of oil.

Among the fatty acids detected in both oils, short chain fatty acids (fewer than 12 carbon atoms) and long chain fatty acids were observed. Indeed, the short chain fatty acids (caproic acid, caprylic acid and capric acid) were found with totals amounts of 17.85% and 15.92%, while long chain fatty acids (dodecanoic acid, myristic acid, palmitic acid, stearic acid, oleic acid and linoleic acid) were detected with total amounts of 82.15% and 84.08

respectively for oil D and oil T. Among these fatty acids, dodecanoic acid known as lauric acid was the major fatty acid with level of 36.87% ± 0.04 and 37.84% ± 0.03 respectively for oil D and oil T.

4. Discussion

The physico-chemical analysis of the two types of palm kernel oil in order to assess the quality of oil suitable for alternative in animal oil in feed showed that the oil yields obtained were similar to that obtained by [4] which was about 50%, but fell below the range 75-80% found by [34]. However, these oil yields fell in that mentioned by [33]. This could be explained by the variety of fruits of oil palm used by [34] which unfortunately was not specified. The density of the two types of oil was similar to that recommended by [33] and was also the same with that of palm oil, moringa seed oil and groundnut reported in the study of [35]. It is obvious that palm kernel oil (PKO) has good value of density. It was also observed that the viscosity of both oils decreased with increase in temperature. The viscosity index (VI) of both oils were consistent with the report of [36]. The extraction of these oils seems to be well done. Indeed, the percentages of impurities fell in that recommended by [33] which is 0.05%. In fact, the amount of insoluble impurities is reflecting the efficiency of clarification during extraction of oil [37].

The acid values of these oils were above that recommended by [33]. However, that of oil T was lower than that of oil D. The highest of the acid values was correlated to the highest of percentage of free fatty acids. That of oil D was the highest. This slightly higher of free fatty acids of oil D indicate the high degree of hydrolysis of this oil during the extraction. In opposite to these parameters, the Iodine values were around that of [33]. This reflects the presence of unsaturated fatty acids in the two types of oils. This is an important criteria for good oil. Indeed, polyunsaturated fats in diet can help reduce bad cholesterol levels in blood which can lower the risk of heart disease and stroke in opposite to saturated fatty acids [14]. However, these Iodine values were below the values reported by [35]. This bring about the stability of oil D and oil T to oxidation. This difference of results could be explained by the

difference of varieties of palm seeds from which the kernel was extracted. In opposite to the Iodine values, the Saponification values of both oil D and oil T fell below that of [33] which range 230-254 mg KOH /g fat. However, the Saponification value of oil T was lower than that of oil D.

This suggests that the mean molecular weight of fatty acids of oil T is lower than that of oil D. The Peroxide value of this oil T was around that of [33] in opposite to that of oil D which was little bite above. That suggests a slight high percentage of rancidity for oil D. Moreover, although the Ester values of both oils were below that of [33], that of oil D was the highest. This high Ester value of oil D indicates the presence of high amount of ester and low molecular weight fatty acid content.

In addition to these physico-chemical properties, the determination of the fatty acids composition show that the two types of oil consist of nine types of fatty acids. However, in the study of [38], eight fatty acids were found in palm kernel oil, while, in that of [39], eleven were identified. These results show that the fatty acids composition depend on the type of the origin of the oil palm. These fatty acids have an effect on oil quality. Indeed, according to [40], good quality of oil mainly refers to high percentages of unsaturated fatty acids, usually oleic and linoleic acids. These two unsaturated fatty acids (oleic and linoleic acids) were found in both oils analyzed in this study but their levels fell below those of saturated acids. Indeed, these oils were richer in saturated fatty acids and thus more stable. These results are in agreement with those obtained by [22]. In addition to this characteristic, the high level of fatty acid found in the oils analyzed was that of dodecanoic acid (lauric acid). According to [41], this fatty acid decreased the ratio of total to HDL cholesterol. Indeed, the ingested lauric acid enters the blood stream, it is rapidly metabolized and only a small amount is stored in the liver as triglycerides. Moreover, it is known that this fatty acid exhibit antimicrobial activities which intensify when it is esterified with glycerol to give monolaurin [42]. According to [43], the lauric acid has the greatest antimicrobial activity of all medium chain aliphatic fatty acids.

