Materials Engineering and Technologies

https://met.cultechpub.com/met

Cultech Publishing

Article

Acoustic and Mechanical Characterization of Sawdust-Reinforced HDPE Composites

Fidjah Abdelkader[1,*], Kolli Khadidja[2], Souddi Abdelhak[3]

[1]Faculty of Mechanical Engineering, University of Djelfa, Algeria

[2]Faculty of Applied Chemistry, University of Tamanrasset, Algeria

[3]Faculty of Science and Technology, University of Adrar, Algeria

[*]Corresponding authors: Fidjah Abdelkader, fidjah.abdelkader@gmail.com

Abstract

To reduce plastic waste and integrate renewable sawdust into the circular economy, this research investigates the properties of sawdust-reinforced plastic (SRP), made from recycled high-density polyethylene (HDPE) and pine sawdust. The results show that adding sawdust to HDPE plastic reduces the density of the samples. A slight increase in compressive strength, up to 22.7 MPa, was also observed. Furthermore, the ultrasonic transmission speed decreased by 12.3%. This study suggests the potential for improving the processing of wafers and integrating them with nanomaterials to enhance their durability, as well as expanding the industrial applications of SRP. The results also provide a comprehensive experimental model that demonstrates the relationship between mixing ratios, structural composition, and function, thereby improving our understanding of the relationship between molecular structure and mechanical and acoustic properties.

Keywords

Wood shavings-reinforced plastic, Polyethylene recycling, Mechanical and acoustic properties, Circular economy

Article History

Received: 14 August 2025 **Revised:** 25 November 2025
Accepted: 04 December 2025 **Available Online:** 17 December 2025

1. Introduction

Global estimates suggest that plastic production is increasing by approximately 8% per year, increasing the volume of plastic waste and threatening to worsen environmental and health damage if sustainable solutions are not adopted [1,2]. Faced with this challenge, plastic-wood composite technology has emerged as a promising alternative that combines the lightness and formability of plastics with the hardness and thermal properties of wood [3]. Most recent studies have used high-density polyethylene (HDPE) and polypropylene (PP) with sawdust, as the mulch has been shown to reduce bulk density while improving thermal and sound insulation properties. Experiments by Najafi, et al. have shown that the increase in hardness is less than 30% in sawdust before mechanical properties decrease at higher ratios [4]. Dányádi et al. highlighted the importance of surface treatments for sawdust particles to improve compatibility with the polymer matrix [5]. In terms of density, research has estimated that overall density decreases by up to 25% when replacing 50% of the HDPE mass with pine sawdust, while maintaining acceptable compressive strength in lightweight applications. Studies have followed the application of ASTM D792 standards for bulk density measurement, indicating an accuracy of ±15 $kg.m^{-3}$ in results when using chips with a uniform particle size (0.5-1 mm) [6]. In the field of sound insulation, research by Hillig et al. showed a decrease in ultrasonic wave transmission velocity of approximately 10% with an increase in sawdust from 0% to 40%, reflecting the compound's ability to scatter waves and reduce internal reflections [7]. A study confirmed that compounds containing mulch ratios ranging from 20 to 30% provide the maximum sound absorption effect at frequencies from 500 to 2000 Hz, due to the microporosity resulting from the heterogeneous distribution of particles [8]. From a thermal perspective, researchers Zine et al. found that the decrease in thermal conductivity ranged from 15 to 30% when 40% sawdust was added, highlighting the importance of this technique in the thermal insulation of buildings, particularly in hot and dry climates such as those prevailing in southern Algeria [9]. Another study also examined the effect of sawdust moisture content on the stability of the compound's thermal properties at temperatures ranging from -10°C to +60°C [10]. Surface bonding agents play a key role in improving the cohesion between mulch and plastic. Research has shown the effectiveness of using maleic acid as a compatibilizer to improve polymer infiltration into the pores of sawdust, increasing tensile and compressive strength by up to 18%-25% [11,12]. Non-destructive ultrasonic evaluation tests are rare in WPC research, despite their importance in detecting interstitial defects and internal voids without damaging the sample. Askadskii et al. highlighted a knowledge barrier in the use of ultrasound and pressure tests according to ASTM D695 to provide a more complete picture of compound quality and mix homogeneity [13]. Based on this, this study aims to prepare sawdust-reinforced plastic composites using recycled pine sawdust with recycled HDPE polymers in ratios ranging from 0% to 90% and 3% maleic acid oil as a compatibility factor. Density is measured according to ASTM D792, and variations resulting from the sawdust percentage are analyzed using precision scales and an internal volume limiter. Non-destructive acoustic properties are assessed using an ultrasonic device according to ASTM E494 to analyze the velocity and propagation of impulses within the material. Compressive strength testing according to ASTM D695 is used to determine the mechanical performance of vehicles subjected to vertical loads.

This study is designed to integrate descriptive experimental approaches with statistical analysis of repetitive tests. The results should also fill the knowledge gap related to the intensive use of high sawdust proportions (up to 90%) and their impact on the functional properties of the compound. Prospects for the application of these materials in the construction, decoration, and lightweight construction sectors will be discussed, with an emphasis on sustainability and the circular economy of local resources.

