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A preliminary study of the physico-chemical properties and fatty acid profile of five palm oil genotypes cultivated in Northeast of Brazil

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ABSTRACT

The palm oil (*Elaeis guineensis* Jacq.) is widely produced in the Brazilian Amazon region; however, the expansion of its cultivation to other environments is mandatory to attend the increasing demand of the industry, especially in the food and biodiesel fields. This study aimed to analyze the lipid profile and physicochemical characteristics of crude palm oil obtained from different palm genotypes cultivated in Goiana-PE, Northeast of Brazil. All genotypes showed high oil yield (> 60%). Lipid profile showed that the palmitic and linoleic acids were predominant in the oil (about 80%). Iodine and saponification index ranged from 50.2 to 55.3g I_2.100 g^{-1} and 184.3 to 185.4 mg KOH.g^{-1} of oil, respectively. Saponification and iodine levels also showed similar values among the studied genotypes. Acid and peroxide indexes presented values within the National Health Surveillance Agency (ANVISA). BRS C7201 genotype presented more attractive and viable results for its cultivation and development in the studied area.

Keywords: Acidity index, *Elaeis guineenses* Jacq., gas chromatography, iodine value, saponification index.

Introduction

The incessant extraction of the raw material of fossil origin for the maintenance of the world energy matrix has severely compromised the environment, especially concerning global warming (Annamalai, Thanapal & Ranjan, 2018). Also, the instability of fuel prices and the imminent shortage of its raw material have become incentives for the research for other energy sources, especially those from renewable sources such as biofuels, as biodiesel, which has economic, social and environmental benefits (Mekhilef, Siga & Saidur, 2011).

The matrices of biodiesel production are vegetable oils, animal fats or residual oils and alcohols. Brazil has great potential for the production of oleaginous plants for this purpose, such as sunflower, soybean, and canola, besides oil palm (*Elaeis guineensis* Jacq.) (Pompelli et al., 2011), which presents itself as a highly profitable oilseed, while producing 3 to 6 ton.ha^{-1} of oil per year, making it one of the primary raw materials in the production of biodiesel (Deser, 2007).

The cultivation of this palm tree has high economic viability and requires wispy mechanization, generating low production costs. Palm oil presents 21% of the world oil market, and Brazil ranks 10th position among the largest palm oil producers. The Brazilian Amazon is concentrated with the largest cultivated area of this species, although, only 0.34% of the theoretically viable area for planting in the Brazilian territory is used for the cultivation of palm oil (César et al., 2013; Levermann & Souza, 2014). In this way, it is essential that the palm oil cultivation is not limited to the Amazon and, for this, it is necessary to encourage the expansion of this culture in other Brazilian regions, in order to increase the productivity and the national competitiveness of the palm oil.

In this sense, the northeastern Zona da Mata of Pernambuco – Brazil, can become an alternative site for palm oil planting, with a high potential for adaptation of this species. Thus, the Instituto Agronômico de Pernambuco (IPA) established experimental cultivation of different genotypes of palm oil in the city of Goiana - PE, in order to evaluate the viability of palm fruit cultivation based on climatic conditions in the region. This crop was planted in the year 2010,

and the plants were obtained by sexual propagation from pre-germinated seeds, acquired from "Embrapa Western Amazon Genetic Improvement Program" (Empresa Brasileira de Pesquisa Agropecuária - Embrapa, Brazil). The plants with approximately six years old and, during the period, they were fertilized, treated to remove dead leaves and performed phytosanitary surveys.

The objective of the study was to analyze the oil characteristics of the palm oil pulp obtained from different genotypes grown in the Zona da Mata of Pernambuco, in order to evaluate its potential for obtaining commercial oil. The fruit morphometry, oil yield, fatty acid profile, and the physicochemical properties of the oil were evaluated.

Material and Methods

Sampling

The palm fruits were collected in March 2016 at the experimental station of the IPA (S 07º 38' 60.5" WO 34° 56' 66.2"), located in the city of Goiana, Pernambuco, Northeast of Brazil. Ninety mature and healthy fruits of five individuals from each of the five palm genotypes identified as BRS C2001, BRS C2301, BRS C2325, BRS C2528, and BRS C7201 were selected. After collection, the fruits were stored in a freezer (-20 ± 1°C).

Morphometry analysis

The morphometric analysis of the fruits was performed using a pachymeter with an accuracy of ± 0.01 mm. The length (mm) and width (mm) were measured for 50 fruits of each genotype.

Methods of oil extraction

The palm fruits were dehydrated in an oven at 50 ± 1°C for 48 hours. Afterward, the pulps were removed manually and then ground in a mill and stored in a desiccator. For the calculation of the oil content, the *Soxhlet* method was used and the artisanal form for the other analyzes.

