

## Chemical characterization and oxidative stability of the oils from three morphotypes of *Mauritia flexuosa* L.f, from the Peruvian Amazon

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### RESUMEN

**Caracterización química y estabilidad oxidativa de los aceites de tres morfotipos de *Mauritia flexuosa* L.f., de la Amazonia Peruana.**

Se estudiaron tres morfotipos de aguaje *Mauritia flexuosa* L. f., clasificados por el color del mesocarpio: "color", "shambo" y "amarillo", recogidos de localidades cercanas a la ciudad de Iquitos- Perú. Del mismo modo a partir del mesocarpio se realizaron los análisis fisicoquímicos, la caracterización de los ácidos grasos por cromatografía gaseosa, la determinación de  $\beta$ -caroteno y  $\alpha$ -tocoferol por cromatografía líquida de alta eficiencia (HPLC) fase reversa y normal y la determinación del tiempo de inducción de la oxidación en el equipo de Rancimat. A partir de la semilla se realizaron los análisis centesimales, de minerales y ácidos grasos. Los mesocarpios de aguaje son ricos en ácido oleico (amarillo: 75.63%  $\pm$  0.31),  $\beta$ -caroteno (amarillo: 342.42  $\mu$ g/g  $\pm$  0.71) y  $\alpha$ -tocoferol (color: 685.81mg/L  $\pm$  1.04), y además el morfotipo "color" tiene un tiempo de inducción superior a los otros morfotipos con 6.91  $\pm$  0.01, asimismo en la semilla de aguaje se encuentran cantidades considerables de  $\omega$ 6 (ácido linoleico) en "shambo" con 36.04  $\pm$  0.09%. Los resultados obtenidos nos indican que estos aceites independientemente de la clasificación que se le asigne contienen importantes compuestos químicos que le brindan un alto valor nutricional.

**PALABRAS CLAVE:** Ácidos grasos – Aguaje – Estabilidad oxidativa – *Mauritia flexuosa* L.f. – Morfotipos.

### SUMMARY

**Chemical characterization and oxidative stability of the oils from three morphotypes of *Mauritia flexuosa* L.f. from the Peruvian Amazon.**

Three morphotypes of aguaje *Mauritia flexuosa* were tested, classified by the color of their mesocarpium: "color", "shambo" and "amarillo", collected from different areas near the city of Iquitos, Peru. Also, physical-chemical analyses of the mesocarpium were performed, such as the characterization of fatty acids by gas chromatography, determination of  $\beta$ -carotene and  $\alpha$ -tocopherol by high efficiency liquid chromatography system in normal and reverse phase and the determination of oxidation induction time in the Rancimat apparatus. Proximate, mineral and fatty acid analyses were done on the seeds. The aguaje mesocarpium is rich in oleic oil ("amarillo": 75.63%  $\pm$  0.31),  $\beta$ -carotene ("amarillo": 342.42  $\mu$ g/g  $\pm$  0.71) and  $\alpha$ -tocopherol ("color": 685.81mg/L  $\pm$  1.04), plus

the morphotype "color" has a superior oxidation induction time compared to other morphotypes with 6.91  $\pm$  0.01. The aguaje seed contains significant amounts of  $\omega$ 6 (linoleic oil) in "shambo" with 36.04  $\pm$  0.09%. The results indicate that these oils, regardless their classification, contain important chemical compounds that give them a special nutritive value.

**KEY-WORDS:** Aguaje – Fatty acids – *Mauritia flexuosa* L.f. – Morphotypes – Oxidative stability.

### 1. INTRODUCTION

*Mauritia flexuosa* L.f. (aguaje), is a palm tree, member of the Magnoliophyta division, the Liliopsida Class, Arecidae Sub-class, Arecales Order, Arecaceae Family (Cronquist, 1978). It grows in poorly drained soils, which suggests great resistance to flooding stress, explaining its tendency to grow and develop mainly in these kinds of soils (Ribeiro *et al.*, 1998).

The geographic distribution of the aguaje is restricted mainly to South America, including the eastern side of the Andes of Colombia, Venezuela, Trinidad, the Guyanas, Ecuador, Peru, Bolivia and Brazil. (Henderson, 1995). There are approximately six million hectares of aguaje forests in the Peruvian territory (Del Castillo *et al.*, 2006), distributed mainly in the regions of San Martín, Huanuco, Madre de Dios, Cuzco, Loreto, Ucayali, Pasco (Kahn and Moussa, 1994), and the Amazons (Delgado *et al.*, 2007).

