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Some Factors Affecting Quality of Crude Palm Oil Sold in Douala, Cameroon

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Abstract

Crude palm oil (CPO) is an essential ingredient of Cameroonian recipes. However, its quality is subject to doubt, considering the very often inadequate conditions of extraction, conditioning, storage, and selling in the fast growing small holder sector or in the market. This work aimed to evaluate the influence of seasons and containers on the microbiologic, physicochemical quality and the carotenoids content of CPO sold in Douala. A total of 194 samples of CPO were randomly collected in seven markets among which: 95 during the rainy season and 99 during dry season; 93 from CPO contained in opened containers and 101 in closed containers. In these samples, aerobic count colony (ACC) load, total yeasts and moulds load, peroxide value (PV), free fatty acids content (FFA), impurity level and carotenoids content were assayed.The samples tested had ACC load of $4.48 \pm 1.86 \times 10^5$ CFU/ml, total yeasts and moulds load of $0.30 \pm 0.14 \times 10^5$ CFU/ml, PV of 1.81 ± 0.74 meqO_2/kg, FFA of 4.30 ± 1.82%, impurity level of 0.34 ± 0.16% and carotenoids content of 756.41 ± 110.67 mg/l. Also, none of these parameters had varied according to the market. Moreover, among these parameters, PV and carotenoids content were not varied whatever CPO is sold during rainy or dry season, in open or closed containers while others parameters analysed were significantly ($P<0.05$) higher during dry season or when the CPO was contained in open containers. Consequently, traders should make efforts to avoid CPO contamination during the selling. They could package it first and store it in an adequate space particularly during dry season.

Keywords: carotenoids content, crude palm oil, Douala markets, microbiology quality, physicochemical characteristics, vitamin A deficiency

1. Introduction

"Oils" is a collective term for more or less viscous, generally organic chemical liquids. Palm oil (orange-red to brownish or yellowish-red in colour) is extracted from the fleshy mesocarp of the fruit of *Elaeis guineensis* Jacq (Okechalu, Dashen, Lar, Okechalu, & Gushop, 2011; Olorunfemi et al., 2014). With an annual global production equating to about 39% of world production of vegetable oils, palm oil has outclassed soybean during the last decade to become the most important oil crop in the world (Oil World, 2015). Like other vegetable oil sources, palm oil has found application in food and industries (Chabiri, Hati, Dimari, & Ogugbuaja, 2009; Berger, 2010). Their major applications include biodiesel production, pharmaceutical, cosmetics, polish, detergents, shampoo, lipstick etc. In food industries, it is an ingredient in margarine and confectionaries (Pleanjai, Gheewala, & Garivait, 2007; Berger, 2010; Ohimain, Izah, & Fawar, 2013). Due to long term local eating habits and cheaper cost, palm oil is extensively used in its crude form for food purposes throughout Africa and Asia regions (Ngando, Mpondo, & Ewane, 2013). This can be nutritionally beneficial, as crude palm oil (CPO) is a rich source of some essential nutrients such as vitamin E and carotenoids (Edem, 2002; Berger, 2010). Palm oil vitamin E has been extensively studied for its nutritional and health properties including antioxidant activities, cholesterol lowering, anti-cancer effects and protection against atherosclerosis (Srivastava & Gupta, 2006; Odia, Ofori, & Maduk., 2015). Because of its high content in provitamin A carotenoids, CPO constitutes an important food that could be used to prevent vitamin A deficiency (Zeb & Mehmood, 2004; Edem, 2009; Mukherjee &

Mitra, 2009; Odia et al, 2015).

Worldwide, CPO is extracted by industrial, semi-industrial or traditional methods; non industrial sector representing about 30% of total production. Traditional methods are employed by individuals who have little or no knowledge neither of modern aseptic production techniques nor of the microbiological implication of poor sanitation and storage methods (Ngando, Mpondo, Dikotto, & Koona, 2011; Nkongho, Feintrenie, & Levang, 2014). Therefore, palm oil is prone to contamination by microorganisms found in the environment, raw materials and equipments used for the processing, as well as those used for storage and distribution (Okechalu et al., 2011). The microbial quality of CPO is essential because they play adverse role in food and feed products. Though, CPO used for cooking is subjected to heat which may reduce and/or kill all the microorganisms that could invade the CPO. Unfortunately, in many countries, some individuals still consume CPO raw. Also, in traditional medicine, CPO is also used as ingredient for the cure of ailments. As a result, microorganisms present in oil could cause others diseases. Moreover, microorganisms are known to cause chemical changes in CPO that lead to deterioration in their quality (Okpokwasili & Molokwu, 1996).

