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Bioactive compounds of fractionated palm oil with a higher content of oleic acid

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Abstract: BRS Manicoré cultivar is an interspecific hybrid between *Elaeis oleifera* and *Elaeis guineensis* (ISH OxG). It has shown high yield potential and genetic resistance to phytosanitary problems in cultivation in Brazil. Studies have indicated differences in the composition of ISH OxG and palm oils, as well as the influence of genotype and environment on palm oil characteristics. The aim of this study was to assess the distribution of fatty acids, carotenoids, and tocochromanols in the olein and stearin fractions of the oil produced by the ISH OxG cultivated in municipality of Una, state of Bahia, Brazil by liquid and gas chromatography. There were significant differences for fatty acids, carotenoids and total tocochromanols between olein and stearin ($p<0.05$). The olein was richer in oleic acid (59% *vs* 57%), while stearin was higher in saturated fatty acids (31% *vs* 29%), *alpha* and *beta*-carotene (232 *vs* 213 mg/Kg, and 347 *vs* 299 mg/Kg, respectively), *alpha*-tocotrienol (136 *vs* 90 mg/Kg), and *alpha*-tocopherol (52 *vs* 32 mg/Kg). No difference was observed for *gamma*-tocotrienol (598 – 450 mg/kg) and *delta*-tocotrienol; nonetheless, the high content of the former in both fractions was notable. The ISH OxG oil fractions showed distinct patterns, indicating different applications.

Index terms: carotenoids; tocochromanols; *Elaeis oleifera* × *E. guineenses*; fatty acids.

Compostos bioativos de frações de óleo de palma com maior teor de ácido oleico

Resumo: BRS Manicoré é um híbrido interespecífico entre *Elaeis oleifera* e *Elaeis guineensis* (ISH OxG). Em cultivo no Brasil, BRS Manicoré demonstrou alto potencial produtivo e resistência genética a problemas fitossanitários. Estudos têm indicado diferença na composição do óleo dos ISH OxG e da palma de óleo, bem como a influência do genótipo e do ambiente nas características do óleo de palma. O objetivo deste trabalho foi determinar a composição em ácidos graxos, carotenoides e tococromanóis das frações oleína e estearina do óleo produzido a partir do ISH OxG cultivado em Una, Bahia, por cromatografias líquida e gasosa. Houve diferença significativa nos ácidos graxos, nos carotenoides e nos tococromanóis entre oleína e

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estearina (p<0,05). Os resultados confirmaram maiores teores de ácido oleico (59% *vs* 57%) e de ácidos graxos saturados na oleína (31% *vs* 29%) e maior concentração de *alfa* e *beta* caroteno (232 *vs* 213 mg/Kg e 347 *vs* 299 mg/Kg, respectivamente), *alfa*-tocotrienol (136 *vs* 90 mg/Kg) e *alfa*-tocoferol (52 *vs* 32 mg/Kg) na estearina; não foi observada diferença significativa em *gama*-tocotrienol (598 – 450 mg/kg) e *delta*-tocotrienol; entretanto, ressalta-se o elevado teor do primeiro em ambas as frações. O fracionamento de HIE OxG originou frações com características distintas e diferentes possíveis aplicações.

Termos para indexação: carotenoides; tococromanóis; *Elaeis oleifera* × *E. guineenses;* ácidos graxos.

Introduction

Oil palm (*Elaeis guineensis* Jacq.) is responsible for most of the vegetable oil produced in the world (USDA, 2021). The species is cultivated in humid tropical regions, with Indonesia and Malaysia being the largest producers, but it is also of great importance in Latin American countries, including Brazil. Particularly in Latin America, Bud Rot, an anomaly of not yet fully known etiology, has decimated some plantation areas of this species (BITTENCOURT et al., 2021). The only efficient control measure for Bud Rot is to plant interspecific hybrids between Caiaué (*Elaeis oleifera* (HBK) Cortés) and Oil palm (*Elaeis guineensis* Jacq.), which inherit the resistance to the anomaly presented by the Caiaué (GOMES JR et al., 2021).

Bahia was the first state in Brazil where *E. guineensis* arrived and grew spontaneously. However, increase in fruit productivity and resistance to pests and diseases, especially the red ring disease in that area are required (PINTO et al., 2019).