The aguaje presents a great variability within the species. In the past, it was believed that there were two species of the *Mauritia* genera (*M. Flexuosa* y *M. Vinifera* Mart), with the first inhabiting the lower flooded areas, while the second was thought to inhabit the poorly drained upper areas along rivers. Now both of the *Muaritia* are considered the same species (Villachica, 1996). Nevertheless, the persistent variability is expressed mainly from the morphological point of view, taking into account the classifications of the species from indigenous persons. The Uitotos from Colombia, for example, have determined 21 "types" of aguaje (Urrego, 1987). There are other

reports based mainly on the pigmentation of the aguaje fruit and, according to Villachica (1996), there are three "ecotypes" of aguaje: the ones with reddish mesocarpium called "shambo", the ones with fully yellow mesocarpium "ponguete", and another called "carnoso". Rojas (2000) adds, in the region of Loreto-Peru, phenotypically different trees are observed, with respect to fruits and as for plants, recognizes three "types" of aguaje according to the color of its mesocarpium: "amarillo", when the entire mesocarpium is yellow, "color" when the external part is red and the internal part is yellow, and "shambo" when the entire mesocarpium is red.

The aguaje, regardless of the morphological variability present in its fruits, represents an important source of chemical compounds such as the micro- and macronutrients sodium, potassium, calcium, iron, magnesium, manganese, copper and zinc, as well as other important phenolic compounds (Vásquez-Ocmín *et al.*, 2009). The most important virtues are found in its oils, because of high rates of  $\beta$ -carotene and the presence of important fatty acids. (Alburqueque *et al.* 2003; Alburqueque *et al.* 2005; Dias Ribeiro 2008; Rodríguez-Amaya 2001).

This work is aimed at chemically analyzing the oils of three *Mauritia flexuosa* L.f. morphotypes from the Peruvian Amazon.

## 2. MATERIALS AND METHODS

### 2.1. Plant material

Three morphotypes, classified by the color of their mesocarpium, were tested: "amarillo" presenting yellow colored mesocarpium, "shambo" presenting reddish colored mesocarpium and "color" presenting reddish colored external mesocarpium and yellow colored internal mesocarpium. These fruits were randomly collected in Aucayo (Coord. W: 0705593 y Coord. S: 09573034), Libertad (Coord. W: 0705846 y Coord. S: 09573256) and Centro Union (Coord. W: 0708456 y Coord. S: 09575376), villages located in the district of Fernando Lorez, province of Maynas, region of Loreto, Peru. The collected fruits were put in separate plastic recipients and then washed and disinfected with a continuous water flow. Water at 60°C was added to each recipient for an hour, with the purpose of forcing the ripening of the fruit, and later the exocarpium (the huso), the mesocarpium (pulp) and seed were separated by hand. The mesocarpium and seeds obtained were coded. The chemical analyses were made in the Laboratory of Natural Bioactive Substances of the Peruvian Amazon Research Institute.

### 2.2. Analytical determination

Proximate analyses were made to the obtained seeds using the methodology suggested by the Adolfo Lutz Institute (1985) and the mesocarpium and seeds oil were extracted using a Soxhlet

apparatus. Successive digestion was performed to the ashes obtained from the seeds, using chloridric acid 0,3 N for the determination of minerals, using the atomic absorption spectrophotometry equipment with an air-acetylene flame (Osborne and Voogt 1978; AOAC 2005).

For the oil extracted from the mesocarpium, physical-chemical analyses were made using the AOAC (2005) methodology. For the characterization of the mesocarpium and fatty acids of the seeds, they were derivatized and sterified using the methodology of Hartman and Lago (1973). The gas chromatography identification was analyzed on the equipment VARIAN 450-GC Supelcowax fused silicacolumn 60 m and 0,25 mm i.d, containing 0,25  $\mu$ m of poliethilenglicol, flame ionization detector (FID), using helium as carrier gas at 1.5 ml/min flow rate, column temperature programming with heating at 1 °C/min, from 170°C to 225°C, temperature detector 260°C, sample in the injector split division rate 1/20 (AOAC, 2005).

