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This is a post-refereeing final draft. When citing, please refer to the published version:

H. Koruk, G. Genc, Investigation of the acoustic properties of bio luffa fiber and composite materials, Materials Letters 157, 166-168, **2015**.
<https://doi.org/10.1016/j.matlet.2015.05.071>

Investigation of the acoustic properties of bio luffa fiber and composite materials

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Abstract

Considering the adverse effects of petroleum-based materials on nature, finding and developing new materials as alternatives to these chemical materials become a necessity in practice. On the other hand, these new materials need characterization to be considered and effectively used in practical applications. The acoustic properties of luffa bio fiber and composite materials are investigated in this study. First, the preparation of various luffa test samples and the method for acoustic characterization of the luffa samples is presented. Then, the acoustic absorption properties of both luffa fiber and composite materials are identified using the impedance tube method. After that, the transmission loss levels of the same luffa samples are determined. All the results are evaluated and the acoustic performances of luffa materials are highlighted.

Keywords: Biomaterials; porous materials; luffa fibers; luffa composites; sound absorption; transmission loss.

1. Introduction

The development of natural fibers is vital due to environmental reasons [1-4] and the use of natural fibers has recently received increasing attention [1, 2, 4, 5]. Furthermore, the natural fibers

are quite low cost and the use of bio materials is expected to increase in the future [1-5]. The bio materials and/or their composites including the luffa fibers, that is grown in many regions of the world including southern region of Turkey [6-10], can be used in house hold appliances, automotive and architectural applications [5]. However, there is a need to investigate the behaviors of these new materials and their composites including their acoustic characterization in order to use them as alternative materials to the chemical based materials in practical applications.

Sound absorption properties of polyurethane foams mixed with natural tea leaf and sponge fibers [11], acoustic insulation performance of rice straw-wood particle composite boards [12], sound absorption coefficient and transmission losses of the panels made from natural organic multi-layer coir fiber [13-15] and sound absorption coefficients of tea leaf [16] have been investigated in the literature. However, the acoustic characterization of the luffa fiber and composite materials has not been conducted in the literature [6-16]. Therefore, sound absorption and transmission loss properties of luffa fibers and composites are explored in this paper. The results are evaluated and the acoustic performances of the luffa materials are highlighted.

2. Material and method

There is a need to evaluate whether the luffa fibers, which have negligible structural stiffness, can be used as acoustic materials. It should also be determined that the luffa composites, which may have considerable structural stiffness, can be used both as load carrying members and acoustic materials. Therefore, the acoustic performances of both luffa fiber and composite materials are evaluated in this study.

Here, four different luffa samples are prepared. The first sample is made just from the luffa cylindrica fiber. It should be noted that the luffa material has a special structure in the sense that the fibers are interlocked. The second sample is almost similar to the first sample; however, it is covered with a perforated linen. Instead of using a glue for covering the linen to the fiber sample,

the line is sewed to the sample to prevent the adverse effect of the glue. The third and fourth samples are some luffa composites with the epoxy/luffa volume fraction values being $V_e/V_f = 0.2/0.8$ and $0.4/0.6$, respectively. The luffa material is compressed using a hydraulic press carrying heated plates to perform the desired process for curing the epoxy resin. The prepared luffa test samples are shown in Fig. 1. Here, the thicknesses of luffa fiber samples in Fig. 1a and 1b are $t = 12$ mm and the thicknesses of luffa composite samples in Fig. 1c and 1d are $t = 9$ mm. It should be noted that the test samples shown in Fig. 1 have almost the same amount of luffa material.