In fact, some microorganisms could have a lipolytic activity and therefore lead to increase of oil acidity (Okechalu et al., 2011; Ohimain et al., 2013). Besides, the most effective degradation process of CPO is acidification. Generally, fatty acids are present in oils as part of triacylglycerol molecules. The presence of free fatty acids (FFA) molecules is an indication of the impairment of the quality of oils, as FFA are liberated from the triacylglycerol molecules under the action of lipases and esterases. Acidification is generally assessed through determination of oil acidity or FFA content which is one of the most important criterion for determining the quality of cooking oils (Chabiri et al., 2009). Another degradation reaction of CPO regarding food safety is lipid peroxidation. This process involves unsaturated molecules such as fatty acids and carotenoids which undergo a chain reaction mechanism involving free radicals as intermediates and generating lipid peroxides as end products. The latter undergo additional chain cleavage at the level of the hydroperoxide group to form secondary oxidation products such as short chain aldehydes and products bearing ketone, epoxy or alcohol groups responsible for the rancid smell and taste of the oil. The determination of peroxide value (PV) gives an indication of the level of lipid peroxidation of cooking oils. Alongside oil acidity and PV, impurity level is also one of the most important criterion for determining the quality of cooking oils and fats regarding food safety (Ngando et al., 2011, 2013; Ohimain et al., 2013; Chuks et al., 2016). Contribution in the fight against vitamin A deficiency being one of the most nutritional benefit of CPO, their carotenoids content is an important parameter in the evaluation of its quality.

In Cameroon, palm oil accounts for about 90% of edible oil needs (Ngando et al., 2011). Its great production areas are around Douala. A survey done there showed that CPO is used in 97% of households and that 87% of population regularly consume foods prepared with CPO. In Douala markets, CPO mainly comes from small holders who use traditional methods for the extraction. It is usually marketed in closed containers (barrels, buckets, cans, bottles) although some traders sometimes use open containers (bowls, basins, buckets). Furthermore, environmental conditions of the areas of CPO production and of the markets of its distribution are not always adequate and change enormously from one season to other. In fact, during rainy season, there is mostly mud and stagnant water puddles whereas during dry season there is mainly dust. Considering these observations, one can assume that the quality of CPO available in local markets is subject to doubt. Very little researches carried out on this aspect in Cameroon, particularly in Douala. The few studies on the quality of CPO done by Ngando et al. (2011, 2013) and by Goudoum, Makambeu, Abdou and Mbofung (2015) were only on physicochemical parameters. Besides, they showed that some of these parameters varied according to the production process, to the storage time and to the market of distribution. What about microbiological quality and carotenoids content? Could the season of distribution and the kind of container used influence this quality?

The present work aimed to assess the microbiological quality, the physicochemical characteristics and the carotenoids content of CPO sold in some markets in Douala and to study the influence of season and of the kind of containers used on these parameters.

2. Materials and Methods

2.1 Study Area

This study was carried out in Douala town, Economic Capital of Cameroon, situated near the Atlantic Ocean (Latitude 4°2′51″N, Longitude 9°42′23″E).

2.2 Samples Collection

A total of 194 samples of CPO were randomly collected in seven markets of Douala town particularly

Bonamoussadi (n = 34), *Makepe Missoke* (n = 23), *Dakar* (n = 30), *Ndogpassi* (n = 21), *New-bell* (n = 33), *Grand Hangar Bonabéri* (n = 25) and *Deido* (n = 28). Among these samples, 95 were collected during rainy season (between September and mid-November 2014) and 99 during dry season (between mid-November and December 2014). Moreover, 93 samples were collected from CPO contained in completely open containers (bowls, basins, buckets) and 101 from oils exposed in closed containers (buckets, cans, bottles). For each sample, about 200 ml of CPO was collected in a sterile plastic bottle. Care was taken not to contaminate the bottles before and during collection of the samples. After collection, samples were transported to the laboratory for tests. Once in the laboratory, a part of each sample was used for microbiological assays (aerobic count colony or ACC load, total yeasts and moulds load) before 24 hours. The rest was kept at 4 °C until analysis of physicochemical parameters (PV, FFA and impurity level) and of carotenoids content.

