

Effect of accelerated carbonation on the properties of wood cement panels from the species *Erythrina poeppigiana*

Efeito da carbonatação acelerada nas propriedades de painéis cimento madeira da espécie Erythrina poeppigiana

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Abstract

Wood particles are an alternative to the reinforcement of wood-cement panels. The aim of this study was to evaluate the use of *Erythrina poeppigiana* wood in the production of wood-cement panels with accelerated carbonation. Wood particles were treated with hot water. Hot water treatment reduced the extractive content by 60% and improved the interaction of particles with the cement, reducing the porosity of the cement-wood panels. Accelerated carbonation reduced water absorption by 52% and swelling in thickness by 76%. The carbonated panels showed an increase of 29 and 38% in flexural MOR and MOE values, respectively. An increase in the compression and internal bonding values of the carbonated panels was also observed. It is technically feasible to use the wood of *Erythrina poeppigiana* for the production of wood-cement panels, valuing the destination of the forest species.

Keywords: Hot water treatment. Accelerated healing. Lignocellulosic material.

Resumo

As partículas de madeira são uma alternativa ao reforço dos painéis madeira-cimento. O objetivo deste estudo foi avaliar a utilização da madeira de *Erythrina poeppigiana* na produção de painéis cimento madeira com carbonatação acelerada. As partículas de madeira foram tratadas com água quente. O tratamento com água quente reduziu o teor de extrativos em 60% e melhorou a interação das partículas com o cimento, reduzindo a porosidade dos painéis cimento-madeira. A carbonatação acelerada reduziu a absorção de água em 52% e o inchaço na espessura em 76%. Os painéis carbonatados apresentaram aumento de 29 e 38% nos valores de flexão MOR e MOE, respectivamente. Também foi observado um aumento nos valores de compressão e ligação interna dos painéis carbonatados. É tecnicamente viável a utilização da madeira de *Erythrina poeppigiana* para produção de painéis madeira-cimento, valorizando a destinação da espécie florestal.

Palavras-chave: Tratamento de água quente. Cura acelerada. Material lignocelulósico.

Introduction

Products developed from wood derivatives are widely used in civil construction, among them wood-cement panels, since they present satisfactory mechanical performance, high durability, resistance to xylophages and weathering agents, reduced production cost, thermal properties appropriate for buildings, dimensional stability and sound insulation (Quiroga; Marzocchi; Rintoul, 2016; Çavdar; Yel; Torun, 2022). The replacement of materials of fossil origins by sustainable raw material allowed the diffusion of wood-cement panels (Wei; Zhou; Tomita, 2000; Hasan; Horvath; Alpar, 2021).

These panels are produced by wood, cement, water, and small amounts of chemical additives (Ashori; Tabarsa; Sepahvand, 2012; Rana *et al.*, 2020). Wood is the reinforcement material and can be used in different sizes, from fibers to wood yarns (Yel, 2022). Among the main advantages of using wood in cement panels, the increase in mechanical strength stands out (Rana *et al.*, 2020; Ferraz *et al.*, 2012; Caprai *et al.*, 2018).

Erythrina poeppigiana is a fast-growing alien species belonging to the family Leguminosae, being used in agroforestry systems in consortium with cocoa. However, the excessive shading provided by *Erythrina poeppigiana* resulted in low productivity of cocoa clones resistant to witches' broom (Marques; Monteiro, 2016). Aiming to guarantee the productivity of cocoa trees, the government of Bahia (Brazil) published an ordinance allowing the removal of trees that are not native to the Atlantic Forest, without the need for prior authorization (SMA; IMARH, 2019).

The stock of wood of this species in the Atlantic Forest of Brazil is estimated at 1,000,000 m³, which has no indication of use as solid wood, and the production of wood blades and panels is an alternative for its final destination, because studies of new species with rapid growth is extremely important to diversify the supply of raw material in the forest market (Sá *et al.*, 2012), in addition to being an alternative to cushion pressure on slow-growing forests (Cabral; Nakanishi; Fiorelli, 2018).

The incompatibility of cement with wood is one of the challenges of the production of the panels, since there is interference in the hydration and curing of the cement. Extractives and impurities present in lignocellulosic materials can affect the balance of the cement hydration reaction (Boulos *et al.*, 2017). More recent studies have demonstrated that the effect of extractives on reducing cement hydration is due to their absorption on the surface of the grains of hydrated cement products (Cabral; Nakanishi; Fiorelli, 2018).

However, pretreatments such as cold/hot water and NaOH extractions have potential for improvements in hydration (Hasan; Horvath; Alpar, 2021; Rana *et al.*, 2020; Nasser *et al.*, 2014).

The degradation of the lignocellulosic material over time, due to the alkalinity of the cement, is another problem to solve in the production of the panels. Carbonation is an alternative to reduce this alkalinity, being a natural phenomenon that affects cementitious materials (Almeida *et al.*, 2013). This phenomenon consists of the reaction of the products of the hydration of the cement with the carbon dioxide (CO₂). Over time, cement absorbs CO₂ from the atmosphere and this process occurs during the life of the structure (Filomeno *et al.*, 2020). In order to optimize the process, providing greater and faster carbonation to cementitious composites, climatic chambers can be used with application of CO₂ and with control of temperature and relative humidity of the air, a process called accelerated carbonation. In addition, accelerated carbonation can decrease porosity and water absorption and improve the mechanical performance of wood-cement panels (Tonoli *et al.*, 2010). Cabral, Nakanishi and Fiorelli (2018) found that wood cement panels produced with sugarcane bagasse and subjected to accelerated carbonation and accelerated aging tests showed inferior physical properties and superior mechanical properties compared to the non-carbonated version.

Accelerated carbonation of cement-based materials is one of the effective methods for preparing construction materials and is therefore an innovative curing procedure that results in the sequestration of carbon dioxide gas (CO₂) and its conversion into stable products, reducing CO₂ emissions from the construction industry. Combined with the fact that *Erythrina poeppigiana* wood has a low calorific value, which makes it unsuitable even for firewood and charcoal, this work seeks to find an alternative use that adds value to this wood. Thus, the objective of the study was to evaluate the potential of *Erythrina poeppigiana* wood in the production of cement-wood panels with accelerated carbonation process.

Material and methods

Raw material

The *Erythrina poeppigiana* wood came from experimental plantations in the city of Ilheus, Bahia, Brazil. The 4 m long logs were where they sectioned into 58 cm long logs and then stored in a tank containing hot water for 24 h for subsequent lamination.

Sheets of 2 mm thickness were obtained in a rolling lathe and were processed in a hammer mill for generation of silver type particles. The particulate material was sieved through a set of overlapping sieves, whose openings were 12 mesh (upper) and 40 mesh (lower), respectively.

