Research Article

Wheat Straw Fibrous Material Reinforced Green Composite Materials Via Ficus vasta and Abyssinica Glue Bio-Resin for Acoustic Application

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KEYWORDS

Abyssinica glue
composite
acoustic material
sound absorption coefficient
noise control

ABSTRACT

Noise, defined as unwanted or disturbing sound that interferes with normal hearing or environmental comfort, is increasingly recognized as a critical environmental stressor in densely populated urban areas, highlighting the need for sustainable materials for acoustic attenuation. This study explores a green composite fabricated from agricultural waste wheat-straw fibers reinforced with a lab-synthesized Euphorbia abyssinica (Abyssinica) glue bio-resin, aiming to provide an eco-friendly alternative to conventional sound-absorbing materials. The sound absorption coefficient (α) of the composites was evaluated using a custom impedance tube across the frequency range of 0–6000 Hz. The natural-fiber composites exhibited low density, favorable mechanical strength, and reduced thermal-emission risk, while their porous microstructure promoted effective sound dissipation. Specimens with a thickness of 6 mm achieved an (A) of approximately 0.48 at 5500 Hz, whereas 8 mm specimens demonstrated superior acoustic performance, with (A) values ranging from 0.53 to 0.71 between 3800 and 5400 Hz. Further increases in thickness beyond 8 mm did not yield significant improvements at higher frequencies. These findings indicate that agro-waste-based composites can provide competitive acoustic performance in the 1–5.5 kHz range, underscoring their potential as sustainable structural acoustic materials for next-generation noise-control applications.

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1. Introduction

Sound is a form of mechanical energy produced by vibrating objects, propagating through a medium such as air, water, or solids as longitudinal waves. These waves cause particles in the medium to oscillate, and when they reach the human ear, they are converted into electrical signals by the auditory system, allowing the perception of pitch, volume, and timbre. While sound and noise are often used interchangeably in fields such as acoustics, physics, and electronics, they are distinguished by human perception. Sound refers to mechanical oscillations that can be interpreted by the auditory system, whereas noise denotes undesired or disturbing acoustic signals. In technical contexts, noise often represents random or meaningless variations in a signal, while sound typically carries informational or perceptible content [1,3].

The accelerated growth of industrialization has brought significant economic benefits and improved daily life convenience; however, it has also led to a marked increase in auditory disturbances and environmental noise. With the widespread adoption of modern technologies and the expansion of urban areas, environmental noise has become a growing public health concern. Noise disrupts the surrounding environment, affects human comfort, and can impair overall well-being, particularly in metropolitan regions, as illustrated in Table 1. Chronic exposure to excessive noise levels, commonly referred to as noise pollution, can have harmful effects on living organisms, impacting both physical and mental health [1,3]. Humans can generally perceive sound in the range of 20 Hz to 20,000 Hz, with peak auditory sensitivity occurring between 20 Hz and 12,000 Hz. Long-term exposure to elevated noise levels can interfere with verbal communication, reduce attention span, impair cognitive function, and degrade quality of life, posing serious health risks. The World Health Organization has recognized noise pollution as a global environmental hazard affecting millions of individuals, with associated health outcomes including headaches, fatigue, irritability, musculoskeletal tension, sleep disturbances, and stress-related complications [4-7]. Persistent exposure to loud noise may also cause permanent auditory damage and significant physiological and psychological stress [8].

Traditionally, sound-absorbing materials reinforced with synthetic fibers such as glass, aramid, and mineral wool have dominated the construction and transportation industries due to their durability, structural strength, and acoustic performance. However, these materials are associated with considerable disadvantages, including high manufacturing costs, substantial energy consumption, and limited recyclability, leading to environmental challenges [9-13]. This has driven the search for sustainable alternatives that are cost-effective, environmentally friendly, and capable of efficient sound absorption. Natural-fiber-based composites have emerged as promising candidates, offering renewable, biodegradable, and eco-friendly solutions that can achieve effective noise reduction while minimizing environmental impact [14-16].

In recent years, researchers have increasingly focused on using natural fibers as reinforcements in composite matrices to replace synthetic fibers. Natural-fiber-based composites can enhance mechanical properties without significantly increasing the cost of automotive components such as dashboards, roof panels, door handles, and interior door panels [17]. These fibers are gaining attention in acoustic applications due to their biodegradability, lightweight nature, low cost, non-toxicity, and nonabrasive characteristics. When combined with polymer matrices, natural fibers can produce high-performance composites that offer both environmental and economic benefits [18-21]. Despite these advantages, the use of natural fibers is limited by certain drawbacks, including lower impact strength and high moisture absorption. Natural fibers inherently contain hydroxyl and other polar groups, which result in weak interfacial bonding with the matrix phase, leading to dimensional instability and reduced mechanical performance. A summary of the general advantages and limitations of natural fibers is provided in Table 2.

