Scholars Academic Journal of Biosciences
Abbreviated Key Title: Sch Acad J Biosci
ISSN 2347-9515 (Print) | ISSN 2321-6883 (Online)
Journal homepage: https://saspublishers.com
NIH National Library of Medicine National Center for Biotechnology Information
NLM ID:101629416
OPEN ACCESS
Agricultural Research

Assessment of Physicochemical and Sanitary Quality of Crude Palm oil Sold in Major Markets of Abidjan

NIAMKETCHI Gilles Léonce[1*], NYAMIEN Yves Bleouh Jean [2], ADIKO Cho Evelyne Judicaël[3], SORO Oumar[2], KONAN Jean Noël[1], BIEGO Henri[4]

[1]La Mé Research Station, National Center for Agricultural Research, 13 BP 989 Abidjan 13, Ivory Coast
[2]Institute of Agropastoral Management, Peleforo Gon Coulibaly University, BP 138 Korhogo, Ivory Coast
[3]Technological Research Station, National Center for Agricultural Research, 08 BP 881 Abidjan 08, Ivory Coast
[4]Laboratory of Biotechnology, Agriculture and Valorization of Agricultural Resources, UFR Biosciences, Félix Houphouët-Boigny University, 22 BP 582 Abidjan 22, Ivory Coast

DOI: https://doi.org/10.36347/sajb.2025.v13i08.012 | **Received:** 13.05.2025 | **Accepted:** 08.08.2025 | **Published:** 16.08.2025

***Corresponding author:** NIAMKETCHI Gilles Léonce
La Mé Research Station, National Center for Agricultural Research, 13 BP 989 Abidjan 13, Ivory Coast

Abstract **Original Research Article**

Côte d'Ivoire has launched a quality control program for artisanal crude palm oil to ensure health safety in local markets. The study evaluated the physicochemical, microbiological, and adulteration status of artisanal crude palm oil (CPO) in four major markets in Abidjan: Yopougon, Bingerville, Abobo and Adjame. The results showed significant differences between samples, with Yopougon showing the highest moisture content (2.24%). Melting points were below the recommended range and indicate poor solid fat content. The same goes for DOBI values which indicate oil bleachability and oxidative stability. The refractive index remained within acceptable limits. However, chemically, free fatty acid levels exceeded Codex's 5% recommendation with Yopougon showing the highest of 12.71%. Iodine values generally met standards, while saponification values were acceptable except for Yopougon. Oxidative stability parameters showed no significant differences between markets, indicating moderate degradation. Fatty acid profiling showed variations among samples. For microbiological analysis, results revealed high contamination with aerobic mesophilic bacteria, yeasts, molds, and total coliforms exceeding acceptable limits. Fraud detection tests identified adulteration with Sudan dye in 20% of samples from Abobo and Adjame. The study highlights the need for improved hygiene, monitoring and regulation in the artisanal palm oil sector.

Keywords: Crude Palm oil, physiochemical properties, microbiological quality, adulterants, sudan dye.

INTRODUCTION

Food consumption is crucial for human growth, development, and health. Nevertheless, when food quality deteriorates, its essential capacity to support life is to sustain life is significantly compromised (Thomas *et al.,* 2024). For centuries, palm oil has been esteemed as both a nutritious food product and a medicinal remedy. It is a reddish, nutrient-rich oil derived from the mesocarp of oil palm fruits (*Elaeis guineensis*) and serves as the primary source of edible oil in West Africa (MacArthur *et al.,* 2021a).

Current global statistics estimate palm oil production at approximately 80.74 million metric tons, with Indonesia and Malaysia being the top producers, followed by Thailand, Colombia and Nigeria. Côte d'Ivoire produces around 600,000 metric tons of crude palm oil annually representing less than 1% of the global output (USDA, 2025). Despite this modest share, the locally produced palm oil is widely consumed domestically and throughout the West African sub-region. In fact, Ivorian households predominantly use crude palm oil for cooking due to its nutritional benefits and relatively low cost compared to other commercially available vegetable oils (Yoboue *et al.,* 2022).

Crude palm oil is a rich source of natural carotenoids, which accounts for its characteristic deep red color. Among these, beta-carotene, which exhibits the highest provitamin A activity, is found in palm oil at concentrations approximately 15 times greater than in carrots and 300 times more than in tomatoes (Odia *et al.,* 2015). This makes crude palm oil one of the best dietary sources of vitamin A for human nutrition (Monde *et al.,* 2020). Accordingly, it is often included in supplementary feeding programs aimed at combating vitamin A deficiency in many developing countries (Sutapa *et al.,* 2009). Crude palm oil is also an abundant source of tocopherols and tocotrienols, which exhibit provitamin E activity and play a key role in protecting biological tissues from oxidative damage (Nanda *et al.,* 2020; Urogo *et al.,* 2021).

In Côte d'Ivoire, palm oil processing is carried out by two main sectors: the industrial sector, accounting for roughly 80% of the total production, and the informal sector dominated by small-scale processors using traditional or semi-mechanized techniques contributing the remaining 20% (Niamketchi *et al.,* 2021). Crude palm oil produced using artisanal methods often contains high levels of moisture and impurities due to suboptimal processing practices, which can promote microbial activity and spoilage (Morcillo *et al.,* 2013).