On the other hand, Caiaué is a palm tree native to the American continent containing mesocarp with oil richer in unsaturated fatty acids and antioxidants, as well as a lower enzymatic activity than *E. guineensis* (LOPES et al., 2008). Although it presents lower oil content than the African species, its higher resistance to Bud Rot and Red Ring makes it an interesting species to be combined with *E. guineensis*. Therefore, as such, diseases do not affect the plant; the cultivation of *E. oleifera* x *E. guineensis* (ISH OxG) hybrid has been encouraged (CUNHA; LOPES, 2010; LOPES et al., 2008; RIOS et al., 2012). In other words, ISH OxG is a combination of high productivity and resistance to diseases.

In 2010, Embrapa Western Amazon (State of Pará, Brazil) launched the first ISH OxG cultivar developed in Brazil, called BRS Manicoré, obtained from crossing Caiaué of Manicoré origin with Oil palm of La Mé origin (CUNHA; LOPES, 2010). ISH OxG is cultivated in Brazil in the State of Pará in areas with Oil palm affected by Bud Rot. In addition to the resistance to such disease, a peculiar characteristic of the oil obtained by the hybrid cultivated in Brazil is its high oleic acid content (C18:1) (ANTONIASSI et al., 2018 a), which is nutritionally favorable, since it has been correlated to lower risks of coronary heart disease (FDA, 2018).

BRS Manicoré cultivar was evaluated under the cultivation conditions at Lemos Maia Experimental Station in the fields of Executive Commission for Cocoa Cultivation Planning (CEPLAC), Una, State of Bahia. The evaluation confirmed high productive performance and resistance to the main sanitary problem in local conditions, namely the Red ring disease (PINTO et al., 2019); however, no information is available regarding oil composition of the presence of bioactive compounds.

The Brazilian Agricultural Research Corporation (Embrapa) provided *Codex Alimentarius* with fatty acid composition data, and as a result, a standard for palm oil with a higher oleic acid (ISH OxG) was included in Standard for Named Vegetable Oils CXS 210-1999 (FAO, 2019). It has also been demonstrated the high content of bioactive compounds in ISH OxG, namely pro-vitamin A carotenoids and tocochromanols (ANTONIASSI, 2018a, 2018b). However, the information is only related to the ISH OxG grown in the State of Pará, Brazil.

ISH OxG oil has been extracted since 2013 and the fractionation has been performed in artisanal conditions by CEPLAC (State of Bahia, Brazil). Pinto et al. (2019) highlighted the potential of the cultivar to improve the quality of the oil produced to use in typical dishes of Bahian cuisine. The products obtained after fractionation by CEPLAC have been used for frying and in preparing traditional dishes such as 'moqueca' and 'acarajé'.

Dry fractionation is a "green" modification process used either in order to enhance edible oil physical stability or to widen its range of applications. The consequence of such a process is a change in the physicochemical properties of the oil or fat by selective crystallization and filtration steps without the need of refining. A number of products can be obtained from dry fractionation with distinct physical and chemical properties. The process basically consists in two steps: the crystallization stage, which produces solid crystals in a liquid matrix; and the separation stage, where the liquid phase (lower melting point) is separated from the crystals (higher melting point), resulting in olein and stearin, respectively (KELLENS et al., 2007). Palm oil is one of the most fractionated oils due to its semi-solid properties. Palm oil various fractions can be used in different food products such as margarine, frying oil, and cocoa butter substitute. Controlling the fractionation conditions is important to produce the fractions with desirable stearin and olein quality (TONG et al., 2021).

Although ISH OxG oil has higher oleic acid content and lower saturated fatty acids than palm oil, it can be fractionated, giving rise to stearin and olein, including a variety of ISH OxG-derived food ingredients for use in either shortenings, margarines, and confectionary zero-*trans* fats, or as liquid oil with potentially higher oxidative and physical stability. The chemical composition of the oil produced by the ISH OxG cultivar grown in the State of Bahia conditions needs to be characterized for greater appreciation and validation of the oil's potential for different applications.

As far as we know, there are few studies about the composition of olein and stearin from ISH OxG. Therefore, the aim of this study was to assess the distribution of fatty acids, carotenoids, and tocochromanols of olein and stearin in unrefined ISH OxG oil obtained from the BRS Manicoré hybrid in the State of Bahia through liquid and gas chromatography.

