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# Assessment of the Authenticity and Detection of Fraud in Artisanal Red Palm Oil Sold in Markets in Douala and Yaoundé, Cameroon

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## Abstract

**Introduction:** Red palm oil is the most consumed vegetable oil in the World. RPO obtained from the mesocarp of the palm nuts is characterised by a deep red colour greatly appreciated by consumers. Its popularity has made it vulnerable to fraud, perpetrated partly to meet demands but mainly for economic gains. Recently, red palm oil adulteration has been reported in West Africa; the main suspected adulterant, Sudan dyes, had been banned as food additives by the WHO due to their perceived carcinogenicity. However, there is inadequate data from Cameroon concerning red palm oil adulteration. This study has assessed the authenticity of red palm oil and detected the presence of various adulterants in red palm oil samples collected from some local markets in Douala and Yaounde, Cameroon. In addition, it has proposed a simple rapid technique for detecting the presence of Sudan dye in red palm oil. Methodology: Red palm oil samples (N=86) were collected from some major markets in Douala (n=49) and Yaounde (n=37) and analyzed for some authenticity-related parameters (moisture content, acid value, free fatty acids), as well as fraud detection: the case of Sudan dye. Results and Discussion: Moisture content analysis of the red palm oil samples revealed a mean (range) of 2.21 (0.25-29.14) % with 85 (99%) samples being above the Codex Alimentarius standard value of 0.25%. For acid value, a mean value of 32.47 (range: 14.03-84.15) mg NaOH/g of red palm oil was detected. For free fatty acids, a mean level of 14.8 3 (range: 6.40-38.42) % was detected. Altogether, three samples (~ 4%) tested positive for Sudan dye and were considered suspicious. Additionally, the studied red palm oil samples were not authentic and were suspected to be adulterated with water (99%) and Sudan dye (~4%). Conclusion: For the first time, this paper reports on red palm oil authenticity and fraud detection in Cameroon. Water and Sudan dye were the suspected adulterants, requiring further studies and public attention.

**Keywords:** red palm oil; fraud; adulterants; authenticity; detection; sudan dye

## Introduction

Red Palm oil is a famous deep, red-coloured oil obtained from the oil palm fruits *Elaeis guineensis*. This vegetable oil is essentially made up of fatty acids (the major ones being palmitic, oleic and linoleic acids) as well as many phytonutrients all of which exhibit nutritional properties and oxidative stability (Carotenoids, tocopherols, tocotrienols, coenzyme Q10, etc…) (Loganathan et al., 2017; Tan et al., 2021). For thousands of years, red palm oil has been produced in Africa serving as an essential ingredient in much of traditional African cuisine (Nchanji et al., 2013; Djomptchouang and Abia, 2024). However, in recent years palm oil has been gaining popularity on the global market partly due to its low cost, ease of decolouration and resistance to high temperatures (Andoh et al., 2019) making it a versatile commodity used in many domains: agroindustry, chemicals (soap, candles, paint, etc), and biodiesel production.

In Cameroon likewise in Africa, red palm oil is produced by two main actors: smallholders or local producers using either manual or semi-motorised processing techniques and industrials using more sophisticated methods (industrial) (Nchanji et al., 2013; Nkongho, Feintrenie and Levang, 2014). However, the red palm oil available on local markets for local consumption is mainly artisanal red palm oil as 99% of the industrial production is destined for agro-industries (Enyegue and Enyegue, 2020) for further processing. Since 2010, there has been a wide gap between local production and consumption of red palm oil in Cameroon (USDA, 2016). Since then, the country has resorted to importation from Malaysia, Indonesia, and recently from Gabon. More recently with the Covid-19 pandemic, Red palm oil costs skyrocketed in the local markets; the length and complexity of the artisanal red palm oil distribution chain coupled with the lack of monitoring and enforcement, poor laboratory testing, the informality of the sector, low consumers' awareness provides motives and opportunities to unscrupulous sellers to resort to alternatives to increase their bulk for economic gains: it is food fraud (Djomptchouang and Abia, 2024).