For the extraction in *Soxhlet* apparatus, 5.0 g of dehydrated and crushed pulp was analyzed and then mixed with 6.5 g of anhydrous sodium sulfate to remove moisture residues. N-hexane P.A. was used as the solvent, and the extraction was carried out for eight hours (Ahmad, Husain & Osman, 1981). The oil was concentrated on a rotary evaporator, and the solvent residue was removed under nitrogen flow. The oil content (%) was calculated by dry weight difference of the dehydrated pulp and the oil stored in amber flasks at -20 ± 1°C. The analyses were performed in triplicate for the five evaluated genotypes.

The artesian extraction of palm oil, based on (Tan et al., 2009), was carried out with distilled hot water (70 ± 5°C) in the proportion of 1: 4 (m/v) of the crushed pulps. The samples were shaken for two minutes on a mechanical stirrer and then centrifuged at 4500 rpm for 10 minutes at 25 ± 1°C. The supernatant oil was collected and stored in amber flasks at -20 ± 1°C until further physico-chemical analyzes.

Peroxide index

The oil (0.5 g) was solubilized in 30 mL acetic acid/chloroform solution (3:1), and then 0.5 mL of a saturated potassium iodide solution was added and allowed to stand for 1 min. Subsequently, was added 30 mL of distilled water. The sample was titrated with sodium thiosulfate solution (0.01 M). Subsequently, the solution was titrated again after the addition of 0.5 mL of starch 0.05% (v/v). The analyses were performed in triplicate for each and the peroxide index (PI), calculated according to Zenebon, Pascuet & Tiglea (2005).

Acidity index

The Acidity Index (AI) was measured from 0.5 g solubilized in 30 mL of ethyl ether/ethyl alcohol solution (2:1). It was added three drops of the phenolphthalein indicator and the samples titrated with sodium hydroxide solution (0.1 $mol.L^{-1}$) (previously standardized with potassium dichromate) (Zenebon et al., 2005). The analyzes were determined in triplicate for each genotype.

Fatty acid profile

The oil (25 mg) of each sample, in triplicate, were transesterified by the addition of 0.5 mL of KOH in methanol (0.5 $mol.L^{-1}$), subsequently vortexed (2 min) and added 2 mL of n-hexane. Samples were shaken again (2 min), centrifuged (4500 rpm, 6 min, 25°C) and filtered supernatant (0.44 μm) and packed in vials for further analysis (Araújo et al., 2018).

The analysis of fatty acid methyl esters (FAMEs) was performed in gas chromatography (Agilent Technologies model 7890A) equipped with a flame ionization detector and coupled to a DB-5MS capillary column (30 m x 0.32 mm x 0.25 μm, Agilent Technologies). The injection volume was 1μL with a division rate of 100:1. The heating ramp was started with an isotherm of 150ºC for five minutes, followed by a heating rate of 4ºC min^{-1} until the temperature reached 280ºC

remaining for five minutes. The temperature of the detector and the injector was 300°C.

The FAMEs identification was performed by comparison with the retention time of an authentic standard (Fatty Acid Methyl Ester mix Supelco™ C4-C24) and the quantification by the percentage based on the area normalization of the peaks obtained.

Iodine and saponification indexes

The data of Iodine Index (I I) and Saponification Index (IS) were calculated using empirical formulas (Equation 1), according to Kalayasiri et al. (1996).

$$I\,I = \sum \frac{254 \times D \times A_i}{MW_i} \quad IS = \sum \frac{560 \times A_i}{MW_i} \qquad \text{Eq. (1)}$$

where I I = the iodine value, I.S. = the saponification index, D = the number of double bonds, Ai = the percentage of fatty acids, and MWi = the molecular weight of the corresponding fatty acid.

Statistical treatment

For all analyzes, the means and its standard deviations were calculated from the triplicates. The data were statistically evaluated by ANOVA with Tukey's *a posteriori* test ($p < 0.05$), using Statistica software version 8.0 (StatSoft, Inc.).

Results

Morphometry results showed that fruit length ranged from 38.2 to 43.3 mm and width from 20.5 to 28.1 mm., and the genotype BRS C2328 presented the highest fruits (43.3 mm; 28.1 mm) (Table 1). The oil content of the fruits was high, ranging from 63.3 to 72.1%. The genotype BRS C7201 showed the highest oil content (72.1%), and the genotypes BRS C2001, C2301 and C2328 had a similar oil yield (67.6 – 69.2%), but superior when compared to genotype BRS C2528 (63.3%) (Table 1).

