Characteristics of pulp and oil from Macauba (*Acrocomia aculeata*) after different post-harvest treatments and storage

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Abstract— *The Macauba Palm fruits (Acrocomia aculeata) can be a promising source of vegetable oil for food purposes, cosmetics and energy, due to the high productivity and by generate two types of oils. However, the main problem is associated with the rapid deterioration of the fruit and the pulp oil acidification. Thus the preservation of fruit quality requires the development and application of appropriate techniques that must starts in the harvest, go through post-harvest treatment, storage, preparation and ends in the extraction of its oils. The objective of this study was to identify post-harvest treatments using simple and inexpensive techniques that promote the preservation of Macauba fruit and pulp oil during 30 days of storage. The results indicate that in order to maintaining the quality of the fruit and its oil the* recommendation is to realize the processing in a shorter time after harvest.

Keywords— ***Acrocomia aculeata, Macauba pulp oil, post-harvest treatments.***

I. INTRODUCTION

Consumption of vegetable oils has increased in the world and currently its market is determined not only by consumption for food purposes and production of pharmaceuticals and lubricants, as well as for the production of biodiesel (BARBOSA et al., 2008).

Among the enormous diversity of plant species which can be extracted oils, there is the Macauba Palm (*Acrocomia aculeate* (Jacq. Lodd. ex Mart.)), a palm tree native to the Tropical Americas that produces a oleaginous fruit (Pires et al., 2013; Silva and Caño-Andrade, 2013). Macauba is considered one of the most notable palm trees in Brazil, growing naturally in large populations, both in degraded areas and in intact areas, adapting well in different ecosystems (Motta et al., 2002; Aquino et al. 2008).

The Macauba presents great economic viability, due to its high oil yield and the possibility of the complete use of each part of its fruits: husk, pulp, endocarp and kernel. Depending on the processed part different products and co-products can be generated, such as: oil rich in oleic acid from pulp; oil rich in lauric acid from kernel; biomass rich in protein produced from pulp and kernel cakes for food or feed purposes; activated carbon or vegetable coal produced from endocarp and husk parts (Pires et al., 2013).

Both the composition of the fruit as the oil content in the pulp and kernel parts is quite discrepant, due to not only the fruit origin but also the different degrees of maturity of fruits submitted to analysis. According to the literature, the oil yield from the Macauba fruit may vary from 1500 to 5000 kg of oil per hectare, thus second only to the *Elaeis guineensis* culture (Manfio et al., 2011; Moura et al., 2010).

The main problem in relation to the application of the crude macauba pulp oil is its high acidity. After complete maturation, the fruits come off the bunch and fall to the ground, suffering contamination by microorganisms, initially in the epicarp and mesocarp parts of the fruit. This contamination causes deterioration and compromises the quality of the fruit and its oils. Studies on techniques for harvesting and post-harvest treatments in order to ensure adequate storage of fruits are required, thus allowing the use of its oil and biomass for unrestricted purposes (Mota et al., 2011).

In this way, the objective of this study was to evaluated post-harvest treatments using simple and inexpensive techniques that promote the preservation of Macauba fruit and its oils considering the storage period of 30 days and that can be used by agriculturalist cooperatives and also for industries. Sanitization techniques including the use of sodium hypochlorite solution and drying was evaluated through the physicochemical characteristics of the pulp and its oil acidity.

II. MATERIAL AND METHOD

2.1 Raw material

Native Macauba Palms with mature fruits were selected in Belo Horizonte, Minas Gerais, Brazil (19^o 51´44´´S; 43^o 56´14´´W). To evaluate whether different harvest periods influence the characteristics of fruit and its oils, were made two different harvests, one in December 2013 and another in January 2014, being the fruits collected directly from the ground, those detached from its bunch in a maximum of up to 7 days.

To examine the effect of different post-harvest treatments the fruits were divided into three lots: Lot 1- stored without cleaning (control); Lot 2- washed with water, quickly immersed in sodium hypochlorite 2 % and dried at room temperature; Lot 3- washed with water, quickly immersed in sodium hypochlorite 2% and dried in the oven at 60 °C for 24 h.

All the lots were stored at room temperature in plastic containers with holes. After each treatment, analyses of the lots were made on the day of harvest (time zero) and after 30 days (time 30). For each evaluated time were used about 15 to 20 fruits at each lot.

