Pressing Temperature Effect on the Properties of Medium Density Particleboard Made with Sugarcane Bagasse and Plastic Bags

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The objective of this work was to evaluate the effects of different pressing temperatures on the physical and mechanical properties of Medium Density Particleboard (MDP) manufactured with sugarcane bagasse and waste plastic bags. The temperatures of 160, 180, 200 and 220°C were evaluated for the panels pressing. The panels were produced with a nominal density of 0.70 g/cm³, a face/core ratio of 40:60, 12% urea-formaldehyde adhesive for the faces and 8% for the core. The panels were evaluated for properties of density, compaction ratio, humidity, water absorption after two and twenty-four hours (WA2h and WA24h), thickness swelling after 2 and 24 hours of immersion in water (TS2h and TS24h), module of rupture (MOR) and module of elasticity (MOE) in static bending, internal bonding, janka hardness and screw pulling. There was no significant effect of pressing temperature on density, MOR, MOE, internal bonding and janka hardness of the panels. The pressing temperature significantly influenced the properties of WA, TS and screw pullout, promoting a decrease in the mean values of WA2h, WA24h, TS2h and TS, and an increase in screw pullout resistance. The temperature of 220°C resulted in MDP panels with sugarcane bagasse and residual plastic bags of better quality.

Keywords: Agroindustrial residues, particleboard, plastic residues, sustainability, reuse, sugarcane bagasse.

1. Introduction

The forestry sector plays a significant role in the Brazilian gross domestic product (GDP) creating jobs and generating income, with current trends and needs demonstrating an increase of planted forests share in the socioeconomic development of various regions of Brazil.²,³

The forest production chain associated with the Eucalyptus and Pine tree plantations is characterized by the great diversity of products, including particleboard panels. However, there is a need for diversification of this industry by using new raw materials on the production process.⁵,⁶

Medium density particleboard (MDP) panels can be produced with any type of lignocellulosic material, as long as they have adequate physico-mechanical properties.⁷,⁸ Although, currently, the industry basically uses wood of pine and eucalyptus species.⁹,¹⁰ Despite this, and due to the high demand from the sectors that consume these panels, the number of researches is increasing with the analysis of the potential of new types of lignocellulosic materials as a source of raw material for MDP panels.¹¹,¹²

According to Jesus et al.,¹¹ the use of agricultural residues may contribute to the demand for raw material for the production of MDP panels, since it presents a wide range of residues and physical-chemical and mechanical properties that can be better utilized, such as maize cob and straw,¹²,¹³ rice husk,¹⁴,¹⁵ castor husk,¹⁵ sorghum bagasse,¹⁶,¹⁷ plant bean parchment,¹⁷ coffee plant stem,¹⁸ and banana tree pseudostem.¹⁹

Studies with sugarcane bagasse demonstrated its potential for use in the production of MDP panels.¹³,¹⁸-²⁰,²¹ The residue is obtained in large volumes, which helps in its application on an industrial scale.²² According to the Brazilian Institute of Geography and Statistics – IBGE, the Brazil production estimate for the 2019/2020 harvest is 665.9 million tons, which means the generation of approximately 186.5 million tons, because for each ton of processed cane a total of 280 kg waste is generated.²³ However, study demonstrates that sugarcane bagasse panels still have greater water absorption and thick swelling than panels with eucalyptus wood, which may limit certain applications.²⁴ Thus, viable alternatives are needed to control such variables in order to increase the applications range for these panels.

However, besides the need to improve the physical properties of sugarcane bagasse panels, there is also a demand for the development of more sustainable panels,²⁴,²⁵ focusing on the use of a second residue; plastic bags. 15 billion units of this residue are produced per year in Brazil posing serious concerns regarding its disposal.²⁶

Particleboard panels produced from agroindustrial and other residues are included in the premise that the product should offer quality, low environmental impact, and competitive price to its direct competitors. In addition to contributing to the panels technological advancement and their large-scale use.²⁷ Therefore, this work aimed at evaluating the technological feasibility of particleboard...
panels produced with sugarcane bagasse using plastic bag residue at different pressing temperatures.

2. Materials and Methods

2.1. Raw material obtaining and characterization

The sugarcane bagasse was obtained from Bocaina Distillery, located in Lavras-MG, Brazil. Low density polyethylene (LDPE) plastic bag waste was supplied by Diplapel located in Divinópolis-MG, Brazil. The plastic waste used in this study had 1.89% volumetric shrinkage, 18 MPa tensile rupture and 389% elongation at break.

