



## Physicochemical Analysis of Palm Kernel Oil Extracts from Traditional Varieties in the West Region of Côte d'Ivoire

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### Authors' contributions

*This work was carried out in collaboration among all authors. Author NGL designed the study, wrote the protocol, fitted the data and wrote the first draft of the manuscript. Authors AC and FI checked the first draft of the manuscript and achieved the submitted manuscript. Authors SD and KD performed the statistical analysis and assisted the experiments implementation. Authors CK and BHM expertized the results interpretations. All authors managed the literature, read and approved the submitted manuscript.*

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## ABSTRACT

**Aims:** This study aims to evaluate the physicochemical properties of palm kernel oil extracted from traditional varieties in the Mountain district, West region of Côte d'Ivoire.

**Study Design:** Palm kernels were collected from women crude palm oil producers in three departments of the western part of Cote d'Ivoire. In each department, 50 kg of palm kernel were purchased per supplier.

**Place and Duration of Study:** This study was carried out June to September 2017. The collected almonds of palm kernels were carried out at the Biochemistry and Food Sciences Laboratory of the Félix Houphouët-Boigny University, Abidjan.

**Methodology:** The palm kernel oils were extracted by maceration and their physicochemical properties were determined using standard methods.

**Results:** The results obtained show that the values for the physicochemical parameters of palm kernel oils from the three departments were similar and fell in those of the standards of Codex Alimentarius 2019. However, physicochemical parameters statistically vary ( $P < 0.05$ ) between the departments. The yields of oils extracted fluctuated between  $39.64 \pm 2.14 \%$  and  $52.26 \pm 1.16 \%$ . The refractive index ranges between  $1.453 \pm 0.01$  and  $1.454 \pm 0.002$ . The relative density varies between 0.90 and 0.91. The level of insoluble impurities ranged from 0.06 to 0.09 %. The moisture and volatile matter content varied between  $0.62 \pm 0.05$  to  $1.94 \pm 0.07 \%$ . The acid value and free fat acid percentage varies from  $6.37 \pm 0.65$  to  $8.54 \pm 0.57$  mg KOH/g and  $3.20 \pm 0.31$  to  $4.29 \pm 0.28 \%$ , the saponification value ranges between  $216.02 \pm 8.96$  mg KOH/g and  $248.16 \pm 2.40$  mgKOH/g, iodine value varies from  $17.52 \pm 0.43$  and  $19.05 \pm 0.95$  g of iodine per 100 g of fat and peroxide value range between  $6.02 \pm 1.13$  to  $8.38 \pm 1.00$  meq  $O_2$  kg of fat. The study of the lipid composition of these fats showed significant presence of fatty acid and unsaponifiable. The major fatty acids are lauric acid (50.50 - 51.00 %), myristic acid (18.35 - 18.80 %) and oleic acid (12.80 - 13.92 %).

**Conclusion:** Given the results, palm kernel oils from the three departments exhibited good physicochemical properties, a clear indication that palm kernel oil could be used as edible and non-edible products in many homes and at various levels of industries in Côte d'Ivoire. There is limited information available about palm kernel oil from the western region of Côte d'Ivoire now and this study systematically researched on it, which can provide useful information for Ivorian oil palm industry.

**Keywords:** Palm kernel oil; physicochemical properties; fatty acids; Western region; Côte d'Ivoire.

## 1. INTRODUCTION

Palm oil accounts for about 90% of edible oil needs in Côte d'Ivoire [1]. Due to long term local eating habits, cheaper cost, and the presence of an important industrial sector representing about 80% of total production, palm oil is extensively used in its crude form (crude palm oil, CPO) and kernel oil (Palm kernel oil, PKO) for food purposes in Côte d'Ivoire and also throughout West African regions [2-3]. These oils are of markedly different composition and characteristics. CPO contains 50% saturated fatty acids, 40% unsaturated fatty acids and 10% polyunsaturated fatty acids [4]. CPO is also known as the richest natural source of carotenoids (500–700 ppm), tocopherols and tocotrienols (600–1200 ppm) contributing to its nutritional and stability properties [5]. The properties and fatty acid composition of PKO and coconut oil (CNO) are very similar, the two oils are called lauric oil because lauric acid among

