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Physico-Chemical and Chromatographic Study of Unrefined Palm Oil in the Yamoussoukro Area (Côte d'Ivoire): Functional and Nutritional Potential

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Abstract Unrefined palm oil produced in village-based systems constitutes a major local lipid source in Côte d'Ivoire but remains insufficiently characterized in terms of nutritional, physico-chemical, and technological properties. This study aims to fill that gap by assessing the quality of palm oil extracted through artisanal methods in Djahakro (Yamoussoukro region), with a focus on its functional valorization. Approximately 45 kg of ripe fruits (*Elaeis guineensis*, tenera variety) were harvested during the dry season (February 2024) and subjected to Soxhlet extraction using hexane. The analyses focused on physico-chemical parameters (pH, density, viscosity, acidity, peroxide, iodine, and saponification indices, etc.) following AFNOR and Codex CXS 210-1999 standards, as well as fatty acid composition determined by gas chromatography (GC-FID). The extracted oil showed a yield of 67.5%, a high oleic acid content (50.05%), and a total of 57.53% unsaturated fatty acids, highlighting good nutritional potential. However, it also exhibited high free acidity (8.46%) and an acidity index of 16 mg KOH/g, requiring refining before direct consumption. The viscosity (43.13 cP at 37.8 °C) and peroxide value (9.3 meq O_2/kg) indicate moderate but acceptable oxidative stability. These results confirm the technological and nutritional potential of this oil for agro-food (margarines, frying), cosmetic (soaps, balms), or nutraceutical applications, provided post-harvest and processing practices are optimized. This study is the first in-depth characterization of palm oil from Djahakro and provides a scientific foundation for structuring high value-added local supply chains.

Keywords Palm Oil, *Elaeis guineensis*, Fatty Acid Composition, Soxhlet Extraction, Nutritional Quality, Artisanal Processing

1. Introduction

In Côte d'Ivoire, a large portion of crude palm oil

production still comes from rural artisanal systems, which remain poorly studied from a scientific perspective. This lack of reliable data on the physico-chemical and nutritional quality of local artisanal oils hinders their industrial valorization, sanitary certification, and integration into structured commercial circuits.

Palm oil, extracted from the mesocarp of the oil palm fruit (*Elaeis guineensis*), is currently one of the most produced and consumed vegetable oils globally. Its dual capacity to produce both crude palm oil (CPO) and palm kernel oil (PKO) provides it with significant economic and industrial advantages, with productivity exceeding 4 tons of oil per hectare—well above that of soybean or rapeseed [1,2]. For over a decade, it has dominated the global vegetable oil market, accounting for nearly 30% of total consumption [3,4].

Nationally, palm oil is a cornerstone of food security and rural economy in Côte d'Ivoire. It is also a major source of bioactive compounds such as essential fatty acids, carotenoids, tocotrienols, and phytosterols, known for their antioxidant, cholesterol-lowering, and neuroprotective properties [5,6]. α-Tocotrienol, in particular, shows strong pharmacological potential in preventing degenerative diseases [3,7].

However, this functional richness does not guarantee consistent quality. The composition of crude oil varies significantly depending on cultivation, harvest, and processing conditions. Traditional village-based units, widespread in regions such as Yamoussoukro, still rely on non-standardized artisanal methods. These processes can either promote oxidative degradation or, conversely, preserve certain thermosensitive compounds [8,9].

This qualitative variability—often linked to local practice heterogeneity (storage time, thermal conditions, materials used)—has practical consequences: reduced yields, premature oxidation, fluctuations in nutritional profiles, and unsuitability for certain industrial applications (frying, cosmetics, margarine). It also limits any prospect of certification or targeted export.

While many studies have focused on palm oils from standardized industrial systems, artisanal oils—particularly those produced in specific agroecological zones such as Djahakro (Yamoussoukro region)—remain largely undocumented. Their technofunctional properties—thermal stability, rheological behavior, and transformation potential—are poorly understood, as are the links between lipid composition and industrial suitability.

In this context, the present study seeks to fill this gap by performing an in-depth characterization of crude palm oil extracted through artisanal means in the village of Djahakro. The aim is to evaluate, through a dual physico-chemical and chromatographic approach (GC-FID), the nutritional and technological quality of the oil. Results are discussed in light of Codex Alimentarius standards (CXS 210-1999, Rev. 2019) and the requirements of the food and cosmetic industries.

Yet, the lack of detailed characterization of these artisanal oils continues to hinder their industrial valorization, health certification, and recognition in differentiated quality schemes.