While artisanal crude palm oil is typically used for cooking at temperatures sufficient to inactivate pathogenic organisms, it is also commonly consumed raw in various traditional dishes, particularly in rural communities in Côte d'Ivoire (Niamketchi *et al.,* 2024). Beyond microbiological concerns, recent years have seen increasing incidences of oil adulteration due to growing domestic and industrial demand. Some vendors have reportedly added synthetic azo dyes to improve the oil's visual appeal and increase its marketability, often with little regard for consumer health (Andoh *et al.,* 2020; Teye *et al.,* 2024). Such adulterated oils are unsuitable for human consumption and pose serious public health risks.

Thus far, limited research has investigated the microbiological and chemical contamination of artisanal processed palm oil in Côte d'Ivoire. Current studies have primarily concentrated on the physicochemical characteristics of crude palm oil (Yeo *et al.,* 2022; Niamketchi *et al.,* 2024) and the risk factors leading to quality degradation (Aka *et al.,* 2021). A thorough examination of microbiological and chemical safety in artisanal crude palm oil available in retail markets is crucial for consumer protection. This study aims to assess the physicochemical properties and sanitary quality of artisanal crude palm oil available in four prominent urban markets in Abidjan.

MATERIALS AND METHODS

Study Area and Sample Collection

The biological material used in this study consisted of artisanal processed red palm oil samples collected in September 2024 from four major markets in Abidjan: Abobo Central Market (5°25'18.8"N, 4°00'58.3"W), Forum Market in Adjame (5°20'43.3"N, 4°01'38.9"W), Bingerville Market (5°21'09.3"N, 3°52'43.8"W) and Siporex Market in Yopougon (5°21'21.4"N, 4°04'30.3"W). These markets play a vital role in the city's food supply chain. As key commercial hubs, they host a large number of vendors and attract a wide customer base from all communes within the Abidjan District (Figure 1). Each sample was carefully labeled, with its specific location of collection recorded, and subsequently transported to the laboratory under appropriate conditions for physicochemical and microbiological analyses.

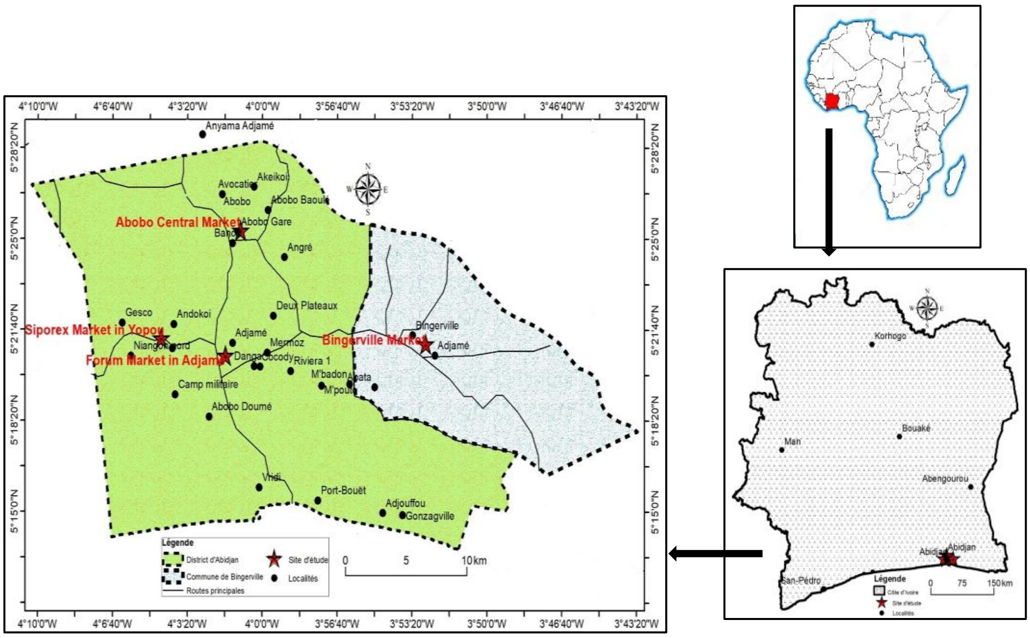

Figure 1: The different markets sampled in the municipality of Abidjan

Sampling of artisanal crude palm oil in market

A non-probability sampling method known as the "snowball technique" was employed to collect artisanal palm oil samples. A total of thirty (30) samples were randomly collected in September 2024 from each of the following markets in Abidjan: Abobo, Adjame, Bingerville, and Yopougon. The samples were obtained directly from female retails, resulting in a total of one hundred and twenty (120) artisanal palm oil samples. Each sample was labeled according to its market origin. The collected samples were then transported to the Laboratory, where they were stored in a fridge at 4°C until analysis.

Physicochemical Analysis of Artisanal Palm Oils

The determination of key physicochemical parameters including moisture content, free fatty acid (FFA) content, iodine value (IV), melting point (MP), deterioration of bleachability index (DOBI), and fatty acid profile was performed using a Bruker MPA II GbmH Near-Infrared (NIR) Spectrometer equipped with OPUSLAB software (version 2020). Prior to analysis, each artisanal palm oil sample was placed on a heated plate to ensure homogeneity. The homogenized palm oil was then transferred into 8 mm diameter glass vials and placed on a heating block maintained at 50 °C for 5 minutes to keep the samples in a fully liquefied and fluid state. The pre-conditioned samples were subsequently subjected to direct analysis using NIR spectroscopy for the rapid and simultaneous determination of the physicochemical parameters. In addition to NIR analysis, standard analytical procedures recommended by the American Oil Chemists' Society (AOCS) were employed to assess further palm oil quality parameters as follows: Refractive index (AOCS Method Cc 7-25), Peroxide value (PV) (AOCS Method Cd 8-53), p-Anisidine value (p-AV) (AOCS Method Cd 18-90) and Saponification value (SV) (AOCS Method Cd 3-25). The total oxidation (Totox) value, which reflects the overall oxidative status of the oil, was calculated using the formula: Totox=2×PV+p-AV.