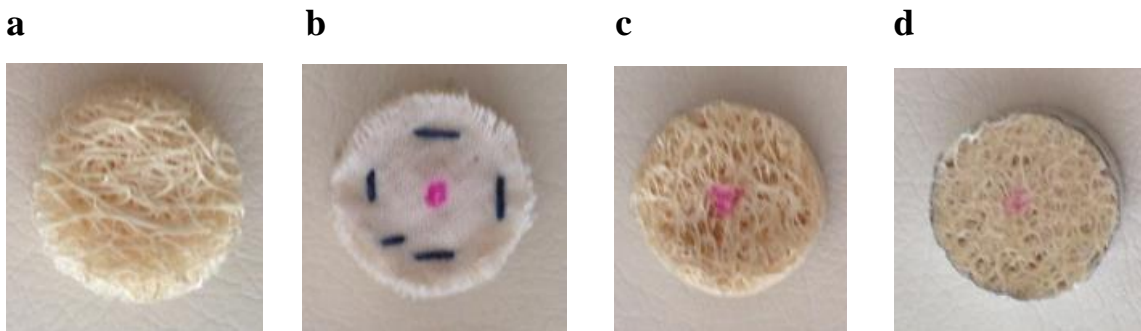


Fig. 1. Luffa test samples: luffa fiber sample (a), luffa fiber sample with a perforated linen (b), luffa composite samples with the epoxy/luffa volume fraction values $V_e/V_f = 0.2/0.8$ (c) and $V_e/V_f = 0.4/0.6$ (d).

The impedance tube method is used to identify absorption properties of luffa materials [17-19]. The schematic of the test setup is shown in Fig. 2 where $d = 29$ mm, $s = 20$ mm and $L = 35$ mm.

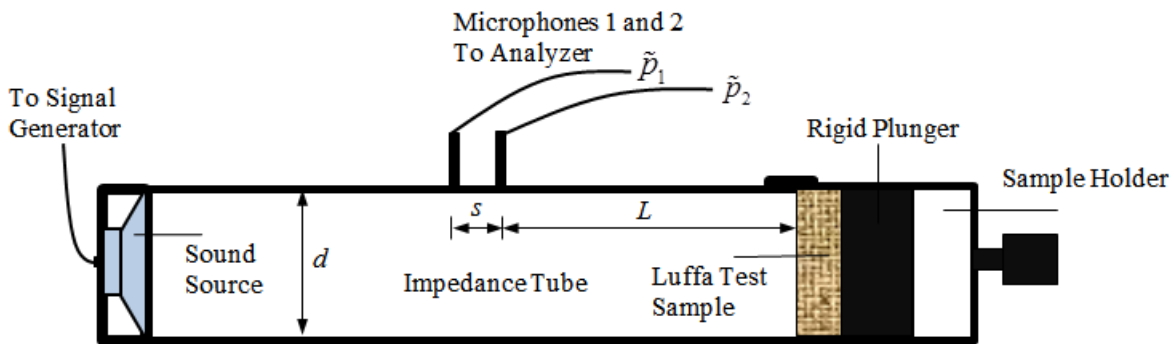


Fig. 2. The impedance tube test setup where two microphones are used to measure sound pressures inside the tube.

In the impedance tube method, the complex valued normal incidence reflection coefficient

$\tilde{R}(f)$ is determined as follows [17]:

$$\tilde{R}(f) = \frac{\tilde{H}_{12}(f) - e^{-jk_s}}{e^{jk_s} - \tilde{H}_{12}(f)} e^{2jk(s+L)} \quad (1)$$

where $\tilde{H}_{12}(f)$ is the complex valued acoustic transfer function from \tilde{p}_1 to \tilde{p}_2 , $k = 2\pi f/c$ is the wave number, c is the speed of sound in the air, f is the working frequency and $j = \sqrt{-1}$. Overall, the sound absorption coefficient at normal incidence is determined as [17-18]:

$$\alpha(f) = 1 - |\tilde{R}(f)|^2 \quad (2)$$

Here, $\tilde{H}_{12}(f)$ is measured and $\tilde{R}(f)$ and $\alpha(f)$ are calculated using Eqs. (1-2). The transmission loss levels of the test samples are determined using the same impedance tube. However, this time, four microphones are used for identification of transmission loss values of the test samples [19].

