

A Review on the Potential of Natural Fibre for Sound Absorption Application

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Abstract. This review covers an alternative material known as natural fibre that can be used to replace synthetic fibre as core material for the production of sound absorber. The review explored natural fibre such as bamboo fibre, arenga pinnata, paddy straw fibre, oil palm mesocarp fibre, and kenaf fibre in terms of acoustic properties such as sound absorption coefficient. It has been found that plenty of research regarding the utilization of natural fibre for sound absorption purposes have been accomplished. The implementation of natural fibre in producing sound absorber brings many environmental benefit as it is much greener compared to existing material such as synthetic fibre. Apart from that, natural fibre does not impose any serious health effect compared to the existing synthetic fibre.

1. Introduction

It is not surprising at all for the fact that the needs of natural fibre to substitute synthetic fibre such as glass wool and rock wool has been widely discuss among acoustician today. This is due to the fact that synthetic fibre produces harmful floating dust particles, imposing serious negative effect to our health such as lung cancer after a prolong exposure [1]. Also, the production of synthetic fibre is very harmful to the environment as well due to the reason that they are made from high temperature industrial processes such as hot extrusion, and the source of synthetic fibre are often taken from petrochemical sources, thus produces a significant amount of carbon footprints [2]. The downside of synthetic fibre causes divert of attention towards the usage of natural fibre as core material for the production of sound absorber. First and foremost, natural fibre has been known as a green material because of its biodegradability. Natural fibre also known to be lower in terms of density compared to synthetic fibre, cheaper, abundance, and most importantly, it is renewable. Apart from that, natural fibre processing is also more economical and greener towards environment compared to synthetic material due to the advancement of modern technology. Furthermore, natural fibre is also much safer for our health compared to synthetic fibre as it does not require any handling precautions. Production of natural fibre involves significantly lower carbon footprint compared to synthetic fibre [2]. Therefore, natural fibre has been categorized as ecologically green material, and may hold the key for an alternative solution to produce greener sound absorber in the future.

2. Natural fibre as porous sound absorbing material

Porous sound absorbing material is usually stiff and possess cavities which contributes to the level of porosity of the structure that can be fully utilized to “trapped” sound wave within the structure, allows



internal reflection of sound and eventually causes acoustical energy loss [3]. Porous sound absorbing materials are usually effective in absorbing sound for medium-high frequency range. Plenty of research has been done by many scholars around the world regarding the possibility of using natural fibre as sound absorbing material due to its low density and high level of porosity, which is very essential for sound absorption mechanism in dissipating the acoustical energy within the structure [4].

2.1. Bamboo Fibre

The idea of using bamboo fibre from natural resource arises in order to protect human health and also the environment. Bamboo fibre can be considered as a renewable source due to the fact that bamboo can be harvested every year as young bamboo tends to grow in a significantly fast manner [5]. Aside from that, bamboo is also known for its biodegradability and thus does not inflict any environmental pollution [6]. It can also be burned due to the fact that it does not release any harmful gases that could harm our health. All these properties caught the interest of several researcher to study the acoustic properties of bamboo fibre as it might hold a great potential in producing a better and greener sound absorber. T. Koizumi, N. Tsujiuchi, and A. Adachi studied the sound absorption coefficient of bamboo fibre according to thickness, air gap, diameter of bamboo fibre, and as well as the apparent density of the fibre [7].

2.1.1. Thickness of Bamboo Fibre

Figure 1 shows the sound absorption coefficient of bamboo fibre with thickness of 25mm, 50mm, and 75mm respectively. As the thickness of the sample increases, the sound absorption coefficient for all range of frequencies increases as well. Based on the result obtained, it can also be seen that variation of thickness affects the peak sharpness. The thicker the bamboo fibre sample, the lower the peak frequency will be as can be seen from Figure 1. According to the results once again, when the sample gets thicker, the frequency for peak absorption reduces as well, thus increasing the effectiveness of absorbing sound at a lower and medium frequency.