Microbiological Quality Assessment of Red Palm Oil
Preparation of Culture Media

The microbiological quality of artisanal palm oil samples was assessed using standard enumeration and detection techniques based on ISO 11133:2014. The targeted microorganisms included aerobic mesophilic bacteria, yeasts and molds, total coliforms, fecal coliforms (*Escherichia coli*), *Staphylococcus aureus* and Salmonella spp. For each culture medium, the appropriate amount of dehydrated powder was weighed and dissolved in a measured volume of distilled water. The mixture was homogenized and heated until complete dissolution was achieved. All prepared media were sterilized in an autoclave at 121 °C for 20 minutes before use.

Preparation of Decimal Dilutions

Artisanal palm oil samples were used as stock suspensions. For each sample, 10 mL of oil was mixed with 90 mL of buffered peptone water (BPW) to form the 10^{-1} dilution. From this suspension, 1 mL was aseptically transferred into 9 mL of sterile tryptone salt (TS) solution to obtain the 10^{-2} dilution. The same serial dilution method was applied up to the 10^{-7} dilution, following the protocol described in ISO 6887-6:2013.

Microbial Enumeration

A 0.1 mL aliquot of the stock solution and each dilution was surface plated on selective agar media as follows: PCA (Plate Count Agar) for aerobic mesophilic bacteria, Sabouraud Dextrose Agar for yeasts and molds, VRBL (Violet Red Bile Lactose Agar) for total coliforms, EMB (Eosin Methylene Blue Agar) for *Escherichia coli*, Baird-Parker Agar for *Staphylococcus aureus.* The PCA and Sabouraud plates were incubated at 30 °C for 48 hours, while VRBL, EMB, and Baird-Parker plates were incubated at 37 °C for 48 hours.

Detection of *Salmonella* spp.

The detection of *Salmonella* spp. was conducted according to ISO 6579. A pre-enrichment step was carried out by mixing 10 mL of artisanal palm oil with 90 mL of buffered peptone water, followed by incubation at 37 °C for 24 hours. Subsequently, 0.1 mL of the pre-enrichment broth was transferred to Rappaport-Vassiliadis selective enrichment broth and incubated at 37 °C for 24 hours. After enrichment, 100 µL of the selective broth was streaked onto Hektoen Enteric Agar and plates were incubated at 37 °C for 24 hours.

Expression of Results

Microbial counts were expressed in colony-forming units per milliliter (CFU/mL). Colonies were counted manually using a fine-tipped marker. The microbial load (N) was calculated using the following formula:

$N=\sum Colonies/V \cdot d \cdot (n_1+0.1 \cdot n_2)$

Where: N = Microbial load (CFU/mL), ∑ Colonies = Total number of colonies counted, V = Inoculated volume (in mL), d = First dilution used for counting, n_1 *= Number of plates counted at dilution d and* n_2 *= Number of plates counted at the next higher dilution.*

Qualitative Detection of Adulteration with Sudan Dyes in Red Palm Oil
Chemical Test for the Detection of Sudan Dyes

The presence of adulterants in red palm oil samples was investigated using a chemical screening method as described by Nwachoko and Fortune (2019) and Ibukun and Augustine (2021) with slight modifications. For each sample, 5 mL of artisanal palm oil was measured and transferred into four separate glass test tubes. To each tube, 15 mL of hexane was added, followed by the addition of 5 mL of varying concentrations of a hydrochloric acid: water (HCl: H_2O) mixture, in the following volume ratios: 4:1, 3:1, 2:1, and 1:1, respectively. After a short period of settling, visual observations were made. In the absence of Sudan dyes or other colorants, the upper phase appeared in various shades of yellow, while the bottom aqueous phase remained clear or colorless. Conversely, samples containing Sudan dyes exhibited a reddish-yellow upper phase and a reddish or pale-yellow lower phase, indicating the presence of artificial colorants.

Depigmentation Test for the Detection of Sudan Dyes

This method is based on the oxidative bleaching of red palm oil using a chlorinated bleaching agent, sodium hypochlorite (NaClO), in the presence of hexane, following the procedure of Nwachoko and Fortune (2019). An aliquot of 2.5 mL of each red palm oil sample was placed into a test tube, followed by the addition of 7.5 mL of hexane, and the mixture was thoroughly agitated. Subsequently, 2.5 mL of sodium hypochlorite solution (1.85%) was added. After five (5) minutes, visual inspection was performed. In samples free of Sudan dyes, complete depigmentation occurred, and the oil phase turned whitish or colorless. In contrast, the presence of Sudan dyes was indicated by a persistent light coloration, the intensity of which depended on the concentration of the colorant present in the oil.

Statistical Analysis

All analyses were carried out in triplicate and data expressed as means ± standard deviation (SD). A one-way analysis of variance (ANOVA) was performed to determine statistically significant differences among the sample means, followed by Tukey's post-hoc test for pairwise comparisons. Differences were considered significant at $P < 0.05$. All statistical analyses were conducted using IBM SPSS Statistics, version 20.

