Experimental investigation of sound absorption properties of perforated date palm fibers panel

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Abstract. This paper presents the sound absorption properties of a natural waste of date palm fiber perforated panel. A single layer of the date palm fibers was tested in this study for its sound absorption properties. The experimental measurements were carried out using impedance tube at the acoustic lab, Faculty of Engineering, Universiti Kebangsaan Malaysia. The experiment was conducted for the panel without air gap, with air gap and with perforated plate facing. Three air gap thicknesses of 10 mm, 20 mm and 30 mm were used between the date palm fiber sample and the rigid backing of the impedance tube. The results showed that when facing the palm date fiber sample with perforated plate the sound absorption coefficient improved at the higher and lower frequency ranges. This increase in sound absorption coincided with reduction in medium frequency absorption. However, this could be improved by using different densities or perforated plate with the date palm fiber panel.

1. Introduction

Vegetable fiber is one of the varieties of natural fibers obtained from stems, leaves, roots, fruits and seeds of plants. However, from commercial and technological points of view, cotton, kenaf, sisal, flax, palm, coir, arecanut and banana fibers acquire utmost significance, since reinforced plastics, strings, cords, cables, ropes, mats, brushes, hats, baskets and fancy articles such as bags are manufactured with those fibers [1].

The date palm (Phoenix dactylifera) is one of the most cultivated palms around the world. It geographically covers the deserts from the Atlantic coastline of Mauritania to India and from the Mediterranean Sea to about 15° in Africa. The main date-producing countries of the world are Iraq, Saudi Arabia, Egypt, Iran, Algeria, Pakistan and the Sudan. The date palm in Sudan is common in the Northern Sudan along the Nile [2]. Date palms have a fibrous structure, with four types of fibers: leaf fibers in the peduncle, baste fibers in the stem, wood fibers in the trunk and surface fibers around the trunk [3]. Riahi et al. [4] investigated the application of date-palm fibers filters as porous medium for the tertiary domestic wastewater treatment. Al-Sulaiman [5] evaluated the performance of the date palm fiber as wetted pads in evaporative cooling.

Most practical sound absorbing products used in the building construction industry consist of glass or mineral-fiber materials. However, the growing concern about the potential health risks popularly seen as being associated with glass or mineral fiber materials provides an opportunity to develop for sound absorption panels made of natural fibers. Many researches have been conducted in developing particle composite boards using agricultural wastes [6,7]. Yang et al. reported that the sound absorption coefficient of rice straw-wood particle composite boards are higher than other wood-based
materials in the 500-8000 Hz frequency range, which is caused by the low specific gravity of composite boards, which are more porous than other wood-based materials [6]. From the view of environmental protection, natural bamboo fibers were used for sound absorbing purposes. Impedance tube measurement of the bamboo fiber samples, revealed similar properties to that of glass wool. Bamboo material formed into a fiber board yields a superior sound absorption property when compared to plywood material of similar density [8]. Ersoy and Kucuk [9] experimentally investigated the sound absorption feature of tea leaf fiber as an industrial waste material. The good acoustic absorption aspect of that fiber with respect to other absorbers was noticed. Coconut is one of the most important harvests in Malaysia. Coir fiber from coconut husk is one of the hardest natural fibers having high amount of lignin. The sound absorption attribute of coir fiber was investigated previously in Automotive Research Group laboratories, Universiti Kebangsaan Malaysia. Those studies covered experimental observations in reverberation room [10] and using impedance tube [11].

The acoustic properties of panels can be improved by using perforated plate design. Davern [12] investigated the effect of the airspace layers, perforated plate, and porosity on the acoustic properties of materials. He found that the porosity of the perforated plate and the density of the porous material would significantly affected the acoustic impedance and sound absorption coefficient of the panel, in which case, the frequency band near the resonance frequency achieved high acoustic absorption. Lee and Chen [13] found that the acoustic absorption of multilayer materials is better with a perforated plate backed with airspaces. Fouladi et al. [14] studied the enhancement of coir fiber acoustical absorption using perforated plates and air gap layers.

The research on the acoustical properties of the date palm fibers started at the University of Khartoum [15]. The sound absorption coefficient of the date palm fiber was simulated using Delany and Bazley model based on the flow resistivity of the fibers. Elwaleed et al. [16] studied experimentally the variation of sound absorption coefficient against frequency for date palm fiber sample at normal incidence as measured by the impedance tube (Figure 1). They studied the effect of effect of varying the air gap distance, between the date palm fiber sample and the back wall, on sound absorption coefficient. It can be seen that introducing air gap between the sample and the rigid backing of the impedance tube can be useful for increasing the absorption coefficient at some lower frequencies range.

The aim of this research is to study the effect of using perforated plate on the sound absorption of date palm fiber.

![Figure 1. Absorption coefficient for the date palm fiber with and without air-gap](imagePath)
2. Materials and Methods

2.1. Date Palm Fiber (DPF)

The fiber is collected from amplexicaul, the sheathing leaf base, which surrounds the stem. It has a netted structure, which is covered by soft or ground tissues (Figure 2). The amplexicaul is carefully collected from the tree. It is dried in shade at room temperature for a period of two days in order to remove any excess moisture content. The pulp (parenchyma) which is present on the individual fiber is removed by combing. Finally, the fiber is scraped to remove the pulp completely. Numbers of 30 samples were selected to obtain an average value for density and fiber diameter. The average diameter and the average density of the fibers are 0.408 mm and 919 kg/m$^3$, respectively.