The study of the effects of adding sawdust to plastics aims to achieve environmental, economic, and technological benefits. It contributes to reducing plastic waste and utilizing organic waste, thus supporting the circular economy. It also helps lower production costs and opens new industrial opportunities. Technically, it enhances acoustic properties and allows for adjustments to density and rigidity, with the potential for incorporating nanomaterials to improve performance. Scientifically, it contributes to understanding the relationship between structure and function, and to developing sustainable composite materials as alternatives to traditional plastics, thereby fostering innovation in the field of multifunctional environmental materials.

2. Materials and Methods

2.1 Materials

2.1.1 Plastic

These experiments used plastic vegetable boxes made of high-density polyethylene (HDPE).Recycled plastic, on the other hand, is an excellent environmental option, as it is used in the manufacture of environmentally friendly boxes within sustainable supply chains. Used in previous studies [14,15]. Figure 1 shows the plastic vegetable box.

Figure 1. Plastic vegetable box [16].

Chemical composition and crystal structure of high-density polyethylene (HDPE).

High-density polyethylene (HDPE) is a polymer consisting of long chains of linearly linked methylene units (CH_2), resulting from the polymerization of ethylene monomers after breaking the double bond within them. HDPE has a highly ordered crystalline structure, in which the molecular chains are tightly packed, giving it a density of 0.93 to 0.97 g/cm^3, as well as excellent tensile strength and durability, high chemical resistance, and low permeability to liquids and gases. Its structure consists of regular crystalline regions and less regular non-crystalline regions, which contributes to its unique physical properties [17]. Figure 2 represents the crystalline structure of polyethylene.

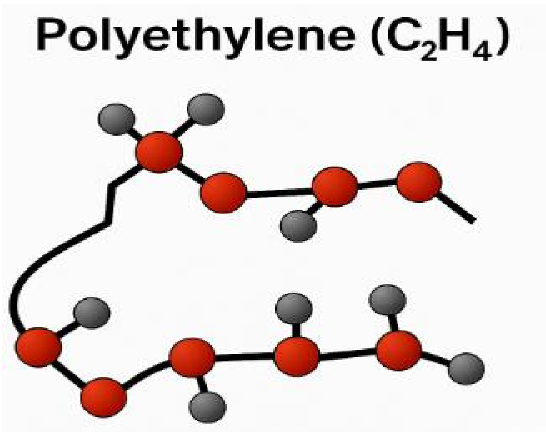

Figure 2. Crystalline structure of polyethylene [18].

2.1.2 Sawdust

This research used pine sawdust, which is characterized by its lightness, yellow to golden brown color, and aromatic aroma due to volatile oils. It has a pH between 4.5 - 6, and decomposes slowly, making it unsuitable as a quick fertilizer but good for long-term mulching. Ecologically, it has a high moisture absorption capacity, also helps improve soil aeration, and provides moderate thermal insulation. Table 1 shows the chemical composition of sawdust [19].

Dry sawdust, as shown in Table 1, is composed mainly of carbohydrates and lignin, which are the main structural components of wood. Carbohydrates account for approximately 62.45% of the dry weight and include glucose (40.30%), which forms cellulose; xylose, mannose, galactose, and arabinose, which are sugars involved in the synthesis of hemicellulose and contribute to the elasticity and strength of cell walls [20], Acid-insoluble lignin accounts for a significant percentage of 29.16%; it is a complex compound that gives wood its hardness and resistance to corrosion and decay. The total extract amounts to 2.27%, of which 1.54% is soluble in ethanol and contains organic compounds such as oils and resins, and 0.73% is soluble in water and includes simple sugars and salts [21]. Ashes, representing inorganic substances, are present in a very insignificant percentage (0.04%), indicating the purity of the wood from minerals. Sawdust also contains 1.22% acetyl groups, which affect the melting and biodegradation properties of the wood.

Table 1. Chemical composition of sawdust.

Composition	Percentage (% dry weight)
Extractives in Ethanol	1.54
Total Extractives	2.27
Ash	0.04
Extractives in Water	0.73
Acid-Insoluble Lignin	29.16
Total Carbohydrates	62.45
Glucans	40.30
Xylans	6.29
Galactans	2.18
Arabinans	0.77
Mannans	11.69
Acetyl Groups	1.22

2.2 Experimental Methods

2.2.1. Raw Material Preparation

Fusing sawdust with molten plastic produces sawdust-reinforced plastic (SRP), an engineered material that combines the properties of wood and plastic, used in architectural, industrial, and even packaging applications.

Plastic boxes, made from polyethylene, are washed. It has been cut into pieces 10mm. It is used with 3% maleic acid to improve adhesion between the shavings and the polyethylene [22].

2.2.2 Sawdust Preparation

Figure 3 shows the sample preparation steps.