Also, peptides which are conjugated with lauric acid show higher antimicrobial activity compared to the unconjugated peptides. This increase in antimicrobial activity was attributed to a change in the helical structure due to lauric acid which enabled the peptides to better interact with the bacterial membrane [44]. In the presence of lauric acid, the production of infectious vesicular stomatitis virus was inhibited in a dose-dependent and reversible manner, after removal of lauric acid the antiviral effect disappeared.

For dental care, lauric acid decreases plaque formation and inhibits hydroxyapatite dissolution [45]. Moreover, currently, the palm kernel cake obtained after extraction of palm kernel oil was majorly commercialized as ingredients of beef and dairy feed [7, 8]. Thus, the two types of palm kernel oil analyzed are more suitable as ingredients of feed and also as feed preservatives due to their high level of lauric acid which has been shown to possess antimicrobial properties.

5. Conclusion

The physico-chemical analysis of oils carried out in order to contribute to the search of oil suitable for alternative in animal oil in feed or food showed that none of the investigated oil samples have a density and oil yield which were exceeded the upper limit of that recommended by the standards of the codex alimentarius 2005. It is also noted that focusing on the physical parameters analyzed except the viscosity index, the two types of oil are similar. However, the analysis for the chemical properties indicated that the two types of oil were significantly different except their Iodine values which were similar. These Iodine values were around the minimum limit of the standards of Codex Alimentarius 2005. However, the Acid values, the free fatty acids and the Peroxide values were upper those of these standard. While, the Saponification values and the Ester values fell below those of the standards of Codex Alimentarius 2005. However, for all these chemical parameters, the values obtained for oil D were all upper to those obtained for oil T.

These oils consist of nine types of fatty acids which are caproic acid, caprylic acid, capric acid, dodecanoic acid, myristic acid, palmitic acid, stearic acid, oleic acid and linoleic acid. The analysis of the levels of the fatty acids identified didn't show any significant difference between the palm kernel oil from variety Dura (oil D) and that from variety Tenera (oil T). Moreover, although these oils contained unsaturated fatty acids (oleic and linoleic acids), they were richer in saturated fatty acids and thus more stable. Among these saturated fatty acids, the level of dodecanoic acid (lauric acid) was the highest.

This indicates a good quality of the oil as this lauric acid decreased the ratio of total to HDL cholesterol and possesses also antimicrobial properties according to previous studies. Thus, as the studies on the effect of the saturated fatty acids on human health are controversial, the two types of palm kernel oil analyzed in this study, could be used as ingredients of feed and also as feed preservatives due on one hand to their high level of lauric acid which is known to possess antimicrobial properties and on the other hand to their content in unsaturated fatty acids (oleic and linoleic acids) which are an indicator of good quality of oil. However, oil T seems more suitable for alternative in animal oil in feed due to its percentage of free fatty acid which is less than that of oil D.

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Table 1: Physico-chemical characteristics of oils analyzed