The determination of  $\alpha$ -tocopherol was carried out by dissolving 1 g of oil in 10 ml of n-butane to achieve the saponification of the sample under a nitrogen flow in a hot water bath at 80°C with constant shaking. Later, water and hexane were added in a proportion of (2:4) and the sample was shaken in a vortex mixer, resulting in the formation of three distinct phases (Katsanidis and Addis, 1999). The intermediate phase was then isolated from the other phases and filtered through Puradisc 0,4  $\mu$ m filters, and later identified through HPLC, using a LiChroCART® 250-4 LiChrospher® NH<sub>2</sub> column, and Hexane/Ethyl acetate (70:30) as the mobile phase, with a 1.0 ml/min flow rate, diode arrangement detector (DAD), with a 290 nm wave length, injection volume 20  $\mu$ L (Doughty *et al.* 1996).

For the identification of  $\beta$ -carotene, samples from the upper phase formed in the last paragraph were put in eppendorf tubes in order to dry them with a nitrogen flow, and after that the sample was suspended in 1 ml of methanol HPLC, and was identified by HPLC reverse phase, using a LiChroCART® 250-4 LiChrospher® RP-18 column, as mobile phase methanol grade HPLC 100%, with 2 ml/min flow rate, diode arrangement detector (DAD), with a wave length of 250 nm, injection volume of 20  $\mu$ L (Doughty *et al.* 1996).

The identification of the two compounds was made by comparison of retention time rates, related to the high purity standard and the quantification of area normalization, obtaining representative chromatograms for each analysis.

The determination of the forced oxidation induction time was made according to the methodology of the Metrohm manual (Rancimat 743), adapted for the Lipid Laboratory of the Faculty of Pharmaceutical Sciences of the University of São Paulo, for which two analysis groups were formed: the first group without any antioxidant, where 3 g of oil per morphotype and 3 g of soybean oil (control) were added separately into the reaction tubes; and the second group, with an antioxidant (Terhidroxibutilquinona – TBHQ, 2mg/ml),

3 g of oil for morphotype and 3 g of soybean oil(control) plus the antioxidant were added separately into the reaction tubes. The equipment was turned off when it was observed that the representative curves of the equipment were constant and the normal coloration of the oils changed. With the obtained times in the equipment, the antioxidant activity was determined using the following formula:

$$\text{Antioxidant Activity} = A / B$$

Where:

A = Induction time of the oils subjected to the study.  
 B = Induction time of s soybean oil.

From the determination of antioxidant activity, the inhibition percentage to forced oxidation was determined by the following formula:

$$\% \text{ Oxidation inhibition} = (\text{Antioxidant Activity} \times 100) - 100$$

### 2.3. Data analysis

Triple analyses were done for all the samples and essays. The data analysis was done by means of an ANOVA using the statistical software JMP IN version 4.0.4 (Sall *et al.* 2001). When significance was observed in this test, the Tukey test was applied, also the letters shown in the tables differ if there are significant differences  $p > 0.05$ .

### 3. RESULTS AND DISCUSSION

Table 1 shows the low amount of oil present in the seeds of each morphotype ( $9.20 \pm 0.43\%$  in morphotype “shambo”), when they are compared to the mesocarpium of each morphotype, as reported by Vásquez-Ocmin *et al.* (2009) they range from  $25,20 \pm 0,10 \%$  (morphotype “shambo”). These values are inferior to those reported for sachá inchi *Plukenetia volubilis* by Bondoli and Della (2006) with  $34.42 \%$ . The average values of oils found is normal in the seeds, because of the majority (especially the smaller ones) are used as a main reserve source in the process of cellular respiration with the purpose of liberating enough energy to

make it possible for the plant to establish and fixate in the soil (Salisbury and Ross 1992). Other important values found are total protein, of which the morphotype “amarillo” shows an outstanding amount, with  $12.37 \pm 0.01\%$ , twice as much as the reported value for the mesocarpium of the morphotype “shambo” with  $6,10 \pm 0,10\%$  (Vásquez-Ocmín *et al.* 2009), and inferior to that reported for sachá inchi with  $34,21 \pm 0,25\%$  (Bondoli and Della 2006).