2.3 Analysis Methods

2.3.1 Microbiological Analysis

Aerobic count colony and total yeasts and moulds of the samples were enumerated using serial dilution pour plate method of Pepper and Gerba (2004). For each sample, a stock solution was obtained by diluting 10 ml of CPO in 90 ml of sterile Tween 80 (Merck, Germany). Three serial decimal dilutions were made from each stock solution. Aliquots of the two last dilutions (10^{-3} and 10^{-4}) were used to determine the ACC and the total yeast and mould according to AFNOR (*Association Française de la Normalisation*) protocols (AFNOR, 2002, 2013).

For ACC enumeration, plate count agar or PCA (Liofilchem, Italy) was used. Sterile nystatin (250 mg/l) was added to suppress fungi growth. The medium was autoclaved at 121 °C for 15 min. For each sample, 1 ml of required dilution was pipetted to appropriate marked duplicate Petri plates. Then, 19 ml of cooled medium was poured into each plate and mixed by rotating and tilting. After solidification, each plate was incubated for 48 to 72 hours at 30 °C.

Concerning yeasts and moulds enumeration, Sabouraud CAF agar containing chloramphenicol (Liofilchem, Italy) was used. The medium was autoclaved at 121 °C for 15 min. For each sample, 1 ml of required dilution was poured to appropriate marked duplicate Petri plates containing 19 ml of cooled medium. After mixing by rotating and tilting, each plate was directly incubated after solidification at 25 °C for 72 hours.

Aseptic conditions were employed in all the procedures. After incubation, the growth colonies were promptly counted and the results were expressed as colony forming units per millilitre (CFU/ml).

2.3.2 Physicochemical Parameters Determination

2.3.2.1 Peroxide Value

Peroxide value was performed by titrimetric method according to Association of Official Analytical Chemists protocol (AOAC, 1990). Briefly, for each sample a mixture of glacial acetic acid and chloroform (Merck, Germany) in the ration 3:2 was added to 2 g of oil sample. Thereafter, one added 0.5 ml of saturated (144 g per 100 mL of distilled water) potassium iodide (Merck, Germany) solution; agitated during 1min and added 15 ml of distilled water and 0.5 ml of starch. Thereafter, this solution was titrated with 0.1N sodium thiosulphate (Merck, Germany) until total disappearance of blue colour. Meanwhile, a blank test without oil was done. Peroxide value was calculated from the equation:

$$PV\ (meqO_2/kg) = 1000 \times (V_2 - V_1) \times N / M \quad (1)$$

Where:

M = mass of oil taken

V2 = volume of sodium thiosulphate for essay

V1 = volume of sodium thiosulphate for blank

N = normality of sodium thiosulphate (0.1N)

2.3.2.2 Free Fatty Acids

Free fatty acids level was evaluated by titrimetric method according to AOAC protocol (AOAC, 1990). Briefly, for each sample 25 ml of ethanol (Merck, Germany) was added to about 2 g of oil sample. The mixture was brought to boil in a water bath and then cooled down. After adding 2 drops of phenolphthalein (Merck, Germany) as indicator, 0.1N NaOH (Merck, Germany) was used to titrate the mixture with constant shaking for proper mixing until end-point (appearance of violet colour). The FFA was calculated as followed:

$$FFA = V \times N \times M / 10xW \quad (2)$$

Where:

V = volume of NaOH

N = normality of NaOH (0.1N)

M = molecular weight of palmitic acid (256 g/mol)

W = weight of the sample

2.3.2.3 Impurities Level

The impurities level were determined after dissolving oil in hexane (Merck, Germany), followed by filtration and oven drying to a constant weight as described in Ohimain et al. (2013). Thus, for each sample about 10 g of CPO was weighed into the beaker and 100 ml of hexane was added. After agitation and filtration, the residue obtained was dried until constant weight in an electric oven (Binder FDL 115, Germany). This residue was calculated as the percentage of impurities.

2.3.3 Carotenoids Content Determination

Carotenoids content was evaluated by photometry at 446 nm according to protocol used previously by Dongho, Ngono, Demasse, Schweigert and Gouado (2014). For each sample, 20 µl of oil was diluted with 2 ml of hexane. After vigorous shakeup, the mixture was read with a photometer (iCheck™ Carotene; BioAnalyt GmbH, Germany) which gives the carotenoids content of solution in mg/l. The carotenoids content of CPO was calculated from this value by taking into account the dilution factor.

