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Compositional Indicators in Palm Oil Fatty Acid Chemistry. How Relevant is the Iodine Value?

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Introduction

Based on the latest USDA report, by the end of 2021, more than 75 million tons [Mt] of palm oil were produced worldwide[1]. In palm oil mills, crude palm oil (CPO) is obtained by mechanical pressing, under specific pressure and temperature conditions of ripe fruits produced by tenera–type African palm cultivars of *Elaeis guineensis* Jacq., Dura × Pisifera cross (CPO D×P) or of the interspecific hybrids between *Elaeis oleifera* (Kunth) Cortés and *Elaeis guineensis* Jacq. species, commonly known as O×G hybrids (CPO O×G). As in CPO D×P, thirteen fatty acid (FA) species typify the lipid matrix of CPO O×G: [lauric (C12:0), myristic (C14:0), pentadecanoic (C15:0), palmitic (C16: 0), palmitoleic (C16:1), margaric (C17:0), stearic (C18:0), oleic (C18:1n9c), vaccenic (C18:1n7c), linoleic (C18:2n6c), α–linolenic (C18:3n3), arachidic (C20:0) and gondoic (C20:1n9)]. Palmitic acid (**Figure 1–a**), a saturated fatty acid (SFA), gives a fraction of the CPO (~50%), a solid appearance at room temperature (~20 °C), by being present in a higher concentration measure than other saturated fatty acid species in the oily matrix. In contrast, oleic (monounsaturated fatty acid (MUFA); **Figure 1–b**) and linoleic (polyunsaturated fatty acid (PUFA); **Figure 1–c**) fatty acids, to a greater extent, give the other CPO fraction a liquid appearance when stored under the same temperature conditions.

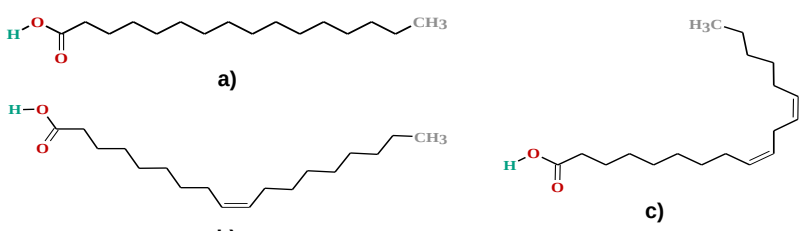


Figure 1. Fatty acids of major preponderance in CPO. a) Palmitic acid, C16:0; b) Oleic acid, C18:1n9c; c) Linoleic acid, C18:2n6c. Structures developed using ChemSketch software[2].

The mixing between CPO D×P and CPO O×G is a very common practice in palm oil mills in Colombia, due to the growing supply of fresh fruit bunches (FFB) of the different cultivars of O×G hybrids planted in the different palm growing areas of the country; by the difficulty of tracing FFBs from different origins in the hoppers; by the ease or otherwise of separating palm oil by origin during processing and storage; and by the feasibility or otherwise of selling blended oils. This practice can decrease the content of free fatty acids and increase the value of the deterioration of bleachability index (DOBI) in the CPO resulting from blending, but, at the same time, it generates important changes in the chemical composition of the resulting lipid matrix[3]. In palm oil refineries, an oil with a high content of CPO O×G in mixture with CPO D×P, requires to be processed under different conditions than those conventionally established for the processing of pure CPO D×P resulting in unforeseen changes in previously established operations. Therefore, this study aimed to determine the effect of compositional changes of unsaturated fatty acids in CPO, achieved in the laboratory by means of mixtures generated between CPO D×P and CPO O×G, on the value of iodine value (IV) in the resulting lipid matrices.

Materials and methods

CPO D×P (n= 40) and CPO O×G samples of the cultivar Coari × La Mé (CPO O×G C×L) (n= 40), were collected at the palm oil mill of Guaicaramo S.A.S, Barranca de Upía–Meta. The CPO O×G samples of the cultivars Brasil × Djongo (CPO O×G B×D) (n= 15), Coari × Super tenera (CPO O×G C×ST) (n= 15) and Manaos × Compacta (CPO O×G M×C) (n= 15), were extracted from FFBs, 2011–2013 planting, collected at the La Providencia Experimental Farm of the Colombian Oil Palm Research Center – Cenipalma, Tumaco–Nariño. The procedure were carried out following the guidelines described in sections C1–47 and Ba 1–38 of the manual of official methods and recommended practices of the American Oil Chemists' Society – AOCS [4]. The pure samples and the mixtures formed between them (Table 1) were analyzed at Cenipalma's Palm Oil Processing Research Program Laboratory, located in the Campo Experimental Palmar de las Corocoras, Paratebueno–Cundinamarca.

