Acoustic properties of different blending ratios of empty fruit bunch and oil palm frond

L S Ewe¹*, Mohammad Nazhan Nasir¹, W K Yew², R Mageswaran¹ and Zawawi Ibrahim³

¹College of Engineering, Universiti Tenaga Nasional (UNITEN), Putrajaya Campus, Jalan IKRAM-UNITEN, 43000 Kajang, Selangor, Malaysia
²School of Engineering and Physical Science, Heriot-Watt University Malaysia, No 1, Jalan Venna P5/2, Precint 5, 62200, Putrajaya, Malaysia.
³Engineering and Processing Division, Malaysian Palm Oil Board (MPOB), No. 6, Persiaran Institusi, Bandar Baru Bangi, Kajang 43000, Selangor, Malaysia

*Corresponding author’s email: laysheng@uniten.edu.my

Abstract. The society understands the importance of using sound-absorbing panels to protect our health against the noise pollution. However, the repercussions of fibreglass as sound-absorbing panels on human health and the environment have increased year by year. Natural fibers are more environmentally friendly and have significantly lower production cost. This research emphasizes the acoustic properties of different blending ratios of Empty Fruit Bunch (EFB) and Oil Palm Frond (OPF at four different thickness. Their acoustic properties were tested by using the Impedance Tube Method (ITM) from frequency range of 0 - 6400 Hz. The findings show the Sound Absorption Coefficient (SAC) value increases as the frequency increases for all samples. Both blending ratios have good SAC results. For blending ratio of 30% EFB – 70% OPF, the SAC of the panels achieved 80% and above at frequency between 3500 - 6400 Hz for samples with thickness of 14 mm, 16 mm and 18 mm. However, for blending ratio of 20% EFB – 80% OPF, the SAC of all samples are found 0.8 and above at frequency between 3500 - 6400 Hz. Notably, the SAC values for both blending ratio are increased with increasing in thickness. It might be attributed to the effect of tortuosity. The SAC values for all samples are also found to achieve unity (~ 0.96) at different frequency range. Furthermore, the frequency range for SAC to reach 0.8 and above has been increased from 4500 – 6400 Hz to 3500 – 6400 Hz with an increased in OPF contents.

Keywords: Empty Fruit Bunch (EFB), Oil Palm Frond (OPF), Sound Absorption Coefficient (SAC), Blending Ratio.

1. Introduction
It has already been more than a decade, that we are facing noise pollution and the harmful consequences of using fibre glass acoustic panels. These noise pollutions are getting out of hand day by day. However, due to the ignorance of human beings, this noise pollution is treated lightly [1]. Based on the statistics done by the Occupational Safety and Health Administration (OSHA), 85 dB is maximum limit of sound that humans able withstand, anything higher than that is injurious to health [2]. Well, one of the precaution methods that could reduce noise pollution is to follow the limit of noise level, control noise level near sensitive area and etc. However certain matters are uncontrollable such as construction sites,
transportation (airports and railways), etc. Thus, the best solution is put in sound-absorbing panels to absorb unwanted noise [3]. Ordinarily these sound-absorbing panels are used in cinema theatres, recording studios, offices, meeting rooms, factory and etc.

The common selections of sound-absorbing panel used in the market are the fiberglass, cotton, mineral fiber, polyester, etc. However, fiberglass as a sound absorbing panel pose severe health threat towards humans due to the shedding of fiberglass [4]. Scientist and researcher found lung tumour in an animal which was triggered by fiberglass, the same material used in making of sound-absorbing panels. In addition, fiberglass can also potentially cause lung infection, irritation to skin, eyes and also pulmonary diseases [5] [6]. This information was shared by the US government when a research was shown on fiberglass. At the same time, the industrial companies that produce this synthetic fiberglass also pollute the air and water with their waste products.

