Semarak Engineering Journal

Journal homepage:
https://semarakilmu.my/index.php/sej/index
ISSN: 3036-0145

An Experimental Study on the Effect of Natural Fillers on the Acoustic Isolation of Composite Materials

Dania Ahmed Salim[1,*], Farag Mahel Mohammed[1], Ahmed Hameed Reja[1]

[1] Electromechanical Engineering Department, University of technology, Baghdad, Iraq

ARTICLE INFO

Article history:
Received 20 November 2025
Received in revised form 29 December 2025
Accepted 10 February 2026
Available online 15 March 2026

Keywords:
Sound insulation; sound pressure level; compassed materials; plant west

ABSTRACT

The effect of natural fillers on the sound insulation property was studied experimentally. Four types of plant residues (orange, lemon, pomegranate, as well as caper tree leaves) are selected for low and high frequencies (100-8000) Hz. The waste was dried, ground and screened separately to produce the natural filler with a particle size of (300 and 600) µm. The most important stage in designing the experiment is manufacturing samples of the materials used with thickness (3 and 6) mm. The sound insulation property of the soundproof box was examined at low and high frequencies. The results showed that all plant waste samples had high sound absorption by measuring the sound pressure level in the sound receiving chamber of the test box. Pomegranate peels gave the highest percentage of sound pressure reduction, reaching (46.7%), followed by lemon peels (41.7%), then orange peels (30%).

1. Introduction

Sound insulation has become one of the problems that has a direct impact on construction residential and service buildings, design of cars and airplanes, etc., and this creates a need for them searching for new composite materials that meet the requirements acoustic performance using new environmentally friendly materials in order to reduce the impact on human health can be defined [1,2].

Composite materials are a mixture of resins with reinforced materials in the form of granules or fillers The results of these mixtures are metallic Intermediate properties depending on combined Components work [3,4]. Many previous researches have used it Synthetic additives with polymers Enhanced to modify properties Polymer [5,6]. Experimental statement on the effect of graphite filler content on the mechanical and tribological properties of a 30% glass-polyester composite system [7,8]. They employed the Taguchi A method to investigate the impact of the type of artificial filler on the tribological behavior of the polymer composite under dry conditions. To identify environmentally sustainable and high-performance alternatives to artificial reinforcements, researchers are interested in using natural fillers as reinforcement in various materials because of their low density,

* *Corresponding author.*
E-mail address: eme.22.32@grad.uotechnology.edu.iq

https://doi.org/10.37934/sej.13.1.2737

low cost, renewable, biodegradable, low energy consumption, non-abrasive character, and high sound insulation. The automotive, construction, and packaging industries are interested in developing new bio composite materials as alternatives to synthetic fiber-reinforced composites. Unsaturated polyester has diverse properties and applications [9,10].

Nadiatul *et al*., [11,12] exposed agricultural waste capable of absorbing sound. To prepare the samples, polyurethane binding agents and hardeners were mixed with banana stems, grass, oil palm leaves and lemongrass in a ratio of 1:4. For testing, several diameters ranging from 28 to 100 mm and thicknesses of 10 mm were used. An impedance tube approach was used. The chosen frequencies affect the sound absorption coefficient of materials. The study used frequencies ranging from 500 to 4500 Hz. The sound absorption coefficients of four distinct green materials were effectively determined. This study looked at a sample with a consistent thickness. The sound absorption coefficient measurements reveal a positive gradient from 500 to 4500 Hz, with values ranging from 0.046 to 0.831. Based on the sound absorption coefficient, all analyzed samples can be classified as Class D materials. All of the components are organic, recyclable, and agricultural waste that is safe for people's health. Composite materials derived from agricultural waste have the potential to create an essentially sustainable product. Azma Putra *et al*., [13,14] examined the sound absorption coefficient of acoustic absorbers manufactured from natural durian husk fibers, which are still considered agricultural waste. The impedance tube method was used to evaluate the sound absorption performance of samples with different fiber densities and thicknesses. The results reveal that with a minimum thickness of durian husk fibers, the absorption coefficient can be greater than 0.5 above 1 kHz for a 20-mm sample with a minimum density of 160 kg/m3.

All countries, including Iraq, suffer from plant waste after its consumption by humans and its impact on the environment. Therefore, these plant wastes must be properly exploited in the fields of agriculture, industry, and others. Therefore, the current study aims to study the behavior of the sound insulation properties of composite materials and their efficiency compared to the traditional industrial materials used and to calculate the sound reduction index for these materials.