Quality parameters	Samples		
	Oil extracted from variety Dura (Oil D)	Oil extracted from variety Tenera (Oil T)	Standards Codex Alimentarius Adopted in 1999 and amended in 2005-2015
Relative density at 20 °C	0.909[a]	0.912[a]	0.899-0.914
Fat content (g)	4.93 ± 0.1[a]	4.967 ± 0.1[a]	-
Oil yield (%)	49.3 ± 0.1[a]	49.67 ± 0.1[a]	50
Viscosity value at 40 °C (cSt)	41.69 ± 0.2[a]	39.7 ± 0.18[a]	-
Viscosity value at 100 °C (cSt)	8.94 ± 0.1[a]	8.2 ± 0.1[a]	-
Viscosity Index	145.13 ± 0.1[a]	188 ± 0.1[b]	-
Acid value (mg KOH / g fat)	20.28 ± 0.37[a]	15.46 ± 0.51[b]	10.0
Free fatty acid (%)	10.19 ± 0.2[a]	7.77 ± 0.25[b]	5.025
Iodine value (g I_2/100 g fat)	13.02 ± 0.13[a]	12.3 ± 0.39[a]	14.1-20.1
Saponification value (mg KOH / g fat	214.8 ± 1.87[a]	183.18 ± 3.68[b]	230-254
Peroxide value (meq/kg fat)	17.26 ± 0.24[a]	14.16 ± 0.41[b]	15.0
Ester value (mg KOH/g fat)	194.53 ± 1.5[a]	167.72 ± 3.17[b]	220-244
Insoluble impurities (%)	0.07 ± 0.01[a]	0.06 ± 0.01[a]	0.05

Values are means ± S.D (n=3)

Means in each row followed by different letters are significantly different ($p<0.05$).

Table 2: Standards Methyl esters of fatty acids (FAME) mix

Compound name	Retention time (min.)	Area [mV.s]	Height [mV]
Methyl butyrate (C4: 0)	4.33	371.312	163.913
Methyl caproate (C6: 0)	6.908	448.722	87.278
Methyl caprylate (C8: 0)	12.84	482.5	164.473
Methyl decanoate (C10: 0)	20.942	474.249	140.996
Methyl undecanoate (C11: 0)	25.083	227.265	67.633
Methyl dodecanoate (C12: 0)	29.135	442.891	125.825
Methyl tridecanoate (C13: 0)	33	217.319	65.41
Methyl myristate (C14: 0)	36.718	408.946	111.151
Methyl myristoleate (C14: 1 [cis-9]	39.737	220.643	55.77
Methyl pentadecanoate (C15: 0)	40.248	225.341	56.592
Methyl pentadecanoate (C15: 1 [cis-10])	43.03	233.132	46.897
Methyl palmitate (C16: 0)	44.002	620.049	121.922
Methyl palmitoleate (C16: 1 [cis-9]	47.435	249.912	32.463
Methyl hepadecanoate (C17: 0)	48.648	218.126	33.009
Methyl heptadecenoate (C17: 1 [cis-10])	51.127	223.281	27.16
Methyl stearate (C18: 0)	52.253	255.901	26.062
Methyl oleate (C18: 1 [cis-9])	52.852	422.583	51.47
Methyl octadecenoate (C18: 1 [trans-9])	53.238	330.006	29.859
Methyl linoleate (C18: 2 [cis-9,12])	54.805	554.819	49.035

Table 3: Methyl esters of fatty acids (FAME) composition of oil D

Compound name	Retention time (min.)	Area [mV.s]	Height [mV]
Methyl caproate (C6: 0)	6.867	54.511	22.793
Methyl caprylate (C8: 0)	12.827	885.696	286.078
Methyl decanoate (C10: 0)	20.938	908.647	249.855
Methyl dodecanoate (C12: 0)	29.4	12983.983	1154.24
Methyl myristate (C14: 0)	36,847	4555.554	641.959
Methyl palmitate (C16: 0)	44.065	2262.702	333.178
Methyl stearate (C18: 0)	52.283	617.745	64.043
Methyl oleate (C18: 1 [cis-9])	53.093	4202.108	291.147
Methl linoleate (C18: 2 [cis-9,12])	54.828	692.923	86.892

