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Acoustic Characterization of Sugarcane Bagasse Particleboard Panels (*Saccharum officinarum L*)

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The use of sugarcane bagasse minimizes the environmental impact and contributes to the creation of a new product with low density, good sound absorption capacity and can improve the acoustic conditions of buildings. The goal of this study aims to determine the intensity response of sugarcane bagasse particleboard panels' sound absorption and compare them with particleboard panels of the species *Pinus* sp. and *Eucalyptus* sp. To accomplish this, the sound pressure levels in different frequency bands were analyzed. The results showed higher sound absorption between the low and high frequency bands for the three types of panels, with an absorption peak in 315 Hz identifying the characteristic frequency of resonance from these materials. However, the sugarcane bagasse panel presented differently than the others, with a greater retention of sound energy in the medium frequency band between 630 Hz and 1,000 Hz with a maximum absorption at 55 dB at the frequency of 800 Hz.

Keywords: *sugarcane bagasse, particleboard, sound absorption, acoustics*

1. Introduction

Noise generates negative effects on human health. Sound absorption and sound insulation allow their control. Materials commonly used for noise reduction are non-biodegradable synthetic sound absorbers used in the construction industry, which despite adequate performance cause pollution to the environment and their production contributes to the emission of harmful gases into the atmosphere. Alternative sound absorption materials, such as substitutes for synthetic materials which have comparable quality, high availability and are biodegradable and recyclable, are of great interest.

Several studies on natural fibers utilized as sound absorbers have been conducted[1] investigated acoustic properties of bamboo fibers and found the equivalent sound absorption of glass wool. Yang et al.[2] employed panels of rice straw particles to substitute for the wood, and on comparing it with common plywood from the manufacturing industry it was found that the rice straw particle panels with low density resulted in better sound absorption in the range 1,000 to 8,000 Hz in comparison with the same panels of superior density of plywood and wood fiber panels.

Materials derived from agricultural waste, in general, may be used in the manufacture of particleboard panels once the environmental impact has been minimized, and they are substitutes for natural wood for various purposes. These panels can be manufactured of any lignocellulosic material with a similar chemical composition to wood. Studies have proven that the panels produced in laboratories with sugarcane bagasse resulted in satisfactory quality products compared to the commercial panels. In a study of sugarcane bagasse panels using polyurethane resin as a binder based on castor oil, Fiorelli et al.[3] obtained values of the mechanical properties equivalent to panels manufactured on an industrial scale with a density between 0.9 and 1.0 g/cm^3.

Sugarcane (*Saccharum officinarum* L.) is commonly found in equatorial countries such as India, Pakistan, Malaysia and Indonesia, and tropical countries such as Brazil. On average, one hectare of sugarcane generates 10 tons of waste. A part of this waste is utilized for energy production in the industries; another part is burned onsite in order to clear the field for the next crop. Some efforts have been made to use the waste in the production of paper[4].

The development of efficient components for construction, which are environmentally friendly utilizing alternative materials such as sugarcane bagasse should be considered, since Brazil is the largest world producer of sugarcane and dominates the technology for the entire production chain[5]. However, it still does not use sugarcane bagasse to produce particleboard on an industrial scale. Countries like India, China and the US produce and market this type of panel[6]. Studies on physical and mechanical properties of these panels have been widely performed, but there are few studies on other properties such as thermal and acoustic.

Battistelli[7] studied the acoustic properties of sugarcane bagasse panels and the fiber of bamboo leaf stalks. The results showed satisfactory values as sound insulation for office partitions and composition of drywall panels.

Although all materials absorb part of the acoustic incident, the term "acoustic material" has been applied particularly for those with the specific purpose of providing high levels of sound absorption. Stacy[8] defined sound absorption as a measure

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of sound energy propagation hitting a surface which is not reflected. However, the determination of sound absorption in alternative fibrous materials is still unknown. In this context, the objective of this study was to characterize the sugarcane bagasse commercial panel against the sound pressure levels and acoustic absorption in the audible frequency spectrum.