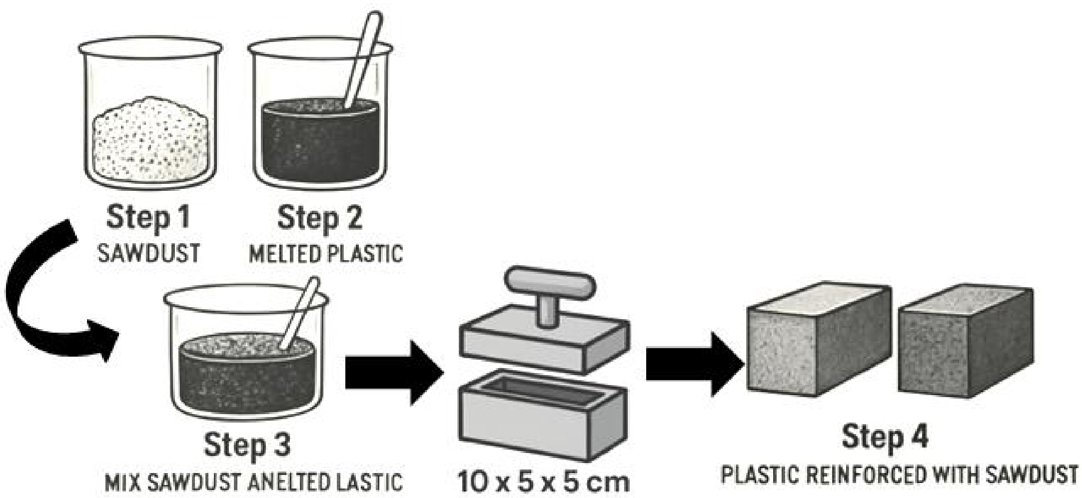

Figure 3. Sample preparation steps [16]

The process of preparing the wood shavings-reinforced plastic composite begins by drying the shavings in an oven at 80°C for 4 hours to ensure a moisture content of less than 1%. The shavings are then ground and sieved to obtain a particle size of 15 mm, and stored in airtight containers to prevent moisture absorption before processing. In the preparation stage, the plastic granules are cut into small pieces (5–10 mm) using a grinding machine and then heated in an oven at 120°C for one hour to become plastic without melting. The required quantity of plastic is weighed before heating and prepared in metal containers. After heating, the wood shavings are sprinkled onto the plastic and thoroughly mixed using an electric mixer to ensure homogeneous distribution. The mixture is placed in a metal mold measuring 10 × 5 × 5 cm and then compressed using a 2 MPa pressure ball to achieve the final shape of the composite.

Figure 4 represents the laboratory sample.

Figure 4. Laboratory sample.

After forming, the samples are left to dry and stored under controlled conditions (e.g., 23°C and 50% relative humidity).Pre-test time: 24 hours to ensure the stability of the physical properties.

Figure 4 illustrates the laboratory samples, where the amount of sawdust and wood is changed from 10% to 90%. Table 2 shows the percentage of plastic and sawdust in the total mass of the mixture.

Samples are prepared according to Table 2

Table 2. Sample preparation

Plastic (%)	Sawdust (%)	Plastic weight (g)	Sawdust weight(g)	Samples
100	0	240	0	P100S0
90	10	216	24	P90S10
80	20	192	48	P80S20
70	30	168	72	P70S30
60	40	144	96	P60S40
50	50	120	120	P50S50
40	60	96	144	P40S60
30	70	72	168	P30S70
20	80	48	192	P20S80
10	90	24	216	P10S90

The samples are left to cool for 60 minutes, then a series of experiments is performed on them.

2.2.3 Experiments

2.2.3.1 Density Change Measurement

Measuring the density of plastic samples after the addition of pine sawdust is a crucial step in assessing the quality of sawdust-reinforced plastic (SRP) compounds, as it provides accurate indicators of the homogeneity of the mixture between the components and the success of the manufacturing process. Density reflects the distribution of sawdust within the polymer matrix, as any decrease or fluctuation in values may indicate the presence of voids or heterogeneous wood agglomerates, which negatively affect the properties of the resulting material.

Density is also linked to the mechanical properties of the compound, as a high density is an indicator of increased stiffness and durability, making it a predictive tool for sample performance in tensile and flexural tests. Densitometry is also used to analyze the effect of sawdust ratios, as increasing them often results in a decrease in density due to the lower density of wood compared to plastic. This requires determining the optimal ratio to achieve a balance between weight and mechanical properties. Density is measured using an accurate balance according to ASTM D792 and using the relationship 1:

$$\rho = \frac{m}{v} \tag{1}$$

Where **m** is the mass of the samples and v represents the volume. The densitometry results are shown in Figure 5.

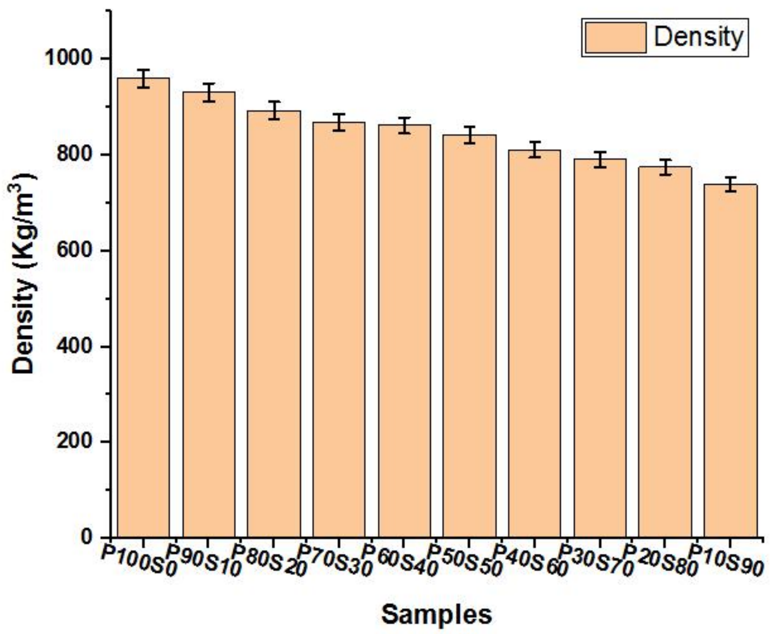

Figure 5. Density change in sawdust-reinforced plastic.