the fatty acids is the major component accounting for about 50% [6]. Palm kernel oil possess inhibitory effect on *Staphylococcus aureus* and *Streptococcus sp.*, with beneficial effects due to the conversion of lauric acid to monolaurin in human or animal body [7]. The oil can be used as an ointment for the body to minimize infections by micro-organisms and this may justify its usage amongst many people in some parts of Nigeria [8]. It is also used as confectioner's hard fat in the production of chocolate-type coatings for baked products. It is also extensively used in margarine manufacture. The oil may be fractionated to produce a hard fat stearin, which is very useful as a cocoa butter substitute [9-10].

There is limited information available about palm kernel oil from the western region of Côte d'Ivoire. This region is an area prized for its red palm oil obtained from sub-spontaneous palms. This palm oil, very popular with consumers in

Côte d'Ivoire, is mainly the object of a highly developed local trade [11-12]. It therefore appeared necessary to characterize the palm kernel oil obtained from these sub-spontaneous palms. The present study aimed to assess the physicochemical and fatty acid composition of palm kernel oil from the Western area of the Côte d'Ivoire.

## 2. MATERIALS AND METHODS

### 2.1 Plant Materials

Palm kernels were collected from women crude palm oil producers in the departments of Zouan-Hounien, Danane and Man of the Tonkpi region, Mountain district in the western part of Cote d'Ivoire. In each city, 50 kg of palm kernel were purchased per supplier from June to September 2017. The collected almonds of palm kernels were transported to Laboratory of Biochemistry and Food Sciences (University Felix Houphouët-Boigny, Abidjan, Côte d'Ivoire). Before analysis, the kernels were sorted, sun-dried for 4-5 days and crushed into fine particles.

### 2.2 Oil Extraction

Extraction was performed according to the method described by Rombaut [13]. The oil contained in the ground palm kernels was extracted by maceration in hexane at a solid/liquid ratio of 1:10 (g/v) for 6 hours in the cold. After vacuum filtration using a Buchner-type device, the filtrate obtained was evaporated under reduced pressure in a rotary evaporator (Rotavapor, Buchi- Switzerland) at 40°C. The fat obtained was dried on anhydrous magnesium sulphate to remove traces of water and then steamed at 70°C for 12 hours to remove traces of hexane. The oil obtained from each sample was kept in a dark bottle in the refrigerator at 4°C until it was used for the various analyses.

### 2.3 Chemical Characterization of Palm Oil Kernel

#### 2.3.1 Physicochemical characteristics of palm oil kernel

The physicochemical characteristics of palm kernel oil were determined according to the methods defined by the AFNOR standards [14]:

- i. Acid value and free fat acid percentage (ISO 660)

- ii. Iodine value (ISO 3961)
- iii. Peroxide value (ISO 3960)
- iv. Saponification and Ester values (ISO 3657)
- v. Unsaponifiable (ISO 3596)
- vi. Refractive index (ISO 6320)
- vii. Relative density or specific gravity (ISO 6883)
- viii. Moisture and volatile matter content (ISO 662)
- ix. Insoluble impurities (ISO 663)

#### 2.3.2 Determination of fatty acid composition of oils

Fatty acid methyl esters were obtained by methylation of fatty acids in oils by the method described by [15] prior to GC-MS analysis. Three drops of oil were added to 3 mL of sodium methoxide solution and the mixture was heated at 60°C for 10 min. After this step, 3 mL acetyl chloride and 10 mL methanol (50 mL/625 mL) were added to the previously heated mixture. The new mixture was heated for 10 min and then cooled to room temperature. Subsequently, 10 mL distilled water and 15 mL hexane were added successively, and the resulting mixture stirred vigorously, left to stand until two phases were clearly separated. The upper hexane phase containing the fatty acid methyl esters was transferred to a vial for GC-MS analysis. The fatty acid methyl ester analysis was performed by gas chromatography coupled to a GC-MS labelled Shimadzu QP2012-SE with a Zebron ZB-5MS apolar capillary column (20 m x 0.18 mm x 0.18 µm). The flow rate of the carrier gas (helium) was set at 2 mL/min. The furnace programming is set at 100°C for 5 min, to reach 230°C at a rate of 10°C/min. The volume of fatty acid methyl esters injected was 1 µL. The temperatures of the injector and the detector are 250 and 260°C respectively. The peak areas were treated with a Merck D-200 type integrator. Fatty acids were identified by comparison of their retention time of palm oil fatty acids and by comparison with values in the literature.

