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EVALUATION OF THE INCORPORATION OF PEANUT POD ASH IN GYPSUM MATRIX COMPOSITES

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Abstract: The aim of this research was to analyze the effects of incorporating peanut pod ash into gypsum matrix composites, with a view to disposing of waste for environmental preservation and also improving the properties of gypsum matrix composites. To this end, the pods were first reduced to particles in a knife mill and evaluated in terms of chemical composition using the total extractives, ash, lignin and holocellulose content tests, as well as physically using the bulk density test. After this procedure, the particles were subjected to heat treatment in a muffle furnace for a period of 3 hours at 300°C. The ash obtained from this process was incorporated into gypsum matrix composites with a constant water : gypsum ratio of 0.6 through different mass substitution levels (0%, 2.5%, 5.0%, 7.5% and 10%) of gypsum for the ash. The specimens measuring 10x10x10mm were then subjected to physical tests of humidity, water absorption at 2 and 24 hours, apparent density and the mechanical compression test. The results of these tests showed that the incorporation of waste ash did not have a significant impact on the moisture test; on the other hand, there was an increase in water absorption which can be explained by the large presence of holocellulose in the peanut particles (41.61%). With regard to apparent density, the composites showed a concomitant decrease with the incorporation of peanut pod ash, which can be explained by the low density of the residue (0.19g/cm³), resulting in lighter composites. With regard to mechanical properties, the sample with 2.5% ash had the highest compressive strength among the test specimens. It is therefore possible to conclude that the ash from the lignocellulosic waste studied proved to be viable for incorporation into gypsum matrices since the composites showed greater strength and lightness. Further studies are needed to confirm the trends analyzed and contribute to the possible dissemination of an innovative composite with a lower environmental impact.

Keywords: Construction. Materials with lower environmental impact. Physical-mechanical properties of composites.

INTRODUCTION

Composite materials can be conceptualized as insoluble elements formed by the combination of two or more materials in which the joining of these materials gives rise to a product with improved properties and different from those found in the constituents separately, such as high strength and stiffness and greater lightness; however, most composite industries have production processes that impact the environment (ASTM D3878, 2016; HAMOUDA et al, 2015).

The 2030 Agenda, however, proposes a global plan to spread sustainable development by the year 2030, which affects the composites industry as well as the agro-industry. The commitments include clauses 9 on inclusive and sustainable industrialization and 12 on sustainable production and consumption patterns (UNITED NATIONS ORGANIZATION, 2020).

As a result, the construction and agriculture sectors have been trying to spread sustainable practices and environmental preservation in their production chains. The premise is that the environmental impact of these industries should be as low as possible. In this way, construction composites produced from industrial by-products have been studied with the aim of creating products that are less aggressive to the environment, more economical, durable and resistant, as well as ensuring the correct disposal of agricultural crop by-products (VELOSO et al., 2021).

One of the most widely used products in the construction industry in this context is gypsum, a material produced from gypsum (COSTA, 2015). Its uses range from paste (smooth plaster), *drywall* or curved boards, especially in interior and decorative environments. However, its production process involves the production of environmental impacts, and its partial replacement by elements less aggressive to the environment could mitigate such impacts (QUEDINA, 2018).

One of the elements with the potential to replace gypsum is ash from agro-industry waste. According to Bilotta and Ross (2016), agro-industry in general is a major producer of waste, such as vegetables from harvesting, processing waste, straw, shells and stones, which have properties in their composition that can be reused for energy. For example, peanut shells can be used to produce biogas. On the other hand, in addition to using these materials as biomass for energy generation, it is interesting to look for other alternatives for their use, such as studies into the feasibility of using this material in civil construction in composites.

Therefore, the general objective of the research was to evaluate the interaction between peanut pod waste ash and gypsum matrices by analyzing the physical-mechanical properties of composites with the incorporation by mass of different levels of waste ash (0%, 2.5%, 5%, 7.5% and 10%) as a partial substitute for gypsum in order to verify the feasibility of producing this composite at an industrial level.