Several studies have investigated the vibration and acoustic characteristics of fiber-reinforced composites. Examples include sisal and cotton–polyester composites [22][23], carbon and glass hybrid epoxy [24], hybrid banana–jute polyester [23, 25], flax and linen epoxy [26, 27], Sansevieria and coconut sheath polyester [28], jute fabric/polyester [29,30], glass/epoxy [31], short wheat-straw fibers and coconut sheath polyester [32], and woven glass/carbon epoxy [33,34]. Key parameters considered in these studies include fiber content, fiber

orientation, stacking sequence, secondary fillers such as nanoclay and red mud, weaving architecture, fiber surface treatments (untreated, alkaline, or silane), and beam support conditions such as cantilever, fixed–fixed, and simply supported configurations [35].

Table 1. Specific Noise Levels Affecting Human Health and Function (D. Fink, 2020, Temesgen et al.,2025)

Noise Level	Effect	Reference
30 dBA (LAeq(8))	Sleep disruption	WHO
45 dB (Ldn)	Disturbance of concentration and interference with learning	EPA
45 dB (LAmax)	Sleep disruption	WHO
55 dB average (Lden)	Non-auditory health effects	WHO
60 dBA (LAmax)	Interference with speech comprehension for hearing impaired	Moulder for U.S. Architectural and Transportation Barriers Compliance Board
70 dB daily average (LAeq(24))	Hearing loss	EPA
70 dBA (LAmax)	Interference with speech comprehension for those with normal hearing	EPA
85 dBA (LAeq(8))	Occupational noise exposure (recommended limit)	NIOSH
85 dBA (LAeq(1))	Recommended exposure limit to prevent hearing loss	WHO

Table 2. Advantages and drawbacks of natural fibers [24].

Advantages	Disadvantages
Are biodegradable, cheaper, and eco-friendly and have low specific weight	Have lower antifungus, durability, moisture, and fire resistant qualities.
Are abundantly available and high electrical resistant.	Have a negative impact on climate change (CO_2 absorption).
Have good thermal and acoustic insulating properties.	Exhibit lower acoustic absorption compared to synthetic fibers, due to a larger diameter.
Have low toxicity and less human health hazards during processing and handling.	Have poor fiber-matrix adhesion and moisture resistance which causes increase in volume for swelling of the fibers.

In this study, novel green bio-composite acoustic materials were developed using agricultural-waste wheat-straw fibers as reinforcement and a lab-synthesized *Euphorbia abyssinica* (Abyssinica) glue bio-resin as the matrix. The fabricated composites were evaluated for their sound absorption coefficient, as well as their mechanical and water absorption properties. The use of agricultural residues offers multiple advantages, including reduced raw material costs and the conversion of waste into value-added industrial products. These residues are renewable, biodegradable, and readily available, making them a sustainable alternative to conventional synthetic materials. Furthermore, the utilization of agricultural by-products helps mitigate environmental pollution and supports circular economy principles by promoting resource efficiency and sustainability.

2. Materials and Methods

2.1. Materials

Euphorbia abyssinica (Kulkual) and Ficus vasta (Warka) Bio-Resins:
Bio-resins are natural resins derived from biological sources such as plant gums, exudates, or vegetable oils, rather than petrochemical sources. In this study, bio-resins from Euphorbia abyssinica (Kulkual) and Ficus vasta (Warka) were used to prepare the resin matrix for fabricating green composite materials.

Euphorbia abyssinica (Euphorbiaceae) grows in dry, moist, and wet Weyna Dega agro-climatic zones across Tigray, Gonder, Gojam, Shoa, Harerge, and Sidamo, typically at elevations of 1,400–2,400 m, often

above 1,900 m [36,37]. The resin used in this study was collected from Kulkual trees in Wollo, Kombolcha, as shown in Figure 1a.

Ficus vasta (Warka) is a large tree characterized by a massive trunk and wide-spreading branches, forming a canopy up to 50 m in diameter and reaching heights of up to 25 m. Gum from Ficus vasta has been reported as a potential pharmaceutical excipient; however, its application as a binder in composite materials remains largely unexplored [38]. In this study, the gums from both plants were modified and blended to enhance their binding performance, enabling the fabrication of lightweight, fully biodegradable green composites.

Wheat Straw Fibrous Material:

Wheat straw was collected from the Southern region of Ethiopia, and fibers were extracted using mechanical decortication. The extracted fibers were thoroughly washed with water to remove impurities and residual bark. The general physical and mechanical properties of the wheat straw fibers are summarized in Table 3 and illustrated in Figure 1b. These fibers served as the reinforcing material in the fabrication of the green composites, providing structural strength and improving acoustic performance.

Table 3. Physical and mechanical properties of Wheat straw fibrous material [39].

Fiber	Width or diameter (km)	Density (kg/m^3)	Cell l/d ratio	Microfibrillar angle (degrees)	Initial modulus (GPa)	Ultimate tensile strength (MPa)	Elongation (%)
Wheat straw fibrous material	80-250	1350	150	10 ±1	7.7-20	54-754	10-13

(a) (b)

Figur 1. Raw material used for bio composite fabrications: (a) Euphorbia Abyssinia (Kulkual) and Ficus vasta (Warka) plants and their mixed resin, (b) Wheat straw fibrous material plan and fiber.

