

Biochemical Characterization by GC-MS of Palm Kernel Oils Produced in Côte d'Ivoire

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Abstract

The objective of this study was to determine biochemical composition of palm kernel oils produced and consumed in Côte d'Ivoire in order to find out those more suitable for human diet. Our preliminary investigations showed that palm kernel oils consumed in Côte d'Ivoire were those extracted from varieties Dura and Tenera of oil palm (*Elaeis guineensis* Jacq.) Thus, the types of oils analyzed in this study were oil extracted from the variety Dura (OD) and oil extracted from the variety Tenera (OT). The GC-MS was used to determine the biochemical composition of these oils. The results obtained show that in each oil, seventeen fatty acids were identified by GC-MS. However, among these fatty acids, undecylenic acid was identified only in OD and heptanoic acid was identified only in OT. The two types of oil are rich in saturated fatty acids. However, OD had a relatively higher unsaturated fatty acids content. For the other compounds identified, OT had significantly the highest contents of polyphenols, α -tocopherol and sterols with the predominance of β -sitosterol. These results support that palm kernel oil extracted from the variety Tenera is rich in natural compounds that could be developed as nutraceuticals and phytomedicine. However, some unexpected compounds such as lactones were also identified in the two types of oils. Moreover, it is noted that these lactones were more abundant in oil extracted from the variety Dura (OD).

Keywords: palm kernel oil, fatty acids, sterols, polyphenols, α -tocopherol, lactones

1. Introduction

Malnutrition is the greatest single threat to the world's public health (WHO, 2019). Indeed, malnutrition leads to several diseases (Stratton *et al.*, 2003). However, people more vulnerable are pregnant and lactating women and also young children less than five years (Weber *et al.*, 2015). For these young children, malnutrition can decrease intellectual development and increases also mortality (Barker & Osmond, 1986). Several metabolic disorders such as obesity, high blood pressure and diabetes are often associated to poor dietary intake (Guh *et al.*, 2009; Daniels, 2009). For pregnant women, the threat due to malnutrition is also remarkable. Indeed, Picone *et al.*, (2011) showed that high fat diet during the gestation leads to congenital malformations (Zaloga, 2015). The quality and quantity of oils in diet can thus have an effect on human health as well as animal health. From up to now it is known that vegetable oils are an important source of nutrients which play important role in the diets of people around the world (Kumar *et al.*, 2016). The source of these oils are oleaginous plants. For many years now, oils are usually used for seasoning and to preserve degradation of foods quality (Tchi égang *et al.*, 2004). These vegetable oils are also used in fields such as pharmaceutical, cosmetic and industry (Aubrey & Huard, 2003). Among the vegetable oils more affordable in Côte d'Ivoire, there is palm kernel oil derived from the kernel which is the residue obtained after palm oil production (Pickard, 2005). This kernel is not only used for oil production. Indeed, the cake of kernel is used for feeding ruminants (Pickard, 2005). It is used also as additive in feed for beef (Ravber *et al.*, 2015).

In Côte d'Ivoire and many African countries, oil extracted from the kernel is used for seasoning the dishes and as food preservative (Yapi & Kouadio, 2019). Previously, Agboola *et al.*, (2015) have shown that palm kernel oil contained saturated fatty acids as well as monounsaturated and polyunsaturated fatty acids used in African dishes. However, it is not used only for diet. Indeed, it is used in folk medicine for the treatment of dermatoses.

Moreover, according to Anonyme (2012), the palm kernel oil with its richness in lauric acid which possesses antimicrobial and antiviral properties could be recommended for the diet of people with weak immune system. However, this information should be confirmed by further research. This palm kernel oil could be stored for a long time easily. Indeed, it can be stored at a temperature of 40 °C for 6 months (Ibiam & Anosike, 2014).

However, despite this literature relatively abundant found on palm kernel oil, most of the analyses on this oil were carried out using Gas chromatography (GC) which shows most of the time, only the major components (fatty acids).

Thus, in this study, the Gas Chromatography coupled with the Mass Spectrometry (GC-MS) was used to make the screening of the biochemical composition (major and minor components) of palm kernel oils produced and consumed in Côte d'Ivoire in order to identify the varieties of oil palm from which oil extracted could be more suitable for human diet.