As shown in Table 2, the aguaje seeds contain important mineral elements, including a high potassium content ( $1042.92 \pm 33.60\text{mg}/100\text{g}$ ) in the morphotype “shambo,” almost twice as much as what was reported for the mesocarpium of the morphotype “shambo” with  $660.81 \pm 3.45\text{mg}/100\text{g}$  (Vásquez-Ocmín, 2009) and much more than in the grain of corn *Zea mays* ( $170.11\text{mg}/100\text{g}$ ), the fruit of the nut *Juglans regia* L. ( $337.92\text{mg}/100\text{g}$ ) and the seed of the peanut *hypogaea* L. ( $603.59\text{mg}/100\text{g}$ ), as reported by Musa (2006).

Another important element in the mineral structure of the seeds is sodium, present in higher concentrations in the morphotype “amarillo” with  $231.48 \pm 39.14\text{mg}/100\text{g}$ , ten times as much as the value reported for the mesocarpium of the morphotype “shambo”, with  $20.76 \pm 0.19\text{mg}/100\text{g}$  (Vásquez-Ocmín *et al.*, 2009) and superior to that reported for corn ( $53.58\text{mg}/100\text{g}$ ), nut ( $65.04\text{mg}/100\text{g}$ ) and peanut ( $78.74\text{mg}/100\text{g}$ ) by Musa (2006). According to the reports of Vásquez-Ocmín *et al.* (2009), superior contents of calcium and magnesium are observed for the mesocarpium of the aguaje ( $132.49 \pm 1.31\text{mg}/100\text{g}$  y  $98.61 \pm 0.06\text{mg}/100\text{g}$  for “shambo”) in comparison to the values obtained from the seeds ( $44.30 \pm 0.58\text{mg}/100\text{g}$  of calcium for “amarillo” and  $67.65 \pm 5.99\text{mg}/100\text{g}$  of magnesium for “shambo”).

According to Table 3, the extracted oils from the mesocarpium show to have an optimum quality for consumption according to the results of the physical-chemical analyses which demonstrate the high peroxide index content and fusion point for the three morphotypes without showing any significant difference, matching with the results obtained by Trevejo (2003). Another important parameter is the acidity index, where the morphotype “shambo”, proves to be different among the three.

Table 1  
 Proximate analyses of the seeds from three morphotypes of *Mauritia flexuosa* L.f.\*

Analysis (%)	Amarillo Mean ± SD	Color Mean ± SD	Shambo Mean ± SD
Humidity	50,55 <sup>a</sup> ± 2,08	48,07 <sup>a</sup> ± 0,94	55,39 <sup>b</sup> ± 1,35
Ashes	1,20 <sup>a</sup> ± 0,06	1,31 <sup>b</sup> ± 0,05	1,32 <sup>b</sup> ± 0,01
Oils	7,37 <sup>a</sup> ± 1,03	7,01 <sup>a</sup> ± 1,45	9,20 <sup>a</sup> ± 0,43
Proteins	12,37 <sup>a</sup> ± 0,01	8,56 <sup>b</sup> ± 0,26	9,90 <sup>b</sup> ± 0,51
Carbohydrates	30,15 <sup>a</sup> ± 2,53	35,03 <sup>a</sup> ± 1,96	24,44 <sup>c</sup> ± 1,68

\*The data shown in the table represent the mean ± Standard deviation (SD), and the letters differ when they are statistically different  $p < 0.05$ .

Table 2  
Mineral concentrations in seeds of three morphotypes of *Mauritia flexuosa* L.f.\*

Minerals Mg/100g	Amarillo Mean $\pm$ SD	Color Mean $\pm$ SD	Shambo Mean $\pm$ SD
Zinc	1,28 <sup>a</sup> $\pm$ 0,07	0,73 <sup>b</sup> $\pm$ 0,03	1,25 <sup>a</sup> $\pm$ 0,01
Calcium	44,30 <sup>a</sup> $\pm$ 0,58	27,19 <sup>b</sup> $\pm$ 0,84	34,81 <sup>b</sup> $\pm$ 5,45
Copper	0,58 <sup>a</sup> $\pm$ 0,04	0,37 <sup>b</sup> $\pm$ 0,02	0,87 <sup>c</sup> $\pm$ 0,04
Sodium	231,48 <sup>a</sup> $\pm$ 39,14	80,25 <sup>b</sup> $\pm$ 2,08	91,57 <sup>b</sup> $\pm$ 5,66
Magnesium	60,53 <sup>ac</sup> $\pm$ 4,80	52,37 <sup>bc</sup> $\pm$ 5,46	67,65 <sup>a</sup> $\pm$ 5,99
Manganeso	7,32 <sup>a</sup> $\pm$ 0,09	5,82 <sup>b</sup> $\pm$ 0,02	13,04 <sup>c</sup> $\pm$ 0,60
Potasium	910,95 <sup>a</sup> $\pm$ 30,24	809,88 <sup>b</sup> $\pm$ 22,87	1042,92 <sup>c</sup> $\pm$ 33,60
Iron	4,16 <sup>a</sup> $\pm$ 0,40	1,51 <sup>b</sup> $\pm$ 0,22	6,32 <sup>c</sup> $\pm$ 0,60