#### 2.4 Statistical Analysis

Analyses were performed in triplicate and results were expressed as percentage. Data were statistically treated using SPSS software (version 20.0). It consisted in analysis of variance. Means derived from parameters were compared with the Tukey High Significant Difference test at 5% significance level.

### 3. RESULTS AND DISCUSSION

#### 3.1 Extraction of Fats

The extraction yield of each palm kernel oil is showing in Fig. 1. The oil yield varied significantly ( $P < 0.05$ ) among the localities, with average levels between  $39.64 \pm 2.14$  % and  $52.26 \pm 1.16$  %. The department of Zouan-Hounien is showing high proportion and the lower proportions at Danané and Man. The result obtained from Man ( $41.14 \pm 2.64$  %) and Zouan-Hounien are consistent with the findings of [16-18] who reported values about 42% to 49.67 % for fat. However, results of this study are low compared to those observed in Malaysia which indicated an oil content ranging from  $53.70 \pm 1.1$  to  $54.88 \pm 2.1$ % [19]. Indeed, this difference can be explained by the extraction methods and also by the origin of palm kernel. However, it should be noted that these yields were in good agreement to those of oleaginous seeds [20]. The high fat content in palm kernel indicated that it is suitable to be used for cooking as well as for other applications.

#### 3.2 Physical Parameters

The physical parameters from the different localities are shown in Table 1. The refractive index measures of how much light bends when traveling through the oil. This index grows with the unsaturation or with the presence on the fatty chains of secondary functions. The refractive index obtained in this study was in accordance with the work of [21] who also obtained 1.45. The refractive indexes of the palm kernel oils from the three departments were also similar to those of the Codex Alimentarius [22] which was 1.45.

Regarding the relative density, value obtained from the palm oil kernel samples ranged from 0.90 to 0.91 with palm kernel oil from Danané and Zouan Hounien having the lowest relative density while Man had the highest. These values are comparable to those found by [18] and also in accordance to those recommended by Codex for palm kernel oil (0.899-0.914) [22]. Concerning moisture and volatile contents, values obtained from the departments were significantly high compared to those recommended for palm kernel oil. Indeed, these values ranged from  $0.62 \pm 0.05$  to  $1.94 \pm 0.07$  % with palm kernel oil from Man had the lowest while palm kernel oil from Danané had the highest moisture and volatile contents. Results of this study are significantly higher than those [23] for palm kernel oil. The high presence of water and volatile matter could promote enzymatic activity. This suggests that oils of this study are more likely to suffer the hydrolytic or enzymatic alteration that leads to the formation of secondary products such as monoglycerides and diglycerides. These high values could also reflect the hygroscopic nature of these oils in the presence of moisture in the air [24]. The level of insoluble impurities is different among the different localities ( $P < 0.05$ ). Impurities ranged from 0.06 to 0.09 %, whereas 0.05% is the standard value recommended for impurity [22]. The relatively high impurity level observed from sample of Zouan Hounien may be influenced by the methods of palm kernel oil extraction and the addition of palm pressed fiber oil to the palm kernel oil during processing which could be increase both FFA and impurities [25]. These values are close to the values reported by [18] which were between  $0.06 \pm 0.01$  to  $0.07 \pm 0.01$ %.

