ACOUSTICAL CHARACTERISTIC OF EMPTY FRUIT BUNCH (EFB) FIBRE WITH INFLUENCE OF SODIUM HYDROXIDE TREATMENT TIME AND DECAY LIFESPAN

LAUREN MAT WAN

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Universiti Tun Hussein Onn Malaysia

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DEDICATION TO:

MY BELOVED PARENT,
Mr. Mat Wan and Mdm. Bawih Tingang

For their prayer, encouragement and supports

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ABSTRACT

Research on natural fibres has gain much interest in recent years due to the sustaibability and avaibility in which demand for green renewable reinforced composites. Natural fibres can be considered as the alternative way to replace the synthetic fibre as well as to implement the sustainability of the materials. However, the natural fibre also has its own disadvantage which is the ability to maintain the quality of absorption due to the lack of information and research on the acoustic application. Thus, in this research, the untreated and treated Empty Fruit Bunch (EFB) fibre was investigated as control unit and the standard used for sound absorption test was ISO 10534-2 and ASTM E1050-98. The EFB has undergone a chemical modification process known as alkali treatment using sodium hydroxide (NaOH). Five parameters were chosen for the alkali treatment process which is the fiber immersion time (at 1 hour until 5 hours) with fixed alkali treatment concentration of 6% NaOH. Cross sectional area of the fibre was measured using Leica stereo video analyser. The results from the test show EFB fibre gives positive value of sound absorption from mid to high frequency which is from 2000 Hz to 5000 Hz. The best sound absorption is performed by the 1 hour of treated fibre with a maximum sound absorption coefficient (α) nearly 1 at 2500 Hz and with thickness of 50 mm. The Noise Reduction Coefficient (NRC) for the 1 hour treated fibre is 0.53. As for decay lifespan, the sound absorptions performance was slightly decreased from 0.68 to 0.55 within 5 to 20 months. This result indicates that the treated EFB are highly absorptive material and it is recommended to become as a natural base for acoustical absorption material.

ABSTRAK

Kajian mengenai gentian semulajadi telah menarik banyak perhatian sejak beberapa tahun kebelakangan ini disebabkan oleh kebolehan dan sumber gentian ini sebagai komposit semulajadi yang boleh diperbaharui. Gentian semulajadi ini boleh dianggap sebagai salah satu cara alternatif untuk menggantikan gentian sintetik. Walaubagaimanapun, gentian semulajadi ini juga mempunyai kelemahan iaitu keupayaannya untuk mengekalkan kualiti penyerapan diragui kerana kekurangan maklumat dan penyelidikan mengenai aplikasi akustik. Oleh itu, dalam kajian ini, gentian tandan kosong sawit (EFB) yang tidak dirawat digunakan sebagai unit kawalan dan alatan yang digunakan untuk mengukur nilai serapan adalah *tiub impedan* yang berlandaskan sistem kawalan dan piawaian ISO 10534-2, ASTM C-1557-03. EFB telah menjalani proses pengubahsuaian kimia yang dikenali sebagai rawatan alkali menggunakan natrium hidroksida (NaOH). Lima parameter dipilih untuk proses rawatan alkali iaitu masa rendaman serat (pada 1 jam hingga 5 jam) dengan kepekatan rawatan alkali tetap 6% NaOH. Kawasan keratan rentas serat diukur menggunakan penganalisis video stereo Leica. Hasil daripada ujian menunjukkan serat EFB memberikan nilai positif penyerapan bunyi dari frekuensi pertengahan hingga tinggi yang dari 2000 Hz hingga 5000 Hz. Penyerapan bunyi terbaik dilakukan oleh 1 jam serat dirawat dengan pekali penyerapan bunyi maksimum (α) hampir 1 pada 2500 Hz dan dengan ketebalan 50 mm. Koefisien Pengurangan Kebisingan (NRC) untuk serat yang dirawat 1 jam adalah 0.53. Bagi jangka hayat peluruhan, prestasi penyerapan bunyi sedikit berkurangan daripada 0.68 hingga 0.55 dalam tempoh 5 hingga 20 bulan. Keputusan ini menunjukkan bahawa EFB yang dirawat adalah bahan yang sangat menyerap dan sesuai digunakan untuk menjadi sebagai asas semula jadi untuk bahan penyerapan akustik.