For chemical characterization, the sugarcane bagasse was processed in a hammer mill and the particles went through 40 and 60 mesh sieves for classification. The chemical tests performed in triplicate. The lignocellulosic material was chemically characterized to quantify ash (NBR 13999), extractives (NBR 14853), lignin (NBR 7989), holocellulose (Browning), cellulose (Kennedy, Phillips & Williams, 1987), and hemicellulose contents (Holocellulose – Cellulose).

For the determination of sugarcane bagasse basic density, which was carried out according to a method adapted from NBR 11941, the particles were saturated in water and their volume was later determined by the water displacement method (immersion method) using a measuring cylinder. The particles were brought to the oven at 105°C where they remained until reaching the constant mass. After that, the dry mass of the particles was established. The plastic residue density was provided by the manufacturer.

The samples morphological characterization was performed using ImageJ® (Powerful Image Analysis software). 30 length and 30 thickness measurements were collected for each type of particle (sugarcane bagasse - face and core; and plastic residue).

2.2. MDP panels production

In order to obtain sugarcane bagasse particles, the material was ground in a hammer mill. Subsequently, the particles were classified in 12 and 20 mesh sieves to discard thicker particles and obtain a uniform particle size. The thicker particles were used in the core, while the thin ones were used on the faces of the panels. After sorting, the particles were oven dried at 70°C until reaching a humidity level close to 5%.

The plastic bag residue was obtained after processing in a plastic reclaimer, on the company’s production line. The equipment consisted of a hammer mill and refrigeration, allowing to keep the material without softening.

Three panels (repetitions) were produced for each treatment, totalling four treatments where the 160, 180, 200, and 220°C pressing temperatures were evaluated. The lowest temperature of 160°C was chosen by the fact that companies use this temperature for the particleboard production in industrial scale, aiming at the adequate cure of the urea-formaldehyde adhesive. While the highest maximum value of 220°C was chosen because it is the value that presents the greatest peak of degradation of hemicellulose which at higher temperatures could result in a decrease in the mechanical resistance of the panels. This panel pressing temperature range between 160 and 220°C is also commonly seen in other scientific articles.

The panels produced were of MDP type, with a 0.70 g/cm³ nominal density and 20/60/20 (face/core/face) particles percentage distribution. A 20% replacement of core sugarcane bagasse particles was made by plastic residue particles. The application of urea-formaldehyde adhesive to the cores and faces particles was performed separately for each panel. 12% of adhesive was used on the faces and 8% on the core. The application of the adhesive was carried out separately for each layer. The adhesive was applied in a rotating drum with spray application. The particles were impregnated with adhesive and then placed in a 30cm x 30cm x 1.5cm mattress-forming box where the layers were distributed one by one (face/core/face) pressed in a manual press at 0.4 MPa. After pre-pressing, 1.5 cm thick metal delimiters were placed and the mattress was hot pressed, following the temperatures set for each treatment, at 4.0 MPa pressure for eight minutes. Pressure and temperature being kept constant during pressing. The physical and mechanical properties of panels were evaluated after removal of the test samples. The production sequence of the panels is shown in Figure 1.

The panels were accommodated in an acclimatization room at 20 ± 2°C and 65 ± 3% relative humidity. The specimens’ removal process for the panels was done using a circular saw. For physical and mechanical properties determination, the MDP panels were tested after reaching the constant mass. The NBR 14810–2 was used to evaluate the properties Water absorption after 2h immersion (WA_2h), Water absorption after 24h immersion (WA_24h), Screw pull-out, Janka Hardness, Thickness swelling after 2h immersion (TS_2h), Thickness swelling after 24h immersion (TS_24h), Humidity, Apparent density and Internal Bonding (IB). The DIN-52362 standard was used to evaluate the properties Static bending – Modulus of elasticity (MOE) and Static bending – Modulus of rupture (MOR).

2.3. Microstructural characterization

The microstructural characterization evaluation of the panels was performed with scanning electron microscopy (SEM). The tests were carried out on a ZEISS equipment, DMS 940 model. The tests used representative fragments of the samples previously tested in the internal bonding test in order to observe the interfacing between the plastic bag and sugarcane bagasse particles.