2.2 Physicochemical characteristics of the pulp

The moisture content was determined gravimetrically at 130 ºC in an oven according to Ac 2-41 (AOCS, 2009). The water activity (Aw) was determined by a portable measure (*AquaLab Model Series 3TE*). The determination of oil content was performed by direct extraction with petroleum ether as solvent in a Soxhlet extractor, according to the method BC 3-49 (AOCS, 2009). The titratable acidity of the pulp, expressed as a percentage of the volume ratio by mass, was determined by titrated with sodium hydroxide (0.1 mo/L) according to the technique describe by Institute Adolfo Lutz (2008), method 310/IV.

2.3 Oil extraction and characterization

Previous to extraction of its oil, the pulp was dried in a forced circulating oven at 130 °C for 3 hours and then triturated with a liquefier. The oil extraction was performed with petroleum ether solvent, according to Method Bc 3-49 (AOCS, 2009). The oil acidity index was determined by titration with potassium hydroxide (0.1 mol/L) according method Cd 3a-63 (AOCS, 2009).

2.4 Statistical analysis

The analyses were performed in triplicate and the differences between the averages were evaluated by Tukey's test at 5% probability using the software Minitab, version 16.

III. RESULTS AND DISCUSSION

The initial moisture content of the pulp immediately after treatment (time 0) and after storage (time 30) is shown in Table 1. In both harvests, the moisture value of lot 3 was statistically different, being smaller than the other lots, as expected since the purpose of drying is reduction of the moisture. The results of the Tukey´s test indicate that was not significant difference in moisture values obtained for lot 2 and lot 1, therefore, the immersion in sodium hypochlorite solution does not lead to an increase in moisture of pulp. The first harvest was carried out in a rainy period, which may explain the higher moisture values found in time zero. The literature presents diverse values to the moisture content in pulp of Macauba fruits. Ciconini et al. (2013) obtained values ranging from 49.06% to 63.00% in fruits collected in Cerrado biome and Pantanal; while fruits collected in Pernambuco showed moisture pulp around 41.85% (Oliveira et al., 2009). For two different subspecies of *Acrocomia aculeata*, harvested in Contagem (state of Minas Gerais) and in Paranaíva (state of Paraná), Lira et al. (2013) found moisture values in Macauba pulps equals to 45.86% and 45.42%, respectively.

As expected, after thirty days of storage there was a significant reduction of moisture in all cases, being the lower values found in lot 3.

TABLE 1
MOISTURE CONTENT (%) IN PULPS OF MACAUBA FRUITS.

	Lot	Time 0	Time 30
1st harvest	1	$47.77^{aA} \pm 0.92$	$21.69^{B} \pm 0.34$
	2	$49.21^{aA} \pm 1.24$	$20.56^{B} \pm 1.39$
	3	$41.49^{bA} \pm 1.19$	$15.02^{B} \pm 0.27$
2nd harvest	1	$44.78^{aA} \pm 0.64$	$22.60^{B} \pm 0.73$
	2	$45.92^{aA} \pm 0.73$	$15.64^{B} \pm 0.30$
	3	$38.49^{bA} \pm 0.20$	$13.14^{B} \pm 0.39$

Mean ± standard deviation.
For each harvest, means in the same column followed by the same lowercase letters do not differ by Tukey's test (p <0.05).
Means in the same row followed by different capital letters differ by Tukey's test (p <0.05).

According to Table 2, the water activity (A_w) presented a similar behavior to the moisture content in the two harvests. Initially A_w ranged from 0.955 to 0.981 and in the two harvests the lowest values were found in the pulp of lot 3 and only this lots differ statistically from the others. The Aw values of this work are higher than those obtained by Sanjinez-Argandoña and Chuba (2011) that found values in the range 0.90 to 0.95 in fruits harvested in Dourados (MS) and Presidente Epitácio (SP).

After thirty days of storage, there was a significant reduction of water activity in all lots, with values ranging between 0.758 and 0.890. The decrease of A_w during the storage period was also observed by Tilahun et al. (2013) and Souza (2013). However, different this work, the value of water activity found by Souza (2013) in fruits pulp that have been kept 31 days in the field, within collectors, was around 0.6.

TABLE 2
WATER ACTIVITY IN PULPS OF MACAUBA FRUITS.

	Lot	Time 0	Time 30
1st harvest	1	$0.976^{aA} \pm 0.002$	$0.849^{aB} \pm 0.008$
	2	$0.974^{aA} \pm 0.003$	$0.840^{aB} \pm 0.020$
	3	$0.962^{bA} \pm 0.002$	$0.787^{bB} \pm 0.003$
2nd harvest	1	$0.981^{aA} \pm 0.003$	$0.890^{aB} \pm 0.002$
	2	$0.979^{aA} \pm 0.003$	$0.796^{bB} \pm 0.002$
	3	$0.955^{bA} \pm 0.004$	$0.758^{cB} \pm 0.006$

Mean ± standard deviation.
For each harvest, means in the same column followed by the same lowercase letters do not differ by Tukey's test (p <0.05).
Means in the same row followed by different capital letters differ by Tukey's test (p <0.05).