2. Material and Methods

This study utilized particleboard sold in Brazil of the species *Pinus* sp. and *Eucalyptus* sp. and the sugarcane panels marketed in China. These panels had defined bulk density and moisture levels.

Fifteen modules were built with cubic dimensions of 600 mm length and 15 mm width, five for each species studied. A hole was drilled in the bottom of the modules to be able pass and position equipment, according to the adapted methodology of Loschi et al.[9]. These procedures are illustrated in Figure 1.

The experiment was conducted in a sound studio with dimensions of 306 cm × 292 cm × 305 cm in height, properly treated acoustically for non-reverberant conditions and external insulation, Figure 2.

A computer was used, a Roland brand UA-25EX sound card, an amplifier/receiver, a speaker with 50 W RMS and frequency response of 22 Hz to 30,000 Hz, one Behringer ECM 8000 microphone with a linear frequency response of 15 Hz to 20,000 Hz and omnidirectional polar pattern, a decibelimeter that meets the recommendations of IEC 651, 1979 and the Smaart v7® software that generated a wave file containing pink noise.

The computer was connected to the speakers and the microphone. The pink noise created through the software passed through the sound card, was subsequently amplified and conducted through the speaker. This was positioned one meter from the microphone and also one meter from the floor. It was then characterized as the source generating the noise. Subsequently, the amplifier was positioned in the center of the module by a support bar adapted from the pedestal that was attached to the bottom of the box and the floor of the studio. A small block of Styrofoam was used to ensure the soundproofing, closing the space between the pedestal and the back of the module. Rubber was also used on the four support brackets that held the module, to isolate the effect of vibration created during the experiment. The microphone placement and the decibelimeter were kept to one meter away from the speaker, now within the module. Figures 3 and 4 illustrate the assembly sequence of the experiment.

Initially pink noise was generated and picked up by the microphone characterizing the primary generating source, noted on screenshot #1; then the noise passed through the speaker to characterize the secondary generating source, without the modules, noted on screenshot #2; finally, with the speaker inside the module, the noise passed through, then characterizing the retention of sound energy of sugarcane

Figure 1. Development of modules; (a) Acquired panel; (b) and (c) Module assembly; (d) Set of modules tested.

Figure 2. Location of the assembly of the experiment; (a) Rehearsal studio; (b) Coating on superior part of the room; (c) Detail of the thickness of the door; (d) Detail of the window double glazing.

