Applied Acoustics 136 (2018) 9–15

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Technical note

Sound absorption of extracted pineapple-leaf fibres

Azma Putra[a,*], Khai Hee Or[a], Mohd Zulkefli Selamat[b], Mohd Jailani Mohd Nor[a], Muhamad Haziq Hassan[b], Iwan Prasetiyo[c]

[a] ViBRO Research Group, Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal 76100, Melaka, Malaysia
[b] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, Durian Tunggal 76100, Melaka, Malaysia
[c] Acoustic Laboratory, Department of Engineering Physics, Institut Teknologi Bandung, Ganesha 10, Bandung 40132, Indonesia

ARTICLE INFO

Keywords:
Sound absorber
Acoustic material
Natural fibres
Pineapple leaf fibres
Sound absorption coefficient

ABSTRACT

This paper reports the utilisation of fibres from the pineapple leaf (PALF) to be an alternative natural acoustic material. We fabricated samples from raw pineapple leaf fibres with different densities and thicknesses to observe their effects on the sound absorption characteristic. Measurement was conducted for the normal incidence sound absorption coefficient in an impedance tube based on ISO 10534-2. It reveals that the pineapple leaf fibres can achieve sound absorption coefficient of 0.9 on average above 1 kHz by controlling the densities of the fibres and/or by introducing the air gap behind the samples. It is also demonstrated that the sound absorption performance is similar to that of the commercial rock wool fibres and synthetic polyurethane foam.

1. Introduction

1.1. Sound absorbers from natural materials

According to World Health Organization (WHO), noise pollution contributes as the source of heart attacks besides annoyance and sleep disturbance [1,2,3,4]. In order to overcome such problems, an effective and efficient noise control is therefore applied. Sound absorber is one of the important elements in industrial noise control system to reduce the radiated sound energy through visco-thermal effect. The application is also commonly found in buildings to control the quality of acoustics inside a room where speech intelligibility is important. Common absorbers found in practice are fibrous porous materials like foam, glass wool and rock wool. It has been known that such materials have good sound absorption performance at mid to high frequencies where the absorber thickness is equal to a quarter wavelength. Apart from these absorbers, resonance based absorbers are also employed which is effective to reduce the acoustic energy at lower frequencies with limited absorption bandwidth.

Besides their acoustic performance, commercial fibrous porous materials are also known for their superiority in terms of their durability, thermal conductivity, fire retardancy and fungus growth resistance. However, environmental issues becomes the main concerns. Life Cycle Assessment (LCA) is a *cradle-to-grave* approach which analyses the potential impacts derived from the entire life history of a product ranging from material extraction, production, transport, construction to operating and management, de-construction and disposal, recycling and reuse. From here, parameters relating to environmental pollution are derived, for examples Non Renewable Energy (MJ/kg), Global Warming Potential (kg CO_2 eq.) and Acidification Potential (kg SO_2 eq.). From LCA, the synthetic and mineral materials, e.g. foam glass, glass fibres and mineral wool have been shown to have the highest 'negative' impacts to environment, while natural materials such as coconut fibres, flax fibres and cellulose provide the lowest impact [5].

Since the past ten years, researchers have focused their studies on natural materials. Numerous works on acoustic materials from natural materials have been published. Fouladi et al. [6] measured natural organic multi-layer coir fibres which showed good absorption coefficient of 0.85 in average from 1 kHz. The performance at lower frequency was then improved by adding granular materials from rice-husk grain in the coir fibre sample [7]. Oil palm fibres from the empty fruit bunch have similar characteristic with coir fibres, where they are type of hard fibres with relatively large diameter. The sound absorption of the former has been studied and measurement showed similar sound absorption performance with the coir fibres [8].

Doost-hoseini et al. [9] studied the sound absorption of bagasse fibres. They found that bagasse samples having density of 400 kg/m^3 and 500 kg/m^3 (mixed with binders) can perform with absorption coefficient greater than 0.5 above 1 kHz.

Other natural materials have been shown to also have good sound absorption performance. These include tea-leaf fibres [10,11], paddy

* Corresponding author.
E-mail address: azma.putra@utem.edu.my (A. Putra).

https://doi.org/10.1016/j.apacoust.2018.01.029
Received 14 November 2017; Received in revised form 29 January 2018; Accepted 31 January 2018

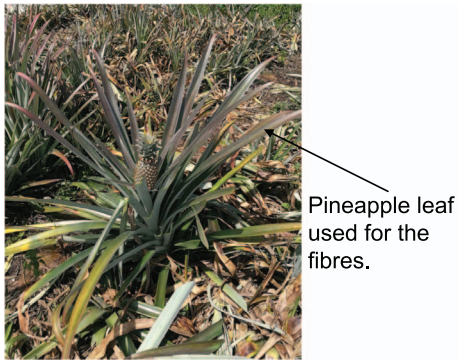

Fig. 1. Pineapple plants at a pineapple farm in Muar, Johor, Malaysia.

fibres [12,13], jute fibres [14], ijuk (Arenga Pinnata) [15], kapok fibres [16], kenaf fibres [17], sisal-kenaf composite [18] and numerous other natural materials in the form of composite.

