Particleboard panels made with sugarcane bagasse waste – an exploratory study

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Abstract

The reuse of natural fibers, in order to manufacture a new product, is already becoming popular due to the generation of a series of advantages in social areas. Sugarcane bagasse is a set of tangled fibers of cellulose, produced in large quantities due to increased acreage and industrialization of sugarcane resulting from public and private investments in production aimed for the alcohol industry. The aim of this study was to evaluate the feasibility of producing sheet timber manufacture from the sugarcane bagasse, analyzing mechanical strength properties. A form of metal sheet for the molding of 12 specimens based on sugarcane bagasse and industrialized resin was made. Soon after molding, specimens were submitted to a three-point bending test, with the aid of a press. The analysis of the results allowed to conclude that the tensile strength and the modulus of elasticity did not obtain the minimum values recommended by the standard. The tensile strength must be improved to allow panels to be useful for ordinary strength applications.

Keywords: Mechanical properties, MDP, Recycling, Sugarcane Bagasse, Waste.

1. Introduction

The production and use of industrialized wood in the world are growing, motivated by the numerous advantages presented in the use of this type of wood, as sheets of the most varied shapes and sizes are obtained, with high strength and limited defects. Its wide use also occurs in the furniture industry, even though there is a rigorous quality control in the manufacturing process (Mendes et al. 2010).

With the growth presented by the sector, the emergence of new products, such as Oriented Strand Board (OSB), Medium Density Particle (MDP) and Medium Density Fiberboard (MDF), combined with the growth of civil construction and the furniture sector, which are the biggest consumers, there is also an increase in demand of matter – material, which leads to the search for new materials for the manufacture of wood. The production of processed wood can become more costly the production of raw-materials which in this case is the plantation wood. This is due to the time required to cultivate these species, since from the planting point to the harvest point it takes approximately 15 years. Some examples of woods that need years to reach maturity are pine and eucalyptus, which take 15 to 20 years to be harvest and taken to industrialized wood production (Mendes et al. 2010).

This entire process of suppression of areas for planting, which involves the preparation of soil, production of seedlings and planting, the cultural treatments and the completion of the harvesting process cause environmental impacts, because due to the demand for wood, there is a greater need for large quantities planting areas. These high numbers caused concerns regarding some natural wood resources consumed to fulfill the growing demand and its effect on the environment (Nadhari et al. 2019). One solution to this growing need for industrialized wood is the use of new materials – materials that can replace conventional wood (Mendes et al. 2010; Garzón-Barrero et al. 2016; Nakanishi et al. 2018a, b, 2019; Brito et al. 2020a; Nadhari et al. 2020; Martins et al. 2021). There are already studies today that present researches on the environmental impacts of particleboards produced from wastes, based on a comparative Life Cycle Assessment (Dos Santos et al. 2014; Piekarski et al. 2017; de Lima Mesquita et al. 2018; Uemura Silva et al. 2021).

The reuse of natural fibers, in order to manufacture a new product, is already becoming popular due to the generation of a series of advantages in social areas. These new methods can provide the use of a new material – material of low cost and environmentally friendly. Furthermore, with the reuse of fibers, the environmental impacts that would be generated can be avoided according to the degree of acceptance by the industry (Silva 2006). The use of agricultural residues in association with wood for panel production has potential to increase value, promote the adequate disposal and ensure adequate panel properties (Fiorelli et al. 2019; Narciso et al. 2021; Vitrone et al. 2021).

The use of natural fibers various purposes is widespread in many parts of the world (Silva 2006; Sales and Lima 2010; Somna et al. 2012; Alavéz-Ramírez et al. 2012; Sua-Iam and Makul 2013; Abdulkadir et al. 2014; Arenas-Piedrahita et al. 2016; Arif et al. 2016; Mangi et al. 2017; Xu et al. 2018; Akinbade et al. 2020; Pozzer et al. 2020; Nicolao et al. 2020; Ramlee et al. 2021; Salhotra et al. 2021; Araújo de Almeida and Colombo 2021; Madhwani et al. 2021; Micheal and Moussa 2021). Among the residues that it is in a large generation in agricultural countries, is the sugarcane bagasse residue. The fibrous residue of sugarcane after crushing and extraction of its juice, known as ‘bagasse’, is one of the largest agriculture residues in the world. It can act as effective reinforcement fiber in the manufacture of polymeric composites. It may also be applied and utilized for composite materials manufacturing and applications in various forms, such as cellulose fiber, lignin extracted, ‘conrimd’, pith, sugar cane bagasse ash, sugar cane straw ash and more (Loh et al. 2013; Toscano Miranda et al. 2021). The bagasse is a set of tangled fibers of cellulose, produced in large quantities due to increased acreage and industrialization of sugarcane, because of many public and private investments in production – alcohol industry.