From a microbiological point of view, A_w reflects the water available for growth of microorganisms. Most microorganisms grow considerably in high values of Aw, between 0.98 and 0.95, and in general, the bacteria are less tolerant to reductions in these values, but some of them can grow up to about 0.85. However, certain species of yeasts can proliferate even in A_w less than or equal to 0.7 and the minimum value registered for the development of fungi (molds) is equal to 0.61. So, there are some exceptions to the general behavior (Ordóñez, 2005). It is important to point out that Microbial activity can contribute to losses in dry matter through the utilization of carbohydrates as energy source and protein degradation (Magan and Aldred, 2007). Additionally, some microorganisms are capable of producing lipases, enzymes that hydrolyze the triglycerides present in the pulp, leading to an increase in free fatty acids in the oil, thus decreasing their quality (Cavalcanti-Oliveira et al., 2015).

The enzyme activity is directly related to the A_w values. Tapeti et al. (2013) found that the enzymatic activity (lipases and peroxidases) in Macauba pulp showed a decrease over the storage period according to water activity reduction. Borrmann et al. (2009) studied soybeans under drought conditions and found that the enzyme activity was lower when A_w values were in the range of 0.6 and 0.7.

The values of the pulp oil content found in this work are presented in Table 3 in time immediately after harvest and treatment, and after thirty days of storage. As the measure was performed on a dry basis it was not expected that the treatments would influence the pulp oil content in the initial time. Therefore, the variation of the oil content can be attributed to the variability of the fruit.

TABLE 3
OIL CONTENT (% DRY BASIS) OF MACAUBA PULP

	Lot	Time 0	Time 30
1st harvest	1	$47.82^{bB} \pm 0.37$	$57.60^{bA} \pm 0.62$
	2	$51.66^{aB} \pm 0.63$	$61.26^{aA} \pm 1.68$
	3	$47.00^{bB} \pm 0.86$	$52.86^{cA} \pm 1.49$
2nd harvest	1	$49.58^{aB} \pm 0.64$	$64.94^{aA} \pm 1.08$
	2	$48.99^{aB} \pm 0.34$	$63.91^{aA} \pm 1.64$
	3	$48.54^{aA} \pm 1.20$	$50.32^{bA} \pm 0.51$

Mean ± standard deviation.
For each harvest, means in the same column followed by the same lowercase letters do not differ by Tukey's test ($p < 0.05$).
Means in the same row followed by different capital letters differ by Tukey's test ($p < 0.05$).

The pulp oil content immediately after collection ranged from 47.00% to 51.66%. These values are higher than those found by Ciconini et al. (2013) that found medium values of 25.07%, in fruits of four distinct regions of the state of Mato Grosso do Sul. Also Lira et al. (2013) found an average value for the pulp oil content in fruits Macauba collected in Contagem (Minas Gerais) equal to 32.76%.

After 30 days there was a significant increase in the oil content of the pulp in all cases, being the smallest increases found in lot 3 of both harvests, the lot that passed by previous drying. This results are in agreement with the work of Martins (2013), that also observed less oil accumulation in pulps from fruits of Macauba dried for four days at 45°C and no oil accumulation in fruits dried during four and eight days at 65°C. The explanation is that the reduction of moisture decreases the fruit metabolism, thus reducing the accumulation of oil. On the contrary, in the fruits with higher water content available, the oil accumulation was higher, especially in fruits without any post-harvest treatment. Souza (2013) also found that the lipid content of the pulp increased with time remaining fruit in the field, reaching the maximum point at 11 days, an increase of 40.35%. Therefore the author concluded that occurs lipid synthesis after removal of the fruit of the bunch.

The titratable acidity of Macauba pulp is shown in Table 4. Both in "time 0" and the "time 30" the titratable acidity values were higher in the first harvest. This may have occurred because the higher moisture content of the fruits of this harvest could have caused further deterioration of the pulp. In all cases, after 30 days of storage titratable acidity increased considerably. It is observed that the lot 3 showed the lowest increase in the acidity in all harvests. Lots that have not gone through any post-harvest treatment had the highest acidity increases, even with a lower initial acidity.

It's important to highlight that the process of drying at 60 °C for 24 h produced smaller increase in acidity of the pulp, however resulted in less accumulation of oil in the pulp during storage.