Material and Methods

Materials

The hybrid (ISH OxG) progenies from crosses between female parents of Caiaué from Manicoré origin and male parents of pisifera oil palm from La Mé (LM2T and LM 10T) origin were produced by Embrapa Western Amazon. The ISH OxG were cultivated at Lemos Maia Experimental Station in the Executive Commission for Cocoa Cultivation Planning (CEPLAC) fields located in Una, State of Bahia, Brazil (15° 17' S, 39° 4' W). This area is located in an Atlantic Forest environment with a humid tropical climate, average annual rainfall of 1,827 mm, annual average temperature of 24.7 °C, a maximum of 30.9 °C and a minimum of 21.2 °C, and relative humidity of 70 to 80%. ISH OxG plants were cultivated in a randomized block experiment totaling 650 plants (PINTO et al., 2019).

Bunches were collected and heated for 24h to soften the fruits (60-80 °C). Then, after their removal, the fruits were macerated in a digester in a way that the seeds were not broken. The fibrous macerated material was pressed in an electric-mechanic press and a mixture of oil and water was obtained. After that, it was heated to evaporate the water. Such process took approximately 2 hours. The oil was filtered, cooled, and packed. The procedure was carried out every 20 days and the oils was collected in order to perform the fractionation.

Static fractionation of the ISH OxG oil was conducted during 60 days at room temperature and olein and stearin were separated, packed, and sent to Embrapa Food Technology for analyses.

Methods

Fatty acid profile was performed in quintuplicate by gas chromatography and the fatty acid methyl esters (FAME) were obtained according to Antoniassi et al. (2018c). Gas chromatography was carried out using an Agilent 7890 gas chromatograph with flame ionization detector operating at 280 °C and a capillary column (25 m; 0.2 mm internal diameter; and 0.30 µm HP FFAP stationary phase) with a temperature program as follows: 150 °C for 1 min; from 150 to 180 °C at a rate of 30 °C/min; from 180 to 200 °C at a rate of 20 °C/min; from 200 to 230 °C at a rate of 3 °C/min; 230 °C for 10 min. The injector temperature was 250 °C operating in split mode at a ratio of 1:50 and injecting 1 µL of the FAME diluted in hexane (1%). The FAME were identified by comparison of their retention times with standard GLC Standard 62, 79 and 87 (Nu-Check Prep Inc.) and Supelco 37 component FAME Mix CRM47885 (Sigma Aldrich, Bellefonte, PA). The quantification was performed by area normalization and the results were expressed as g of FAME by the total of FAME.

Simultaneous determinations of carotenoids and tocochromanols were performed according to Antoniassi et al. (2018b) using C_{30} reverse-phase column YMC C_{30} (250 mm x 4.6 mm x 5 µm) kept at 35 °C with a gradient mobile phase consisting of methanol:MTBE, v/v (from 90:20 to 85:15 in 30 s, and then to 15:85 in 15 min) at a flow of 0.8 mL/min. The oil was dissolved in acetone and analyzed in quadruplicate. Samples were kept at 15° C, and the injection volume was 10 to 15 µL. Waters 2695 HPLC System with Waters 2998 diode array (DAD) and Waters 2424 fluorescence (FLD) detectors equipped with a Quaternary Pump, online degasser, automatic injector with Rheodyne valve (Rheodyne LCC, Rohnert Park, USA) and attached column oven was used. Carotenoids quantification was performed using photodiode array detector (DAD, at 450 nm wavelength) and the identification was based on the chromatographic behavior, the wavelengths of maximum absorption, and the shape of the UV/visible absorption spectrum according to Rodriguez-Amaya and Kimura (2004). The tocochromanols were quantified with a fluorescence detector (FLR, excitation at 290 nm and emission at 330 nm) using external calibration of the standards *alpha*-tocopherol (T3251) and *delta*-tocopherol (T2028) from Sigma Aldrich and *alpha, beta, gamma* and *delta* tocotrienols (1.08524) from Merck (Merck KGaA, Darmstadt, Germany). The concentration of the tocochromanols standards was checked with the absorption coefficient according to AOCS (2009).