\*The data shown in the table represent the mean  $\pm$  Standard deviation (SD), and the letters differ when they are statistically different  $p < 0,05$ .

Table 3  
Physical-chemical analyses of the oils extracted from the mesocarpium of three morphotypes of *Mauritia flexuosa* L.f.\*

Analysis	Amarillo Mean $\pm$ SD	Color Mean $\pm$ SD	Shambo Mean $\pm$ SD
Iodine index	70,99 <sup>a</sup> $\pm$ 0,28	70,38 <sup>a</sup> $\pm$ 0,11	70,17 <sup>b</sup> $\pm$ 0,31
Saponification index	191,34 <sup>a</sup> $\pm$ 0,28	186,25 <sup>b</sup> $\pm$ 0,22	194,89 <sup>c</sup> $\pm$ 0,41
Fusion point ( $^{\circ}$ C)	11,0 <sup>a</sup> $\pm$ 1,0	12,0 <sup>a</sup> $\pm$ 1,0	10,3 <sup>a</sup> $\pm$ 0,57
Peroxide index (meq.de ox./Kg)	11,12 <sup>a</sup> $\pm$ 5,36	10,0 <sup>a</sup> $\pm$ 1,0	12,46 <sup>a</sup> $\pm$ 0,49
Acidity index	2,69 <sup>a</sup> $\pm$ 0,19	2,13 <sup>a</sup> $\pm$ 0,40	3,54 <sup>b</sup> $\pm$ 0,32

\*The data shown in the table represent the mean  $\pm$  Standard deviation (SD), and the letters differ when they are statistically different  $p < 0,05$ .

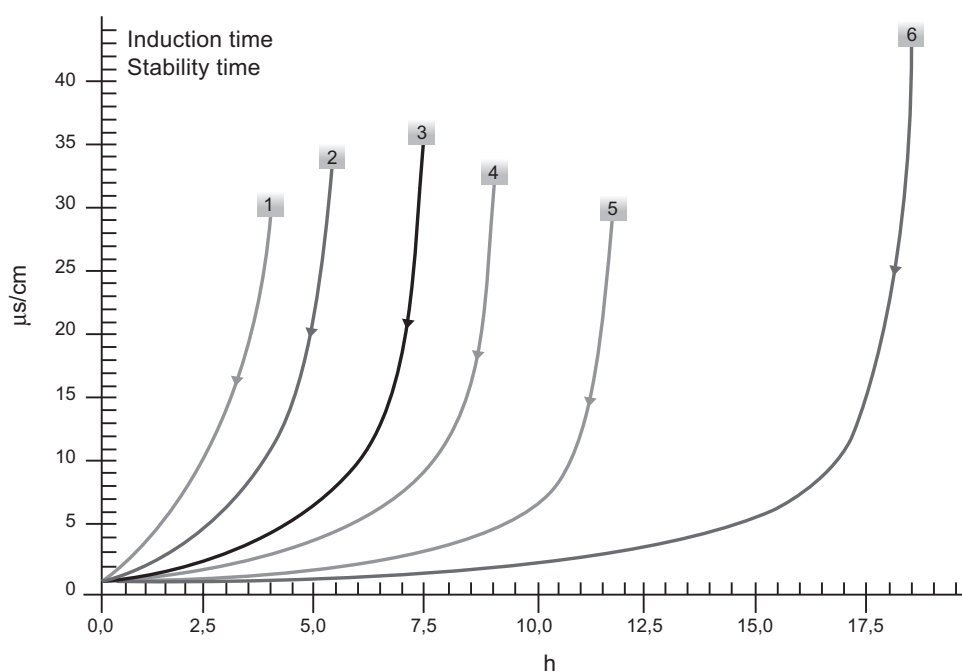


Figure 1.

