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New Process for Peanut Husks Panels: Incorporation of Castor Oil Polyurethane Adhesive and Different Particle Sizes

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Abstract. New materials are being developed for architectural and design purposes. The recycling of waste is presented as an opportunity for new applications based on increased industrial waste and raw material shortages. Seeking an alternative to wooden panels, regional waste without sustainable disposal is being used as inputs in the production of lignocellulosic panels.

We present the results of two experiments. The first one consists in the development of peanut husks ground-treated and untreated panels made in order to determine the influence of different particle sizes, shapes and their combinations, aiming to the physical and mechanical characterization of compact panel's properties. In the second experiment, compact panels with whole peanut husks were made with polyurethane resin using castor oil painting. The object of this study was to analyze the influence of this new resin, without formaldehyde emissions, in the resulting panel's physical and mechanical properties. It was concluded that the smaller particles had a positive influence in the panel's physical-mechanical properties, and that the property characterization of panels made with castor oil resin was satisfactory for use in interior furniture. Peanut husks panels show good prospects for their integration in the field of design and architecture.

Introduction

In the early days, natural materials were used for human habitation. Wood, stone, and earth defined the first architectures. The changes caused by the industrial revolution in terms of production techniques, has resulted in an extensive variety of industrial materials used in architecture and design. This evolution has redefined the conception of architecture and design [1], allowing new construction techniques and refurbished expressive resources. While the production model characterized by the extraction, manufacture, use and disposal, has been modified as processes, its essence has not changed. It is possible to produce increasingly complex products, in less time, while increasing sometimes the environmental pressure or load upon the planet [2].

The increased availability of materials favors the production and consumption of products. As a result of the intensive use of resources from non-renewable or even renewable sources, their future availability is being compromised. The effects of increased production cause environmental impact by greenhouse gas emissions and waste generation at the end of products life. According to Hawken [3] only 6% of the total flow of material finishes into desired products, while most pristine materials are returned to the atmosphere in the form of liquid, solid or gas. The idea of the world as a source of endless resources and an infinite waste receiver should be matter of the past.

The current sustainable development paradigm leads us to think not only in means of our own needs, but also in those of future generations. Based on the concept of sustainable development emerged in 1987 by the Brundtland report, there is some consensus about "meeting the needs of the present without compromising the satisfaction of the needs of future generations" [4]. Changes in the productive sector and in product design have occurred, with the need to conserve resources and to mitigate the environmental consequences arising from their transformations [5].

In recent years, new materials have been developed in the fields of architecture and design in order to minimize environmental impacts. Materials derived from plants and agricultural waste provides interesting design possibilities. Alternative lignocellulosic panels are being developed using abundant local waste that doesn't has its production scales final destination resolved. Sugarcane bagasse, rice hulls, wheat, cereals and maize residues, kenaf fibers, flax and hemp etc. are bonded with synthetic resins, generally the urea formaldehyde type, into forming compact panels [6,7,8,9,10].

Peanut husks are overabundant residues. In the province of Cordoba - period 2010-2011- , the groundnut production was 967,254 thousand tons, of which 33% of the total (357,884 thousand tons) was husks [11]. Some husk destinations include boilers fuel; livestock feed, and activated carbon production. Its application in the development of compact panels not only adds value but points out the use of this waste turning it into a suitable product to be used in architecture and design. Gatani (2010) develops compact and light weighted bonded panels from agroindustrial peanut husk waste, optimizing physical and mechanical properties as well as the environmental ones, in view of their application in architecture and interior design.

Outstandingly, some drawbacks are found in relation to the use of urea formaldehyde resin as a binder. One of the environmental problems of formaldehyde resin emissions is the pungent-smelling gas, which at high concentrations irritates the mucous membranes and that if sustained, could cause cancer [12]. The severity of the effect of formaldehyde is confirmed by the International Agency for Research on Cancer [13], which determined that formaldehyde is carcinogenic to humans, concluding that there is sufficient evidence that it causes nasopharyngeal cancer. Furthermore, this study describes the production of agglomerated particle board and similar materials used in the construction sector as the most common source of emission. Its difficulty to be replaced rests mainly in the resulting materials low cost and good physical and mechanical property.