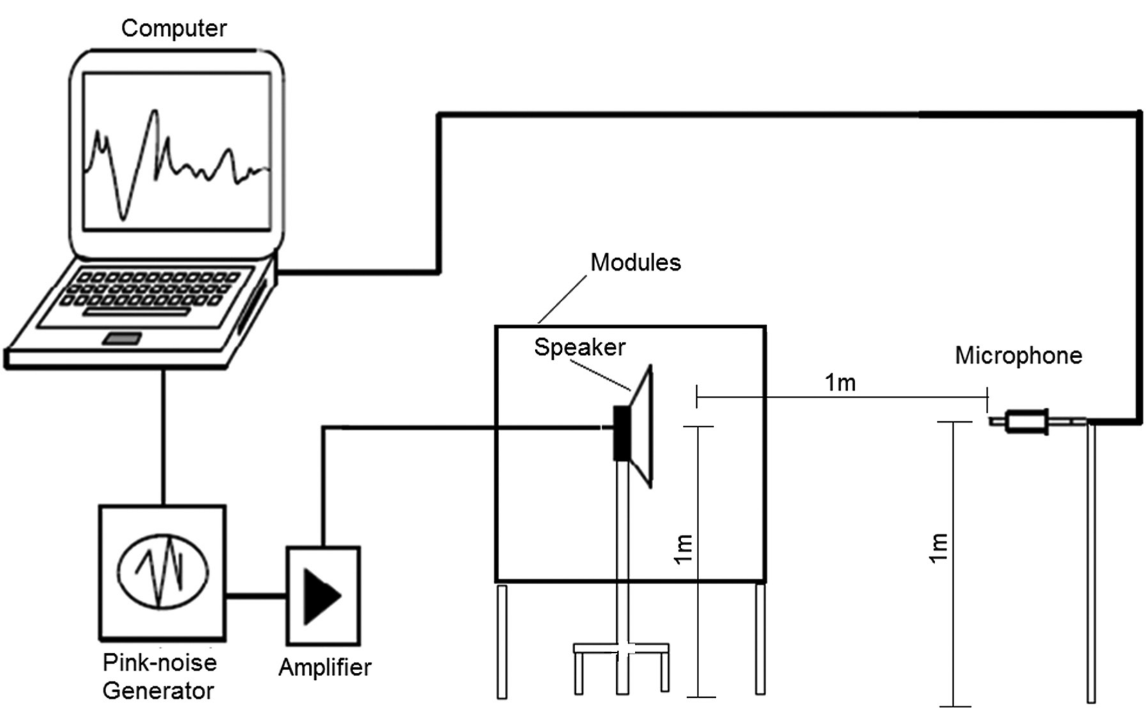

Figure 3. Schematic display of the experiment.

Figure 4. Photos of the assembly of the experiment; (a) Positioning for characterization of the source of noise; (b), (c) and (d) Positioning with the modules and (e) Rubber buffer supports.

bagasse on screenshot #3, of *Pinus* sp. on screenshot #4, and *Eucalyptus* sp. on screenshot #5, as can be seen in Figure 5.

Twenty measurements were registered to characterize the secondary source. Then, three measurements were taken per module, five modules for each species, totaling 45 measurements for the three species.

Sound pressure levels were analyzed for three frequency bands, namely from 0 to 500 Hz, 500 Hz to 2,000 Hz and from 2,000 to 20,000 Hz, which were termed low, medium and high, respectively.

3. Results and Discussion

3.1. Physical characteristics of the panels

Sugarcane bagasse panels presented with a lower density than the others, with values within the parameters for low density panels below 0.55 g/cm^3. In Table 1, the mean values of bulk density (g/cm^3) and moisture (%) for three species of panels evaluated.

According to Asdrubali[10], effective sound absorbers have low density. In a study of the acoustic properties of bamboo fiber panel with the density of 0.50 g.cm^{-3}; Koizumi et al.[1], observed high absorption coefficient in high frequencies. Xiang et al.[11] working with kapok fiber panel observed that there is an ideal density range for noise reduction in fibrous materials; above this value, such performance decreases. For also being a fibrous material, with the density near the bamboo and less than other wood panels, the sugar cane bagasse panel showed a better sound absorption behavior; as the sound wave has less velocity in air than in water, the resistance that this medium offers to its transmission promotes greater energy dissipation in the panel with lower moisture and consequently greater sound absorption. Moisture

