



## EXPERIMENTAL STUDY OF SOUND ABSORPTION PROPERTIES OF REINFORCED POLYESTER BY SOME NATURAL MATERIALS

Dr. Muna S. Kassim  
Al-Mustansiriya University

### ABSTRACT

Sound absorption in living, traveling and working environment constitutes one of the major requirements for human comfort today. Sound insulation requirements in automobiles, in manufacturing environments, and in equipments, generating higher sound pressure, strives the need to develop more efficient and economical ways of producing absorption materials. Traditionally, economics of recent research has enforced the research to focus on waste materials.

The aim of this study is to use waste materials (particles of egg shell, palm leaf, jute, wood dust, chicken feather) for producing reinforced and polyester resin composite structures with 17% weight fraction. Two natural material composite plate shapes (flat and corrugated) with the same area is manufactured, where the echoic chamber is built and insulated with cork and sponge for different inside wall shape (flat, concave and pyramids) .

The study concluded that the jute woven and saw dust composite exhibited a greater ability to absorb normal incidence sound waves than the composites with chicken feather, particles of egg shell, and palm leaf fiber for different shape cork and sponge insulator. The analysis of sound transmission loss revealed that the particles of egg shell and saw dust still obeyed the mass law of transmission loss. The composite surface layer of particles of egg shell and saw dust possessed a higher fabric density and therefore showed a better sound insulation than the composites with jute woven, chicken feathers, and palm leaf.

**KEYWORDS:** natural composite materials, absorption properties, insulation.

### دراسة عملية لخواص امتصاص الصوت للبوليستر المقوى ببعض المواد الطبيعية

#### الخلاصة

يعتبر امتصاص الصوت من اهم متطلبات راحة الانسان في محيط المعيشة والتنقل والعمل. ان الحاجة الى العزل الصوتي في وسائل النقل واجواء المصانع وفي المعدات التي يكون فيها ارتفاع ضغط صوتي حاجة ماسة لتطوير مواد ماصة للصوت تكون ذات كفاءة اعلى واقتصادية اكثر. يركز البحث الحالي من الناحية التجارية والاقتصادية على المواد المهمة.

يتناول البحث الحالي دراسة العزل الصوتي للمواد المركبة المصنعة من : قشور البيض ، ليف النخيل، الجوت، نشارة الخشب وريش الدجاج) مع البوليستر لنسبة وزنية تساوي 17%. لقد تم دراسة شكلين من الصفائح هما: الصفحة المستوية والصفحة المتعرجة. كما تم تصنيع غرفة العزل الصوتي وتم وضع الاسفنج والفلين كمواد عازلة من الداخل وتغيير شكل هذه العوازل (مستوي ومحدب وهرمي) .

لقد استنتجت الدراسة ان المواد المركبة من حصيرة الجوت ونشارة الخشب لها قابلية عالية لامتصاص الضوضاء بالمقارنة مع ريش الطيور وحببيبات قشور البيض وليف النخيل لمختلف اشكال العوازل الداخلية (الفلين، الاسفنج) للغرفة المستخدمة. ان تحليل خسائر انتقال الصوت اظهرت ان المركبات المكونة من نشارة الخشب وحببيبات قشور البيض تقع ضمن قانون الكتلة لخسارة الانتقال حيث ان مركبات هاتين المادتين لها كثافة بناء عالية لهذا فهي عوازل صوتية افضل من مركبات حصيرة الجوت و ريش الطيور وليف النخيل .

**NOMENCLATURE**

A	total absorption in the receiving side, expressed in units consistent with S
L	Length of test plate (cm)
NR	noise reduction(the difference between the sound pressure level of the source and receiving side)
S	total area of the sound-transmitting surface of the test specimen (cm <sup>2</sup> )
TL	transmission losses (dB)
t	Thickness of test plate (cm)
Wf	weight of fibre
W <sub>fr</sub>	weight fraction (cm <sup>3</sup> )
Wt	total weight of test plate (cm <sup>3</sup> )
Z	width of test plate (cm)
$\alpha$	Sound absorption coefficient
$\Delta L$	the difference between the maximum and minimum sound levels of the standing wave measured in the box

**1. INTRODUCTION**

Acoustics is currently one of the most important fields of study in all countries of the world. Large amounts of research have been carried out, and new findings have uncovered potential new materials for sound absorption applications. Previous research on natural fibers shows that they have potential to be used as sound absorption panels. In Malaysia, agricultural waste such as coconut fibre (*Cocosnucifera*), rice fibre (*Oryza sativa*) and oil palm frond fibre (*Elaeis Guinnesis*) are abundant and usually burned or used as agricultural by-products. These natural fibres, such as coir fibre, are suitable as a substitute for synthetic fibres and wood-based materials for acoustic absorption purposes. These fibres have many advantages because they are cheaper, renewable and abundant, non-abrasive and do not give rise to health and safety issues during processing and handling (Zulkifli et al, 2009).

Most practical sound absorbing products used in the building construction industry consist of glass- or mineral-fiber materials. Because of the dominance of these materials in the commercial market, the study of sound propagation in alternative materials has been limited. However, the growing concern about the potential health risks popularly seen as being associated with fiber shedding from glass- or mineral-fiber materials provides an opportunity for wood-based sound absorbers to be developed for use in applications traditionally occupied by glass- or mineral-fiber products (Wassilieff, 1996).

## 2. PREVIOUS RESEARCH

The sound absorption of an industrial waste, developed during the processing of tea leaves has been investigated. Three different layers of tea-leaf-fibre waste materials with and without backing provided by a single layer of woven textile cloth were tested for their sound absorption properties. The experimental data indicate that a 1 cm thick tea-leaf-fibre waste material with backing, provides sound absorption which is almost equivalent to that provided by six layers of woven textile cloth. Twenty millimeters thick layers of rigidly backed tea-leaf-fibres and non-woven fibre materials exhibit almost equivalent sound absorption in the frequency range between 500 and 3200 Hz (Ersoy and Kuçuk, 2009).

An activated carbon fiber nonwoven (ACF) was manufactured with a cotton nonwoven fabric. For the ACF acoustic application, a nonwoven composite of ACF with cotton nonwoven as a base layer was developed. The study concluded that the ACF composite exhibited a greater ability to absorb normal incidence sound waves than the composites with either glassfiber or cotton fiber. The analysis of sound transmission loss revealed that the three composites still obeyed the mass law of transmission loss. The composite with the surface layer of cotton fiber nonwoven possessed a higher fabric density and therefore showed a better sound insulation than the composites with glassfiber and ACF (Jiang et al, 2009). **Absorption** panel produced from particle composite boards using agricultural wastes were successfully developed by previous researchers (Yang et al, 2003). The functions of this board, among others are to absorb noise, acting as heat insulation and preserving the temperature of indoor living spaces. Yang et al, 2003, produced rice straw-wood particle composite boards and they 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 (Yang et al, 2003).

To improve the acoustic properties further, a perforated plate design should be used in the construction of the panels. Davern, 1977, studied the effect of the perforated plate, airspace layers 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. As a natural resource, sound absorption characteristics of rock wool are measured to be similar to glass fiber (Wang, 2001). From the view of environmental protection, natural bamboo fibers were used for sound absorbing purposes. Impedance tube measurement of the bamboo fiber samples reveals similar properties to that of glass wool. Enclosing the surface of the bamboo material fiberboard yields a superior sound absorption property when compared to plywood material of similar density (Koizumi, 2002).

