THE INFLUENCE OF ALKALINE TREATMENT ON THE ACOUSTICAL PERFORMANCE OF EFB, MF, CF AND KF NATURAL FIBER

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DEDICATION

This thesis is dedicated to Abah & Mak.

For your endless love, support and encouragement.

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ABSTRACT

Nowadays, emerging noise pollution by external factors causes harmful diseases. For decades synthetic materials have been widely used as acoustic insulations materials. Nevertheless, rapid growth has been observed in the innovations and use of natural fiber based materials for acoustic applications due to their diverse capabilities. However, natural fibers are inherent features of plant-based natural fibers, including high moisture absorption, lower strength, poor adhesion with matrix resin and low durability than synthetic fiber. These are the major driving factors for the surface modification of fibers. Therefore, this present research deals with the impact of chemical treatment, primarily by using sodium hydroxide (NaOH) on enhancing empty fruit bunch (EFB), mesocarp fiber (MF), coir fiber (CF) and kenaf fiber (KF) sound insulation properties. The effect of alkalization in fiber morphologies, changes in fiber diameter and changes occurring in fibers functional groups were detailed analyzed using SEM and FTIR analysis. The sample was fabricated at a constant thickness of 45 mm and a density of 0.4g/cm^3 prior to the evaluation of sound properties including sound absorption coefficient (SAC) and sound transmission loss (STL) using Impedance Tube methods. Results indicated, NaOH treatment successfully reduced fiber diameter and changed fiber surface morphologies. This finding was supported by the peak changes observed on the FTIR spectra. The results conclusively indicated that sound absorption performances of treated EFB, MF, CF and KF increased significantly. This is followed by a substantial increase of STL values at a higher frequency range of treated fibers than untreated ones. The evidence from this research confirmed that natural fibers of EFB, MF, CF and KF treated using NaOH treatment are potential and good alternatives as raw fibers for future acoustic applications. The findings also suggested that kenaf fiber treated using 6% NaOH concentrations is the most suitable materials for acoustical application due to the lowest fiber diameter and highest absorption capabilities.

ABSTRAK

Pada masa kini, pencemaran bunyi yang terjadi disebabkan faktor luaran boleh mengakibatkan penyakit berbahaya kepada manusia. Selama beberapa dekad bahan sintetik telah digunakan secara meluas sebagai bahan penebat akustik. Namun begitu, pertumbuhan yang sangat pesat telah dilaksanakan dalam inovasi dan penggunaan bahan berasaskan bahan semulajadi untuk aplikasi akustik. Walau bagaimanapun, serat semula jadi ini mempunyai ciri-ciri penyerapan kelembapan tinggi, kekuatan yang rendah, lekatan dan daya tahan yang rendah. Ini adalah faktor pendorong utama pengubahsuaian permukaan serat. Oleh itu, penyelidikan ini membincangkan kesan rawatan kimia menggunakan natrium hidroksida (NaOH) dalam meningkatkan kesan penebat bunyi terhadap tandan buah kosong (EFB), serat mesocarp (MF), serat sabut (CF) dan serat kenaf (KF). Kesan alkalisasi dalam morfologi serat, perubahan pada diameter serat dan perubahan yang berlaku pada kumpulan fungsi serat dianalisis secara terperinci menggunakan analisis SEM dan FTIR. Sampel dibuat pada ketebalan tetap 45 mm dan ketumpatan 0.4 g/cm^3 sebelum penilaian sifat bunyi termasuk pekali penyerapan bunyi (SAC) dan kehilangan transmisi bunyi (STL) menggunakan kaedah Impedance Tube. Hasil kajian menunjukkan, rawatan NaOH berjaya mengurangkan diameter serat dan mengubah morfologi permukaan serat. Hasil kajian menunjukkan bahawa prestasi penyerapan bunyi EFB, MF, CF dan KF yang dirawat meningkat dengan ketara. Hal ini diikuti oleh peningkatan ketara nilai STL untuk serat yang dirawat pada julat frekuensi lebih tinggi berbanding serat yang tidak dirawat. Bukti daripada penyelidikan ini mengesahkan bahawa gentian semula jadi EFB, MF, CF dan KF yang dirawat menggunakan rawatan natrium hidroksida (NaOH) adalah satu alternatif yang berpotensi dan baik sebagai gentian mentah untuk aplikasi akustik masa hadapan. Dapatan kajian juga mencadangkan serat kenaf yang dirawat menggunakan 6% NaOH merupakan bahan yang paling sesuai sebagai aplikasi akustik kerana mempunyai saiz diameter serat yang kecil dan kebolehserapan bunyi yang tinggi.