2. Materials and Methods

2.1. Plant Material and Sampling Site

The plant material consisted of ripe oil palm fruits (*Elaeis guineensis Jacq.*), *tenera* variety—an oil-rich hybrid widely cultivated in southern and central Côte d'Ivoire. Fruits were collected in the village of Djahakro, located in the Yamoussoukro region (central Côte d'Ivoire) (Figure 1), an agroecological zone favorable to oil palm cultivation.

This site holds scientific interest due to its limited documentation in previous studies on the chemical quality of Ivorian palm oils, despite being an active production area based on low-mechanization village systems.

2.2. Sampling

Sampling was carried out in February 2024, during the dry season, which is considered the optimal harvest period for oil palm due to high lipid accumulation in the mesocarp and low moisture content—factors that help limit post-harvest microbiological degradation [10].

Fruits were harvested at physiological maturity, corresponding to phenophase BBCH 805 [11], characterized by a uniform reddish-orange coloration of the mesocarp and the spontaneous dropping of a few fruits. The bunches were collected from oil palms aged between 8 and 12 years, considered to be at their peak lipid productivity [12].

A total of three representative batches of fruit bunches were collected from local producers, totaling approximately 45 kg of fresh fruit (15 kg per batch), representing around 10 bunches. After sorting out healthy fruits, they were packed in opaque insulated bags and transported within 24 hours to the Laboratory of Industrial Processes, Synthesis, Environment and New Energies (LAPISEN), Process Engineering and Environment unit (GPE) at the National Polytechnic Institute Félix Houphouët-Boigny (INPHB) in Yamoussoukro. Photographic documentation of the site and cultivation practices was used to ensure sampling traceability.

2.3. Oil Extraction (Soxhlet Method)

Oil extraction was performed in the laboratory using sorted fruit pulp, washed with distilled water, and manually separated from the kernels. The pulp was then oven-dried at 100 °C for 2 hours and gently crushed using a porcelain mortar.