MATERIAL AND METHODS

PROCESSING RAW MATERIALS

The peanuts were collected from the Pimentas farm, located in the municipality of Lavras - Minas Gerais. After harvesting, the material pods were processed at the Experimental Wood Panel Unit (UEPAM), located at the Federal University of Lavras, by grinding in a knife mill and sieving the particles between 40 and 60 mesh sieves.

After collection and preparation, the *raw* material was characterized physically using the bulk density test - NBR 14810-2 (ABNT, 2018) and chemically in terms of total extractive content - NBR 14853 (ABNT, 2010), insoluble lignin - NBR 7989 (ABNT, 2010) and ash - NBR 13999 (ABNT, 2003). The holocellulose content was calculated by difference from the other chemical constituents according to Equation (1).

$$H (\%) = 100 (\%) - \text{total extractives} (\%) - \text{lignin content} (\%) - \text{ash content} (\%) \quad (1)$$

The gypsum used was IPUBI gypsum (Figure 1) purchased from a supplier in Lavras, Minas Gerais.

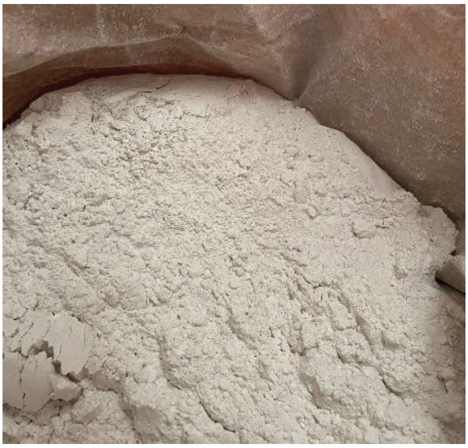

Figure1 - Gypsum obtained in Lavras.

Source: From the authors (2024).

Subsequently, the peanut pod particles were subjected to heat treatment in a muffle furnace for a period of 3 hours at 300°C . This procedure for producing the ash is described in Figure 2.

PRODUCTION OF COMPOSITES

After obtaining the raw materials, the composites were molded using a constant ratio of water to gypsum of 0.6, which provided a better workability of the mixture, making it homogeneous and not flowing through the molds. The different levels of gypsum gradually replaced by peanut pod ash by mass are described in Table 1

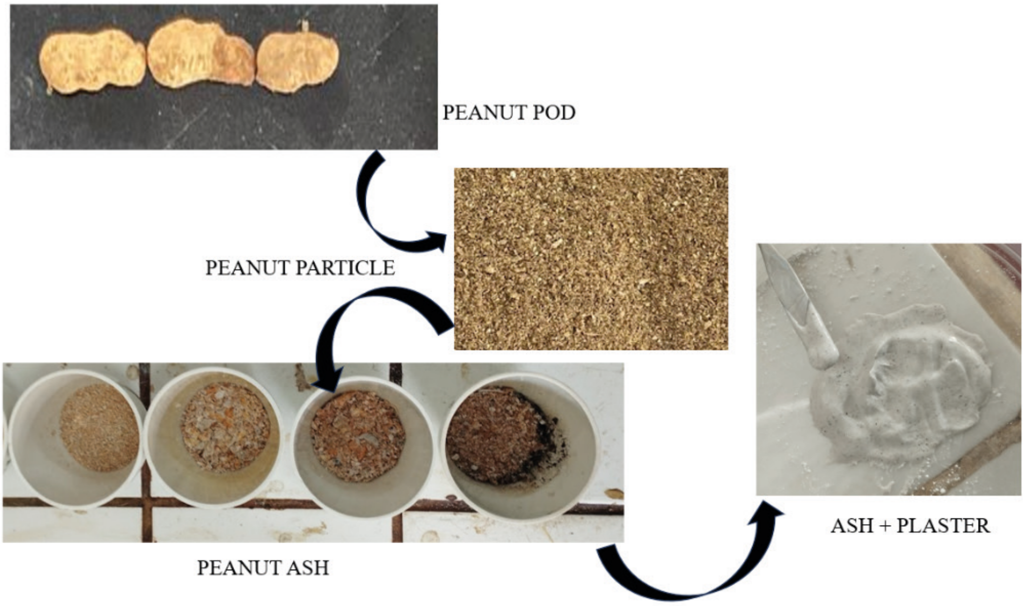

Figure2 - Peanut pod ash production process .