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α	-	sound absorption coefficients
λ	-	wavelength
υ	-	sound velocity
f	-	frequency
A_t	-	equivalent sound absorption coefficient
Hz	-	hertz
dB	-	decibel
ρ	-	bulk density
ϕ	-	apparent porosity
ρ	-	density
m	-	meter
cm	-	centimeter
mm	-	millimeter
µm	-	micrometer
s	-	second
hr	-	hour
ktonnes	-	kilo tonne
kg	-	kilogram
g	-	gram
m^3	-	cubic meter
m/s	-	meter per second
kg/m^3	-	kilogram per cubic meter
g/cm^3	-	gram per cubic centimeter
Mt	-	million tonnes
Ha	-	hectare
%	-	percentage
psi	-	pound square inch

°C	-	degree Celsius
Ø	-	diameter
π	-	pi (3.142)
V	-	room volume
S	-	total area of sample
r	-	pressure reflection coefficient
Ea	-	absorption
Ei	-	incident
Et	-	transmitted
Er	-	reflection
NRC	-	noise reduction coefficients
SAC	-	sound absorption coefficients
STL	-	sound transmission loss
SPL	-	sound pressure level
ASTM	-	American Society for Testing and Materials
ISO	-	International Organisation for Standardisation
OPEFB	-	oil palm empty fruit bunch
EFB	-	empty fruit bunch
FFB	-	fresh fruit bunch
MF	-	mesocarp fiber
CF	-	coir fiber
KF	-	kenaf fiber
POFS	-	palm oil flower spikes
PU	-	polyurethane
DPF	-	date palm fiber
OP	-	oil palm
POW	-	palm oil waste
OPT	-	oil palm trunks
OPF	-	oil palm fronds
PPF	-	palm pressed fibers
PKS	-	palm kernel shells
POME	-	palm oil mill effluent
PKC	-	palm kernel cake
POMFS	-	palm oil male flower spikes

TLF	-	tea-leaf-fiber
PALF	-	pine apple leave fibers
CCF	-	coconut coir fiber
CGF	-	coccinia Grandis.L fibers
PLB	-	porous layer backing
PP	-	perforated panel
WCC	-	woven cotton cloth
BF	-	bamboo fiber
CF	-	corn fiber
GF	-	grass fiber
SCF	-	sugar cane fiber
MDF	-	medium density fiberboard
FRP	-	fiber reinforced polymer
PB	-	particleboard
CO_2	-	carbon dioxide
O_2	-	oxygen
C	-	carbon
UF	-	urea formaldehyde
MF	-	melamine-formaldehyde
UMF	-	urea-melamine-formaldehyde
PU	-	polyurethane
UHMWPE	-	ultra-high molecular weight polyurethane
PLA	-	polylactide
NaOH	-	Sodium Hydroxide
$KmnO_4$	-	Permanganate
SEM	-	Screening electron microscope
FTIR	-	fourier transforms infrared
UTHM	-	Universiti Tun Hussein Onn Malaysia
FKAAB	-	Fakulti Kejuruteraan Awam dan Alam Bina
FKMP	-	Fakulti Kejuruteraan Mekanikal dan Pembuatan
JKM	-	Noise and Vibration Laboratory
WHO	-	World Health Organisation
DOE	-	Department of Environmet
DOSH	-	Department of Occupational Safety and Health Malaysia

MPOC	-	Malaysian Palm Oil Council
MPOB	-	Malaysian Palm Oil Board
MOA	-	Kementerian Pertanian & Industri Makanan Malaysia
MARDI	-	Malaysian Agricultural Research & Development Instutute
GDP	-	gross domestic product