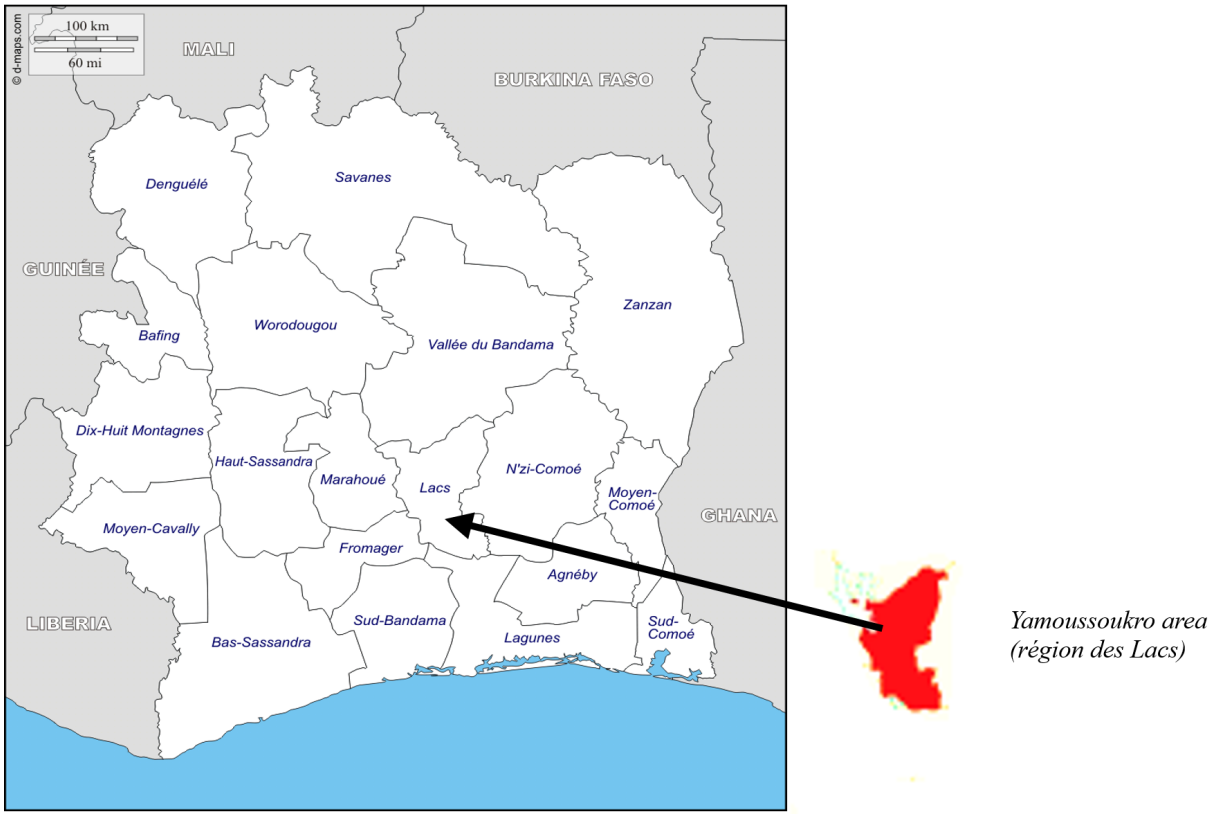

Figure 1. Study area for palm seed harvesting

Oil was extracted following the Soxhlet method, a reference technique for accurate quantification of total lipids. Approximately 50 g of dry matter was placed in a cellulose cartridge inserted into a Soxhlet extractor connected to a 1 L round-bottom flask containing 250 mL of hexane (a non-polar solvent). The apparatus included a water-cooled condenser to ensure solvent condensation and recycling.

The extraction lasted 12 hours, with automatic percolation cycles ensuring exhaustive lipid extraction. The vaporized hexane was condensed, dripped onto the sample, became lipid-enriched, and was siphoned back into the flask. This cycle was repeated until saturation. The extracted oil was recovered by gentle evaporation of the solvent, weighed, and subjected to physico-chemical and chromatographic analyses.

This method was chosen for its ability to maximize oil yield, provide reproducible analytical results, and its relevance for inter-study comparisons under laboratory conditions [13,14]. Although it does not replicate traditional village techniques, it allows for standardized experimental conditions to ensure scientific comparability.

2.4. Physico-Chemical Characterization

The physico-chemical characterization of crude palm oil extracted from Djahakro was carried out in accordance with standardized AFNOR protocols and the recommendations of the Codex Alimentarius (CXS 210-1999), with the aim of assessing nutritional quality, oxidative stability, and compliance with international standards. Analyses were conducted in triplicate at the Laboratory of Industrial Processes, Synthesis, Environment and New Energies (LAPISEN), Process Engineering and Environment unit (GPE) at INPHB (Yamoussoukro), and results are expressed as means with standard deviations.

pH and conductivity were measured using a HANNA HI 98150 pH meter equipped with a combined electrode, calibrated with standard buffer solutions (pH 4, 7, and 10). Density and specific gravity were determined at 40 °C and 25 °C using a pycnometer and a digital densimeter, respectively. Dynamic viscosity, essential for evaluating the rheological properties of the oil at culinary temperatures, was measured at 37.8 °C using a Brookfield rotational viscometer.

The acidity and peroxide values were quantified by volumetric titration with potassium hydroxide (KOH) in an ethanolic medium for acidity, and by oxidation of potassium iodide in an acidic medium followed by sodium thiosulfate titration for peroxide value. These parameters indicate the level of triglyceride hydrolysis and the primary oxidation state of the oil.

The iodine value, determined using the Wijs method, assesses the degree of unsaturation of fatty acids, while the saponification value—obtained through alkaline saponification followed by titration of residual KOH—provides information about the average fatty acid

chain length. The ester value, calculated by subtracting the acid value from the saponification value, reflects the proportion of non-hydrolyzed esters.

The unsaponifiable fraction was extracted in a hydroalcoholic medium and isolated using diethyl ether. It includes sterols, tocopherols, and other bioactive lipophilic compounds often valued for their antioxidant properties. The refractive index was measured at 25 °C using an ABBE refractometer to assess the optical density and purity of the lipid mixture.

Residual moisture and total ash content were determined by drying at 105 °C and incineration at 550 °C, respectively, providing key indicators of microbiological stability and mineral content. Finally, specific extinction at 270 nm was measured by UV-visible spectrophotometry in 1% cyclohexane solution using a PERKIN-ELMER Lambda 2 spectrophotometer. This parameter detects secondary oxidation products such as conjugated dienes, ketones, and aldehydes.

Collectively, these parameters offer a comprehensive quality profile of the crude oil, enabling assessment of its freshness and stability, as well as its suitability for various uses—including food, cosmetics, or technical applications—by comparing them to Codex standards and the Ivorian NI 210 standard.

2.5. Determination of Fatty Acid Composition by Gas Chromatography (GC-FID)

Analyses were performed in triplicate at the CEISAM Laboratory (Chemistry and Interdisciplinarity, Synthesis, Analysis, Modeling), CORAIL team (Catalysis, Organometallic chemistry And synthesis of Ligands), University of Nantes (France), and the results are expressed as means with standard deviations.