Particles pre-treatment

The wood particles were treated with hot water initially at 100 °C. For this treatment it was used water: particle ratio of 15:1. After the hot water treatment, the particles were washed in running water and dried in an oven at 60 °C for 72 h, until reaching a relative humidity of 8%.

Characterization of the wood

The basic density of the wood was determined according to a methodology adapted from the NBR 11941 standard (ABNT, 2003). The wood was chemically characterized according to the levels of Extractives: NBR 14853 (ABNT, 2010a), Lignin: NBR 7989 (ABNT, 2010b), Holocellulose (cellulose + hemicelluloses): (Browning, 1963); Cellulose: (Kennedy; Phillips; Williams, 1987). The hemicellulose content was quantified by the difference between the holocellulose and cellulose contents; and Ashes: NBR 13999 (ABNT, 2017). Mean values for all analysis were obtained in triplicate.

Characterization of the wood

To produce the panels, Portland cement CPV-ARI (Portland Cement of High Initial Strength) was used as binder. The chemical additive used was calcium chloride (CaCl_2), to reduce the total setting and hardening time of the mixture. Hot water treated and in nature wood particles were used. The materials for panel production were homogenized in a mixer, following the methodology applied by Souza *et al.* (2021). The variables used for the production of the panels are shown in Table 1.

After homogenization, the resulting mass of the mixture for each panel was properly weighed, separated and randomly distributed in aluminum plates greased with low viscosity oil to facilitate the removal of the panel after its pressing and stapling, and with the aid of iron rims with dimensions of 48 x 48 x 1.5 cm to control the dimensions and thickness of the panels.

The panels were arranged in a cold press, loaded with three panels and the apparatus for stapling, to reach a pressure of 4 MPa. The panels remained stapled for 24 h, after the removal of the staples the panels were conditioned in an acclimatized chamber with a temperature of 20 ± 2 °C and a relative humidity of $65 \pm 3\%$, for a period of 28 days.

Table 1 - Variables for the production of wood-cement panels

Parameters	Values
Wood:cement ratio	1:2.75
Water:cement ratio	1:2.5
Additive CaCl_2	4%
Nominal density	1.25 g/cm ³

Accelerated carbonation

After 3 days of healing, panels produced with particles treated with hot water and in nature, were destined to the accelerated carbonation process (Figure 1). Samples taken using a circular saw were subjected to accelerated carbonation according to the methodology proposed by Arantes *et al.* (2023). For this, a vertical autoclave was used connected by a hose to an industrial grade CO₂ cylinder with a purity of 99%, maintaining a constant pressure of 0.75 kgf/cm². The temperature (T), relative humidity (RH), and CO₂ concentration [CO₂] in the chamber used for the accelerated carbonation test were set at 25 ± 2 °C, 70 ± 5%, and 20 ± 3%, respectively.

The samples remained in this system for 10 hours at a constant pressure of 0.75 kgf/cm², and were then removed and placed in a climate-controlled chamber with a temperature of 20 ± 2 °C and relative humidity of 65 ± 3%, remaining in this condition for 25 days for curing to occur.

Table 2 shows the experimental plan that was used in this study. The control treatment represents the panels that did not have the particles treated with hot water and were not subjected to the accelerated carbonation process.

Evaluation of the physical and mechanical properties of the panels

To determine the physical and mechanical properties, the panels were tested after reaching 28 days of curing. Table 3 describes the tests and standards used in this work to evaluate the panels. Mechanical tests were carried out on a Universal Testing Machine (AROTEC, model WDW-20E) with a 2 ton load cell.

It was also determined the compaction ratio of the produced panels, obtained by the bulk density of the panels over the basic density of the wood.

Microstructural analysis

The fractured wood cement panels were visualized in a Leica DM4000B (LM) compound optical light microscope coupled with a Moticam X - Motic Europe CMOS digital camera with 100x magnification. The fractured region and the surface of the panels were evaluated, in order to evaluate the surface porosity of the panels and the particle-matrix interaction.

Figure 1 - Accelerated carbonation process of wood-cement panels

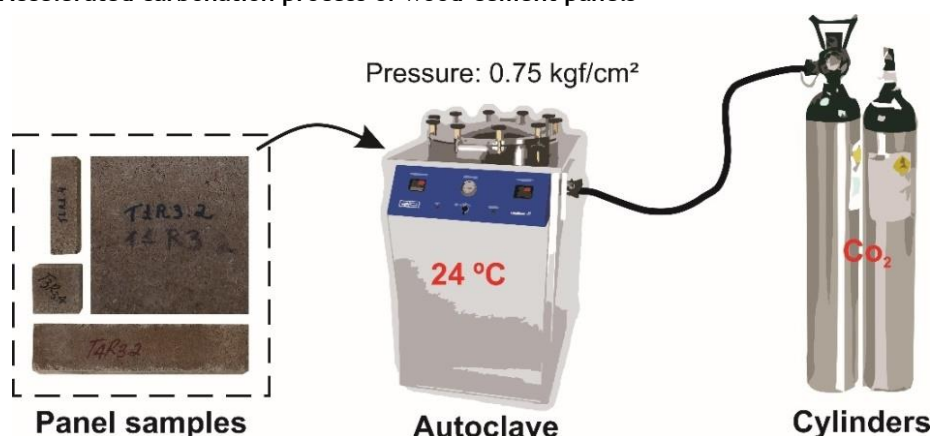


Table 2 - Experimental plan

Treatment	Parameters	Repetition
T1	Control	3
T2	Hot water	
T3	Carbonated	
T4	Hot water + carbonated	

Table 3 - Tests and standards for determining the physical and mechanical properties of wood-cement panels

Tests	Standards
Bulk density	D-1037 (ASTM, 2012)
Apparent porosity	Adapted C 948-81 (ASTM, 2001)
Thickness swelling after 2 and 24 hours in immersion	D-1037 (ASTM, 2012)
Water absorption after 2 and 24 hours in immersion	D-1037 (ASTM, 2012)
Compression parallel to the panel surface	D-1037 (ASTM, 2012)
Internal bond	D-1037 (ASTM, 2012)
Static bending – Modulus of rupture (MOR) and Modulus of elasticity (MOE)	Adapted DIN-52362 (DIN, 1982)

Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infrared spectroscopy was performed to verify the efficiency of accelerated carbonation through the analysis of calcium carbonate (CaCO_3) peaks. Analyses of the panels were performed on a Varian 600-IR Fourier transform (FTIR) FT-IR spectrometer, with GladiATR accessory from Pike Technologies coupled for measurements by total attenuated reflectance (ATR) at 45° with a zinc selenide crystal. The spectral range analyzed was 450 to 4.000 cm^{-1} , 2 cm^{-1} resolution and 32 scans.