Table 1. Morphometry and fruit yield of palm genotypes grown in Goiana-PE.

Genotypes	Morphometry (mm)*		Oil content (%)**
	Length	Width	
BRS C2001	38.2 ± 3.8^{c}	20.6 ± 2.9^{bd}	69.2 ± 2.1^{ab}
BRS C2301	38.7 ± 4.7^{bc}	19.3 ± 2.3^{cd}	69.1 ± 5.7^{ab}
BRS C2328	43.3 ± 6.6^{a}	28.1 ± 4.7^{a}	67.6 ± 2.7^{ab}
BRS C2528	41.3 ± 5.1^{ab}	20.5 ± 3.0^{bc}	63.3 ± 1.6^{b}
BRS C7201	39.3 ± 4.3^{bc}	22.0 ± 3.1^{b}	72.1 ± 1.9^{a}

* Data are averages (n = 50) ± SD; ** Data are averages (n = 3) ± SD. Different letters in the same column indicate a significant difference between the genotypes, according to ANOVA and Tukey's test ($p < 0.05$).

The palm oil presented five fatty acids in its composition: myristic (C14:0), palmitic (C16:0), stearic (C18:0), oleic (C18:1) and linoleic (C18:2). Palmitic acid was the primary compound (42.3 – 46.6%), followed by oleic acid (36.6 – 41.6%), comprising approximately 80% of the oil (Table 2).

Table 2. Fatty acid profile of the oil of genotypes of palm oil grown in Goiana-PE.

Genotypes	Fatty acid (%)				
	C14:0	C16:0	C18:0	C18:1	C18:2
BRS C2001	0.3 ± 0.4^{a}	44.3 ± 0.5^{a}	5.8 ± 0.4^{a}	39.4 ± 0.4^{a}	10.2 ± 0.4^{a}
BRS C2301	0.5 ± 2.0^{a}	46.6 ± 3.2^{a}	6.5 ± 2.5^{a}	36.6 ± 3.3^{a}	9.8 ± 3.3^{a}
BRS C2328	0.3 ± 0.9^{a}	42.3 ± 1.3^{a}	7.0 ± 1.3^{a}	41.6 ± 0.5^{a}	8.8 ± 0.9^{a}
BRS C2528	0.2 ± 2.4^{a}	46.2 ± 3.2^{a}	6.7 ± 3.6^{a}	38.1 ± 2.4^{a}	8.8 ± 2.4^{a}
BRS C7201	0.2 ± 1.4^{a}	45.6 ± 0.4^{a}	6.0 ± 0.3^{a}	39.9 ± 1.9^{a}	8.2 ± 1.4^{a}
Palm oil*	1.2	47.9	4.2	37.0	9.0
ANVISA (RDC 482)	0.5 – 2.0	35.0 – 47.0	3.5 – 6.5	36.0 – 47.0	6.5 – 15.0

Data are mean (n = 3) ± SD. Different letters in the same column indicate a significant difference between the genotypes according to ANOVA and Tukey's test ($p < 0.05$); C14:0 = myristic acid, C16:0 = palmitic acid, C18:0 = stearic acid, C18:1 = oleic acid C18:2 = linoleic acid; * Crabbe et al. (2001).

The values of the acidity, iodine, saponification, and peroxide indices are shown in Table 3. The acidity of the oil ranged from 4.6 (BRS C7201) to 7.2 mg KOH.g^{-1} (BRS C2528). The oils of the genotypes BRS C2528 (7.2 mg KOH.g^{-1}), BRS C2328 and BRS C2001 (5.5 mg KOH.g^{-1}) were more acidic than the other evaluated oils.

Table 3. Physical and chemical properties of palm oil genotypes cultivated in Goiana-PE.

Genotypes	Acidity (mg KOH.g^{-1})	Saponification Index	Iodine Index (g I_2.100 g^{-1})	Peroxide index (meq.kg^{-1})
BRS C2001	5.5 ± 0.9^a	185.1± 0.5^a	53.8 ± 4.5^a	12.6 ± 1.2^a
BRS C2301	5.1 ± 0.3^b	185.4 ± 0.9^a	52.5 ± 4.0^a	13.2 ± 1.1^a
BRS C2328	5.5 ± 0.5^a	184.3 ± 0.4^a	55.3 ± 0.2^a	11.0 ± 1.0^a
BRS C2528	7.2 ± 1.0^a	185.4 ± 0.8^a	50.2 ± 2.0^a	9.3 ± 1.2^b
BRS C7201	4.6 ± 0.1^b	185.1 ± 0.5^a	53.8 ± 3.5^a	11.3 ± 1.1^a
ANVISA (RDC 270)	Maximum 10.0	-	-	Maximum 15.0

Data are mean (n = 3) ± SD. Different letters in the same column indicate a significant difference between the genotypes, according to ANOVA and Tukey's test ($p < 0.05$).