2.2.3.2 Non-destructive Testing

Non-destructive testing (NDT) is an essential tool for evaluating the performance of sawdust-reinforced plastics (SRP) without affecting the integrity of the samples or altering their structure, allowing their reuse in subsequent tests or practical applications. These tests aim to analyze the internal structure of the sample and detect hidden defects such as voids, microcracks, or heterogeneous distribution of sawdust within the polymer matrix, factors that directly affect the quality of the final product. An ultrasonic tester is a non-destructive instrument used to analyze solids such as plastics. It works by sending high-frequency sound waves through the material to detect internal defects, measure thickness, and sound transmission velocity. It is used in assessing weld quality, monitoring corrosion, and analyzing structural changes without damaging the sample. It features high accuracy and ease of use in the field, and relies on a transducer and coupling material to ensure wave transmission. This device is essential in engineering and industrial inspection to ensure the safety of facilities and materials. It is widely used in non-destructive testing technologies to save time and costs. Use Ultrasonic Pulse Velocity Tester.According to ASTM E494 The results of the sound wave transmission measurement are shown in Figure 6.

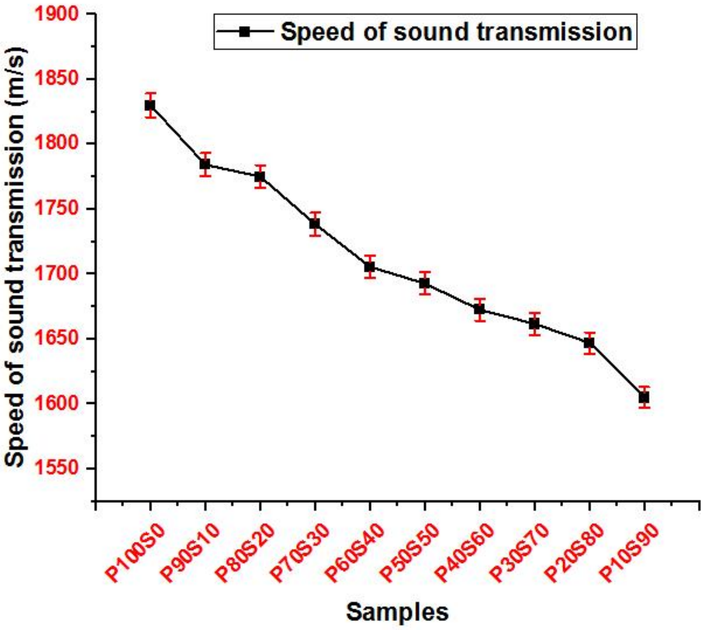

Figure 6. Change in the speed of sound transmission in sawdust-reinforced plastic.

2.2.3.3 Compressive Strength Test

Measuring the compressive strength of sawdust-reinforced plastics (SRP) is an essential step in evaluating the mechanical performance of these composite materials, particularly in applications subject to vertical loads such as floors, slabs, and supports. This test aims to determine a material's ability to withstand compression without permanent deformation or fracture, providing a clear indication of its durability and toughness. Measuring compressive strength also allows for analysis of the effect of adding chips to the polymer, as the chip ratio and internal distribution affect the material's behavior under pressure. This data can support the engineering design of SRP components and determine the appropriate thickness and safety parameters required. Furthermore, any unexpected decrease in compressive strength can reveal internal manufacturing defects, such as poor cohesion or the presence of voids, making this test an effective tool for ensuring the quality of the finished product and its durability in practice. The headlock crimping press is used according to ASTM D695. Pressure is applied to an area of 10 x 5 cm at a speed of 0.8 MPa/s. Relationship 2 is used to relate the applied force F to the area A.

$$\sigma = \frac{F}{A} \tag{2}$$

The measurement results are shown in Figure 7.

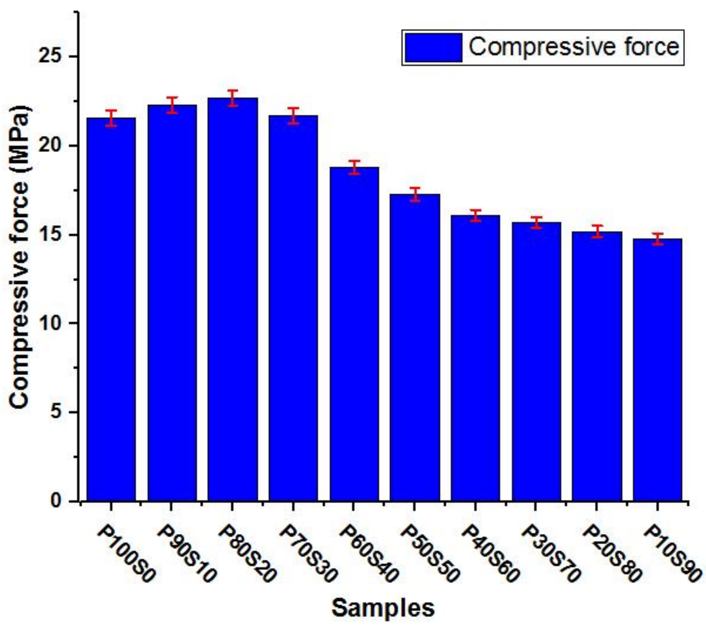

Figure 7. Compressive strength change in sawdust reinforced plastic.