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LIST OF SYMBOLS AND ABBREVIATIONS

EFB	Empty Fruit Bunch
ASTM	American Society for Testing and Materials
NaOH	Sodium Hydroxide
Hz	Hertz
cm	Centimetre
m	Metre
ml	Millilitre
m/s	Metre per second
vol	Volume
SEM	Scanning Electron Microscope
w/v	Weight per volume
%	Percentage
σ	Sigma
pH	Acidity or Basicity of solution
atm	Atmosphere
°C	Degree Celsius
UTHM	Universiti Tun Hussein Onn
SAC	Sound Absorption Coefficient
NRC	Noise Reduction Coefficient
τ	Tortuosity

CHAPTER 1

INTRODUCTION

1.1 Research background

The effects of noise are widely discussed and it is not more than a nuisance but it can lead to negative implications to human health. One of the most famous effects is hearing loss problem due to the excessive noise for a human being. Other significant effects of noise pollution include interference with communication, sleeplessness, and reduced efficiency. Besides, the extreme effects such as deafness and mental breakdown also ruled out (Singh & Davar, 2017). There are other common effects of noise which have an impact on human such as headache, dizziness, hypertension, cardiac disease and colitis (Blomkvist *et al.*, 2005). Despite all these, there are some sorts of way to control this noise by considering the source, the receiver or the path. At least one of these three elements is necessarily needed to be treated to help in controlling the level of noise.

However, the main characteristic of sound absorbing materials is its ability to absorb most of the sound energy that strikes on them, hence making them useful for noise control. Either it is from a synthetic material or any other material from a natural resource, the material must be effective to reduce the noise level. The sound absorbing materials are generally used to overcome the undesirable sound instead of reducing the reverberant noise level. Most of the materials depend on its ability and effectiveness to absorb the sound. Although there are wide ranges of synthetic sound absorption materials that exist with an excellent absorbing performance, it also caused a lots of issues on human health and side effect of pollution that has increase the public awareness to demand much on environmentally friendly material, recycled products as well as less contaminating process (Arenas & Crockert, 2009). On the other scenario, generation of solid waste from agricultural activities has caused several problems on-site such as disposal issues, hazards to workers as well as becoming a breeding ground for vermin and other pests that carrying diseases (Reddy & Yang, 2005).

By considering this to the public awareness and health concerns, researchers started to look into the new source from agricultural waste as an alternative material. Various types of natural sound absorbers material have been developed to overcome the noise. Daud *et al.* (2013) told that in order to develop a green technology, the concept of "from waste to wealth" and "recyclable material" must be established through the development of materials sustainability and the effectiveness of using the waste resource as the main material for a particular products Daud *et al.* (in Han, 2013). Due to this factor, natural fibres are widely discussed in terms of its functionality that is similar to synthetic fibre. Ashik & Sharma (2015) mentioned that this type of material has many benefits such as cheaper, non-abrasive and renewable (Ashik & Sharma, 2015). Despite to the current constraint on environmental concern, the use of the natural resource of a grow fibre crops will make the agriculture-based fibres as the most effective alternative to convert the usage of natural fibres into sound absorbing material.

Most of the available absorbing materials are from the fibrous material which is considered as composites medium where the fibres are suspended in air under certain binding forces (Sides, Attenborough, & Mulholland, 1971). Fibrous material usually consists of glass, rock wool or polyester fibres and it also has a high sound absorption (Braccesi & Bracciali, 2008). Over the decades, Malaysia has become one of the famous countries that produce palm oil in the international market. The total productions in West Malaysia are about 57% and 5 million hectares of palm oil has been planted all over Malaysia (Malaysia Oil Palm Board, 2011). EFB (Empty Fruit Bunch) is one of the largest oil palm biomass materials in Malaysia. The chemical compositions in EFB are quite comparable to coir and low content of cellulose (Khalil, Rozman, Ahmad, & Ismail, 2000). EFB has been applied in many industrial and farming fields as a material for the wood-based product such as particleboard and fibre board, composites panel, pulp and paper, soil stabilization and horticultural application. The attractive of EFB fibre are higher absorption and drying shrinkage as its contents reduced the self-weight which can be classified as lightweight (Kolop *et al.*, 2010).