Materials and methods

Results from the two experiments are presented below. In the first one, chip boards made of peanut husks were developed at the Institute of Wood Technology (FCF-UNSE) in order to determine the influence of using different size and shapes of particles and their combinations in the characterization of physical and mechanical properties of compact panels. Whole and milled particles were used (Figure 1), and characterized by means of their density between 0.081 g/cm3 and 0.20 g/cm3 for crushed shells. Four types of particle boards measuring 40 x 40 cm with a 15mm thickness were prepared according to the following formulations:

(F): Fine particles plates (crushed particles)

(F-W-F): Fine and whole Particle Boards (combination of fine particles on the surface and milled particles inside the board)

(W-F-W): Whole and fine particles boards (combination of whole particles on the surface and milled particles inside the board)

(W): Whole particles boards (particles without milling treatment)

a b

Figure 1: Peanut husks. a: Milled particles and b: Whole particles

In the second experiment, compact panels were developed at the laboratory of Construções e Ambiência, Faculdade de Engenharia de Alimentos (FZEA), Universidade de São Paulo (USP). Bonded panels were characterized. They were made with traditional resin (urea-formaldehyde), with and without additives (paraffin and ammonium sulphate), and with an alternative resin (polyurethane resin of castor bean oil) without formaldehyde emissions. The aim of the study was to analyze the influence of this new resin in the physical-mechanical properties of resulting panels, by evaluating the behavior of different panels with equal density. Four types of 15mm thick panels were prepared, distinguished each one according to density and type of binder used:

(W1) Peanut husks panels bonded with castor oil resin, medium density

(W2) Peanut husks panels bonded with urea resin, medium density

(W3) Peanut husks panels bonded with urea resin and additives, medium density

The panels preparing method was similar in both cases. Whole and ground particles were impregnated with the respective resins and homogenized for 10 minutes in electric mixer. The resin quantity was 10 % in mass, respect to the husks mass. Afterwards, this mixture was poured into wooden molds and then cold pre-pressed, in order to form a cushion of particles, and subsequently the final molding was carried out for 10 minutes at 100 ton hydraulic press with a temperature of 100 ° C. Next, the panels were removed and stockpiled for stabilization after the mechanical and physical characterization. They were performed according to ABNT NBR 14810-3:2006 [14] for chipboard panels. The essay consists in the determination of physical properties (density, water absorption and swelling at 2 h and 24 h) and properties from mechanical bending test: modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB)

Results

Characterization of different particle sized panels

Figure 2 shows the surface and cross section of the panels obtained. We highlight their attractive appearance obtained result of the association of natural looking colors and textures typical of peanut shells. This feature distinguishes them from traditional wooden boards, and gives them an aesthetic advantage for application in architecture and interior design.