Table 3 represents a summary of all research results.

Table 3. Experimental experiment for variables

samples	Density ($kg.m^{-3}$) ± 17	speed of sound transmission (m/s) ±9	compressive force (MPa) ±0.4
P100S0	960	1830	21,6
P90S10	931	1784	22,3
P80S20	893	1775	22,7
P70S30	869	1739	21,7
P60S40	862	1706	18,8
P50S50	842	1693	17,3
P40S60	811	1673	16,1
P30S70	791	1662	15,7
P20S80	775	1647	15,2
P10S90	739	1605	14,8

3. Results and Discussion

3.1 Density Change

Figure 5 shows the change in density value when shavings were added to the molten plastic. A decrease in bulk density is observed between 3% and 20% compared to the sample without signal. The diagram shows the change in density of plastic samples (mostly HDPE) with increasing proportions of mulch. It is noted that the density decreases progressively with increasing mulch content. The decrease in density can be explained by several factors related to the physical and morphological properties of the plastic and mulch, including the fact that HDPE has a density of approximately 930 to 970 $kg.m^{-3}$. Furthermore, sawdust has a much lower density, often between 200 and 600 $kg.m^{-3}$, depending on the type and humidity. When replacing part of the HDPE with mulch, a less dense material is introduced, resulting in a decrease in the overall density of the composite. Furthermore, the chips do not fuse perfectly with the polymer, creating internal voids or pores. Such voids reduce the bulk density of the composite material. In previous research, I discussed the production of wood-plastic composites from cedar sawdust waste and a mixture of plastics. Increasing the proportion of sawdust reduced the density of the composite, as the density decreased by 29% when the wood content increased from 40% to 70%. This is consistent with the research results [23].

When mixing sawdust with plastic, several physical and structural effects occur that result in a decrease in the overall density of the composite. According to equation 3, the effect of the sawdust ratio on the composite material is represented:

$$\frac{1}{\rho_{comp}} = \frac{w_{\rho}}{\rho_p} + \frac{w_s}{\rho_s} \tag{3}$$

Where (w_p), ratio of the mass of plastic to the total mass. (w_s), ratio of the mass of sawdust to the total mass. (ρ_p), density of plastic 0.95 g/cm3 (HDPE). (ρ_s), density of sawdust is 0.60 $g.cm^{-3}$. Sawdust particles have micropores (open or closed wood cells) that increase the volume of the composite without adding corresponding mass. The lack of fusion of the mulch with the plastic leaves a void homogeneously between the particles, increasing the apparent size. The higher the percentage of mulch, the larger the relative size of the voids and, consequently, the lower the overall density [24].

3.2 Sound Pulse Velocity

When analyzing Figure 6, which shows a decrease in sound transmission velocity in the samples as the sawdust content increases, The sound transmission velocity decreases from 1830 m/s to 1605 m/s, with a decrease of 2.5% to 12.3%. This is explained by the low uniform density of the material. This increases internal wave dispersion due to the contrast between the polymer and the sawdust. These factors cause poor bonding between the components, creating areas that absorb or reflect waves [25]. In a study consistent with the research findings, Shaharudin investigated the development of sustainable, low-cost acoustic panels using kapok fibers and sawdust as organic components as alternatives to commercial panels. Since the increased sawdust content is observed, it reduces the sound absorption efficiency at high frequencies due to reduced porosity [26].

The material's properties change due to the difference in density and elasticity between the polymer and the chips, leading to the appearance of heterogeneous interstitial boundaries within the composition. These boundaries cause reflections and scattering of ultrasonic waves, reducing their transmission efficiency through the material. Furthermore, the poor bonding of the chips with the plastic contributes to the formation of fine voids or low-density areas, which slow down the sound wave [27]. In research on the use of wood-plastic composites for noise containment, the researchers concluded that larger sawdust particles (1 to 2 mm) created more air voids, which improved sound dissipation. This is consistent with the results of this research [28]. From a physical perspective, the speed of sound in a material is related by the coefficient of elasticity and density according to the relationship 4:

$$v = \sqrt{\frac{E}{\rho}} \tag{4}$$

E: Modulus of elasticity, ρ: Density, When mulch is introduced, the modulus of elasticity often decreases due to poor cohesion, while the density changes depending on the type of mulch and its ratio, resulting in a decrease in the speed of sound. This decrease is used as a non-destructive tool to assess material quality, as it indicates poor internal homogeneity or the presence of microdefects. Thus, measuring the speed of sound is an effective way to analyze the internal structure of sawdust-reinforced plastics, determining how well the component combination will work, particularly in industrial and research applications requiring precise mechanical properties [29].