Analysis by thermogravimetry

The thermal analysis of the panels was performed using a TA Instruments (Delaware, USA) TGA Q500 thermal analyzer, to verify the influence of hot water treatment and accelerated carbonation on the thermal stability of the panels. Samples of 10 mg of the ground panels were added to the crucible of the equipment and heated from 25 to 800°C . The established analysis condition was in synthetic air atmosphere ($80\%\text{ N}_2$ and $20\%\text{ O}_2$) flowing at 50 mL/min and heating rate of 10°C/min (Raabe *et al.*, 2015).

Analysis of results

The treatments were analyzed according to experimental design entirely randomized. To verify the influence of hot water treatment and accelerated carbonation on the physical and mechanical properties of the panels, the means of the treatments were compared using the Tukey test at 5% significance level. The statistical analyses were performed using the SISVAR statistical program.

Results and discussion

Wood characterization

The basic density found for *Erythrina poeppigiana* (0.262 g/cm^3) (Table 4) was lower compared to those found in the literature for *Pinus spp.* and *Shizolobium amazonicum* (Amaral; Ferreira; Couto, 1977; Mendes *et al.*, 1999; Silva *et al.*, 2016; Lobão *et al.*, 2012) which are commercial woods used for veneer and wood panel production. Matos *et al.* (2019) find for *Pinus oocarpa* and *Shizolobium amazonicum* woods a basic density of 0.530 and 0.310 g/cm^3 , respectively. According to Iwakiri (2005) the density of wood for the production of wood-cement panels should be medium to low to ensure the compaction ratio of the panel within adequate levels for densification and consolidation of the material.

The treatment with hot water provided different contents of total extractives, lignin and ash. The most important chemical component for the present study is the quantification of the extractives content, since the presence in large amounts of extractives can affect the cement curing and consequently affect the interaction between the wood particle and the cementitious matrix (Almeida *et al.*, 2013; Iwakiri *et al.*, 2012; Ferreira *et al.*, 2012). In the study by Borges *et al.* (2022) the value of extractives found was 13.69% for soybean residues. Souza *et al.* (2021), a high amount of extractives in coconut fibers (19.8%) was observed, being the main responsible for hindering and delaying the cement curing process, reducing the mechanical resistance of the panels. However, the treatment with hot water was efficient in reducing the content of total extractives, which is desirable for the production of this type of panel.

Table 4 - Average values of basic density and chemical components of *Erythrina spp.*

Analyses	Treatment	
	<i>In nature</i>	Hot water
Total extractives (%)	9.54a (± 1.36)	3.85b (± 0.73)
Insoluble lignin (%)	18.92b (± 1.03)	24.61a (± 5.34)
Cellulose (%)	43.01a (± 1.53)	41.69a (± 5.03)
Hemicellulose (%)	24.40a (± 1.97)	28.80a (± 5.01)
Ashes (%)	3.13a (± 0.07)	1.05b (± 0.04)
Basic density (g/cm ³)	0.262 (± 0.002)	

Note: means followed by the same horizontal letter are not statistically different by Tukey's test ($p > 0.05$). Values in parentheses correspond to the standard deviation.

Physical properties of the panels

In the apparent density of the panels there were no statistical differences between the treatments (Figure 2a). The values showed a low standard deviation, which demonstrates homogeneity of production within each situation evaluated. The treatments presented bulk density below the nominal density (1.25 g/cm³), due to the losses that occur during the stages of the panel formation process and the return in thickness after the pressing.

The compaction ratio showed no variation between treatments (Figure 2a). According to Scatolino *et al.* (2017), the low density of wood is one of the key factors for the use of lignocellulosic materials in the production of reconstituted panels with this a higher compaction ratio can result in better mechanical properties.

There was a reduction in apparent porosity for treatments T2 and T4 (Figure 2b). The hot water treatment increased the interaction of the particles with the cement, consequently reducing the porosity of the panels. Accelerated carbonation provided lower apparent porosity in treatment T4 when compared to the panels evaluated under the different conditions. In their studies, Tonoli *et al.* (2010) and Soroushian, Won and Hassan (2012) verified a decrease in porosity in carbonated cementitious composites, corroborating the present study.

Figure 3a shows that the surface of treatment T1 is more porous in relation to the other conditions evaluated. Larger pores are observed for treatment T3 (Figure 3c). On the other hand, Figures 3b and 3d show less porous surfaces for treatments T2 and T4.

No influence of the hot water treatment was verified on the WA2h and WA24h properties of the T2 panels (Figure 4a), as the values were statistically equal to that of the control (T1). Iwakiri *et al.* (2015) also found no influence of hot water treatment for 6h on WA24h in paricá wood-cement panels. Iwakiri *et al.* (2015) did not find statistical differences in WA2h and WA24h values for *Eucalyptus benthamii* wood cement panels produced with *in nature* and hot water treated particles for 6h.

The panels that underwent accelerated carbonation (treatments T3 and T4) showed lower values for WA2h and WA24h properties compared to the treatments without carbonation (T1 and T2). The accelerated carbonation enhances the formation of calcium carbonate in the pores of cementitious materials. The reduction in water absorption in treatment T3 can be explained by the filling of the pores of the panels with calcium carbonate. Regarding treatment T4, the decrease in water absorption can be explained by the lower porosity found for this panel (Figure 2B).

For TS2h and TS24h, there was also no influence of the hot water treatment (T2), because the values were statistically equal to the control (T1) (Figure 4B). The thickness swelling of wood-cement panels is influenced by the amount of wood and its adequate covering by the cementitious matrix (Mendes *et al.*, 2017). Due to the fact that carbonation accelerates cement curing, the covering of wood particles by the cement matrix was more efficient for the panels submitted to accelerated carbonation (T3 and T4), resulting in the lowest TS2h and TS24h values after immersion in water.

According to the BISON process (2017) wood-cement panels should present TS2h values lower than 1.0% and for TS24h lower than 1.5%. In this study only the panels submitted to accelerated carbonation (treatments T3 and T4) complied with the recommended by BISON (2017) for TS2h. As for TS24h, only the control (T1) did not reach the values recommended by BISON (2017).

Mechanical properties

The treatments T1 and T2 showed statistically similar values of MOR and MOE (Figure 5a and 5b). Wood is used in cementitious materials to optimize flexural properties and post-cracking behavior (Cabral *et al.*, 2021). Extractives inhibit cement solidification, negatively influencing the mechanical properties of wood cement panels, which was not verified in this study, since the hot water treatment reduced the total extractives contents (Table 4). According to Quiroga, Marzocchi and Rintoul (2016) the setting inhibition does not depend only on the amount of extractives but also on the type.