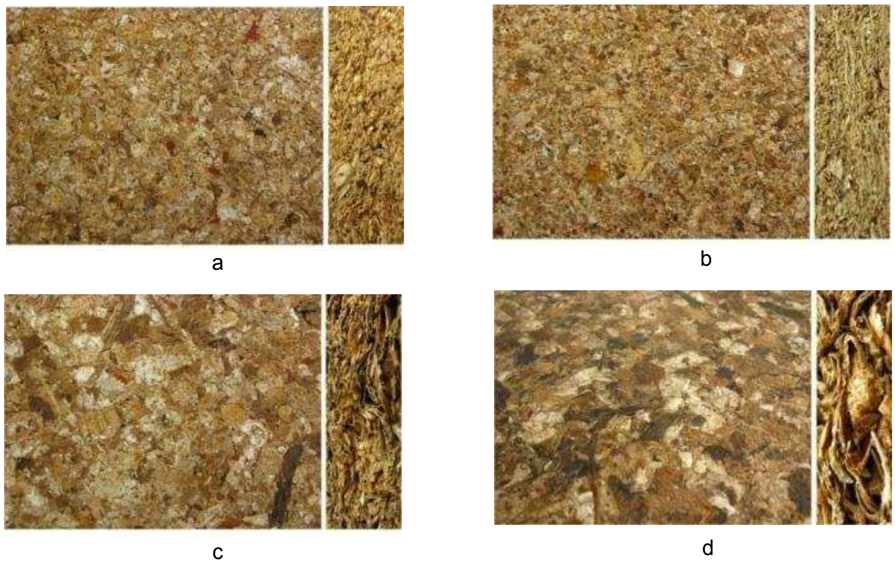


Figure 2: Surfaces and cross section of peanut husks panels. a: Milled particles panel (F). b: Combined whole and milled particles panel (F-W-F). c: Combined whole and milled particles panel (W-F-W). d: Whole particles panel (W)

The resulting panels can be classified as LD-1 (Low Density, Type 1) [15], with values between 0.49 and 0.63 g/cm3. Figure 3 shows the density values obtained. The higher density obtained in the case of composite panels only for fine particles, is emphasized.

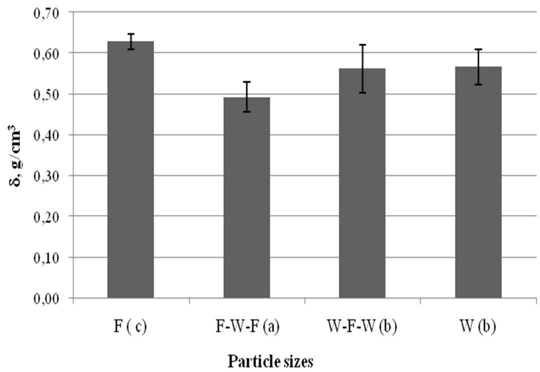


Figure 3: Density values of the peanut husks panels according with their particle sizes

Levels of water absorption and thickness swelling (Figure 4) are shown, according to standards, above the recommended values, and therefore are suggested to be used in indoor applications with natural moisture and rain protection. The better behavior of panels with fine particles is highlighted, concluding that the smaller particle size favors the resin distribution, resulting in better performance against water absorption and swelling.

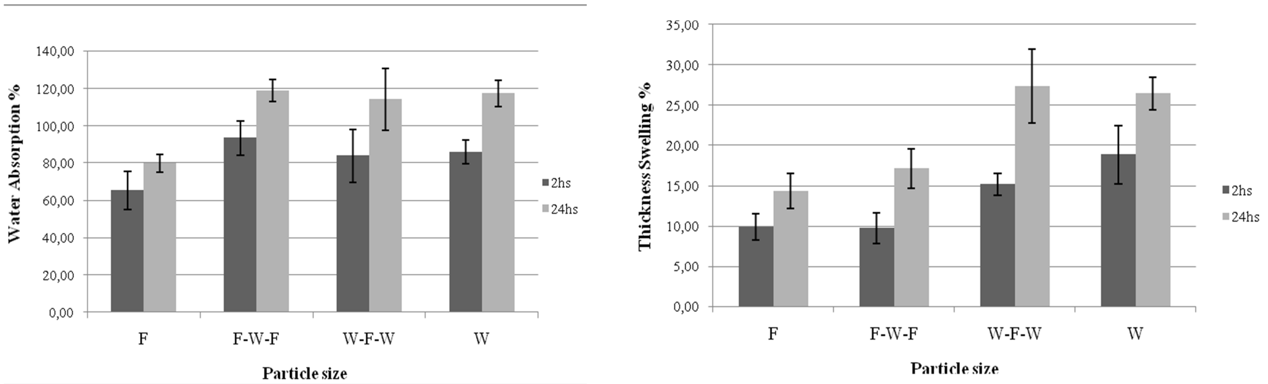


Figure 4: Physical properties. a: Water absorption 2 y 24 h. b: Thickness swelling 2 y 24 h