Food fraud is a collective term used to encompass the deliberate and intentional substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging; or false or misleading statements made about a product for economic gain (Spink and Moyer, 2011; Elliott, 2014; Abia, 2023). Fraud takes different forms and has been described as adulteration, tampering, product overrun, theft, diversion, simulation, and counterfeiting (Spink and Moyer, 2011; Elliott, 2014; Abia, 2023). Food fraud affects a wide range of foodstuffs worldwide including fruit juices, milk and dairy products, oils and fats, fish, honey, spices, wine, and meat among its victims. In Africa, more and more fraud occurrences have been reported: the addition of the embalming agent, formaldehyde, to preserve fish and meat between capture or slaughter and sale has been reported in Nigeria, Ethiopia, Uganda and Cameroon (Ssali, 2018; Deudjui, Chongwang and Nakweya, 2020; Idris, 2021). Similarly, the adulteration of Red Palm Oil with the carcinogenic dyes of the Sudan family to deepen the colour of the product is a common practice in Ghana and Nigeria (Andoh et al., 2019; Teye et al., 2019; Andoh et al., 2020; Ibukun and Augustin, 2021). Recently, many consumers in sub-Saharan Africa e.g. Ghana (Abayase, Mohammed and Karbo, 2022) and Cameroon (Djomptchouang and Abia, 2024) are becoming interested in the authenticity of the red palm oil they consume.

Therefore, facing the growing phenomenon of food fraud, more and more concern is placed upon Food Authenticity which refers to the quality of a food that should be genuine and undisputed in its nature, origin, identity, and claims, and to meet expected properties (**CAC, 2018**). Generally, food authenticity matters include economic adulteration of high-value foods; misdescription of the geographical origin; non-compliance with the established regulatory standards, and or the implementation of non-acceptable process practices. Therefore, there's a need to assess the authenticity of foods by ensuring their compliance with food legislation and traceability requirements (Carcea et al., 2009). According to Codex Alimentarius, Food adulterants are mostly substances that are not legally recognized for application in a given food production; and are susceptible to pose a serious health hazard as a result of adulteration, hence adulteration is a serious issue and there is a need to institute policies and regulatory measures to preserve public health.

In a recent survey report, targeting the stakeholders of artisanal red palm oil production, the participants (producers, sellers, and customers) revealed speculative red palm oil adulterants in Cameroon. Those included, water (more probably wastewater originating from the processing), dyes (Sudan dyes mainly III or IV), and cassava flour. Detecting the presence of such adulterants remains a challenge in low-income countries like Cameroon (Djomptchouang and Abia, 2024). As a follow-up to the survey, the current work has measured some potential red palm oil authenticity indicators including moisture contents, acid values, and free fatty acid levels, and detected the presence of adulterant, specifically, the carcinogenic azo colourant dye, Sudan dye, that is a banned as a food additive and thus should not be present in red palm oil. Finally, a simple and practical method for detecting the presence of Sudan dye in red palm oil has been proposed.

## Materials and methods

### Sample collection

This study was done in two cosmopolitan cities of Cameroon (Douala and Yaounde) with the highest ethnicity mix. The study targeted red palm oil producers, sellers and consumers earlier surveyed on their awareness, perception, and knowledge of red palm oil authenticity and fraud (Djomptchouang and Abia, 2024). Consecutively with the survey, 75 artisanal red palm oil samples (1 L each) were purchased from sellers in 10 major local markets of Douala (including Dakar, Deido, Oyac, Sandaga, Dogpassi, Grand Hangar, Non-glacé, PK12, Central, Ndokoti) and 7 major local markets of Yaounde (such as Acacia, Etoudi, Mendong, Mfoundi, Mokolo, Mvog-Ada, Mvog-Antagana-Mballa). An additional 11 samples were purchased from local producers in Douala and Yaounde between January - February 2023. The samples collected were then transported to the Laboratory of Food Sciences and Metabolism of the University of Yaounde I, Cameroon. The samples were analysed for moisture content, acid value, and free fatty acids. Also, the samples were screened for the presence of Sudan dye.