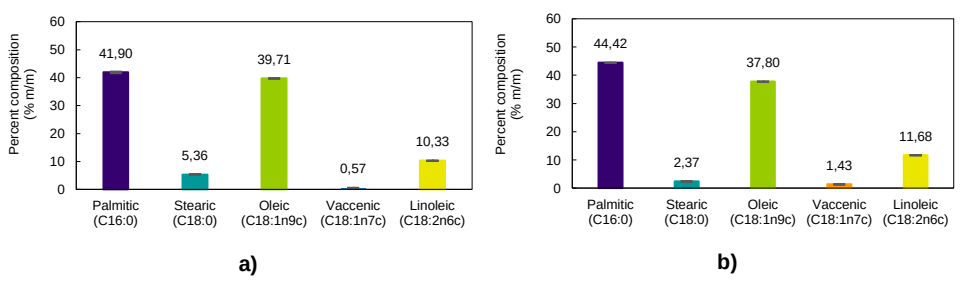
From the collected CPO samples, mixtures were prepared at different percentage levels of concentration between the oils obtained from the different palm cultivars (Table 1) using an Ohaus analytical balance (Ohaus Scale Corp. Florham Park, NJ, USA) with a precision of 0.0000±0.0001 g and a Memmert heating oven with temperature control (60±0.5 °C) (Memmert™, Germany). The lipid matrices collected, shaped and characterized in this study are presented in Table 1. The determination of the fatty acid profile of the CPO samples was carried out by gas chromatography with a flame ionization detector (GC–FID) according to the AOCS methods Ce 2–66 and Ce 1–62 [4].

Table 1. Mixing ratio between CPO D×P and CPO O×G.

Analysis group	Analysis matrix	CPO D×P (% m/m)	CPO O×G C×L (% m/m)	*n*=
1: mix between CPO D×P and CPO O×G C×L	CPO D×P	100	0	40
	Mixture 1	80	20	40
	Mixture 2	60	40	40
	Mixture 3	40	60	40
	Mixture 4	20	80	40
	CPO O×G C×L	0	100	40
	Analysis matrix	**CPO D×P (% m/m)**	**CPO O×G C×ST (% m/m)**	***n*=**
2: mix between CPO D×P and CPO O×G C×ST	CPO D×P	100	0	15
	Mixture 1	80	20	15
	Mixture 2	60	40	15
	Mixture 3	40	60	15
	Mixture 4	20	80	15
	CPO O×G C×ST	0	100	15
	Analysis matrix	**CPO D×P (% m/m)**	**CPO O×G M×C (% m/m)**	***n*=**
3: mix between CPO D×P and CPO O×G M×C	CPO D×P	100	0	15
	Mixture 1	80	20	15
	Mixture 2	60	40	15
	Mixture 3	40	60	15
	Mixture 4	20	80	15
	CPO O×G M×C	0	100	15
	Analysis matrix	**CPO D×P (% m/m)**	**CPO O×G B×D (% m/m)**	***n*=**
4: mix between CPO D×P and CPO O×G B×D	CPO D×P	100	0	15
	Mixture 1	80	20	15
	Mixture 2	60	40	15
	Mixture 3	40	60	15
	Mixture 4	20	80	15
	CPO O×G B×D	0	100	15

Results and discussion

Figure 2. Shows the behavior of the most relevant fatty acid species in pure CPO extracted from the different cultivars of O×G interspecific hybrids characterized in this study and CPO from *E. guineensis* D×P.



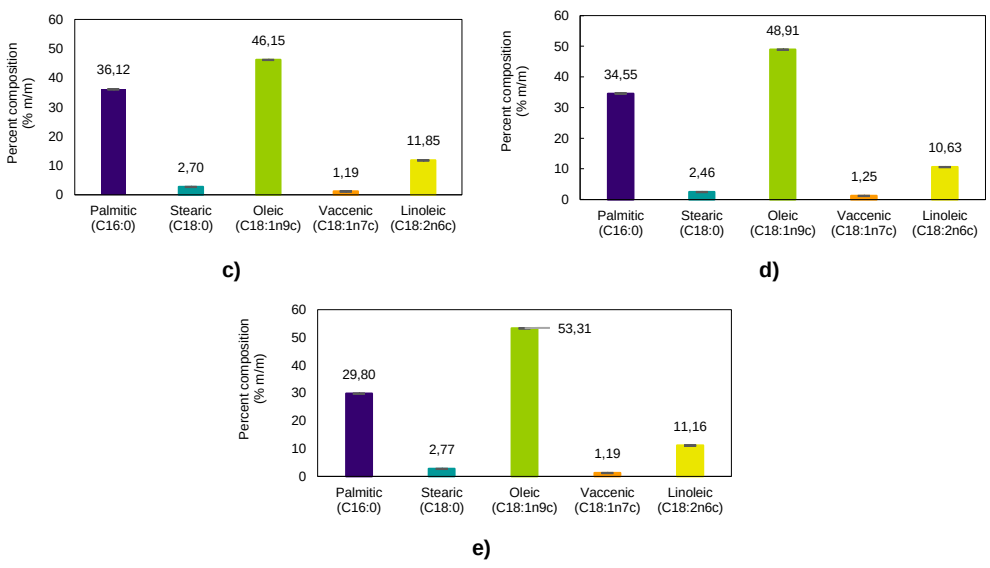


Figure 2. Mass percentage composition of the most relevant fatty acid species in the CPO of different origin. The error bars correspond to the standard error of the mean. a) CPO D×P (*n= 40*); b) CPO O×G B×D (*n= 15*); c) CPO O×G C×ST (*n= 15*); d) CPO O×G M×C (*n= 15*); e) CPO O×G C×L (*n= 40*).