The values of MOR and MOE are connected with the results of density. More stable behavior was observed in panels with fine particles who achieve higher MOR and MOE values. This behavior is attributed to better distribution of resin between the particles and smaller flat particles. The content of larger particles decreases the mechanical properties of the compounds. The behavior of the mixture of small particles on the surface and inside large particles should be studied. It is possible that in this case, the surface layers are thinner than the center thickness, and this situation has little influence on the mechanical behavior of these pads.

The results obtained for the mechanical behavior of the panels are summarized in Table 1.

Table 1: Mechanical behavior of peanut husks panels

Mechanical Property	F	F-W-F	W-F-W	W
MOR, MPa	3,58 (b)	2,01 (a)	3,29 (b)	2,78 (a-b)
MOE, MPa	627,7 (b)	417,8 (a)	588,9 (a-b)	480,7 (a-b)

Characterization of panels with castor oil adhesive resin

The influence of the density and the use of polyurethane castor oil resin were assessed.

The density values obtained are summarized in Figure 5. Statistical analysis allowed us to infer that the W1 panels, W2 and W3 have similar density.

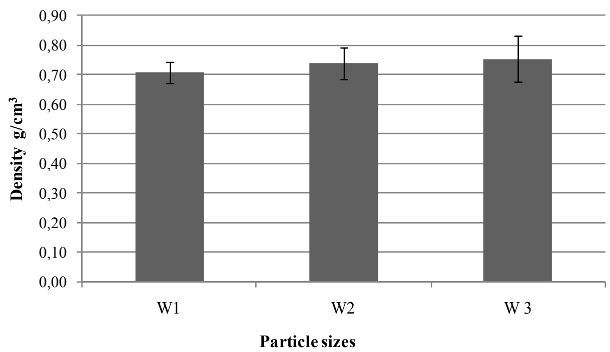


Figure 5: Average density of different peanut husk panels according with binder.

The water absorption values obtained within 2 h (Figure 6a) group the W2 panels as lower absorption, and W3 and W4 as higher absorption. This situation indicates that in the short term, castor oil polyurethane resin influences the water absorption behavior of the material. The swelling values recorded at 2h and 24 h (Fig. 6b) enable to observe less swelling in panels with castor oil resin than in those with urea formaldehyde resin.

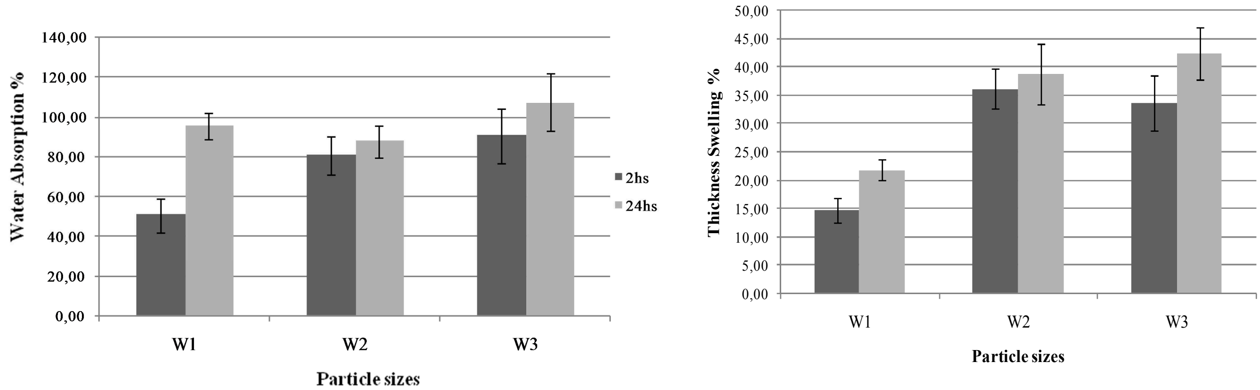


Figure 6: Physical properties. a: Water absorption 2 y 24 h. b: Thickness swelling 2 y 24 h

Figure 7a shows that the obtained values of MOR in medium density panels are lower than those recommended by the standard reference [16] (<11 MPa). Also, in all observed cases, they exceed the standard value for low-density panels. As to the value MOE (Figure 9b), it shows that the panels classified as M (medium density) have lower values than those recommended by the norm (<1725 MPa).