Overall, the main objectives of this study are as follows: (i) Prepare some luffa fiber and composite samples; (ii) determine the sound absorption properties of the fiber and composite samples; (iii) identify the transmission loss levels of the same luffa samples; and (iv) evaluate the acoustic performance of the luffa materials and highlight their superior features.

3. Results and discussion

The identified sound absorption coefficients (α) of the luffa fiber and composite samples in Fig. 1 are presented in Fig. 3. It is seen that the sound absorption coefficients of the luffa composite sample with a high epoxy ratio (i.e., $V_e/V_f = 0.4/0.6$) are lowest as expected. However, the α values of the luffa composite sample with a low epoxy ratio (i.e., $V_e/V_f = 0.2/0.8$) are close the results of the luffa fiber sample. Furthermore, the α values for the luffa composite sample with a low epoxy ratio are slightly higher than the results of the luffa fiber sample at higher frequencies (i.e., $f > 4$ kHz). Note that the luffa composite sample with $V_e/V_f = 0.2/0.8$ has more elasticity strength

compared to the pure luffa fiber sample; hence, it may be used in the practical applications where the structural stiffness is required (it can be used as a load carrying component as well as a sound absorption material). It is also apparent that the luffa fiber sample with a perforated linen has quite high sound absorption coefficients; thus, such samples can be used as sound absorption materials where the structural stiffness is not required. It is also seen that the sound absorption coefficients for all luffa test samples increase with frequency.

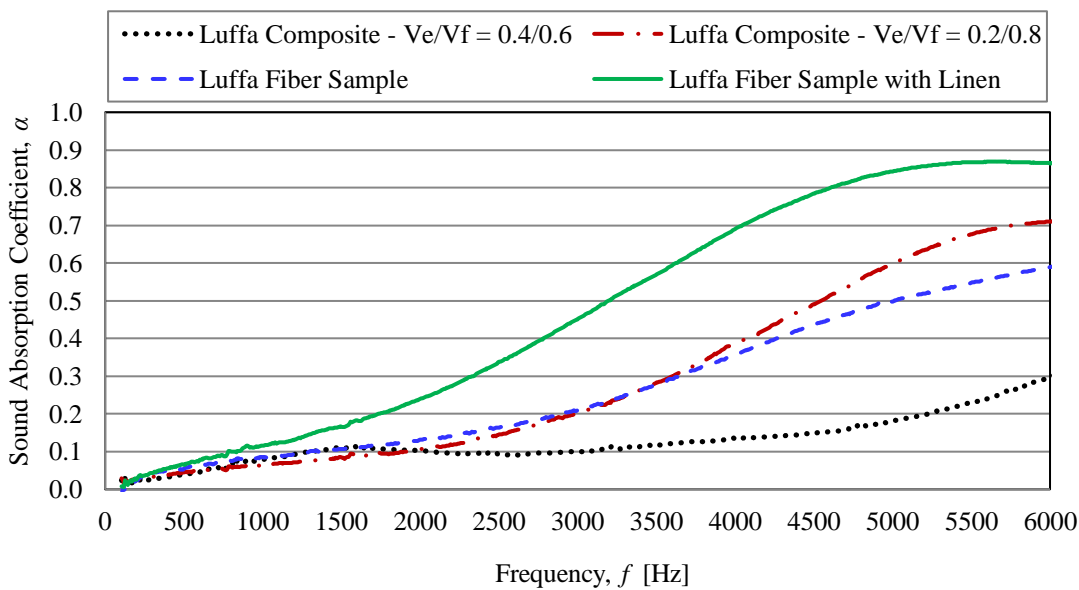


Fig. 3. Sound absorption coefficients of different luffa samples.

