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Review

A review of main factors affecting palm oil acidity within the smallholder oil palm (*Elaeis guineensis* Jacq.) sector in Cameroon

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Crude palm oil from the mesocarp of *Elaeis guineensis* Jacq fruits is one of the most consumed vegetable oil in the world. The quality of palm oil assessed mainly by its free fatty acids (FFA) content and impurities, varies between the artisanal and industrial extraction and supply systems. The objective of this paper is to highlight the main parameters that influence the acidity or FFA content of crude palm oil produced by the smallholder artisanal sector. Three parameters examined are: crude palm oil production and extraction methods, microbial activity and oil palm genotype. These three parameters strongly increase lipase activity and hence palm oil acidity. In addition to endogenous lipase in fruit mesocarp, microorganisms found in palm oil are also involved in lipase activity e.g. *Aspergillus* sp, *Mucor* sp, *Penicillium* and *Candida* for fungi; and bacteria such as *Bacillus*, *Pseudomonas*, *Micrococcus, Staphylococcus* and *Enterobacter*. To improve the quality of palm oil, smallholders must first seek oil palm progenies with low acidity oil and respect the standard cultural practices for palm oil production.

Key words: *Elaeis guineensis* Jacq, palm oil acidity, microorganisms, production systems, genotype.

INTRODUCTION

Palm oil from the mesocarp of the oil palm (*Elaeis guineensis* Jacq.) fruit is the most produced vegetable oil in the world. Its consumption in 2015 was estimated at 35% (Soystat, 2016). In Cameroon for example, 70% of crude palm oil (CPO) is produced by the industrial sector constituted of major companies while the informal sector (smallholders) produces 30% CPO. Oil from industrial sector, which is acceptable for its dietary quality, is

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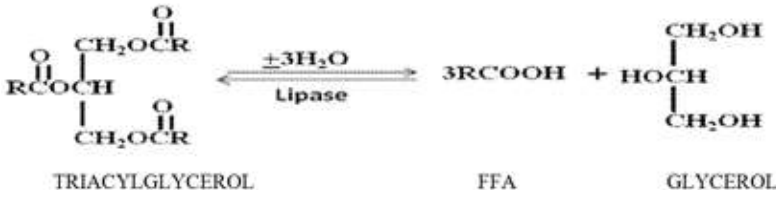

Figure 1. Origin of oil acidity (Patil et al., 2011).

destined for local consumption. Palm oil assures about 90% of locally consumed oil in Cameroon (Hirsch, 1999; Ngando et al., 2013).

Like most vegetable oils, palm oil is mainly composed of triglycerides or triacylglycerols which represent 95% of the total weight constituents. It also contains minor compounds such as diacylglycerol, mono glycerol and free fatty acids (FFA) issued from the biosynthesis and / or hydrolysis of triacylglycerols. Sterol, tocopherol, pigments and metal ions are also represented (Sundram et al., 2003). The majority of fatty acids are palmitic acid followed by oleic acid (Sambanthamurthi et al., 2000; Sundram et al., 2003; Corley and Tinker, 2008; Mancini et al., 2015).

Palm oil quality is usually evaluated on the basis of its acidity (indicator of FFA content) and impurities (Tagoe et al., 2012; De Almeida et al., 2013).

In fact, the FFA content could serve as an indicator for a good harvest and a good method of extraction. Their presence in palm oil indicates the level of oil degradation during the extraction process. If the FFA content is high, this indicates that the fruits were damaged between harvest and extraction or harvested fruits were rotten (De Almeida et al., 2013). High values of acidity due to lipase activity are a reflection of oil quality impairment. Without refining, such oil may be unsuitable for human consumption.

