Oil Palm Wastes as Sustainable Sound Absorbing Particleboard

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Abstract. One method to absorb noise is by using acoustic absorber. Empty fruit bunch fibres (EFB) and mesocarp fibres (MF) are waste materials generated from palm oil mills. This research aimed to fabricate sustainable acoustic absorbing particleboard using EFB and MF to replace conventional materials currently used. Two parameters that were investigated are the mix ratio of the EFB and MF and the addition of binder (urea formaldehyde, UF) into the fibres. Sample thickness was maintained at 20 mm and 30 mm for samples with and without binder. The sound absorption coefficient (SAC) of the samples were tested using an impedance tube according to ISO 10534 – 2 standards. Samples produced using 50% EFB and 50% MF with and without binder shown the best SAC of 0.699 and 0.982 at 1200 Hz respectively. This is equal or better than conventional materials such as mineral wool with SAC values of 0.875 at 1000 Hz. Swelling test however shown that all samples do not meet the criteria by JIS A 5908 for particleboard. Future studies could include the use of green binder and different percentages of EFB, MF and binder.

1. Introduction
Malaysia is one of the top producers of palm oil in the world, accounting to 39% of world production and 44% of world exports [1]. One of the main challenges faced by this industry is the proper disposal of the biomass wastes such as oil palm trunks, empty fruit bunches (EFB), fronds and shells. The implementation of Malaysian Sustainable Palm Oil (MSPO) Certification requires oil palm mills to have a proper waste disposal management programme especially for the waste after the extraction processes. EFB and mesocarp fibres (MF) are the biomass wastes generated after the extraction process. Conventionally, MF are used as feedstock for boiler in palm oil mills to generate electricity locally. However, EFB are underutilised for energy generation and are usually incinerated which causes air pollution [2]. Previous research has shown that natural fibres have the potential to be used as acoustic absorber.

Sound absorber is a material that absorbs sound energy wave generated by the source and through the process, it reduces the noise to the environment. The sound energy is absorbed partly and is turned into other forms of energy. Sound frequency is related to the resonance effect of the material itself. All structures have their own natural frequencies and resonance will occur when the vibrational mode exists similarly. A system can store the energy and transfer it at resonance frequency modes. When the system
is working, the process of energy transfer is expected to lose some energy whereby it depends on the
damping factor. The study of the resonance phenomena is crucial especially when it comes to sound
absorption effect for all kinds of fibres. This is to be able to emphasise on the acoustical/sound properties
and able to make changes for noise control applications. Designing of sound absorber depends on the
frequency or the damping effect of the material. Besides that, the impedance and sound absorption
properties are also affected by the porosity level of the panel itself. For natural fibres sound absorber, it
is believed that by mixing different types of fibres with different length and density will change the
porosity level of the panel. In order to absorb and impedes higher level of noise, it is believed that the
thickness of the sample will affect the sound absorption properties.

In mathematical format, the sound absorption coefficient (SAC), \( \alpha \), can be expressed as equation (1):

\[
\alpha = 1 - \frac{I_R}{I_I}
\]

where \( I_R \) and \( I_I \) are the one-sided intensity of the reflected sound and the one-sided intensity of the
incident sound respectively. SAC varies from 0 to 1.

The use of oil palm wastes for sound absorption has been studied in the past. Or et al. [3] used EFB
and investigated the effects of density, thickness and air gap on SAC. They found that 40 mm and 50
mm samples having density of 292 kg/m\(^3\) have the best SAC of 0.9 in average above 1 kHz. The authors
also found that the performance of EFB is similar to that of rock wools. Samsudin et al. [4,5] studied
mixture of EFB and MF with urea formaldehyde (UF) as the binder. EFBMF acoustic panel using 15%
of UF as matrix binder achieved 0.58 noise reduction coefficient at a density of 0.4 g/cm\(^3\) [4]. In another
research using reverberation room measurement, acoustic panel made from 100% MF coir had the best
A rating according to ISO 11654. This means that the panel could absorb more than 90% of incident
sound [5]. Istana et al. [6] used palm oil fronds and UF as binder and observed to have excellent sound
absorption capability. Nasidi et al. [7] studied the effects of fibre length and UF content on SAC of EFB.
The optimum fibre length was reported to be 2 – 5 mm. In terms of UF content, all samples up to 40%
shown good noise reduction coefficient of 0.70 and above with density of around 0.3 g/cm\(^3\).