2.2 Methods

Preparation of Lab-Made Bio-Resin: White latex fluids from *Euphorbia abyssinica* (Euphorbiaceae) and *Ficus vasta* (Warka) were collected from trees in Kulkual and Wollo, Komolcha. The collected Kulkual and Warka latex fluids were mixed to prepare a lab-modified bio-resin. The mixture was boiled at 170 °C for 1 hour under continuous agitation until the desired viscosity was achieved. A material-to-liquid ratio of 1:20 was applied, and 1% w/v of a wetting agent was added to enhance the resin properties. After boiling, the bio-resin was allowed to cool for 24 hours to attain the final usable form, as illustrated in Figure 2a.

Fabrication of Green Composites: Green composite boards were fabricated entirely from natural, biodegradable materials with sample thicknesses of 6.0 mm and 8.0 mm. The composites were produced using a hand lay-up technique. Two layers of wheat straw fibrous material served as reinforcement, while the lab-modified bio-resin acted as the binder. The resin was incorporated into the fibers at three different weight percentages: 70%, 75%, and 80%. The fabricated composites were oven-dried at 115 °C for 20 minutes to

remove residual moisture and subsequently conditioned at room temperature for 24 hours prior to testing, as shown in Figure 2b.
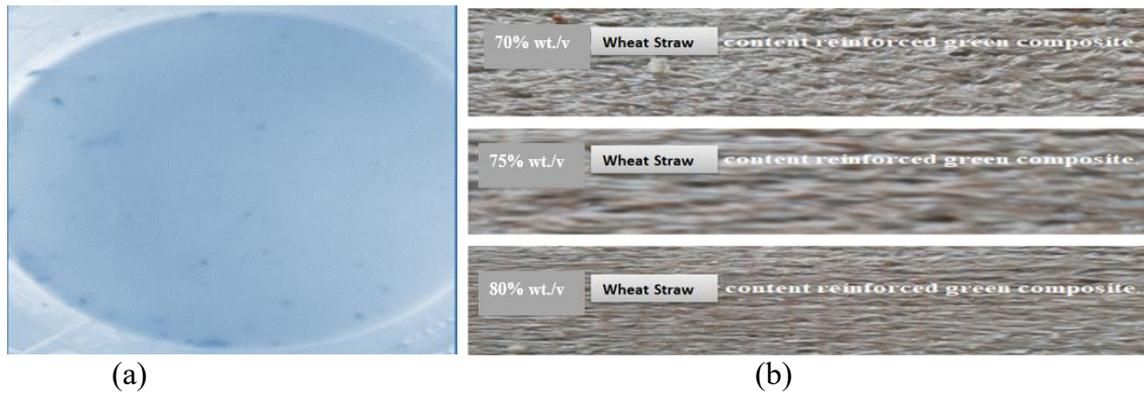

Figure 2. Lab made bio resin and green composite fabrication: (a) Lab made bio resin from mixed Abyssinica glue and Ficus vasta (Warka) gum (b) Biodegradable composite.

Measure the Sound absorption coefficient: - The sound absorption coefficient (α) of the fabricated green composites was evaluated using the Impedance Tube Method, following the ASTM E1050-98 standard. This method is widely used to determine the acoustic insulation performance of materials by measuring the amount of sound energy that is transmitted through a sample. The tests were conducted over a frequency range of 100 Hz to 5500 Hz to capture the material's performance across low, mid, and high frequencies. Recorded data were analyzed using REW (Room EQ Wizard) software to extract key acoustic parameters, including transmission loss. The experimental setup of the impedance tube apparatus used for this characterization is shown in Figure 3.
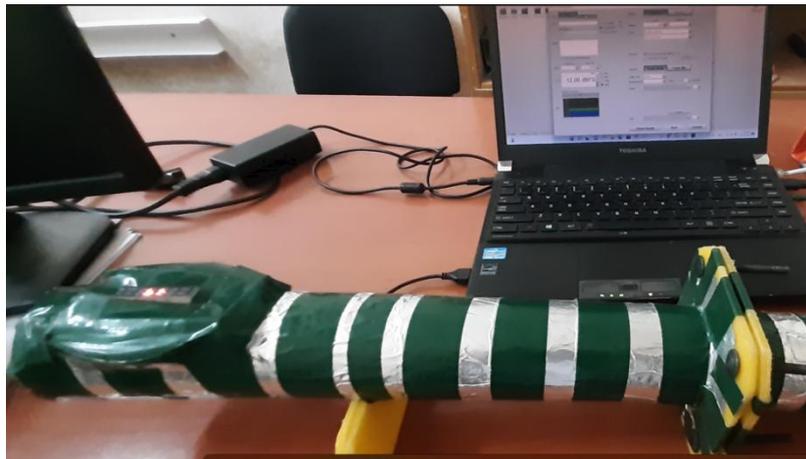

Figure 3. Impedance tube; Double-microphones standing wave tube.

Moisture Absorption Test: Water absorption testing was performed to evaluate the ability of the green composite materials to absorb moisture under controlled conditions. Test specimens were prepared according to ASTM D570 standards. Each composite sample was initially weighed to obtain the dry weight (W_1) and then fully submerged in a cylinder containing distilled water for 72 hours at room temperature. After immersion, the samples were removed, surface water was wiped off, and the specimens were reweighed. The percentage of water absorption, expressed as the weight gain relative to the initial weight, was calculated using the method described by Venkateshwaran et al. (2011) and Birniwa et al. (2019) (Equation 1). This test provides insight into the material's susceptibility to moisture uptake, which is critical for evaluating its dimensional stability and durability in humid environments [28,29].

$$\% \ weight = ((W2\text{-}W1)/W1) \ *100 \qquad (1)$$

Where W1 = initial weight, w2 = final weigh of the sample.