### Samples analysis

### Moisture content

The moisture content was determined using a thermo-gravimetric method (MacArthur, Teye and Darkwa, 2021). Five grams (5g) of each sample of red palm oil was weighed into a crucible. Then the sample was oven dried at 103°C for 24 hours until a constant weight was obtained.

### Acid value

The Acid value of the samples was determined using the titrimetric method; 0.5 g of each Red Palm Oil sample was weighed, and introduced into a 250 mL conical flask. Then, 50 mL of ethyl alcohol and 1 mL of phenolphthalein indicator solution were added. The mixture was heated in a water bath (75-80°C) for 15 minutes. Each mixture was directly titrated while still hot with a sodium hydroxide solution (0.5N) until a light pink colour was observed and persisted for 15 seconds.

### Free fatty acids content

The content of Free Fatty Acids expressed as palmitic acid was obtained from the calculated acid value using the formula described by Basiron *et al.* (2004):

% FFA as Palmitic acid = Acid value / 2,19

### Sudan dyes qualitative fraud detection techniques

### Chemical test

Based on the method described by both Nwachoko and Fortune. (2019) and Ibukun and Augustine. (2021), 5 mL of each palm oil sample was measured and placed into four glass tubes. Then, 15 mL of hexane was added, followed by 5 mL of each concentration of (Acid: Water) mix: 4:1; 3:1; 2:1; or 1:1 into the four test tubes respectively. After a few minutes, different shades of yellow were observed at the top and a clear/colourless base indicated the absence of adulterants. Samples containing adulterants showed a reddish-yellow top and a reddish or yellowish clear base.

### Depigmentation test

This method was developed based on the decolouration (bleaching) of red palm oil by chlorine bleach (Sodium hypochlorite NaClO) in the presence of hexane. 2,5 mL of each palm oil sample was measured and placed in a test tube. After, 7,5 mL of hexane was added and mixed, followed by 2,5 mL of NaClO (1,85%). After five (05) minutes, the NaClO added provoked the decolouration of the palm oil, which then gave a white colour when the dye was absent and a persisting light colour depending on the quantity of the dye when it was present.

## Results

Table 1 presents findings on the moisture, acid value and free fatty acid contents. As per moisture content, one (1/86; 1.05%) of the studied red palm oil, irrespective of purchase location (market in Douala or Yaounde) and or purchasing point (seller or producer) conformed to the *Codex Alimentarius* Standard value for red palm oil moisture content of 0,25%. The majority (85/86; 99%) were above the standard value and ranged between 0,25 and 29,14%. For acid value and free fatty acid contents, irrespective of purchase location (market in Douala or Yaounde) and or purchasing point (seller or producer), all samples were superior to the *Codex Alimentarius* standard value of 10 mg NaOH/g and 5 % respectively.

**Table 1:** Mean and range of the moisture contents, acid value and free fatty acid contents of the 86 studied red palm oil samples according to their zone of collection and purchasing point.

| Sample origin | Sample source | Mean moisture content (range) in % | Mean acid value content (range) in mg NaOH/g | Mean free fatty acids content (range) in % |
|---|---|---|---|---|
| Markets in Yaounde | Sellers (n=36) | 2.83 (0.25– 29.14) | 31.87 (14.03– 56.10) | 14.55 (6.40 – 25.62) |
| (Yde, n=37) | Producers (n=1) | 1.16 | 28.05 | 12.81 |
| | Sub-Total: | 2.78 (0.25– 29.14) | 31.76 (14.03– 56.10) | 14.50 (6.40-25.62) |
| Markets in Douala | Sellers (n=39) | 1.92 (0.44 – 9.08) | 34.81 (16.83– 84.15) | 15.90 (7.68 – 38.42) |
| (Dla, n=49) | Producers (n=10) | 1.18 (0.45– 3.30) | 25.95 (14.03– 35.06) | 11.85 (6.40 – 16.01) |
| | Sub-Total: | 1.75 (0.44– 9.08) | 33.00 (14.03 – 84.15) | 15.07 (6.40 – 38.42) |
| Markets from Yde and Dla (N=86) | Sellers (n=75) | 2.36 (0.25– 29.14) | 33.40 (14.03 – 84.15) | 15.25 (6.40– 38.42) |
| | Producers (n=11) | 1.18 (0.45 – 3.30) | 26.14 (14.03 – 35.06) | 11.93 (6.40– 16.01) |
| | Sub-Total: | 2.21 (0.25– 29.14) | 32.47 (14.03 – 84.15) | 14.83 (6.40 – 38.42) |
| Codex Alimentarius Standard Value: | | 0.25 | 10 | 5 |
| Percentage higher than Codex Alimentarius Standard Value (%) | | 99% | 100% | 100% |