Source: From the authors (2024)

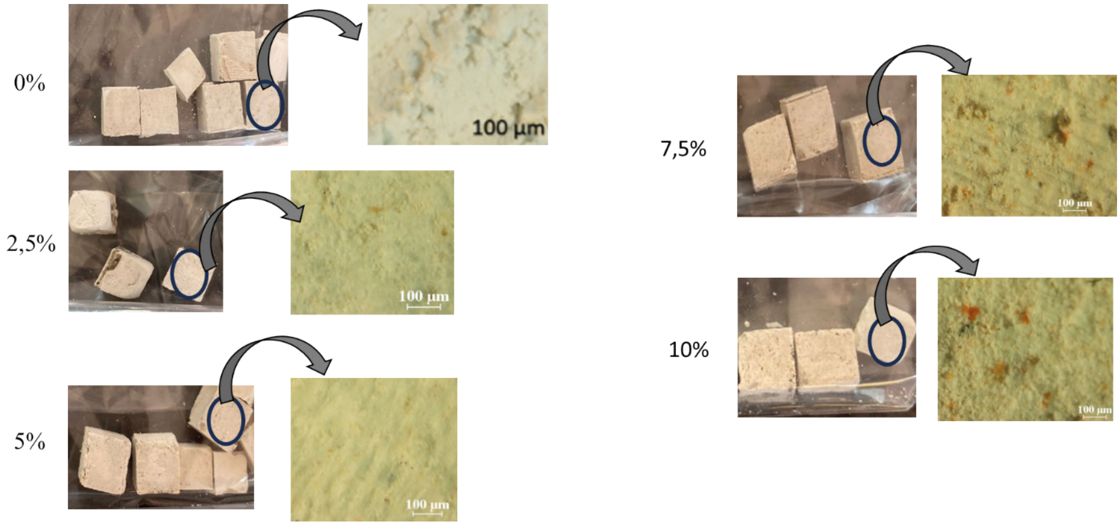

Figure3 - Specimens from the different treatments studied.

Source: From the authors (2024).

Density (g/cm^3)	Extractives (%)	Lignin (%)	Ashes (%)	Holocellulose (%)
0,19 ± 0,01*	6.62± 1.06	37.35± 33.59	12.96± 0.76	47.04± 1.47

*Standard deviation of the mean values obtained for the physical-mechanical properties.

Table2 - Results of the physicochemical analysis of the peanut particle.

Source: From the authors (2025).

Treatment	Gypsum (%)	Groundnuts (%)
T1	100	0
T2	97.5	2.5
T3	95.0	5.0
T4	92.5	7.5
T5	90.0	100

Table1 - Specimens with different compositions of groundnut ash and gypsum .

Source: From the authors (2024).

Polyethylene molds measuring 10x 10x 10mm were used to make the specimens, following specifications adapted from standard EN 13279-2 (CEN, 2006). These smaller dimensions were used in order to use less material due to the low yield of ash. Three samples were molded for each treatment, giving a total of fifteen for the study (Figure 3).

After 24 hours of mixing, the specimens were removed from the molds and stored in a cold room at the Experimental Wood Panel Unit (UEPAM) for a curing period of 7 days.

EVALUATION OF THE PHYSICAL AND MECHANICAL PROPERTIES OF THE COMPOSITES

After manufacturing, the impact of incorporating peanut pod ash into plaster matrices was measured using physical and mechanical tests. The mechanical test was uniaxial compression using a universal testing machine to obtain the compressive strength (MOR) of the samples (adapted to standard EN 13279-2, CEN 2006).