The fatty acid composition of the crude palm oil extracted from Djahakro was determined by gas chromatography coupled with a flame ionization detector (GC-FID), following the NF EN ISO 5509 standard, which specifies the prior transesterification of triglycerides into methyl esters (FAMEs) to allow analysis in the gas phase.

Sample preparation involved transesterifying 100 mg of oil in a 2% methanolic potassium hydroxide solution under mild reflux for 15 minutes. After cooling, the addition of distilled water enabled phase separation, and the fatty acid methyl esters were extracted with hexane. The organic phase was then dehydrated over anhydrous sodium sulfate, filtered, and gently evaporated under a nitrogen stream.

Analyses were carried out using an Agilent Technologies 7820A gas chromatograph equipped with a Split/Splitless injector, an FID detector, and controlled by OpenLAB software. Separation was achieved using a BPX70 capillary column (30 m × 0.22 mm × 0.25 µm) with a polar stationary phase based on cyanopropyl-modified polysiloxane, ideal for FAME separation. Helium was used as the carrier gas at a constant flow rate of 1 mL/min. The temperature program was as follows: injector at 250 °C, detector at 270 °C, initial oven temperature at 120 °C (held for 1 min), followed by a ramp of 4 °C/min up to 230 °C, held for 15 minutes.

Fatty acids were identified by comparing retention times with those of a commercial FAME standard mixture. Peak integration was performed automatically, and relative percentages were calculated based on the total detected fatty acids.

The mass percentage of each fatty acid was calculated using the following formula, commonly used in standardized chromatographic analyses [15]:

$$\% \text{ Fatty Acid} = (S / \Sigma s) \times 100$$

Where S is the peak area of the fatty acid considered, and Σs is the sum of all peak areas.

This method provides accurate quantification of the distribution between saturated and unsaturated fatty acids—an essential parameter for evaluating the nutritional profile, oxidative stability, and technological potential of the oil.

3. Results and Discussion

3.1. Justification of the Extraction Protocol and Comparative Limitations

The oil extraction protocol used in this study is based on the Soxhlet method, a reference technique for lipid analysis in laboratory settings. Although this method does not reflect the empirical procedures used in artisanal production units, its selection is supported by several scientific and experimental justifications.

Firstly, Soxhlet extraction ensures complete recovery of total lipids from the pulp, without resorting to mechanical pressing that could induce losses or biases due to temperature, pressure, or inconsistent yield. This technique is widely used in the literature for standardized analytical comparisons [16,17], as it guarantees high reproducibility, maximal yield, and homogeneous extraction—independent of human or contextual factors.

Secondly, using this protocol in a laboratory environment allows for the standardization of oil production conditions, thereby facilitating comparisons between regions, studies, or varieties. This standardization aims to neutralize biases associated with artisanal methods (e.g., manual hot pressing, variable pressing time, exposure to air), which may affect oxidation, fatty acid quality, or the preservation of functional compounds.

It is nevertheless important to emphasize that the oil obtained by Soxhlet represents an estimate of the maximum lipid potential of the raw material under optimal conditions. It does not aim to faithfully reflect the actual quality of oil produced in villages but instead provides an objective benchmark to evaluate deviations observed in artisanal value chains.

Additionally, to minimize the impact of time on lipid

degradation, extraction was performed within 24 hours of fruit harvest. This is crucial, as it is well established that prolonged storage of fruit bunches at ambient temperature promotes enzymatic lipolysis, leading to increased release of free fatty acids (FFA) and a rise in the acid value [18,19]. In this case, despite a rigorous protocol, the relatively high FFA levels observed (8.46%) suggest that post-maturation transformations may have started before processing.

Finally, this controlled approach paves the way for future comparative assessments between oils extracted by different methods (artisanal vs. laboratory) to quantify functional losses or alterations induced by local practices. Such an approach is essential for envisioning the structuring of improved artisanal oil value chains, based on technically guided processes with high value-added applications in food, cosmetics, or nutraceutical industries.

3.2. Physical and Physico-Chemical Characteristics

The physical and physico-chemical characteristics of the crude palm oil are summarized in Table 1.

The physico-chemical analysis of crude palm oil from the Djahakro region reveals a product with interesting technical and nutritional characteristics, although marked by certain limitations linked to artisanal processing conditions. The slightly acidic pH (4.55 ± 0.03), combined with a high acid value (16 ± 0.7 mg KOH/g), indicates advanced hydrolysis of triglycerides into free fatty acids (FFA), with a content reaching 8.46 ± 0.45%, well above the Codex Alimentarius limit (3–5%). This high level, often attributed to prolonged storage or delayed processing, compromises oxidative stability and requires refining prior to human consumption [18,19].