RESULTS AND DISCUSSION

Physicochemical Analysis of Artisanal Crude Palm Oil Samples

The physicochemical properties of artisanal CPO samples collected from four major markets in Abidjan are shown in Table 1. Statistically significant differences ($p < 0.05$) were observed for the physical parameters, including refractive index, moisture content, melting point (MP) and DOBI (Deterioration of Bleachability Index). All artisanal CPO samples exhibited moisture content exceeding the Codex Alimentarius recommended value of 0.25%. Moisture values ranged from 0.62 ± 0.23% to 2.24 ± 2.15%, with highest value recorded in samples from Yopougon market. Melting points for all samples were found to be lower than the international reference range of 30-39 °C, with values ranging from 16.69 ± 3.11 °C to 22.73 ± 2.35 °C. Similarly, DOBI values which indicate poor oxidative stability and bleaching quality of oil were all below the reference value of 2.7. Observed values were between 1.88 ± 0.07 to 2.23 ± 0.10. The highest DOBI value was recorded in samples from the Adjame market. As for the refractive index, all samples fell within the Codex Alimentarius standard range of 1.454 - 1.456.

Regarding chemical parameters, analysis revealed significant differences ($p < 0.05$) between samples. Free Fat acidity (FFA) ranged from 9.63 ± 3.31 to 12.71 ± 2.54%, with Yopougon samples showing the highest acidity values. These values are all higher than the reference value of 5% recommended by Codex Alimentarius for edible oils. For iodine value, values varied from 51.77 ± 1.46 to 56.29 ± 1.50 g I_2/100g oil. While samples from Yopougon exhibited the lowest values, all remained within or close to the Codex Alimentarius range of 50.0–55.0 g I_2/100g oil. Saponification values for most samples were conformed to Codex standards, ranging from 194.30 ± 11.52 to 204.88 ± 8.07 mg KOH/g oil. However, samples from Yopougon market had a notably lower saponification value of 180.73 ± 17.53 mg KOH/g oil, falling below the acceptable threshold.

Table 1: Physicochemical parameters of artisanal crude palm oil sampled from the four markets of Abidjan

	Abobo	Adjame	Bingerville	Yopougon	Codex values
Refractive index	1.456 ± 0.02^{ab}	1.456 ± 0.01^{ab}	1.455 ± 0.01^{a}	1.456 ± 0.02^{b}	1.454 - 1.456
Moisture (%)	0.83 ± 0.44^{a}	0.62 ± 0.23^{a}	0.75 ± 0.47^{a}	2.24 ± 2.15^{b}	0.25
MP (°C)	20.06 ± 5.13^{ab}	16.69 ± 3.11^{a}	20.76 ± 2.08^{b}	22.73 ± 2.35^{b}	30 - 39*
DOBI	1.95 ± 0.29^{a}	2.23 ± 0.1^{b}	2.03 ± 0.14^{a}	1.88 ± 0.07^{a}	2.7**
FFA (%)	9.63 ±3.31^{a}	9.77 ± 1.23^{a}	9.78 ± 2.24^{a}	12.71 ± 2.54^{b}	5
Iodine (g I_2/100g)	56.10 ± 2.82^{b}	56.29 ± 1.5^{b}	55.94 ±1.02^{b}	51.77 ± 1.46^{a}	50.0 - 55.0
Saponification (mg KOH/g)	203.11 ± 8.74^{b}	204.88 ± 8.07^{b}	194.30 ± 11.52^{b}	180.73 ± 17.53^{a}	190 - 209

*MP= Meelting point; DOBI= Deterioration of Bleachability Index; FFA= Free Fat acidity; *: Haizam (2008); **: Gibon et al (2009). Data are presented as means of triplicate analyses ± SD. Means with different letters in the same raw for a single parameter are different at P < 0.05.*

Oxidative Stability Indexes

The oxidative stability parameters of the artisanal crude palm oil (CPO) samples collected from the four markets are summarized in Table 2. Generally, values observed indicate acceptable primary oxidation levels. Thus, peroxide value (PV) ranged from 12.82 ± 4.25 to 14.62 ± 2.27 meq O_2/kg of oil, with no statistically significant differences ($P > 0.05$) observed between the markets. These values fall within the Codex Alimentarius limit of less than 15 meq O_2/kg oil for oils intended for human consumption. A similar trend was observed for the p-anisidine value (p-AV), which ranged from 9.38 ± 3.45 to 11.54 ± 0.90, with no significant variation between markets ($P > 0.05$). The total oxidation value (Totox), calculated as Totox = 2 × PV + p-AV, ranged from 35.02 ± 11.11 to 40.04 ± 5.09. No statistically significant differences were observed between the markets ($P > 0.05$). These results indicate that, although the oils exhibit some degree of oxidation, the levels remain within an acceptable range and are relatively consistent across sampling sites.

Table 2 showed the results of the fatty acid composition analysis of the artisanal crude palm oil (CPO) samples collected from the four markets in Abidjan. Statistically significant differences ($p < 0.05$) were observed in the proportions of palmitic acid, oleic acid, linoleic acid, and alpha-linolenic acid, with notably higher levels of linoleic and alpha-linolenic acids detected in oils from the Bingerville and Abobo markets. The levels of palmitic (C16:0), linoleic (C18:2), and alpha-linolenic (C18:3) acids were all within the acceptable ranges established by the Codex Alimentarius. Specifically, palmitic acid ranged from 38.59% to 46.37%, oleic acid from 35.43% to 46.99%, linoleic acid from 9.25% to 10.94%, and alpha-linolenic acid from 0.29% to 0.53%.