Besides fibres, natural materials in non-fibrous form have also been demonstrated to be potential acoustic absorbers. Oldham et al. [19] measured the natural hollow-reeds in reverberation chamber. The hollow structures and the pits on the inner structures of reed provide advantages for sound absorbing mechanism. Good absorption coefficient of average 0.8 was recorded up to 4 kHz. The longer the reed, the better the absorption towards low frequencies. A more details study on the hollow-reed plant as sound absorber has been published by Asdrubali et al. [20]. Similar configuration using bamboo materials also showed good sound absorption depending on the length, the diameter of the holes and also the arrangements of the bamboo structures relative to the incoming sound [21].

In this study, we focus our work on pineapple leaf fibres (PALF). The PALF have been reported to have high Young's modulus and tensile strength [22], including its thermal conductivity [23] among other natural fibres. The established works concerned on the PALF as the reinforced fibres in composites [24,25,22]. The fibres are also well known to have high content of cellulose and thus can be used as the source of cellulose nanofibrils for biomedical applications and biotechnological applications [26].

We reported the performance of the PALF as the sound absorbing material, which according to our knowledge, is still lack in discussion. The PALF were placed in a round container and the sound absorption performance was measured using the impedance tube method. The effect of air cavity at downstream side at particular depth were investigated in order to seek some benefits in improving the absorption at low frequencies. Such a combination can extend the absorption capability of the pineapple leaf fibres without mixing them with other material as usually found in composite materials.

1.2. Pineapple leaf fibres

Pineapple (*Ananas comosus*) is a tropical plant having 1–2 m height and belongs to *Bromeliaceae* family. The fruits are famous in variety of cuisines and the fibres from its leaves have long been used for textiles in Phillipines [27]. The species of the pineapple cultivar used in this study is *Moris Gajah*, which is one of the popular pineapple cultivars in Malaysia. The pineapple leaves were obtained from a pineapple farm in Muar, Johor, Malaysia. Fig. 1 shows the pineapple plant where its leaves were utilised as the source of fibres for this study.

2. Preparation of the materials

2.1. Extraction of pineapple leaf fibres

The extraction of the PALF started with the pineapple leaves (Fig. 2(a)) fed into an extraction machine as shown in Fig. 3. In the machine, the pineapple leaves went through rollers, a feed roller and a scratching roller by means of 'grinding' process. Here, parts of the cellulose, waxy layers and water from the pineapple leaves were scrapped and removed. The extracted raw PALF (Fig. 2(b)) was then obtained by pulling the leaves from the extraction machine. A pineapple leaf contains 2.5 to 3.5% of fibres from its total weight [28]. The extracted PALF was then dipped into 1% of sodium hydroxide (NaOH) solution for the alkaline treatment process as shown in Fig. 2(c). This was done to remove the chemical constituents, dirt and any other particles which were attached to the PALF. Finally, the treated PALF (Fig. 2(d)) was obtained by washing the PALF with distilled water and by drying the fibres under the sun to remove the moisture content.

2.2. Sample fabrication

The samples of PALF sound absorber were designed with variation in bulk density and thickness. Thus, the samples can be investigated through the effect of density and the effect of thickness on their sound absorption characteristics. The bulk density of the sample is defined by the mass of the PALF m, over the total volume of the cylindrical shape of the sample V given by $\rho_{bulk} = m/V$. The PALF was weighted and inserted into 33 mm diameter aluminium web casing for sample preparation as shown in Fig. 4. The casing were designed in a cylindrical shape in order to fit into an impedance tube for the measurement of normal incidence sound absorption coefficient. The thickness of the PALF samples was defined through the thickness of the aluminium web casing. No compression was performed for the fibres and therefore the application of this absorber in practice is also aimed to be similar with the arrangement of this test sample. The fibres can also be a layer in front of hard and thick fibre such coir fibre, where arrangement of this multilayer has been found to improve the sound absorption (for the thick fibre) in the mid frequency range [29].

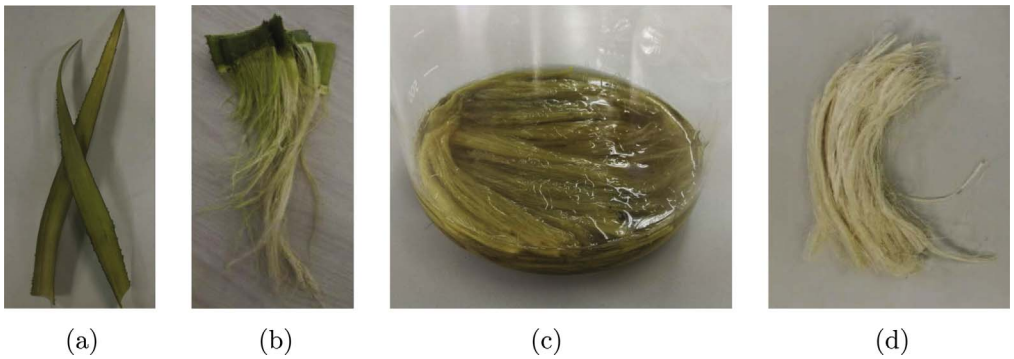

Fig. 2. The extraction of PALF: (a) pineapple leaves, (b) the extracted raw PALF, (c) the PALF treated with 1% of sodium hydroxide (NaOH) solution, and (d) the treated PALF.