Buyukakinci et al, 2011, used natural cotton, bamboo and wool fibers as reinforcement agents in a polyurethane-based matrix to improve the sound absorption and thermal conductivity properties of the composite. Generally, adding cotton, bamboo or wool fibers to polyurethane foam, improves its sound absorption coefficient. In this study, cotton fibers were observed to provide the best sound absorption coefficient. At higher frequencies, increasing the bamboo or wool fiber content decreases the sound absorption coefficient for the composite. Adding cotton, wool or bamboo fibers to polyurethane foam does not result in a significant change in the thermal conductivity of the material. The best thermal conductivity value was observed with a composite including 4% cotton fiber. This research was carried out to study the potential use of coir fibre in replacing synthetic an industrial applications of sound insulation, generally includes the use of materials, such as particles of egg shell, wood dust, jute, palm leaf and chicken feathers with polyester risen composites.

Although these materials possess acoustical insulating properties, they don't cause environmental pollution and they don't pose a danger to human health.

### 3. EXPERIMENTAL WORK

#### 3.1 Sound Measurement Apparatus

The sound insulation measurement apparatus are shown in **Figs. 1-a and b**, this device consists of six components: the sound signal-processing (Type Hewlett Packard 3312A, 0.1Hz-1MHz), the sound signal amplifier (Type Brule&Kjaer, 6 KVA), the sound source (is made from loud speaker its volume=8 in), the sound chamber, the sound level meter (Type RS-232, 30-130 dB), and the material sample holder. The white noise with the sound frequencies ranging from 0 Hz to 2,000Hz is used for the sound insulation measurements.

The signal-function generator generates the sound signals. The signals are amplified by the signal amplifier. The amplified signals are sent to the sound source to be converted to sound waves. The material to be tested is mounted in on sample holder, placed in the sound path. The sound wave is transmitted inside the sound chamber passing through the sample material to the sound level meter. If no sample is in the path of the sound wave, a background reference is obtained and sample data can be compared to this air reference. If two samples are compared, data from one sample is compared to the other with no changes to the settings of the instrument.

This sound spectrometer is not an ideal sound chamber with perfect acoustical properties, but it provides a comparison of the samples under the same conditions and therefore yields a direct acoustical comparison. It should be noted that the reproducibility of the apparatus can be verified by the fact that when, after initial calibration and Fourier Transformation, subsequent tests are made with no specimen in the sample holder, no transfer function magnitude data are generated – i.e. the plotted results are identical to the base line.

#### 3-2 Anechoic Chamber

The test set-up consists of a double wall partition, formed by two plane, wood board plate with the mineral sponge or cork with different shape (flat, concave, and pyramids) inside the chamber. The thickness of the wood plate is 1.2 cm and the inner installation is 4 cm respectively. The anechoic chamber is (42.5cm depth, 22cm height, and 21cm width) as shown in **Figs. 2-a, b, and c**. A loudspeaker located in the one side of this rectangular volume provides the acoustical excitation of the tested structure. The microphone located in the other side of the tested structure. At the upper there are two gates open and closed easily to put and remove the specimen.

#### 3.3. Materials and Composite Production

As a natural and environmentally friendly material, jute, chicken feather, palm leaf, particles of egg shell, saw dust have been tested for its (NR) and (TL).

The values of  $\alpha$  is calculated using the following equation (Bell, 2008):

$$\alpha = 1 - \left( \frac{10^{\log_{10}^{-1}\left(\frac{\Delta L}{20}\right)} - 1}{10^{\log_{10}^{-1}\left(\frac{\Delta L}{20}\right)} + 1} \right) \quad (1)$$

Similar to the sound absorption, the transmission loss is defined by the following equation (Bell, 2008):

$$TL = NR + 10 \log \left( \frac{S}{A} \right) \quad (2)$$

These natural material fibre is a waste product. Besides being a hygienic material, These natural material-fibre is a product of renewable bio-resources that makes it biodegradable, Davern,1977. Polyester based non-woven fibre samples of volume fraction 17% have a dimensions 21 cm width and 20 cm length and 1.5 cm thickness flat plate and corrugated plate with height of 2 cm were prepared for testing, shown in **Fig.3**. The weight is found by using an electronic portion scale (up to 2000g). The thickness of each type of natural composite was found by using dial calipers. The volume of each sample( $V_t$ ) is found after determining the thickness and the dimensions each type of natural composite plate according to equation

$$V_t = L \times Z \times t \quad (3)$$

The weight fraction of sample ( $W_{fr}$ ) in the composites is calculated using the following equation (Jeffrey, 2006):

$$W_{fr} \% = \frac{W_f}{W_t} \quad (4)$$

### 3.3. 1 Composite Fabrication

The matrix material used for the fabrication of natural fiber reinforced composites consists of low temperature curing polyester resin and corresponding hardener (United Oil Projects Company). Resin and hardener are mixed in a ratio of 25:1 by volume as recommended (United Oil Projects Company). The natural fibers collected from any unacceptable units and cleaned .

### 3.3.2 Composite Plate Manufacturing

To fabricate the composite plate of size (21 cm×20 cm×1.5 cm) is cast the mixture in mould which made from cast iron for flat and corrugated plates, **Figs. 4-a** and **b**. This operation are done in a closed space and used buffer material to avoid direct contact between the specimen and the mould surface. After moulding the sample insulating cover is used and apply compressive load of distributed equally all over the cover to avoid keeping any air gap trapped in the sample for about 24 hours at room temperature. The fibers must be free from decay and the time between casting the mixture (polyester & natural fibers) and closing the mould are not above 60 seconds otherwise the mixture will burn .

## 4. RESULTS AND DISCUSSION

The acoustical insulation behavior comparison among the nonwoven fabrics made from two different shaped and five different natural fibers were used to study the effect of the fiber denier, and fiber cross-sectional shape on fabric acoustical insulation.

Data from the test device are appropriate for obtaining the acoustical insulation information, because the sound spectrometer measures sound transmission, and fewer transmitted sound waves equate to better acoustical insulation. The results are given in the form of plots between the frequency (Hz) and the transfer function magnitude (dB). Following a Fourier Transformation, the data from the test without the test sample serves as the base line or zero point on the x-axis. Data from each test material are plotted as negatively increasing sound frequency values. If the transmitted sound difference is not more than 1dB, the difference is not significant, because of the accuracy of the device and the range of human hearing. The

sound level meter used in this experiment has the capability of measuring frequencies between 0Hz and 30,000Hz. Because the frequency range of human hearing is between 0Hz and 20,000Hz, this zone was selected as the test frequency range.

#### 4.1 Sound Absorption

The normal incidence sound absorption coefficients ( $\alpha$ ) of the natural material composites are determined as a function of the sound frequency ( $f$ ), as shown in **Figs. 5-12** for different natural fibre. The plotted curves combine the measured data in the frequency range of 50–2000 Hz to indicate a whole bandwidth of the 1/3 octave band frequency. By examining the curve, it can be seen that jute and saw dust exhibits the highest ability for normal incident sound absorption, superior to particles of egg shell, chicken feathers, and palm leaf. Mostly because of a hollow jute woven and saw dust.

The jute woven as surface layer absorbs more sound waves than the palm leaf, chicken feather nonwoven. The reason why the jute woven and saw dust possess a significantly higher sound absorption coefficient than others may be explained by the highly porous surface structure of the jute woven and saw dust. More porous areas mean more air volumes allowed to flow into the jute woven and saw dust structures.