Table 4: Methyl esters of fatty acids (FAME) composition of oil T

Compounds name	Retention time (min.)	Area [mV.s]	Height [mV]
Methyl caproate (C6: 0)	6.892	42.495	18.841
Methyl caprylate (C8: 0)	12.847	661.529	218.868
Methyl decanoate (C10: 0)	20.962	654.056	193.393
Methyl dodecanoate (C12: 0)	29.393	9718.438	1024.617
Methyl myristate (C14: 0)	36.86	3492.994	566.114
Methyl palmitate (C16: 0)	44.093	1831.504	295.524
Methyl stearate (C18: 0)	52.33	496.272	52.899
Methyl oleate (C18: 1 [cis-9])	53.118	3559.879	273.254
Methl linoleate (C18: 2 [cis-9,12])	54.863	489.537	64.325

Table 5: Fatty acids composition of oils analyzed

Compounds name	Oil D (%)	Oil T (%)
caproic acid (C6:0)	0.73 ± 0.04[a]	0.70 ± 0.02[a]
caprylic acid (C8:0)	9.14 ± 0.01[a]	8.08 ± 0.02[a]
capric acid (C10:0)	7.98 ± 0.01[a]	7.14 ± 0.03[a]
dodecanoic acid (lauric acid) (C12:0)	36.87 ± 0.04[a]	37.84 ± 0.03[a]
myristic acid (C14:0)	20.51 ± 0.02[a]	20.91 ± 0.04[a]
palmitic acid (C16:0)	10.64 ± 0.01[a]	10.91 ± 0.02[a]
stearic acid (C18:0)	2.05 ± 0.01[a]	1.95 ± 0.02[a]
oleic acid (C18: 1 [cis-9])	9.30 ± 0.02[a]	10.09 ± 0.03[a]
linoleic acid (C18: 2 [cis-9,12])	2.78 ± 0.02[a]	2.38± 0.01[a]

Values are means ± S.D (n=3)

Means in each row followed by different letters are significantly different ($p<0.05$).

(A)

(B)

Figure 1: Fruits of variety Dura (A) and variety Tenera (B) of oil palm (*Elaeis guineensis* Jacq.)