TABLE 4
TITRATABLE ACIDITY (% V/W) OF MACAUBA PULP.

	Lot	Time 0	Time 30
1st harvest	1	$1.93^{aB} \pm 0.29$	$28.34^{A} \pm 0.13$
	2	$2.03^{aB} \pm 0.15$	$24.76^{A} \pm 0.18$
	3	$2.24^{aB} \pm 0.13$	$16.66^{A} \pm 0.34$
2nd harvest	1	$0.86^{bB} \pm 0.07$	$24.91^{A} \pm 0.19$
	2	$0.87^{bB} \pm 0.11$	$21.31^{A} \pm 0.70$
	3	$2.48^{aB} \pm 0.07$	$15.64^{A} \pm 0.34$

Mean ± standard deviation.
For each harvest, means in the same column followed by the same lowercase letters do not differ by Tukey's test (p <0.05).
Means in the same row followed by different capital letters differ by Tukey's test (p <0.05).

The titratable acidity has been determined often in studies that perform physical-chemical analysis to evaluate the quality of plant foods, as well as those of animal origin (Souza et al., 2010). By determining the titratable acidity can obtain valuable information on the condition of the fruit storage and analysis of the increase in acidity may constitute a method to indicate the degree of deterioration of the fruit. Currently, most research involving Macauba are focused on the use of oil. However, the pulp can also be used for preparing food (Oliveira et al. 2013), and the cake generated in the oil extraction can also be used as an ingredient for food production (Silveira et al., 2014). In such cases, it should take into consideration the Macauba conservation status. According to Magro et al. (2006) the increase of acidity is related to food decomposition process whether by hydrolysis, oxidation or fermentation.

The acidity index of the pulp oil immediately after harvest and treatment (time 0), and its variation after storage (time 30) are shown in Table 5. Initially, Macauba pulp oil presented low acidity index ranging from to 0.44 to 0.87 mg KOH/g which corresponds to approximately 0.23 – 0.44% of acidity expressed in terms of oleic acid. The acid value of the oil obtained from fruits that passed by drying after harvest (lot 3) were similar to other values, so it can be said that the combination of time and temperature used in the drying did not affect the oil quality.

TABLE 5
ACIDITY INDEX (mg KOH /g) OF THE PULP OIL.

	Lot	Time 0	Time 30
1st harvest	1	$0.46^{cB} \pm 0.2$	$22.86^{bA} \pm 0.67$
	2	$0.87^{aB} \pm 0.02$	$24.12^{abA} \pm 0.86$
	3	$0.55^{bB} \pm 0.04$	$25.01^{aA} \pm 0.62$
2nd harvest	1	$0.44^{bB} \pm 0.06$	$19.84^{cA} \pm 0.11$
	2	$0.50^{bB} \pm 0.07$	$25.07^{aA} \pm 0.18$
	3	$0.81^{aB} \pm 0.11$	$22.99^{bA} \pm 0.23$

Mean ± standard deviation.
For each harvest, means in the same column followed by the same lowercase letters do not differ by Tukey's test (p <0.05).
Means in the same row followed by different capital letters differ by Tukey test (p <0.05).

After thirty days of storage, there was a marked increase in acidity in all cases, indicating that none of the treatments were effective in maintaining the oil acidity. Goulart (2014) also reports the rise in acid value of the pulp oil during 45 days of storage of fruits, which increased from 0.48% to about 30.0%. Contrary to what was expected, in both harvests, the lot 1 was the one that showed the lowest value of oil acidity. This result indicates that although both treatments tested (cleaning with sodium hypochlorite and cleaning with sodium hypochlorite followed by drying) are more effective in maintaining the acidity of the pulp they are not sufficient to ensure that the fruits can be stored and yet are capable of producing oil with low acidity.

IV. CONCLUSION

The possibility of preservation of the Macauba fruit and its pulp oil during 30 days of storage was evaluated by application of two post-harvest treatments by simple and inexpensive techniques. The behavior of the physic chemical properties of the fruit pulp (moisture, water activity, titratable acidity, oil content) and of the oil extracted from the pulp(acidity index) were evaluated. The results indicate that although there is a considerable increase in the fruit oil content with the storage time, there is a loss of quality of fruit pulp and its oil measured by the increase in acidity. Therefore, the posterior industrial application of the raw materials extracted from the fruit should be the parameter that will indicates the need of to process the fruit right after the harvest, in order to ensure high level of quality, or to store the fruit for around 30 days, in order to get a greater quantity of oil.

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