It can be observed that all the ( $\alpha$ ) values for the five composite were within the range of 0.01–0.98. The jute woven and saw dust used as surface layer is significantly better than particles of egg shell, palm leaf and chicken feathers. This indicates that the jute woven and saw dust could be used as a biobased acoustic material with an outstanding ability to absorb normal incidence noise and a substantially lighter weight compared to the other composite used in this research. Therefore, in the present case the jute woven and saw dust composite seems an optimal acoustic material for the application of noise absorption .

#### 4.2. Transmission Loss

**Figs. 13-20** show the curves for transmission loss (TL) as a function of the sound frequency ( $f$ ) within the frequency range of 50–2000 Hz. The curves indicate that the five surfaces of jute, chicken feather, particles of eggshell, palm leaf, and saw dust all improve the nonwoven performance of sound insulation. It seems that the particles of egg shell and saw dust nonwoven show better transmission loss than the chicken feather, palm leaf and jute woven during high frequency range from 1000 to 2000 Hz.

All five types of surface show no difference during the low frequency range from 50 to 950 Hz. The reason why the surface layer particles of egg shell and saw dust nonwoven show slightly better sound insulation than the jute woven, chicken feather, and palm leaf nonwoven is that sound TL mostly depends on the mass law. The sound TL mass law states that TL increases as the mass increases.

#### 4.3 Effect of Plate Shape

The acoustical insulation comparison for the flat and concave plate composite test materials made from jute woven, particles of egg shell, chicken feather, palm leaf and saw dust was used to study the effect of expanded surface area. **Figs. 5, 7, 9, and 11** show the absorption sound results for flat plate where jute woven has the higher value while for corrugated shape, **Figs. 6, 8, 10, and 12**, saw dust composite has the higher value for higher rang frequencies (1000-2000) Hz. Meanwhile for low frequencies all natural composite (jute woven, particles of egg shell, chicken feather, palm leaf, and saw dust) behave in the same way. **Figs. 13, 14, 15, 16, 17, 18, 19, and 20**. Transmitted sound results for flat and corrugated fabrics made from jute woven, particles of egg shell, chicken feather, palm leaf,

and saw dust. As shown in figures, flat and corrugated plate made from saw dust fibers have better sound insulation characteristics for pyramid sponge inner insulator box than jute woven, particles of egg shell, chicken feather, and palm leaf fibers. For the frequencies between 50 Hz and 2000Hz, the difference in sound insulation data between the cork and sponge inner insulator box for flat and concave shapes inner insulated plate reaches 13 dB. The reason for this result may be because of the effect of surface area in the fabric. As shown in figures, pyramid insulator has approximately three times more surface area than flat insulator. Higher surface area in a nonwoven fabric increases the possibility of the sound wave interaction with the fibers and results in more effective sound deadening in the nonwoven fabric.

## **5. CONCLUSION & PERSPECTIVES**

1- Several examples of waste material (jute woven, particles of egg shell, palm leaf, wood dust, and, chicken feathers) for sound absorption purposes have been briefly presented. Under some conditions it has been shown this concept can improve acoustic performances (for absorption or transmission purposes) of usual single scale media.

2- The manufactured rig was used for measuring the normal incidence sound absorption coefficient and transmission loss of the experimental composites.

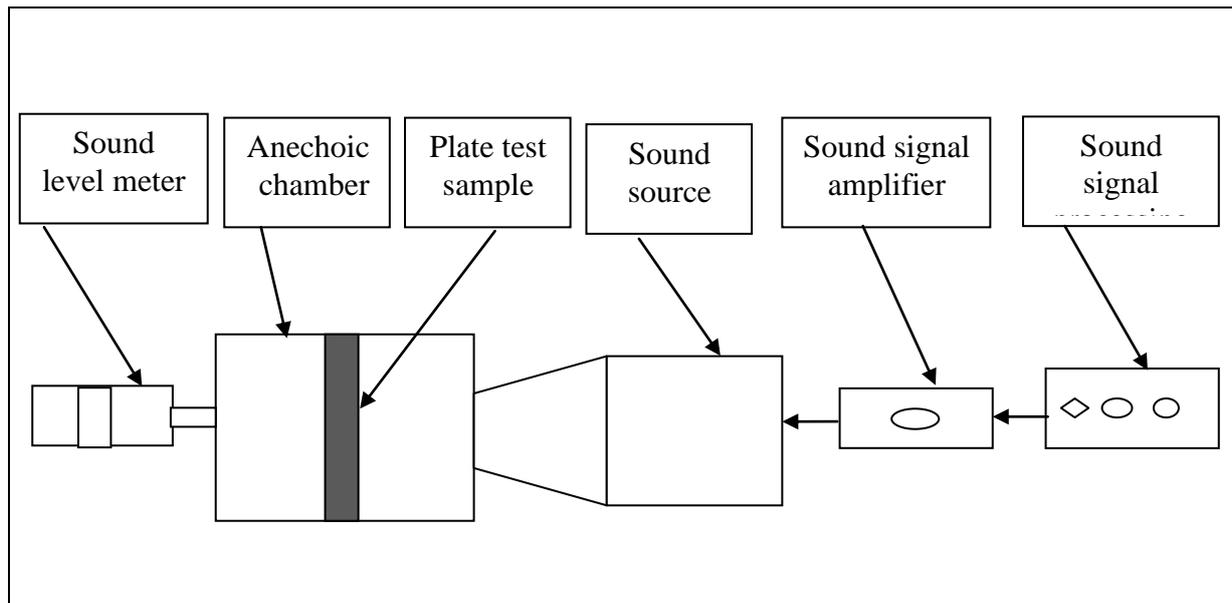
3- The comparison of the sound properties was carried out using the statistical method of variance analysis. The results showed that the jute woven, saw dust composites for flat and concave shape plate had significantly higher sound absorption coefficients than the chicken feathers, particles of egg shell, and palm leaf composite in the frequency range from 50 to 2000 Hz.

4- For the sound transmission loss, there was no significant difference among the five natural composite especially in the range from 50 to 950 Hz. Considering the lightweight, biodegradability and low cost of these material, the saw dust and particles of egg shell have a potential to be used as high-performance and cost-effective acoustical materials.

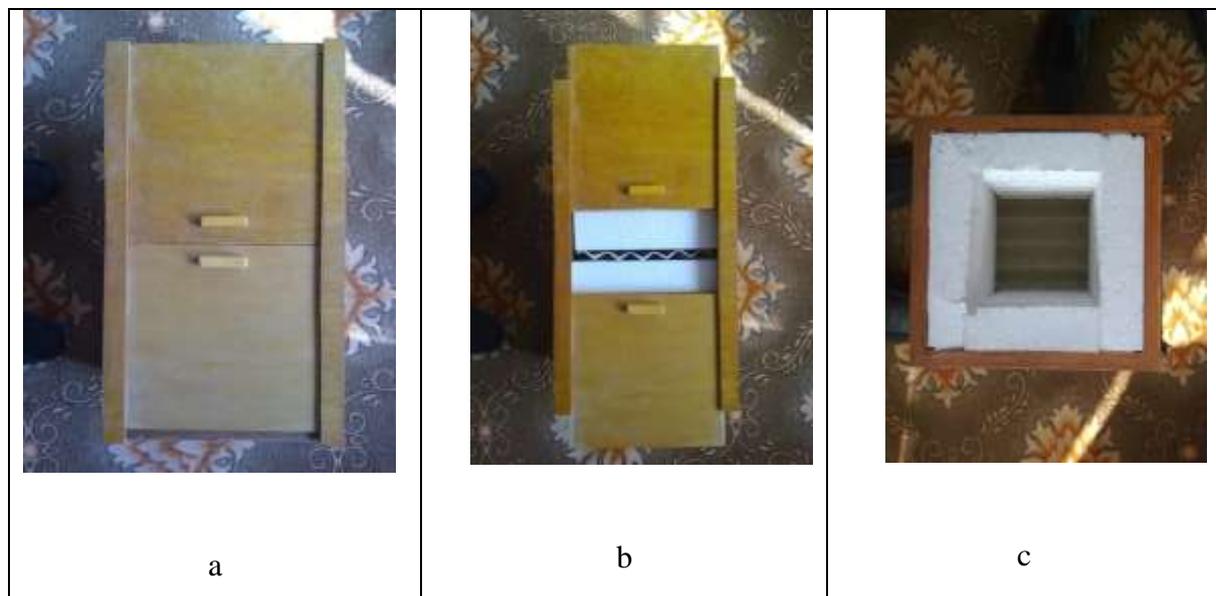
5- This type of materials should also be considered as potential solutions to multi-physical applications (acoustics, thermics, mechanics, design...).