Figure 2 - Average values and standard deviation of: (a) bulk density, compaction ratio and (b) apparent porosity of wood-cement panels - means followed by the same horizontal letter are not statistically different by Tukey's test ($p > 0.05$)

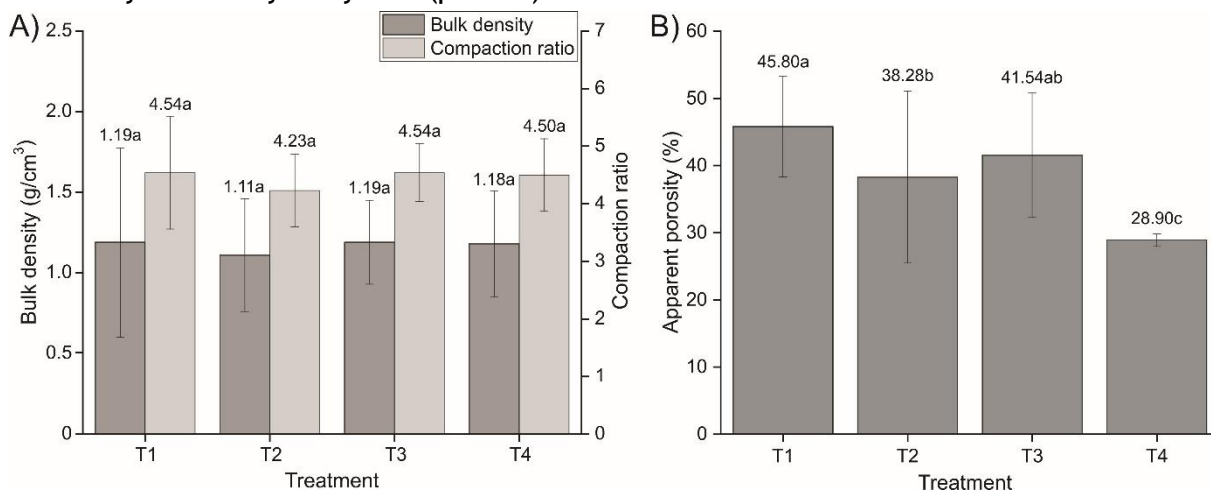


Figure 3 - Light microscopy images of the wood-cement panels surfaces: (a) control (T1); (b) hot water treatment (T2); (c) carbonated (T3) and (d) hot water and carbonated (T4)

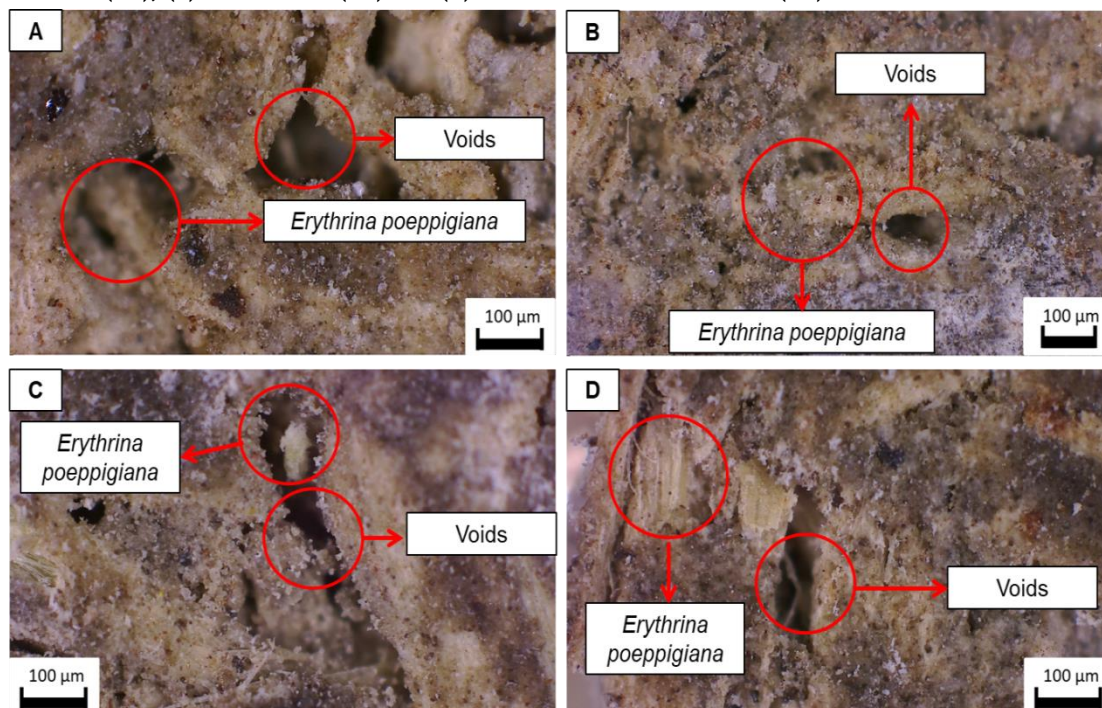


Figure 4 - Average values and standard deviation of (a) water absorption (WA) and (b) thickness swelling (TS) of wood-cement panels - means followed by the same horizontal letter are not statistically different by Tukey's test ($p > 0.05$)