The following figures below present the results obtained from the Sudan dye detection test (Nwachoko and Fortune, 2019; Ibukun and Augustine, 2021); Figure 1 shows the appearance of non-adulterated samples upon testing and Figure 2 presents the adulteration suspected samples. Figure 3 below shows the results obtained using the method developed using chlorine to detect Sudan dye in red palm oil.

**Figure 1:** Non-adulterated samples from the chemical test.

**Figure 2:** Adulterated samples from the chemical test.

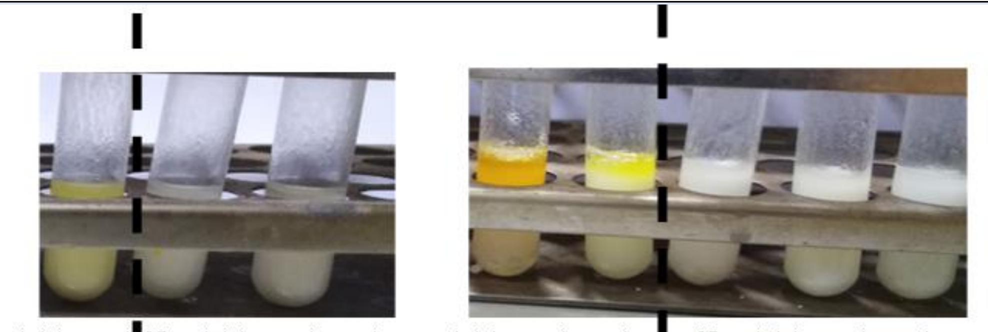


**Figure 3:** Adulterated sample and non-adulterates samples from the depigmentation test

## Discussion

Given the moisture content in red palm oil, previous studies conducted in Cameroon showed that the moisture content of Red Palm Oil from smallholders was relatively higher than palm oil originating from industrial mills (< 0.25% standard value) (Ngando et al., 2013) surely because of the inadequate processing of palm oil by smallholders failing to evaporate sufficient amounts of water to conform to standards (MacArthur, Teye and Darkwa, 2021). Ngando et al. (2013) recorded the highest value of 3.06% in a sample collected from a local market in Douala. In this study, 99% of the samples had a moisture content between (0.25-3%) which was similar to the results obtained by Okechalu et al. (2011) and by Ngando et al. (2013) from small holders' palm oil samples in Nigeria and in Cameroon respectively. Out of these 86 samples, 13 samples (15,12%) had a moisture content higher than 3% with the majority of those samples (53,85%) collected from the Centre region (Yaounde), followed by 46,15% from the Littoral (Douala). These unusually high values may in part be suspected to be an intentional addition of water (much likely wastewater originating from palm oil processing as suggested by Djomptchouang and Abia (2024) to palm oil: Adulteration. As explained by Ngando et al. (2013), though oil and water are immiscible, the presence of water can be compatible with red palm oil at low concentrations. Water is then considered as an adulterant in red palm oil when the moisture content is relatively high compared to the standard. Water may seem inoffensive, a vague parameter that depends on the quality of the water, but it catalyzes Biochemical and microbiological biodegradation reactions taking place in the oil that could affect human health upon consumption. Additionally, previous studies revealed that high moisture content enhances oxidative degradation and thus oil acidity and peroxide value (Ngando et al., 2011, 2013). Concerning oil acidity, in the presence of moisture content above the maximum limit, Free Fatty Acids (FFA) will be formed by a chemical process called autocatalytic hydrolysis where FFA moieties initially present, act as catalysts for the reaction between triacyl glycerols and water to generate more FFA (Ngando et al., 2011, 2013). Furthermore, water can enhance Peroxide Value and peroxidation is known to make the oil dangerous for human health as the free radicals generated by this process are proven to be carcinogenic (Rossel, 1999) cited by Ngando et al. (2011, 2013). Therefore, high moisture content in Crude Palm oil or Virgin Palm Oil may become a real concern regarding food safety.