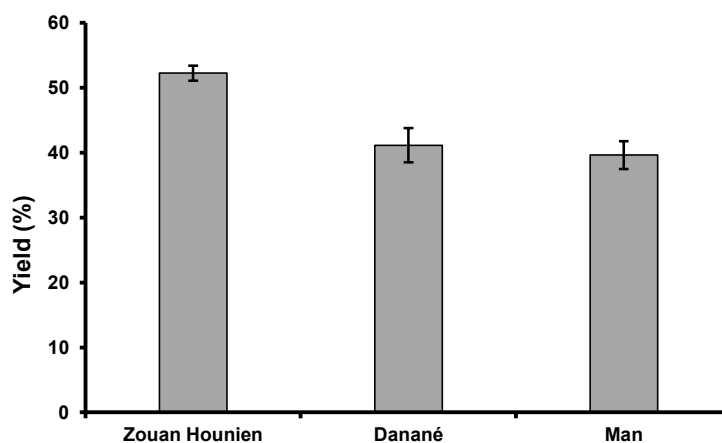


Fig. 1. Extraction yield of the palm kernel oils from the traditional varieties of the three departments

### 3.3 Chemical Parameters

The chemical parameters from the different localities are shown in Table 2. The analysis indicated that there was a significant difference ( $p < 0.05$ ) in all the parameters analysed except for iodine and unsaponifiable values. The acid value and free fatty acid percentage (FFA) obtained ranges from  $6.37 \pm 0.65$  to  $8.54 \pm 0.57$  mg KOH/g and  $3.20 \pm 0.31$  to  $4.29 \pm 0.28\%$ . The department of Man having the lowest value and Danané had the highest value. Results of this study are in agreement with those of the standard set by the Codex Alimentarius (10 mg KOH / g of fat and 4% for FFA) [22]. Low levels of % FFA in oils indicate that the oils are good edible oils that may store for a long time without spoilage via oxidative rancidity [26]. Results of analysis fell in those of [27] who reported a value of  $1.97 \pm 0.05$  mg KOH/g in PKO extracted from Dura palm oil varieties in China. In opposite, results of this study are lower than the value of  $15.46 \pm 0.51$  and  $20.28 \pm 0.37$  mg KOH/g reported by [18] in the characterization of palm kernel oil extracted respectively from the Tenera and Dura varieties of palm oil from Côte d'Ivoire. The peroxide value is an indicator of the level of lipid peroxidation or oxidative degradation. In this study, the peroxide value ranged from  $6.02 \pm 1.13$  to  $8.38 \pm 1.00$  meq O<sub>2</sub> kg<sup>-1</sup> of fat, and the lowest values were recorded for samples from Man. The peroxide value for all samples corresponded to normal Codex Alimentarius values [22], which recommend a maximum peroxide value of 15 meq O<sub>2</sub> kg<sup>-1</sup> of fat (Table 2). The results revealed that the iodine value of the palm kernel oil from the different departments were between  $17.52 \pm 0.43$  and  $19.05 \pm 0.95$  g I<sub>2</sub>/100 of fat. The values obtained from the analysis were below that recommended by Codex Alimentarius [22] which range between 14.1 - 21 g I<sub>2</sub>/100 g. The relatively low iodine numbers in PKO, may be indicative of the presence of few unsaturated bonds in PKO and hence low susceptibility to oxidative rancidity. The iodine numbers found in this study is similar to that reported by [21] and [27] with respective iodine value of  $16 \pm 3$  g I<sub>2</sub>/100 g and  $20.15 \pm 0.21$  g/100g. The saponification value was between  $216.02 \pm 8.96$  mg KOH/g and  $248.16 \pm 2.40$  mg KOH/g of fat. The departments of Man and Danané recorded lower values under the recommended value for palm kernel oil [22]. Saponification value from Zouan Hounien is close to the value of 254 mg KOH/g of fat [28]. Based on the fact that there is an inverse relationship between saponification value and

weight of fatty acids in the oil, it can be inferred that the palm kernel oil from Zouan Hounien contains a great number of fatty acids of low molecular weight. The ester value ranged from  $209.65 \pm 9.60$  to  $240.33 \pm 3.32$  mg KOH/g of fat with palm kernel oil from Zouan Hounien having the highest, while palm kernel oil from Man had the lowest ester value (Table 2). These values obtained are higher than which reported by [18] who recorded value from  $167.72 \pm 3.17$  to  $194.53 \pm 1.5$  mg KOH/g of fat. However, the ester values of palm kernel oil from Man and Danané were below that recommended value by Codex which range 220-244 mg KOH/g of fat [22]. Unsaponifiable generally consist of several families of compounds such as tocopherols, sterols, carotenoid pigments and fat-soluble vitamins. The results of analysis show that all samples ( $0.25 \pm 0.05$  to  $0.41 \pm 0.04$  %) are below than those of vegetable oils in general ( $\leq 1\%$ ) [22].