According to the Bulletin of the National Supply Company of Brazil (CONAB 2020), the production of sugarcane crop estimated for the 2019/2020 is 622.3 million tons, accounting for the country generating around 175 million tons of sugarcane bagasse. Each ton of sugarcane processed generates a total of 280 kg of waste. Generally, bagasse is burned to generate energy. The ashes resulting from burned may be used to partially replacement cement in concrete (Yogitha et al. 2020; Katare and Madurwar 2021; Khawaja et al. 2021; Kolawole et al. 2021; Loganayagan et al. 2021; Quedou et al. 2021). With the advancement of research, sugarcane bagasse is also being used as animal feed (Silva 2006).

The planet's pollution must be reduced, and it is important to avoid the extraction of virgin raw materials from nature. The development of the circular economy in our planet is mandatory. Therefore, an exploratory study was carried out to evaluate the ability of producing MDP panels from sugarcane bagasse. The analyzes of the research included bending tests to determine the tensile strength and the modulus of elasticity.

2. Materials and methods

The fiber collected was a residue coming from the sugarcane milling process (sugarcane juice) located in the municipal market in the city of Montes Claros, northern of Minas Gerais, Brazil. This material was collected after going through the cane milling process, in the form of crushed strips. After pressing, the material was washed in filtered water to remove sucrose. As mentioned by (Viana Neto et al. 2018), the compositional variability leads to a decrease in the quality of the aggregate produced, restricting them to applications with low performance requirements. But, despite of this, in addition to the benefits in terms of environmental preservation, with the proper disposal of waste, economic gains are added, considering that the cost of this input has been lower than that of natural aggregates (Viana Neto et al. 2018).

The preparation followed the recommendations of (Silva 2006), as shown in Fig. 1. The bagasse was submerged in filtered water (Fig. 1A) for some intervals lasting four hours each. After each interval, the water was changed so that fermentation did not occur, preventing the increase in acidity. This process took 36 hours. The drying process (Fig. 1B) was done naturally using solar radiation, being completed after 12 hours. Soon after drying, the material was crushed (Fig. 1C) with the aid of a disintegrator motor DPM 2CV and the crushed biomass was mixed with industrial resin by manual mixing, to agglutinate the particles bagasse (Fig. 1D).

Fig. 1. Processes performed: A) submerged bagasse, B) drying of bagasse in sunlight, C) crushed bagasse and D) mixing of resin with bagasse.

For the manufacture of panels, were used, besides the sugarcane bagasse and the resin for wood, a catalyst, which accelerates the healing process, as shown in the Fig. 2. The Figs. 2A, 2B and 2C shows the materials respectively, catalyst, sugarcane bagasse and resin for wood. To the mixture 300 ml of resin were used for bonding the fibers 3 ml catalyst, ½ kg of sugarcane fiber triturated the in pieces 2 mm. After mixing the fibers, they were placed in the tray, previously made, to start molding.

To manufacture the press, were required metal sheets. In addition, some tools were necessary: welding machine, for welding coated conduit, a circular saw and two lathes to assist in closing the press, according can be seen in

Fig. 3. All tools can be seen in Fig. 3A. The tray was built, as shown in Fig. 3B. The lathes were used to apply pressure in shape and mold parts with fiber sugarcane bagasse, as shown in Fig. 3C.

Fig. 2. Materials: (A) catalyst, (B) sugarcane bagasse and (C) resin for wood.

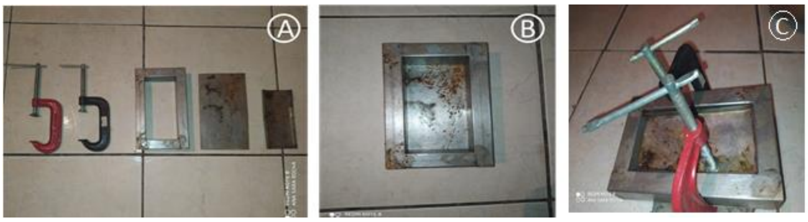


Fig. 3. Manufacture of the press: (A) tools and materials used, (B) the tray of the press and (C) press mounted to mold the panels.