From the results obtained in the characterization of the group of samples in Table 1 and from a regression analysis to estimate possible correspondences between the study variables, a significant relationship was found between the percentage mass content of the CPO extracted from certain cultivars of O×G hybrids, when mixed with CPO D×P, and the value of the iodine index calculated from the fatty acid profile of the samples analyzed (Figure 2). Figure 3 shows the simple linear regression models developed from the results obtained in the characterization of the group of samples of pure CPO of the cultivars O×G and D×P and of the mixtures processed from these same oil samples (Table 1).

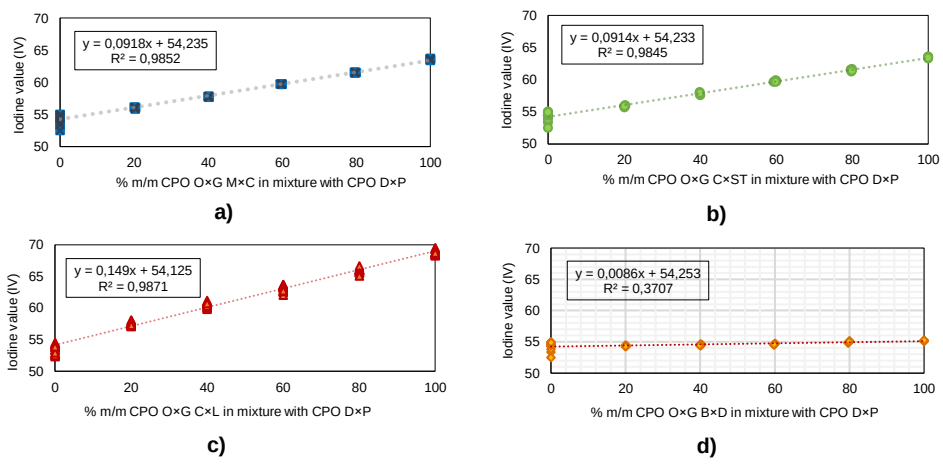


Figure 3. Simple linear regression models that relate the value of the IV and the mass percentage composition of the CPO of the O×G cultivars, in mixture with CPO D×P. a) CPO O×G M×C in mixture with CPO D×P; b) CPO O×G C×ST mixed with CPO D×P; c) CPO O×G C×L in mixture with CPO D×P; d) CPO O×G B×D mixed with CPO D×P.

The relationships found between the calculated IV and the composite mixtures between the CPO D×P and the CPO of the different O×G hybrid cultivars, allowed adjusting the following models:

$IV = 0{,}0918x_1 + 54{,}235$ R² = 0,9852 **Model 1.** For CPO O×G M×C mixed with CPO D×P.

$IV = 0{,}0914x_2 + 54{,}233$ R² = 0,9845 **Model 2.** For CPO O×G C×ST mixed with CPO D×P.

$IV = 0{,}149x_3 + 54{,}125$ R² = 0,9871 **Model 3.** For CPO O×G C×L mixed with CPO D×P.

$IV = 0{,}0086x_4 + 54{,}253$ R² = 0,3707 **Model 4.** For CPO O×G B×D mixed with CPO D×P.

For each of the models developed, the coefficient of determination (R^2) explains the variability of the response data (IV) around its mean by 98.52% for the model "CPO O×G M×C in mixture with CPO D×P" (Model 1); 98.45% for the model "CPO O×G C×ST in mixture with CPO D×P" (Model 2); in 98.71% for the model "CPO O×G C×L in mixture with CPO D×P" (Model 3), and 37.07% for the model "CPO O×G B×D mixed with CPO D×P" (Model 4). Also indicating good fits (linear association between variables) for Models 1 to 3 and a "questionable" or "low" fit for Model 4. The above, based on what was described by Mcdonald, (2009)[5].

Conclusions

Under the terms of this work, the IV allows to know, in an approximate way, the presence of mixtures between CPO of different origins, from the characterization of a sample of material by means of analytical methodologies conventionally used in the laboratories of the palm oil mills in Colombia.

In the palm oil mills, the models obtained from the simple linear regressions achieved in this study for the mixtures between: CPO O×G M×C and CPO D×P; CPO O×G C×ST and CPO D×P and CPO O×G C×L and CPO D×P, can be considered as useful tools that allow establishing, easily and with a good level of reliability, compliance with the maximum permissible limits for mixtures between CPO D×P and O×G, which can be agreed upon during negotiations with customers.

Acknowledgements

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