3. Results and Discussion

The Microscopic analysis confirmed that the multi-scale, porous, and hollow structure of wheat-straw fibers contributes to higher sound absorption performance compared to most other natural fibers. According to Yang W. D. et al. (2012), the theoretical prediction of the sound absorption properties of natural wheat-straw fibers, as proposed by the Delany-Bazley and Garai-Pompoli models, requires the determination of airflow resistivity values. These values can be calculated using the Mechel model, which is expressed by:

$$\sigma = (6.8\eta * (1-\varepsilon)^{1.296})/(\alpha^2\varepsilon^3) \tag{2}$$

Where η is the viscosity of air which is equal to $1.84\times10\text{-}5$ Pa s, α is the radius of the wheat straw fibrous material s and ε is the porosity which can be determined by wheat straw fibrous material to lab made bio matrix density and bulk density [40]. The sound absorption results of wheat-straw fibrous material measured using the impedance tube generally followed the trends predicted by the Delany-Bazley and Garai-Pompoli theoretical models. These experimental results were further compared with those of commonly used commercial natural fibers, as summarized in Table 4.

Table 4. Theoretical calculated parameters of Wheat straw fibrous compared with common Natural Fibers.

yNatural fibers	Fiber diameter (μm)	Fiber bulk density (g/cm3)	Calculated porosity (%)	Fiber matrix density (g/cm3)	Calculated flow resistivity (Pa s/m2)	Reference
Wheat straw fibrous material	11	0.338	78.37	1.31	85673	-
Flax	15	0.341	77.29	1.5	83421	
Jute	58	0.411	70.03	1.37	19790	[42]
Ramie	25	0.443	70.44	1.5	123782	