2. Acoustic Models

Acoustic Models Acoustics is a science that studies the generation and propagation of sound via various materials. Humans can hear the sound at audio frequencies ranging from about 20 Hz to 20 kHz. The sources of noise are found both outside and inside buildings, which produce higher noise levels. Examples include sound reproduction systems, traffic, residential electricity, and appliances, among others. There are numerous mathematical models that describe the acoustic behavior of these soundproof layers using elastic characteristics [15,16]. The acoustic behavior of absorbent materials cannot be characterized using the same properties [17,18]. So, the properties to evaluate are tortuosity, viscosity, and porosity based on fiber dispersion. Many theories exist to predict the acoustic isolation of both airborne and impact noise.

2.1 Sound Pressure

Sound pressure, also known as acoustic pressure, is the local pressure difference from the surrounding air pressure (average or equilibrium) caused by a sound wave. The microphone can be used to detect sound pressure in the air. Pascal (Pa) is the SI unit of sound pressure (p) [19,20].

2.2.1 Sound pressure level

Sound pressure level (SPL) is a logarithmic measure of the effective pressure of sound compared to a reference value. It is expressed in units (dB) above a predetermined reference level. The conventional reference for sound pressure in air or gases is 20 µPa, which is usually considered the threshold of human hearing (at 1 kHz). The sound pressure level (Lp) can be calculated using equation (1) [19,21]:

$$SPL = 10\,.\log_{10}\left(\frac{{P_{rms}}^2}{{P_{ref}}^2}\right) = 20\,.\log_{10}\left(\frac{P_{rms}}{P_{ref}}\right) \quad (1)$$

Where: P_{rms} is the measured RMS sound pressure in Pascal [Pa], P_{ref} is the reference sound pressure in Pascal [Pa].

3. Experimental Work

3.1 Materials

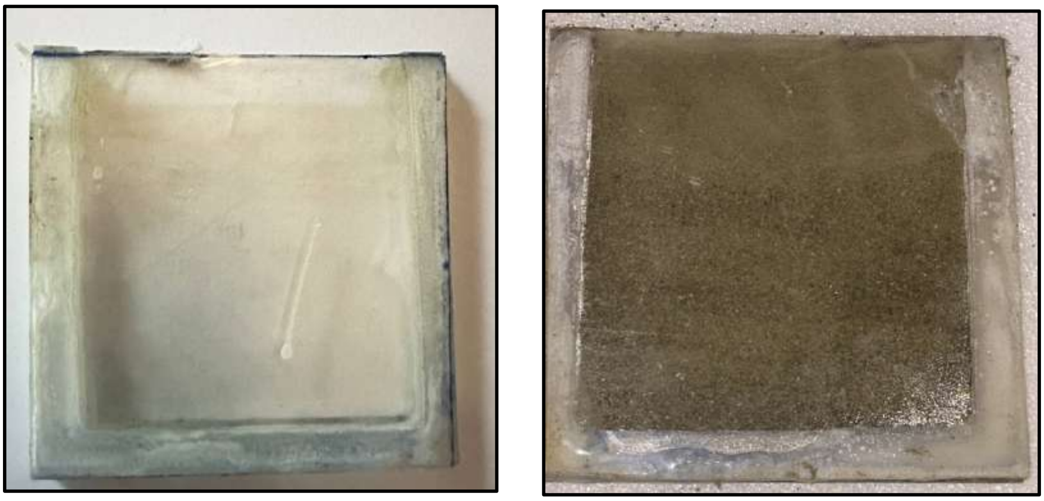
Investigations were performed at room temperature in the facilities of the Department of Materials Engineering at the University of Technology. The materials used in this piece are plant peels (orange, lemon, and pomegranate, in addition to caper tree leaves). Natural fillers with particle diameters of (300 and 600) micrometers were used. To make the fillers, the natural fillers are dried at different temperatures, as shown in Table 1, in special drying ovens before being individually crushed in a mill into fine particles. Particles were sieved using sieve diameters of (300 and 600) micrometers. The product is a filler with a particle size of (300 and 600) micrometers.

Table 1
The temperature of heating samples

No.	*Material name*	*Temperature*	*Time*
1	*Caprice leaves*	*40 °C*	*13min*
2	*Lemon peels*	*70°C*	*15min*
3	*Orange peels*	*100 °C*	*25min*
4	*Pomegranate peel*	*200°C*	*45min*

3.2 Specimens Preparation

All samples were made using the dry hand method in thin glass molds with dimensions of 10 × 10 cm and thicknesses of 3 mm and 6 mm, as shown in Figure 1(a). They are filled with crushed plant waste (orange peels, lemon peels, pomegranate peels, and caper leaves) and pressed to produce compressed composite materials. Two samples were made for each of the materials used (3 mm and 6 mm), depending on the diameter of the powder grains (300 and 600) µm, as shown in Figure 1(b).