Table 2: Oxidative Stability Indexes and Fatty Acid Profile of artisanal crude palm oil sampled from the four markets of Abidjan

	Abobo	Adjame	Bingerville	Yopougon	Codex values
Peroxyde (meq O₂/kg)	14.62 ± 2.27^a	14.24 ± 2.38^a	12.82 ± 4.25^a	13.84 ± 0.46^a	15
Anisidine value	10.63 ± 0.34^a	11.54 ± 0.90^a	9.38 ± 3.45^a	9.52 ± 2.15^a	10
Totox	39.86 ± 4.27^a	40.04 ± 5.09^a	35.02 ± 11.11^a	37.19 ± 2.31^a	40
Palmitic acid (%)	38.59 ± 2.38^a	40.72 ± 3.57^a	39 ± 4.17^a	46.37 ± 2.87^b	39,3-47,5
Oleic acid (%)	44.65 ± 1.95^{bc}	46.99 ± 1.17^c	40.88 ± 5.79^b	35.43 ± 3.93^a	36,0-44,0
Linoleic acid (%)	10.22 ± 0.39^{ab}	9.25 ± 0.84^a	10.94 ± 1.35^b	9.7 ± 2.32^{ab}	9,0-12,0
Linolenic acid (%)	0.53 ± 0.06^b	0.37 ± 0.18^a	0.39 ± 0.13^a	0.29 ± 0.05^a	ND-0,5

Data are presented as means of triplicate analyses ± SD. Means with different letters in the same raw for a single parameter are different at P < 0.05.

Microbiological Quality of Artisanal Crude Palm Oil Samples

Table 3 presents the results of the enumeration of microbiological flora of interest in the artisanal crude palm oil (CPO) samples. The microbiological analysis revealed significant contamination across the samples, with aerobic mesophilic bacteria counts ranging from 1.2×10^6 to 2.4×10^9 CFU/g, yeasts and molds from 2.3×10^6 to 1.2×10^8 CFU/g, and total coliforms from 7.5×10^4 to 3.9×10^7 CFU/ml. All samples, except those from the Bingerville market, exhibited aerobic mesophilic bacterial loads exceeding the recommended limit of 10^6 CFU/g, according to food safety guidelines. Furthermore, yeast, mold, and total coliform counts in all samples were significantly higher than the permissible limits, indicating poor hygienic conditions during processing, handling, or storage. Additionally, fecal contamination indicators, notably *Escherichia coli*, were detected in all oil samples from the four markets, confirming unsanitary conditions in the production or post-production chain. However, none of the samples tested positive for pathogenic microorganisms such as Salmonella spp. and *Staphylococcus aureus*, which are commonly associated with foodborne illnesses.

Table 3: Hygienic and microbiological quality of Artisanal Crude Palm Oil sampled from the four markets of Abidjan

	Abobo	Adjame	Bingerville	Yopougon	Microbiological criteria
MAG	$1.2.10^7$	3.10^7	$1.2.10^6$	$2.4.10^9$	3.10^6
Yeasts and Mold	$3.2.10^7$	$2.6.10^6$	$2.3.10^6$	$1.2.10^8$	$\leq 10^4$
TC	3.10^6	9.10^4	$7.5.10^4$	$3.9.10^7$	$\leq 10^2$
FC (E. coli)	$>10^2$	$>10^2$	$>10^2$	$>10^2$	<10
S. aureus	Not present	Not present	Not present	Not present	Not present
Salmonella	Not present	Not present	Not present	Not present	Not present

Each value is the average of the analysis of three tests; MAG: Mesophilic Aerobic Germs; TC: Total Coliforms; FC: Fecal Coliforms

Chemical Fraud Detection and Decolorization Test

The results of the chemical fraud detection test, performed on a total of 120 artisanal red palm oil samples (30 samples per market), revealed evidence of adulteration in some samples (Table 4). Specifically, six (06) samples from the Abobo market exhibited a reddish-yellow coloration at the top of the test tube and a pale reddish base. This corresponds to 20% of the samples tested from that market being adulterated. A similar observation was made for six (06) samples from the Adjame market, which also displayed the same characteristic coloring pattern associated with Sudan dye. In contrast, the remaining samples from other markets showed a yellowish upper phase and a pale or colorless base.

Decolorization Test

The decolorization test was conducted to assess the presence of natural pigments or synthetic dyes in the artisanal palm oil samples by using a chlorine-based bleaching agent. The results of this test were consistent with the chemical fraud detection findings. The six (06) artisanal palm oil samples from Abobo and Adjamé that had tested positive for dye adulteration retained a persistent yellow coloration. Conversely, all other samples underwent complete decolorization, turning white, thereby confirming the absence of synthetic colorants in those samples (Table 4).

Table 4: Percentage of adulterated samples in selected markets from the chemical and depigmentation tests

	Abobo (n = 30)	Adjame (n = 30)	Bingerville (n = 30)	Yopougon (n = 30)
Chemical test	6 (20%)	6 (20%)	0	0
Depigmentation test	6 (20%)	6 (20%)	0	0

DISCUSSION

This study aimed to evaluate the physicochemical quality, fatty acid composition, microbiological safety, and potential adulteration of artisanal red palm oil samples collected from four major markets in Abidjan: Abobo, Adjame, Bingerville, and Yopougon.

Significant differences were observed in key physical parameters, namely moisture content, melting point, DOBI and refractive index. Moisture content across all samples exceeded the maximum threshold of 0.25% recommended by the Codex Alimentarius. This suggests a high risk of microbial contamination, particularly by molds and yeasts, as elevated moisture facilitates hydrolysis of triglycerides and microbial proliferation (Odoh *et al.,* 2017). High moisture levels are often attributed to traditional oil extraction methods and suboptimal hygienic conditions during processing (MacArthur *et al.,* 2021). These findings are consistent with previous studies (Ngando-Ebongue *et al.,* 2013; Yeo *et al.,* 2022). The melting points of the oils ranged from 16.69 to 22.73°C, significantly lower than the international standard range of 30–39°C (Haizam *et al.,* 2008), which may affect the oil's stability and shelf life. DOBI values (1.88–2.23) were below the standard value of 2.70, reflecting delayed fruit processing and inappropriate heating during artisanal oil production (Gibon *et al.,* 2009; Bomfim *et al.,* 2024). Refractive index values, however, were within the Codex range (1.454–1.456), suggesting acceptable levels of purity and consistent fatty acid profiles (Codex, 2023).