2.4. Statistical analysis

The experiment was carried out according to a completely randomized design with four treatments. Each treatment was performed in triplicate totalling 12 panels. The results were submitted to analysis of variance (ANOVA) using the Sisvar software and Scott-Knott test, both at a 5% significance level.

3. Results and Discussion

3.1. Morphological, physical, and chemical properties of particles

Table 1 shows the average values for the morphological characterization of sugarcane bagasse and plastic bag
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The average length of sugarcane bagasse particles classified to be used on the faces and cores of panels were respectively 1.8 mm and 3.59 mm and the average length of plastic bag particles was 5.34 mm. For thickness, the sugarcane bagasse particles of the face had 0.55mm average value, varying from 0.93mm (maximum value) and 0.26mm (minimum value). The sugarcane bagasse particles used in the core showed 0.74 mm average thickness value, varying from 1.31mm (maximum value) and 0.41mm (minimum value). The plastic bag particles showed 4.05mm average thickness value, varying from 6.4mm (maximum value) to 2.61mm (minimum value).

For slenderness, which is the length and thickness ratio of particles, 3.62mm and 5.32mm average values were found for the particles of the face and for the core, respectively. A 1.36mm average value was found for the plastic bags. According to Iwakiri37, the slenderness ratio, exerts influence on the quality of finish and machinability, besides affecting the mechanical and dimensional properties. The average basic density with the respective standard deviation of the sugarcane bagasse particles was 0.175 ± 0.011 g/cm³.

Barros et al.38 characterized and compared particleboard panels produced with sugarcane bagasse with urea-formaldehyde and melamine-formaldehyde and found an 0.099 g/cm³ average value for bagasse basic density. Protásio et al.39, when evaluating Brazilian lignocellulosic residues for bioenergy production, found a 0.104 g/cm³ average value for sugarcane bagasse basic density. Soares et al.1, when evaluating the physical and mechanical properties of particleboards made with different amounts of sugarcane bagasse and Eucalyptus grandis wood found 0.12 g/cm³ for sugarcane bagasse basic density. The difference in basic density values found for sugarcane bagasse particles was related to the raw material source.

For plastic bag particles, an apparent density average value of 0.95 ± 0.012 g/cm³ was found. This value is consistent with the one found by Coutinho et al.40, who reported apparent density values ranging between 0.94-0.97 g/cm³.

Sugarcane bagasse particle chemical composition is shown in Table 2. The extracts from the material are mainly responsible for its pH37. This pH could influence the adhesive curing since the presence of such substances favours its prehardening20. The hemicellulose levels were high, which might have contributed to the increased water absorption of the sugarcane bagasse panels, further demonstrating the need for new processes and addition of materials that could improve the MDP panels’ final quality26.

Satyanarayana et al.41 evaluated sugarcane bagasse chemical composition from several countries. When evaluating

| Parameters       | Sugarcane bagasse | Plastic bag |
|------------------|-------------------|-------------|
| Lenght (mm)      | 1.80 ± 0.4        | 3.59 ± 0.89 | 5.34 ± 1.05 |
| Thickness (mm)   | 0.55 ± 0.12       | 0.74 ± 0.18 | 4.05 ± 0.85 |
| Slenderness ratio| 3.62 ± 1.29       | 5.32 ± 1.76 | 1.36 ± 0.28 |

| Chemical component | Mean         |
|--------------------|--------------|
| Holocellulose      | 62.15 ± 0.69 |
| Cellulose          | 30.71 ± 0.10 |
| Hemicelluloses     | 31.43 ± 0.10 |
| Total extractives  | 20.87 ± 0.21 |
| Insoluble Lignin   | 21.12 ± 0.28 |
| Ashes              | 0.93 ± 0.19  |

* Average values in percentage found in dry base.
sugarcane bagasse from Brazil the contents ranged from 54.3 to 55.2% cellulose, 25.3 to 24.6% lignin, 16.8 to 29.7% hemicellulose, 0.9 to 1.1% ash, and 0.7 to 3.5% extractives. Protásio et al. 35, in a study on Brazilian lignocellulosic residues for bioenergy production, obtained 26.7% lignin, 55.7% holocellulose, 16.6% extractives, and 1% ash values for sugarcane bagasse chemical composition. The difference between the contents found by the authors and this work was due to the method used in the chemical analysis as well as the material source.

