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Eco-particleboard manufactured from chemically treated fibrous vascular tissue of acai (*Euterpe oleracea Mart.*) Fruit: A new alternative for the particleboard industry with its potential application in civil construction and furniture

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A R T I C L E I N F O

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A B S T R A C T

Generation and availability of agro-industrial waste in the world present an opportunity to obtain raw materials for the development of new sustainable materials. In order to contribute to the dissemination of using agro-industrial residues in lignocellulosic particleboard (eco-particleboard) manufacturing, this work aimed to investigate the influence of a chemical mercerization treatment on the physical and mechanical properties of eco-particleboards. The treatment consisted of 0.5% sodium hydroxide (NaOH). Results of analysis of variance (ANOVA) revealed that treating the fibers was responsible for significantly reducing water absorption by 35% (2 h) and 17% (24 h), as well as thickness swelling by 36% (2 h) and 40% (24 h). The apparent density of treated (WT) and untreated (UT) eco-particleboards showed homogeneity and uniformity of the test specimens analyzed, mainly due to the manufacturing process in eco-particleboard pressing. The efficiency of the chemical mercerization treatment of the fibers of acai fruit eco-particleboard (WT) was established because the eco-particleboard produced with these fibers showed higher values in their mechanical properties: screw pullout (top) 54%, modulus of rupture in static bending (31%), and internal bonding (89%) compared to eco-particleboards composed of untreated fibers (UT). The physical-mechanical results presented by the eco-particleboards composed of treated acai fibers (WT) suggest that acai fibers could be a potentially useful raw material for the production of medium density homogeneous particleboards and consequent commercial use in the construction and furniture industries.

1. Introduction

Brazil has a great potential for renewable resources. The correct and appropriate use of residues minimize environmental and energetic impacts, as well as generating products with relevant applications in the industry (Khiari et al., 2011; Johansson et al., 2012; Centeno et al., 2016). Corn cobs, sugarcane bagasse, oats (rice, coffee, coconut, castor beans and peanuts), bamboo, banana and cassava stalks, among others, are sources of the great diversity of lignocellulosic residues produced by the Brazilian agroindustry.

The intensified demand for renewable materials, population growth and consumption patterns contribute to the depletion of the planet's natural resources, notably native forests. These factors highlight the need for reforestation, thus reducing deforestation. In Brazil, *Pinus* sp. and *Eucalyptus* sp. are the most used trees for reforestation (Manhães, 2008), and are also most frequently used in the fiber and particleboard

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industries.

These industries, in Brazil, preferentially use wood chips from *Pinus* and *Eucalyptus* genera in order to improve the control of raw material homogeneity, producing a higher quality product. However, lignocellulosic materials from agro-industrial waste have been a new economic, social and environmental alternative for particleboard, medium density particleboard (MDP), and medium density fiberboard (MDF) manufacturing in Brazil (Iwakiri et al., 2004).

The production of lignocellulosic particleboards from agro-industrial waste is an alternative that provides added value to this by-product, making it possible to meet the growing demand of the wood board industry. In addition to this, it will contribute to the reduction of wood use and reduce the pressure on native and planted forests. Thus, the production costs of the boards will be reduced, making them more competitive in the economic scene (Mendes et al., 2010).

In this context, research has been carried out on the feasibility and use of new raw materials for the preparation of particulate composites based on lignocellulosic residues. Some mechanical properties of eco-particleboards, especially modulus of elasticity (MOE), modulus of rupture (MOR), and internal bonding were affected by variables involved in the production process, such as board density and composition, resin and paraffin dosages, and particle size (Mendes et al., 2010), as well as the compaction ratio. The use of waste generated by the agro-industry and of resins such as the castor oil-based polyurethane (Campos et al., 2014 and Nadzi et al., 2015) is an alternative in the production of homogenous particleboards like: wood residues (Fiorelli et al., 2015), coconut fiber (Fiorelli et al., 2012), sugarcane bagasse (Castro et al., 2014), peanut shell (Gatani et al., 2014).

The plant fibers of the Amazon have been the subject of countless studies for the elaboration of polymeric composites with vegetal fibers (Fagury, 2005; Nogueira et al., 2012; and Fonseca et al., 2013). Fagury (2005) studied the chemical, physical, and mechanical properties of acai, coconut, jute fibers, and fiberglass as reinforcement in polymers. The values described by author for the modulus of elasticity are: acai fiber 0.57 ± 0.27 GPa; coconut fiber 0.62 ± 0.02 GPa; jute fiber 2.06 ± 0.19 GPa; and fiberglass 0.52 ± 0.02 GPa. According to the author, the three natural fibers can be used in composites respecting the peculiar characteristics of each fiber. According to Marconcini et al. (2008), polyolefin composites recycled with fibers from acai residue increased the composites‘ mechanical strength.