(a) **(b)**

Fig. 1. Experimental samples a) Blank sample b) Filled sample

3.3 Experimental Instruments
3.3.1 Test box

For the purpose of conducting practical experiments to measure the efficiency of the tested samples in sound insulation, a closed wooden box with dimensions of (70 × 60 × 60) cm was manufactured and lined with 2 cm thick sound-insulating foam for the purpose of isolating external noise from the tested samples. This box is divided into two chambers, the first containing the sound source (an amplifying speaker) installed at one end through which sound is emitted at the specified frequencies. The second chamber contains a sound pressure gauge, which is installed on the side opposite the speaker and through which the level of sound pressure reaching the second chamber is measured. The sample is fixed in the middle of the two chambers. Figure 2 shows the schematic diagram of the test box.

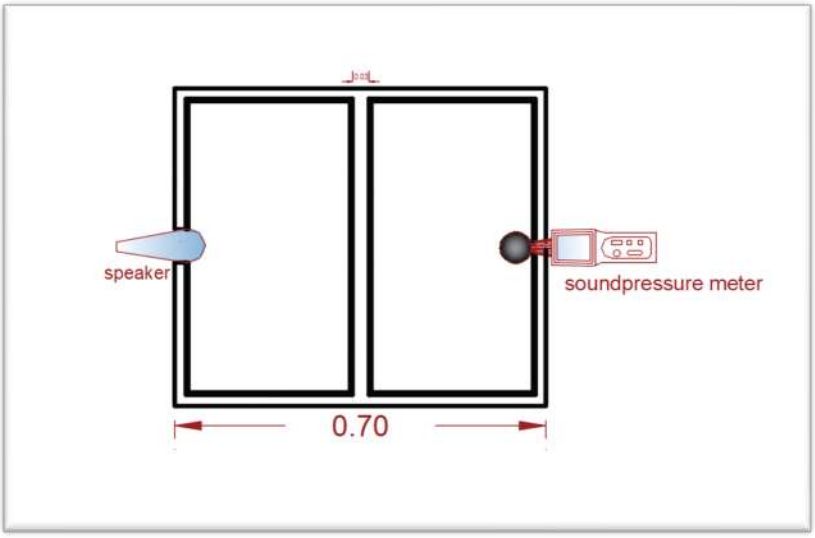


Fig. 2. The schematic diagram of the test box

3.3.2 Sound pressure meter

It is a device used as a sound level meter for acoustic measurements. It is usually a hand-held instrument with a microphone. In this research, a Digital Sound Level Meter 352 type, Shown in Figure 3 was used, the specification of device shown in Table 2.

Fig. 3. Sound pressure meter

Table 2
The specification of sound pressure meter device used in experimental

Measurements	*Range*
Range of dB	*30-130 dB*
Frequency	*31.5Hz ～8000Hz*
Sample Rate	*FAST: 8 Times/s* *SLOW: 1 Times/s*
Power	*1.5V Batteries (LR6) X 4*
LCD Size	*53mm X 41mm*
Product Net Weight	*330g*
Product Size	*273mm X 70mm X 39mm*
Standard Accessories	*Batteries, Windscreen, Leather Box*

3.4 Sound Absorption Test

The effect of using plant waste on the sound insulation properties of composite materials was studied. Test samples were evaluated in the soundproof box shown in Figure 2, which was designed to measure the sound absorption of different materials. The sound source was mounted at one end of the box and consisted of stationary random waves with a wide frequency range from 100 to 5000 Hz. The sound produced by the loudspeaker was sent to the sample plate installed in the middle of the box, and the sound intensity was measured using a sound pressure level meter installed at the other end of the box. The device took about 8 seconds to generate the absorption spectrum. 10 experiments were conducted to measure the sound pressure level of various plant waste samples (orange peels, lemon peels, pomegranate peels, and caper leaves) used in the research.

4. Results and Discussion

Acoustic absorption is a major component that influences acoustic characteristics. Table (3, 4, 5,6 ,7 and 8) shows the results of experimental testing at low and high audio frequencies for all samples. Low-frequency sound generation from (100 - 900) Hz was evaluated, and high-frequency sound generation from (1 - 8) kHz was studied. Table 3 and 4 displays the results for the tested plates not filled with plant residues for (3 and 6) mm Thickness respectively, while Tables (5 ,6,7 and 8) represent the results of the experimental tests for the tested plates filled with plant waste used in the experiment for the diameters of the powder particles (300 and 600) µm. It has been observed in general, and at all levels, that the sound pressure level increases with the increase in frequency generated by the sound. The experimental panel filled with plant waste used in the experiment shows higher sound absorption than the empty panel.