We hope this paper will egg on decision makers like you to use further this concept outside of laboratories in a growing number of real-world transportation applications.





**Figure 1b: Schematic diagram of measuring system configuration.**



**Figure 2: Picture of the anechoic chamber.**

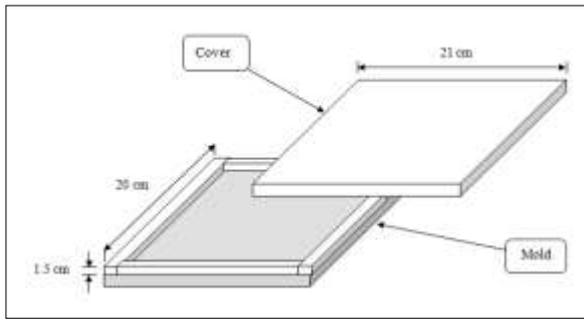


Figure 4a: Schematic diagram of cast iron mold for flat plate specimen.

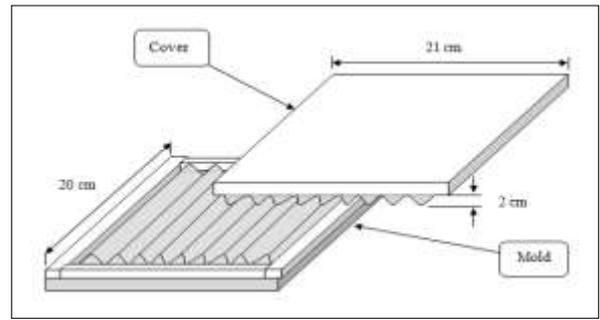


Figure 4b: Schematic diagram of cast iron mold for corrugated plate specimen.

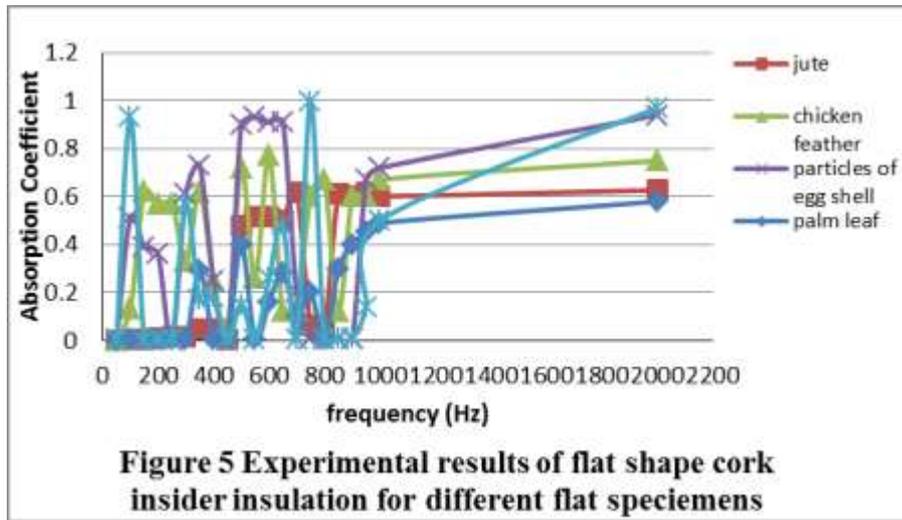


Figure 5 Experimental results of flat shape cork insider insulation for different flat specimens

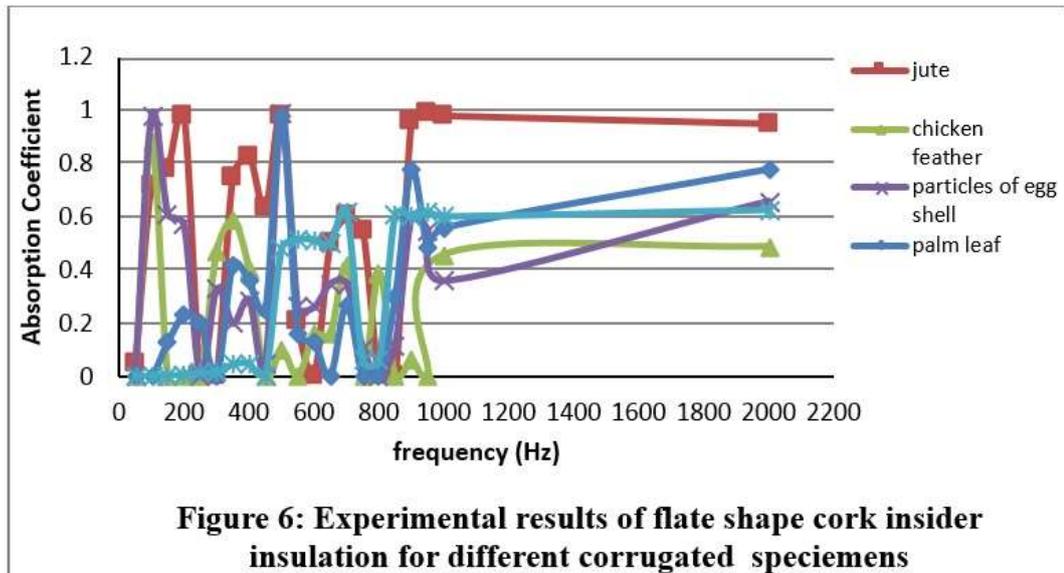
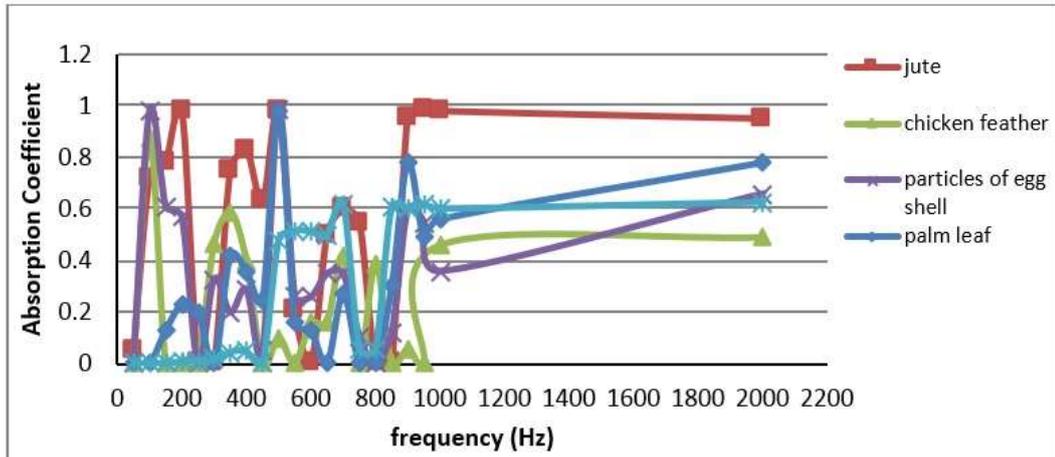
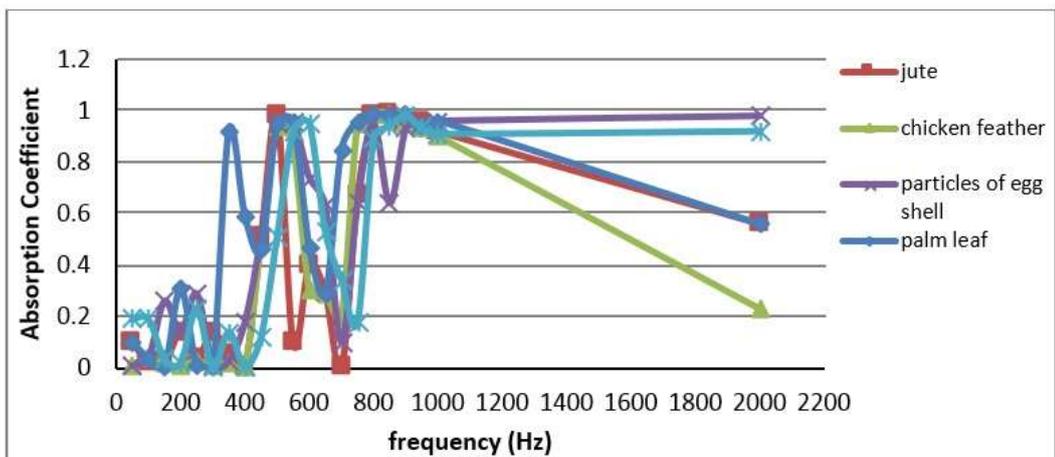