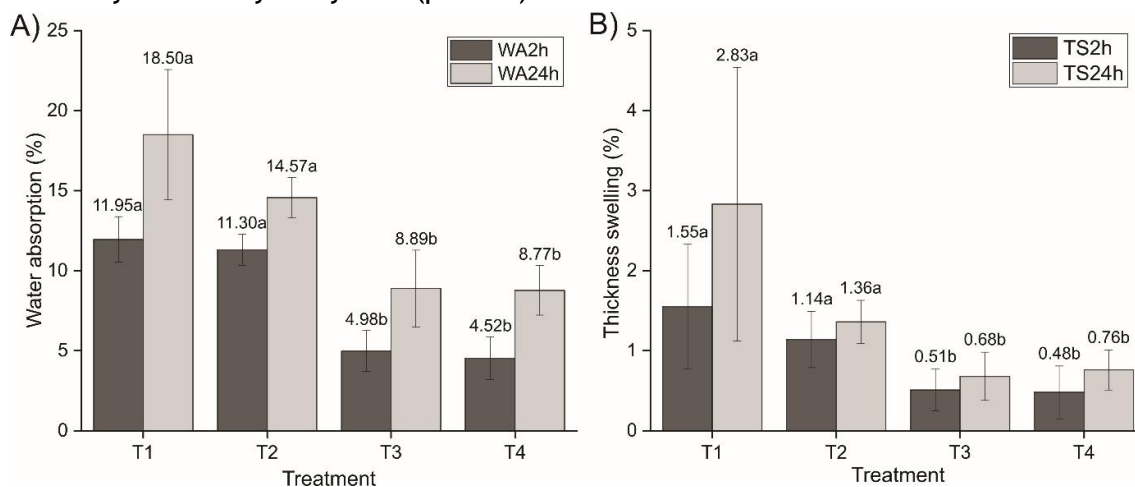
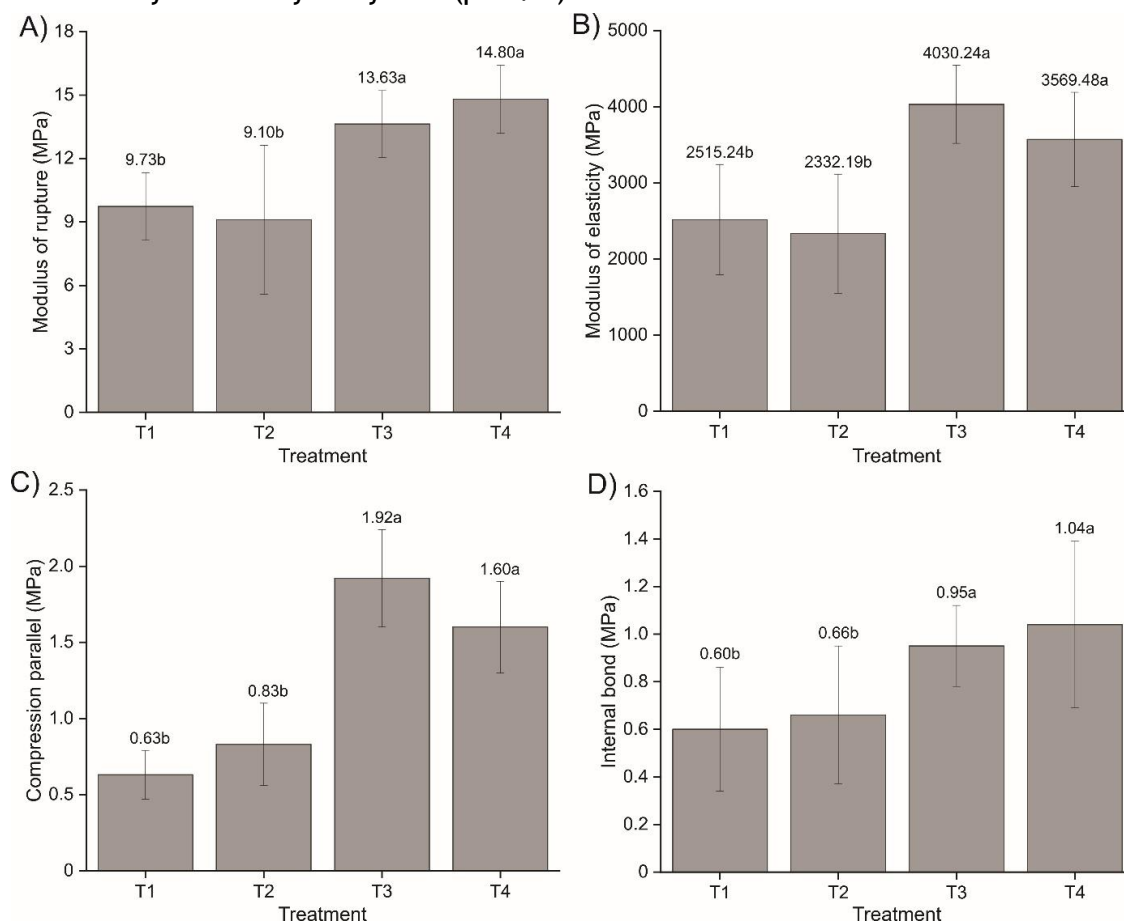


Figure 5 - Average values and standard deviation of mechanical properties of wood-cement panels produced with particles of *Erythrina poeppigiana* Means followed by the same horizontal letter are not statistically different by Tukey's test ($p > 0.05$)



The highest values of MOR and MOE were found for treatments T3 and T4, which were statistically similar. In Figure 6C and D it is observed that the carbonated panels (treatments T3 and T4) had no torn and fractured particles, providing a dense and compact cement matrix that favors the adhesion of the particles and results in higher mechanical strength. According to Tonoli *et al.* (2010) carbonation causes a reduction in the alkalinity

of the matrix, reducing the degradation of the lignocellulosic material. Thus, the strength of the particle is preserved due to the lower alkalinity, improving the mechanical performance and bonding of the particle in the matrix of carbonated panels. The BISON (2017) determines a minimum value of 9.0 MPa for MOR and 3000 MPa for MOE. Thus, all treatments studied met the marketing standard for MOR, and for MOE only treatments T3 and T4. Cabral *et al.* (2018), examining cementitious panels produced with sugarcane bagasse subjected to accelerated carbonation, found an increase in the flexural rupture modulus of 78.69% and in the flexural elasticity modulus of 125.13%, compared to the non-carbonated cementitious panel.

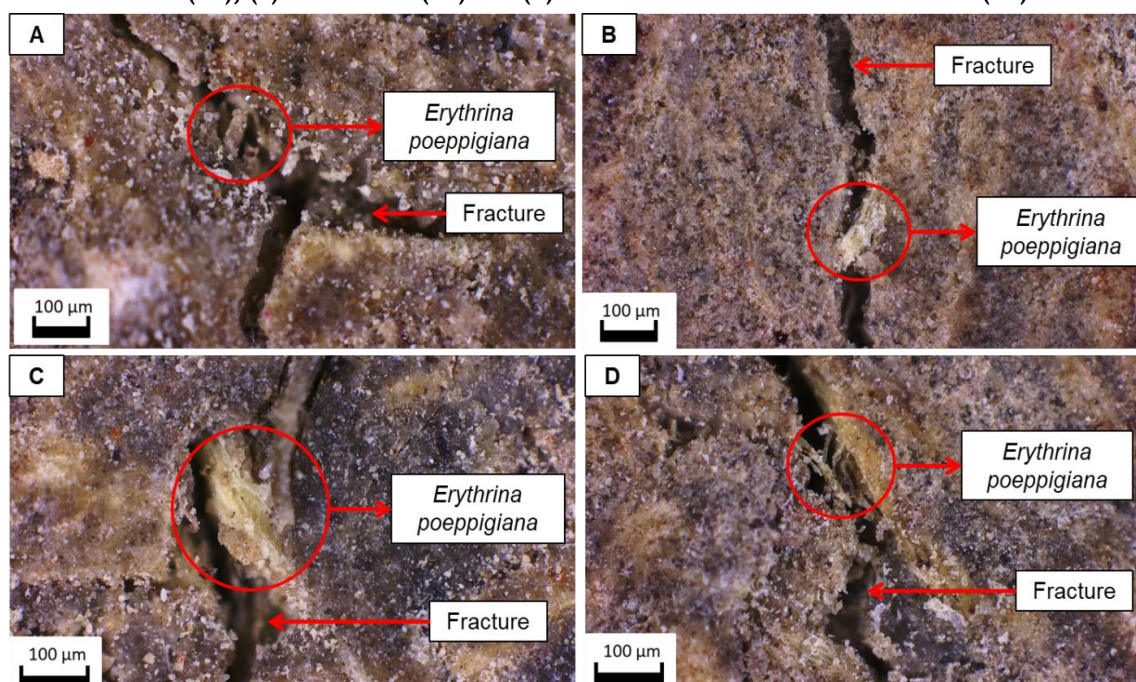
The panels presented in their fracture the tenacification mechanisms associated to the particles, which act in the fracture process of the composite, such as debond, pull-out and bridging, capable of improving the capacity of the material to absorb energy and deform permanently without fracturing, through the slipping of the particles, instead of their rupture (Figure 6). The images revealed panels with particles adhered and anchored to the matrix, with transverse fissures, interrupted by the *Erythrina poeppigiana* particles, and covered by the hydration products, which may contribute to the petrification process of the particles. The panels showed micro cracks that can be attributed to calcium hydroxide crystals of lower strength, responsible for filling the spaces left by water, and that presented an altered morphology due to impurities present in the system. These characteristics can present themselves with different intensity and reflect in the mechanical behavior of the composite. Therefore, it is possible to visualize in the images the hydration products adhered to the particles, the displacements of some particles in the matrix and cracks in the transition zone.