3.2.3 Compressive Strength Measurement

Figure 7 shows the change in the compressive strength of sawdust-reinforced plastic. A slight increase is observed from 21.6 MPa to 22.7 MPa, between 0.42% and 4.8%, then decreases after 30% of the sawdust, from 21.7 MPa to 14.8 MPa, with a decrease of 45.9%. This figure shows the effect of adding wood shavings to the plastic on the compressive strength of the composite samples. The results show that the compressive strength decreases as the mulch percentage increases, with the highest value recorded at P80S20 (22.7 MPa), then begins to decrease to 14.8 MPa at P10S90. This decrease is due to several factors. Sawdust is a mechanically weak material compared to plastic, which reduces the sample's ability to withstand pressure. Furthermore, an increase in mulch leads to heterogeneous distribution within the matrix, creating internal weaknesses.

Samples with a low percentage of sawdust (such as P90S10 and P80S20) showed a slight improvement in compressive strength, suggesting that a small amount can help improve distribution or temporarily strengthen the structure before adverse effects begin to appear with increasing the ratio. In a study by Saljoughian & Mostofinejad on the effect of mechanical properties on wood-plastic compounds, it was noted that compressive strength decreased by 35% when the sawdust content increased from 20% to 60%. This is consistent with the results of research [30].

Moreover, in another study on the compressive behavior of recycled polypropylene composites reinforced with sawdust, the authors concluded that an increase in sawdust content from 10% to 50% resulted in a decrease in compressive strength [31]. Previous research results show that chemical treatment of sawdust significantly reduces their mechanical properties and moisture resistance, making them less suitable for construction applications. This is directly related to a decrease in the compressive strength of sawdust-reinforced plastic (SRP), as the use of untreated sawdust results in poor fiber-matrix bonding, increased porosity, and, consequently, decreased performance under pressure [32]. In a study investigating the potential of sawdust ash in improving the compressive strength of construction materials, particularly when used as a partial substitute for cement or sand, a structural performance exceeding 20 MPa was achieved. However, sawdust-reinforced plastic has a decreasing compressive strength due to poor fiber-matrix bonding, which compares to the properties of untreated sawdust [33]. In this study, the sawdust was not treated and was mixed directly with the plastic in the presence of a malic acid solution. In this context, research by Vengadesan and others has confirmed that sawdust treatment helps reduce moisture absorption and improve cohesion between the polymer and the filler, thereby improving mechanical strength and thermal stability [34].

4. Significance of the Research Results

In terms of sound insulation, measurements showed a significant decrease in the transmission speed of ultrasonic waves with an increase in the percentage of chips. This decrease reflects wave dispersion within the compound due to the difference in mechanical properties between the polymer and sawdust and the presence of micropores. The importance of this phenomenon extends to its ability to absorb acoustic energy and reduce reflections, making SRP a practical choice for interior surfaces or insulation panels in theaters, offices, and sound rooms.

A reduction in the compound's bulk density by up to 29% (at 70% mulch) contributes to better thermal insulation. Low density is generally associated with increased porosity and low thermal conductivity, as the air spaces within the material act as a natural insulator, preventing heat transfer. This is important in the design of summer- and winter-resistant walls and floors in buildings without the need for additional insulation materials.

In studying the mechanical properties, it was found that a sawdust ratio of up to 20%-30% increases the relative hardness, which promotes even distribution of the components and temporarily improves durability. This strikes a balance between mechanical performance and insulation effectiveness, allowing the engineer to select the optimal thickness and ratio based on application requirements, while maintaining sufficient durability to support vertical loads in load-bearing floors or walls.

From an environmental and economic perspective, SRP provides a sustainable solution by combining sawdust waste—a renewable and inexpensive material—with recycled polymers such as HDPE. This reduces carbon emissions and limits the depletion of fossil resources, while also lowering manufacturing costs through a reduced need for expensive raw materials. Furthermore, the use of mulch maintains the ecological balance by reducing discarded wood waste.

Sawdust-reinforced plastic technology is characterized by its ease of manufacture and control over mixing and compression rates, enabling the production of panels of various sizes and flexible geometric shapes suitable for interiors and lightweight construction applications. It is also less dense than concrete and many conventional plastics, facilitating transportation, installation, and labor-saving facilities.

This research opens new avenues for the use of sawdust in the manufacture of insulating, quiet, and environmentally friendly building materials. SRP offers a balanced combination of sound insulation, thermal insulation, and mechanical durability, with tangible economic and environmental benefits. The adoption of this technology contributes to the realization of sustainable building principles and fosters innovation in the building materials sector.

5. Conclusion

The results of this research show that incorporating sawdust into a recycled HDPE polymer improves certain physical and functional properties of the composite, with effects varying according to the mixing proportions. A progressive decrease in density, reaching up to 29%, was observed for the highest sawdust content, reflecting the introduction of a less dense material and the formation of internal voids. Samples containing between 20% and 30% sawdust showed a slight improvement in compressive strength, reaching a peak of 22.7 MPa, before gradually decreasing with increasing sawdust content. Regarding acoustic properties, the ultrasonic transmission velocity decreased by 12.3%, indicating increased internal dispersion and improved sound absorption. Despite these positive results, the research has several limitations, notably the use of untreated sawdust, which could affect fiber cohesion within the polymer matrix. Furthermore, the study was limited to pressure, density, and acoustic velocity tests, without addressing other properties such as tensile and flexural strength or long-term thermal behavior. The impact of humidity or other environmental factors on the composite's stability was also not analyzed. Therefore, the following research is recommended for future studies:

Investigate the effect of chemical or surface treatment of the sawdust on improving mechanical cohesion. Expand the scope of testing to include tensile and flexural strength as well as thermal elasticity. Analyze the composite's performance under different environmental conditions (humidity, temperature, UV radiation).