As research has shown, oil palm wastes have the capability to be used as acoustic absorber. The aim
of this paper was to investigate the use of EFB and MF, with and without binder, for use as sound
absorbing particleboard according to JIS A 5908.

2. Methodology

2.1. Fibre Preparation

In this research, two types of palm oil residuals, empty fruit bunch (EFB) and mesocarp (MF) fibres,
were obtained from Golconda Palm Oil Mill. The obtained fibres were washed thoroughly with water
and then immersed in water for 24 hours to remove all the impurities. After that, the fibres were sun-
dried for 2 to 3 days. The dried fibres then undergone separation process to remove the kernel shells and
other impurities from the fibres.

2.2. Sample Fabrication

The weight of the fibres was measured before placing into the mould for hot compression. For the sound
absorber mixed with binder, the weight ratio of binder to fibres was 15:100. The binder used was Urea
Formaldehyde (UF) resin, UF 252, obtained from S.A. Wood Chemicals Sdn. Bhd.

A cylindrical mould with a diameter of 100 mm was used to produce the samples. A hot press was
used to compress the samples at a temperature of 180 °C and a pressure of 9 MPa for 10 minutes. The
amount of EFB, MF and UF used are shown in table 1. For each sample, a total of three specimens were
prepared for testing. The density of the samples was calculated by measuring the mass and the volume
of each sample and shown in table 1. The density of samples without binder is targeted to be 0.30 g/cm³ whereas that with binder at 0.50 g/cm³. The thickness of the samples is remained constant at 30 mm and 20 mm for samples without and with binder respectively.

Table 1. Sample composition and measured average density of three samples.

| Sample                | Composition | Density (g/cm³) |
|-----------------------|-------------|-----------------|
|                       | EFB (%)     | MF (%) | UF (%) |                |
| 100MF                 | 0           | 100    | 0      | 0.28            |
| 100EFB                | 100         | 0      | 0      | 0.27            |
| 50EFB50MF             | 50          | 50     | 0      | 0.30            |
| 100MF+UF              | 0           | 100    | 15     | 0.49            |
| 100EFB+UF             | 100         | 0      | 15     | 0.48            |
| 50EFB50MF+UF          | 50          | 50     | 15     | 0.48            |

2.3. Sound Absorption Coefficient Measurement

The SAC of the samples was measured using B&K impedance tube kit type 4206 according to ISO10534-2, i.e. the two microphones transfer function method. During the testing, a sample was placed in the opposite end of the sound wave source generator. The measurement frequency was set to 200 – 2000 Hz. Distance between microphones and distance to samples were 50 mm and 210 mm respectively. All necessary calibrations were carried out before starting the measurement.

2.4. Noise Reduction Measurement

Noise reduction measurement was carried out to assess the ability of the sound absorber to reduce noise. It consists of a PVC tube covered with fabric to reduce the effect of noise from the environment. Two covers were made using epoxy to cover the ends of the tube. The white noise source was generated using NCH Tone Generator software with a frequency range 200 – 2000 Hz. Sound level meter, Lutron SL-4011, was used to measure the noise. The background noise generated for this test was 110.8 – 108.7 dBA. Noise reduction is the difference between background noise generated and the measured noise.

2.5. Swelling in Thickness Test

Swelling in thickness test was carried out according to JIS A 5908 for samples with UF binder. This is an important parameter for particleboard. All samples were prepared as before and then cut into 50 x 50 mm cube. The samples were immersed horizontally 30 mm below water surface for 24 hours. The thicknesses of the samples were recorded before and after immersion. The percentage of swelling in thickness after immersion in water is calculated using equation (2).

\[ \text{Swelling in thickness after immersion in water} = \frac{t_2 - t_1}{t_1} \times 100\% \]

where \( t_1 \) (mm) and \( t_2 \) (mm) are thickness before and after immersion in water respectively.