Table 3
Test results for the tested plates not filled with plant residues for 3mm thickness

Frequency (Hz)	*Sound pressure level(dB)*	*Frequency (Hz)*	*Sound pressure level(dB)*
100	*74.4*	*1000*	*87.2*
200	*77.4*	*2000*	*70.7*
300	*75.3*	*3000*	*54.5*
400	*74.4*	*4000*	*51.5*
500	*72.7*	*5000*	*49.7*
600	*76.9*	*6000*	*46.4*
700	*75.3*	*7000*	*43.6*
800	*74.8*	*8000*	*42.2*
900	*73.6*		

Table 4
Test results for the tested plates not filled with plant residues for 6mm thickness

Frequency (Hz)	*Sound pressure level(dB)*	*Frequency (Hz)*	*Sound pressure level(dB)*
100	*71.4*	*1000*	*79.2*
200	*70.4*	*2000*	*69.7*
300	*68.3*	*3000*	*51.5*
400	*67.4*	*4000*	*48.9*
500	*66.7*	*5000*	*47.7*
600	*69.9*	*6000*	*44.4*
700	*67.3*	*7000*	*41.6*
800	*65.8*	*8000*	*41.2*
900	*63.6*		

Table 5
Test results of sound pressure level at low frequencies sound generated and for plant peels with 3mm thickness filled with powder grains (300 µm diameter)

Frequency HZ	*Cappres SPL (dB)*	*Orange SPL (dB)*	*Lemone SPL (dB)*	*Pomegranate SPL (dB)*
100	*70.1*	*70.1*	*69.9*	*73.5*
200	*72.3*	*68.3*	*66.4*	*76.4*
300	*70.2*	*68.7*	*66.7*	*74.2*
400	*72.4*	*69.5*	*67.3*	*70.6*
500	*70.7*	*66.9*	*66.3*	*69.2*
600	*74.6*	*68.5*	*65.9*	*70.1*

700	73.1	69.4	67.3	70.1
800	72.7	70.5	64.7	71.6
900	71.3	68.3	63.4	70.9

Table 6
Test results of sound pressure level at high frequencies sound generated and for plant peels with 3mm thickness filled with powder grains (300 µm diameter)

Frequency Hz	*Cappres SPL (dB)*	*Orange SPL (dB)*	*Lemone SPL (dB)*	*Pomegranate SPL (dB)*
1000	82.2	80.5	78.4	81.1
2000	66.3	62.6	59.4	56.8
3000	48.4	45.5	39.7	44
4000	44.8	42.1	36.7	40.3
5000	43.6	40.8	32.8	38.6
6000	41.5	38.4	32.4	35.6
7000	39.2	35.6	31.6	33.2
8000	36.6	32.3	29.9	30.1

Table 7
Test results of sound pressure level at low frequencies sound generated and for plant peels with 6mm thickness filled with powder grains (600 µm diameter)

Frequency HZ	*Cappres SPL (dB)*	*Orange SPL (dB)*	*Lemone SPL (dB)*	*Pomegranate SPL (dB)*
100	67.2	65.3	60.1	55.5
200	66.4	61.1	58.1	54.1
300	65.7	60.4	57.1	53.2
400	64.2	59.2	55.4	52.7
500	62.1	59.9	53.4	51.1
600	60.1	56.3	51.1	49.4
700	59.2	54.4	49.1	45.3
800	58.9	54.2	46.2	43.4
900	58.4	52.8	44.8	42.1

Table 8
Test results of sound pressure level at high frequencies sound generated and for plant peels with 6mm thickness filled with powder grains (600 µm diameter)

Frequency HZ	*Cappres SPL (dB)*	*Orange SPL (dB)*	*Lemone SPL (dB)*	*Pomegranate SPL (dB)*
1000	61.8	58.3	56.1	51.1
2000	56.1	52.2	46.1	44.2
3000	46.3	42.2	37.4	35.4
4000	40.4	35.1	31.4	28.4
5000	38.2	32.2	26.3	25.1
6000	35.6	30.5	23.2	20.8
7000	32.2	28.3	22.7	19.3
8000	29.6	25.8	20.6	17.4