CHAPTER 1

INTRODUCTION

1.1 Introduction

Rapid growth in population density, transportation and industrial sector increased the demand for sound comfort by human. Despite, individual acceptance towards sound is very subjective. It might be differing from one person to another and totally relying on individual perception. Normal hearing capability of human ranges approximately between 20 Hz to 20,000 Hz. In spite, most adults are more sensitive to sound between 3000 Hz to 4000 Hz of frequency range (Erman, 2015). Even though sound is very useful and important for human, excessive sound could lead to major problem. For example, mechanization and industrialization that become the landscapes in most countries nowadays had caused noise pollution. This could lead to major health disturbances to human such as hearing loss, insomnia, heart attack and hypertension due to long exposure to noise (Memon *et al*., 2015). Excessive noise also might cause some other adverse effect on human psychology such as annoyance, speech interference, sleep disturbance and reduce work performance.

It is undeniable that most of surrounding noises are not able to be eliminated. Even so, it can be brought down to one acceptable level for human hearing. Since noise pollution has been discovered since long and realizing the adverse risk on human, acoustical control issues were being handled by applying appropriate sound absorber to the affected areas as one of the most practical solutions in maintaining hearing comfort in buildings and create acoustically pleasing environment. Historically, asbestos being used as the main material for sound absorber, however this material contributes to adverse human health level. By 1970s, asbestos was replaced by synthetic material for the same purpose (Ravandi *et al*., 2015). Among the types of synthetic sound absorbers are glass wool, polymeric fibrous materials and foams, normally been used to absorb noise (Niresh *et al*., 2016). Research shows that, the production of synthetic materials contributes to greenhouse gas such emissions particularly carbon dioxide, methane and nitrous oxide, which are harmful to human (Arenas and Crocker, 2010). Moreover, synthetic sound absorber made of mineral wool is hazardous when inhaled or exposed to human during fiber shredding process and could lead to other related health problems (Asdrubali, 2006).

Therefore, many researchers have started utiizing or incorporating natural fibers as the raw fiber for acoustics material (Rachman *et al*., 2018). Natural fibers such as palm oil fiber, coconut fiber, kenaf, grass fiber is among the most favorable acoustic material fiber. Natural fiber poses unique physical characteristics such as hollow and cellular configurations on its structure, making this material a good source of fiber for acoustic and thermal insulators (Kumar & Mohanraj, 2017). In the early years, Ballagh (1996) presented a study on wool, which later concluded wool could be used in various acoustical applications. Asdrubali (2007) found natural fibers such as kenaf, hemp, flax, coconut fibers show excellent sound absorption and reasonable substitutions for synthetic materials with similar performances. A review has been presented by Berardi and Iannace (2015) on kenaf, wood, hemp, coconut, cork, cane, cardboard and sheep wool. They suggested those materials were suitable for absorption materials and environmentally friendly. In the last few years, many more studies were reported on the suitability of natural fiber as acoustical materials, such as sheep wool (Rey *et al*., 2017), kenaf (Lim *et al*., 2018), hemp (Santoni *et al*., 2019), coir fiber (Taban *et al*., 2019), fique (Gomez *et al*., 2020) and jute (Sengupta *et al*., 2020). These new sustainable sound absorption and insulations materials were studied, and some of the results were comparable to synthetic and commercial materials.

Despite, natural fiber also has gained widespread attention as an alternative to synthetic materials in many disciplines of industries including automotive, marine, building and transportation (Zhao *et al*., 2017). Natural fiber presents many advantages and comes with a porous cell structure that serves few advantages compared to traditional synthetic materials such as low density, having good mechanical properties, easy processing, health-friendly, cheap, abundance and reducing the impact on the environment (Berardi *et al*., 2016). However, even with many undoubtedly advantages of natural fiber, they also possess several drawbacks and incompatibility, including high moisture absorption, lower strength, poor adhesion with matrix resin and low durability than synthetic fiber (Pickering et *al*., 2016). Therefore, many applications of lignocellulose fibers also require the fibers to have specific physical and mechanical properties (Yan *et al*., 2016; Faizi *et al*., 2018).