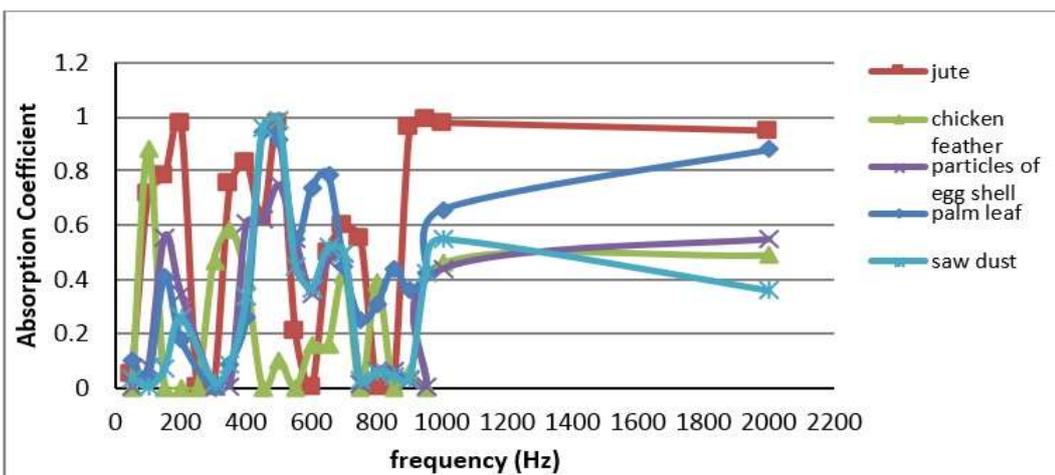
Figure 6: Experimental results of flat shape cork insider insulation for different corrugated specimens



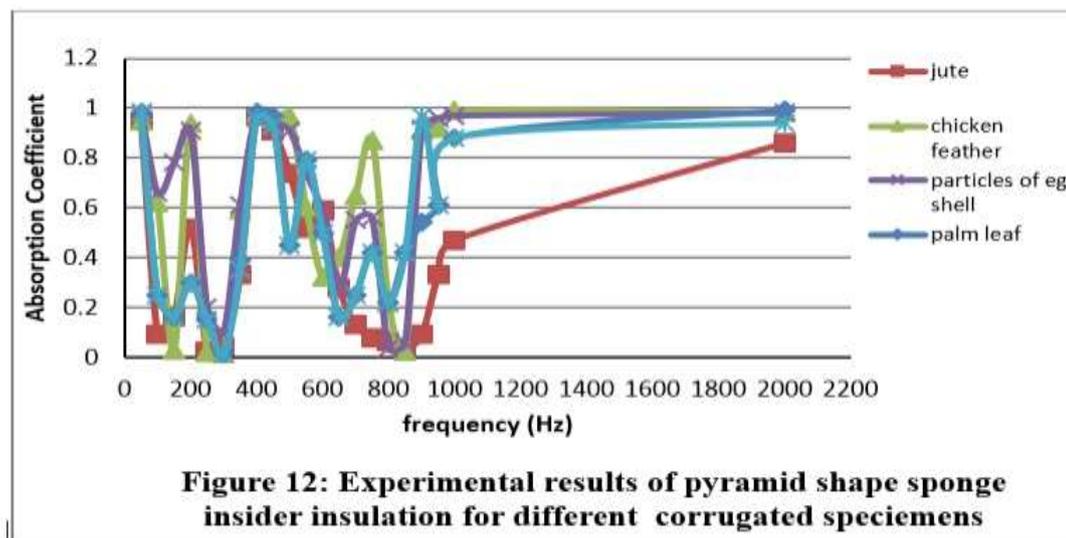
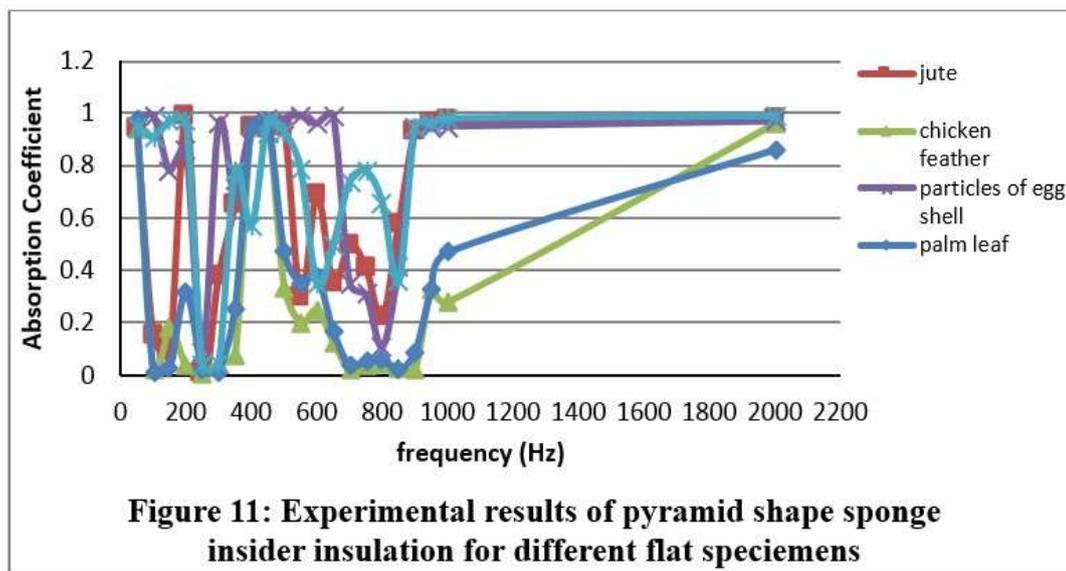
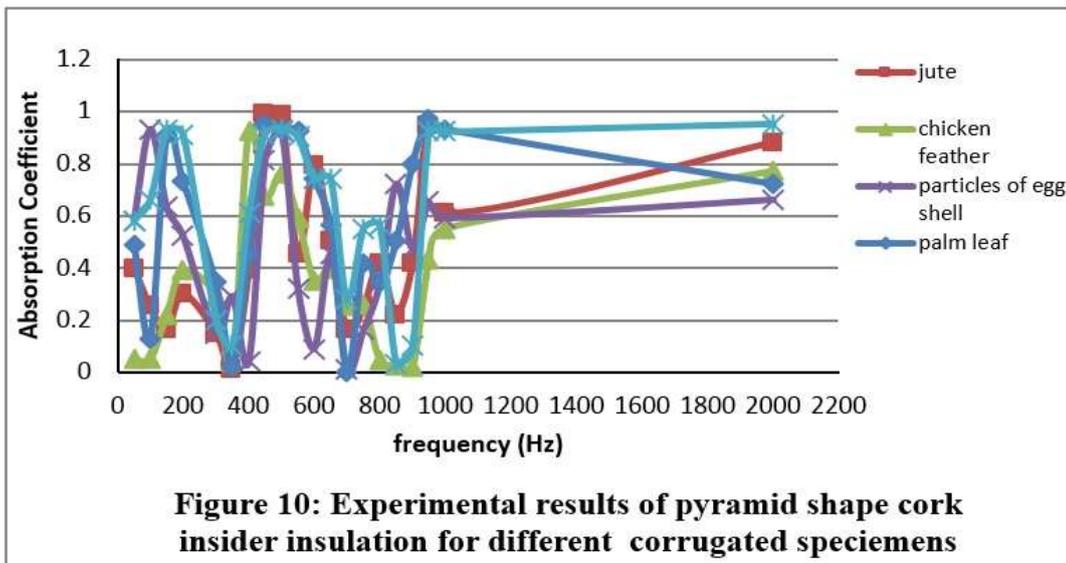
**Figure 7: Experimental results of concave shape cork insider insulation for different flat speciemens**