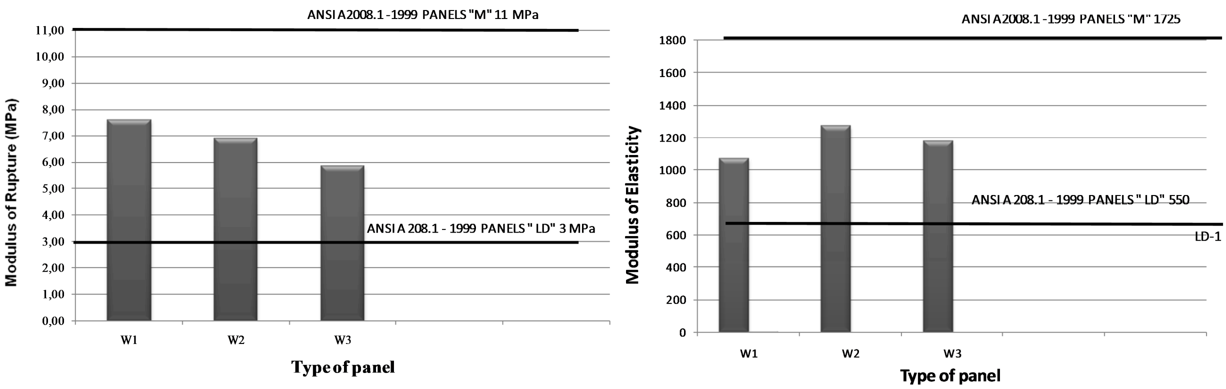


Figure 7: Mechanical properties according binder. a: MOR. b: MOE

Regarding internal bond (ID), all panels exceed the recommended value stated by the *classification according to low density* standard (Figure 8). Being 0.1 MPa the benchmark for low-density panels and 0.4 MPa the one for medium density panels.