However, other parameters such as peroxide value (9.3 ± 0.4 meq O_2/kg), moisture (500 ± 15 mg/kg), and specific extinction at 270 nm (0.25 ± 0.01), remain below critical thresholds, indicating moderate oxidation and a product that is still generally stable. The saponification value (193 ± 2.1 mg KOH/g) suggests a prevalence of short- and medium-chain fatty acids, making the oil particularly suitable for soap-making and biolubricant formulation [16].

Table 1. Average physico-chemical parameters of crude palm oil (n = 3)

Parameter	Mean ± Standard Deviation (SD)	Codex Standard (CXS 210-1999)
pH at 36.4 °C	4.55 ± 0.03	--
Electrostatic potential Eo (mV)	150.9 ± 1.2	--
Melting temperature (°C)	40 ± 0.5	36 – 40
Viscosity at 37.8 °C (cP)	43.13 ± 0.42	39.6 – 43.13
Density at 60 °C (g/mL)	0.88 ± 0.01	0.915 – 0.920
Specific gravity at 25 °C (g/cm³)	0.915 ± 0.01	--
Conductivity at 23.3 °C (µS)	0.00 ± 0.00	--
Total dissolved solids (TDS) at 23.3 °C (ppm)	0.00 ± 0.00	--
NaCl at 23.3 °C (%)	0.1 ± 0.01	--
Unsaponifiables (%)	0.5 ± 0.03	< 1.5
Saponification value (mg KOH/g)	193 ± 2.1	192 – 205
Ester value (mg KOH/g)	149 ± 1.8	--
Iodine value (mg I_2/g)	59 ± 1.2	30 – 55
Peroxide value (meq O_2/kg)	9.3 ± 0.4	< 20
Refractive index at 25 °C	1.456 ± 0.002	1.4677 – 1.4705
Oil content (%)	67.5 ± 0.6	--
Moisture (mg/kg)	500 ± 15	< 1000
Ash (mg/kg)	0.01 ± 0.001	--
Acid value (mg KOH/g)	16 ± 0.7	10
Free fatty acids (%)	8.46 ± 0.45	3 – 5 %
Molecular weight (g/mol)	857.14 ± 5.3	--
Number of double/triple bonds	63 ± 2	--
Specific extinction at 270 nm	0.25 ± 0.01	< 0.3

The pseudoplastic behavior observed in these margarines, modeled by Herschel-Bulkley laws, largely depends on the intrinsic plasticity of palm fats, similar to that measured here (viscosity at 37.8 °C: 43.13 ± 0.42 cP). This is especially relevant considering the recent study by Bredikhin et al. [20] on the rheological properties of high-fat hard margarines, which showed that the addition of palm oil helps structure a stable viscoelastic crystalline network, thanks to its high saturated fatty acid content and intermediate melting characteristics (36–40 °C).

Moreover, the iodine value measured in this study (59 ± 1.2 mg I_2/g) slightly exceeds the upper limit of Codex standards for palm oils (30–55 mg I_2/g). Although marginally above, this value can be considered moderately high compared to other more unsaturated vegetable oils (e.g., sunflower, flaxseed, rapeseed), whose iodine values often exceed 100. This intermediate position reflects good oxidation resistance while maintaining some lipid flexibility, which is desirable in structured food formulations such as semi-solid margarines. This property is crucial for food products requiring a balance between consistency and stability, including margarines, spreads, and food coatings [14]. It also avoids the need for partial hydrogenation, which leads to the formation of harmful trans fatty acids.

Furthermore, the results align with local valorization prospects. The oil yield (67.5 ± 0.6%) is excellent, suggesting a real economic potential for village-level units. However, to ensure this oil's full competitiveness both nationally and internationally, technical improvements must be implemented throughout the value chain. The adoption of good manufacturing practices (GMP), rapid post-harvest pressing, and controlled storage conditions (humidity, temperature, light) is essential to reduce FFA content and prevent lipid peroxidation [21].

In summary, while some alterations are present, the analyzed palm oil displays promising physico-chemical qualities for both food and technical uses. Its lipid composition, viscosity, and melting point align with the requirements for high-fat margarine formulations, as described by Bredikhin et al. [20]. The implementation of stabilization processes and complementary analyses (including rheological tests: G', G", and Herschel-Bulkley modeling) could further validate its potential in high-value structured food applications.