Therefore, the empty fruit bunch fibre which is from an oil palm tree, are discussed in order to develop and evaluate the performance of the fibre in terms of sound absorption coefficient that based on the fibre's time range of treatment as well as the lifespan of the fibre. Along with this research, an impedance tube is used to study the effect of the fibre treatment, lifespan of fibre, porosity, tortuosity and its apparent density on sound absorption coefficient. Data obtained from the experiment are verified with a theoretical model as it is necessary to have the comparison results between experimental and theoretical.

1.2 Problem statement

Due to the current trend in green technology, lots of absorption materials which based on natural fibre are widely discussed and continously searching for more alternatives to produce the desired result of sound absorption performance of the natural fibre. Several studies have found that workers who are exposed to the man-made or synthetic fibre increase the risk of the human respiratory system (Nony *et al.*, 2014).

Therefore, natural fibres can be considered as an alternative way to replace synthetic fibre as well as to implement the sustainability of the materials. Variation of research on natural fibre significantly consist of the same functionalities of synthetic fibre such as the electrical insulation, mechanical, thermal and acoustic properties. Natural fibres exhibit many advantageous on the properties which are a low-density material, yielding relatively and lightweight (Chandramohan & Marimuthu, 2011).

In the other scenario, this EFB fibre has its disadvantages that need to be identified. The most common problem is its ability to maintain the quality of absorption due to it's natural are still lack of information and research on the acoustic application. Plus, it is less information about the lifespan of this natural fibre. Therefore, the purpose of this research is to investigate the potential of the natural fibre of palm oil's EFB on acoustical performance.

1.3 Research objectives

The aim of this research is to convert the EFB fibre waste into sound absorbing material. In order to achieve the aim, several objectives are outlined as follows:

i. To determine the effect of physical acoustical characteristic treated and untreated of EFB fibre.
ii. To investigate the effect of treatment time and decay lifespan of EFB fibre on sound absorption performance.
iii. To verify the sound absorption coefficient obtained experimentally with the value obtained by the theoretical method.

1.4 Research scopes

The scope of this study includes:

i. EFB fibre is treated with 6% of sodium hydroxide (NaOH).
ii. Five samples with different time of treatment durations which are 1 hour, 2 hours, 3 hours, 4 hours and 5 hours.
iii. Four samples with different decay lifespans which are 5 months, 10 months, 15 months and 20 months in room temperature (28°C) and indoor condition (average humidity).
iv. The sample physical parameters studied are fibre density, fibre diameter, thickness, tortuosity, flow resistivity and porosity.
v. The acoustical characteristics are the sound absorption coefficient (SAC) and the noise reduction coefficient (NRC).
vi. The research is conducted by using the impedance test tube accordance with ISO 10534-2 and ASTM E1050-98.
vii. The experiment results are compared to the theoretical models which are Delany-Bazley model.

1.5 Research questions

There are a few questions that need to be answered based on the research objective above which are:

1. Can EFB of palm oil be applied as sound absorber?
2. What are the acoustical characteristics of EFB if it can be applied as sound absorber?
3. How physical characteristics can influence the sound absorption characteristic of EFB fibre?
4. How does fibre treatment time influence the sound absorption coefficient?
5. What is the maximum lifespan for natural fibre to maintain its sound absorption performance?

1.6 Organization of thesis

There are five chapters involved in this thesis according to the organized sequence. The first chapter outlines the research background, problem statements, objectives and scopes of the research questions.

Chapter 2 gives comprehensive studies on previous works related to the topic. It starts by laying out the review about acoustical characteristic, types of absorption materials, natural fibres and other related parameters involved in this research.