2. Material and Methods

2.1 Raw Material

The biological material used is the palm kernel oil extracted from the kernel of the fruits of varieties of oil palm (*Elaeis guineensis* Jacq.). Two varieties of oil palm more consumed in Côte d'Ivoire were identified during our preliminary investigations. Indeed, there are variety Dura and variety Tenera.

2.2 Oil Extraction

Oil extraction was carried out by using the Soxhlet method described by Yapi and Kouadio (2019). The solvent used was hexane which gives the best oil yield with solid sample according to Mohd-Setapar *et al.* (2004). The extraction was made at 60 °C.

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

$$\text{FA (Total fat content)} = M2 - M1$$

$$\text{Oil yield} = (\text{FA}/M0) \times 100$$

$$\text{Oil yield} = [(M2 - M1) / M0] \times 100$$

Where: M0: mass (g) of the test sample; M1: mass (g) of the empty flask

M2: mass (g) of the flask and the total fat extracted.

Three samples of palm kernel of each variety were analyzed.

2.3 Determination of Fatty Acids Composition by Gas Chromatography Coupled to Mass Spectrometry (GC/MS)

The analysis started with the conversion of the oil into fatty acid triméthyl silyl ester. This esterification was conducted following the procedure used by Kloos *et al.* (2014) and described in the study of Yapi and Kouadio (2020). After the silylation, of the fatty acids by the reagent of N-methyl-N-trimethylsilyltrifluoroacetamide (MSTFA), the analysis was carried out by GC-MS using an apparatus of the PerkinElmer brand, model Clarus 680GC 600C MS. The chromatographic conditions were those described by Yapi and Kouadio (2020).

2.4 Minor Components Determination

Several minor components useful for human diet such as sterols, α -tocopherol and polyphenols were determined in palm kernel oils.

For sterol determination, saponification of oil was done in order to extract firstly the unsaponifiable. The method of AFNOR NF T60-205 (1984) was used. In order to obtain the trimethylsilyl ether (tms) of sterols which are detectable by gas chromatography coupled to a mass spectrometer (GC-MS), the unsaponifiable fraction was derived by silylation using the method used by Grandgirard and Gordelet (1998). These tms sterols were then identified and quantified by GC-MS using chromatographic conditions used previously by Yapi and Kouadio, (2020).

The quantities of the various sterols of oils studied were calculated as follows:

$$\text{Sterol x (mg/100 g of oil)} = (\text{Px} \times \text{ms} \times 100) / \text{Ps} \times \text{m}$$

The content of each single sterol is expressed in milligrams per 100 grams of oil.

With:

Px: peak x area of the sterol,

Ps: peak area of the 5 α -cholestane,

ms: mass of added 5 α -cholestanol (mg)

m: mass of the test portion (g).

The percentage of each sterol is given by the relation: % sterol x = (Px / S) x100

With Px: area of the peak x

S: sum of the areas of all the peaks.

The α -tocopherol which is the most active form of vitamin E was also determined. The analysis was carried out using the standard ISO 14565 (2000) described in previous study by Yapi and Kouadio, (2020). The quantification of the α -tocopherol was also done by using a gas chromatograph equipped with a mass spectrometer with the chromatographic conditions described by Yapi and Kouadio (2020). The α -tocopherol contents were determined using Emporio brand software.

The total polyphenolic content was also evaluated. This evaluation was done according to the Folin-Ciocalteu method described by Albano and Miguel (2011). The total polyphenols content was determined using a Gallic acid calibration line performed at different concentrations (20 μ g / mL; 40 μ g / mL; 60 μ g / mL; 80 μ g / mL and 100 μ g / mL). The total polyphenol content of the oil samples (T), expressed in milligrams of Gallic acid equivalent per gram of oil (mg EAG / g of oil) was calculated according to the formula below:

$$T = (V \times C \times d) / m$$

With: V: final volume of the extract (mL),

C: concentration of the extract obtained with the calibration curve (mg / mL),

d: dilution,

m: mass of oil in the test sample (g).

2.6 Statistical Analysis

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

3. Results and Discussion

3.1 Fat Content of Palm Kernel of Variety Dura and variety Tenera

The extraction of the fat content did not show a significant difference between the total oil extracted from the variety Dura (OD) and that extracted from the variety Tenera (OT) (P>0.05). Indeed, the palm kernel oil yields obtained for these two varieties were around 50% (Table 1).