Two plastic molds were fabricated to prepare samples of two different sizes equivalent to the diameters of the impedance tubes to cover the low and high frequency range of measurements. Figure 3 shows the plastic molds and samples of date palm fibers. The thickness and the density of the prepared samples are 30 mm and 77 kg/m$^3$, respectively.

![Figure 2. Date palm amplexicaul](image1)

![Figure 3. Plastic molds and date palm fiber samples](image2)

2.2. Experimental Measurement in Impedance Tube

The experiment was conducted using two impedance tubes of 28 mm and 100 mm diameters, noise generator, two channel data acquisition system 01 dB, two ¼ in microphones type GRAS-40BP in each tube, software package SCS8100. The measurements were made based on ISO 10534-2 standard [17]. The microphones’ sensitivity was calibrated using calibrator type GRAS-42AB at 114 dB level and 1 kHz. Photo of the system is shown in Figure 4. Noise generator transmitted a random noise into the tubes. Interior sound pressure spectrum was measured by the two microphones and transfer functions between them were calculated. The acoustical absorption coefficient was calculated from these transfer functions and distances between the microphones and date palm fiber sample. The frequency span of experiment was 100–5000 Hz with 3 Hz resolution. Before running the experiment the two impedance tube microphones were calibrated relatively to each other using the standard switching technique. This was based on mounting the sample in the sample holder and conducting the measurement to make sure that the sound field inside the tube is well defined.
Perforated plate (PP) was used to enhance the sound absorption of the fiber. The PP used in this study was made of Aluminum (Figure 5). The experiment was conducted for the panel without air gap, with air gap and with PP facing. Three air gap thicknesses of 10 mm, 20 mm and 30 mm were used between the date palm fiber sample and the rigid backing of the impedance tube. Figure 6 shows a sketch of the set-up used for the measurement of the sound absorption of the sample and the PP inside the impedance tube. The flowchart of Figure 7 shows the method of running the experiment.
3. Results and Discussion

The effect of using perforated plate facing on the sound absorption of the palm date fiber is shown in Figure 8. It can be observed that the sound absorption coefficient increased between 1000 Hz and 3000 Hz by shifting the peak toward the lower frequency range. However, the sound absorption coefficient decreased above 3000 Hz and the peak decreased by 4%.

![Figure 8. Absorption coefficient for the date palm fiber with and without air-gap](image)
The results from Figure 9 show the sound absorption for the palm date fiber with rigid backing, PP facing, 10 mm air gap backing and a combination of PP facing and 10 mm air gap backing. The results show that the best performance for improving the sound absorption at the low frequency range can be obtained using the palm date fiber combined with the PP facing and the 10 mm air gap backing. However, this is coincided with a decrease in the sound absorption at the medium frequency range.

Further increasing the air gap thickness between the date palm fiber and the impedance tube rigid backing results in more improvement in the sound absorption of the date palm fiber in the lower and higher frequency ranges (Figure 10). It can be seen that increasing the air gap thickness can be useful for increasing the absorption coefficient at some lower frequencies range. The general indication is that air-gap shifts the resonance absorption towards the low frequency range. Below 1500 Hz frequency there is improvement in sound absorption coefficient for all air gap thicknesses. It can be observed that the increase in the air gap thickness moved the peaks toward lower frequencies and improved the low frequencies absorption and above the 4000 Hz (Figure 10). However, that increase coincided with reduction in medium frequency absorption. Table 1 shows the increase of the sound absorption coefficient at 1257 Hz for all air gap thicknesses. At this frequency the increase of the air gap by 10 mm, 20 mm and 30 mm increase the sound absorption coefficient by 31%, 61% and 64%, respectively. As reported by Fatima and Mohanty [18] this increase is due to loss of acoustical wave energy of transmitted wave in the presence of sample-air passage and of reflected wave from rigid backing, through air-sample passage in the propagation of acoustical wave.
Figure 10. Absorption coefficient for the palm date fiber with PP facing for different air gap backing thicknesses

Table 1. Effect of increasing the air gap on the sound absorption coefficient for palm date fiber with PP facing

| Air Gap (mm) | Absorption Coefficient at 1257 Hz | Increase of Absorption Coefficient at 1257 Hz (%) |
|--------------|----------------------------------|-----------------------------------------------|
| 0            | 0.28                             | -                                             |
| 10           | 0.39                             | 31                                            |
| 20           | 0.45                             | 61                                            |
| 30           | 0.46                             | 64                                            |

4. Conclusions
Improvement of sound absorption of date palm fiber using perforated plate was investigated in this study. A constant thickness sample was considered in this study. An enhancement in the sound absorption in the lower frequency range was achieved by facing the sample with a perforated plate and backing the sample with air gap of different thicknesses of 10 mm, 20 mm and 30 mm. The increase in the air gap thickness moved the peaks toward lower frequencies and improved the low frequencies absorption and above the 4000 Hz. However, that increase coincided with reduction of absorption in medium frequency range. The performance of the date palm fiber can be improved by increasing the density of the sample and using plate of different perforation.

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