Researcher and scientist have strived forward for an environmentally friendly solution which uses natural fiber as sound-absorbing material and to test their acoustic properties. Natural fiber has more advantageous properties compared to synthetic fibers. They are renewable, biodegradable, and most important of all, it is safe to humans and surrounding [7]. There are many other natural fibers that have been tested for their acoustic properties such as bamboo fiber [8], pineapple [9], tea-leaf [10] etc. Till today oil palm trunk (OPT) has shown prominent acoustic result according to Kalaivani et. al [11]. OPT natural fiber was able to reach sound absorption coefficient (SAC) of 0.99, which meant that 99% of the sound is absorbed and 1% of the sound is reflected to surrounding as heat energy. This was achieved at a frequency range of 3000 - 6000 Hz for sample thickness of 12 mm [11]. Moreover, arenga pinnata and kenaf fiberboard had their acoustic properties tested out. The SAC results from arenga pinnata and kenaf were good as well [12] [13].

As can be seen from the previous research, it shows that natural fibers have a very promising acoustical property, therefore this research is captivating and engaging your attention. This research emphasizes on the acoustic properties of natural fibers of empty fruit bunch (EFB) and oil palm frond (OPF) at different thickness. With this research, we can solve the environmental pollution and concurrently would be able to replace the synthetic made fiberglass sound-absorbing panels with natural fiber sound-absorbing panels.

2. Methodology
Dry method process has been used to fabricate the low density fiberboard (LDF). The amounts of EFB and OPF natural fibers are required in preparing a total of 8 fiberboards have been computed. Urea Formaldehyde (UF) glue used as resin to blend the fibers. The mass of the natural fibers and moisture content are calculated using a pre programme excel sheet prepared by MPOB, where it can achieve the targeted blending ratio (30% EFB – 70% OPF, 20% EFB – 80% OPF), density (ρ = 120 kg/m$^3$) and thickness (12 mm, 14 mm, 16 mm and 18 mm). The fiberboards were fabricated at Research Station MPOB / UKM located at Pekan Bangi Lama, Kajang.

The fabrication process involved chipping, refining, glue bending, mat-forming, pre-press, hot press and cool down as shown in Figure 1. For further interpretation can refer to our previous publications [3] [7] [14]. For Acoustic testing, the SAC value were obtained using the Bruel & Kjaer (B&K) Impedance Tube Type 4206 apparatus as shown in Figure 2. SAC was measured using 2 microphones, where the impedance tube attached to the analyser. Measurement of 2 microphones transfer function method is based on the international standards of ASTM E1050-2 for sound absorption coefficient. The labview software was used to calculate the SAC.

3. Results and discussion
The acoustic properties of the materials is determined by analyzing its sound absorption coefficient, SAC (α). The ratio of sound transmitted through a material and the incident sound that emitted from a material is the concept behind SAC (α) [15]. For instance, when a material achieved SAC (α) value of 0.98 at a certain frequency. It indicates that this material can absorb 98% of the noise and only 1% of the remaining noise is reflected to the surrounding as heat energy at this frequency. The SAC, (α) is
obtained and measured from impedance tube method (ITM), which is following the ASTM E1050-95 (ISO 10534-2) test technique [16].

Figure 3 displays the SAC, $\alpha$ of four different thickness with the blending ratio of 30% EFB – 70% OPF. SAC, $\alpha$ values are found to rise as the frequency increases from 0 - 6400 Hz for all samples. It is notable that, at the lower region medium frequency (~1500 Hz), sample thickness 18 mm has the highest SAC, $\alpha$, which is 0.52 if compared to the samples with thickness of 12 mm, 14 mm, and 16 mm. Where the SAC, $\alpha$ values are ranging from 0.24 - 0.38. Above 4500 Hz, it is noticeable that the SAC for samples with thickness of 14 mm and 16 mm surpass the sample with thickness of 18 mm. The SAC for these two samples (14 mm and 16 mm) almost reached unity (≥ 0.98) above 4500 Hz too. While, sample with thickness of 14 mm reached unity ($\alpha = 1.00$) at the frequency range of 5500 - 6000 Hz. Furthermore, the $\alpha$ for all samples, except for sample with thickness of 12 mm possessed the $\alpha$ of 0.8 and above from a frequency range of 3250 - 6400 Hz. Whereas, the sample thickness of 12 mm only achieved $\alpha$ more than 0.80 at frequency above 4750 Hz. On average, all the samples performed splendidly at high frequency (4000 – 6400 Hz) with maintaining more than 90% sound absorption rate except for sample with thickness of 12 mm. If compared with the research of Wood Fiber Board (WFB), at high frequency of 4000 Hz, the SAC value for WFB was only 0.68 while the average SAC for EFB and OPF mixture was 0.89 at high frequency range [17].