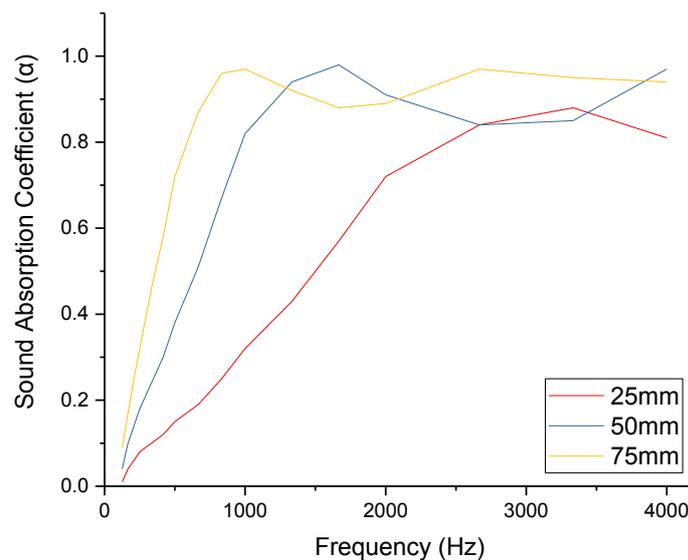


Figure 1. Sound absorption coefficient of bamboo fibre for thickness of 25mm, 50mm, and 75mm [7]

2.1.2. Diameter of Bamboo Fibre

Figure 2 shows the sound absorption coefficient of bamboo fibre according to the diameter of the fibre itself, 90-125 μm , 125-210 μm , and 210-425 μm respectively. For the case of variation in terms of diameter of fibre, as the diameter of the bamboo fibre decreases, the sound absorption coefficient of the sample increases. This is due to the reason that when the diameter of the bamboo fibre decreases, the porosity of the sample increases. The greater the porosity of the sample, the greater the value of sound absorption coefficient for the sample will be. When a sound wave strikes a porous sound absorber, the sound wave will be trapped inside the structure and reflects internally, causes energy loss and thus, absorbing sound. However, when a sound wave strikes a less porous material, the sound wave will eventually be reflected right back and thus, reducing the ability to absorb sound [8].

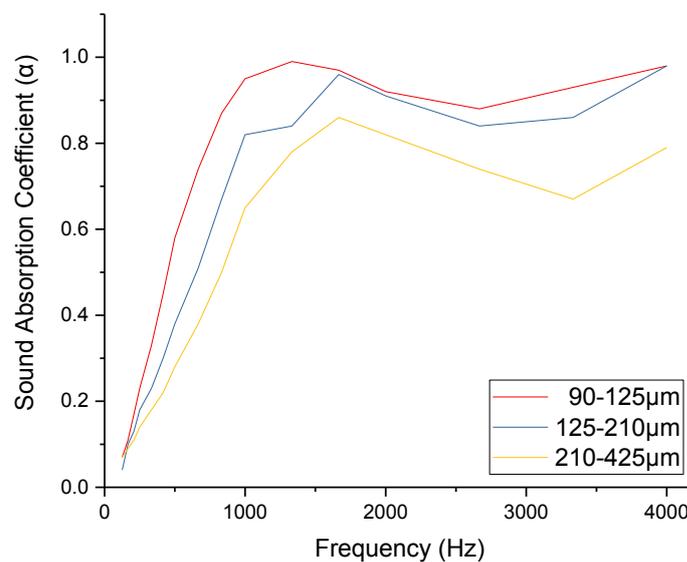
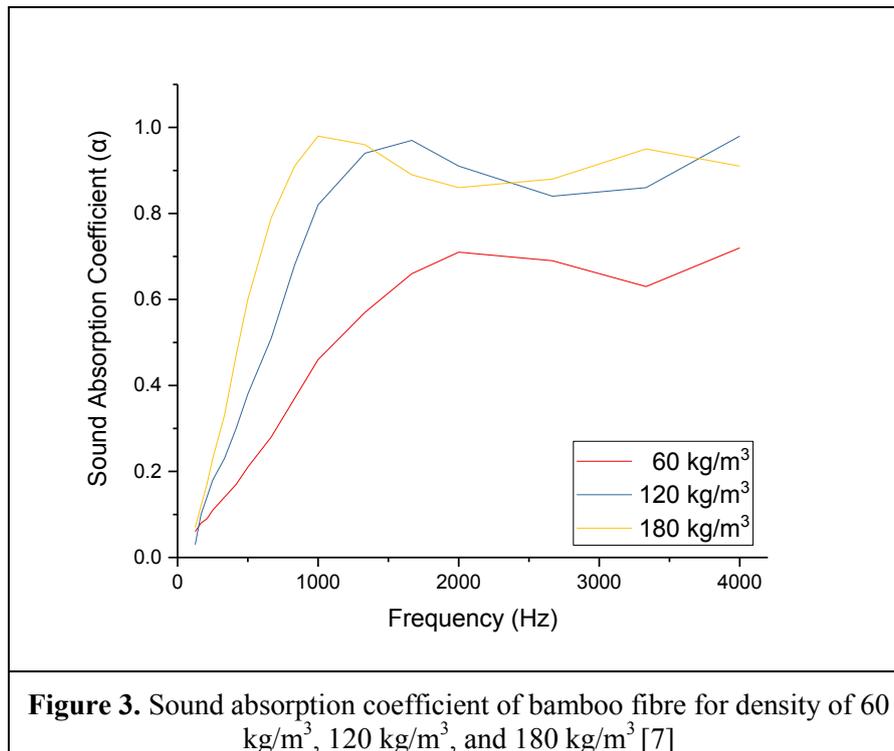