Treatment T1 showed fractured particles, pulled and detached from the matrix, indicating low adherence (Figure 6a). Treatments T2 and T4 showed particles forming bridges and slipping in the matrix, indicating that the hot water treatment causes interface improvement (Figure 6b and 6d), which justifies the reduction of porosity in these treatments (Figure 2b).

The accelerated carbonation provided higher compressive strength values for treatments T3 and T4 compared to treatments T1 and T2 (Figure 5c). Accelerated carbonation improves the durability of cementitious composites, reducing porosity and making them less susceptible to cracks and fissures, resulting in higher compressive strength.

Higher internal bond values were found for treatments T3 and T4 compared to treatments T1 and T2 (Figure 5d), demonstrating that there was a better coverage of the particles in the cement matrix of the carbonate panels. The BISON (2017) determines a minimum value for internal bond of 0.40 MPa, thus all treatments met the marketing standard for the internal bond property.

Figure 6 - Light microscopy images on the fracture of wood-cement panels: (a) control (T1); (b) hot water treatment (T2); (c) carbonated (T3) and (d) hot water and carbonated treatment (T4)



Fourier Transform Infrared Spectroscopy (FTIR)

The band sizes of 940 and 1415 cm^{-1} (Figure 7) are typical peaks of calcium carbonate (Reig; Adelantado; Moreno, 2002; Santos *et al.*, 2021). A higher intensity of the peaks is verified for the treatment T3, indicating a greater amount of calcium carbonate, and a lower intensity for the T1 treatment.

The carbonation reactions in cementitious composites can be divided into three steps: First occurs to CO_2 diffusion in the matrix, then CO_2 is dissolved in the pores and Ca^{2+} ions are migrated from the cement particles. The third step is the formation of calcium carbonate (Teir; Eloneva; Zevenhoven, 2005; Wang *et al.*, 2019). Accelerated carbonation promotes greater formation of calcium carbonate, which influenced the physical and mechanical properties of *Erythrina poeppigiana* cement-wood panels.

The FTIR technique allows revealing characteristic peaks of functional groups. In Figure 7, in addition to the calcium carbonate peaks, the peak in the 3367 cm^{-1} range also stands out for its intensity and is characteristic of OH⁻ groups (Popescu *et al.*, 2013).

Thermogravimetry

Figure 8 depicts the thermogravimetry (TG) and differential weight loss (DTG) of the panels in the different conditions evaluated. Endothermic events can be identified in the temperature zones of 100-250 °C (hydrated C-S-H phases) (Morandau; Thiery; Dangla, 2014), 300-400 and 450-550 °C ($\text{Ca}(\text{OH})_2$ and calcium carbonate), and 700-800 °C (stable and less stable carbonates) (Figure 8b).

Figure 7 - FTIR spectra of wood-cement panels produced with particles of *Erythrina poeppigiana*

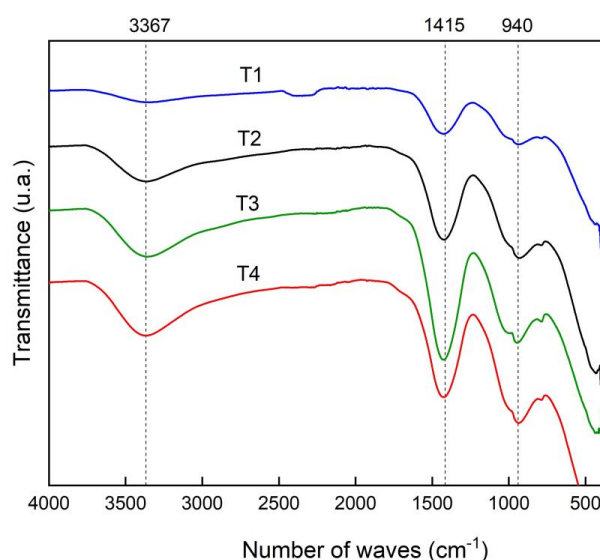
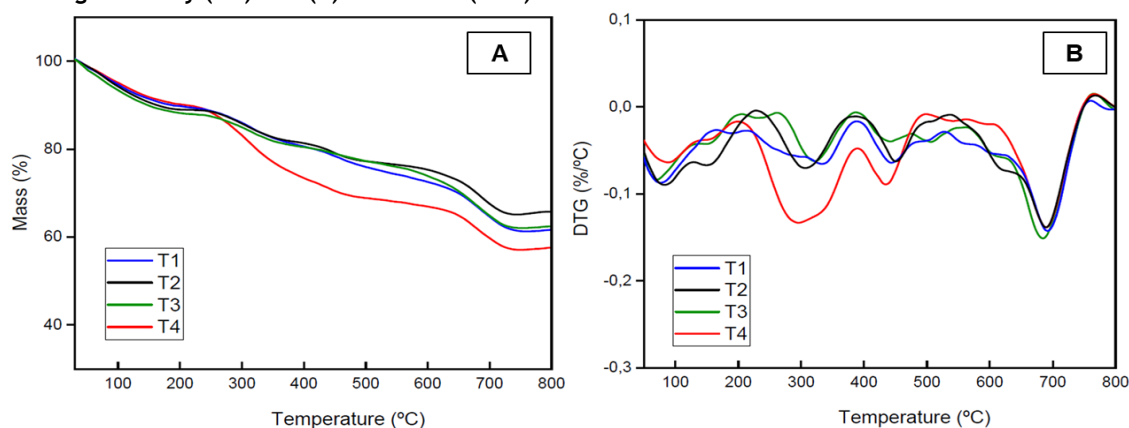