The acai industry is an important economic source in the northern region of Brazil. The State of Pará is currently the largest producer in Brazil, accounting for 87.1% of the total pulp consumed in the country, with around 80–90% coming from the northeast of that state. Of this production, about 24% are generated in cultivated areas and 76% have extractive industry origins (Santana et al., 2012), revealing a growth in the proportion of cultivated and managed native acai areas; which is interesting in environmental and productive efficiency terms.

The agro-industrial residues from acai juice production (called seeds or pits) in the metropolitan region of Belém – Pará – Brazil, are producing around 93,521 tons/year. About 16,000 tons from the pulp industry are produced daily and discarded or used as a source of energy in ovens and boilers. In this context, our study used acai waste, looking to find a sustainable and conscious use for it. The methods of chemical mercerization and natural extraction of acai fruit fiber were studied, aiming to determine the most efficient process among them to design this particleboard referred to as an eco-particleboard (Mesquita de Lima et al., 2015).

Conventional treatments on vegetable fiber surfaces aim to reduce their hygroscopicity and/or increase fiber-resin interaction capacity, which may influence the final characteristics of the composite (Bertoti et al., 2009; Kim and Netravali, 2010). The process of chemical mercerization is a common method of producing high-quality fibers. In this process, the fibers are chemically treated to remove lignin, pectin, waxy substances and natural oils which coat the outer surface of the cell wall of the fiber. This removal exposes the fibrils and provides a rough surface on the fiber's topography (Cai et al., 2015). Sodium hydroxide (NaOH) is the most commonly used chemical for bleaching and/or cleaning the surface of plant fibers. It also changes the fine structure of native cellulose I to cellulose II, a process known as mercerization (Mwaikambo and Ansell, 2002).

Therefore, this study aimed to investigate the influence of the treatment by chemical mercerization with 0.5% NaOH, on the improvement of the fiber quality and, consequently, in the physical-mechanical properties of the eco-particleboard produced from acai fruit fibers. In addition, this acai fiber residue could be a new sustainable alternative for the particleboard industry increasing the value of the acai production chain. This also provides innovative materials developed for the construction and furniture industries, thus, reducing the pressure on the amazon forest and the negative impacts of conventional material production.

2. Materials and methods

2.1. Mechanical extraction and chemical mercerization treatment of the fibers.

The extraction of the fibers of the acai fruit by mechanical means was performed using a circular bench sander (Fig. 1a and b). For the extraction of these fibers in this experimental condition no additional treatments were performed. These were considered as reference fibers for the manufacture of untreated (UT) eco-particleboard.

The chemical mercerization process consisted of the treatment of acai fibers with 0.5% sodium hydroxide solution (NaOH), (Fig. 1c). 2.88 kg of seed pits were added into the autoclave (Fig. 1d), and then their respective solution until total immersion of the pits was achieved. Finally, the pits were baked for about 45 min and exposed to a pressure of 10 Atm and a temperature of 40 °C. These fibers were used for the production of the treated eco-particleboard (WT).

2.2. Acai fruit fiber-based eco-particleboard production

Ten medium density homogeneous eco-particleboards of fibrous vascular tissue of acai (*Euterpe oleracea* Mart.) fruit were manufactured: 5 with untreated fibers (UT) and 5 with 0.5% NaOH treated fibers (WT). Natural fibers from mechanical extraction and the chemical

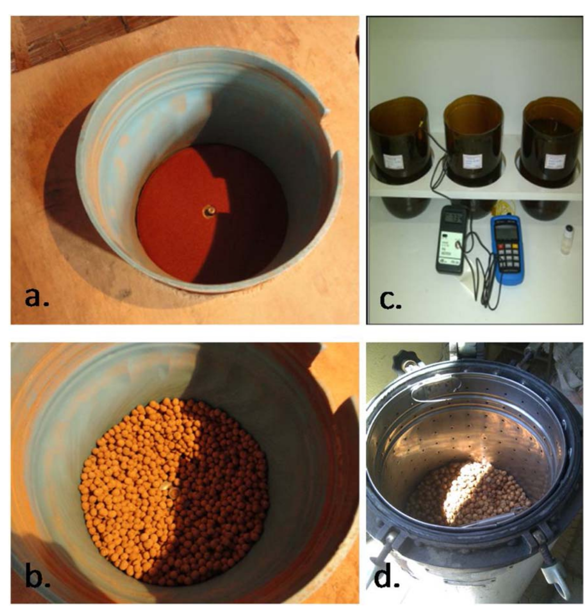

Fig. 1. Mechanical extraction process: (a) Circular bench sander and (b) Fiber extraction; Chemical mercerization process (NaOH autoclave): (c) 0.5% NaOH solution and (d) autoclave.