Figure 2. Sound absorption coefficient of bamboo fibre for fibre diameter of 90-125 μm , 125-210 μm , and 210-425 μm [7]

2.1.3. Apparent Density of Bamboo Fibre

Figure 3 shows the sound absorption coefficient of bamboo fibre for the case of variation in terms of apparent density. As the apparent density of the bamboo fibre increases, the sound absorption coefficient of the sample also increases, specifically at medium frequency and high frequency range. This is due to the fact that when the apparent density increases, the number of bamboo fibre per unit area of the sample increases too and thus, porosity increases as well. Due to the increment of surface friction, the loss of acoustic energy happens to be increases as well and therefore contributes to the increment of sound absorption coefficient of the sample [9].



2.2. Arenga Pinnata Fibre

Arenga pinnata can be found abundantly in Southern Asia, especially in Malaysia, Indonesia, and Philippines [10]. Arenga pinnata fibre can be categorized as a renewable source as well due to its abundance in Asia [11]. Lindawati Ismail *et al.* studied the arenga pinnata fibre thoroughly and presented the scientific data of the sound absorption coefficient of the fibre in a very systematic manner. Authors utilized the impedance tube method based on the standard of ASIM E1050-98 to determine the sound absorption coefficient of the arenga pinnata fibre. Arenga pinnata fibre was cylindrically shaped based on the size of the impedance tube, 100mm in diameter to cover up the measurements for frequency range between 150 Hz and 1600 Hz, and 28mm in diameter to cover up the measurements for frequency range between 1200 Hz and 6000 Hz [12]. All the samples were prepared in four different thickness, 10mm, 20mm, 30mm, and 40mm respectively. From Figure 4, it can be observed that arenga pinnata shows promising results of sound absorption coefficient. As the thickness of the sample increases, the sound absorption coefficient of the arenga pinnata fibre increases as well. The result shows that the sound absorption coefficient was at its best when the sample thickness was 40mm thick, where the optimum sound absorption coefficient value of 0.88 has been obtained at high frequency. Generally, porous material is known to exhibit poor sound absorption coefficient at lower frequency range, which can also be seen from the result obtained for arenga pinnata fibre, where the sound absorption coefficient is lower than 0.2 when frequency is less than 500 Hz [13]. Nonetheless, based on the result obtained, arenga pinnata fibre is a promising raw material that can be used for the production of a greener sound absorber compare to the existing sound absorber which is made out of synthetic fibre that may inflict negative effect towards the environment and to our health.