2.3.4 Statistical Analysis

Data were processed using format designed in Microsoft Excel version 2010. Statistical analyses were performed with Graph Pad Prism package version 5.00 (San Diego California USA). T-Student and one-way ANOVA (analysis of variance) tests were used for multiple comparisons. P-values were used as measure of significance and P<0.05 was considered significant.

3. Results

3.1 Quality of CPO According to the Market

The microbiological and physicochemical quality and carotenoids content of CPO sold in some Douala markets are given in the table 1. The results showed that none of the parameters analysed varied significantly according to the market. For microbiological quality, one noted that ACC load and total yeasts and moulds population are higher than values recommended by standards i.e. $<3x10^5$ UFC/mL for ACC (AFNOR, 2013) and $<10^2$ UFC/mL for total yeasts and moulds (AFNOR, 2002). Concerning physicochemical parameters, contrary to PV and FFA that the values obtained are acceptable according to the recommended standards (i.e. <10 $meqO_2/kg$ for PV and <5% for FFA), the impurity level has the values higher than the recommended values i.e. <0.05% (Codex Alimentarius Commission/FAO/WHO Food Standards, 2015). As for carotenoids content, their values are ranged in normal values i.e. from 700 and 900 mg/L (Codex Alimentarius Commission/FAO/WHO Food Standards, 2015).

Table 1. Quality and Carotenoids Content of Crude Palm Oil Sold in Douala According to the Market

PARAMETERS	MARKETS							TOTAL	P
	Bonamoussadi (n = 34)	*Missoke* (n = 23)	*Dakar* (n = 30)	*Ndogpassi* (n = 21)	New-*Bell* (n = 33)	*Grand Hangar Bonabéri* (n = 25)	*Deido* (n = 28)		
ACC (CFU/ml x 10^5)	4.18±1.83[a] 1.47-8.00[b]	4.13±1.92 1.70-8.10	4.63±1.98 1.30-8.70	4.70±1.96 1.50-8.00	4.58±1.74 1.90-9.10	4.71±1.82 2.80-8.90	4.48±1.90 2.5-8.7	**4.48±1.86** **1.3-9.10**	***0.638***
Total yeasts and moulds (CFU/ml x 10^5)	0.28±0.12[a] 0.08-0.60[b]	0.32±0.15 0.09-0.60	0.32±0.15 0.10-0.61	0.30±0.13 0.12-0.60	0.25±0.13 0.09-0.61	0.32±0.14 0.10-0.69	0.30±0.14 0.1-0.68	**0.30±0.14** **0.08-0.69**	***0.658***
PV ($meqO_2/kg$)	1.82±0.73[a] 0.90-4.30[b]	1.69±0.67 0.70-3.00	1.70±0.60 0.8-3.00	1.82±0.79 0.80-3.10	1.94±0.84 0.70-3.50	1.80±0.77 0.70-3.10	1.87±0.82 0.70-3.10	**1.81±0.74** **0.70-4.30**	***0.8710***
FFA (%)	4.07±1.64[a] 2.10-10.00[b]	4.87±2.25 2.00-11.00	3.86±1.33 1.70-7.80	4.03±1.44 1.90-7.80	3.97±1.60 1.50-7.00	4.71±1.90 1.70-9.00	4.81±2.31 2.10-10.10	**4.30±1.82** **1.50-11.00**	***0.1355***
Impurity level (%)	0.32±0.23[a] 0.128-1.280[b]	0.37±0.18 0.160-0.800	0.33±0.14 0.144-0.640	0.32±0.16 0.036-0.640	0.35±0.13 0.144-0.640	0.36±0.11 0.224-0.640	0.34±0.14 0.128-0.640	**0.34±0.16** **0.036-1.28**	***0.8823***
Carotenoids content (mg/L)	755.82±112.55[a] 548-960[b]	747.41±110.49 590-915	724.87±105.57 510-915	779.90±100.36 619-915	768.82±124.89 497-1009	785.32±106.07 597-975	739.71±106.72 603-954	**756.41±110.67** **497-1009**	***0.3961***

Note. ACC: aerobic count colony; CFU: colony forming units; PV: peroxide value; FFA: free fatty acids; *a:* mean ± standard deviation; b: range

3.2 Influence of the Season

The results (Table 2) showed that contrary to PV and carotenoids content of CPO which did not vary according to the season of commercialisation, ACC load, total yeasts and moulds, FFA and impurity level were significantly higher in samples collected during dry season than those collected during rainy season.