Chapter 3 describes the method used in this research. It mainly brief about the research methodology including the method of sample preparation, material preparation, impedance tube and all other parameters that involved. The preparation of chemical dilution is also clarified in this section.

Chapter 4 presents the experimental and theoretical results. The influences of the physical characteristic on all samples are also discussed in this section. This includes the graph of the sound absorption coefficient as well as the result of noise reduction coefficient of the fibre samples.

Finally, Chapter 5 summarizes and concludes the results of the whole research with some of other further research and ideas to be point out as recommendation for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Sound waves can be analyzed in terms of their amplitude and frequency. The loudness of a sound is measured in decibels and it is corresponding to the amplitude of the wave. The pitches of the sound that we heard are affected by the frequency of a sound wave. The numbers of sound absorbing method have been developed over the last few decades. There were varieties of methods which are the porous absorbent, cavity absorbent and panel or membrane absorbent (Si *et al.*, 2018). The development, improvements and investigation of these methods require many experiments. For example, a study by Rozli, Jailani & Nor (2010) where he uses coconut coir with layer baking and perforated plates where the effectiveness of absorption depends on their construction (Zulkifli *el at.*, 2010).

2.2 Sound

Sound that causes unpleasant or undesirable environment is called as noise. However, the noise level is depending not only on the sound quality, but depending on our acceptance level as well. Kang (2007) found out the sound can also be damaging and destroying, for examples a sonic boom could shatter the windows and damaging the plaster of the wall as well as considering the major sources of sound in urban area such as road traffic noises, noise from railways, industrial operation activities and sound that generated from the construction activities. He also mentioned that these phenomenon eventually become perceives in domestic environment especially for places that located near to any residential compounds, public parks or educational institutions.

A sound that produces a high frequency can be detrimental because it can damage the delicate mechanism in human ears that has been designed to receive the sound. According to Ambekar (2013), the sound can be described as a disorder that is spread through physical or elastic. The noise power measured in units of decibels (dBA), where each sound source has different decibels strength as shown in Table 2.1. Sound also can be classified as something that can be heard, other than the human voice as described by Dobie & Hemel, (2005). They also described that in physics, the sound is a vibration that occurred in the air which then admitted to the ear. While the sound that exceeds the requirements of acceptance for hearing level is called noise.

Table 2.1: Sound power from different sources (Ambekar, 2013)

Source of sound	Sound Intensity Level (dB)	Sound Intensity $\left(\frac{W}{m^2}\right)$
Threshold of hearing	0	1×10^{-12}
Breathing	20	1×10^{-10}
Whispering	40	1×10^{-8}
Talking softly	60	1×10^{-6}
Loud conversation	80	1×10^{-4}
Yelling	100	1×10^{-2}
Loud Concert	120	1
Jet takeoff	140	100

Therefore, Liu & Liptak (1997) stated that the loud sound that can lead to injury of physically or emotionally could be defined as noise. It can also be defined as any changes in pressure in the ear that can be detected between the levels of noise can damage the hearing system. Those excessive noise levels can also cause noise which is inevitable in human life as a result of technological developments that have contributed to the improvement in the level of noise mainly from machinery, factories and vehicles on the road.

Efficiency is significantly reduced when hearing of an increasing age for organ whose function is to convert sounds to impulses that are understood by the brain will become more intense or damp. According to Liu & Liptak (1997) also, continuous exposure to loud noise will cause a person to lose the ability to hear. Noise also affects the level of tension of mind and sleep. When sleep is disturbed gradually, it will cause difficulty to sleep and difficulty awakened from sleep or even lack of sleep quality. That is why methods to reduce the noise level are very important so that it can be accepted by humans in particularly.

Various types of sound-absorbing devices have been developed as it helps the stage of hearing in order to make sure the sound reception is suitable and acceptable for every human being. Basner *et al.* (2015) also agreed that noise could give negative effects to the human's psychological or physiological such as causing anger, increase the heart rate, distress and loss of hearing, well asleep disturbances, increase the blood pressure and communication disturbances. Figure 2.1 shows the sound pressure level from various sound sources among human by Raichel (2006).