Analysis of variance and Tukey's test were performed using Statgraphics (Statgraphics Technologies Inc.) at a significance level of 0.05. The study was registered in the National System of Genetic Resource Management and Associated Traditional Knowledge (SisGen) number A051036.

Results and Discussion

Table 1 and Figure 1 display the fatty acid composition of ISH OxG stearin and olein. C18:1 was the most abundant fatty acid, consisting of the sum of C18:1n-9 (Oleic acid) and C18:1n-11, followed by palmitic (C16:0), linoleic (C18:2), stearic (C18:0), and linolenic acid (C18:3). C14:0, C16:1, C20:0, C20:1, and C22:0 were found in lower amounts. There were significant differences ($p<0.05$) between stearin and olein fractions for C16:0 (26.6 vs 24.6), C18:0 (3.6 vs 3.5), C18:1 (57.5 vs 59), C18:2 (10.6 vs 11) and C18:3 (0.38 vs 0.37).

Table 1. Fatty acid composition (g/100g) of the fractions obtained compared to *Codex Alimentarius* (FAO, 2019), and Brazilian legislation (BRASIL, 2021).

Fatty acid (g/100 g of total FA)	ISH OxG stearin	ISH OxG olein	Palm oil with higher oleic acid[1,2]	Palm stearin[1]	Palm olein[1]	Palm Superolein[1]
C14:0	0.27±0.005[a]	0.26±0.008[b]	ND-0.8	1.0-2.0	0.5-1.5	0.5-1.5
C16:0	26.40±0.32[a]	24.63±0.25[b]	23.0-38.0	48.0-74.0	38.0-43.5	30.0-39.0
C16:1	0.17±0.002[a]	0.17±0.002[b]	ND-0.8	ND-0.2	ND-0.6	ND-0.5
C18:0	3.64±0.019[a]	3.46±0.013[b]	1.5-4.5	3.9-6.0	3.5-5.0	2.8-4.5
C18:1	57.54±0.23[a]	58.99±0.19[b]	48.0-60.0	15.5-36.0	39.8-46.0	43-49.5
C18:2	10.61±0.10[a]	11.01±0.03[b]	9.0-17.0	3.0-10.0	10.0-13.5	10.0-15.0
C18:3	0.38±0.002[a]	0.37±0.002[b]	ND-0.6	ND-0.5	ND-0.6	0.2-1.0
C20:0	0.29±0.002[a]	0.28±0.005[b]	ND-0.4	ND-1.0	ND-0.6	ND-0.4
C20:1	0.17±0.003[a]	0.17±0.006[b]	ND-0.2	ND-0.4	ND-0.4	ND-0.2
C22:0	ND	0.07±0.002	ND-0.3	ND-0.2	ND-0.2	ND-0.2
∑ saturated	30.89	28.7	-	-	-	-
∑ monounsaturated	57.71	59.16	-	-	-	-
∑ polyunsaturated	10.99	11.38	-	-	-	-
Iodine Value (g/100g)	69.14	71.05	58-75	≤48	≥56	≥60
Saponification Value (mg KOH/g)	197.15	197.07	189-199	193-205	194-202	180-205

FA: fatty acid; ND: not detected; average ± standard deviation. Means followed by different lowercase letters on the lines are statistically different $p \leq 0.05$; [1]FAO (2019). [2]BRASIL (2021). *Results of stearin and olein expressed as an average of five replicates