3.1. Acoustic Properties of Wheat Straw Fibrous Material Reinforced Green Composite

Figures 4 and 5 illustrate that, within specific low-frequency ranges, both sound absorption and sound absorption coefficient increased as the thickness of the green composite increased from 6.0 mm to 8.0 mm. This improvement is primarily attributed to the greater absorption of acoustic waves within the thicker composite boards at low frequencies [41]. Increasing the composite thickness allows the incident sound waves to travel a longer path through the material, resulting in higher energy dissipation and enhanced sound absorption. From Figure 4, the maximum sound absorption coefficient reached 0.68 in the higher frequency region, peaking at 5.5 kHz. Figure 5 shows that the maximum sound absorption coefficient of 0.72 occurred over a broader frequency range, from 4000 Hz to 5.5 kHz. Additionally, at 1000 Hz, the wheat-straw-fiber-reinforced green composite exhibited a sound absorption coefficient of 0.61, demonstrating effective sound absorption even at lower frequencies. These findings confirm that wheat-straw-fiber-reinforced green composites have strong potential for lightweight acoustic applications. Their enhanced noise reduction capability, particularly at higher frequencies, makes them especially suitable for aeronautical and other high-frequency noise environments.
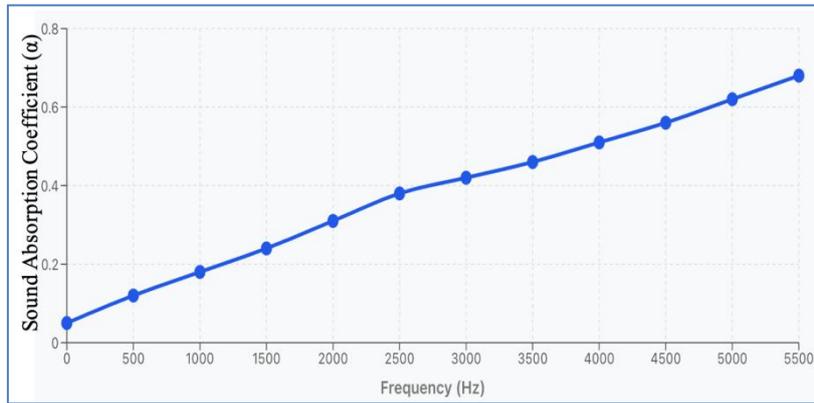
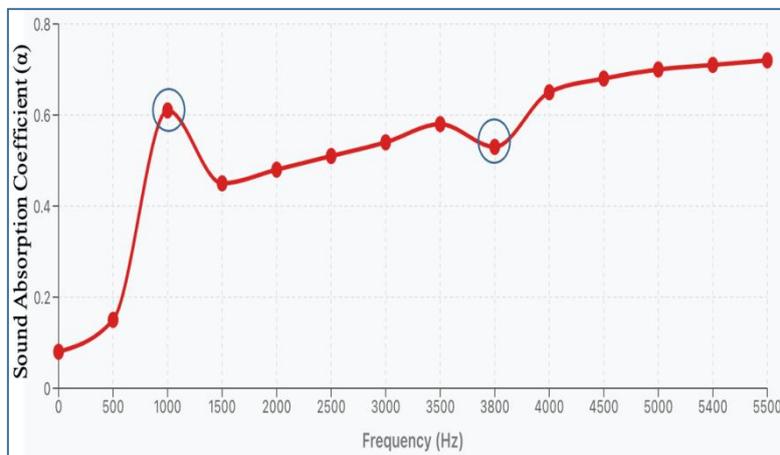**Figure.4.** Sound absorption coefficientes (6.0 mm thickness) wheat straw fibrous material reinforced green composite.
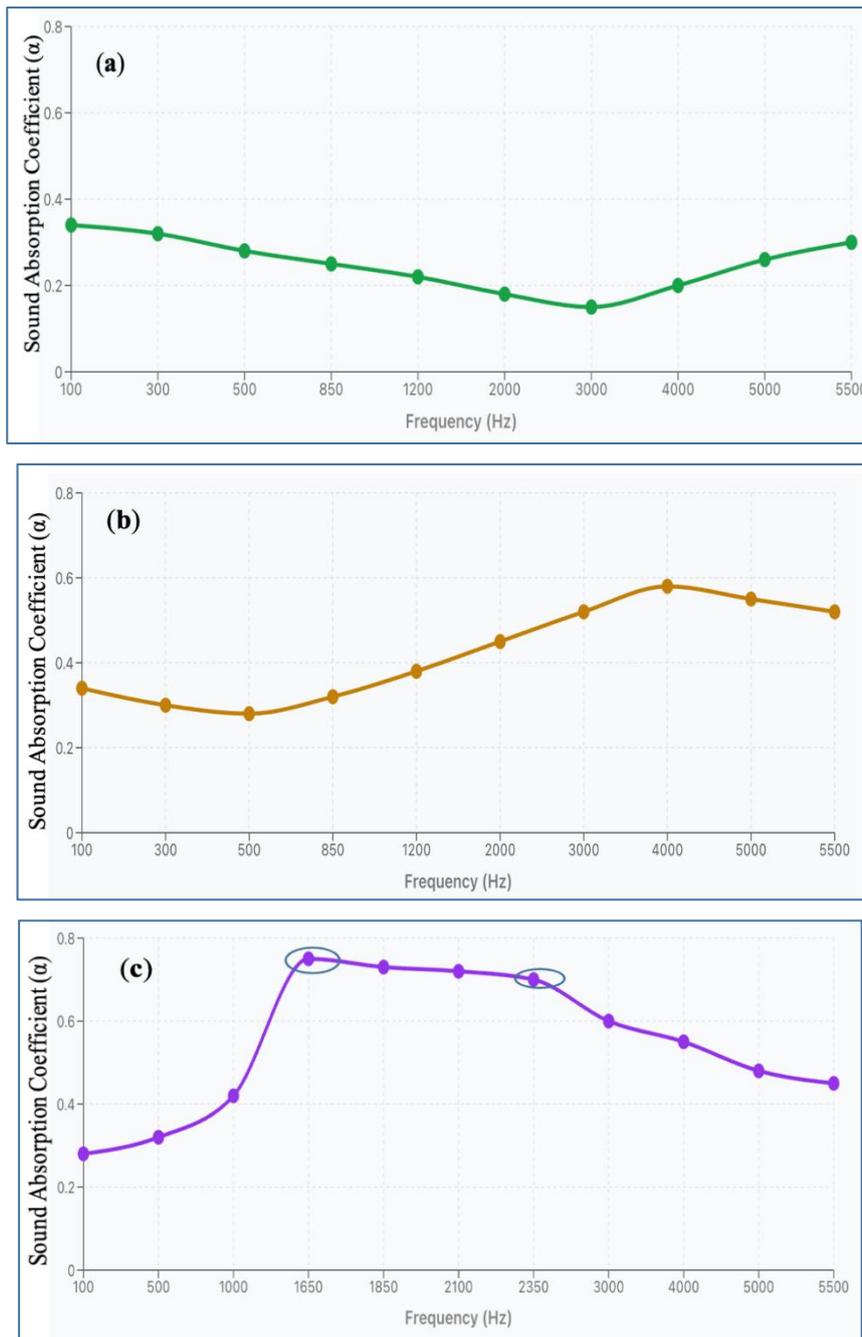

Figure. 5. Sound absorption coefficient (8.0 mm thickness) wheat straw fibrous material reinforced green composite