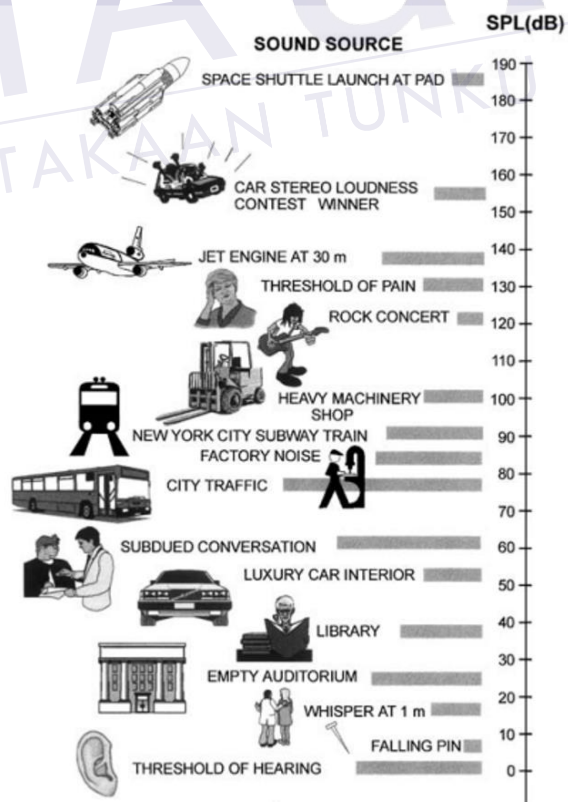

Figure 2.1: Sound pressure level (Raichel, 2006)

Everest & Pohlmann (2009) stated the vibrations of frequency and amplitude transmit the sound, where is frequency experienced as pitch while amplitude experienced as loudness. The movement of an instrument string is normally a transverse wave, based on the movement that perpendicular to the direction of travel as shown in Figure 2.2. When the air molecules move back and forth parallel to the direction of wave travel centred on an average position and causes no net movement of the molecules, it is called longitudinal waves of compression and rarefaction. These waves strike another object by exerting a force on them and cause the object to vibrate. It also should be noted that the velocity of the sound is different from the particle velocity. The velocity of the sound determines how fast the sound energy moves across a medium while the particle velocity is determined by the loudness of the sound.

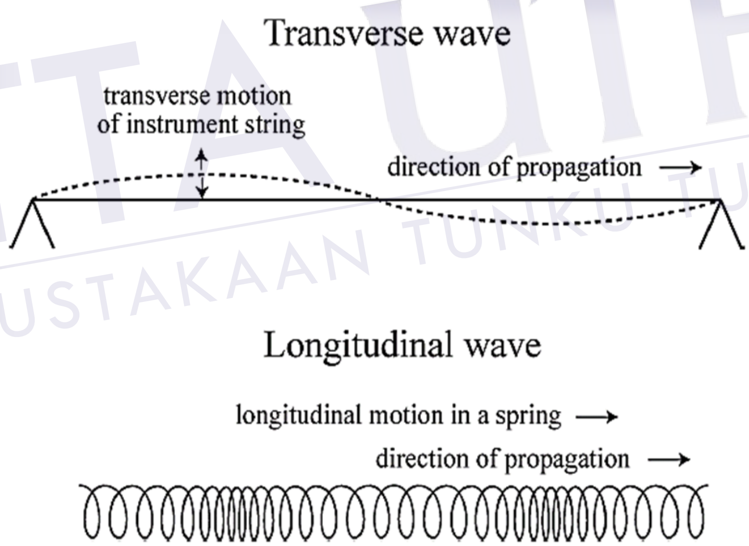

Figure 2.2: Transverse and longitudinal waves (Everest & Pohlmann, 2009)

2.3 Sound absorbers

Sound absorbers are used to reduce the noise level with noisy activities as well as to optimise the reverberation time in any room for speech or music. The absorption factors vary with frequencies and angles of incidence of the sound. Moreover, the area of the

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