Curves for the aguaje oils expressed in time of induction. 1= induccion time of "aguaje amarillo"; 2= induction time of "aguaje shambo"; 3= induction time of "aguaje color"; 4= induction time of "aguaje amarillo + TBHQ"; 5= induction time of "aguaje shambo + TBHQ"; 6= induction time of "aguaje color + TBHQ".

Table 4  
**Characterization of fatty acids of the oils extracted from the mesocarpium and seeds of the morphotypes of aguaje compared to other oil crop species**

Fatty acid %	<i>M. flexuosa</i> <sup>*</sup> "amarillo"	<i>M. flexuosa</i> <sup>*</sup> "color"	<i>M. flexuosa</i> <sup>*</sup> shambo"	<i>M. flexuosa</i> <sup>**</sup> amarillo"	<i>M. flexuosa</i> <sup>**</sup> "color"	<i>M. flexuosa</i> <sup>**</sup> shambo"	<i>M. flexuosa</i> <sup>*</sup> "shambo" Trevejos, 2003	<i>M. flexuosa</i> <sup>**</sup> "shambo" Trevejos, 2003	<i>M. flexuosa</i> <sup>*</sup> Albuquerque, 2003	<i>M. flexuosa</i> <sup>*</sup> França, 1999	<i>M. flexuosa</i> <sup>*</sup> Manhães, 2007	<i>M. flexuosa</i> <sup>*</sup> Ucciani, 1995	<i>M. flexuosa</i> <sup>*</sup> Ucciani, 1995	<i>O. batataú</i> <sup>*</sup> Momtúfar, 2009	<i>O. europaea</i> <sup>*</sup> Ucciani, 1995
8:0 (Caprylic)	-	-	-	-	-	-	-	-	-	-	0,59 ± 0,13	-	-	-	-
12:0 (Lauric)	-	-	-	-	-	-	-	0,4	-	-	-	-	-	0,01 ± 0,01	-
13:0 (Tridecanoic)	-	-	-	-	-	-	-	-	-	-	-	-	-	0,10 ± 0,06	-
14:0 (Myristic)	-	-	-	-	-	-	-	1,3	0,1	-	-	-	-	0,09 ± 0,05	-
15:0 (Pentadecanoic)	-	-	-	-	-	-	-	-	-	-	-	-	-	0,27 ± 0,08	-
16:0 (Palmitic)	19,61 <sup>a</sup> ± 0,41	20,26 <sup>a</sup> ± 0,11	21,68 <sup>b</sup> ± 0,18	18,07 <sup>a</sup> ± 0,12	24,22 <sup>b</sup> ± 0,19	24,28 <sup>b</sup> ± 0,09	17,3	18,7	17,34-19,2	17,34	19,31 ± 0,13	17,3-23,7	17,3-23,7	18,12 ± 5,58	7,4-14,3
16:1 ω7 (Palmitoleic)	0,15 <sup>a</sup> ± 0,01	0,28 <sup>b</sup> ± 0,00	0,27 <sup>b</sup> ± 0,00	-	-	-	0,3	1,6	-	-	-	-	0,3-0,7	0,89 ± 0,37	0,9-3,0
17:0 (Margaric)	-	-	-	-	-	-	-	-	-	-	-	-	-	0,06 ± 0,01	-
17:1 (Heptadecanoic)	-	-	-	-	-	-	-	-	-	-	-	-	-	0,07 ± 0,01	-
18:0 (Stearic)	1,57 <sup>a</sup> ± 0,02	1,40 <sup>b</sup> ± 0,01	1,86 <sup>c</sup> ± 0,00	5,50 <sup>b</sup> ± 0,02	3,83 <sup>b</sup> ± 0,07	5,41 <sup>b</sup> ± 0,16	2,0	5,8	2,0	-	1,86 ± 0,03	1,4-2,0	1,4-2,0	1,74 ± 0,79	3,5-4,8
18:1 ω9 (Oleic)	75,63 <sup>a</sup> ± 0,31	75,02 <sup>b</sup> ± 0,10	71,67 <sup>c</sup> ± 0,10	27,59 <sup>a</sup> ± 1,76	52,96 <sup>b</sup> ± 0,26	31,52 <sup>c</sup> ± 0,16	76,5	22,2	73,3-78,73	78,73	73,32 ± 0,10	70,7-76,5	70,7-76,5	72,69 ± 5,39	63,3
18:1 ω7 (cis-Vaccenic)	-	-	-	-	-	-	-	-	-	-	-	-	-	22,8 ± 0,66	-
18:2 ω6 (Linoleic)	2,19 <sup>a</sup> ± 0,25	2,29 <sup>b</sup> ± 0,01	3,70 <sup>b</sup> ± 0,01	34,58 <sup>a</sup> ± 0,06	16,24 <sup>b</sup> ± 0,14	36,04 <sup>c</sup> ± 0,09	2,1	44,0	2,4-3,93	3,93	2,69 ± 0,12	1,9-2,1	1,9-2,1	1,93 ± 0,43	5,1-15,5
18:3 ω3 (α-Linolenic)	0,82 <sup>a</sup> ± 0,06	0,72 <sup>b</sup> ± 0,02	0,80 <sup>b</sup> ± 0,08	13,33 <sup>a</sup> ± 0,13	1,74 <sup>b</sup> ± 1,50	2,58 <sup>b</sup> ± 0,31	1,0	2,0	2,2	-	2,17 ± 0,03	1	1	0,79 ± 0,19	-
20:0 (Araquidic)	-	-	-	-	-	-	-	-	-	-	-	-	-	0,07 ± 0,02	1,2-2,6
20:1 (Eicosenic)	-	-	-	-	-	-	-	-	-	-	-	-	-	0,11 ± 0,01	-