Statistically significant differences were observed in acidity, iodine value, and saponification value. All oil samples exhibited acid values well above the Codex limit of 5%, reflecting advanced hydrolysis of triglycerides likely due to endogenous lipase activity and poor processing practices (Domonhédo *et al.,* 2018; Niamketchi *et al.,* 2024). The iodine values (51.77–56.29 g I_2/100g) fell within the Codex range (50–55 g I_2/100g), suggesting moderate unsaturation. This may offer nutritional benefits as higher iodine values correlate with greater unsaturated fatty acid content. Saponification values (180.73–204.88 mg KOH/g) were relatively high, indicating the presence of short-chain fatty acids and confirming the oil's potential suitability for soap and cosmetic production. Peroxide values (12.82–14.62 meq O_2/kg) and anisidine values (9.38–11.54) slightly exceeded Codex limits, reflecting minor primary and secondary lipid oxidation. These values may result from improper fruit handling or prolonged exposure to air during processing (Yoboue *et al.,* 2022). Totox values (35.02–40.04) confirmed a moderate level of overall oxidation.

The fatty acid composition of the red palm oil samples was consistent with values reported by Zoué *et al.,* 2018; Monde *et al.,* 2020, though slight variations were observed among the markets. These differences may be attributed to fruit varietals, postharvest handling, and local processing techniques (Konan *et al.,* 2018; Zoué *et al.,* 2018). All samples fell within the Codex range for palmitic acid (38.59–46.37%), oleic acid (35.43–46.99%), linoleic acid (9.25–10.94%), and linolenic acid (0.29–0.53%).

Microbiological analysis revealed widespread contamination by aerobic mesophilic bacteria, with colony counts ranging from 10^6 to 10^9 CFU/g, exceeding the Codex maximum limit of 10^6 CFU/g. High levels of total and fecal coliforms were also detected, highlighting poor hygiene during oil production and sale (Odoh *et al.,* 2017; Okwelle & Nwabueze, 2020). The loads of coliforms across the four markets could be attributed to the differences in sources of the raw material (palm fruits), processing and packaging, as well as environmental factors and conditions that prevail in the respective market (Marc Arthur, 2021b). These microorganisms are commonly used as indicators of sanitary practices (Okechalu *et al.,* 2011). All oil samples were contaminated with yeasts and molds, with the highest counts recorded in samples from Yopougon. This may result from unsanitary storage and production environments (Okogbenin, et. al., 2014). The presence of molds is particularly concerning due to the potential production of harmful mycotoxins (Nwachukwu *et al.,* 2019). Notably, no samples tested positive for pathogenic bacteria such as *Salmonella spp.* or *Staphylococcus aureus*, suggesting at least some level of hygiene during storage and retail.

Chemical tests for food fraud revealed that several red palm oil samples from Abobo and Adjame were adulterated with Sudan dye, as indicated by the characteristic reddish-yellow top layer and reddish-clear base in the test tubes. The depigmentation test corroborated these findings, with six samples showing persistent yellow color after treatment, indicating the presence of synthetic dye. Sudan dyes, commonly used in plastics and textiles, are banned in food products due to their carcinogenic potential (Onyeka *et al.,* 2022; Ugo *et al.,* 2024). Nevertheless, some unscrupulous vendors add these dyes to enhance the visual appeal of low-quality oil. Such fraudulent practices have led to import bans on Ivorian palm oil in some countries (Teye *et al.,* 2024). These findings align with reports from Ghana and Cameroon, where similar adulteration practices were observed (MacArthur *et al.,* 2021; Djomptchouang *et al.,* 2024). Given the widespread use of palm oil in daily diets, even low levels of Sudan dyes can pose serious long-term health risks.

CONCLUSION

This study focused on evaluating the physicochemical and sanitary quality of artisanal red palm oil sold in four major markets in Abidjan. The results revealed that while the oils generally exhibited acceptable physicochemical characteristics, some critical parameters notably moisture content, acidity, and melting point deviated from Codex Alimentarius standards. The fatty acid composition remained within acceptable ranges, although slight variations were noted between markets. Microbiologically, all oil samples were found to be unsatisfactory, exhibiting high loads of aerobic mesophilic bacteria, yeasts, molds, and total coliforms, indicating significant hygiene deficiencies during processing and storage. Furthermore, food fraud detection tests identified the presence of prohibited Sudan dyes in several samples from the markets of Abobo and Adjamé. These findings underscore the urgent need to improve hygiene practices throughout the artisanal palm oil production chain. Strengthening regulatory oversight, enhancing food safety education among producers and vendors, and promoting the adoption of good manufacturing and storage practices are essential. Additionally, routine microbiological testing should be implemented to reduce contamination risks and safeguard consumer health.

Acknowledgments

The authors express their sincere gratitude to the National Public Health Laboratory of Abidjan, Côte d'Ivoire, for the support provided during this study. Special thanks go to Professor GBASSI Komenan Gildas, Head of the Food Control Laboratory, and his team for their valuable contribution.