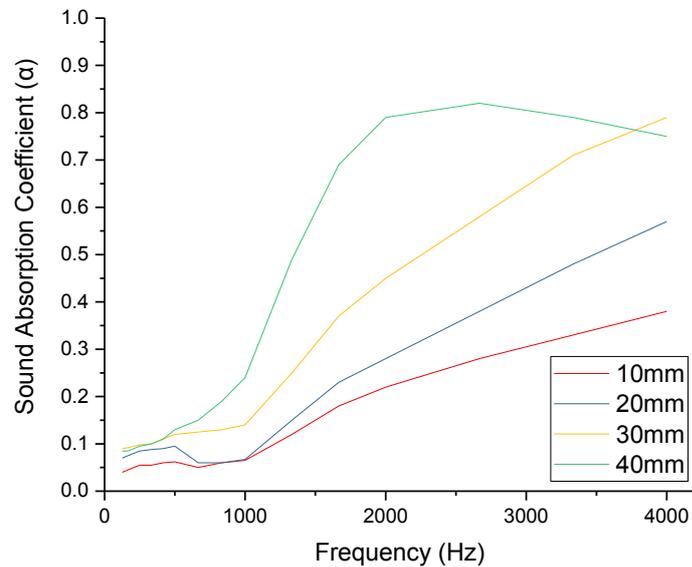


Figure 4. Sound absorption coefficient of arenga pinnata for thickness of 10mm, 20mm, 30mm, and 40mm [12]

2.3. Paddy Straw Fibre

Asian countries are rich with abundant resources of natural fibre, and paddy straw fibre is one of the example. Y. Abdullah *et al.* studied and determined the sound absorption coefficient of dried paddy straw fibre by employing the impedance tube method, based on ISO 10534-2 (2001) international standards [14]. Authors prepared two different samples with different composition of carboxymethyl cellulose (CMC), which will be used as binder in order to increase the strength property of the sample.

Table 1. Weight ratio of binder, bowing agent, and filler against paddy straw fibre [14]

No	Separation energies				
	Paddy	CMC	Al ₂ O ₃	Gypsum	H ₂ O
1	1	0.05	2	2	Depends
2	1	0.10	2	2	Depends

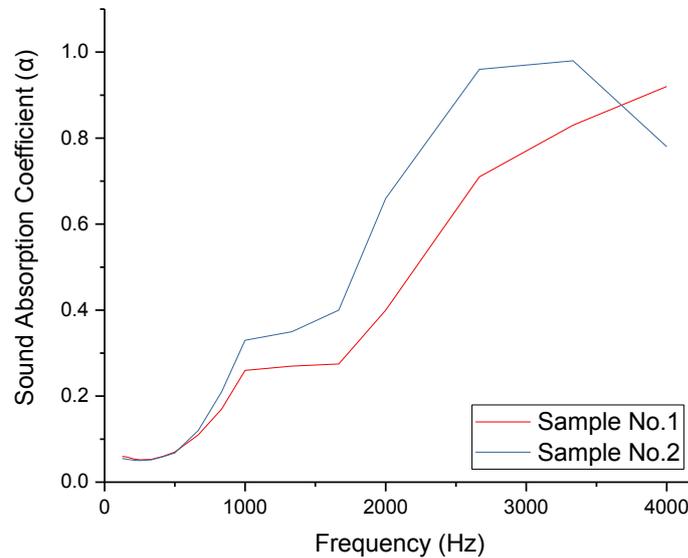


Figure 5. Sound absorption coefficient of paddy straw fibre for sample No.1 and sample No.2 [14]

Table 1 shows CMC weight ratio and the blowing agent, consist of gypsum and water, as well as aluminium oxide that act as filler. Figure 5 shows the result of sound absorption coefficient of both samples in comparative manner. For both samples, it has been found that the sound absorption coefficient is quite poor when the frequency is lower than 1500 Hz, where the sound absorption coefficient is less than 0.5. The sound absorption coefficient increases for both samples when the frequency is above 2000 Hz, where the average sound absorption coefficient is approximately between 0.8 and 0.9. The presence of CMC affects the performance of sound absorption where the sound absorption coefficient deviated towards lower frequency when the CMC composition increases, thus reducing the performance of sound absorption at high frequency. This is due to the matter that the stronger the binding between fibres, the more likely the dispersion of acoustic energy to be monopolized by overall vibration of the entire sample structure, instead of vibrating locally if the binding is weak [2]. Hence, in a simpler manner, the sound absorption coefficient at lower frequency can be increased through the increment of CMC composition for the case of paddy straw fibre.