The results shown in the table for the mesocarpium are represented by mean ± Standard deviation (DS) and the letters differ when they are statistically different p<0,05, as is the case for the seeds. \* = mesocarpium; \*\* = seed.

Table 4 illustrates that the fatty acid compositions of the different mesocarpiums do not vary, but there are some differences in the individual concentration of them, mainly the high oleic acid concentrations. The morphotype "amarillo" showed greater differences with  $75,63 \pm 0,31\%$  of oleic acid, similar to the reported figure by Trevejo (2003) with  $76,5\%$ ; Albuquerque (2003) with  $73,3-78,73\%$ ; Ferreira (1999) with  $78,73\%$ ; Manhães (2007) with  $73,32 \pm 0,10\%$  and Ucciani (1995) with  $70,7-76,5\%$ , and topping the reports for other species are unguirahui *Oenocarpus bataua* with  $72,69 \pm 5,39\%$  (Momtúfar, 2009) and olive oil *Olea europaea* with  $63,3\%$  (Ucciani, 1995).

The composition of fatty acids in the seeds is different to the composition of fatty acids in the mesocarpiums. The seeds demonstrate a high content of  $\omega 6$  (linoleic acid), an important fatty acid and functional nutrient which, along with other antioxidant compounds, is capable of diminishing the disturbances occasioned by oxidative stress (Calder, 2003). Linoleic acid is found mainly in the morphotype "shambo" with  $36,04 \pm 0,09\%$ , with a concentration higher than that found in *Plukenetia volúbilis* sacha inchi with  $33,67\%$  (Bondoli and Della 2006), oil palm *Elaeis guineensis* with  $10,60 \pm 0,46\%$  (García *et al.* 2008) and olive oil *Olea europaea* with  $7-9,8\%$  (Gunstone and Padley 1997), but inferior to the concentration reported by Trevejo (2003) for the seed of the aguaje "shambo"

with  $44,00\%$ . The morphotype "color" presents low  $\omega 6$  concentration in comparison to the other two morphotypes, however this is the one that presents higher oleic acid concentrations with  $52,96 \pm 0,26\%$ , succeeding the reported figure by Trevejo (2003) for aguaje "shambo" with  $22,2\%$ .