### 3.4 Fatty Acids Composition of PKO

The fatty acid composition is shown in Table 3. The GC-MS analysis results show a significant difference ( $p < 0.05$ ) between free fatty acid compositions of palm kernel oil from the three departments. The most abundant fatty acids in palm kernel oil samples were lauric acid (C12:0), myristic acid (C14:0) and oleic acid (C18:1). The major fatty acid found in both materials was lauric acid,  $50.50 \pm 0.05$  % to  $51.00 \pm 0.01$  % in kernel oil of the three departments with Danané and Zouan Hounien showing higher value. The fatty acid composition found in this study was in agreement with a previous report [19,21,29,30]. Myristic acid (C14:0) was the second most abundant fatty acid determined in the palm kernel oil sample. The high content of saturated fatty acid (SFA) in palm kernel oil is attributed to the presence of both lauric and myristic acids. The SFA content was slightly higher in palm kernel oil from Danané ( $85.52 \pm 0.02$  %) than in palm kernel oil from Man ( $84.02 \pm 0.03$  %). The high amount of SFA in palm kernel oil makes it suitable for soap, lubricants and cosmetics manufacturing as they solidify when exposed to air. Due to its high level of lauric acid which is known to possess antimicrobial properties, palm kernel oil for the both localities can be used widely for medical purposes [8,10]. Palm kernel oil from Zouan Hounien and Man showed higher monounsaturated fatty acid (MUFA) content compared to palm kernel oil from Danané. This can be explained by the presence of more oleic acid ( $p < 0.05$ ) in the palm kernel from Zouan

**Table 1. Physical characteristics of palm kernel oils from the traditional varieties of the three departments**

	Zouan Hounien	Danané	Man	Codex Alimentarius
Refractive index	1.454 ± 0.01 <sup>a</sup>	1.453 ± 0.01 <sup>a</sup>	1.454 ± 0.02 <sup>a</sup>	1.448-1.452
Relative density at 20°C	0.90 ± 0.00 <sup>a</sup>	0.90 ± 0.00 <sup>a</sup>	0.91 ± 0.00 <sup>b</sup>	0.899-0.914
Moisture and volatile contents (%)	0.85 ± 0.05 <sup>b</sup>	1.94 ± 0.07 <sup>c</sup>	0.62 ± 0.05 <sup>a</sup>	0.2
Insoluble impurities (%)	0.09 ± 0.01 <sup>a</sup>	0.05 ± 0.05 <sup>a</sup>	0.06 ± 0.01 <sup>a</sup>	0.05

<sup>a, b</sup> Means in same row followed by different letters are significantly different ( $p < 0.05$ )

**Table 2. Chemical characteristics of palm kernel oils from the traditional varieties of the three departments**

Parameters	Departments			Codex Alimentarius
	Zouan Hounien	Danané	Man	
Acid value (mg KOH/g)	7.83 ± 0.91 <sup>ab</sup>	8.54 ± 0.57 <sup>b</sup>	6.37 ± 0.65 <sup>a</sup>	10
Free fatty acid (%)	3.93 ± 0.46 <sup>ab</sup>	4.29 ± 0.28 <sup>b</sup>	3.20 ± 0.31 <sup>a</sup>	4.0
Iodine value (g I <sub>2</sub> /100 g)	17.52 ± 0.43 <sup>a</sup>	18.96 ± 1.01 <sup>a</sup>	19.05 ± 0.95 <sup>a</sup>	14.1-21
Peroxide value (meq/kg)	7.42 ± 0.58 <sup>ab</sup>	8.38 ± 1.00 <sup>b</sup>	6.02 ± 1.13 <sup>a</sup>	15.0
Saponification value (mg KOH/g)	248.16 ± 2.40 <sup>b</sup>	223.61 ± 15.49 <sup>ab</sup>	216.02 ± 8.96 <sup>a</sup>	230-254
Ester value (mg KOH/g)	240.33 ± 3.32 <sup>b</sup>	215.07 ± 16.05 <sup>ab</sup>	209.65 ± 9.60 <sup>a</sup>	220-244
Unsaponifiable content (%)	0.41 ± 0.04 <sup>a</sup>	0.28 ± 0.10 <sup>a</sup>	0.25 ± 0.05 <sup>a</sup>	≤10