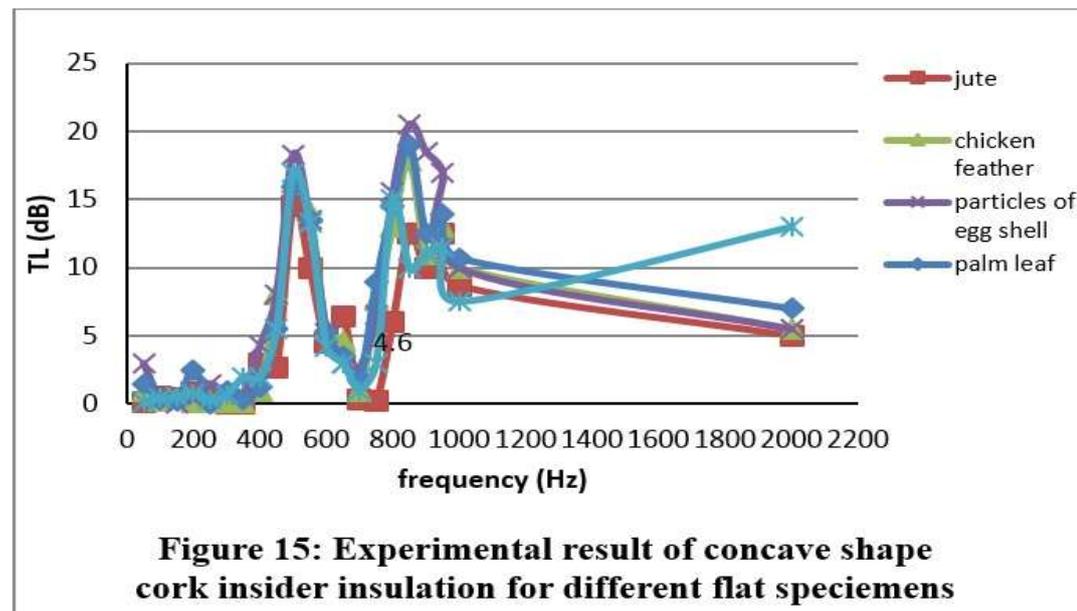
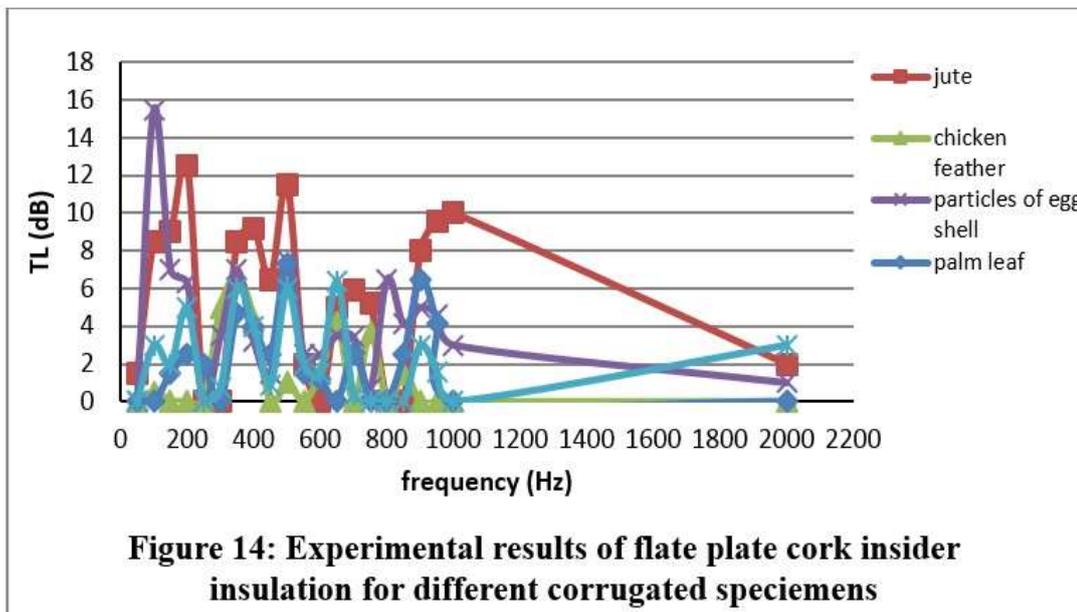
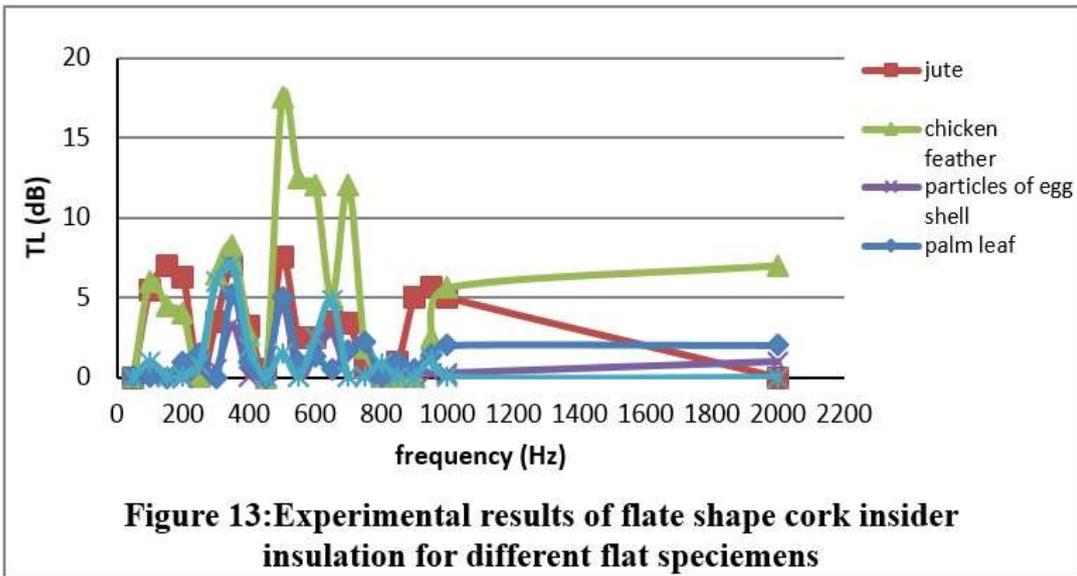


