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Harvest and post-harvest conditions influencing macauba (*Acrocomia aculeata*) oil quality attributes

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ABSTRACT

Macauba (*Acrocomia aculeata*), also known as macauba palm, is a good source of vegetable oil in tropical America. Its fruits are highly suitable for biodiesel production owing to the high quantity and quality of its oil. However, commercial exploitation of this species remains insufficient. Forms of harvesting, the storage period, and the use of chemicals for the postharvest preservation of macauba fruits and their effects on the associated microbiota were investigated. Mature fruits were collected only once from the mother tree and separated in two groups, a group of fruits not exposed to the ground surface (0 days) and a larger group of fruits that was placed in contact with the soil surface for 7, 14, and 21 days, to allow infestation of soil-borne microorganisms. Then the fruits were treated with 3 doses of fungicide fungicide (0, 0.2, and 0.4% v/v) and storage at room temperature during 0, 10, 20, 30 and 40 days. Hence the experiment was set in a randomized block design with four replications in a factorial Scheme $4 \times 3 \times 5$ (period of ground surface contact, doses of fungicide and period of storage). The mesocarp oil content (OC), free fatty acids, and oxidative stability of the oil were evaluated, and the presence of microorganisms in the mesocarp and epicarp of the macauba fruits was quantified. Fungicide was found to be effective in maintaining low oil acidity of fruits unexposed to the soil surface for up to 20 days of storage and for maintaining oil oxidative stability. Regardless of the fungicide dose applied, an increase in the OC was noted for all harvest times during the first 10 days of storage. Therefore, for biodiesel production, it is recommended that the fruits should be harvested when in pre-absciscion stage (directly from the mother tree) or collected from the ground after no more than 7 days after abscission. In both cases, the fruits must be pre-treated with fungicide if storage is intended.

1. Introduction

Acrocomia aculeata (Jacq.) Lodd. ex Mart known as macauba, is an oleaginous palm native to tropical America. It occurs naturally in biomes characterized by semi-deciduous forest or savanna as well as in anthropized areas such as deforested sites and pastures (Scariot et al., 1995). Pires et al. (2013) and Motoike and Kuki (2009) reported that macauba have similar productive potential to African palm (*Elaeis guineensis*), which is among the highest oil-yielding plants in the world (FAO, 2013), rendering it an important role as an alternative oil crop. Highly productive, the macauba plant generates spadix inflorescences and usually produces four bunches/year (Manfio et al., 2011). These bunches are voluminous and contain 300 to 600 drupaceous fruits, weighting about 66 g/each. The macauba fruit consists of the epicarp (shell) (23% d.b.); mesocarp (pulp) (46.7% d.b.), endocarp (23.8% d.b.), and endosperm (almond) (6.3% d.b.). The mesocarp oil content reaches 55% to 69% of the dry matter while the almond presents 55% to 58% (CETEC, Centro Tecnológico de Minas Gerais, 1983).

Accordingly to these traits, in recent years, the research on macauba renewable energy source has intensified (Evaristo et al., 2016; Gonçalves et al., 2013; Machado et al., 2015; Navarro-Díaz et al., 2014). The oil from the mesocarp of the macauba fruit is an excellent raw material for biodiesel production due to the predominance of unsaturated fatty acids (±73%), especially oleic acid (±52%) (Coimbra and Jorge, 2011). For the industry, the oil fatty acid

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composition, water content, acid value, and oxidation stability are important parameters that influence the process of oil transesterification (Meher et al., 2006). According to the Brazilian and European standards, biodiesel should have ≤0.25% acidity (0.5 mg KOH/g), oxidative stability ≥6 hand water content ≤0.05% (ANP, 2008; CEN, European Committee for Standardization, 2003). These characteristics are highly influenced by the type and quality of raw material used (Pinzi et al., 2009). Furthermore, pre-harvest and post-harvest management of agricultural products directly affect the quality of the extracted oil.

The macauba production system adopted in this study is based on extractivism, which takes advantage of the extensive native stands of this plant in Brazil and Paraguay. In this system, only fruits that naturally fall on the ground are collected, usually at the end of the fruiting period. In this model of exploitation the fruit is unavoidable exposed to soil–borne microorganisms, which can accelerate its degradation. In addition, the fruits are stored without any control, resulting in low yields and poor quality of the extracted oil. Hence, it is believed that the loss of oil quality may be directly influenciated by how and when harvesting and/or storage are handled.

Among the biggest challenges to turn macauba palm into a domesticated species, and fulfill its potential is to establish both pre and pos harvest protocols. The lack of information regarding the best stage to crop mature fruits, the maximum residence time of mature fruits on the ground that would not compromised its quality, the storage period, and the associated microbiota are some of the reigning issues. Clearing these issues will help guarantee a sustainable exploitation of the palm and the quality of its fruits. transform the current extractive exploration in commercial crops so as to enable sustainable exploitation of the palm. Therefore, this study aimed to investigate the requirements for macauba fruit harvesting (as and when), the use of plant protection products on the post-harvest conservation of the fruits and the ideal storage period, in order to maintain the mesocarp oil quality. In addition, the densities of bacteria, yeasts, and filamentous fungi associated with macauba fruits were evaluated at different storage periods.