<sup>a, b</sup> Means in same row followed by different letters are significantly different ( $p < 0.05$ )

**Table 3. Fatty acid profile in palm kernel oils from the traditional varieties of the three departments**

Compounds (%)	Zouan Hounien	Danané	Man	Codex Alimentarius
Caprylic acid (C8 :0)	2.35 ± 0.04 <sup>c</sup>	2.14 ± 0.01 <sup>a</sup>	2.27 ± 0.02 <sup>b</sup>	2.4-6.2
Capric acid (C10 :0)	3.20 ± 0.01 <sup>b</sup>	3.07 ± 0.02 <sup>a</sup>	3.05 ± 0.05 <sup>a</sup>	2.6-5.0
Lauric acid (C12:0)	50.50 ± 0.05 <sup>b</sup>	51.00 ± 0.01 <sup>a</sup>	50.92 ± 0.07 <sup>a</sup>	45.0-55.0
Myristic acid (C14 :0)	18.70 ± 0.03 <sup>b</sup>	18.35 ± 0.02 <sup>a</sup>	18.80 ± 0.05 <sup>b</sup>	14.0-18.0
Palmitic acid (C16 :0)	7.86 ± 0.04 <sup>a</sup>	9.54 ± 0.04 <sup>c</sup>	8.54 ± 0.08 <sup>b</sup>	6.5-10.0
Stearic acid (C18 :0)	1.23 ± 0.02 <sup>a</sup>	1.25 ± 0.03 <sup>a</sup>	1.20 ± 0.04 <sup>a</sup>	1.0-3.0
Oleic acid (C18: 1)	13.92 ± 0.03 <sup>c</sup>	12.80 ± 0.01 <sup>a</sup>	13.70 ± 0.03 <sup>b</sup>	12.0-19.0
Linoleic acid (C18: 2)	1.88 ± 0.01 <sup>c</sup>	1.50 ± 0.01 <sup>b</sup>	1.14 ± 0.04 <sup>a</sup>	1.0-3.5
Arachidic Acid (C20 :0)	0.18 ± 0.02 <sup>ab</sup>	0.16 ± 0.01 <sup>a</sup>	0.19 ± 0.01 <sup>b</sup>	ND-0.2
Eikosenoic acid (C20 :1)	0.18 ± 0.02 <sup>a</sup>	0.18 ± 0.02 <sup>a</sup>	0.19 ± 0.01 <sup>a</sup>	ND-0.2
SFA	84.02 ± 0.03	85.52 ± 0.02	84.97 ± 0.02	
MUFA	14.10 ± 0.03	13.08 ± 0.01	13.89 ± 0.03	
PUFA	1.88 ± 0.01	1.50 ± 0.01	1.14 ± 0.04	

<sup>a, b</sup> Means in same row followed by different letters are significantly different ( $p < 0.05$ ). SFA, saturated fatty acid; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.

Hounien and Man ( $13.70 \pm 0.03$  to  $13.92 \pm 0.03$  %) material compared to that of palm kernel from Danané ( $12.80 \pm 0.01$  %). The palm kernel oil contained low amount of unsaturated fatty acids, which makes it less sensitive to oxidation [27].

#### 4. CONCLUSION

The present study shows that, in general, the physicochemical composition of palm kernel oils from three departments of the Western region of Côte d'Ivoire differ significantly. However, all palm kernel oils studied presented good quality criteria as acid, iodine, peroxide, ester and saponification indices met the standards. In addition, the oil extracts of palm kernel contain higher amounts of saturated fatty acids, which are valuable for both food and cosmetic industries.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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