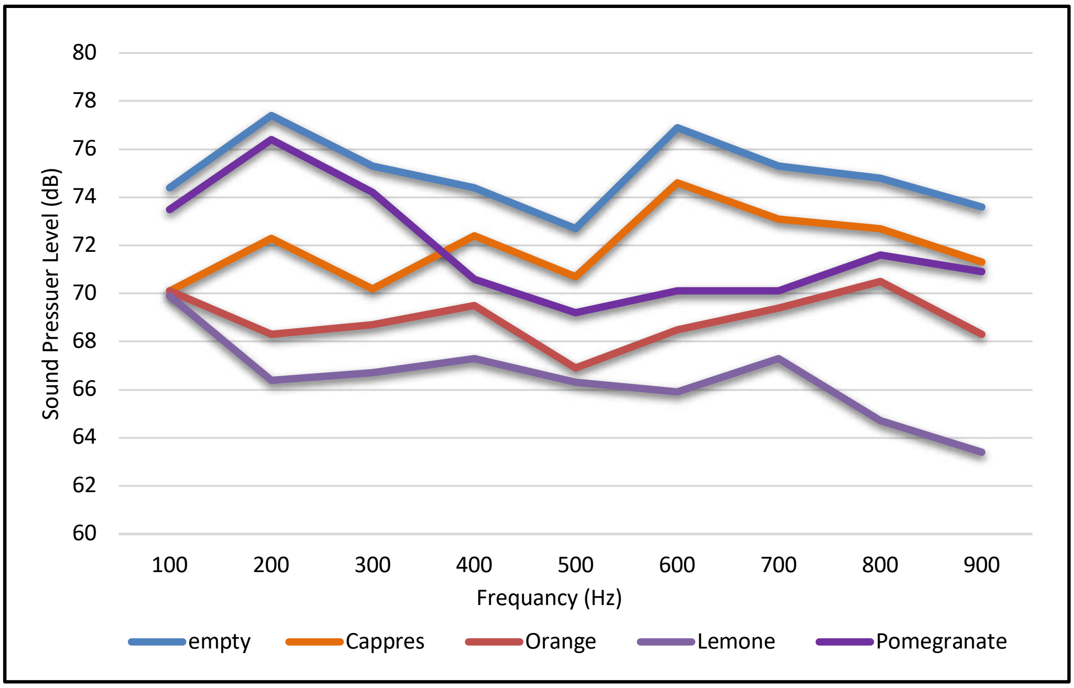


Fig. 3. Sound pressure level at low frequencies sound generated and for plant peels with 3mm thickness filled with powder grains (300 µm diameter)

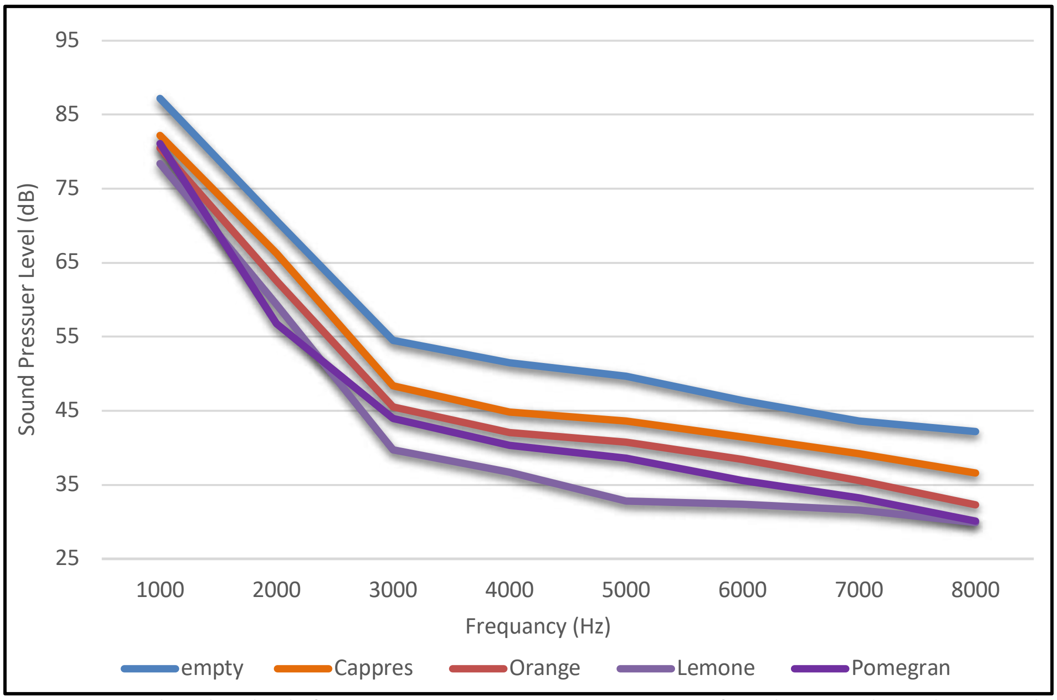


Fig. 4. Sound pressure level at high frequencies sound generated and for plant peels with 3mm thickness filled with powder grains (300 µm diameter)