Figure 8 - Thermal degradation curves of *Erythrina poeppigiana* Wood-cement panels: (a) Thermogravimetry (TG) and (b) derivative (DTG)



The mass loss between 250-350 °C corresponds to the degradation of wood cellulose (Protásio *et al.*, 2015), already between 400-450 °C occurs the degradation of Ca(OH)_2 and calcium carbonate and in the range of 550-700 °C only calcium carbonate (Choi *et al.*, 2017) (Figure 8B). Among the evaluated conditions, treatments T1, T2 and T3 present similar thermal degradation curves in the range 50-600 °C (Figure 8a), but between 600-800 °C (calcium carbonate degradation range) the mass loss of treatment T2 is lower, due to the lower amount of calcium carbonate in this treatment (Figure 7). The T4 treatment presents the lowest thermal stability among the evaluated conditions, presenting the highest mass loss in the range of 300-800 °C (Figure 8a). In their studies with oriented cement slabs using particles of *Eucalyptus spp.*, Cabral *et al.* (2023) observed smaller peaks of Ca(OH)_2 in carbonated plates, indicating greater consumption of Ca(OH)_2 for the formation of CaCO_3 caused by curing with CO_2 .

Conclusions

The treatment with hot water decreased the extractive content and improved the interaction of the *Erythrina poeppigiana* particles with the cement, reducing the porosity of the wood-cement panels.

The accelerated carbonation allowed better physical and mechanical properties of the *Erythrina poeppigiana* Wood-cement panels, and all the quality requirements of BISON's standard were achieved.

The *Erythrina poeppigiana* wood is technically feasible for the production of wood-cement panels, a fact that might allow adding value and an appropriate destination for this specie.

References

- ALMEIDA, A. E. F. S. *et al.* Improved durability of vegetable fiber reinforced cement composite subject to accelerated carbonation at early age. **Cement and Concrete Composites**, v. 42, p. 49-58, 2013.
- AMARAL, A. C.; FERREIRA, M.; COUTO, H. T. Z. Métodos de avaliação da densidade básica da madeira de populações de pinheiros tropicais. **Instituto de Pesquisas e Estudos Florestais**, v. 15, p. 47-67, 1977.
- AMERICAN SOCIETY FOR TESTING AND MATERIALS. **C 948-81**: dry and wet bulk density, water absorption, and apparent porosity of thin sections of glass-fiber reinforced concrete. Philadelphia, 2001.
- AMERICAN SOCIETY FOR TESTING AND MATERIALS. **D-1037**: standard methods of evaluating properties of wood-base fiber and particles. Philadelphia, 2012.
- ARANTES, L. S. *et al.* Pre-treatment with calcium hydroxide and accelerated carbonation for cellulosic pulp fibrillation. **Nordic Pulp Research Journal**, v. 38, n. 2, p. 343-358, 2023.
- ASHORI, A.; TABARSA, T.; SEPAHVAND, S. Cement-bonded composite panels made from poplar strands. **Construction and Building Materials**, v. 26, p. 131-134, 2012.
- ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICA. MADEIRA. **NBR 14853**: determinação do material solúvel em etanol-tolueno, em diclorometano e em acetona. Rio de Janeiro, 2010a.
- ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICA. **NBR 11941**: determinação da densidade básica da madeira. Rio de Janeiro, 2003.
- ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICA. **NBR 13999**: papel, cartão, pastas celulósicas e madeira: determinação do resíduo (cinzas) após a incineração a 525 °C. Rio de Janeiro, 2017.
- ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICA. **NBR 7989**: pasta celulósica e madeira: determinação de lignina insolúvel em ácido. Rio de Janeiro, 2010b.
- BISON. Wood-Cement Board: Technical Handbook. **BISON Report**. Berlin, 2017.
- BORGES, I. O. *et al.* Potential for use of waste from soybean culture treated with water and sodium hydroxide for production of agglomerated panels. **Research, Society and Development**, v. 11, n. 2, 2022.
- BOULOS, L. *et al.* Wetting analysis and surface characterization of flax fibers modified with zirconia by sol-gel method. **Surface and Coatings Technology**, v. 313, p. 407-416, 2017.
- BROWNING, B. L. **The chemistry of wood**. New York: J. Wiley, 1963.
- CABRAL, M. R. *et al.* Enhancement of oriented cement-bonded boards' properties through CO_2 curing. **Environmental Science and Pollution Research**, v. 30, p. 117214-117224, 2023.