This value fell in that obtained by Yapi and Kouadio (2019) and also in that indicated by the Codex Alimentarius (2015). It is also noted that the oil yields obtained were similar to that obtained in previous study (Pickard, 2005) which was 50%, but fell below the range of 75-80% found by Asuquon (2008). This could be explained by the method of analysis used by this author. However, although no difference was observed between the oil yields of the two types of oil, a difference was noted between the color of oil extracted from the variety Dura (OD) and that extracted from variety Tenera (OT). Indeed, OD was yellow light while OT was orange yellow (Figure 1).

Table 1. Fat content

Quality parameters	Samples		Standards Codex Alimentarius Adopted in 1999 and amended in 2005-2015
	(OD)	(OT)	
Fat content (g)	4.94 \pm 0.1 ^a	4.99 \pm 0.1 ^a	-
Oil yield (%)	49.40 \pm 0.1 ^a	49.87 \pm 0.1 ^a	50

Values are means \pm S.D (n=3)

Means (means of three samples analyzed) in each row followed by the same letters are similar (p>0.05).

Oil extracted from variety Dura (OD)

Oil extracted from variety Tenera (OT)

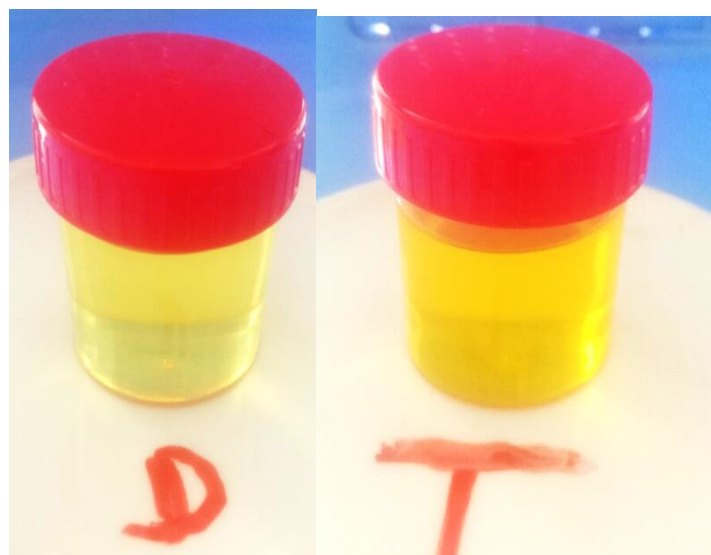


Figure 1. Oils extracted from the variety Dura (OD) with yellow light color and from the variety Tenera (OT) with orange yellow color

3.2 Fatty Acids Composition

The analysis showed 17 types of fatty acids in the two types of oils (OD and OT) (Table 2). The number of fatty acids found in our study was higher than those obtained in previous studies (Mancini *et al.*, 2015; Yapi and Kouadio, 2019). These results show that the fatty acids composition of the palm kernel oil could depend on the type of variety of the oil palm and also on the technic used for the analysis. Indeed, in the present study, the GC-MS was used, while in these previous studies mentioned above, the gas chromatography coupled to flame ionization detection (GC/FID) was used. These oils are rich in saturated fatty acids (Figure 2). This was shown by the ratios of unsaturated fatty acids and saturated fatty acids which fell under that mentioned by the standard of Codex Alimentarius (2015) which is 1. Indeed, these ratios were 0.250 and 0.220 respectively for OD and OT (Table 2). These results were similar to those obtained by Agboola *et al.*, (2015) and Yapi and Kouadio (2020).

Table 2. Fatty acids composition of palm kernel oils analyzed by gas chromatography coupled to mass spectrometry (GC-MS)