4. Physical and Mechanical Properties of Panels with the Varying Pressing Temperatures

Table 3 presents the average values for apparent density, compaction ratio, and humidity of the panels as a function of temperature levels evaluated during pressing.

There was no statistical difference for apparent density, compaction ratio, and humidity as a function of the applied temperature. The apparent density values ranged from 0.591 to 0.609 g/cm³, characterized as medium density panels, in accordance to NBR 14810-2 classification42, which establishes a 0.55 to 0.75 g/cm³ range.

The compaction ratio of the panels produced with sugarcane bagasse ranged from 3.42 to 3.58. These values were consistent with those obtained in the literature for particleboard panels produced with agroindustrial residues. Mendes et al. 39 evaluated the effect of sugarcane bagasse associated with Eucalyptus wood in different levels and adhesives types for particleboard production and found compaction ratio values ranging from 1.39 to 3.07.

The panels produced presented humidity values between 5.07 and 5.89%, complying to the average values set by NBR 14810-2 standards42 for particleboard panels (from 5 to 11%) and they also comply with the EN 312 trading standard43 which stipulates 5 to 13% as suitable values for panel humidity. Oliveira et al. 44 found an average of 9% humidity values for commercial sugarcane bagasse panels.

Figure 2 shows the average water absorption values for MDP panels after 2 h (WA2h) and after 24 h (WA24h) immersion, for each treatment.

Significant differences were observed among all treatments for water absorption property after 2 h immersion (WA2h). As the pressing temperature increased, a reduction in the average values for water absorption was noted. This reduction is associated with the degradation of the hydroxyl groups from the sugarcane bagasse as the pressing temperature increased34, 45 as well as a greater lignin softening, which promotes greater particles convergence and decreases empty spaces in the panel44, and also the effect of the higher temperature level, that allowed better softening of the plastic bag residue at 220°C, resulting in greater recovery of sugarcane bagasse particles and pore filling between the particles, promoting a reduction in the water absorption panels. Despite the plastic bags softening, which are made of Low Density Polyethylene (LDPE), happen with the application of 160°C30, 46, as its use was in the core of the panels, the polymeric residue demanded a higher pressing temperature in order to be able an adequate flow of heat between the sugarcane bagasse particles, which demonstrate a certain capacity for thermal insulation, thus allowing the softening of the plastic bag particles in an adequate manner at higher temperatures.

For water absorption after 24 h immersion (WA24h), the panels produced at 220°C pressing temperature were statistically different from the other treatments, presenting the lowest water absorption average value. The panels produced at 180°C and 200°C pressing temperatures were statistically similar differing from the panels pressed at 160°C, obtaining lower average values. As explained for WA2h, WA24h reduction was associated with the decrease of hydroxyl groups as a function of temperature increase, especially those related to hemicelluloses that present high contents in sugarcane bagasse (Table 2) and lower temperature of thermal degradation, ranging from 180 to 280°C, with a maximum peak of 220°C34. Another factor that affected the property was the softening of the plastic bag residue and temperature level.

**Table 3.** Apparent density, compaction ratio and humidity of panels produced as a function of pressing temperature.

| Treatment | Apparent density (g/cm³) | Compaction ratio | Humidity (%) |
|-----------|---------------------------|------------------|--------------|
| 160°C     | 0.592 ± 0.01 A            | 3.485 ± 0.01 A   | 5.83 ± 0.3 A |
| 180°C     | 0.591 ± 0.02 A            | 3.480 ± 0.02 A   | 5.89 ± 0.12 A|
| 200°C     | 0.603 ± 0.01 A            | 3.549 ± 0.01 A   | 5.65 ± 0.08 A|
| 220°C     | 0.609 ± 0.03 A            | 3.581 ± 0.02 A   | 5.07 ± 0.41 A|

*a Averages followed by a similar letter on each column did not differ statistically by the Scott-Knott test at a 5% significance level.
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consequently the covering of the sugarcane bagasse particles and pores filling of the panels.

Battistelle et al.\textsuperscript{22} when evaluating sugarcane bagasse panels with 12\% castor oil bicomponent adhesive found values between 8 to 10\% for WA2h and 29 to 37\% for WA24h. Mesquita et al.\textsuperscript{47} when evaluating sugarcane bagasse MDP panels with urea-formaldehyde adhesive and 160\(^\circ\)C pressing temperature, with and without the addition of cellulose nanocrystals, obtained WA2h values in the range between 52 to 81\% and for WA24h values between 86 to 112\%.