The physical analyses carried out were dry humidity - adapted to standard NBR 7190 (1997), apparent density - adapted to standard NBR NM 45 (2006) and water absorption after 2 hours and 24 hours - adapted to standard EN 1015-18 (CEN, 2002).

Given the results obtained, a completely randomized design was used and the data obtained was subjected to Tukey's analysis at 5% significance and linear regression.

RESULTS AND DISCUSSION

CHARACTERIZATION OF PEANUT PARTICLES

The average values for bulk density, extractive content, lignin, ash and holocellulose of the peanut pod particles can be seen in Table 2.

The particle density was 0.19g/cm³, a considerably low value according to the Technological Research Institute (1985) (<0.50g/cm³). The result found was also lower than that found for bean waste (0.24g/cm³) (MIRANDA et al., 2023) and higher than the density of jupati petioles (0.11g/cm³) (GOMES et al., 2024) and sugarcane bagasse (0.12g/cm³) (SOARES et al., 2017). The low density calculated in comparison with gypsum (0.80g/cm³) shows that the use of this material is attractive since it can produce a lighter composite.

The extractive content found was 6.62%, a low value compared to that found by Gomes et al. (2024), who analyzed jupati petiole residues and obtained extractive content values of 6.90%, Miranda et al. (2023), who evaluated the influence of adding bean waste to gypsum matrices and obtained a chemical composition of extractives of 8.16% and Paula et al. (2011) who analyzed sugarcane bagasse waste for energy generation and found an extractive content of 31.76%. This low extractive content found in peanut particles is an important characteristic for the bond between the matrix and the reinforcement in composites, as this component acts to block the empty spaces in the lignocellulosic material, which can prevent it from coming into contact with the matrix and make difficult for these composites to cure (GOMES et al., 2024).

On the other hand, the lignin content found for the material in question (37.35%) was higher than that obtained for other lignocellulosic waste such as jupati petioles (33.52%) (GOMES et al., 2024) and bean waste (8.13%) (MIRANDA et al., 2023). A high lignin content is responsible for increasing the setting time, as these components act as retarders of the composite's hydration kinetics because they are hydrophobic components (SHIROMA et al. 2016). However, lignin is responsible for greater rigidity and resistance to compression, which can boost the mechanical behavior of composites containing lignocellulosic materials with a large amount of lignin (FONSECA et al. 2021).

The ash content found for the material in question (12.96%) was close to that other lignocellulosic residues such as jupati petioles (13.90%) (GOMES et al., 2024) and bean residue (16.94%) (MIRANDA et al., 2023). According to Iwakiri and Trianoski (2020), a significant ash content in agricultural by-products is mainly attributed to differences in the production and harvesting processes, including factors such as the place of planting, the type of soil and the climatic conditions of the region.

Finally, the holocellulose content found (47.04%) for the lignocellulosic residue was close to that found for jupati petioles (45.68%) (GOMES et al., 2024) and lower than that found in bean waste (56.55%) (MIRANDA et al., 2023). A high holocellulose content gives the material a higher moisture and water absorption value since this structure is hygroscopic (GUIMARÃES JÚNIOR et al., 2016)

PHYSICAL TESTING OF THE COMPOSITES

Apparent density

The results of the apparent density of the composites are shown in Figure 4. A significant reduction in the apparent density of the composite materials can be seen after the addition of peanut pod ash, with values for this property varying from 1.48g/cm³ in the reference sample to 0.61g/cm³ in the sample with 10% ash.

The sample with 0% ash, which had the highest apparent density, was significantly the same as the treatment with 2.5% ash and significantly higher than the other treatments. On the other hand, the composite with 5% ash showed no significant difference from treatments 2 and 4 (2.5% and 7.5% ash). Finally, the sample with 10% ash, which has the lowest apparent density, differs significantly from all the other treatments.