3.3. Characterization by Gas Chromatography

The gas chromatogram illustrates the fatty acid composition of palm oil, as shown in Figures 2 and 3. The retention times and fatty acid contents of the palm oil are summarized in Table 2.

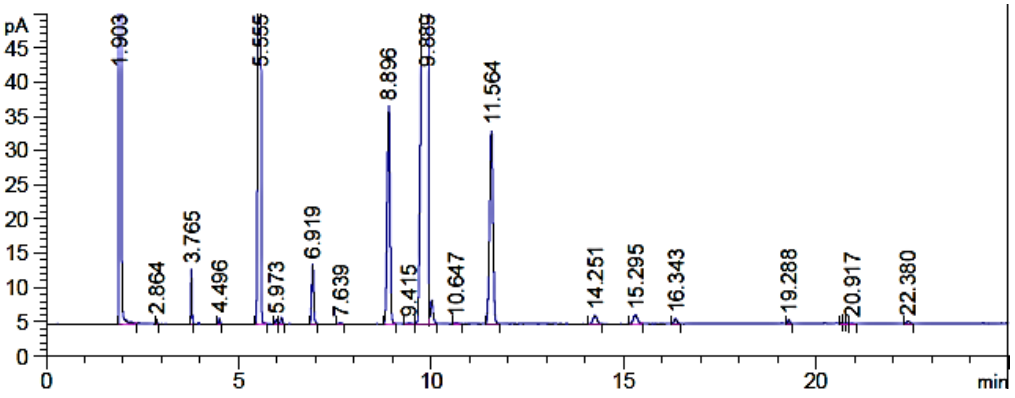

Figure 2. GC Chromatogram of palm oil extracted with hexane from the Yamoussoukro region

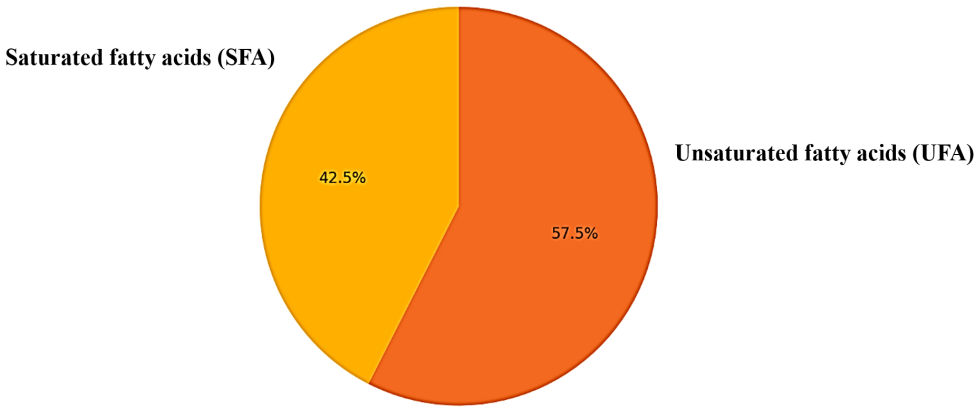

Figure 3. Distribution of fatty acids in crude palm oil

Table 2. Fatty acid composition of extracted palm oil (n = 3)

Fatty Acid	Retention Time (min)	Content (%) ± SD	Codex Standards (%)
Saturated fatty acids			
Lauric acid (C12:0)	2.864	0.22 ± 0.02	< 0.5
Myristic acid (C14:0)	3.764	0.57 ± 0.03	0.5 – 2
Palmitic acid (C16:0)	5.555	35 ± 1.5	39.3 – 47.5
Stearic acid (C18:0)	8.896	6.29 ± 0.4	3.5 – 6.5
Arachidic acid (C20:0)	15.301	0.34 ± 0.02	< 0.5
Behenic acid (C22:0)	19.288	0.1 ± 0.01	< 0.2
Unsaturated fatty acids			
Oleic acid (C18:1)	9.889	50.05 ± 2.1	36 – 44
Linoleic acid (C18:2)	11.564	7.15 ± 0.3	9 – 12
Linolenic acid (C18:3)	14.25	0.16 ± 0.01	< 0.2
Eicosenoic acid (C20:1)	16.343	0.17 ± 0.01	< 0.4

The chromatographic analysis of palm oil extracted from the Djahakro region reveals a typical oleic-type oil composition, with a predominance of unsaturated fatty acids (57.53%) over saturated fatty acids (42.52%). This distribution is consistent with expected profiles for palm oils derived from the mesocarp of *Elaeis guineensis*, although some variations were observed compared to Codex Alimentarius standards (CODEX STAN 210-1999, Rev. 2019) [22].