According to Table 5, high  $\beta$ - carotene concentration is observed in the morphotype "amarillo" with  $324,42\mu\text{g/g}$ , similar to the one mentioned by De Rosso and Mercante (2007), with  $514\mu\text{g/g}$  of total carotene, of which it was identified that  $372,32\mu\text{g/g}$  corresponded to  $\beta$ - carotene; also Rodríguez-Amaya (2001) reports  $360\mu\text{g/g}$ , a content similar to the reported concentration in palm oil *Elaeis guineensis* with  $363\mu\text{g/g}$  (Trujillo-Quijano *et al.*, 1990). A high concentration of  $\alpha$ - tocopherol can be observed in the morphotype "color" with concentrations of  $683,35\text{mg/L}$ , these being superior to its concentrations in corn oil *Zea mays* ( $600\text{mg/L}$ ) and in olive oil *Olea europaea* ( $354\text{mg/L}$ ), as reported by Sayazo *et al* (2007).

In Table 6, the induction times of aguaje oils are shown, where the morphotype "color", has the highest time with  $6,91$  hours, being superior even to the obtained time for colza oil *Brassica napus* and olive oil *Olea europea*, reported by Boletín de aplicación Methrom (2008). Also in Table 7, forced oxidation inhibition percentage is demonstrated, where the morphotype "color", has the highest percentage at  $87,96\%$ , which could be the result of

Table 5  
Determination of  $\beta$ - carotene,  $\alpha$ - tocopherol by HPLC in oils extracted from the mesocarpium of three morphotypes of *Mauritia flexuosa* L.f.\*

Vitamines	Amarillo Mean $\pm$ SD	Color Mean $\pm$ SD	Shambo Mean $\pm$ SD
$\beta$ - caroteno ( $\mu\text{g/g}$ )	$324,42^a \pm 0,71$	$264,60^b \pm 0,44$	$283,57^c \pm 0,48$
$\alpha$ - tocoferol ( $\text{mg/L}$ )	$683,35^a \pm 0,46$	$685,8^b \pm 1,04$	$677,58^c \pm 0,63$

\*The data shown in the table represent the mean  $\pm$  Standard deviation (SD), and the letters differ when they are statistically different  $p < 0,05$ .

Table 6  
Induction time of the oils of *Mauritia flexuosa* L.f., and oil of *Glycine max* soybean (positive control)\*

Induction time (hours)	Amarillo Mean $\pm$ SD	Color Mean $\pm$ SD	Shambo Mean $\pm$ SD	Soja Mean $\pm$ SD
Without Antioxidant	$3,55^a \pm 0,01$	$6,91^b \pm 0,01$	$4,74^c \pm 0,03$	$3,68^d \pm 0,03$
UIT Antioxidant	$10,85^a \pm 0,02$	$17,96^b \pm 0,01$	$7,61^c \pm 0,03$	$6,68^d \pm 0,03$

\*The data shown in the table represent the mean  $\pm$  Standard deviation (SD), and the letters differ when they are statistically different  $p < 0,05$ .

Table 7  
Forced oxidation inhibition percentage of the oils of three morphotypes of *Mauritia flexuosa* L.f.\*

% Forced oxidation inhibition	Amarillo Mean $\pm$ SD	Color Mean $\pm$ SD	Shambo Mean $\pm$ SD
Without Antioxidant	$-3,44^a \pm 0,38$	$87,96^b \pm 1,45$	$28,80^c \pm 0,23$
With Antioxidant	$62,47^a \pm 0,59$	$168,86^b \pm 1,05$	$14,02^c \pm 0,78$

\*The data shown in the table represent the mean  $\pm$  Standard deviation (SD), and the letters differ when they are statistically different  $p < 0,05$ .

a high content of  $\alpha$ -tocopherol present in the oil. It can also be observed that the oils of the morphotypes with the right antioxidant mixture increase the induction time by three times (Figure 1).

#### 4. CONCLUSIONS

The main virtue of the mesocarpium of aguaje *Mauritia flexuosa* L.f, independent of the morphotype, is expressed in its high  $\beta$ -carotene,  $\alpha$ -tocopherol, oleic acid contents and its oxidation resistance, which make it a high quality oil, superior to olive oil *Olea europaea* and palm oil *Elaeis guineensis*, which can be easily used by the nutraceutical product manufacturers. An important alternative to the use of aguaje seeds which are thrown in the streets of Iquitos and other cities where it is consumed, is the extraction and use of its oils which contain a considerable concentration of  $\omega$ 6 (linoleic acid), important for diminishing the effects caused by oxidative stress.

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