Table 2. Quality and Carotenoids Content of Crude Palm Oil Sold in Douala According to the Season

PARAMETERS	SEASON		P
	Dry season (n = 99)	Rainy season (n = 95)	
ACC (CFU/ml x 10^5)	4.98±2.01	3.95±1.52	*<0.0001*
Total yeasts and moulds(CFU/ml x 10^5)	0.34±0.15	0.26±0.12	*0.0002*
PV (meqO_2/kg)	1.81±0.72	1.81±0.77	*0.9945*
FFA (%)	4.70±1.94	3.88±1.58	*0.0016*
Impurity level (%)	0.37±0.18	0.31±0.12	*0.007*
Carotenoids content (mg/L)	750.22±119.85	762.82±100.51	*0.4295*

Note. ACC: aerobic count colony; CFU: colony forming units; PV: peroxide value; FFA: free fatty acids; values are given as mean ±standard deviation

3.3 Influence of the Kind of Container Used

Table 3 gives the quality and the carotenoids content of CPO sold in Douala according to the kind of container used. As previously, we noted that PV and carotenoids content of CPO did not vary that samples have been collected from CPO exposed in open containers or in closed containers. On the contrary, AAC load, total yeasts and moulds, FFA and impurity level significantly varied from one kind of container to other. In fact, these parameters were significantly higher in samples collected from CPO exposed in open containers compared to those exposed in closed containers.

Table 3. Quality and Carotenoids Content of Crude Palm Oil Sold in Douala According to the Kind of Container Used

PARAMETERS	CONTAINER		P
	Open (n = 93)	Closed (n = 101)	
ACC (CFU/ml x 10^5)	5.48±1.94	3.56±1.19	*<0.0001*
Total yeasts and moulds (CFU/ml x 10^5)	0.37±0.14	0.24±0.10	*<0.0001*
PV (meqO_2/kg)	1.85±0.75	1.77±0.74	*0.4891*
FFA (%)	4.60±1.97	4.02±1.63	*0.0262*
Impurity level (%)	0.39±0.18	0.29±0.12	*<0.0001*
Carotenoids content (mg/L)	764.87±115.56	748.58±106.00	*0.3072*

Note. ACC: aerobic count colony; CFU: colony forming units; PV: peroxide value; FFA: free fatty acids; values are given as mean ±standard deviation

4. Discussion

This study was done to assess the microbiological quality, the physicochemical characteristics and the carotenoids content of CPO sold in Douala. The result showed that ACC load and total yeasts and moulds population were higher than values recommended by standards (AFNOR, 2002; 2013). This result agrees with similar studies done in Nigeria by Ekwenye (2006), Okechalu et al. (2011), Enemuor, Adegoke, Haruna and Oguntibeju (2012), and Chuks et al. (2016). The presence of microorganisms in CPO gets us to ask questions about the health of consumer. Indeed, although the majority of Cameroonian dishes CPO-based are prepared hot, there also exist some which are prepared when cold such as yellow sauce. Likewise, CPO is sometimes used as vehicle of traditional medicine. In fact, even if microbial load is an essential marker of the food quality, it is the nature of the microorganisms present which is a sure indicator. Indeed, a food can have a low load, but contain microorganisms that could be harmful for the consumer or that could contribute to the deterioration of that food (Codex Alimentarius Commission/FAO/WHO Food Standards, 2015). Besides, Ekwenye (2006), Okechalu et al. (2011), Enemuor et al. (2012), Izah and Ohimain (2013), Ohimain et al. (2013), and Chuks et al. (2016) revealed the presence in CPO of bacteria and fungi that could be dangerous for the consumers (implication in affections