Conflict of interest statement: The authors declare that they have no conflict of interest.

Ethics statement: No human or animal subjects were used in this research.

REFERENCES

- Aka Z. E. B., Djeni N. T., Amoikon T. L. S., Kannengiesser J., Ouazzani N., Dje K. M. (2021). High-throughput 16S rRNA gene sequencing of the microbial community associated with palm oil mill effluents of two oil processing systems. *Scientific Reports*, 11:13232. https://doi.org/10.1038/s41598-021-92513-4.
- Andoh S. S, Nyave K., Asamoah B., Kanyathare B., Nuutinen T., Mingle C., et al. (2020). Optical screening for presence of banned Sudan III and Sudan IV dyes in edible palm oils. FoodAdditives & Contaminants: Part A, DOI: 10.1080/19440049.2020.1726500.
- AOCS Methods. Official methods and recommended practices of the AOCS. 6th ed. Urbana, III: AOCS 2009.
- Bomfim R. S., Velasco J., Cardoso L. A., Ribeiro C. D. F., Marinho L. Q. M., Ribeiro P. R., de Almeida D. T. (2024). Processing practices and quality of crude palm oil produced on a small scale in Valença, Bahia, Brazil. *Grasas Aceites,* 75 (2), 2084. https://doi.org/10.3989/gya.1191231.208
- Codex Alimentarius Commission FAO/WHO food standards. Standard for named vegetable oils CODEX-STAN 210, Ed. FAO/WHO. 2023.
- Djomptchouang H. T., Abia W. A., Tchana A. N., Mbassi G. M., Mkounga P., Fokou E. (2024). Assessment of the Authenticity and Detection of Fraud in Artisanal Red Palm Oil Sold in Markets in Douala and Yaoundé, Cameroon. *Clinical Research and Reports, BioRes Scientia Publishers, 2*(6):1-7. DOI: 10.59657/2995-6064.brs.24.039
- Domonhédo H., David C., Léifi N., Norbert B. & Corneille A. (2018). Enjeux et amélioration de la réduction de l'acidité dans les fruits mûrs du palmier à huile, *Elaeis guineensis Jacq*. (Synthèse bibliographique) *Biotechnology Agronomy Social Environment* 2018 22(1), 54-66
- Gibon V., Ayala J.V., Dijckmans P., Maes J. & De Greyt, W. (2009). Futurs prospects for palm oil refining and modifications, *Oilseeds and fats,Crops and Lipids*, 16 (4), 193–200.
- Haizam TA, Lin SW, Kuntom A. Palm-Based Standard Reference Materials for Iodine Value and Slip Melting Point. Analytical Chemistry Insights. 2008, 3: 127–133.
- Ibukun K. et Augustine A. (2021). Prevalence of Azo Dye Adulterated Palm Oil in Ondo State (Nigeria) and Toxicological Effects on Liver, Kidney and Testicular Tissues of Albino Rats.
- ISO 11133:2014. Microbiology of food, animal feed and water - Preparation, production, storage and performance testing of culture media, pages 103.
- ISO 6887-6:2013. Microbiology of food and animal feed - Preparation of test samples, initial suspension and decimal dilutions for microbiological examination, pages 10.
- Konan J-N, Diabate S, N'goran B, Gouai A, Konan KE. Prospecting and physicochemical characterization of some traditional oil palm specimens from Man, western region of Côte d Ivoire. *Journal of Animal & Plant Sciences*. 2018, 38(3) : 6283-6291.
- Macarthur R., Teye E., Darkwa S. (2021a). Quality and safety evaluation of important parameters in palm oil from major cities in Ghana. *Scientific African. Elsevier B.V*, *13*, 2468–2276. https://doi.org/10.1016/j.sciaf.2021.e00860