This study represents a first step towards the development of sustainable composite materials that combine functional performance with environmental responsibility, thus opening up promising prospects for innovation in the circular economy.

Acknowledgments

We are grateful to the Public Works Laboratory of the South for the facilities provided to conduct the experiments and for the continuous support of their staff throughout this research.

Funding

Open access funding provided by the Algerian Ministry of Higher Education.

Data Availability Statement

All data are available in the research.

Author Contributions

All authors approved the final version of the manuscript.

Conflict of Interest

The researchers declare no conflict of interest.

Generative AI Statement

The authors declare that artificial intelligence was used to support the article by generating references and checking errors, in addition to academic translation to facilitate access to global sources. It was also used in statistical data analysis.

References

[1] Gündoğdu S, Bour A, Köşker AR, Walther BA, Napierska D, Mihai FC, et al. Review of microplastics and chemical risk posed by plastic packaging on the marine environment to inform the Global Plastics Treaty. Science of the Total Environment, 2024, 946, 174000. DOI: 10.1016/j.scitotenv.2024.174000

[2] Donuma KU, Ma L, Bu C, George LY, Gashau M, Suleiman AO. Environmental and human health risks of indiscriminate disposal of plastic waste and sachet water bags in Maiduguri, Borno State Nigeria. Waste Management Bulletin,2024, 2(2), 130-139. DOI: 10.1016/j.wmb.2024.04.002

[3] Mitaľová Z, Mitaľ D, Berladir K. A concise review of the components and properties of wood–plastic composites. Polymers, 2024, 16(11), 1556. DOI: 10.3390/polym16111556

[4] Najafi SK, Hamidinia E, Tajvidi M. Mechanical properties of composites from sawdust and recycled plastics. Journal of Applied Polymer Science, 2006, 100(5), 3641-3645. DOI: 10.1002/app.23159

[5] Dányádi L, Móczó J, Pukánszky B. Effect of various surface modifications of wood flour on the properties of PP/wood composites. Composites Part A: Applied Science and Manufacturing, 2010, 41(2), 199-206. DOI: 10.1016/j.compositesa.2009.10.008

[6] Ferreira RS, Jesus GA, Monteiro JP, Martins AF, Tessari RK, Bonafé EG. Eco-friendly and cost-effective high-density polyethylene-based composites: Optimizing wood–plastic composites for enhanced performance. ACS omega, 2025, 10(7), 6437-6445. DOI: 10.1021/acsomega.4c06422

[7] Hillig É, Bobadilla I, Arriaga F, Íñiguez-González G. Using acoustic testing to estimate strength and stiffness of wood-polymer composites. Maderas. Ciencia y tecnología, 2024, 26. DOI: 10.22320/s0718221x/2024.04

[8] Charai M, Sghiouri H, Mezrhab A, Karkri M, Elhammouti K, Nasri H. Thermal performance and characterization of a sawdust-clay composite material. Procedia Manufacturing, 2020, 40, 690-697. DOI: 10.1016/j.promfg.2020.03.098

[9] Zine O, Taoukil D, El Abbassi I, Laaroussi N, Kadri EH, lhassane Lahlaouti M. Experimental and theoretical thermal investigation of bio-composite panels based on sawdust particles. Journal of Building Engineering, 2023, 76, 1072541. DOI: 10.1016/j.jobe.2023.107251

[10] Perišić S, Kalevski K, Grujić A, Nedeljković D, Stajić-Trošić J, Radojević V. Effect of moisture on the mechanical properties of wood–plastic composites hybridized with metal grid layers. Polymers, 2023, 15(24), 4705. DOI: 10.3390/polym15244705

[11] Thomas A, Dabai FN, Aderemi BO, Sani YM. Extraction of lignin from sawdust (Chlorophora excelsa). Chemistry Proceedings, 2025, 17(1), 2. DOI: 10.3390/chemproc2025017002

[12] Goda I, Padayodi E, Raoelison RN. Enhancing fiber/matrix interface adhesion in polymer composites: Mechanical characterization methods and progress in interface modification. Journal of Composite Materials, 2024, 58(29), 3077-3110. DOI: 10.1177/00219983241283958

[13] Askadskii A, Askadskii A, Matseevich T. Structure and properties of Wood-Polymer Composites (WPC). Cambridge Scholars Publishing, 2019

[14] Duruaku JI, Okoye PA, Onuegbu TU, Onwukeme VI, Okoye NH, Nwadiogbu JO. Physicomechanical properties of sustainable wood plastic composites of tropical sawdust and thermoplastic waste for possible utilization in the wood industry. Journal of Sustainable Bioenergy Systems, 2023, 13(4), 149-71.