After the bagasse was mixed with the resin and the catalyst, the mixture was taken to the prefabricated press. The processes at the preparation for making the panels is illustrated in Fig. 5. With the material inside the press, lathes have been used to promote two pressing in order to ensure the application of load and consequent mind, the material compression. This pressing process lasted 12 hours. Following guidelines (Silva 2006), each panel was placed in the vertical position, remaining so for seven days. The Fig. 5 shows some details regarding the pressing and curing equipment of the samples.

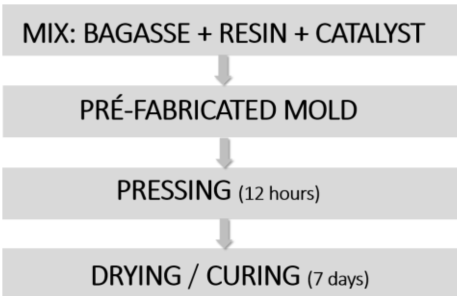


Fig. 4. Flow chart of the execution process

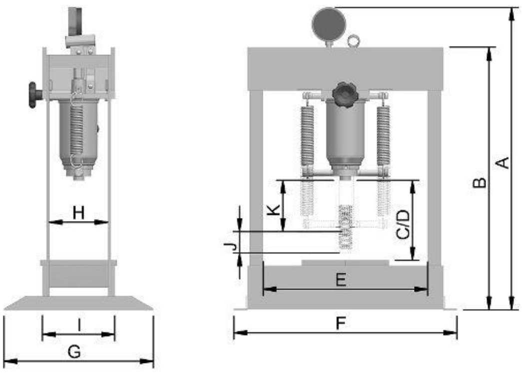
Fig. 5. Manufacture: (A) Prefabricated tools and (B) panels arranged vertically for curing

This time was necessary to guarantee the stabilization of the pressing temperature of the panels to that of the environment, completion of the resin curing and uniformity of moisture from the faces to the center of the plate.

After the panel drying process, they were submitted to a simple bending test. To carry out this test, a press that works manually, as if it were a hydraulic jack, was used.

When the lever movement is triggered manually, this ejects a cylinder down and press the specimen. The press used, schematically, is shown in Fig. 6, with the measurements of the press used in the test.

After placing the specimens on the supports, the lever was activated from the top to the bottom, until the cylinder pressed the center of the specimen, transmitting to it the force of the press, as shown in Fig. 7. The specimens were placed on two bases supported at the end. And then, was applied to force the central part for checking support of flexion, and the tensile strength and the modulus of elasticity were obtained.



Item	Length (mm)
A	708
B	615
C	187
D	187
E	385
F	522
G	350
H	150
I	170
J	85
L	120

Fig. 6. Hydraulic press for bending test and press measurements

Fig. 7. Press acting on the specimen

3. Results and Discussions

Initially, specimens produced with bagasse fibers with approximate 1 cm length dimension were tested, as shown in Fig. 8. The first panel was manufactured with white glue and, despite having worked well for molding purposes, it did not reach the expected tensile strength in the bending test which, according to NBR 14810-2 (ABNT 2013). The minimum tensile strength would be 16 MPa. The standard do not establish parameter for modulus of elasticity. Then, that panel was dropped from the process. The Fig. 8A represents the initial test piece. The second test panel with the same fiber dimensions, was molded with industrial resin, illustrated in Fig. 7B.

In Fig. 8, it was possible to observe the excess of resin used for the panel to become a solid board, which significantly affected the results of the bending mechanical tests. It was observed that the size of the fibers interferes with the agglutination of the particles, leaving many gaps, which contributes to change the test results of bending. Therefore, the panels with fibers of 1 cm in length, produced both with white glue and resin, were discarded from the process. For this reason, the process of crushing sugarcane bagasse was chosen to produce new samples, reaching the size of approximately 2mm length of the fibers.

Fig. 8. Specimen with a particle size of approximately 1cm: (A) with white glue and (B) with resin.

When starting the molding process put specimen with resin blending with crushed bagasse in a press, could be observed that the press will the surrounding printed on the medium caused the expulsion of the resin, which made the molding of the panel unfeasible with the material. The solution found, then, was to place the mixture inside a plastic bag to perform the molding, as can be seen in Fig. 9. The test results of the specimens were organized in Table 1. The results demonstrated an average of tensile strength equal to 1.14 MPa and modulus of elasticity of 13.68 N/mm².

Fig. 9. Specimen: (A) fibers 2 mm granulometry and (B) protected with plastic bag.