Fatty acids	OD Content (%)	OT Content (%)
Caproic acid (C6:0), (tms)	0.03 ± 0.001 ^a	0.1 ± 0.003 ^b
Heptanoic acid (C7:0), (tms)	Abs	0.02 ± 0.01
Octanoic acid (C8:0), (tms)	1.03 ± 0.11 ^a	4.53 ± 0.11 ^b
Nonanoic acid (C9:0), (tms)	0.03 ± 0.01 ^a	0.05 ± 0.01 ^a
Decanoic acid (C10:0), (tms)	1.5 ± 0.21 ^a	3.4 ± 0.18 ^a
Undecanoic acid (C11:0), (tms)	0.02 ± 0.01 ^a	0.04 ± 0.01 ^a
Lauric acid (C12:0), (tms)	50.70 ± 0.22 ^a	50.63 ± 0.19 ^a
n-Tridecanoic acid (C13:0), (tms)	0.04 ± 0.01 ^a	0.04 ± 0.01 ^a
Undecylenic acid (C11:1 [cis - 1]), (tms)	0.01 ± 0.001 ^a	Abs
Myristic acid (C14:0), (tms)	18.60 ± 0.24 ^a	12.70 ± 0.17 ^b
n-Pentanoic acid (C5:0), (tms)	0.01 ± 0.001 ^a	0.08 ± 0.004 ^b
Palmitic acid (C16:0), (tms)	6.70 ± 0.21 ^a	9.05 ± 0.21 ^b
Heptadecanoic acid (C17:0), (tms)	0.01 ± 0.001 ^a	0.02 ± 0.001 ^a
Trans-9-octadecenoic acid (C18: 1 [trans-9]), (tms)	7.30 ± 0.21 ^a	4.61 ± 0.18 ^b
Oleic acid (C18: 1 [cis-9]), (tms)	10.40 ± 0.1 ^a	10.60 ± 0.2 ^a
Stearic acid (C18:0), (tms)	1.14 ± 0.02 ^a	1.33 ± 0.11 ^a
Linoleic acid (C18: 2 [cis-9,12]), (tms)	2.60 ± 0.2 ^a	2.70 ± 0.3 ^a
Arachidic acid (C20:0), (tms)	0.04 ± 0.01 ^a	0.04 ± 0.01 ^a

Values are means ± S.D (n=3)

Means (means of three samples analyzed) in each row followed by different letters are significantly different ($p < 0.05$).

Oil extracted from variety Dura (OD)

Oil extracted from variety Tenera (OT)

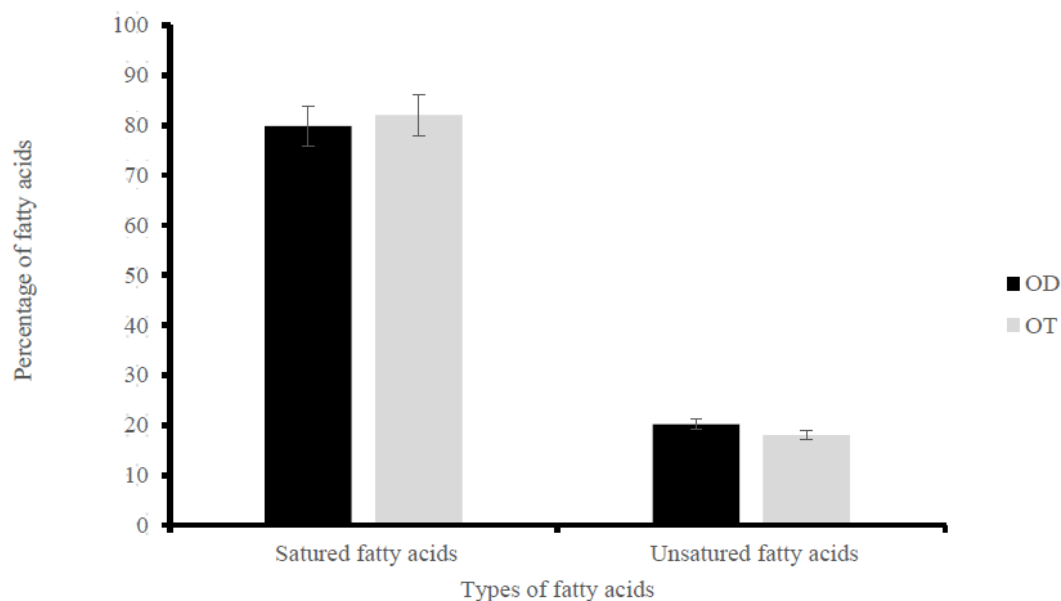


Figure 2. Fatty acids contents of palm kernel oils extracted from varieties Dura (OD) and Tenera (OT)