Concerning the acid values. all the studied samples had an acid value higher than the Codex Alimentarius standard value of 10 mg NaOH/g, implying that all studied samples suffered from quality deterioration which could be due to the processing technique or to the observed extremely high moisture content. The results were similar to those obtained by MacArthur, Teye and Darkwa (2021) in Ghana and Ngando et al. (2011, 2013) in Cameroon. Solely based on the process used by smallholders, it is very likely for their red palm oil to have unusually high acid values partly because fresh fruit bunches before extraction are fermented for 5-7 days to enable the fruits to be easily detached from the trunk. During this period, the fruits that were probably bruised could have accumulated triacylglycerol molecules and, under the activation of lipase, this could be further enhanced during the fermentation of fruit bunches, when microbial lipolytic action takes place. Upon sterilization the enzyme is deactivated, as well as the microbes; but the Free Fatty acids (FFA) formed remain and may increase during storage as a result of autocatalytic hydrolysis where FFA act as a catalyst between water and triacylglycerols to produce more

FFA (Ngando et al., 2013). However, the high acid Values in this current study could suspect the use of rotten fruits for palm oil extraction. The highest value recorded originated from a sample collected in Douala where the mean value was 33 mg NaOH/g followed by the Centre region with a mean of 31,76 mg NaOH/g (Table 15). Generally, samples obtained from producers recorded lower values when compared to those collected on the markets which could be explained by the difference in storage time (Table 15).

For the Free Fatty acid (FFA) contents, it was the same pattern as with the Acid value: the South-West ranking was first followed by the Centre (Yaounde), Littoral (Douala), and West regions with the producers recording lower values than those recorded for samples collected in the markets (Table 15). It is in accord with the results from Ngando et al. (2011,2013), and these high FFA may be as a result of the high moisture content. It can result from microbial contamination during processing, packaging, transport, storage and even selling conditions.

Upon testing for the presence of the carcinogenic banned azo dyes, Sudan dye, out of 86 samples, only 3.49% (3/86 samples) tested positive and thus considered as suspected samples. Two of the three suspicious red palm oil samples were collected from local markets in Yaoundé and the other one was from a local market in Douala. From these results, we confirmed that adulteration of red palm oil using Sudan dyes is a reality in Cameroon, although low but, cannot be underestimated when considering the toxicity of those dyes.

## Conclusion

Red palm oil is a very important component of Cameroonian and African cuisine very appreciated by consumers, especially for its bright red colour; which makes it irreplaceable in many recipes. Generally produced by the smallholders (or local producers, and known as artisanal RPO – mainly for cooking) and RPO industries (less often for cooking), the quantities produced mostly fail to meet customers' demand which has been growing over the years leading to a situation where demand is higher than offer; therefore giving way to unscrupulous individuals to resort to adulteration (addition of water to increase the bulk or dyes to enhance its colour) to attract more customers and gaining more. In this study, moisture content, acid value, as well as free fatty acids content were used as indicators to assess red palm oil adulteration; however, two other analyses were used to detect the presence of dyes in Red Palm Oil. Out of the 86 studied samples 3 were suspected of adulteration with dyes while adulteration with water was mostly certain as 99% of the samples did not conform to the Codex Alimentarius Standard value for moisture content. As inoffensive as it may seem adulteration with water induced consequences on the final product quality and safety as it impacts the acid value and free fatty acids content which are both out of the norm for all the studied samples. Therefore, more efforts are needed to better understand the red palm oil adulteration pattern in Cameroon and ways of detection.

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