This reduction in the apparent density of the samples was expected due to the low density of the lignocellulosic material in relation to the gypsum (Table 2) and is also observed in other studies such as Villela et al. (2020) and Rivero et al. (2014), which incorporated rubber into gypsum matrices.

According to Merino (2018), composites with a density of less than 1.00g/cm³ are considered lightweight; therefore, composites with 7.5% and 10% peanut pod ash can be considered in this classification.

Humidity

The results obtained for the dry moisture content of the composites are shown in Figure 5.

The data shows that there was no statistically significant difference between the treatments. There was, however, an absolute decrease in moisture when incorporating peanut pod waste up to 5.00%. After this level of substitution, moisture increases up to the 7.50% ash sample and then decreases again in the composite with 10% ash.

The average moisture content found was 0.17%, lower than the values found in studies of gypsum composites reinforced with coconut, jute, wool, cotton and banana plant fibers by Chinta et al. (2013).

It was expected that there would be an increase in the moisture content of composites with peanut pod ash, given that the *raw* particles of this material have a high holocellulose content (41.61%), a fact that was not confir-

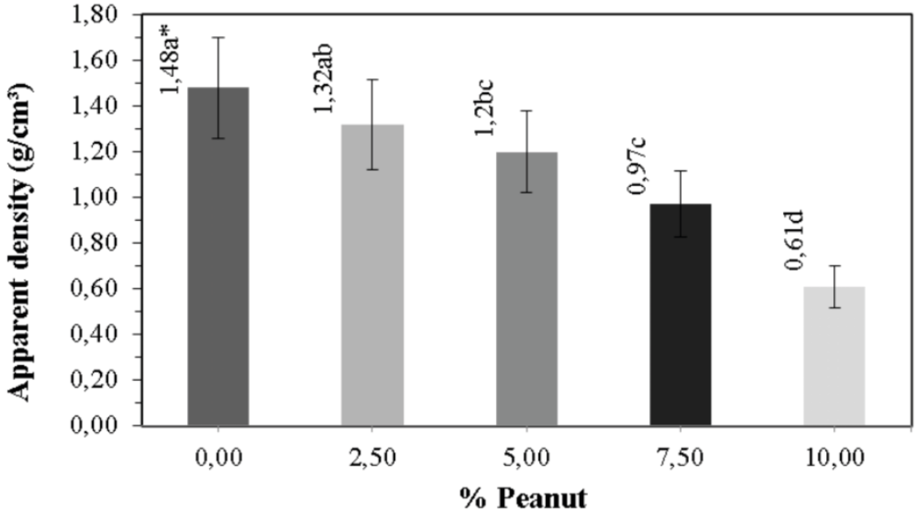

Figure4 - Apparent density results for composites containing ash.

*Averages of values followed by the same letter do not differ according to Tukey's test at 5% significance.

Source: From the authors (2025).

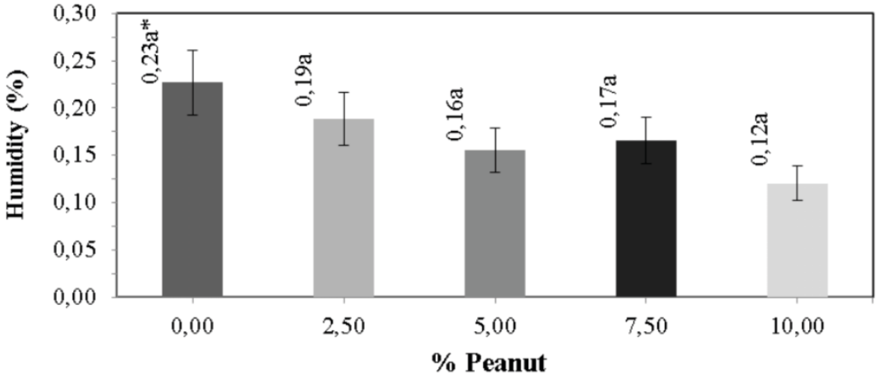

Figure5 - Moisture of the composites.