3. Results and Discussion

3.1. Manufactured Samples

The samples produced are shown in figure 1. As seen in the figure, the samples are of good quality. However, 100MF samples were too soft due to the fine diameter of the fibres and could not be made into shape properly for acoustic testing. Figure 1(a) is the cylindrical sample with a diameter of 100 mm for SAC measurement whereas figure 1(b) are the samples cut into 50 x 50 mm for swelling in thickness test.
3.2. Sound Absorption Coefficient

Figure 2 shows the SAC of different samples for the frequency range 200 – 2000 Hz. Samples made from 100% MF (100MF and 100MF+UF) were not tested as mentioned before. All the samples, with and without binder, show the highest SAC at frequencies between 1200 – 1400 Hz. For samples with binder, the SAC was around 0.694 – 0.699 whereas for that without binder, the SAC was around 0.983. Addition of UF binder lowers the maximum SAC by around 29%. This is because the binder reduces the porosity of the samples, which is essential for sound absorption. Comparing between 100EFB and 50EFB50MF samples, the mixed fibres samples have improved sound absorption capability, increasing the SAC by a maximum of 10% at 800 Hz. As MF fibres have smaller diameter compared to EFB, the compactness of the samples produced enhanced the SAC.

Figure 1. Samples of the particleboard for (a) SAC measurement and (b) swelling in thickness test.

Figure 2. SAC of samples with and without UF binder for the frequency range 200 – 2000 Hz.
The SAC obtained are comparable to or better than synthetic materials such as mineral wool and polystyrene foam as shown in figure 3. Polystyrene foam has the lowest SAC, ranging from 0.041 – 0.514 at 200 – 2000 Hz. Comparing mineral wool and 50EFB50MF, both are comparable up to 800 Hz, after which SAC of 50EFB50MF are higher than mineral wool. Therefore, oil palm wastes have the potential to replace existing material for sound absorption.

![Figure 3](image.png)

**Figure 3.** Comparison of SAC for 50EFB50MF, mineral wool and polystyrene foam for the frequency range 200 – 2000 Hz. All samples are 30 mm thick.

### 3.3. Noise Reduction

Noise reduction results are shown in table 2. All the samples have similar noise reduction range between 5.38-5.85 dBA, around 5% decrease from the generated noise. According to the Malaysian Factories and Machinery (Noise Exposure) Regulations 1989, the permissible exposure time at 85 dBA is 16 hours per day. With every increase of 5 dBA above this, the permissible exposure time is reduced to half. Therefore, a reduction in 5 dBA provided by the samples is seen as significant.

| Sample          | Noise Reduction (dBA) |
|-----------------|-----------------------|
| 100EFB          | 5.43±0.37             |
| 50EFB50MF       | 5.85±0.56             |
| 100EFB+UF       | 5.45±0.38             |
| 50EFB50MF+UF    | 5.38±0.12             |

### 3.4. Percentage Swelling in Thickness

Figure 4 shows the percentage of swelling in thickness after 24 hours immersion in water. Samples with 100% EFB show the highest swelling of around 18% whereas MF only samples at around 12%. The mixed samples gave a value of 15.4%. The swelling in MF samples was the lowest because it has finer fibres, allowing the samples to be more compact. Higher compactness reduces the porosity of the samples. Therefore, water cannot easily penetrate through the bonding between the fibres and the binder.
According to JIS A 5908:2003 for particleboard, the maximum allowable value is 12%. Therefore, the current samples are not suitable for use as particleboard. In the future, addition of additives which can reduce swelling could be investigated.

Figure 4. Percentage swelling in thickness after immersion in water for samples with UF binder.

4. Conclusions
This paper aimed to produce sound absorbing particleboard from oil palm wastes. The results obtained have shown that palm oil wastes can be utilised as efficient sound absorbing materials, comparable to or better than the synthetic materials currently used. However, the samples did not pass the swelling in thickness test, which is an important parameter for particleboard. In the future, different ratios of EFB, MF and UF could be investigated. Other green binders could also be looked into to replace UF, resulting in a truly sustainable and green sound absorbing particle board.

5. References
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