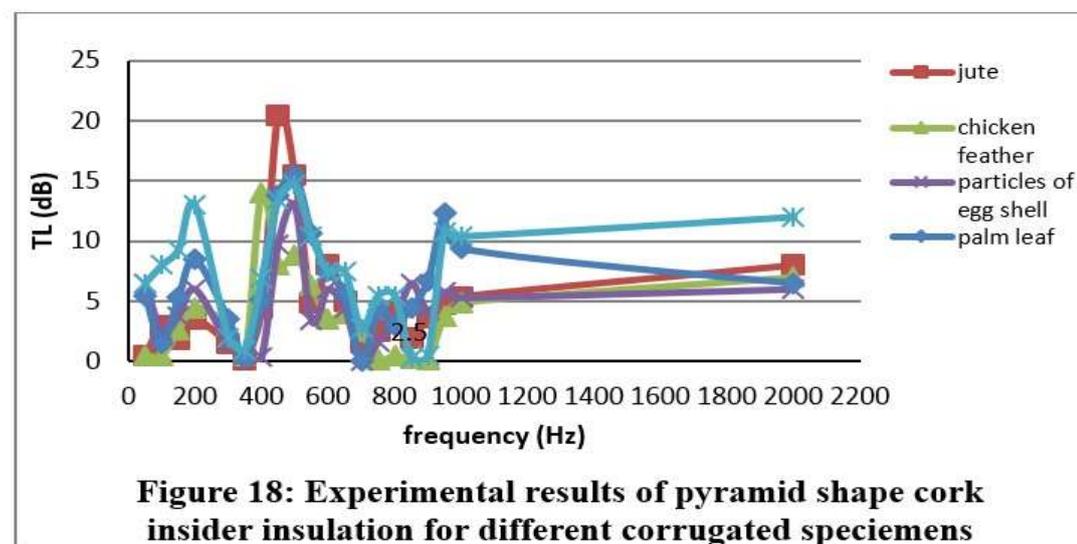
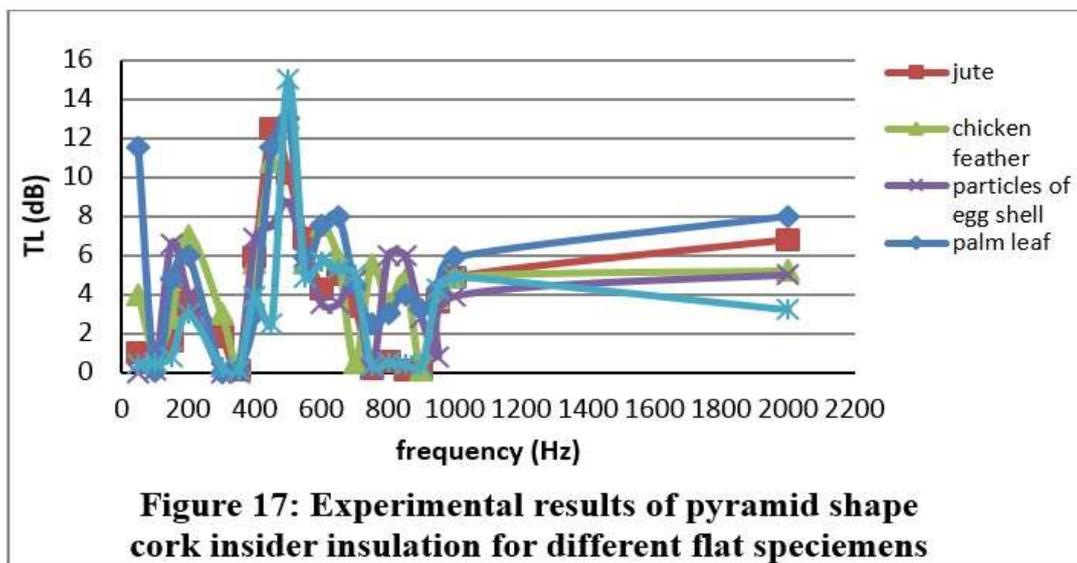
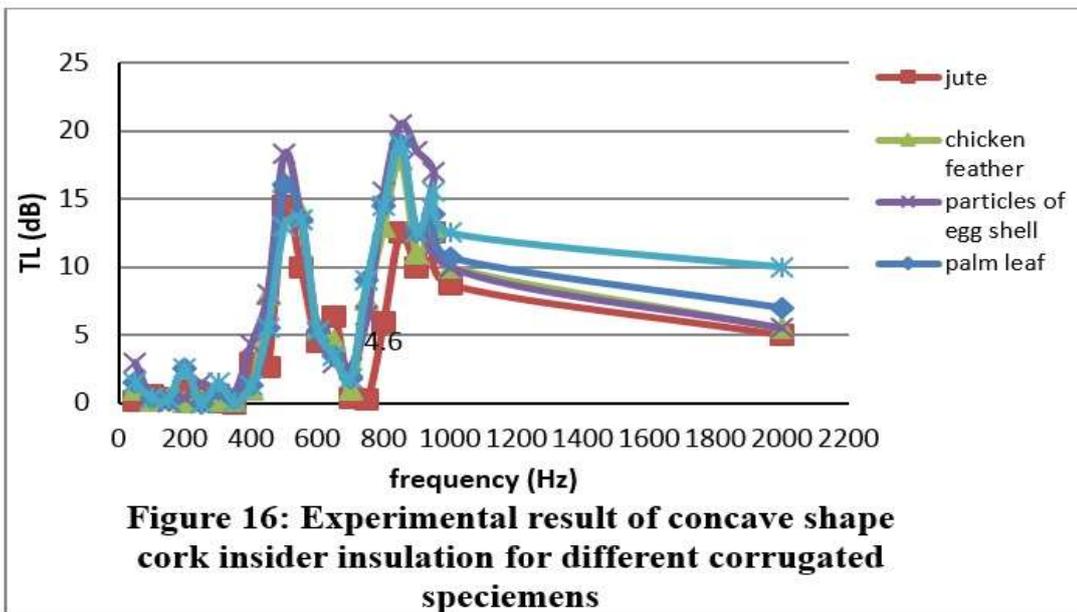
**Figure 8: Experimental results of concave shape cork insider insulation for different corrugated speciemens**