The identified transmission loss (TL) levels of the luffa fiber and composite samples are presented in Fig. 4. It is seen that the transmission loss levels of the luffa fiber samples without and with a linen are almost the same; note that the effect of the linen on the transmission loss is expected to be quite low. It is also seen that the transmission loss levels of these samples are less than 5 dB. However, the transmission loss levels of the luffa composite sample with $V_e/V_f = 0.2/0.8$ are considerably higher. Furthermore, the transmission loss levels of the luffa composite sample with $V_e/V_f = 0.4/0.6$ can be quite high (i.e., $TL > 20$ dB).

Note that the results in Figs. 3 and 4 are obtained using some test samples with small thicknesses (i.e., $t = 9$ and 12 mm). It is clear that the acoustic performances of the luffa samples will increase

as sample thicknesses increase and much more effective luffa samples can be obtained by just increasing the sample thickness.

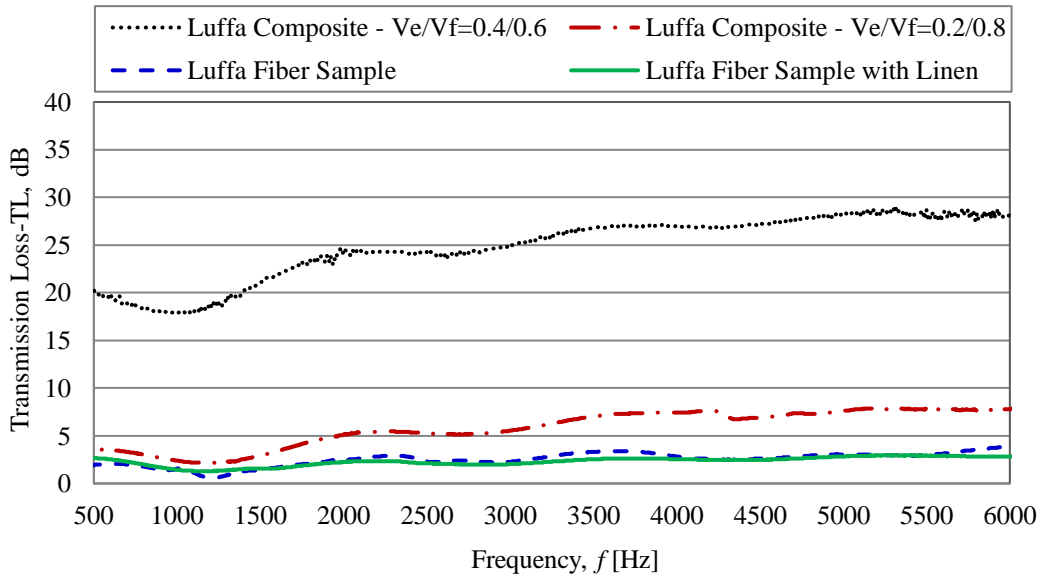


Fig. 4. Transmission loss levels for different luffa samples.

4. Conclusion

This paper investigates the sound absorption and isolation properties of luffa fiber and composite samples and evaluates their performances. To the best of the Authors' knowledge, this is the first paper in the literature conducting acoustic characterization of the luffa bio materials. Results show that the sound absorption coefficients of a luffa fiber sample without a matrix can be quite high even for a small sample thickness (i.e., $t = 12$ mm). Furthermore, the sound absorption values can increase when a linen is covered on the luffa fiber sample. It should be noted that some linens can be used to prepare acoustic samples using only the luffa material in practice and those samples can be used in acoustic design of halls, etc. However, if high sound isolation property is also required (in addition to sound absorption property), then a luffa composite material with an appropriate matrix composition may be used. It is clear that the determination of the appropriate matrix composition needs an optimization work. The optimization of the matrix composition of luffa

samples for better acoustic performance as well as the investigation of the effect of sample thickness is the subject of a future work.

Acknowledgement

This research is supported by Marmara University, Scientific Research Projects Committee (BAPKO) with Grant number FEN-A-110913-0377.

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