Table 1 - Test results in specimens with 20x10x3 [cm]

Specimen	**Load (N)**	**Tensile strength (MPa)**	**Modulus of elasticity (MPa)**
CP1	490.3	1.47	17.66
CP2	392.3	1.18	14.13
CP3	294.2	0.88	10.59
CP4	392.3	1.18	14.13
CP5	490.3	1.47	17.66
CP6	490.3	1.47	17.66
CP7	392.3	1.18	14.13
CP8	343.2	1.03	12.36
CP9	196.1	0.59	7.06
CP10	392.3	1.18	14.13
CP11	392.3	1.18	14.13
CP12	294.2	0.88	10.59
Average	380.0	1.14	13.68

The decrease in modulus of elasticity and tensile strength due to the addition of lignocellulosic residues in the particleboard has been reported in the specialized literature (Soares et al. 2017). Similar result was found by (Silva et al. 2015). The author found an average value for equal 1.87 MPa, also below the standard. (Soares et al. 2017) mention that a possible explanation for the decrease in the mechanical properties of conventional chipboard panels is the low density of the residue and, consequently, the increase in the compaction ratio, resulting in lower availability of adhesive per particle. The author found that the addition of 1% residue in the panel promotes a reduction of approximately 8.5 MPa for the modulus of elasticity and 0.1 MPa for the tensile strength.

According (Brito et al. 2020b), in the manufacture of bamboo particleboards, the addition of a larger proportion of smaller particles implies a decrease in tensile strength and modulus of elasticity. Thus, it is possible to improve the static bending properties of the particleboards with the incorporation of long and fine particles with a high slenderness ratio. On the other hand, short and thick particles can positively influence properties such as the internal adhesion of the particleboards (Brito et al. 2020b).

Other studies proved that the sugarcane bagasse fibers can highly be possible to be used as a substitute material. For asbestos roofing tiles, the results revealed that sheets with high density had low moisture content, low water absorption and low thickness swelling (Kittisak and Prayoon 2021). It was also found that the higher density they had, the better mechanical properties they owned, and that the thermal properties of sugarcane bagasse fiber has the best thermal conductivity and thermal resistance. As well as the bagasse, the use of coconut fibers provided an improvement in the physical and thermal properties of MDP panels, and although the increase in the amount of coconut fibers reduces the mechanical properties, being allowed to state that it is possible to produce MDP panels only with coconut fibers (Narciso et al. 2021). Most of the results obtained for binder less fiberboards showed a great competitiveness with commercial ones in terms of mechanical, physical, and thermal properties. Study of (Tabarsa et al. 2011) demonstrated that panels made with bagasse particles had superior properties compared to the poplar and mixed hardwoods particles. Other study (Ribeiro et al. 2020) demonstrated that the heat treatment of the sugarcane bagasse particles at a temperature of 230 °C markedly improves the quality of the agglomerated panels. The water absorption and the thickness swelling decrease, and the modulus of elasticity increases (Ribeiro et al. 2020) (Ribeiro et al. 2020).

Despite the low values found, particleboard panels could be considered useful for application that require small efforts. For ordinary applications the tensile strength must be improved.

4. Final Remarks and Conclusions

Sugarcane bagasse is a by-product generated in greater volume in the Brazilian agri-business. An exploratory study about the sugarcane bagasse ability to produce MDP panels was carried out. The main conclusion from this exploratory study is that MDP panels produced with sugarcane bagasse can be a sustainable alternative for temporary constructions and uses as forms in civil construction and others.

Although the results obtained with the realization of the tests are preliminary, with low tensile strength and modulus of elasticity, the panels present results satisfactory for use in making elements that have no function structural. By observing the economic and environmental aspects, this product becomes even more interesting, since the raw material is abundant in Brazil and, in most of the time, wasted or incinerated. These benefits, combined with easy handling, make the product a viable option, as conventional woods can take years to be harvested and destined for MDP industry.

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Ethical Approval

Not applicable

Consent to Participate

Not applicable

Consent to Publish

Not applicable

Authors Contributions

Nara Cangussu – Conceptualization, Funding acquisition, Methodology, Resources, Writing – original draft, Visualization

Patrícia Chaves – Data curation, Investigation

Welis da Rocha – Formal analysis, Investigation

Lino Maia – Funding acquisition, Supervision, Validation, Writing – review & editing

Competing Interests

The authors declare that they have no competing interests

Availability of data and materials

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