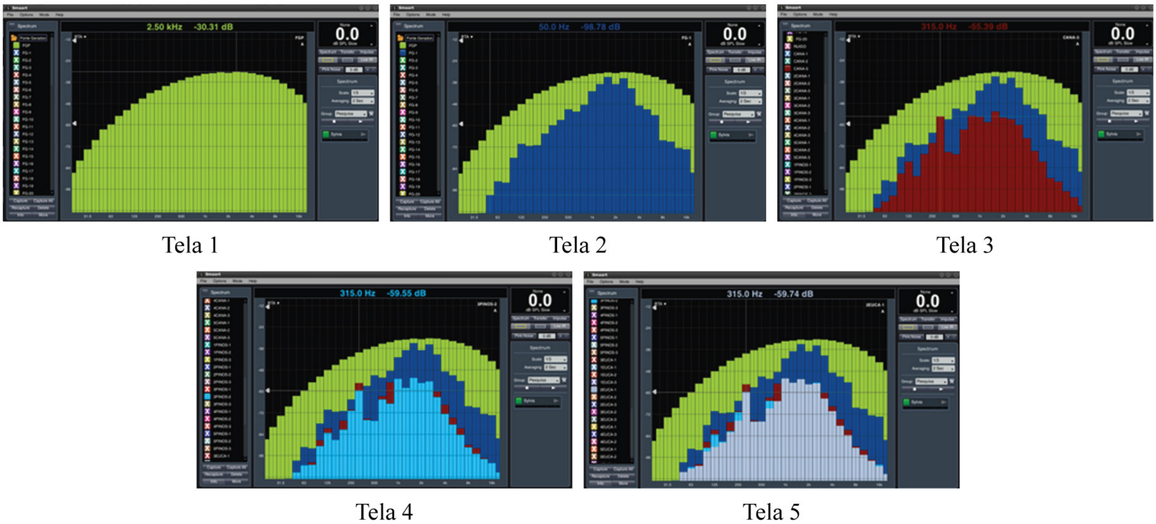

Figure 5. Records from the panels sound absorption areas created by the smaart software v7. Screen 1: pink noise; Screen 2: generating source; Screen 3: cane bagasse panel; Screen 4: Pinus sp. panel; Screen 5: Eucalyptus sp. panel.

Table 1. Bulk Density (g/cm^{-3}) and Moisture (%) of the Panels.

Species	Bulk Density (g/cm³)			Moisture (%)		
	Average	CV %	Standard Deviation	Average	CV %	Standard Deviation
Pinus sp.	0.645	1.432	0.009	8.88	2.589	0.229
Eucalyptus sp.	0.636	1.190	0.007	9.69	0.783	0.075
Sugarcane bagasse	0.543	1.127	0.006	8.08	1.107	0.080

CV= Coefficient variation.

influences the sound absorption; thus, the Sugarcane bagasse panels also had the lowest moisture balance and, therefore, better sound absorption performance at frequencies between 630 Hz and 1,000 Hz.

3.2. Characteristics of sound pressure levels as a function of frequency

The three panels had low sound absorption in bands of 0 to 150 Hz and above 2,000 Hz. Within these frequency bands the panels showed an increasing trend in sound absorption and stabilization near 60 dB. In this range, the *Eucalyptus* panel, which has the highest density, showed different performances with similar values of sound absorption compared to the others, but in a higher frequency range, as shown in Figure 6.

Koizumi et al.[1], working with bamboo fiber particleboard panels of 0.06, 0.12 and 1.18 g/cm³ found that high sound absorption rates increase in correlation with increases in panel density.

It should also be noted that the frequency of 315 Hz was the phenomenon of resonance, i.e., the frequency of the emitting wave coincided with the natural frequency of the oscillation of the panels, and the sound energy captured by the microphone issued by the speaker was superior, as is indicated by the circle in Figure 6. This power increase is due to vibration suffered by the panels in this resonant frequency. This fact indicates that you should not use this type of panel in environments subject to this frequency range as they will suffer more vibrations.

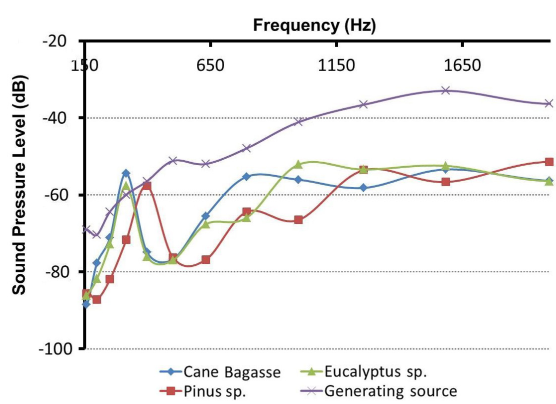

Figure 6. Levels of sound pressure between frequencies of 100 Hz to 2,000 Hz.

3.2.1. Charateristics of low frequencies

It can be seen that the sound absorption was lower for the three panels in the frequency range of 0 to 150 Hz, as shown in Figure 7.