Among the saturated fatty acids, palmitic acid (C16:0) dominates at 35 ± 1.5%, slightly below the Codex range (39.3–47.5%) but consistent with artisanal profiles reported by Yoboué [19] for unrefined Ivorian oils (32.95–48.04%). Stearic acid (C18:0), measured at 6.29 ± 0.4%, falls within the recommended range (3.5–6.5%), contributing to the oil's physical stability and resistance to thermal oxidation, which is particularly important for frying and margarine production [14].

Lauric, myristic, arachidic, and behenic acids are present in low proportions (<1%), confirming that this oil does not belong to the group of lauric oils (e.g., palm kernel or coconut oil) but rather the semi-saturated oils category.

Regarding unsaturated fatty acids, oleic acid (C18:1) reaches a high value of 50.05 ± 2.1%, well above the Codex range (36–44%) [22]. This abundance in omega-9 fatty acids is nutritionally beneficial, as oleic acid is known for its cardioprotective and cholesterol-lowering effects [4,23]. It also aligns palm oil with more premium oil profiles, such as olive oil.

Linoleic acid (C18:2), an essential ω-6 polyunsaturated fatty acid, accounts for 7.15 ± 0.3%, a slightly lower value than Codex standards (9–12%). Conversely, the low linolenic acid (C18:3, 0.16 ± 0.01%) content enhances the oil's oxidative stability, as this fatty acid is highly prone to peroxidation.

The low linolenic acid content (0.16%) of crude Djahakro palm oil is a significant industrial advantage. This compound, highly sensitive to oxidation, contributes to rancidity and degradation in oils rich in unsaturations. Its scarcity improves thermal and oxidative stability, making the oil ideal for high-temperature applications (frying, margarines) and cosmetic uses, where it minimizes off-odors and prolongs shelf life. It also reduces the need for antioxidants or chemical treatments, lowering processing costs [9,24].

This stability makes the oil better suited for intensive thermal applications, such as cooking or high-fat margarine production. The high oleic and linoleic acid content, along with minimal linolenic acid, is particularly desirable in food formulations with cardioprotective aims. Furthermore, the content of long-chain saturated fatty acids like palmitic (C16:0) and stearic (C18:0) acids gives the oil excellent thermal stability, supporting its use in margarines, pastries, and biolubricants [14,20,25].

A study by Bredikhin et al. [20] on margarine rheology showed that a moderate level of saturated fatty acids combined with a high oleic acid content favors the formation of a structured crystalline network at room temperature, improving the plasticity and mechanical resistance of the final product. Thus, the fatty acid composition observed in Djahakro is technologically favorable for such applications. It provides a semi-solid consistency without the need for hydrogenation, thereby avoiding the formation of harmful trans fatty acids [25,26].

Finally, slight variations from international standards may be explained by pedoclimatic factors specific to the Yamoussoukro region, fruit ripening conditions, or the artisanal extraction method used [10,27]. These findings emphasize the need to regulate harvesting and processing practices to standardize lipid quality, especially if the oil is intended for industrial or export purposes.

In conclusion, the fatty acid composition of locally produced palm oil presents a balanced and technologically exploitable profile. Its richness in oleic acid, low content of highly unsaturated fatty acids, and controlled proportion of saturated fats make it a valuable raw material for the food industry (margarines, frying and bouillons), cosmetics (emollients), and pharmaceuticals (lipid vectors), provided that production conditions are improved to ensure consistent quality.

3.4. Regional and International Comparison of the Nutritional Quality of Palm Oil

The results obtained in this study show that the crude palm oil extracted in Djahakro presents a fatty acid composition and physico-chemical characteristics favorable for nutritional valorization. To situate this quality in a broader context, a comparison was made with oils produced in other regions of Côte d'Ivoire, as well as with those from major producing countries such as Nigeria and Indonesia.

A study conducted in the Man region (western Côte d'Ivoire) reported lower levels of oleic acid (42.12%) and higher proportions of saturated fatty acids (up to 52.8%), reflecting lower oxidative stability and a lipid profile less favorable to cardiovascular health [10]. In contrast, the Djahakro oil displays a high oleic acid content (50.05%), comparable to that found in semi-high oleic oils such as peanut or refined olive oil [28]. This profile is particularly sought after for its cholesterol-lowering and cardioprotective effects [4,23].