3.2. Influence of Fiber Loading on the Structural and Sound Absorption Performance of Wheat Straw-Based Composites

As shown in Figure 6, which depicts the variation of the acoustic absorption coefficient and sound absorption coefficient for green composites reinforced with lab-prepared mixed Euphorbia abyssinica (Kulkual) and Ficus vasta (Warka) bio-resin, the fiber content significantly influenced acoustic performance across the frequency range of 100 Hz–5500 Hz. Table 5 and Figures 6a–c show that, for composites containing 20–30 wt.% wheat-straw fibers, both sound absorption coefficient and acoustic absorption were notably enhanced in the low-frequency range of 100 Hz–850 Hz, reaching a value of 0.34 (Figures 6a and 6b). When the fiber content was increased to 20 wt.%, the sound absorption coefficient further improved, attaining a maximum of 0.75 in the frequency range of 1650 Hz–2350 Hz, as illustrated in Figure 6c. Table 5 also summarizes the mechanical properties of wheat-straw-fiber-reinforced green composites. Variation in fiber content in the lab-modified mixed Euphorbia abyssinica and Ficus vasta bio-resin had a significant effect on the modulus of elasticity [43-45]. Specifically, the modulus of elasticity of the composite with 20 wt.% wheat-straw fibers was approximately double that of the composite containing 30 wt.% fibers. Similar trends were observed in tensile properties: both tensile strength and elongation at break were higher for composites with 20 wt.% fiber content. In particular, the tensile strength of the 20 wt.% wheat-straw-fiber composites increased by 59% compared to that of the 30 wt.% fiber composites. These findings indicate that both acoustic and mechanical performance are strongly dependent on the fiber content of the green composite [41].

Table 5. Mechanical properties of green composite based on their % wt. Wheat straw fibrous material content.

% wt. Wheat straw fibrous material content	Modulus of Elasticity [N/mm²]	Tensile Strength [MPa]	Elongation at Break[%]	(α)
30 % wt. Wheat straw fibrous material	745 (±50)	15.20 (±0.8)	1.94 (±0.05)	0.34
25 % wt. Wheat straw fibrous material	1291 (±50)	20.42 (±0.8)	3.86 (±0.05)	0.58
20 % wt. Wheat straw fibrous material	1471(±50)	24.21 (±0.8)	2.93 (±0.05)	0.75

Figure 6. Sound absorption coefficient (α): (a) 30 % wt./v Wheat straw fibrous material content, (b) 25 % wt./v Wheat straw fibrous material content, (c) 20 % wt./v Wheat straw fibrous material content reinforced green composite.

3.3. Effect of Fiber Hygroscopicity on the Sound absorption coefficient Behavior of Wheat Straw Composites

The mechanical strength of wheat-straw-fiber-reinforced green composites was significantly affected by moisture absorption. Both the tensile strength and sound absorption coefficient of the bio-composites exhibited substantial differences between dry samples and those immersed in water [43-45]. Specifically, the tensile strength of the green composite decreased by approximately 48%, while the sound absorption coefficient was reduced by about 80%, as summarized in Table 6. This performance degradation is attributed to the weakening of the interfacial bonding between the wheat-straw fibers and the lab-made bio-resin upon exposure to moisture. The fibers, which act as reinforcement within the composite, became defibrillated when the composite structure absorbed water. To mitigate this issue, further alkalization treatment of the natural bio-based binder in the lab-made bio-resin matrix, along with surface coating of the green composite, is recommended to enhance moisture resistance and maintain both mechanical and acoustic performance.

Table 6. Sound absorption coefficientes Behavior of Wheat Straw Composites Before and After Water Absorption

Properties	% of Water Absorption ion	(α)
Before water absorption	-	0.63
After water absorption	0.11	0.35

4. Conclusions

Polymer composites reinforced with natural fibers have attracted significant attention as environmentally sustainable alternatives to synthetic materials, particularly in geotextile, automotive, and construction applications. Conventional synthetic sound-absorbing materials, such as foam, aramid, and glass fibers, dominate the commercial market due to their superior mechanical properties. However, these materials have notable drawbacks, including high production costs, substantial energy consumption, and limited biodegradability. In the present study, wheat-straw-fiber-reinforced green composites incorporating lab-made bio-resin were evaluated for their acoustic performance. The results indicated that increasing the composite thickness did not significantly enhance sound absorption at higher frequencies. The optimum sound absorption coefficient (α) of 0.75 was achieved at 4000 Hz for a composite with a 25 wt.% fiber content. Additionally, the maximum transmission loss of 13.3 dB was recorded for a 20 wt.% fiber-content composite board, while an average transmission loss of 10.21 dB was observed for a composite with 70 wt.% fiber content. Overall, these findings demonstrate that wheat-straw-fiber/lab-made bio-resin green composites exhibit strong potential as acoustic insulation materials for construction and lightweight industrial applications. Their combination of effective noise reduction and environmentally friendly composition positions them as a sustainable alternative to conventional synthetic composites.

Author's Contributions

Funding

Acknowledgments

Conflicts of Interest

The authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Reference

[1] Hariprasad K., Ravichandran K., Jayaseelan V., Muthuramalingam T. 2020Acoustic and mechanical characterisation of polypropylene composites reinforced by natural fibres for automotive applications. JMR&T., 9(6), pp.14029-14035. https://doi.org/10.1016/j.jmrt.2020.09.112

[2] Temesgen, A.G., Eren, R., Aykut, Y. and Süvari, F., 2021. Evaluation of enset fabric reinforced green composite as sound absorber structure. Textile and Apparel, 31(2), pp.73-81.

[3] Temesgen A.G. 2021. Research on the use of enset woven fabric structures for the applications of sound absorption and biodegradable composite material development (Doctoral dissertation, Bursa Uludag University (Turkey)).