Hence, many studies have been conducted to improve the compatibility of these natural fibers, including an adequate treatment process to enhance the fiber properties. Past research revealed that treatment helps clean the fiber from impurities, remove some amount of lignin content, cellulose, wax and oil residue on the fiber surface, enhance fiber and matrix bonding quality and lower the rate of water absorption on the fiber (Ibrahim *et al*., 2015). Many treatment methods have been conducted by the previous researcher, yet it is still difficult to choose the most suitable treatment for a particular type of fiber (Peças *et al*., 2018). Treatment or surface modifications can be grouped into four categories, 1) physical treatment, 2) chemical treatment, 3) biological treatment, and 4) physiocochemical treatment. Alkali treatment or otherwise called mercerization, falls in the chemical treatment group. Sodium hydroxide (NaOH), the main chemical used in alkali treatment, is one of the extensively used by many researchers and an effective surface modification process that can increase the properties of lignocellulosic fiber (Then *et al*., 2015; Sepe *et al*., 2018). This included improvement in fiber surface morphology, cellulose content, and success in removing of lignin and hemicellulose layer, which decreased fiber moisture content and reduced fiber diameter (Sari *et al*., 2017).

Malaysia has been blessed with fertile land and tropical weather, known as one of the countries rich in agricultural by-products. This included palm oil, paddy, cocoa, natural rubber, kenaf, paper, coconut, sugarcane and pineapple planted on agricultural land distributed throughout 13 states in Malaysia. According to the Department of Statistics Malaysia, the agriculture sector contributed RM 99.5 billion to Malaysia's Gross Domestic Product (GDP) in 2019. Oil palm contributes the major contributor, followed by the other types of crops in the agricultural industry. Palm oil was the main economic contributor of Malaysia, which was early known as a decorative plant when first brought to Malaysia in 1971. Now, Malaysia is one of the biggest palm oil exporters in the world after Indonesia (MPOB, 2017). Empty fruit bunch (EFB) and mesocarp were two fiber types from palm oil processing mills and known as waste. EFB is the fibrous mass leftover from the separation of the oil fruits caused by the sterilization process at the oil palm mill. On the other hand, mesocarp, also referred to

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APPENDIX B

PUBLICATIONS

1. **Ida Norfaslia Nasidi,** Lokman Hakim Ismail, Emedya Murniwaty Samsudin and Muhammad Ismail Jaffar. (2022), Effect of Kenaf Fiber Strand Treatment by Sodium Hydroxide on Sound Absorption, Journal of Natural Fiber, 19(13), 6727-6736. (IF: 5.323) (WoS/Q1).
2. **Ida Norfaslia Nasidi,** Lokman Hakim Ismail and Emedya Murniwaty Samsudin. (2021), Effect of Sodium Hydroxide (NaOH) Treatment on Coconut Coir Fiber and its Effectiveness on Enhancing Sound Absorption Properties, Pertanika Journal Science and Technology, 29(1), 693-706. (WoS/Q3).
3. **Ida Norfaslia Nasidi**, Lokman Hakim Ismail and Emedya Murniwaty Samsudin. (2018), The Effect of Natural Fiber Sound Absorption on Sodium Hydroxide Treatment, 25th International Congress on Sound and Vibration (ICSV25 Hiroshima). (Scopus).
4. **Ida Norfaslia Nasidi**, Lokman Hakim Ismail, Emedya Murniwaty Samsudin, Muhammad Firdaus Abdul Khodir and Muhammad Aizat Kamarozaman. (2018), The Effect of Different Fiber Length and Different Urea Formaldehyde (UF) Content on Sound Absorption Performance of Empty Fruit Bunch (EFB), MATEC Web of Conference, 150(03003). (Scopus).
5. Emedya Murniwaty Samsudin, Lokman Hakim Ismail, **Ida Norfaslia Nasidi**, Hasniza Abu Bakar, Ahmed A. Elgadi. (2019), Formaldehyde and VOC Emissions from EFBMF Panel for Sound Absorption Material, International Journal of Advanced Trends in Computer Science and Engineering, World Academy of Research in Science and Engineering, 8(262). (Scopus).
6. Emedya Murniwaty Samsudin, Lokman Hakim Ismail, Aeslina Abdul Kadir, **Ida Norfaslia Nasidi**, and Shahida Samsudin. (2017), Rating of Sound Absorption for EFBMF Acoustic Panels according to ISO 11654:1997, Conference: Malaysian Technical Universities Conference on Engineering and Technology.