[15] Oliveros-Gaviria C, Cumbalaza E, Mina-Hernandez JH, Valencia-Zapata ME, Suarez-Bonilla JN, Martinez-Mera N. Wood plastic composite based on recycled high-density polyethylene and wood waste (sawdust). Polymers, 2024, 16(22), 3136. DOI: 10.3390/polym16223136

[16] Albrecht S, Bertling J, Fischer M, Gehring F, Kabasci S, Prescher T, Schulte A, Oldenburg J, Prescher T, Schulte A. Reusable plastic crates vs. single-use cardboard boxes. Fraunhofer Institute for Environmental, Safety and Energy Technology, 2022. DOI: 10.24406/publica-456

[17] Ferede E, Muhammed A, Kassa A, Kedir S, Tesfaye T, Zerefa W. Fabrication and characterization of recycled polyethylene terephthalate composites reinforced with sisal fibre and wood sawdust. Textile & Leather Review, 2024, 7, 493-516. DOI: 10.31881/TLR.2023.221

[18] Chen L, Huan TD, Ramprasad R. Electronic structure of polyethylene: Role of chemical, morphological and interfacial complexity. Scientific Reports, 2017, 7(1), 6128. DOI: 10.1038/s41598-017-06357-y

[19] Kangas H, Felissia FE, Filgueira D. 3D printing high-consistency enzymatic nanocellulose obtained from a soda-ethanol-O2 pine sawdust pulp. Bioengineering, 2019, 6(3), 60. DOI: 10.3390/bioengineering6030060

[20] Murugapoopathi S, Ashwin Prabhu G, Chandrasekar G, Selvam R, Gavaskar T, Sudhagar S. Fabrication and characterisation of saw dust polymer composite. Journal of The Institution of Engineers (India): Series D, 2025, 106(1), 139-44. DOI: 10.1007/s40033-023-00596-2

[21] Thomas A, Dabai FN, Aderemi BO, Sani YM. Extraction of Lignin from Sawdust (Chlorophora excelsa). Chemistry Proceedings, 2025, 17(1), 2. DOI: 10.3390/chemproc2025017002

[22] Cui Y, Lee S, Noruziaan B, Cheung M, Tao J. Fabrication and interfacial modification of wood/recycled plastic composite materials. Composites Part A: applied science and manufacturing, 2008, 39(4), 655-661. DOI: 10.1016/j.compositesa.2007.10.017

[23] Lopez YM, Paes JB, Gustave D, Gonçalves FG, Méndez FC, Nantet AC. Production of wood-plastic composites using cedrela odorata sawdust waste and recycled thermoplastics mixture from post-consumer products-A sustainable approach for cleaner production in Cuba. Journal of Cleaner Production, 2020, 244, 118723. DOI: 10.1016/j.jclepro.2019.118723

[24] Kuforiji C, Durowaye S, Kassim K, Lawal G. Influence of sawdust particles reinforcement on physical and mechanical characteristics of high-density polyethylene (HDPE) matrix composites. Kathmandu University Journal of Science, Engineering and Technology, 2023, 17(1), 1-7. DOI: 10.3126/kuset.v17i1.62382
[25] Železnik A, Čurović L, Prezelj J. Sustainable sound absorption using shredded plastic particles: Adjusting low-frequency acoustic performance with particle size. Journal of Low Frequency Noise, Vibration and Active Control, 2025, 44(2), 1139-1150. DOI: 10.1177/14613484251314934
[26] Shaharudin MA. Acoustic panel: using kapok and sawdust as absorbent material. Undergraduate Final Year Project Report, 2016.
[27] Santhanam S, Subramanian A. Sustainable polymer acoustic composites from waste cotton, coffee husk, and sawdust for functional applications. Fibers and Polymers, 2025, 26(6), 2557-2568. DOI: 10.1007/s12221-025-00962-9
[28] Kim KB, Huang RZ, Xu XW, Lee SY, Kunio J, Wu QL. Sound transmission properties of mineral-filled high-density polyethylene (HDPE) and wood-HDPE composites. CABI Digital Library, 2015, 10(1), 510-526.
[29] Nyumutsu J, Agyei-Agyemang A, Andoh PY, Tawiah PO, Asaaga BA. The potential of sawdust and coconut fiber as sound reduction materials. Journal of Applied Engineering and Technological Science, 2023, 4(2), 734-742.
[30] Saljoughian A, Mostofinejad D. Axial-flexural interaction in square RC columns confined by intermittent CFRP wraps. Composites Part B: Engineering, 2016, 89, 85-95. DOI: 10.1016/j.compositesb.2015.10.047
[31] Younesi M, Bahrololoom ME. Producing toughened PP/HA-LLDPE ternary bio-composite using a two-step blending method. Materials & Design, 2009, 30(10), 4253-4259. DOI: 10.1016/j.matdes.2009.04.029
[32] Rahman A, Khondoker MAH. Effect of treatment methods on material properties and performance of sawdust-concrete and sawdust-polymer composites. Polymers, 2024, 16(23), 3289. DOI: 10.3390/polym16233289
[33] Olaiya BC, Lawan MM, Olonade KA. Utilization of sawdust composites in construction—a review. SN Applied Sciences, 2023, 5(5), 140. DOI: 10.1007/s42452-023-05361-4
[34] Vengadesan E, Arunkumar T, Muralidharan S, Debnath K, Dutta H, Kadirgama K. Hybrid bio-composites reinforced with natural wood saw dust and eco-friendly graphite: evaluation of physical, mechanical, and thermal properties. Fibers and Polymers, 2025, 26(2), 833-854. DOI: 10.1007/s12221-025-00848-w