[4] Nilgün Ö., Gonca Ö.K. and Gamze S.M. 2020. Investigation of Sound Absorption Characteristics of Textile Materials Produced from Recycled Fibers. Waste in Textile and Leather Sectors, 1-36. https://doi.org/10.5772/intechopen.92792

[5] Küçük M., Korkmaz Y. 2012. The enect of physical parameters on sound absorption properties of natural fiber mixed nonwoven composites. Text. Res. J., 82(20), 2043-2053. https://doi.org/10.1177/0040517512441987

[6] Padhye R., Nayak R. 2016. Acoustic textiles: An introduction. In: Padhe R, Nayak R, editors. Acoustic Textiles, Textile Science and Clothing Technology. Singapore: Springer; 2016.https://doi.org/10.1007/978-981-10-1476-5. ISBN: 978-981-10-1474-1

[7] Temesgen, A.G., Kaufmann, J. and Cebulla, H., 2025, December. Development and Characterization of Sustainable Bio-Resins from Agricultural Waste for Eco-Friendly Lightweight Industrial Applications. In Proceedings (Vol. 131, No. 1, p. 81).

[8] Zhao F., Ahmed F. & Faraz N. A. 2020. Caring for the caregiver during COVID-19 outbreak: Does inclusive leadership improve psychological safety and curb psychological distress? A cross-sectional study. Int. J. Nurs. Stud.,110, 103725. https://doi.org/10.1016/j.ijnurstu.2020.103725

[9] Temesgen, A.G. and Sahu, O., 2014. Process ability enhancement of false banana fibre for rural development. Cellulose, 67(67.89), pp.67-63.

[10] Jiahui S., Xiaocai L. and Xiong Y. 2021. Mechanical and Acoustic Properties of Jute Fiber-Reinforced Polypropylene Composites. ACS Omega., 6,v31154−31160.https://doi.org/10.1021/acsomega.1c04605

[11] Temesgen A.G., Turşucular Ö.F., Eren R. and Ulcay Y. 2018. Novel applications of nanotechnology in modification of textile fabrics properties and apparel. Int. J. Adv. Multidiscip. Res, 5(12), pp.49-58.

[12] Zhou W. 2019. The development of composites used in automobile. J. Mater. Eng. 1992.4, 47−50.

[13] Temesgen A.G., Eren R. and Aykut Y.2019. Investigation and characterization of fine fiber from enset plant for biodegradable composites. In 17th national 3rd international the recent progress symposium on textile technology and chemistry, Bursa, Turkey (pp. 356-361).

[14] Kumar R., Durgesh D., Pradeep L., Menezes E. 2019. A review. Fiber-reinforced polymer composites: manufacturing, properties, and applications J. Polym.,11 (1667), 1-37. https://doi.org/10.3390/polym11101667

[15] Getu A. and Sahu O. 2014. Green composite material from agricultural waste. International Journal of Agricultural Research and Reviews, 2(5), pp.56-62.

[16] Temesgen, A.G., Eren, R. and Aykut, Y., 2024. Investigation of mechanical properties of a novel green composite developed by using enset woven fabric and bioresin materials. Polymer Bulletin, 81(5), pp.4199-4219. https://doi.org/10.1007/s00289-023-04905-3

[17] Chandramohan D., Bharanichandar J. 2013. Natural Fiber reinforced polymer composites for automobile accessories Am J Environ Sci.,9 (6), 494-504.https://doi.org/10.3844/ajessp.2013.494.504

[18] Temesgen A.G. and Sahu O. 2022. Comparative study on the mechanical properties of weft knitted and warp fabric reinforced composites. Journal of Modern Materials, 9(1), pp.21-25.

[19] Hasina M., Mohammad H.F., Mushtak A., and Satesh N.N. 2016. Acoustic Absorption of Natural Fiber Composites. Journal of Engineering, pp.1-11.

[20] Temesgen A.G. and Sahu O. 2021. Effect of Weaving Structures on the Mechanical Properties of Woven Fabric Reinforced Composites. Indian J. Eng, 18, pp.102-108.

[21] Avella M., La G., Rota E. 2000. Poly(3- hydroxybutyrate-co-3-hydroxyvalerate) and wheat straw fibre composites: thermal, mechanical properties and biodegradation behavior. J. Mater. Sci., 35(4), 829–836. https://doi.org/10.1023/A:1004773603516

[22] Sathishkumar T.P, Naveen J., Navaneethakrishnan P. 2017. Characterization of sisal/cotton fibre woven mat reinforced polymer hybrid composites. J Ind Text., 47, 429–452 .https://doi.org/10.1177/15280837166487

[23] Kaufmann J., Temesgen A.G. and Cebulla H. 2025. A comprehensive review on natural fiber reinforced hybrid composites processing techniques, material properties and emerging applications. Discover Materials, 5(1), p.227.