| CHIPPING PROCESS          | The Maier Chipper was used to chip the raw EFB and OPF fibres to smaller size. |
|----------------------------|---------------------------------------------------------------------------------|
| REFINING PROCESS           | Hammer mill was used to break down the fibres by striking the EFP and OPF fibres into fined fibres. |
| HEATING PROCESS            | Oven was used to heat the fined fibres of the empty fruit bunch and frond at temperature of 100°C. This is to ensure all the dust in the fibres was eliminated and the moisture content of the fibres is below 10%. |
| GLUEING PROCESS            | Urea Formaldehyde (UF) was used to blend the EFB and OPF fibres for 15 seconds. The mass for the UF glues and fibres were calculated perfectly beforehand. |
| MAT-SHAPING PROCESS        | The sample was transferred into the mould of square box with the dimension of (1 ft x 1 ft) to get the fibreboard shape. The sample was formed softly and manually by hand from the the top to remove the pores contained. |
| PRE-PRESS PROCESS          | The metal flattener was used to compress the fibres manually to remove the pores contained. |
| HOT-PRESS PROCESS          | The sample was heated at 200°C and pressed as per desire density. |
| COOLING PROCESS            | The fibreboard was then cooled to room temperature for few minutes. |

**Figure 1.** Low density fiberboard (LDF) fabrication process.

**Figure 2.** Setup of B&K Tube Type 4206.
Figure 3. SAC, α versus frequency (Hz) in four different thickness with blending ratio of 30% EFB – 70% OPF.

Figure 4. SAC, α versus frequency (Hz) in four different thickness with blending ratio of 20% EFB – 80% OPF.

Figure 4 exhibits the SAC, α of four different thickness with the blending ratio of 20% EFB – 80% OPF. SAC, α values are found to increase as the frequency increase from 0 - 6400 Hz for all samples. From the figure above, samples with thickness of 16 mm and 18 mm performed better at mid-range frequency compare to samples with thickness of 12 mm and 14 mm. Based on past research, thickness plays a vital role in acoustic performance [18]. Sample with thickness of 12 mm was able to perform very well at a high frequency range of 6000 Hz to 6400 Hz with achieving 100 % sound absorption rate. Moreover, all samples exhibit the SAC more than 0.80 at the frequency range above 3500 Hz to 6400 Hz and SAC of 0.90 and above at frequency above 4000 Hz except for sample with a thickness of 12 mm, where it only achieves SAC of 0.87 at the same frequency. Based on sound absorption values and
classes over a range of standard test frequencies according to BS EN ISO 354, the SAC of 0.8 and above is considered as A-rated products having the highest rated sound absorption.

It is remarkable that the SAC values increase with increasing in thickness from 12 mm to 18 mm for these two blending ratio at different frequency range. It can be explained by the tortuosity effect. The tortuosity is a measure of the shape of the air void passages and it brings a direct effect to the material sound absorption properties. The amount of fibers used is increasing with the sample’s thickness increased. For porous material, an increase in the amount of fibers used will lead to a more complex and tortuous path and hence more energy dissipation due to high friction loss and more absorbing capability. The thicker the fiberboard, the more straight or twisted path that prolongs the time taken for the wave in contact with the fibers. Hence, it leads to better sound absorption for each of the reflection with the fibers. Thus, tortuosity plays a vital role in determining the sound absorption of the fiberboard.

4. Conclusion

In overall, the acoustic properties of blended OPF & EFB natural fibres were studied according to their different blending ratio and thickness. The experimental results above imply that the frequency range for SAC to reach 0.8 and above has been increased from 4500 – 6400 Hz to 3500 – 6400 Hz with an increased in OPF contents. This research has been shown the tortuosity plays a crucial role in determining the acoustic properties from low to medium frequency range. The increased of sinuous path in the fibers due to the increase in sample’s thickness led to more sound absorption for the sample.

Acknowledgments

The authors would like to thank The Energy University’s BOLD grant with project code: RJO 105178441060 and the Malaysian Oil Palm Board (MPOB) for supporting this research work.