The MDP average swelling values in thickness for panels after 2 h water immersion (IE2h) and after 24 h water immersion (IE24h), for each treatment, are shown in Figure 3.

The panels produced at 160\(^\circ\)C were statistically different from the other treatments, obtaining the highest TS2h and TS24h average values. Both 200 and 220\(^\circ\)C pressing temperatures presented statistical equality and differed from the 180\(^\circ\)C one, obtaining the lowest TS2h values. There was no differentiation between the 180, 200, and 220\(^\circ\)C pressing temperatures when evaluating TS24h. The lower swelling thickness after 2 h water immersion for treatments at 200 and 220\(^\circ\)C pressing temperatures in relation to the ones at 180 and 160\(^\circ\)C was related to lower water absorption of sugarcane bagasse particles, which occurred due to the greater plastic residue coating and the water absorption obstruction by the particles cell wall. The use of a higher temperature for panels pressing allowed a greater softening of the plastic waste and, consequently, a better covering of the sugarcane bagasse particles (Figure 4B), reducing the water absorption of the lignocellulosic material and its swelling in the first hours of contact with the water. While for the panels produced with lower temperatures, greater spaces were observed between the two types of residues (Figure 4A), allowing greater ease for water absorption and thickness swelling.

However, greater water penetration in the particles cell wall occurred after increasing time exposure to water, allowing for statistical equality of treatments with 180, 200 and 220\(^\circ\)C. It is also observed that there was no strong interaction between the plastic bags residue and the sugarcane bagasse particles, capable of reducing the thickness swelling, therefore, not functioning as an adhesive between the particles\textsuperscript{48}.

Barros et al.\textsuperscript{38} evaluated the quality of particleboard panels made with sugarcane bagasse in conjunction with \textit{Eucalyptus} and pine wood and using urea-formaldehyde and melamine-formaldehyde adhesives, with 160\(^\circ\)C pressing temperature, and obtained values between 7.0 to 26.5\% for TS2h and between 16.3 to 36.2\% for TS24h. Ribeiro et al.\textsuperscript{27} evaluated the effect of heat treatment on the properties sugarcane bagasse panels MDP with urea-formaldehyde adhesive and 160\(^\circ\)C pressing temperature, and obtained mean values ranging from 34 to 45.5\% for TS2h and 53 to 69.7\% for TH24h. Mesquita et al.\textsuperscript{47} when studying the effect of the use of cellulose nanocrystals on the properties of sugarcane bagasse MDP panels, with and 160\(^\circ\)C pressing temperature, obtained values between 8 to 16\% for TS2h and between 13 to 20\% for TS24h.

The results for physical properties were satisfactory according to data found in the literature. According to NBR 14810 standard\textsuperscript{42}, all treatments met the standard that was set the limit at 15\% for swelling thickness after 24 h immersion. EN 312\textsuperscript{43} sets at 8\% the maximum value for swelling thickness after 24 h immersion. None of the treatments met this standard. Although no treatment meets the EN312 standard\textsuperscript{43}, as previously seen, treatments with

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{The swelling thickness of particleboard panels produced with sugarcane bagasse and plastic bag particles at different pressing temperatures. *Averages followed by a similar letter (uppercase for TS2h and lower case for TS24h) did not differ statistically by the Scott-Knott test at a 5\% significance level.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.png}
\caption{Images obtained by scanning electron microscopy for panels produced at 160\(^\circ\)C (A) and 220\(^\circ\)C (B).}
\end{figure}
180, 200 and 220°C showed marked reductions in TS24h compared to panels with 160°C, which are in the order of 24.5, 40.1 and 36.7%, respectively. This fact demonstrates the potential of associating plastic bags waste and temperature to improve physical properties, but it also demonstrates the need to associate adjustments to other variables, such as the association with paraffin, which helps repel water and has not been used in this study, as well as a small increase in the adhesive amount, an increase in the plastic waste amount, among other associations.

5. Mechanical Properties

The modulus of rupture (MOR) and modulus of elasticity (MOE) for static bending, and Internal Bonding (IB) values for each treatment are presented in Figures 5, 6, and 7, respectively.