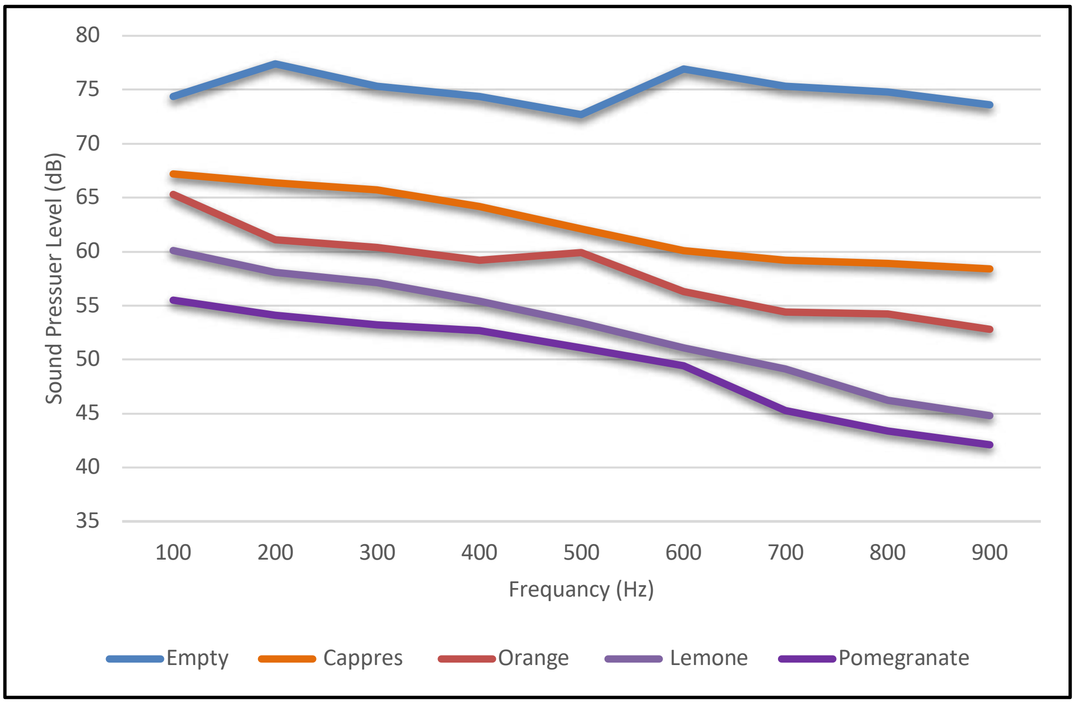


Fig. 5. Sound pressure level at high frequencies sound generated and for plant peels with 6mm thickness filled with powder grains (300 µm diameter)

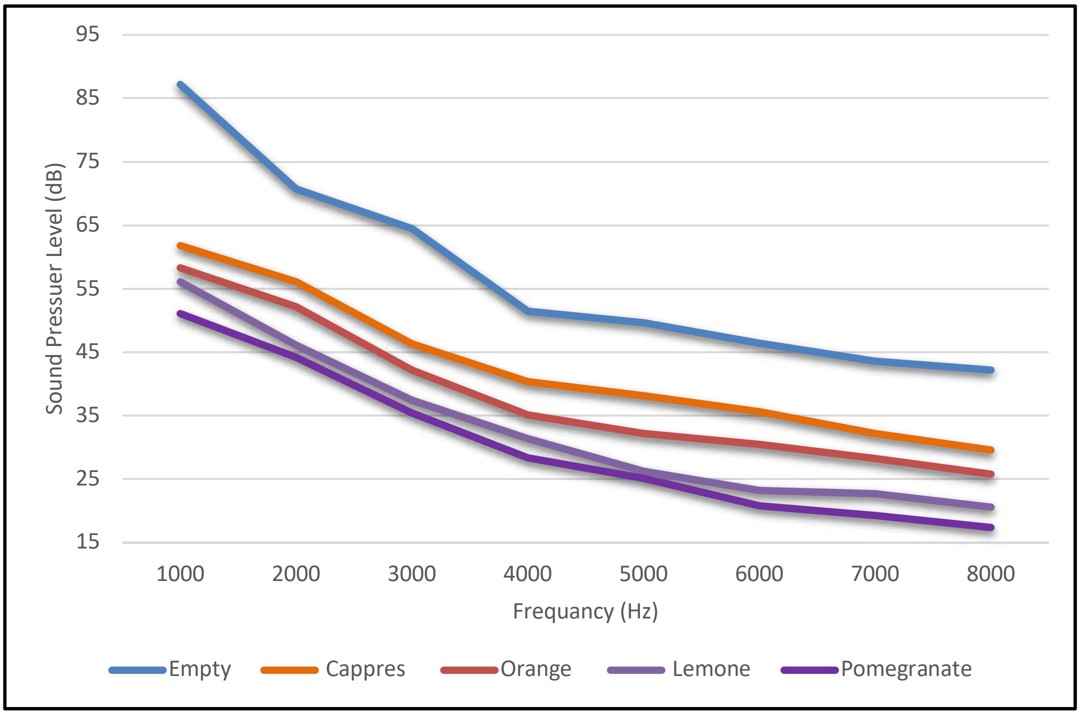


Fig. 6. Sound pressure level at high frequencies sound generated and for plant peels with 6mm thickness filled with powder grains (600 µm diameter)