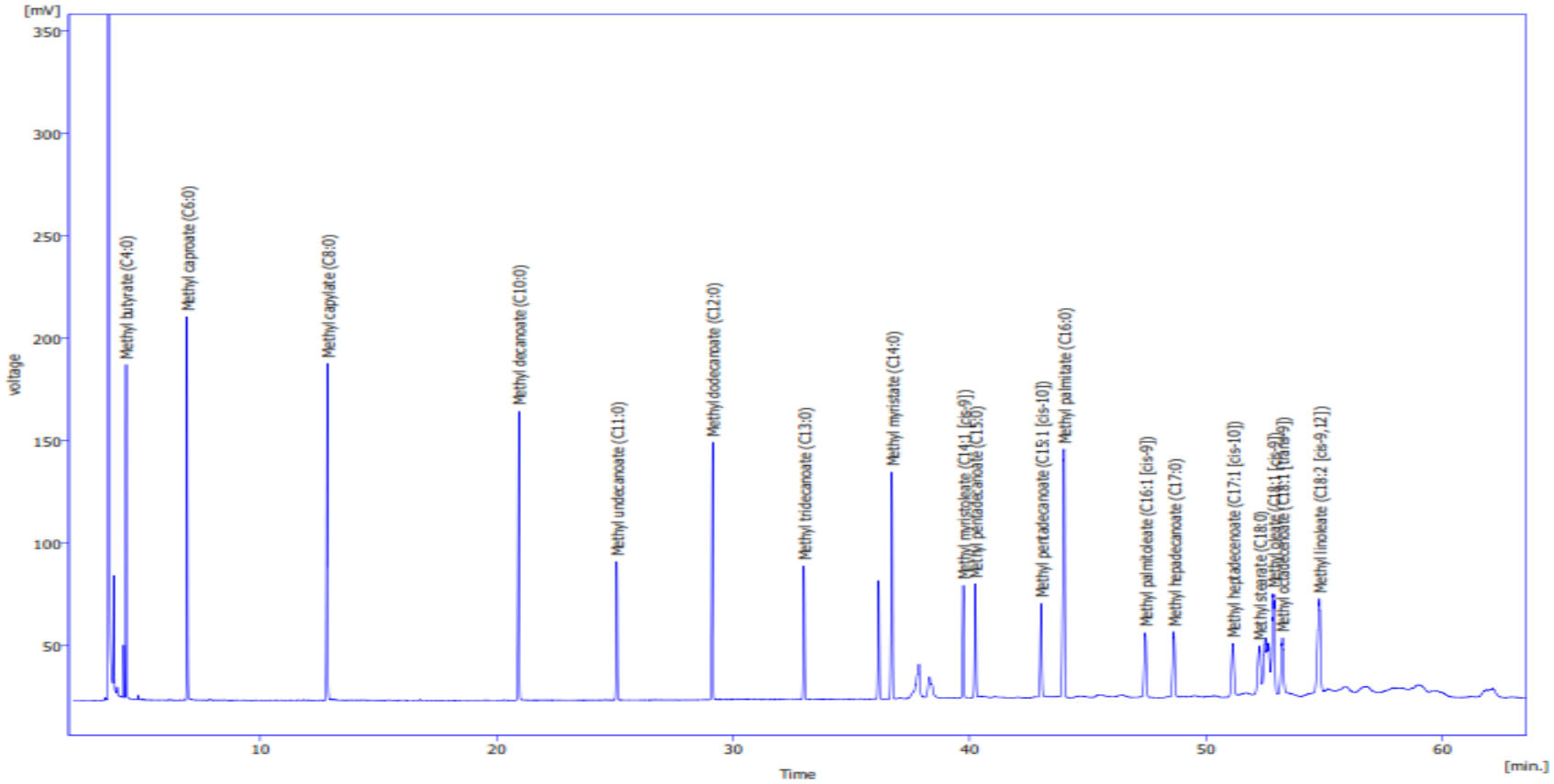

Figure 2: Chromatogram for standards methyl esters of fatty acids (FAME) mix

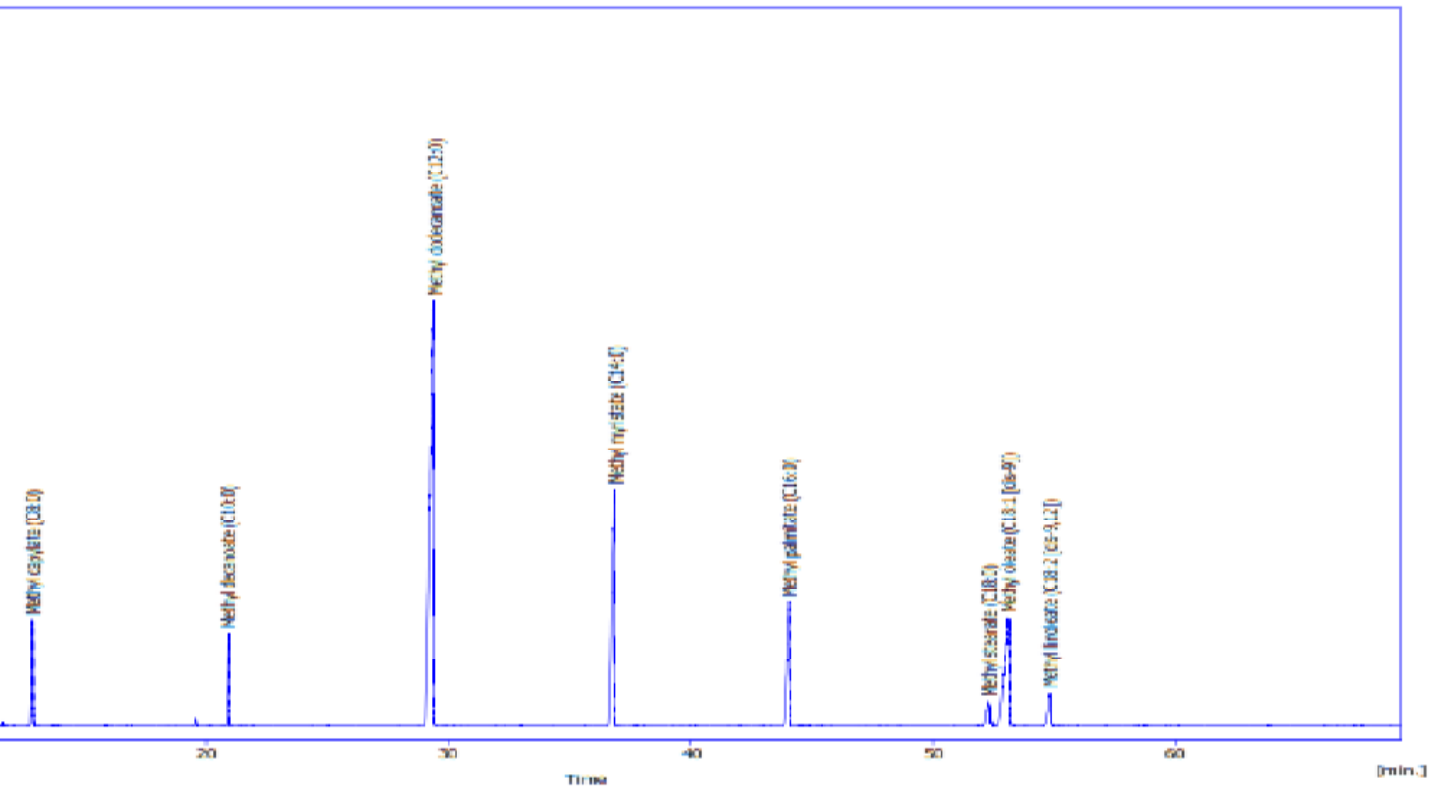