The saponification index among the genotypes ranged from 184.3 (BRS C2328) to 185.4 (BRS C2301 and BRS C2528) and 50.2 (BRS C2528) iodine index at 55.3 (g I_2.100 g^{-1}) (BRS C2328), being similar among the five genotypes. The peroxide index ranged from 9.3 (BRS C2528) to 13.2 meq.kg^{-1} (BRS C2301) among the genotypes. Among the genotypes tested, the BRS C2328 genotype showed a lower saponification index (184.3) and higher iodine value (55.3 g I_2.100 g^{-1}), showing that this genotype showed a good quality crude palm oil.

Discussion

The fruit morphometry is considered an important parameter to evaluate crop productivity. Phenotypic variability of the tested genotypes, as well as the influence of environmental factors, such as seasonality or cultivation, resulting in different fruit sizes (Borges et al., 2007; Camargo et al., 2010), yet the fruit size observed in this study was lower than previously reported by Feroldi et al. (2014). From this parameter, it is possible to identify and select which palm genotype can be the most productive. The oil content observed in all genotypes was higher than that reported for this species (45 – 55%) (Edem, 2002). The tested genotypes seem to be well adapted to produce oil in the studied environment. The Brazilian Ministry of Agriculture, Livestock, and Supply (MAPA) (DEQ/CGAL, 2014) estimated yield of 25% oil content of palm oil from the fruit. Therefore, palm fruits grown in Goiana presented yields higher than those predicted by MAPA and other studies demonstrating high oil yield in the region under study.

The evaluated genotypes did not present quantitative and qualitative differences in fatty acids; probably the genetic variation between them is not enough to modify the route of fatty acid biosynthesis. The major fatty acids (C16:0 and C18:1) were similar to those observed for palm oil cultivated in other regions of the world (Ben-Youssef et al., 2017; Crabbe et al., 2001; El-Araby et al., 2018), in addition to being in accordance with the National Health Surveillance Agency (ANVISA) for the crude palm oil (Brasil, 1999). The predominance of C16:0 and C18:1 acid allows extensive use of palm oil in several industrial sectors, besides biodiesel (Crabbe et al., 2001). It can be used in the food industry as edible oil for food frying and as the raw material in the production of oleochemicals (Edem, 2002).

Others minors fatty acids, including lauric (C12:0), linolenic (C18:3), and arachidic (C20:0) (Crabbe et al., 2001; Ben-Youssef et al., 2017; El-Araby et al., 2018), frequently cultivated in palm oil from other Brazilian regions, were not demonstrated in the studied genotypes. In general, environmental factors, such as temperature and rainfall, are mainly responsible for modifications in the fatty acid synthesis pathway (Barbosa et al., 2014). Thus, the differences between environments of cultivation could be considered the cause of the modifications in the fatty acids biosynthesis.

The acidity levels observed in most genotypes were lower than the crude palm oil reported by Crabbe et al. (2001) (6.9 mg KOH.g^{-1}); also, they agreed with those required by ANVISA. The acidity index is indicative of the degradation of the oil, so all genotypes indicate that they have a low amount of free fatty acids, facilitating the process of transesterification for the production of biodiesel or food consumption (Brasil, 2005; Crabbe et al., 2001). The iodine values observed in the genotypes were similar to those observed by Okogeri & Uchenna-Onu (2016) for crude palm oil.

The peroxide index can measure the state of oxidation of the oil, being a parameter of quality of an oil. These values were higher than those observed by Okogeri & Uchenna-Onu (2016) for crude palm oil. However, it is in concordance with the maximum values allowed by the ANVISA resolution nº 270 (Brasil, 2005).

It is known that the lower the acidity and peroxide value of oil, the better the quality. Thus, the genotype that showed the highest quality for these two parameters was BRS C7201, probably because it suffered less with external factors that could be degraded (Brasil, 2005; Okogeri & Uchenna-Onu, 2016).

Conclusion

It was concluded that genotype BRS C2328 presented a high yield of oil (above 60%). The composition of the primary fatty acids (C16:0 and C18:1) was similar to others cultivated in different regions of the world. There was no variation in iodine and saponification, and the acidity and peroxide indices were in concordance with the Brazilian legislation for crude palm oil. Among the evaluated genotypes BRS C7201 showed higher oil yield, together with a lower acid and peroxide index, showing a better quality concerning others. Therefore, from these analyzes, this genotype is the most promising to obtain oil in the study area

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