However, refining leads to the loss of palm oil nutritional value. In fact, once released from triglycerides, fatty acids are more susceptible to peroxidation process which breaks the bonds of unsaturated fatty acids and generates aldehydes and ketones responsible for palm oil rancidity. In the presence of water, FFA already present in small amounts act as catalysts in the reaction between the triglyceride and water, generating other FFA. This process occurs in the oil essentially when the water content is greater than 0.1% (Ngando et al., 2013). In oil production process, smallholders do not usually check this aspect.

In addition, oxidation caused by light and temperature is a factor that influences the organoleptic value of the oil by increasing its FFA content. In tropical regions where palm oil is used for domestic purposes, consumers who obtain palm oil from the market are not very concerned about the quality of this oil. Analysis of oil samples from 10 major markets in Douala, Cameroon, showed that oil acidity values of more than 50% of the samples were above 5% (Ngando et al., 2013), which is the maximum limit recommended for dietary CPO. Lipid peroxidation and oil acidity was also reported to increase significantly in CPO samples from none industrial oil mills during the first four weeks of storage making them unfit for consumption (Ngando et al., 2011).

It was also found that CPO contained a wide variation of FFA between 6.49 and 9.44% before storage which increased significantly during the first three months of storage with samples reaching up to 16.50% FFA at 30°C (Goudoum et al., 2015). A study in Nigeria also reported that palm oil acidity varied from 0.97 to 8.43% (Ohimain et al., 2013). The palm oil acidity comes from the hydrolysis of the triglycerides in oil by lipase (Figure 1).

This reaction is enhanced by several factors even though the endogenous lipase activity remains the leading cause of palm oil acidification. Desassis (1957) and De Almeida et al. (2013) showed a significant hydrolytic activity on mesocarp triglycerides of oil palm fruit which are wounded or fallen by abscission during the harvest and fermentation process. In addition, microbial lipase has been identified on palm oil (Morcillo et al., 2013). The FFA content of oil is determined by the analysis of its acidity. Several factors account for the increase of the palm oil acidity and include extraction system especially of the informal sector or smallholder artisanal oil producers (Figure 2); microorganisms present in palm oil (Table 1) and the genotype of oil palm (Table 2). The objective of this review was to highlight the situation of the informal CPO production sector as well as the main factors influencing the acidity of CPO as a contribution towards food safety.

MAJOR FACTORS AFFECTING PALM OIL ACIDITY

Artisanal extraction system

The first main influential factor is the oil extraction system. In this regard, artisanal production of palm oil by smallholders who lack mechanical fruit detaching equipment as in the industrial extraction systems, involves leaving bunches for several days after harvest and before

Figure 2. Some materials used by smallholders for artisanal palm oil production in Cameroon; a: fruits stored for several days; b: boiling of fruits with inappropriate apparatus; c: 'round the world' press and d: motorized press.

oil extraction in order to facilitate the detachment of fruits (Figure 2a). During this process, the lipase activity increases resulting in the hydrolysis of palm oil triglycerides. Before oil extraction, the detached fruits are boiled in drums (inappropriate equipment) using firewood for several hours (Figure 2b). Then the fruits are immediately introduced into the manual continuous screw presses called "round the world" (Figure 2c) or into a motorized press (Figure 2d).

The mixture obtained is boiled in drums containing water. The clarification by heating (using firewood) which removes the last traces of water from the oil is most often incomplete due to energy costs. The residual moisture of artisanal palm oil may reach 0.5% which is the major cause of its rapid acidification during storage (Ngando et al., 2013).

Preliminary studies have shown that palm oil lipase becomes more active in the mature fruits when they are detached or injured; this subsequently increases the acidity value of the palm oil produced (Ngando et al., 2008). By assessing palm oil produced by smallholders, Ngando et al. (2011) found significant differences between the acidity values of oil from smallholders and an industrial company in Cameroon. In addition to that, further studies attribute this significant difference to the long period of fruit storage before the extraction process

Table 1. Some lypolytic microorganisms of palm oil.