2. Materials and methods

2.1. Site description, experiment outline, and statistical design

Fruits were collected from the experimental farm of the Agricultural Research Company of Minas Gerais (EPAMIG) in the municipality of Sete Lagoas, Minas Gerais, Brazil. A total of 100 macauba plants were selected and georeferenced. Of these plants, bunches of physiologically mature fruits (start of mesocarp yellowing and natural abscission) were detached from the mother tree with a manual sickle and its fall protected by a foam mattress,15 cm thickness, layed on the ground to prevent the fruits against damages and undesirable contact with the soil surface. Afterwards, fruits with broken epicarp or attacked by insects were excluded and the remaining fruits were separated in two groups in regards to their fruit-ground contact period (F-GC) (ground-harvested): a group of fruits without prior contact with the ground surface (F-GC 0 days) and a larger group of fruits in contact with the soil surface for 7, 14, and 21 days. Each experimental unit consisted of 20 fruits contained in polyethylene mesh bags. The experimental units were randomly arranged under the crowns of two macauba trees in the pasture area, were the ground was mostly covered by *Brachiaria* sp. grass and plant debris. The area was surrounded by a steel mesh fence to avoid cattle and wild animal foraging.

After each pre-establish fruit-soil surface contact period was reached (i.e., F-GC 0, 7, 14, and 21), the fruits were treated with fungicide (Tecto SC—thiabendazole) at 3 different concentrations, 0 (only water), 0.2, and 0.4% v/v (i.e., D = 0, 50, and 100, respectively), for 2 minutes. The solutions were prepared using water as vehicle. The concentration of 0.4% v/v (D100) was selected as suggested by the manufacturer for postharvest in most crops. After drying in the open, the sample fruits were transported to the facilities at the Federal University of Viçosa (UFV), Viçosa/MG, and storage in a warehouse, without climatic control, in individually polyethylene plastic boxes (perforated and without cover) randomly arranged. The fruit storage period (S) was 0, 10, 20, 30, and 40 days.

The temperature and relative humidity (RH) were monitored both in the field (EPAMIG farm) as in the warehouse. The temperature and RH sensor automatically recorded the temperature and RH at every 2 h. The amount of rainfall was recorded in the period when the fruits have remained in the soil. These data were obtained from the meteorological station of the EPAMIG farm. Along the 21 days of exposure to ground conditions, the air temperature varied between 14.3 °C and 45.8 °C, with an average temperature of 25.4 °C .The RH ranged from 27.3% to 98.1% (average 72.9%) over the days. The total accumulated rainfall in this period was 130.9 mm, and the fifth day recorded the highest daily precipitation of 57.6 mm. In the warehouse, the average temperature over the days was 25.1 °C (18.2 °C to 41.2 °C). The RU ranged from 34.1% to 92.8%, with an average RU of 70.5% during the storage.

2.2. Mesocarp oil analyses

Fruits were processed in the Laboratory of Biotechnology and Postharvest of Macauba, of the Department of Plant Science of UFV. After manually breaking and removing the exocarp, the mesocarp was cut into pieces with a knife.

For the oil extraction, the minced mesocarp was dried at 60 °C for 15 h and then submitted by a stainless steel hydraulic press. The obtained oil was stored in amber bottles, wrapped in aluminum foil, and stored at −20 °C until further analyses. The following parameters were evaluated: acidity index of the oil, by means of the amount of free fatty acids (FFA), oxidative stability of the oil (OSI), mesocarp oil content (OC), and numbers of microorganisms in the epicarp and mesocarp. All analyses were performed immediately after the end of the storage time of each treatment.

2.2.1. Free fatty acids (FFA)

The FFA content of mesocarp oil was determined according to the Ca 5a-40 method (AOAC International, 2005) and converted to the acidity percentage in oleic acid.

2.2.2. Oxidative stability (OSI)

Oxidative stability was determined according to the Cd 12b-92 method (AOAC International, 2005) by using the Rancimat® equipment (873 Biodiesel Rancimat model), in which 2.5 g ± 0.01 g of mesocarp oil was heated to 110 °C, with air flow rate of 10.0 L h^{-1}. The results were expressed in hours, and the induction period (IP) indicated the oxidative stability of the oil. Thus, higher IP values indicated greater oil stability in relation to oxidation processes.

2.2.3. Mesocarp oil content (OC)

Mesocarp oil content (OC) was determined by nuclear magnetic resonance (NMR; MQC NMR Analyser, Oxford) and expressed in percentage on dry basis of mesocarp following the ISO 10565 method (ISO, 1999). This method was selected after determination of its accuracy in comparison to results of OC obtained by using oil extractor (AOAC International, 1992). In this trial, the mesocarp OC of 20 samples was evaluated, and the data was verified by *F*-test at 99% confidence level so that there was no statistical difference between the methods for measuring the OC of macauba's mesocarp.