- MacArthur R.L., Teye E., Darkwa S. (2021b). Microbial Contamination in Palm Oil Selected from Markets in Major Cities of Ghana, *HELIYON*, https://doi.org/10.1016/j.heliyon.2021.e07681.
- Monde A. A., Cisse-Camara M., Ake A. A., Koffi G., Gauze G.-A. et al. (2020). Biochemical properties, nutritional values, health benefits and sustainability of palm oil. Biochimie 178, 81-95.
- Morcillo F., Cros D., Billotte N., Ngando-Ebongue G-F., Domonhédo H., Pizot M. (2013). Improving palm oil quality through identification and mapping of the lipase gene causing oil deterioration. *Nat. Commun*, 4 :21-60. DOI: 10.1038/ncomms3160.
- Nanda D., Kansci G., Rafflegeau S., Bourlieu C., Ngando E., Genot C. (2020). Impact of post-harvest storage and freezing of palm fruits on the extraction yield and quality of African crude palm oil extracted in the laboratory. OCL, 27(52): 1-12. https://doi.org/10.1051/ocl/2020046.
- Ngando Ebongue GF, Mpondo Mpondo EA, Dikotto EEL, Koona P. (2011). Assessment of the quality of crude palm oil from smallholders in Cameroon. J. Stored Prod. Postharvest Res., 2(3):52-58.
- N'Goran K. D. V., Kouassi K. A., Pohé J., Angbo-Kouakou M. E., Yéléhi D., Adima A. A. (2017). Indication Géographique de l'Huile de Palme (District des Montagnes-Côte d'Ivoire) : Une Analyse Comparative des Propriétés Physico-Chimiques et des Profils en Acides Gras de Quelques Huiles de Palme Rouge de Côte d'Ivoire. Journal scientifique européen, 13(18), 373-385. https://doi.org/10.19044/esj.2017.v13n18p373
- Niamketchi G. L., Konan J. N., Adolphe M. G., N'guessan H. A., Adou C. B., Kablan A. B. M., Gouai A. (2024). Quality assessment of artisanal palm oil from smallholders in the department of Man, western region of Côte d'Ivoire. *World Journal of Advanced Research and Reviews,* 24(01), 846–856.
- Nwachoko N. et Fortune A. R. (2019). Toxicological effect of Sudan III azo dye in palm oil on kidney parameters of albino rats. World Journal of Pharmaceutical and Medical Research.
- Nwachukwu I. N., Amadi E. S., Umeh S. I., Opurum C. C., Ogueke C. C. et al. (2019)., Microbial and Physicochemical Qualities of Edible Palm Oil Sold in Major Markets of South-Eastern Nigeria. *Journal of Agricultural Science and Food Technology*, 5 (6), pp. 117-125. http://pearlresearchjournals.org/journals/jasft/index.html.
- Odia O.J., Ofori S., Maduka O. (2015). Palm oil and the heart: a review, World J. Cardiol. 7 (3) 144, doi: 10.4330/wjc.v7.i3.144.
- Odoh C. K., Amapu T. Y., Orjiakor I. P., Martins P. E., Seibai B. T., Akpi U. K., Ugwu C. S., Lerum N. I., Nwankwegu A. S. (2017). Assessment of mold contamination and physicochemical properties of crude palm oil sold in Jos, Nigeria. *Food Science & Nutrition*, 5(2): 310–316.
- Okechalu, J. N., Dashen, M. M., Lar, M. P., Gushop, T., & Okechalu, B. (2011). Microbial quality and chemical characteristics of palm oil sold within Jos Metropolis, Plateau State, Nigeria. Journal of Microbiology and Biotechnology Research, 1(2), 107-112.
- Okogbenin, O. B., Okogbenin, E. A., Okunwaye, T., Odigie, E. E., & Ojieabu, A. (2014). Isolation of food pathogens from freshly milled palm oil and the effect of sterilization on oil quality parameters. Journal of Food Security, 2(2), 65-71.
- Okwelle A. A. & Nwabueze F. C. (2020). Microbiological Quality Assessment of Unbranded groundnut oil sold in major Markets in Port Harcourt City, Rivers State, Nigeria. *International Journal of Current Microbiology and Applied Science*, *9*(5): 2964-2974.
- Onyeaka H., Ukwuru M., Anumudu C. & Anyogu A. (2022). Food fraud in insecure times: Challenges and opportunities for reducing food fraud in Africa. Trends in Food Science and Technology,125, 26–32 [DOI: 10.1016/j.tifs.2022.04.017]
- Sutapa M., Analava M. (2009). Health effects of palm oil, J. Hum. Ecol. 26 (3) 197–203, doi: 10.1080/09709274.2009.11906182
- Teye E., Nyorkeh R., Essuman E. K., Haughey S. A., Elliott C., Logan N. (2024). 18 Years Analysis of RASFF Notifications on Sudan Dye Adulterated Cases in Palm Oil (2004 to 2022) and the Principles of Technique for its Detection. *Sustainable Food Technol.*, 1-33, DOI:10.1039/D3FB00190C.
- Thomas A., Alpha A., Barczak A., Zakhia-Rozis N. (2024). Durabilité des systèmes pour la sécurité alimentaire. Combiner les approches locales et globales. coll. Synthèses, Versailles, Quæ, 246 pages.
- Ugo C. H., Eme P. E., Eze P. N., Obajaja H. A., Omeili A. E. (2024). Chemical assessment of the quality of palm oil produced and sold in major markets in Orlu zone in Imo state, Nigeria. *World Journal of Advanced Research and Reviews,* 21(02), 1025–1033. https://doi.org/10.30574/wjarr.2024.21.2.0529
- Urugo M. M., Teka T. A., Teshome P. G., Tringo T. T. (2021). Palm Oil Processing and Controversies over Its Health Effect: Overview of Positive and Negative Consequences. J. *Oleo Sci. 70, (12) 1693-1706. doi : 10.5650/jos.ess21160*
- USDA (2025). Palm Oil Explorer, International Production Assessment Division (IPAD) (.gov). Available from https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=4243000. (last consult: 2025/04/10)
- Yao N. J. C., Adima A. A., Niamke B. F., Kouakou N. D-V., N'da K. P. et Adje A. F. (2018). Activité Antioxydante, propriétés physico-chimiques et composition en rétinol et α-tocophérol de l'huile de

palme raffinée et des huiles issues de six plantes oléagineuses de Côte d'Ivoire. *Afrique SCIENCE*, 14(2), 15-27.

- Yeo MA, Niamketchi GL, Akely PM, Konan AG. Quality assessment of crude palm oil from smallholders in Alepe department, southeast Côte d Ivoire. *Int. J. Adv. Res.* 2022, *10(01): 06-11. DOI: 10.21474/IJAR01/14003.*
- Yoboue, B.A., Diallo, K., Diomande, I., Tiahou, G.G. and Assidjo, N.E. (2022) Evaluation of the Nutritional Quality of Red and Refined Palm Oils Marketed in Yamoussoukro (Cote d'Ivoire). Food and Nutrition Sciences, 13, 97-107. https://doi.org/10.4236/fns.2022.132010
- Zoué L, Zoro A., Niamké S. (2018). Studies of Physicochemical and Nutritive Properties of Oil Extracts from Local and Improved Varieties of Palm Fruits. *Journal of Scientific Research & Reports, 21(6): 1-9. DOI: 10.9734/JSRR/2018/46025*