The panels produced at different pressing temperatures did not differ statistically in terms of MOR and MOE for static bending and internal bonding. It is shown that the plastic bag residue particles did not promote adequate chemical and/or mechanical interaction among the sugarcane bagasse particles (Figure 4), thus not affecting the bonding properties amongst the particles (Figure 7).

The low average values for internal bonding might be related to the lower amount of adhesive available per particle, since to obtain a 0.70 g/cm³ nominal density MDP panel, larger amounts of sugarcane bagasse particles are required when compared to pine tree and Eucalyptus particleboard panels due to lower basic density of sugarcane bagasse.

Barros et al. evaluated the quality of particleboard panels produced with sugarcane bagasse combined with Eucalyptus and Pine wood using urea-formaldehyde and melamine-formaldehyde adhesives, with and 160°C pressing temperature, found average values of 0.20 to 0.63 MPa for internal bonding (IB), from 710.8 to 1129 MPa for MOE, and 3.42 to 5.91 MPa for MOR.

Tabarsa et al. evaluated panels of Three-layer mats, density of 0.70 g/cm³ and variable factors were as wood species (bagasse, poplar and mixed hardwood species), moisture content of mat (face layer: 12%, 14% and core layer: 9%, 13%) and press time (6 and 8 min) and with 170°C press temperature constant, the authors obtained for the sugarcane bagasse panels average values between 1400 to 2120 MPa for MOE, 14 to 20.5 MPa for MOR and 0.26 and 0.42MPa for IB.

Kariuki et al. evaluated particleboard of sugarcane bagasse, corn straw and rice husk bonded with chemically modified Cassava peel starch, the authors obtained average values between 2364 to 3329 MPa for the MOE, 13.5 to 14.8 MPa for MOR and 1.6 to 2.37MPa for IB.

ANSI A208.1 standard establishes for standard type (M-S) panels, minimum values of 12.8 MPa MOR, 1943.8 MPa MOE, and 0.40 MPa IB. EN 312 standards establishes 13 MPa for MOR, 1800 MPa for MOE, and 0.30 MPa for IB as the minimum values. NBR 14810-2 standard sets 11 MPa for MOR, 1600 MPa for MOE, and 0.40 MPa for IB as the minimum values. Therefore, all treatments met trading standards when evaluating MOR at static bending. No treatment met the standards for internal bonding and ANSI A208.1 and EN 312 standards for MOE.
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The panels produced at 160 and 220°C meet NBR 14810-2 standards for MOE at static bending. The average values for Janka hardness (JH), face screw (FSP), and top screw (TSP) pull-out properties are shown in Figures 8 and 9, respectively. No pressing temperature effect on the Janka hardness property occurred for MDP panels made with sugarcane bagasse and plastic bag residue. For face and top screw pull-out, the panels produced at 220°C pressing temperature differed statistically from the other treatments, obtaining the highest resistance values. There was no significant difference between panels produced at 160°C, 180°C and 200°C for top and face screw pull-out from the panels.

The significant improvement for screw pull-out using 220°C pressing temperature for panels is correlated to a greater plastic residue softening and the greater void-filling by the polymer, as well as the greater particles compaction due to lignin softening, as discussed for the water absorption.

None of the treatments managed to meet the ANSI A208.16 and ABNT NBR 14.810-24 standards that set minimum values at 92 Kgf and 81.6 Kgf, respectively. According to Oliveira et al., this may have occurred due to smaller adhesive amounts available per particle, since a larger amount of sugarcane bagasse particles is required to obtain a 0.70g/cm³ nominal density MDP panel when compared to Pine wood and Eucalyptus particles panels.

6. Conclusions

The pressing temperature significantly influenced only the properties of water absorption, thickness swelling and screw pullout (Top and Face). There was no effect of the pressing temperature on the other physical and mechanical properties of the sugarcane bagasse panels in association with plastic bag.

The use of the 220°C temperature resulted in the lowest WA2h and WA24h values and in the highest values of screw pullout at the top and face. The temperatures of 200 and 220°C obtained the lowest TS2h values, and the temperatures of 180, 200 and 220°C obtained the lowest TS24h values. These properties were influenced by the covering of the sugarcane bagasse particles and also by filling in the empty spaces due to the melting of the polymeric residue.

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