like respiratory tract infection, septicaemia, meningitis, hepatitis and cancers) or increase the acidity of oil (microorganisms with lipase activity). This presence of microorganisms in CPO could be due to the manipulations after production. In fact, according to its extraction process, one will not expect the presence of microorganisms because during the stages of cooking/sterilisation of palm nuts (at about 100 ℃) and of cooking of oil paste (at about 100 ℃), all the microorganisms initially present should be death. So, it is probably after production that CPO can be contaminated particularly during the operations of packaging, storage, transport or distribution. This explanation is as much true that the results obtained from our study and from the studies of Ekwenye (2006), Okechalu et al. (2011) and Enemuor et al. (2012) with CPO collected in the markets were in order of 10^4-10^5 for bacteria and of 10^3-10^4 for fungi while the results obtained by Izah and Ohimain (2013) and Ohimain et al. (2013) with CPO newly produced were only in order of 10^3-10^4 for bacteria and of 10^2-10^3 for fungi.

Concerning the physicochemical parameters, we noticed that contrary to PV and FFA the values obtained were acceptable according to the recommended standards, the impurity level has the values higher than the values of recommended standards (Codex Alimentarius Commission/FAO/WHO Food Standards, 2015). These results tally with those obtained in similar studies in Nigeria by Ekwenye (2006), Okechalu et al. (2011), Agbaire (2012), Enemuor et al. (2012), Izah and Ohimain (2013), Ohimain et al.(2013), Olorunfemi et al. (2014), and Chuks et al. (2016); in Egypt by Abd El-Gawad, Hamed, Zidan and Shain (2015) and in Cameroon by Ngando et al. (2011 ; 2013) and Goudoum et al. (2015).

Peroxide value is a parameter used to assess the quality of cooking oils and fats through the measurement of the amount of lipid peroxides and hydroperoxides formed during the initial stages of oxidative degradation and thus, estimate to which extent spoilage of the oil (expressed by the level of rancidity) has advanced. Beside these visible harmful effects on the sensory quality of the oil, peroxidation also makes the oil dangerous for human health, as the free radicals generated by this process are proven to be carcinogenic (Pignitter & Somoza, 2012). Regarding oxidation, PV does not help us to find out the real oxidation level of oil. In fact, this parameter assesses the peroxides contained in oil. These peroxides are very unstable and can later undergo additional chain cleavage to form secondary oxidation products such as short chain of aldehydes and products bearing ketone, epoxy or alcohol groups responsible for the rancid smell and taste of the oil (Ngando et al. 2011). Unfortunately, PV does not take into account these products. So this parameter just gives the oxidation of oil at a precise moment. Indeed, peroxide formed before the moment of analyse could be already transformed to secondary products. It is the reason why the best method of evaluating of the real oxidation level of oil must take into account not only the peroxides, but also these products. The latter are evaluated by anisidine value (AV) which takes into account aldehydes, ketones, epoxides and alcohols. Total oxidation (TOTOX) of oil can be calculated using the equation: $TOTOX = 2PV + AV$ (Ngando et al., 2011; Pignitter & Somoza, 2012). Thus, even if we obtained a PV respecting the standards in this study, we cannot guarantee that CPO sold in Douala was not oxidised enough after its production.

As for FFA, it is known that their accumulation in CPO is mainly due to the action of an active endogenous lipase presents in the mesocarp of the fruit of the oil palm. This lipase is activated in the fruit at maturity upon wounding and/or bruising and is responsible for the hydrolysis of triglycerides and the liberation of FFA (Ngando et al., 2011). In order to limit the action of this lipase, fresh fruit bunches must be processed rapidly after harvest. The presence of FFA in the CPO could also be explained by the contaminating lipases from microorganisms (Ekwenye, 2006). In fact, although microorganisms present in the palm nuts and in others intrans used during the extraction are almost destroyed during the sterilisation, CPO produced could be contaminated as brought up above by microorganisms (among which those lipase activity) during the operations of packaging, storage, transport or distribution. Moreover, once the fruits are processed, the lipase is no more active, but the FFA of the resulting palm oil may also increase during storage as a result of autocatalytic hydrolysis. In that case, FFA acts as catalysts for the reaction between triacylglycerols and water to produce more FFA (Ngando et al., 2013).

The impurities usually present in oils are all the compounds and/or particles insoluble in oils. We have between others carbohydrate compounds such as gums, metals, metallic particles, metallic ions, metallic complexes and all others solid particles. Their level in CPO is usually associated to production method (Ohimain et al., 2013, Chuks et al., 2016). Besides, Ngando et al. (2011) showed that CPO produced traditionally had an impurity level higher than that of CPO produced industrially. Furthermore, these impurities could come from the environment during the operations of packaging, storage, transport or distribution. The high level of impurities obtained in this study could be explained by the methods of extraction. In fact, CPO sold in Douala mainly comes from small holders who produce oil by traditional method. The important part of CPO produced industrially being

generally dedicated to oil refineries and soap factories.