- CABRAL, M. R. *et al.* Orientation effect on the physical and mechanical properties of strand cement boards. **Construction and Building Materials**, v. 275, 2021.
- CABRAL, M. R.; NAKANISHI, E. Y.; FIORELLI, J. Cement-bonded panels produced with sugarcane bagasse cured by accelerated carbonation. **Journal of Materials in Civil Engineering**, v. 30, p. 04018103, 2018.
- CAPRAI, V. *et al.* Influence of the spruce strands hygroscopic behaviour on the performances of wood-cement composites. **Construction and Building Materials**, v. 166, p. 522–530, 2018.
- ÇAVIDAR, A. D.; YEL, H.; TORUN, S. B. Microcrystalline cellulose addition effects on the properties of wood cement boards. **Journal of Building Engineering**, v. 48, p. 103975, 2022.
- CHOI, S. G. *et al.* Methods for calcium carbonate content measurement of biocemented soils. **Journal of Materials in Civil Engineering**, v. 29, 2017.
- DEUTSCHES INSTITUT FÜR NORMUNG. **DIN 52362**: testing of wood chipboards bending test, determination of bending strength. Berlin, 1982.
- FERRAZ, J. M. *et al.* Compatibility of pretreated coir fibres (*Cocos nucifera* L.) with Portland cement to produce mineral composites. **International Journal of Polymer Science**, v. 2012, 290571, 2012.
- FERREIRA, S. R. *et al.* Effect of sisal fiber hornification on the adhesion with portland cement matrices. **Matéria**, Rio de Janeiro, v. 17, p. 1024-1034, 2012.
- FILOMENO, R. H. *et al.* Optimizing the modified atmosphere parameters in the carbonation process for improved fiber-cement performance. **Journal of Building Engineering**, v. 32, p. 101676, 2020.
- HASAN, K. M. F.; HORVATH, P. G.; ALPAR, T. Development of lignocellulosic fiber reinforced cement composite panels using semi-dry technology. **Cellulose**, v. 28, p. 3631-3645, 2021.
- IWAKIRI, S. *et al.* Avaliação do potencial de utilização da madeira de *Schizolobium amazonicum* “Paricá” e *Cecropia hololeuca* “Embaúba” para produção de painéis cimento-madeira. **Cerne**, v. 18, p. 303-308, 2012.
- IWAKIRI, S. *et al.* Propriedades tecnológicas de painéis cimento madeira produzidos com partículas de eucalipto. **Revista de Ciências Agroveterinárias**, v. 14, p. 217-223, 2015.
- IWAKIRI, S. **Painéis de madeira reconstituída**. Curitiba: FUPEF, 2005.
- KENNEDY, F.; PHILLIPS, G. O.; WILLIAMS, E. P. A. Wood and cellulose: industrial utilization, biotechnology, structure and properties, ellishor wood. **Chichester: E. Horwood**, p. 1130, 1987.
- LOBÃO, M. S. *et al.* Qualidade do lenho de árvores de *Schizolobium parahyba* var. *amazonicum* Acre, Brasil. **Floresta e Ambiente**, v. 19, p. 374-384, 2012.
- MARQUES, J. R. B.; MONTEIRO, W. R. Substituição sustentável de eritrina por seringueira em SAF de cacauero. **Agrotropica**, v. 28, p. 101-122, 2016.
- MATOS, A. C. *et al.* Influência de diferentes composições de lâminas de *Shizolobium parahyba* var. *amazonicum* (Huber ex Ducke) Barneby e *Pinus oocarpa* var. *oocarpa* (Schiede ex Schltdl) para produção de compensados multilaminados. **Scientia Forestalis**, v. 47, p. 799-810, 2019.
- MENDES, L. M. *et al.* Variação da densidade da madeira de *Pinus oocarpa* Schiede ex Schltdl. no sentido longitudinal dos caules. **Cerne**, v. 5, p. 102-111, 1999.
- MENDES, R. F. *et al.* Lignocellulosic residues in cement-bonded panels. **Sustainable and Nonconventional Construction Materials using Inorganic Bonded Fiber Composites**, v. 1, p. 3-16, 2017.
- MORANDEAU, A.; THIERY, M.; DANGLA, P. Investigation of the carbonation mechanism of CH and C-S-H in terms of kinetics, microstructure changes and moisture properties. **Cement and Concrete Research**, v. 56, p. 153-170, 2014.
- NASSER, R. A. *et al.* Effects of tree species and wood particle size on the properties of cement-bonded particleboard manufacturing from tree prunings. **Journal of Environmental Biology**, v. 35, p. 961–971, 2014.
- POPESCU, M. C. *et al.* Structural modifications of *Tilia cordata* wood during heat treatment investigated by FT-IR and 2D IR correlation spectroscopy. **Journal of Molecular Structure**, v. 1033, p. 176-186, 2013.

- PROTÁSIO, T. P. *et al.* Thermal stability of particleboards of sugar cane bagasse and *Pinus spp.* wood. **Scientia Forestalis**, v. 43, n. 107, p. 683–691, 2015.
- QUIROGA, A.; MARZOCCHI, V.; RINTOUL, I. Influence of wood treatments on mechanical properties of wood-cement composites and of *Populus Euroamericana* wood fibers. **Composites Part B: Engineering**, v. 84, p. 25-32, 2016.
- RAABE, J. *et al.* Biocomposite of cassava starch reinforced with cellulose pulp fibers modified with deposition of silica (SiO₂) nanoparticles. **Journal of Nanomaterials**, p. 493-439, 2015.
- RANA, M. N. *et al.* Influence of chemical additive on the physical and mechanical properties of cement - bonded composite panels made from jute stick. **Journal of Building Engineering**, v. 31, p. 101358, 2020.
- REIG, F. B.; ADELANTADO, J. V. G.; MORENO, M. C. M. M. FTIR quantitative analysis of calcium carbonate (calcite) and silica (quartz) mixtures using the constant ratio method. **Application to geological samples**, v. 58, p. 811-821, 2002.
- SÁ, V. A. *et al.* Mistura de três espécies de reflorestamento na produção de painéis cimento-madeira. **Revista Árvore**, v. 36, p. 549-557, 2012.
- SANTOS, V. H. J. M. *et al.* Application of Fourier Transform infrared spectroscopy (FTIR) coupled with multivariate regression for calcium carbonate (CaCO₃) quantification in cement. **Construction and Building Materials**, v. 313, p. 125413, 2021.
- SCATOLINO, M. V. *et al.* *Eucalyptus* wood and coffee parchment for particleboard production: physical and mechanical properties. **Ciência e Agrotecnologia**, v. 41, p. 139-146, 2017.
- SECRETARIA DO MEIO AMBIENTE; INSTITUTO DO MEIO AMBIENTE E RECURSOS HÍDRICOS. **Portaria Conjunta nº 03**: dispõe sobre os critérios e procedimentos para a concessão da Autorização de Manejo da Cabruca - AMC. Bahia, 2019.
- SILVA, M. G. *et al.* Estudo anatômico e físico da madeira de *Schizolobium parahyba* var. *amazonicum* proveniente de povoados nativos da Amazônia. **Scientia Forestalis**, v. 44, p. 293-301, 2016.
- SOROUSIAN, P.; WON, J. P.; HASSAN, M. Durability characteristics of CO₂-cured cellulose fiber reinforced cement composites. **Construction and Building Materials**, v. 34, p. 44-53, 2012.
- SOUZA, M. J. C. *et al.* Wood–cement boards with addition of coconut husk. **Wood Material Science & Engineering**, v. 17, p. 1-10, 2021.
- TEIR, S.; ELONEVA, S.; ZEVENHOVEN, R. Production of precipitated calcium carbonate from calcium silicates and carbon dioxide. **Energy Conversion and Management**, v. 46, p. 2954-2979, 2005.
- TONOLI, G. H. D. *et al.* Effect of accelerated carbonation on cementitious roofing tiles reinforced with lignocellulosic fibre. **Construction and Building materials**, v. 24, p. 193-201, 2010.
- WANG, J. *et al.* Accelerated carbonation of hardened cement pastes: Influence of porosity. **Construction and Building Materials**, v. 225, p. 159–169, 2019.
- WEI, Y. M.; ZHOU, Y. G.; TOMITA, B. Study of hydration behavior of wood cement-based composite. Effect of chemical additives on the hydration characteristics and strengths of wood cement composites. **Journal of Wood Science**, v. 46, p. 444-451, 2000.
- YEL, H. Effect of alkaline pre-treatment and chemical additives on the performance of Wood cement panels manufactured from sunflower stems. **Journal of Building Engineering**, v. 52, p. 104465, 2022.

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