References

[1] Singh, N. & Davar, S.C., “Noise pollution-sources, effects and control,” J. Hum. Ecol., vol. 16, no. 3, pp. 181–187, 2004.
[2] P. A. Niquette, “Noise exposure: Explanation of OSHA and NIOSH safe exposure limits and the importance of noise dosimetry,” Can. Hear. Rep., vol. 9, no. 3, pp. 22–29, 2012.
[3] R. Mageswaran, E. L. Sheng, and Z. Ibrahim, “The Thickness Effects On Acoustic Properties Of Oil Palm Trunk Natural Fiber In Density Of 170 Kg/m3,” Sci Int, vol. 30, no. 6, pp. 845–849, 2018.
[4] Navy Environmental Health Center, “Man-Made Vitreous Fibers,” vol. 12, no. October, p. 110, 1997.
[5] Iarc, “Iarc Monographs on the Evaluation of Carcinogenic Risks To Humans,” Iarc Work. Gr. Eval. Carcinog. Risks To Humans, vol. 96, pp. i-ix+1-390, 2002.
[6] K. H. Kilburn, D. Powers, and R. H. Warshaw, “Pulmonary effects of exposure to fine fibreglass : irregular opacities and small airways obstruction,” pp. 714–720, 1992.
[7] R. Mageswaran, L. S. Ewe, W. K. Yew, and Z. Ibrahim, “Acoustic Properties of Mixing Empty Fruit Bunch and Oil Palm Frond Natural Fibres,” Int. J. Recent Technol. Eng., vol. 8, no. 4, pp. 6347–6349, 2019.
[8] T. Koizumi, N. Tsujiuchi, and A. Adachi, “The development of sound absorbing materials using natural bamboo fibers and their acoustic properties,” INTER-NOISE NOISE-CON Congr. Conf. Proc., vol. 2002, no. 5, pp. 713–718, 2002.
[9] A. Putra, K. H. Or, M. Z. Selamat, M. J. M. Nor, M. H. Hassan, and I. Prasetiyo, “Sound absorption of extracted pineapple-leaf fibres,” Appl. Acoust., vol. 136, no. November 2017, pp. 9–15, 2018.
[10] S. Ersoy and H. Küçük, “Investigation of industrial tea-leaf-fibre waste material for its sound absorption properties,” Appl. Acoust., vol. 70, no. 1, pp. 215–220, 2009.
[11] R. Kalavani, L. S. Ewe, B. K. Yap, N. A. Talik, and Z. Ibrahim, “The effects of density on microstructure and acoustic properties of OPT natural fibers,” J. Fundam. Appl. Sci., vol. 10, no.
3s, pp. 434–445, 2018.

[12] M. Saad and I. Kamal, “Kenaf Core Particleboard and Its Sound Absorbing Properties,” J. Sci. Technol., vol. 4, no. 2, pp. 23–34, 2013.

[13] L. Ismail, M. I. Ghazali, M. Shahruddin, and M. A. . Ahmad, “Sound Absorption of Arenga Pinnata Natural Fiber,” Int. J. Mater. Metall. Eng., vol. 4, no. 7, pp. 438–440, 2010.

[14] Z. Ibrahim, “Production of Medium Density Fibreboard (MDF) FROM Oil Palm Trunk,” J. Appl. Sci., vol. 11, 2014.

[15] F. D’Alessandro, F. Asdrubali, and N. Mencarelli, “Experimental evaluation and modelling of the sound absorption properties of plants for indoor acoustic applications,” Build. Environ., vol. 94, pp. 913–923, 2015.

[16] S.Jung, Y. Kim, Y. Lee, S. Cho and J. Lee, "Measurement of sound transmission loss by using impedance tubes", Journal of the Korean Physical Society, vol. 53, no. 2. pp. 596-600, 2008.

[17] A. Nandanwar, M. C. Kiran, and K. C. Varadarajulu, “Influence of Density on Sound Absorption Coefficient of Fibre Board,” Open J. Acoust., vol. 07, no. 01, pp. 1–9, 2017.

[18] E. M. Samsudin, L. H. Ismail, A. A. Kadir, and I. Norfaslia, “Thickness, density and porosity relationship towards sound absorption performance of mixed palm oil fibers,” 24th Int. Congr. Sound Vib., pp. 0–8, 2017.