Regarding the number of fatty acids found in both oils analyzed, OD and OT seem to be similar. However, it is noted that undecylenic acid was identified only in OD, while heptanoic acid was found only in OT (Table 2). These results were similar to those obtained by Yapi and Kouadio (2020). Among these saturated fatty acids, lauric acid was the predominant fatty acid with level of $50.70\% \pm 0.22$ and $50.63\% \pm 0.19$ respectively for OD and OT. Similar results were obtained by Yapi and Kouadio, (2019) with palm kernel oil. As the benefic effects of lauric acid on health has been shown in previous studies (Orsavova *et al.*, 2015), its presence in oil is an index of quality. Thus, palm kernel oils could be used in many dishes not because they are affordable but also because of their nutritional quality. These oils contained also unsaturated fatty acids with a relative abundance of monounsaturated fatty acids. Indeed, the proportions of monounsaturated fatty acids were $17.64\% \pm 0.5$ and $15.30\% \pm 0.4$ respectively for OD and OT. As it is noted, OD is relatively richer in monounsaturated fatty acids than OT. This characteristic is recommended as it makes oil be very stable even in applications such as fried foods (Warner & Knowlton, 1997). Thus, as it has been shown by Lopes *et al.*, (2016), the consumption of oils contained monounsaturated fatty acids could protect consumers from cardiovascular crisis. Palm kernel oil from variety Dura could thus be used for fried foods.

3.3 Sterols Composition

The sterols were also identified in the oils analyzed. The total contents of these sterols were significantly different ($P < 0.05$). Indeed, the sterols content of OD was 350.0 ± 1.01 mg / 100 g of oil, while that of OT was 4980.0 ± 1.8 mg / 100 g of oil (Table 3). As it noted, OT had the highest total sterols content. The value obtained for this oil is similar to that obtained by Yang *et al.*, (2019) in olive oil. This OT is thus, a good source of sterols. The identification of the sterols fraction revealed the presence of β -sitosterol, campesterol, and stigmasterol. The predominant sterol in the two types of oil was the β -sitosterol with proportions of $75.09\% \pm 1.34$ and $76.29\% \pm 1.8$. These amounts of β -sitosterol were followed by those of campesterol ($13.42\% \pm 1.06$ and $12.35\% \pm 0.91$) and stigmasterol ($11.50\% \pm 0.8$ and $11.40\% \pm 0.75$) respectively for OD and OT (Table 4). However, it is noted that OT was also rich in β -sitosterol (3799.242 mg / 100 g of oil) than OD (262.815 mg / 100 g of oil). This β -sitosterol has several beneficial effects on health such as the treatment of many types of cancers (AbuMweis *et al.*, 2014). It has also a positive effect on diabetes type II (Yang *et al.*, 2019) and on the improvement of the immune system (Bouic, 1999). That makes this OT very interesting for human diet mainly in this period of the COVID-19 pandemic in which everybody needs a strength immune system to protect himself against this virus

and other microorganism's infection.

Table 3. Minor components contents of palm kernel oils analyzed

Components	OD	OT
Polyphenols content (mg EAG/g of oil)	62.30 ± 1.02 ^a	94.07 ± 1.16 ^b
α-Tocopherol content (mg/100 g of oil)	44.10 ± 0.52 ^a	58.90 ± 0.76 ^b
Sterols content (mg/100 g of oil)	350 ± 1.01 ^a	4980 ± 1.8 ^b
Lactones content (mg/100 g of oil)	220 ± 1.1 ^a	190 ± 0.91 ^b

Values are means ± S.D (n=3)

Means (means of three samples analyzed) in each row followed by different letters are significantly different (p<0.05).

Oil extracted from variety Dura (OD)

Oil extracted from variety Tenera (OT)

Table 4. Sterols composition of palm kernel oils analyzed

	OD	OT
Sterols (%)		
Campesterol	13.42 ± 1.06 ^a	12.35 ± 0.91 ^a
Stigmasterol	11.50 ± 0.8 ^a	11.40 ± 0.75 ^a
β-Sitosterol	75.10 ± 1.34 ^a	76.30 ± 1.8 ^a

Values are means ± S.D (n=3)

Means (means of three samples analyzed) in each row followed by different letters are significantly different (p<0.05).

Oil extracted from variety Dura (OD)

Oil extracted from variety Tenera (OT)

3.4 α-Tocopherol Content

The α-tocopherol content which is the most active form of vitamin E was also determined in the oils. The highest content of α-tocopherol was found in OT. Indeed, the α-tocopherol contents were 44.10 ± 0.52 mg / g of oil and 58.90 ± 0.76 mg / g of oil respectively for OD and OT (Table 3). The analysis shows that there is a significant difference between the α-tocopherol contents of the two types of oil (P <0.05). As it is known, this compound is important for human being because of its antioxidant property (Kaya, 2009). This compound makes OT great for human diet.