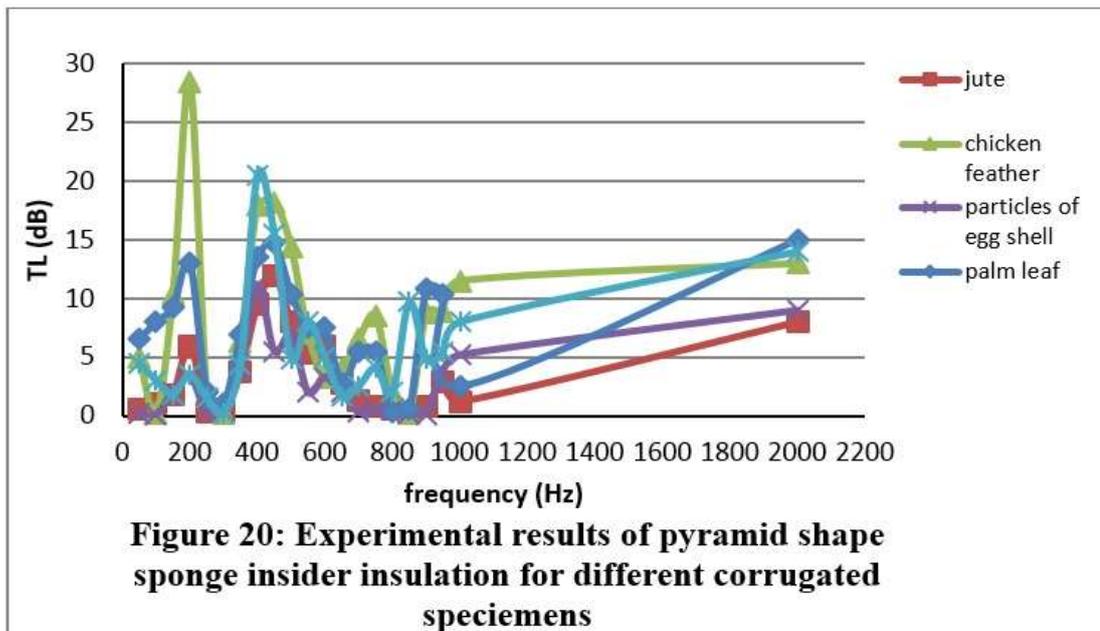
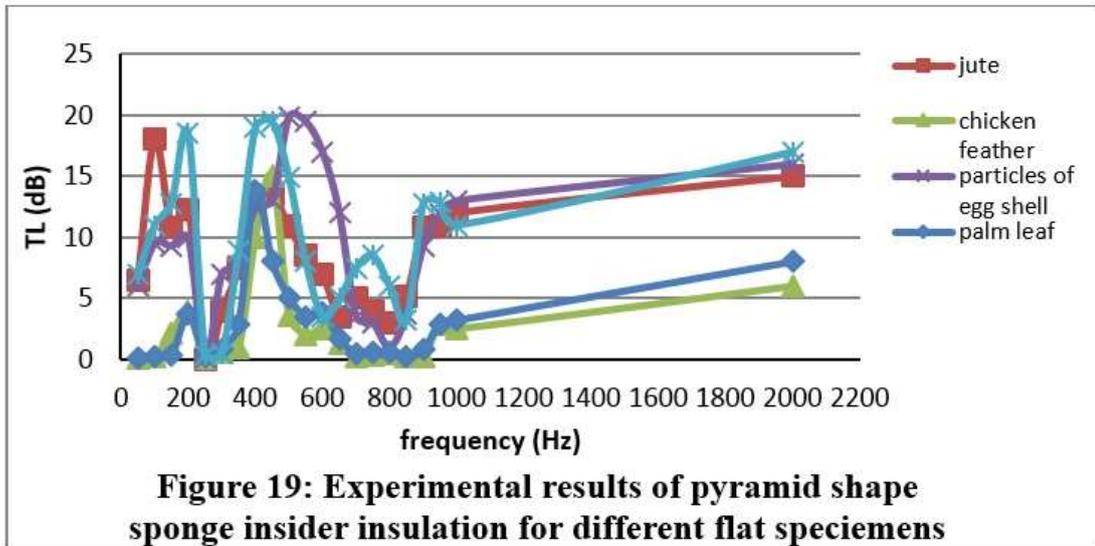


**Figure 9: Experimental results of pyramid shape cork insider insulation for different flat speciemens**









## **REFERENCES**

ASTM E795-83, Standard Practices for Mounting Test Specimens During Sound absorption Tests, American Society for Testing and Materials (ASTM), West Conshohocken, PA, 200.

ASTM E2249, Standard Test Method for Laboratory Measurement of Airborne Transmission Loss of Building Partitions and Elements Using Sound Intensity, American Society for Testing and Materials (ASTM), West Conshohocken, PA, 2002.

Bell, H. B., Industrial Noise Control, Marcel Dekker Inc., New York and Basel, 2008.

Buyukakinci, B. Y., Sokmen, N., Kukcuk, H., "Thermal Conductivity and Acoustic properties of Natural Fiber Mixed Polyurethane Composites", *TEKSTİL ve KONFEKSİYON* 2, 124-132, 2011.

Davern, W.A., "Reinforcement of Acoustical Material Properties Using Multiple Scales", *Applied Acoustic* 10, 85, 1977.

Ersoy, S., Kuşcuoğlu, H., "Investigation of Industrial Tea-Leaf-Fibre Waste Material for its Sound Absorption Properties", *Applied Acoustics* 70, 215–220, 2009.

Heckl, M., The tenth Sir Richard Fairey memorial lecture: "Sound transmission in building", *Journal of Sound and Vibration*, 77(2), 165-189, (1981).

Jeffrey W. Kock, "Physical and Mechanical Properties of Chicken Feather Materials", MS.c thesis, School of Civil Engineering, Georgia Institute of Technology, May, 2006.

Jiang, N., Chen. J.,Y., Parikh D., V., Acoustical Evaluation of Carbonized and Activated Cotton Nonwovens, *Bioresource Technology* 100, 6533–6536, 2009.

Koizumi, T., Tsujiuchi, N., Adachi, A., "The development of Sound Absorbing Materials Using Natural Bamboo Fibers", pp. 157-166 in *High Performance Structures and Composites 4, High Performance Structures and Materials*, Edited by: C. A. Brebbia, and W. P. De Wilde, Witpress, 2002.

United Oil Projects Company Tel: 23263297/23263497, FAX: 23260179.

Wang, C. N., Torng, j. H., "Experimental Study of the Absorption Characteristics of Some Porous Fibrous Materials", *Applied Acoustics*, 62, 447-459, 2001.

Wassilieff, C., "Experiments on the Active Reduction of Sound Transmission through Light-Weight Constructions", *Applied Acoustics* 48(4), 339, 1996.

Yang, H. S., Kim, D. J., Kim, H. J., "Rice Straw–Wood Particle Composite for Sound Absorbing Wooden Construction Materials", *Bioresource Technology*, 86, 117–121, 2003.

Zulkifli, Z., Mohd Nor, M. J., Ismail A. R., "Effect of Perforated Size and Air Gap Thickness on Acoustic Properties of Coir Fibre Sound Absorption Panels," *European Journal of Scientific Research*, 28, 242-2522, 2009.