The sound absorption corresponds to the ratio between the absorbed sound energy and the incident[12]). In Figure 7, an increase in the absorption of sound energy in the frequencies of 100Hz and 240 Hz to 310 Hz in which the area between the curves decrease can be observed. The sound absorption in a material depends on the frequency of the emitted wave. This is because the wave form moves with a greater or lesser ease depending on the wavelength (λ) and the medium in question. The lower the frequency, the greater the wavelength and consequently more difficulty in penetrating the material. Therefore, the pore size of a material may make it more difficult to control low frequency sound compared to high frequency.

3.2.2. Characteristics of medium frequencies

The three panels showed an increase in sound absorption in the range of 50 to 60 dB starting at the frequency of 600 Hz and remained in this range until the frequency 2,000 Hz, as shown in Figure 8. According to a study on the sugarcane bagasse fiber material as a sound absorber, Azma Putra et al.[13] found similar sound absorption coefficients to a commercial insulating fabric, above 0.5 for frequencies between 1,000 Hz and 3,000 Hz. In this study, the authors concluded that sugarcane bagasse fiber materials demonstrate good sound absorption properties for this frequency range.

The best levels of sound absorption were observed in the medium frequency range, occurring with a sharp increase in sound absorption by sugarcane bagasse panels at the frequency of 630 – 1,000 Hz, standing out especially from the others as shown in Figure 9.

Studies conducted by Yang et al.[2] with panels of rice husk particles with densities of 0.4 g/cm³ and 0.6 g/cm³, showed high sound absorption coefficients in the frequency range between 500 and 4,000 Hz, while panels with a density above 0.8 g/cm³ showed lower absorption coefficients in this range and higher absorbency in the range of 8,000 Hz. This corroborates that panels with lower densities have favorable performance as acoustic absorbers in the medium frequency bands. In addition to this, one of the most important properties that characterizes the sound-absorbing fibrous material is in specific flow resistance per unit thickness of the material. The fibers are intertwined frictional elements that provide resistance to movement of the sound wave. When the sound penetrates these materials, their amplitude is reduced by the friction of the fibers. Thus, the sound energy is reversed in heat[14].

3.2.3. Characteristics in high frequencies

For frequencies above 2,000 Hz, the three panels showed a decrease in the level of sound absorption, as shown in Figure 10.

This is due to the fact that there are limiting factors for a porous material which allow the passage of the wave with greater or lesser efficiency sound absorption. The sound absorption of porous materials depends on the anatomical features of its structure, the density of the material and the frequency of the incident sound wave[15]. The porosity of these panels is due to the fiber composition and the empty spaces between them, which offer resistance to air pressure caused by the sound wave. Being the source of noise directed to the element that captures this medium pressure change and knowing that the high frequency sound wave tends to become one-way, the air pressure exerted on the panel is reduced in area. As the intensity of a sound wave is defined as the ratio between the sound energy rate per unit area, the smaller the area hit by the wave, the greater the intensity or sound pressure level. Thus, the sound wave will pass through

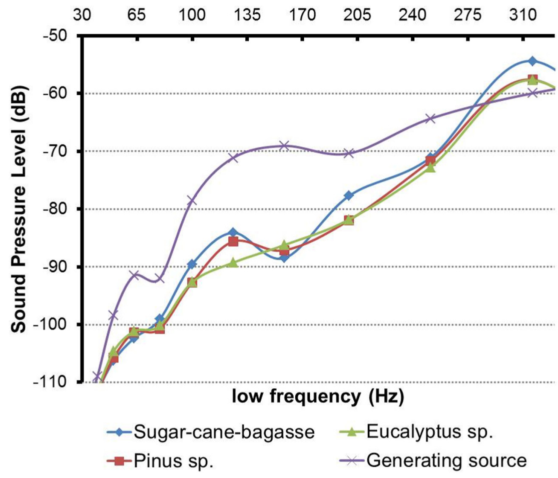

Figure 7. Sound pressure levels for low frequencies (0 - 500 Hz).