*Averages of values followed by the same letter do not differ according to Tukey's test at 5% significance.

Source: From the authors (2025).

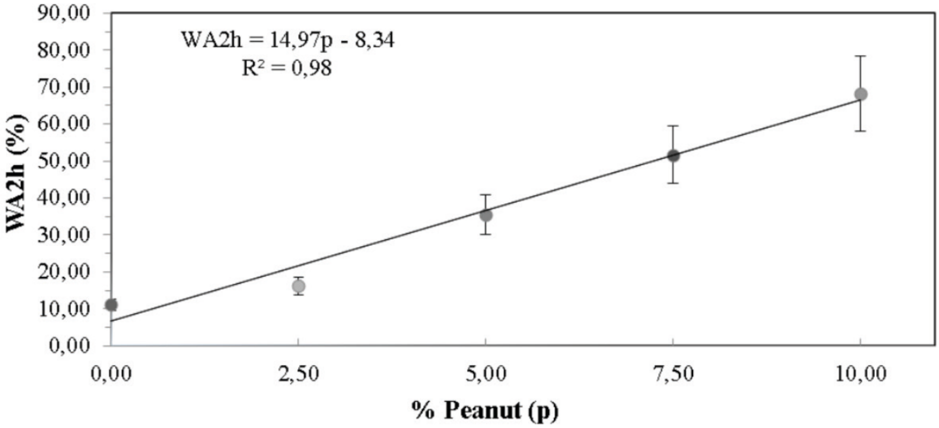

Figure6 - Absorption results after 2 hours of immersion.

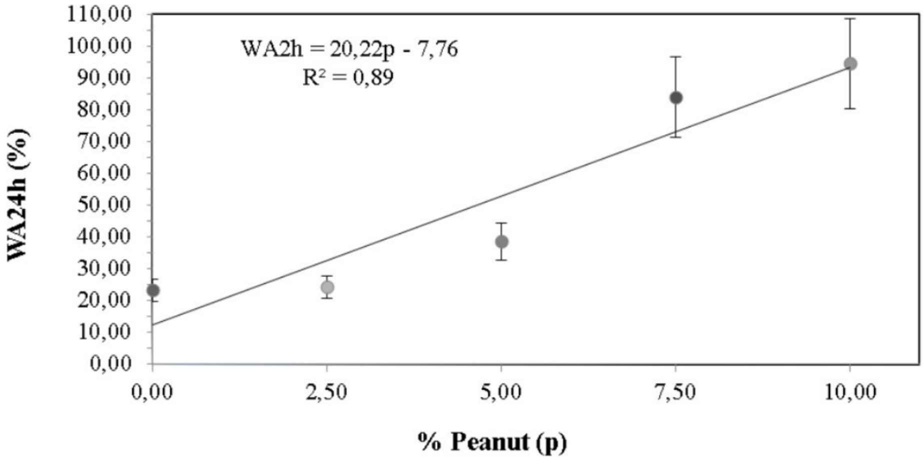

Figure7 - Results of the water absorption of the composites after 24 hours of immersion.

Source: From the authors (2025).