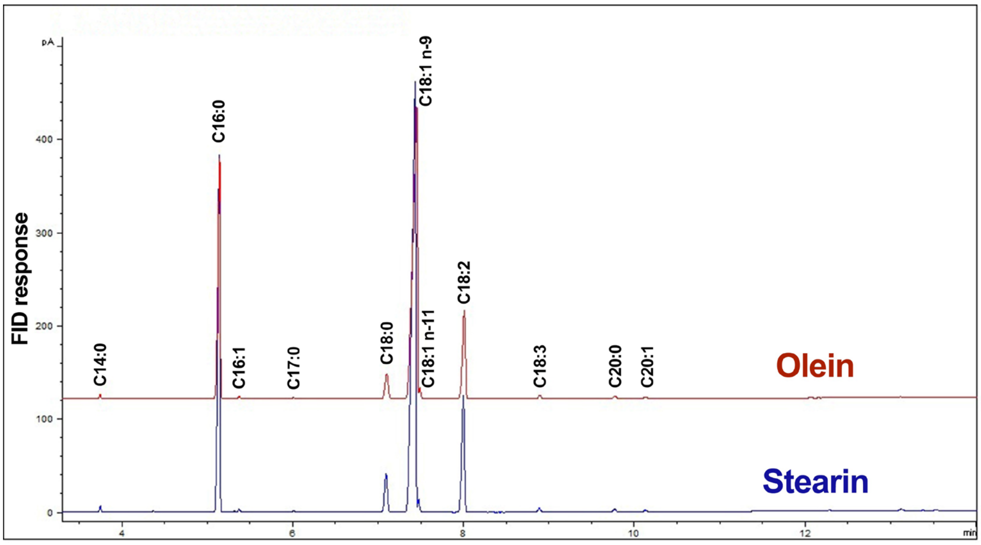

Figure 1. Fatty acid composition of ISH OxG olein and stearin

It was observed that the fatty acid composition of the fractions was in agreement with the range established in standard for palm oil with higher content of oleic acid of the *Codex Alimentarius* (FAO, 2019) and the Brazilian Regulation (BRASIL, 2021), with C18:1 content close to the upper limit of the legislation for both fractions. Antoniassi et al. (2018b) found similar results for non-fractionated ISH OxG oil from the State of Pará, Brazil. The sum of saturated fatty acids was higher for the stearin (30.89%), while the sum of monounsaturated (59.16%) and polyunsaturated fatty acids (11.38%) were higher for olein. Although the differences between olein and stearin obtained from ISH OxG were not very high, they showed large variation compared to the palm olein and palm stearin from *Codex Alimentarius* (FAO, 2019). These ranges were based on the results of palm oil industrial fractionation. Fractionation is a process carried out by palm oil extraction and refining companies to obtain specific products to meet the demand for fats in the food industry, as well as to obtain the olein fraction to be used as cooking oil and frying oil that does not present the undesirable aspect of the presence of palm oil sediments. The industrial process allows agitation and temperature control which results in olein and stearin fractions with greater differences between fatty acids and therefore triacylglycerol. Nevertheless, the procedure reported in this study was a static fractionation without temperature control and the stearin fraction had to be separated by settling, using only the force of gravity to cause separation between the heavier solid phase and the lighter liquid phase.

Although small companies without the need of investment for industrial fractionation can carry out this artisanal process, small differences in fatty acids were observed between the fractions. However, as the ISH OxG composition differs greatly from palm oil, different applications of olein and stearin from ISH OxG may be possible. For example, the C18:1 content for superolein and olein from palm oil fractionation ranges from 38 to 49.5% (FAO, 2019) (Table 1), while the olein from ISH OxG presented around 59% of oleic acid, with advantages regarding to possible sedimentation for the product obtained. Additionally, it has been suggested that a higher proportion of monounsaturated fatty acids (MUFA), notably oleic acid, in the diet potentially reduces the risk of coronary heart disease (CHD) (LOPEZ et al, 2010).

The low C16:0 content in olein possibly reduces the tripalmitin triacylglycerol content, which gives it higher physical stability. The Iodine value of 71 g iodine/100g for olein from ISH OxG was obtained from static fractionation, while the "superolein" from palm oil requires a specially controlled crystallization process to achieve an iodine value of 60 or higher (FAO, 2019). Therefore, the olein from ISH OxG may be valued as a product to be used as salad (dressing) oils and liquid frying oils, for instance. Additionally, the stearin from ISH OxG showed a different pattern from the palm stearin (FAO, 2019), pointing out different application for products requiring consistency, such as typical Brazilian dishes (moqueca, and acarajé) which are colored products. Additionally, the high oleic red palm olein, which is a commercial product called "HORO", was used in cookies and presented high retention of bioactive compounds after baking (PEREZ-SANTANA et al., 2021).

Although not performed in the present study, it has been shown that positional distribution of fatty acids in triacylglycerol structure between ISH OxG and palm oil does not differ, with the sn-2 position of TAGs in ISH OxG expected to be predominantly esterified with oleic acid, which is interesting from a nutritional point of view (MOZZON et al., 2013).