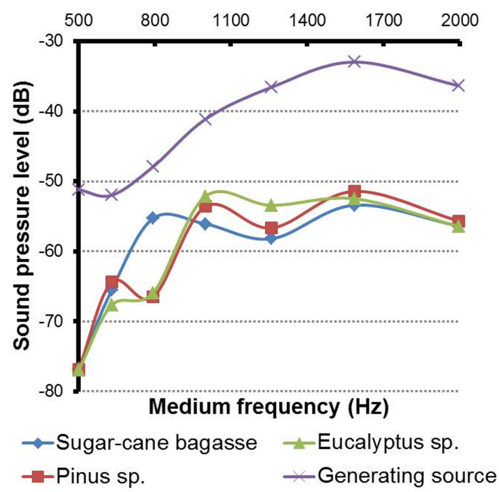

Figure 8. Sound pressure levels for medium frequencies (500 – 2,000 Hz).

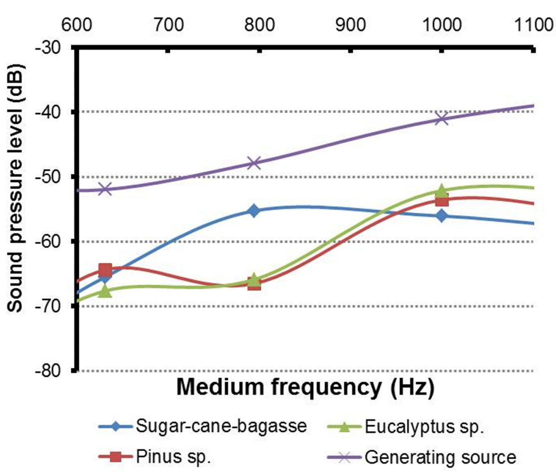

Figure 9. Levels of sound pressure for frequencies between 630 and 1,000 Hz.

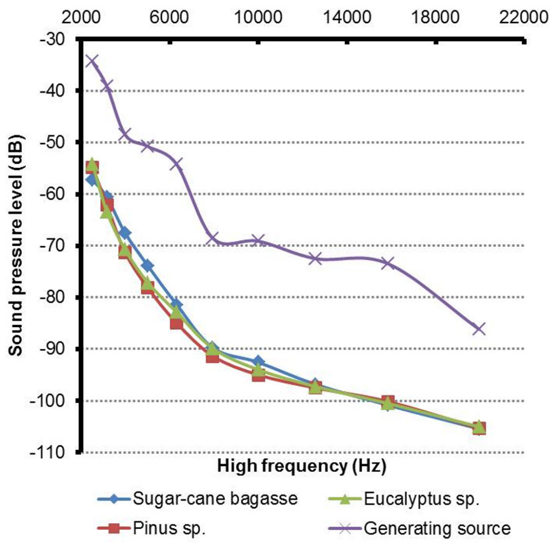

Figure 10. Sound pressure levels for high frequencies (2,000 – 20,000 Hz).

the panel with greater intensity than the resistive power of it. However, materials having microporous surfaces may have better responses to the high frequency absorption as the wavelength is small and the large pore surface area of the sound wave will penetrate and spread throughout the material being partially dissipated therein.

4. Conclusion

The panels showed a lower sound absorption in the frequency bands below 500 Hz and above 2,000 Hz. At 315 Hz, they showed resonance, i.e., a peak sound energy absorption frequency which is matched to the frequency of vibration of the material particles. Sugarcane bagasse panels showed the best performance in terms of sound energy absorbed in the frequency range of 630 Hz to 1,000 Hz. Above 1,000 Hz the other panels had higher sound absorption. The lowest values of density and moisture of the sugar cane bagasse panel directly influenced the sound absorption performance in specific frequency bands. At 2,000 Hz three panels showed a decrease in the levels of sound pressure. Sugarcane bagasse panels prove to be a material with potential for addressing sounds acoustics that range from 500 Hz to 2,000 Hz.

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Erratum

In the article "Acoustic Characterization of Sugarcane Bagasse Particleboard Panels *(Saccharum officinarum L)*", DOI number: http://dx.doi.org/10.1590/1516-1439.010515**,** published in Mat. Res., 18(4): 821-827, in the page 821 where it read:

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