2.4. Oil Palm Mesocarp Fibre

Hanif Abdul Latif *et al.* studied the potential of oil palm mesocarp fibre in absorbing sound as the cost required to acquire mesocarp fibre is low [15]. Aside from low cost, mesocarp fibre also can be found abundantly in Asian country, especially in Malaysia and Indonesia due to the drastic increase of palm oil industry in order to fulfil international market demand [16]. Mesocarp fibre exhibits low density properties and most importantly, it is renewable and biodegradable [17]. Authors employed impedance tube method according to ASTM E1050-09 standard, in order to determine the sound absorption coefficient of mesocarp fibre sample. Mesocarp fibre has been mixed with polyurethane (binder) with 70:30 ratio. Sample with different thickness, 10mm, 200mm, 30mm, and 40mm were prepared and was cylindrically shape with diameter of 28mm to cover up high frequency measurements (125 Hz to 1600 Hz) and 100mm in diameter to cover up low frequency measurements (1200 Hz to 6000 Hz) [15]. Figure 6 shows the result of sound absorption coefficient for all mesocarp fibre samples with different thickness.

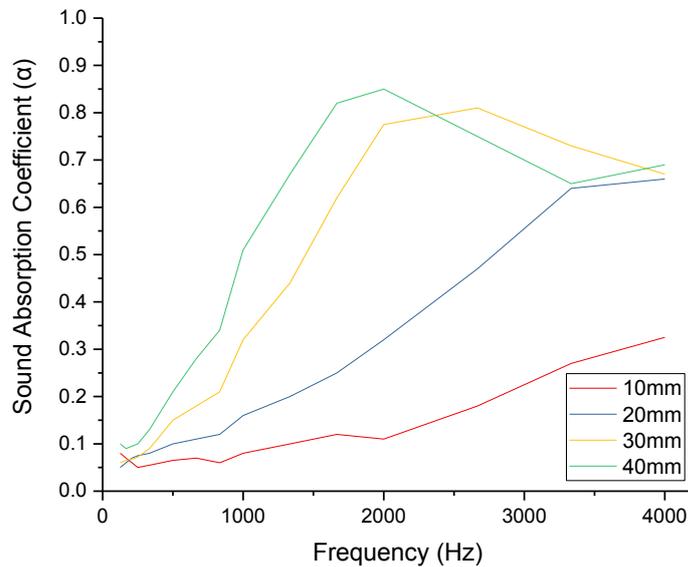


Figure 6. Sound absorption coefficient of oil palm mesocarp fibre for thickness of 10mm, 20mm, 30mm, and 40mm [15]

It has been found that mesocarp fibre is an excellent sound absorbing material with the optimum sound absorption coefficient 0.93 for 40mm thick sample at 500 Hz of frequency. When the sample thickness increases, the sound absorption coefficient increases too, specifically at frequency range from 100 Hz to 1000 Hz. The result clearly shows that mesocarp fibre is indeed a porous material. Acoustic energy can enter through porous material easily and the fact that sound with lower frequencies will tend to pass through porous material effortlessly, compared to sound with higher frequencies [2].