3.5 Polyphenols Content

The polyphenols content was also determined in the oils extracted. The linear regression equation of the calibration curve plotted for Gallic acid (Figure 3) was used for this determination. The OT had the highest polyphenols content with a value of 94.07 ± 1.16 mg EAG / g oil compared to that of the OD which was 62.3 ± 1.02 mg EAG / g oil (Table 3). It is noted a significant difference between the polyphenols content of OD and that of OT (P <0.05). As these polyphenols are known to be natural antioxidants which are used for the conservation of edible foodstuffs and also in the treatment cancers (Kouamé *et al.*, 2009). Thus, therapeutically, cosmetically and nutritionally, the OT can be considered as interesting oil to recommend for diet.

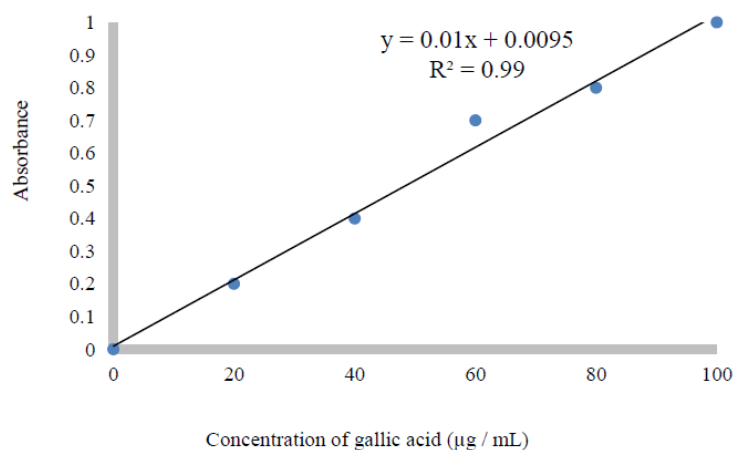


Figure 3. Calibration curve of Gallic acid

3.6 Lactones Content

In addition to the minors compounds mentioned above, lactones were found in the two types of oil analyzed.

However, the OD was richer in these lactones than the OT. Indeed, in the OD, the γ dodecalactone ($84.65\% \pm 0.95$) and the δ -dodecalactone ($15.35\% \pm 0.44$) were identified, while in the OT, the lactones identified were the δ -decalactone ($52.17\% \pm 0.68$) and the δ -dodecalactone ($47.83\% \pm 0.32$). As it has been shown in previous studies, the γ lactones have the highest flavoring power (Sofiane, 2009). Thus, the richness in γ -dodecalactone of oil extracted from the variety Dura (OD) makes this oil an excellent source of natural flavoring agents.

Table 5. Sterols composition of palm kernel oils analyzed

Type de lactones (%)		
OD	γ Dodécalactone	84.65
	δ -Dod écalactone	15.35
OT	δ -D écalactone	52.17
	δ -Dod écalactone	47.83

Values are means \pm S.D (n=3)

Means (means of three samples analyzed) in each row followed by different letters are significantly different ($p < 0.05$).

Oil extracted from variety Dura (OD)

Oil extracted from variety Tenera (OT)

4. Conclusions

This study highlights the variability of the components of oils extracted from varieties of a same oleaginous plant. Indeed, although 17 fatty acids were found in the two types of palm kernel oil derived from varieties Tenera and Dura of oil palm (*Elaeis guineensis* Jacq.), it is noted that undecylenic acid was found only in OD extracted from the variety Dura while, heptanoic acid was found only in OT extracted from variety Tenera. The OD was relatively richer in unsaturated fatty acids than the OT. However, the predominant fatty acid in both oils was lauric acid. Moreover, the determination of the minor compounds showed that, OT had the highest content of sterols with the β -sitosterol as predominant sterol. This OT had also the highest contents of α -tocopherol and polyphenols. These compounds possess many biological properties such as antioxidant and cholesterol lowering properties. Thus, these results support that palm kernel oil extracted from variety Tenera (OT) with its richness in natural compounds, is more suitable to be developed as nutraceuticals and phytomedicine.

Moreover, OD with its richness in γ -dodecalactone could be used as a flavor enhancer of dishes.

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Competing interests

Authors have declared that no competing interests exist.

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