Figure 3: Chromatogram for methyl esters of fatty acids (FAME) of oil D

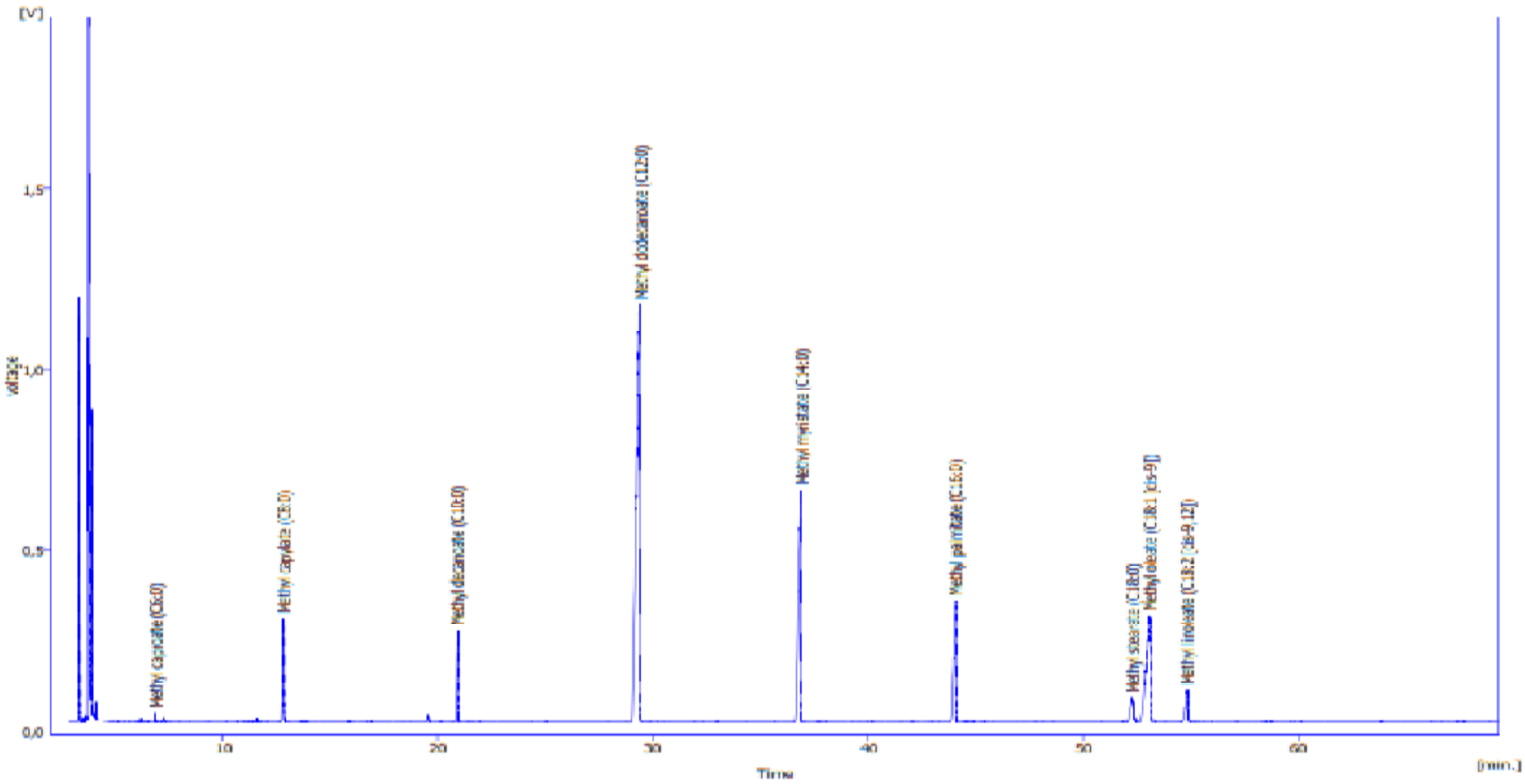

Figure 4: Chromatogram for methyl