Although, there are not sufficient data to conclude palm oil as a causative agent for cardiovascular disease (MAY; NESARETNAM, 2014; URUGO et al., 2021), the World Health Organization (WHO, 2020) recommends the total fat, saturated fat and trans fat intake do not exceed 30%, 1%, and 1%, respectively (WHO, 2020).

Linoleic acid (C18:2 n-6) and linolenic acid (C18:3 n-3) are essential fatty acids (Otten et al. 2006) but the contribution of ISH OxG stearin and olein to daily intake of linoleic acid is low and marginal for linolenic acid. On the other hand, high oleic oils may be associated to risk reduction of mortality and cardiovascular events (SCHWINGSHACKL; HOFFMANN, 2014; HUTH et.al, 2015).

Although the difference in fatty acid composition between fractions was small, the bioactive compounds were partitioned more in the stearin fraction than in olein (Tables 2 and 3). The main carotenoids found in both stearin and olein fractions were *all-trans alpha*-carotene and *all-trans beta*-carotene (232 *vs* 213 mg/Kg and 347 *vs* 299 mg/Kg, respectively), and their concentration and total carotenes (900 vs 791 mg/Kg) was higher in stearin ($p<0.05$). These results were higher than those obtained by Perez-Santana et al. (2021) for high oleic red palm olein (HORO). The *all-trans alpha*-carotene and *all-trans beta*-carotene are major dietary sources of vitamin A for humans and for many animals throughout the world. Carotenoids are natural pigments that exhibit yellow, orange, and red hues responsible for a number of benefits conferred to human health, such as being a precursor of vitamin A, enhancing the immunological system, or reducing the risk of degenerative and cardiovascular diseases (RODRIGUES-AMAYA et al., 2008).

Table 2. Carotene composition and total content (mg/Kg)* of ISH OxG stearin and olein, and from *Codex Alimentarius* (FAO, 2019)

	ISH OxG stearin	ISH OxG olein	Unbleached palm stearin[1]	Unbleached palm olein[1]
all trans alpha-carotene	231.99±3.40[a]	213.11±6.70[b]	-	-
all trans beta-carotene	347.56±15.51[a]	298.96±10.93[b]	-	-
Total carotene	902.42±32.4[a]	791.35±4.0[b]	300-1500	550-2500

*Results expressed as an average of four replicates. Means followed by different lowercase letters on the lines are statistically different $p \leq 0.05$.[1]FAO (2019).

Carotenoid content of ISH OxG oil usually lies in a range between the two parental species, for example, 20 to 200 mg/Kg of *trans-alpha*-carotene, and 300 to 500 mg/Kg of *trans-beta*-carotene for *E. guineensis*; and approximately 400 mg/Kg of *trans-alpha*-carotene and around 1,000 mg/Kg of *trans*-beta-carotene for *E. oleifera* (RODRIGUES-AMAYA et al., 2008).

The total carotene content obtained was lower than found in Antoniassi et al. (2018a) for ISH OxG oil cultivated in Mojú and Santa Bárbara do Pará, municipalities in the State of Pará, Brazil (1,041 – 1,633 mg/Kg); and higher than the result found by Almeida et al. (2021) for ISH OxG oil cultivated in Santa Bárbara do Pará (830 mg/Kg). The differences found for carotenoid content in ISH OxG oil by different studies could be due to local environmental conditions, samples collected in different seasons, or even genotypes, as well as the differences regarding the processing conditions.

Figure 2 depicts the chromatogram of carotene profile and it is possible to observe other compounds present in the fractions close to the *alpha* and *beta*-carotenes. These compounds were derived from the isomerization due to the hot processing of the bunch and pressing. This occurrence was observed for commercial ISH OxG and Caiaué oils (ANTONIASSI et al., 2018 b). Heat, light and acids are able to promote isomerization of *trans*-carotenoids to the *cis*-form (RODRIGUEZ-AMAYA, 1997; RODRIGUEZ-AMAYA et al, 2008).