[24] Temesgen A. G., & Workneh A. 2025. Extraction of Enset Pseudostem Fiber and Manufacturing of Erosion Control Mats. Climate-Adaptive Materials Engineering, 1(1), 46-61. https://doi.org/10.65773/came.1.1.54

[25] Rajesh M. and Pitchaimani J. 2018. Dynamic mechanical and free vibration behavior of natural fiber braided fabric composite: comparison with conventional and knitted fabric composites. Polym Compos., 39, 2479–2489. https://doi.org/10.1002/pc.24234

[26] Yan L. 2012. Effect of alkali treatment on vibration characteristics and mechanical properties of natural fabric reinforced composites. J Reinf Plast Compos.,31, 887–896. https://doi.org/10.1177/073168441244939

[27] Bennet C., Rajini N., Jappes J.W. 2015. Effect of the stacking sequence on vibrational behavior of Sansevieria cylindrica/ coconut sheath polyester hybrid composites. J Reinf Plast Compos., 34, 293–306. https://doi.org/10.1177/07316844155706

[28] Temesgen A.G. and Kemal S. 2025. Sustainable Recycled Cotton Fabric and Clay Powder Composites for Improved Thermal and Mechanical Performance in Home Furniture. Climate-Adaptive Materials Engineering, 1(1), pp.12-27.

[29] Rajesh M. and Pitchaimani J. 2017. Experimental investigation on buckling and free vibration behavior of woven natural fiber fabric composite under axial compression. Compos Struct., 163, 302–311. https://doi.org/10.1016/j.compstruct.2016.12.046

[30] Temesgen A.G., TURŞUCULAR Ö.F., EREN R. and AYKUT Y. 2020, January. Potential of Ethiopian Enset Fiber for Textile Application. In Conference: 6th International Fiber and Polyme r Research Symposium (6th IF&PRS), Bursa Uludag University, Bursa, Turkey.

[31] Alexander J. and Augustine B.M. 2015. Free vibration and damping characteristics of GFRP and BFRP laminated composites at various boundary conditions. Indian J Sci Technol., 8, 54208.https://doi.org/10.17485/ijst/2015/v8i12/54208

[32] Senthil K.K., Siva I., Rajini N. 2016. Layering pattern effects on vibrational behavior of coconut sheath/ false false ensetfiber hybrid composites. Mater Des., 90, 795–803. https://doi.org/10.1016/j.matdes.2015.11.051

[33] Temesgen A.G., Eren R. and Aykut Y. 2021. Green synthesis of cellulosic nanofiber in enset woven fabric structures via enzyme treatment and mechanical hammering. Textile and Apparel, 31(1), pp.63-72.

[34] Murugan R., Ramesh R. and Padmanabhan K. 2016. Investigation of the mechanical behavior and vibration characteristics of thin walled glass/carbon hybrid composite beams under a fixed-free boundary condition. Mech Adv Mater Struct.,23, 909–916. https://doi.org/10.1080/15376494.2015.1056394

[35] Yashwant S.M., Ravindra B. 2019. Vibration damping and acoustic characteristics of sisal fibre–reinforced polypropylene composite. Noise Vib. Worldw., 50(1) ,13–21. https://doi.org/10.1177/0957456518812784

[36] Alhayat G.T., Recep E., Yakup A. and Omprakash S. 2021. Effect of the Quantity of Bio Resins on the Tensile Strength of Agro Waste Enset Woven Fabric Reinforced Composite. Chemical Science and Engineering Research. Chemical Science and Engineering Research, 3(6), pp.8-13.

[37] Temesgen, A.G., Eren, R., Aykut, Y. and Süvari, F., 2021. Evaluation of enset fabric reinforced green composite as sound absorber structure. Textile and Apparel, 31(2), pp.73-81.

[38] Kalia S., Kaith B.S. and Kaur I. 2009. Pretreatments of natural fibers and their application as reinforcing material in polymer composites—a review. Polym. Sci. Eng.,49(7), 1253–1272. https://doi.org/10.1002/pen.21328

[39] Wellington E.O, Peters D. E, Onyeike E.N. 2019. Chemical Composition Of Phytochemicals And Essential Oil Of Euphorbia Heterophylla. Int J Adv Res, ,3(11), 78-85 ISSN: 2456-9992.

[40] Ashagrachew T. Y., Tesfa M., Motlalepula M., Gebremariam B. W. 2023. Physicochemical Characterization and Evaluation of Ficus vasta Gum as a Binder in Tablet Formulation. Biomed Res. Int., Article ID 8852784, 18. https://doi.org/10.1155/2023/8852784

[41] Temesgen A.G., Cebulla H. and Kaufmann J. 2025. Investigation of the sound absorption performance of cellulosic fine fibres fabricated from agricultural waste fibres. Agricultural Sciences: Techniques Innovations, 3, pp.13-33.

[42] Venkateshwaran N., Ayyasamy E.P., Aziz A. and Thiruchitrambalam M. 2011. Mechanical and water absorption behaviour of banana/sisal reinforced hybrid composites. Materials & Design,32(70), 4017-4021. https://doi.org/10.1016/j.matdes.2011.03.002

[43] Temesgen A.G. and Sahu O. 2022. Investigation of Warp and Weft Knitted Fabric Acoustic Structures Derived from Garment Waste. Journal of Textile Science and Technology, 8(1), pp.35-42.

[44] Yang W.D. and Yan L. 2012. Sound absorption performance of natural fibers and their composites. Sci. China Technol. Sci., 55, 2278-2283.https://doi.org/10.1007/s11431-012-4943-1

[45] Temesgen A.G, Eren R. 2024. A comparative study on the acoustic absorption properties of green synthesis cellulose nano enset fibers. Polym. Bull. 81, 7089–7104. https://doi.org/10.1007/s00289-023-05050-7