esters of fatty acids (FAME) of oil D

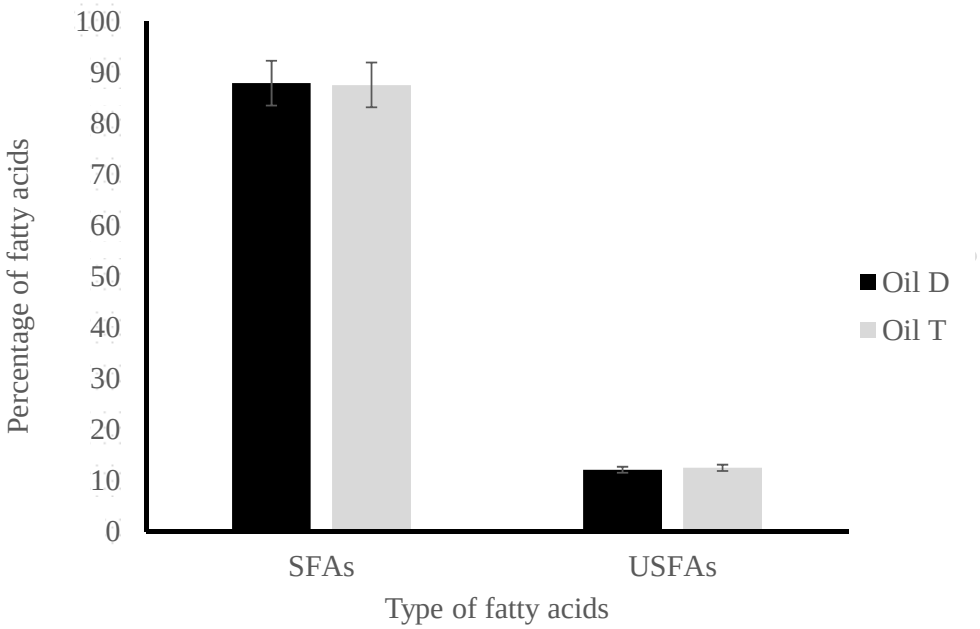

Figure 5: Total saturated and unsaturated fatty acids of the oils analyzed