From observing the results obtained from the experiment, the best material from plant waste that helps in sound insulation at all low and high frequencies is lemon, orange, and pomegranate peels. When the plate thickness is 3 mm and the powder diameter is (300 and 600) µm, the sound pressure level at low frequencies (100-900) Hz decreases by 17.5% for lemon peels, 7.9% for orange peels, and 3.8% for pomegranate peels. Research results showed that these materials are more efficient in reducing sound pressure levels at high frequencies ranging from (1000 - 8000) Hz, as pomegranate peels gave the highest percentage of insulation (40.6%), and lemon peels gave (36.5%), and orange peels (23.5%).

If the thickness of the test plate was increased to 6 mm, the pomegranate peels gave better results for all low and high frequencies and for powder diameters (300 and 600) µm, and the sound pressure level decreased by (33.2%) for low frequencies and by (46.7%) for high frequencies. As for lemon peels, they led to a decrease in the sound pressure level by (29.1%) for low frequencies and (41.7%) for high frequencies. The experimental results also showed an increase in the decrease in the sound pressure level of orange peels if the sample thickness increased to 6 mm, as it decreased by (22.8%) for low frequencies and (30%) for low frequencies. High. This indicates that increasing the density of the material helps in obtaining better sound insulation.

5. Conclusions

In this study, plant waste was used (orange peels, lemon peels, pomegranate peels, and caper leaves) To be applied as noise insulation panels with thickness (3 mm) and (6mm). These materials showed loss and lack of transmission of very high-level sound. The sound pressure level for low frequencies (100-900) Hz and high frequencies (1000 - 8000) Hz has generally decreased in all samples used.

References

[1] López, Joan Pere, Nour-Eddine El Mansouri, Jesús Alba, Romina Del Rey, Pere Mutjé, and Fabiola Vilaseca. "ACOUSTIC PROPERTIES OF POLYPROPYLENE COMPOSITES REINFORCED WITH STONE GROUNDWOOD." *BioResources* 7, no. 4 (2012). https://doi.org/10.15376/biores.7.4.4586-4599

[2] Abdewi, Elfetori F., and Tariq Alwuheeshi. "Testing of mechanical properties of composite materials made of almond shells fiber." In *AIP Conference Proceedings*, vol. 3125, no. 1, p. 020003. AIP Publishing LLC, 2024. https://doi.org/10.1063/5.0214775

[3] Sridhar, D. R., and Y. S. Varadarajan. "Significance of the type of reinforcement on the mechanical behavior of thermoplastic composites." *Materials Today: Proceedings* 5, no. 5 (2018): 13139-13145. https://doi.org/10.1016/j.matpr.2018.02.303

[4] Smait, Drai A., Farag M. Mohammed, and Jamal J. Dawood. "Natural filler effect on the mechanical properties behavior of unsaturated polyester composite plate." In *AIP Conference Proceedings*, vol. 3002, no. 1, p. 080031. AIP Publishing LLC, 2024. https://doi.org/10.1063/5.0207535

[5] Mohammed, Farag M., and Drai A. Smait. "Mechanical and tribological behavior of glass-polyester composite system under graphite filler content." *Eng. & Tech. Journal* 30, no. 4 (2012). https://doi.org/10.30684/etj.30.4.13

[6] Nagy, Balázs, Karel Struhala, Lukáš Bosák, and Piotr Kosiński. "Evaluation of bio and natural-based thermal insulation materials in Visegrad countries." In *AIP Conference Proceedings*, vol. 2918, no. 1, p. 020046. AIP Publishing LLC, 2023. https://doi.org/10.1063/5.0170926

[7] Smait, Drai A., Farag Mahel Mohammed, and Hussam Lefta Alwan. "Application of Taguchi approache to study the Effect of filler type on tribological behavior of polymer composite under dry conditions." *Eng. & Tech. Journal* 32 (2014). https://doi.org/10.30684/etj.32.8A3

[8] Sathishkumar, S. D. "Design and analysis of leaf spring by using composite materials." In *AIP Conference Proceedings*, vol. 2853, no. 1, p. 020297. AIP Publishing LLC, 2024. https://doi.org/10.1063/5.0197546