Classes	Microorganism	Role	References
Bacteria	*Bacillus* sp. *Pseudomonas* sp. *Staphylococus aureus* *Micrococcus* sp. *Enterobacter* sp.	Production of lipase and amylases Microorganism from contaminate oil	Okechalu et al. (2011), Tagoe et al. (2012), Ohimain et al. (2013)
Fungi	*Mucor* sp. *Aspergillus niger* *Penicillium* sp.	Production of lipolytic enzymes	Khan et al. (2005), Okechalu et al. (2011), Izahet al. (2013), Ohimain et al. (2013), Ezediokpu et al. (2015)
	Candida sp. *Aspergillus fumigatus* *Geotrichum*	Production of lipase	Okechalu et al. (2011), Tagoe et al. (2012), Agu et al. (2013), Izah et al. (2013), Ohimain et al. (2013)

Table 2. FFA contents in the mesocarp of fruits from different oil palm origins and progeny.

Origin	N°	Cross	Acidity (% palmitic acid)
Déli x La Mé	1	LM 2 T x DA 115 D	24.02
	2	LM 2 T x DA 115 D	30.95
	3	PO 3174 D x PO 3349 P	7.3
La Mé	4	PO 3281 T self	27.63
	5	PO 4973 T x PO 4749 P	5.25
	6	PO 4973 T x PO 4749 P	23.29
	7	PO 3281 T	39.6
Déli x YA	8	LM 8102 D x PO 4257 T	24.17
	9	LM 8102 D x PO 4257 T	28.56
Yangambi	10	LM 718 T self	28.67
	11	LM 718 T self	17.36
	12	PO 4257 T x PO 4260T	36.58
	13	PO 4257 T x PO4260 T	46.93

Source: Ngando et al. (2008).

(Tagoe et al., 2012). These authors evaluated the quality of palm oil from the fruits stored at different durations which showed that the acidity value of palm oil increases with the fruit storage time. Moreover, after its production and in order to increase profits, palm oil is often stored to be either consumed or sold during lower production periods. Oil acidity increases during such conservation periods. Gulla and Waghray (2011) showed that, the storage time influences FFA content of oil. Moreover, the duration of heat treatment and screen pore sizes were found to influence palm oil extraction yield and quality (Mulindi et al., 2016).

It can be concluded in line with Noviar et al. (2016) that, all activities conducted by humans in the informal palm oil production sector are liable to increase CPO acidity.

Influence of microorganisms on palm oil quality

The second influential factor is the action of micro-organisms. The microorganisms present in palm oil constitute a major determinant of increased oil acidity. Microorganisms are minute living things classified as: bacteria, fungi, mold and unicellular algae. They play several roles in human diet. In vegetable oils in general and especially in palm oil, these organisms play a fundamental role in the deterioration of dietary oil quality by increasing lipase activity. It has been reported that

45% of existing lipases are produced by bacteria, 21% by fungi, 18% by animals, 11% by plants and 3% by algae (Patil et al., 2011). An examination of the factors that influence palm oil quality revealed 15 fungi and 14 bacteria in palm oil (Tagoe et al., 2012). Okechalu et al. (2011) also found 11 microorganisms on commercialized palm oil.

These microorganisms secrete lipase during their metabolism, which activates the hydrolysis of palm oil triglycerides and increases FFA content. Lipases catalyze various reactions such as hydrolysis of triglycerides, esterification and transesterification of lipids (Demirbas, 2009; Ridha et al., 2015). Lipolytic activity of fungi like *Aspergillus* sp, *Mucor* sp and *Penicillium* sp has been demonstrated on rotten oil palm spikelets (Khan et al., 2005). The *Aspergillus* genus and *Enterobacter* were also identified in palm oil (Izah et al., 2016). Agu et al. (2013) showed a high lipolytic activity of microorganisms in oil containing soil. The microorganisms identified in this case belonged to the genera *Mucor* sp., *Aspergillus flavus* and *Candida* sp. Moreover, microbial lipase was identified on palm oil (Morcillo et al., 2013) in addition to endogenous lipase of the mesocarp of ripe fruit (Ngando et al., 2006).