2.5. Kenaf Fibre

Kenaf, or scientifically known as *Hibiscus Canabinus*, is a type of hibiscus plant that can be found abundantly in southern Asia [18]. Kenaf is known to be very light and porous with bulk density between 0.10 to 0.20 g/cm³. Aside from that, kenaf fibre has been proven to be biodegradable and does not impose any harm to the environment, nor to our health too [19]. All these qualities caught the interest and attention of many scholars to study the acoustical properties of this natural fibre. Research on the sound absorption of kenaf fibre has been done by Z. Y. Lim *et al.* and result shows that it has a huge potential to be used as material for producing acoustic panel. Impedance tube method was utilized in obtaining the sound absorption coefficient of the kenaf fibre samples [20]. Figure 7 shows the result for sound absorption coefficient of kenaf fibre with thickness of 10mm, 20mm and 30mm respectively [20]. For the sample thickness of 10mm, the sound absorption coefficient is greater than 0.5 when the frequency of sound is more than 3500 Hz. As for the sample of 30mm thickness, when the frequency of sound is more than 1000 Hz, the sound absorption coefficient obtained is greater than 0.5 and about 2000 Hz of frequency, the sound absorption coefficient almost equals to unity. From the results obtained, the greater the thickness of the kenaf fibre sample, the greater the sound absorption coefficient will be at lower frequencies.

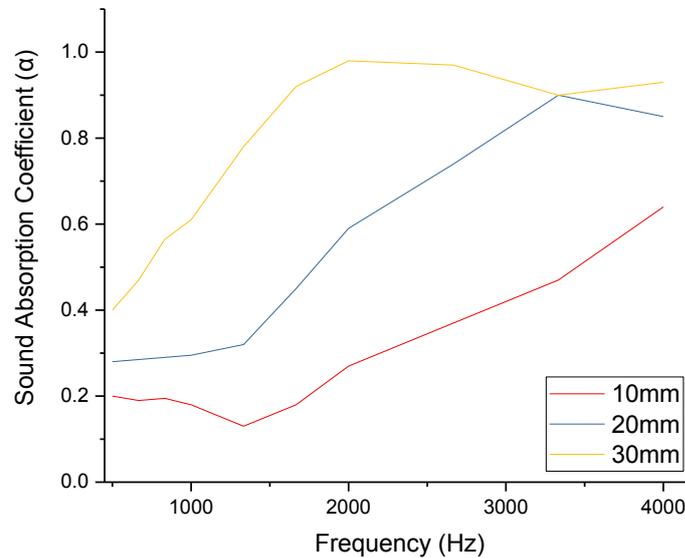


Figure 7. Sound absorption coefficient of kenaf fibre for thickness of 10mm, 20mm, and 30mm [20]

3. Discussion

Based on the review that has been done, there are several methods that can be applied to further improve the sound absorption coefficient of natural fibre. For instance, if all the thickness of natural fibre mentioned are the same, it is most likely that kenaf fibre will outperform the rest of the natural fibre in absorbing sound, especially at low frequency range. As can be seen from the results, the sound absorption coefficient of kenaf fibre is more than 0.2, specifically at 500 Hz of frequency. Meanwhile, the rest of the natural fibres could not surpass kenaf fibre in absorbing sound at low frequency range, where the sound absorption coefficient is less than 0.2. It is very interesting to see that natural fibre such as kenaf fibre has the capability to absorb sound at low frequency range effectively. However, the sound absorption performance of natural fibres can be further enhance by tweaking parameter such as density, thickness, and diameter accordingly. As can be seen from the results for sound absorption coefficient of bamboo fibre, when all the parameters mentioned increase, the sound absorption coefficient also increase at most of the frequency range. Thus, all these parameters could be used to produce a better sound absorber that can absorb sound effectively at specific range of frequency.

4. Conclusion

Considering all the review that has been described, it can be concluded that natural fibre does hold a huge potential to be used as raw material for the production of sound absorber, replacing the existing sound absorber which is mainly made out of synthetic fibre that could be very harmful to the surrounding environment and as well as towards our health. The utilization of natural fibre for the production of sound absorber can promote many environmental and health benefits that synthetic fibre could not offer. Apart from the fact that natural fibre is biodegradable and renewable, it also possesses good sound absorption qualities that has been proven experimentally. Thus, natural fibre could be the answer for the production of green sound absorber in order to preserve our environment without neglecting our health concern.

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