On the international level, traditional Nigerian oils are often characterized by high free acidity (>10%) and high peroxide values (>12.5 meq O_2/kg), making them unsuitable for direct consumption without refining [9]. In contrast, Indonesian industrial oils, produced through highly controlled processes, contain much lower levels of free fatty acids (3.2%) and moisture (300 mg/kg), ensuring better oxidative stability [29]. Table 3 summarizes the comparative data for these three origins.

The Djahakro oil thus stands out for its high oleic acid content, exceeding that of both traditional Nigerian and industrial Indonesian oils, and for its iodine value of 59 mg I_2/g—slightly higher than that of some industrial Ivorian oils (50–55 mg I_2/g) [30]. This parameter reflects a good proportion of unsaturated fatty acids, giving the oil better fluidity at room temperature, which is advantageous for functional food formulations such as low-melting-point margarines [20].

However, the FFA content (8.46%) and moisture level (500 mg/kg) remain relatively high, indicating room for improvement in oxidative stability. Although the extraction was performed within 24 hours of harvest, early enzymatic lipolysis likely occurred, as observed in other studies on oils with limited post-harvest treatment [18,23].

These comparisons, based on our own results (Tables 1–3), show that the specific pedoclimatic conditions of Yamoussoukro, combined with a gentle artisanal method (non-intensive heating, laboratory Soxhlet extraction), yield palm oil with a balanced lipid profile, reconciling oxidative stability and technological functionality. Similar observations have been reported for other Ivorian regions, particularly the Man area [23], highlighting the influence of terroir and local practices on oil quality.

They further strengthen the case for structuring artisanal Ivorian supply chains through the introduction of good post-harvest practices, standardized procedures, and the implementation of quality labels or protected geographical indications (PGIs), positioning these oils as high-value local alternatives on the agri-food and cosmetic markets.

Table 3. Comparative data on palm oils (Côte d'Ivoire, Nigeria, Indonesia)

Country	Oleic Acid (%)	Palmitic Acid (%)	FFA (%)	Iodine Value (mg I_2/g)	Peroxide Value (meq O_2/kg)	Moisture (mg/kg)	Typical Use
Côte d'Ivoire (Djahakro)	50.05	35.0	8.46	59	9.3	500	Local processing, margarine, soap
Nigeria (traditional)	42.0	41.2	10.5	52	12.5	750	Local consumption, direct frying
Indonesia (industrial)	39.5	43.5	3.2	54	7.0	300	Export, food industry

4. Conclusions

In the context of promoting local production and finding alternatives to industrial oils, this study provides a solid scientific foundation to support the development of a quality artisanal oil sector in Côte d'Ivoire. The results obtained from the crude palm oil extracted in Djahakro (Yamoussoukro region) reveal a promising lipid profile and open concrete industrial perspectives, particularly in terms of certification, PGI registration, and access to specialized agri-food and cosmetic markets.

With an oil yield of 67.5%, this oil stands out due to its high unsaturated fatty acid content (57.53%), especially oleic acid (50.05%), which is widely recognized for its cardioprotective properties. The share of saturated fatty acids (42.52%), mainly palmitic acid (35%) and stearic acid (6.29%), gives the oil good thermal stability, making it suitable for industrial applications.

However, certain parameters exceed regulatory thresholds for direct consumption, notably the high acid value (16 mg KOH/g) and free fatty acid content (8.46%), indicating significant lipid hydrolysis likely due to suboptimal post-harvest storage. These values remain compatible with refined use or in technical formulations (e.g., soap-making, lubricants, margarines).

Other indicators reflect satisfactory oxidative stability, with a peroxide value of 9.3 meq O_2/kg and a specific extinction coefficient at 270 nm of 0.25, both below Codex Alimentarius limits. The rheological properties, such as viscosity at 37.8°C (43.13 cP) and melting temperature (40°C), confirm the oil's suitability for structured uses such as semi-hard margarines, frying, and stable-texture cosmetics.

These findings highlight the importance of technical supervision of artisanal units, through the introduction of good harvesting, post-harvest, and processing practices, as well as standardization and certification mechanisms, for structured commercial valorization. Such a strategy would increase the competitiveness of local oils while emphasizing the geographical and varietal specificities of the Yamoussoukro region.

This type of oil could therefore represent a local alternative with high economic potential, with the possibility of valorizing over 60% of current artisanal production if post-harvest conditions are optimized and certification mechanisms implemented.

Finally, this study opens the door to further research, focusing on sensory analysis and consumer perception, exploration of advanced functional properties (such as rheology and extended thermal stability), socioeconomic evaluation of these value chains for smallholders, and interregional comparison to better understand the influence of agronomic practices and pedoclimatic conditions ("terroir effect") on the final quality of Ivorian artisanal oils.

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