Thus, palm oil acidity increases as a function of the microbial load. The presence of yeast in the mesocarp of the oil palm fruit was also demonstrated (Tombs and Stubbs, 1982). Yeasts which belong to the group of fungi secrete digestives enzymes including lipases and proteases. Palm oil acidity varies with the degree of fruit infection by microorganisms (Tombs and Stubbs, 1982). Their frequency in the commercialized palm oil was clearly defined in three markets within Jos Metropolis in Nigeria (Okechalu et al., 2011). The divergence between microorganisms and their variability could be explained by the diversity of the mode of production of marketed CPO.

These microorganisms are mostly present in the environment and are found in palm oil due to contamination by poor conditions prior to oil extraction which is common in the case of Cameroonian small-holder sector. The contamination could come from water and soil (Table 1, Figure 2). In general, palm oil producers do not take these parameters into consideration. They mostly use contaminated material (Figure 2). The lipolytic action can also occur when the fruit is bruised, releasing 8 to 10% of FFA within 40 minutes (Ekwenye, 2006).

Influence of palm genotype on oil acidity

Thirdly, the genotype of oil palm also determines the quality of oil it produces with regards to its acidity value. Palm oil acidity comes from the hydrolysis of palm oil triglycerides by active lipase present in the mesocarp of oil palm fruits at maturity (Ngando et al., 2006). This hydrolysis releases FFA in the palm oil. Lipases belong to the proteins group, derived from DNA by transcription and translation mechanisms. Since DNA depends on plant genome, it appears that palm oil acidity depends on the plant's genome. Analysis of palm oil acidity of some 11 oil palm progenies has shown that this trait is transmitted with the dominance of high acidity (Likeng et al., 2016). Other studies showed that palm oil acidity varies with respect to palm genotype or geographic origins (Table 2) and oil palm progenies (Ngando et al., 2008).

All progenies in Table 2 are used for seed production at the oil palm Specialized Research Centre of La Dibamba (Douala-Cameroon), which provides commercial seeds to producers. The study of palm oil acidity of individual palms have shown a great variability between the progenies on the one hand and within each progeny on the other hand. Likeng et al. (2016) working on the genetic determinism of palm oil acidity obtained only 4 out of 11 progenies (analyzing oil derived from between 17 and 32 individuals per progeny) with 100% high acidity. This could be due to the fact that the palm oil acidity (POA) gene being dominant (whatever the type of cross), results either in a high-acid homogeneity or heterogeneous progeny. The work of Likeng et al. (2016) suggested that the gene responsible for the acidity of palm oil is monogenic with strong dominant acidity and that a progeny is homogeneous with high acidity, if at least one of the crossed parents exhibits high acidity. Guedes (2014) reported that there is variability of fruit acidity of *Jabuticaba* (*Myrciaria jabuticaba*, Myrtaceae) progeny grown in a tropical climate.

León et al. (2004) also showed the influence of crossing type on FFA composition. All these observations highlight the possible heritability of fruit acidity in general and that of palm oil in particular, as confirmed by several studies (Iwanami et al., 2012; Morcillo et al., 2013; Likeng et al., 2016).

CONCLUSION

It can be reiterated from this and other studies that the acidity of palm oil is affected by several factors, the major ones being extraction procedures, presence of microorganisms and genotype of the palm tree. Since high acidity oil is unfit for human consumption, the production of hybrid seeds with low acidity remains the ideal approach to enhance this product thanks to the knowledge on heritability of the acidity trait.

To achieve this, a study of the acidity of individual genitors used for commercial seed production is imperative since such palm trees could be used in hybridization towards the production of better quality oil. In this light, a study to identify the low palm oil acidity genitors of La Dibamba germplasm underway is already revealing promising preliminary results.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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