[9] Habibi, Youssef, Waleed K. El-Zawawy, Maha M. Ibrahim, and Alain Dufresne. "Processing and characterization of reinforced polyethylene composites made with lignocellulosic fibers from Egyptian agro-industrial residues." *Composites Science and Technology* 68, no. 7-8 (2008): 1877-1885. https://doi.org/10.1016/j.compscitech.2008.01.008

[10] Mohapatra, R., Antaryami Mishra, and B. Choudhury. "Investigations on thermal conductivity of palm fibre reinforced polyester composites." *IOSR Journal of Mechanical and Civil Engineering* 11, no. 1 (2014): 48-52. https://doi.org/10.9790/1684-11144852

[11] Shahid, Nadiatul Syima Mohd, Mohamad Ali Ahmad, and F. L. Tahir. "Sound absorption coefficient of different

green materials polymer on noise reduction." *Int. J. Innov. Tech. Explor. Eng* 9 (2020): 2773-2777. https://doi.org/10.35940/ijitee.C9208.019320

[12] Sai, Devarakonda Shiva, Subham Kumar Singh, Anish Chattaraj, Kamireddi Varun Chandhu, Devarakonda Sri Laxmi Durga, Lakshman Pradeep Samudram, Devarakonda Harish Kumar, and Jai Inder Preet Singh. "Development of bagasse/PLA composites, it's mechanical & chemical properties: A review." In *AIP Conference Proceedings*, vol. 2962, no. 1, p. 020018. AIP Publishing LLC, 2024. https://doi.org/10.1063/5.0192258

[13] Putra, Azma, Muhammad Nur Othman, Thaynan Oliveira, M'hamed Souli, Dg Hafizah Kassim, and Safarudin Herawan. "Waste durian husk fibers as natural sound absorber: performance and acoustic characterization." *Buildings* 12, no. 8 (2022): 1112. https://doi.org/10.3390/buildings12081112

[14] Sobolev, Ilya, Dmitry Azanov, Dmitry Dityatev, Mansur Sutaev, Irina Vornacheva, Anton Tancura, and Nikolay Gaidash. "Research of the possibility of applying the acoustic emission method in searching for internal defects in materials and structures." In *AIP Conference Proceedings*, vol. 3154, no. 1, p. 020021. AIP Publishing LLC, 2024. https://doi.org/10.1063/5.0201642

[15] Alba, J., J. Ramis, and V. J. Sánchez-Morcillo. "Improvement of the prediction of transmission loss of double partitions with cavity absorption by minimization techniques." *Journal of sound and vibration* 273, no. 4-5 (2004): 793-804. https://doi.org/10.1016/S0022-460X(03)00783-1

[16] Yuliza, Elfi, Rinaldi, Supiyati, and Riska Ekawita. "Sound sensor for simple sound level meter: A case study of composite based on oil palm frond waste." In *AIP Conference Proceedings*, vol. 2623, no. 1, p. 050002. AIP Publishing LLC, 2023. https://doi.org/10.1063/5.0129853

[17] Del Rey, Romina, Jesus Alba, Jorge P. Arenas, and Vicente J. Sanchis. "An empirical modelling of porous sound absorbing materials made of recycled foam." *Applied Acoustics* 73, no. 6-7 (2012): 604-609. https://doi.org/10.1016/j.apacoust.2011.12.009

[18] Jaiswal, Pratik, Shivprakash Barve, Vilas Kanthale, and Shailendra Shisode. "Design of composite elliptical shape leaf-spring mount." In *3RD INTERNATIONAL CONFERENCE ON MANUFACTURING, MATERIAL SCIENCE AND ENGINEERING (ICMMSE 2021)*, vol. 2548, no. 1, p. 040007. AIP Publishing LLC, 2023. https://doi.org/10.1063/5.0118460

[19] A. M. Jaramillo and C. Steel, "Architectural Acoustics," *Archit. Acoust.*, pp. 1–253, 2014. https://doi.org/10.4324/9781315752846

[20] Yuliza, Elfi, Rinaldi, Supiyati, and Riska Ekawita. "Sound sensor for simple sound level meter: A case study of composite based on oil palm frond waste." In *AIP Conference Proceedings*, vol. 2623, no. 1, p. 050002. AIP Publishing LLC, 2023. https://doi.org/10.1063/5.0129853

[21] Kassim, Muna S., Ehsan Sabah Al-Ameen, Ammar Fadhil Hussein Al-Maliki, and Raid A. Mahmood. "Investigating the acoustic properties of recycled natural waste materials." In *2ND INTERNATIONAL CONFERENCE ON ENGINEERING AND ADVANCED TECHNOLOGY:(ICEAT 2022)*, vol. 2787, no. 1, p. 030004. AIP Publishing LLC, 2023. https://doi.org/10.1063/5.0148058