Carotenoids are naturally presented in the mesocarp of palm nuts. Besides, CPO is known as the richest food in carotenoids (700 and 900 mg/L) mainly β-carotene (Codex Alimentarius Commission/FAO/WHO Food Standards, 2015). The results of this study confirm this observation and corroborate with those obtained by Agbaire (2012) and Olorunfemi et al. (2014) in a similar study done in Nigeria.

The results showed that any parameters analysed significantly varied according to the market where samples were collected. These results were not surprising because the major part of CPO sold in Douala markets comes from the same areas of production particularly *Moungo*, *Sanaga Maritime* and *Fako* divisions. Furthermore, sampling was practically the same in all the markets tested. Indeed, in each of these markets, the samples were collected during the rainy season as well as during the dry season. They were collected from CPO contained in open containers as well as from those in closed containers. Our results are not comparable to those of Ngando et al. (2013) which showed a significant difference of the quality of CPO (PV and FFA) from one market to another. The difference noticed between the two studies could be explained by the size of sampling because in this study, we analysed at least 21 samples per market while Ngando et al. (2013) analysed only 04 samples per market.

As for the effect of season, we noticed that contrary to PV and carotenoids content which did not vary according to the season, others parameters analysed (ACC, total yeasts and moulds load, FFA and impurity level) were significantly higher in samples collected during the dry season than those collected during the rainy season. This difference could be attributed to the environment of the areas of production, packaging, transportation and distribution which changes considerably from one season to the other. Indeed, during the rainy season, the environment is most often humid and one usually has water puddles and mud while during the dry season there is usually a dust because the environment is always dry. Contrary to mud, dust is volatile. Therefore, when the wind blows, they can settle on CPO during the operations of packaging, storage, transport or distribution (Nkongho et al., 2014; Bechoff et al., 2015; Goudoum et al., 2015). This dust most often contains microorganisms; hence the direct increase of microbial load of CPO contaminated by dust is evident. Some of these microorganisms could have a lipase activity (Izah & Ohimain, 2013; Ohimain et al., 2013), so it is normal that increasing level of microbial load of a sample automatically lead to its FFA. Beside microorganisms, this dust could contain solid particles insoluble in oil that could explain the increasing of impurity level of samples contaminated by dust. Furthermore, the dust could not contain any factors able to act on oxidation of oil, this could justify why the PV and the carotenoids content did not vary according to the season.

Concerning the effect of the kind of containers used, we observed as previously that PV and carotenoids content did not vary from one kind of container to another while other parameters analysed were significantly higher in samples collected from CPO contained in open containers compared to those collected from CPO contained in closed containers. As previously, this increase could be attributed to the environment of the markets. In fact, whatever the season, CPO samples contained in open containers are more exposed to contamination compared to those contained in closed containers. Indeed, during the dry season, we can have the contamination by dust and in the rainy season, contamination by water or mud spatters. Be it, dust or water/mud spatters, they can contain microorganisms (that could explain the increase of microbial load and of FFA) or solids particles (explaining the increase impurity level).

5. Conclusion

At the end of this study which consisted of evaluating the microbiological quality, the physicochemical characteristics and the carotenoids content of CPO sold in Douala town, we can conclude that with the exception of PV, FFA and carotenoids content which had acceptable values as recommended by standards; impurity level, ACC load, total yeasts and moulds had values higher than the standards. Also, none of these parameters had varied according to the market. Moreover, among these parameters, PV and carotenoids content didn't vary which ever CPO is sold during the rainy or the dry season, in open or closed containers while other parameters analysed were higher during the dry season or when the CPO was contained in open containers. We can recommend traders to make efforts to avoid CPO contamination during the selling. They could for examples keep CPO in closed containers and store it in an adequate space particularly during dry season. Thus, in order to complete this work, we are intent in our next researches to study the effects of these solutions on the quality of CPO.

Conflict of interests

FJS is shareholder of BioAnalyt GmbH, Germany. All other authors declare no conflict of interests regarding the publication of this paper.

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