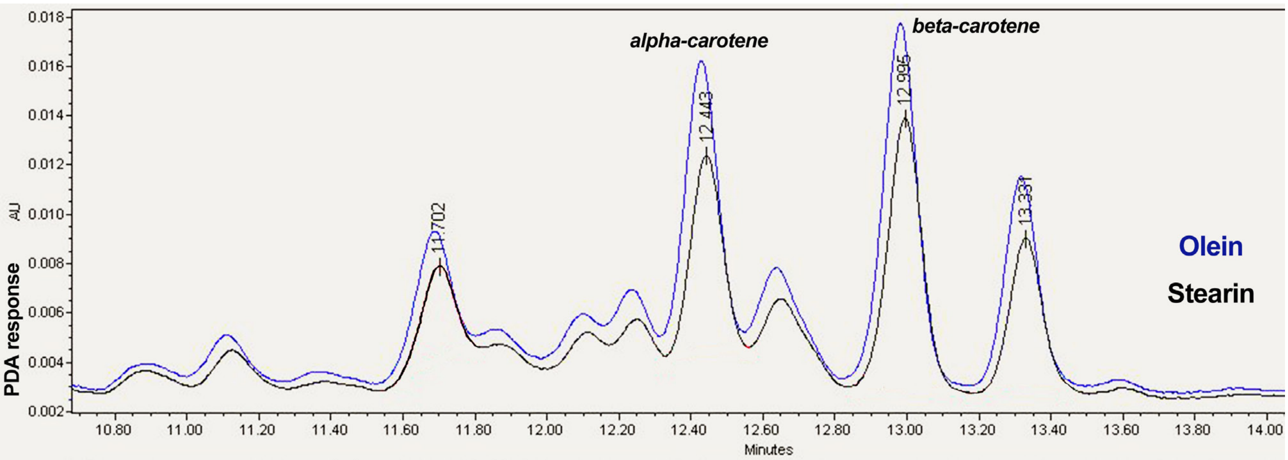

Figure 2. Carotenoid profile of samples recorded in the range of 200-800 nm.

There are companies in Brazil processing ISH OxG. The extraction process consists of bunches harvesting and sterilization, detaching the fruits, pressing and centrifuging to separate solids, oil and water. Sterilization takes place with steam treatment in order to inactivate enzymes and softening the fruits to enhance the oil yield. The temperature during pressing is still high, and the temperature of oil after the centrifugation steps is around 90 °C (WAI-LIN, 2023). The isomerization of carotenes was observed in the industrial ISH OxG oil (ANTONIASSI et al., 2018a) and even in the artisanal extraction process carried out in this study.

The tocochromanols profile of the fractions can be seen in Figure 3. The sum of tocopherols and tocotrienols, *alpha*-tocotrienol and *alpha*-tocopherol were higher in stearin (861 vs 626 mg/Kg) ($p<0.05$), while no difference was observed for *gamma* and *delta*-tocotrienols (Table 3); nonetheless, it is worth emphasizing the high *gamma*-tocotrienol content in both fractions (598 mg/Kg and 450 mg/Kg). The tocochromanol contents were consistent with *Codex Alimentarius* standard for palm oil with higher oleic acid content and previous studies on crude ISH OxG oil (ANTONIASSI et al., 2018b; FAO, 2019). Gamma tocotrienol was similar, but a*lpha*-tocopherol and *alpha*-tocotrienol was lower than the results presented by Perez-Santana et al. (2021) for high oleic red palm olein (HORO); however, the results of individual tocochromanols were in the range of Palm oil with higher oleic acid and palm olein content presented in FAO (2019).

Table 3. Tocochromanol composition and total content (mg/Kg)* of ISH OxG stearin and olein, and from *Codex Alimentarius* (FAO, 2019)

	ISH OxG stearin	ISH OxG olein	Palm oil with higher oleic acid[1]	Palm olein[1]
Delta-tocotrienol	74.35±13.53[a]	54.01±14,38[a]	33-86	40-120
Gamma-tocotrienol	598.59±135.02[a]	450.54±10.29[a]	406-887	20-700
Alpha-tocotrienol	135.98± 28.60[a]	89.70± 8.96[b]	74-256	50-500
Alpha-tocopherol	52.25± 10.70[a]	32.24± 1.94[b]	49-188	30-280
Beta-tocopherol	-	-	-	ND-250
Delta-tocopherol	-	-	ND-31	ND-100
Gamma-tocopherol	-	-	4-138	ND-100
Total tocopherol and tocotrienol	861.17± 187.44[a]	626.49± 35.25[b]	562-1417	300-1800

*Results expressed as an average of four replicates. Means followed by different lowercase letters on the lines are statistically different $p \leq 0.05$. [1]FAO (2019).