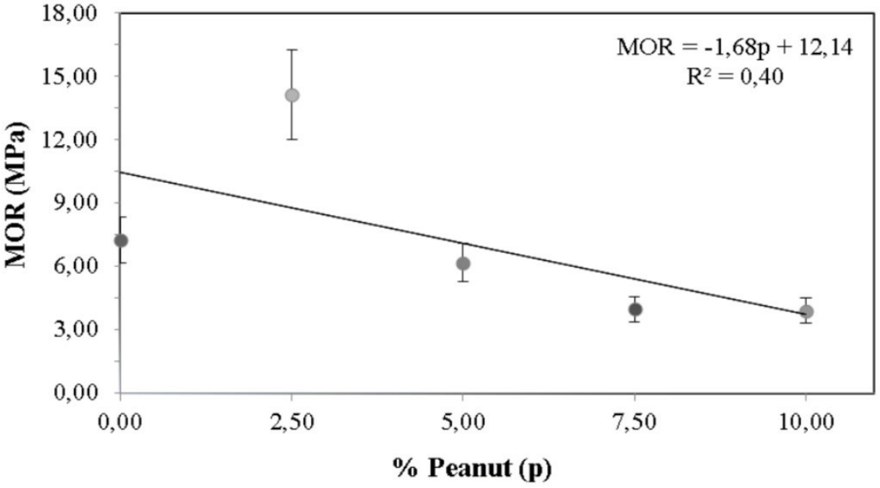

Figure8 - Composite compressive strength results.

Source: From the authors (2025).

med. According to Veloso et al. (2021), the increase in hydrophobicity with the insertion of the residue is a beneficial characteristic for gypsum, since it reduces its restriction to dry environments and expands its use for composites.

Thus, the addition of the residue to the gypsum matrix is a viable alternative and did not affect this property , since the humidity of the composites remained constant and absolutely lower than that of the reference treatment, even with the use of different types of reinforcements.

Absorption of water

The data obtained from the water absorption test after two hours' immersion (WA2h) of the composites can be seen in Figure 6

Figure 7 shows the data obtained after the samples had been immersed in water for 24 hours (WA24h).

It can be seen that at both measuring times, the specimens showed an increase in their water absorption concomitant with the increase in the ash content of the peanut pod particles. According to Carneiro and Fernandes (2022), the increase in water absorption is explained by the intrinsic characteristics of the lignocellulosic material such as the holocellulose content (41.61%) and the possible formation of pores and cavities in the specimens with the insertion of particles with a large number of voids.

There is also a relationship between the water of crystallization and the insertion of hydrophilic materials , which has led to an increase in the rate of water absorption, especially in the first two hours immersion (LANZÓN et al., 2022).

MECHANICAL TESTING OF COMPOSITES

The results of the modulus of rupture (MOR) derived from the mechanical compression test are shown in Figure 8.

The compressive strength values ranged from 3.91 MPa to 14.16 MPa, results close to those presented by Gomes et al. (2024) who analyzed the addition of jupati particles to gypsum matrices.

It can be seen that the values decreased as the amount of peanut pod ash incorporated into the composites increased, with the exception of the 2.5% treatment, which proved to be superior to the others and had a compressive strength 14.16 MPa.

Thus, the addition of greater quantities of lignocellulosic material may have caused a weak interaction between the reinforcement and the matrix, which can be explained by the constituents of peanut pod ash as extractives (Table 2) (VELOSO et al. 2021).

However, despite the progressive decrease in compressive strength increasing levels of particle incorporation, all the composites met the specification of standard EN 13279-1 (CEN, 2008) which establishes a minimum MOR value of 2.0 MPa for gypsum composites with dimensions of 40x40x40mm tested in compression.

CONCLUSION

The aim of this research was to analyze the effects of incorporating peanut pod ash into gypsum matrix composites.

The results of the analysis of the influence of the addition of ash to the gypsum matrix showed that the low density of the residue contributed to a significant reduction in the apparent density of the composites, which is attractive for various applications in the construction industry, since it makes it possible to obtain lighter composites. In addition, the moisture values of the samples tested were not statistically significant.

On the other hand, the residue's high holocellulose content led to an increase in the rate of water absorption in the composites. In this respect, this characteristic is unfavorable, as it restricts its use to dry environments, since the material is highly hydrophilic.

In terms of mechanical properties, peanut pod ash caused a reduction in the compressive strength of gypsum matrix composites as the ash content increased, with the exception of the treatment with 2.5% ash. However, it was observed that all the composites met the normative standards.

Thus, the addition of the waste to the gypsum matrix proved to be viable in most of the tests and further studies are needed to confirm the trends analyzed and contribute to the possible diffusion of an innovative composite with a lower environmental impact.

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