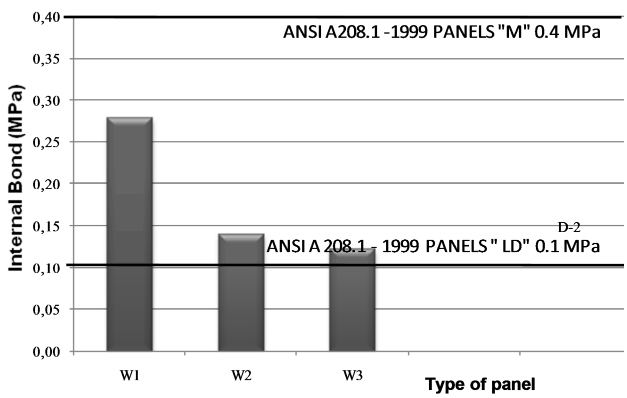
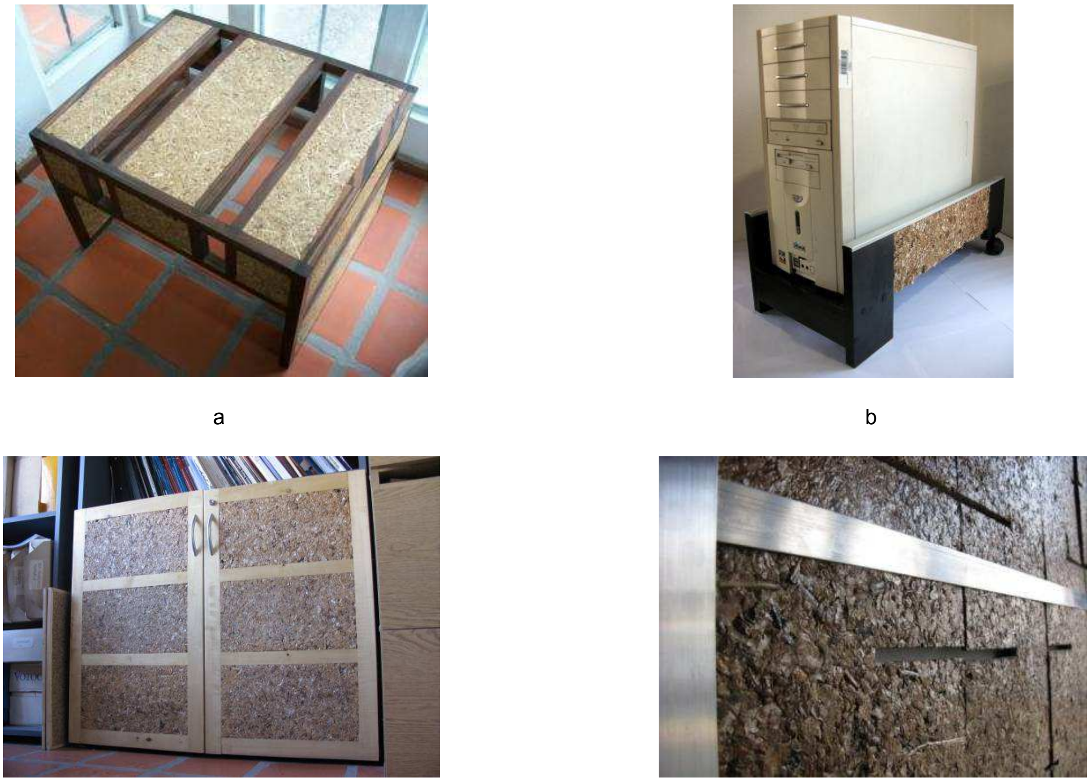


Figure 8: Internal Bond average values

The results allowed us to determine the density of each sample in relation to the panel's physical and mechanical behavior. In panels with similar density values, the use of castor oil resin enables the achievement of superior mechanical performances in comparison with those made with urea resin. Furthermore, it was demonstrated that in the preparation of ureic panels, the use of additives in the resin did not improve the mechanical properties of peanut husks panels.

Applications

Applications of the resulting materials have been carried out in order to determine their suitability in terms of use in architecture and design. Agglomerated peanut husk panels were used in office equipment and interior residence furniture (Figure 9 a, b), glued, screwed and or combined with wood. Modular interior walls supported with metal profiles were also made (Fig. 9d).



a b

c d

Figure 9: Applications of compact panels of peanut husks. a: Side table . b: CPU holder c: Furniture doors. d:Wall covering

Conclusions and Prospects

The use of lignocellulosic feedstock waste in chip boards is a growing trend accompanied by the replacement of binders containing organic compound emissions harmful to human health. The results obtained demonstrate the great opportunities that peanut husks particle boards have as a viable alternative for use in architecture and design.

Improvements in the panels manufacturing process must be incorporated to achieve the properties of industrial wooden panels. This work suggests highlighting the attractive appearance given by the presence of large peanut husk particles on the surface, more aesthetically appealing than the one in timber panels.

We recommend the use of medium density peanut husk panels and castor oil resin as an alternative to traditional wooden panels. Their small level of pollutant emissions and their good physical and mechanical properties makes them suitable as coatings and non-bearing structures in civil constructions.

Future research will be centered on the production process of panels with crushed husks, high density and castor oil resin. Also in the study of flame retardant materials incorporated after additives, which act positively in this aspect. On later stages, the materials obtained will be studied in relation to their applications in architecture and design according with life cycle analysis assessments and ecodesign.

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