Similar to palm oil, the vitamin E profile of ISH OxG oil is also composed of both tocopherols and tocotrienols (MBA NGADI, 2015). Three tocotrienol homologues (*alpha*, *gamma*, and *delta*) are the most commonly identified in palm oil (SHAHIDI, DE CAMARGO, 2016) and its derivatives or hybrids.

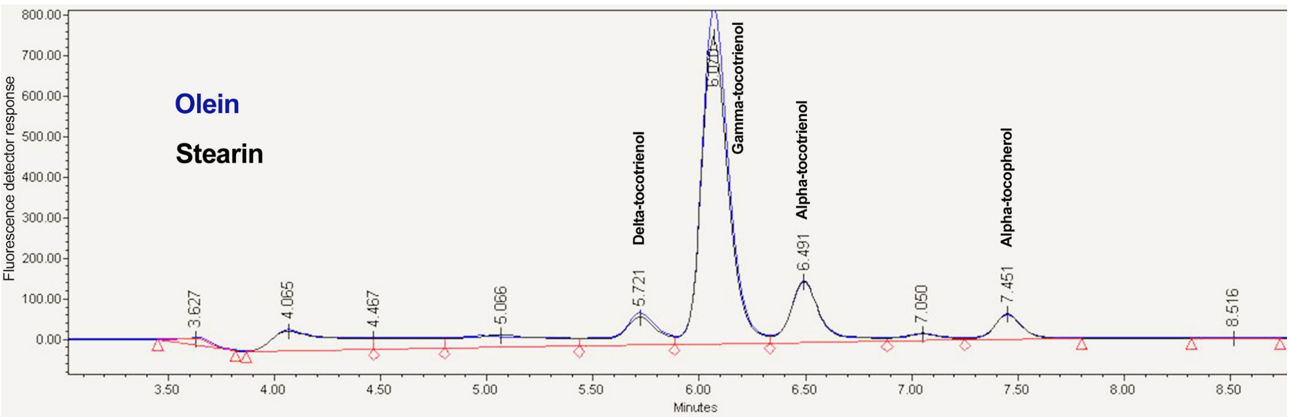

Figure 3. Tocochromanol profile of samples recorded in the range of 200-800 nm.

Recent studies have shown that tocotrienols are potentially chemo-prevention and chemotherapy agents for degenerative diseases (GEE, 2007; JIANG, 2017), have superior anti-oxidant, anti-inflammatory, anti-cholesterolaemic, anti-diabetic, anti-atherogenic, blood pressure lowering, and neuroprotective effects than tocopherol, and their content was preserved in both olein and stearin fractions (MUSA, 2021; SHAHIDI; DE CAMARGO, 2016).

Interestingly, some bioactive compounds were found in higher concentrations in the stearin fraction, although bioactive compounds tend preferentially to partition into the olein fractions (KELLENS et al., 2007; MBA et al., 2015; SAMBANTHAMURTHI et al., 2000).

Fractionation is typically performed on fully refined oil, and around 99% of carotenoids are removed in palm oil refining during the bleaching stage while approximately 36% of vitamin E content is lost during refining (GONZALEZ-DIAZ; GARCÍA-NUÚÑEZ, 2021). Crude ISH OxG olein and stearin have been proven to retain such micronutrients that are potentially attractive for consumers of nutritionally valuable vegetable oils.

Conclusion

Fatty acids, carotene, tocopherol and tocotrienol were quantified for the first time in olein and stearin from ISH OxG from the State of Bahia, Brazil. Static fractionation of unrefined palm oil produced by ISH OxG cultivated in the State of Bahia, Brazil, resulted in olein and stearin with potential as fortifying ingredients due to the high carotene and tocochromanol concentrations. Olein and stearin presented higher oleic and lower palmitic acid content than the commercial products from the palm oil fractionation. The olein fraction displayed potentially higher physical stability, while the highly retained bioactive compounds tended to partition into the stearin fraction, and showed different edible applications.

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