

# ANALYSIS OF SOUND ABSORPTION PROPERTIES OF SPENT TEA LEAVES-POLYPROPYLENE COMPOSITES



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

# ANALYSIS OF SOUND ABSORPTION PROPERTIES OF SPENT TEA LEAVES-POLYPROPYLENE COMPOSITES



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016



## **UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

### **ANALYSIS OF SOUND ABSORPTION PROPERTIES OF SPENT TEA LEAVES-POLYPROPYLENE COMPOSITES**

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) (Hons.)

اونيورسي تيكنيكل مليسيا ملاك  
by  
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**WONG YUNG CHENG**

**B051310055**

**921214-12-5981**

**FACULTY OF MANUFACTURING ENGINEERING**

**2016**

## DECLARATION

I hereby, declared this report entitled “Analysis of Sound Absorption Properties of Spent Tea Leaves-Polypropylene Composites” is the results of my own research except as cited in references.

Signature	.....
Author's Name :	WONG YUNG CHENG
Date :	22 <sup>nd</sup> JUNE 2016



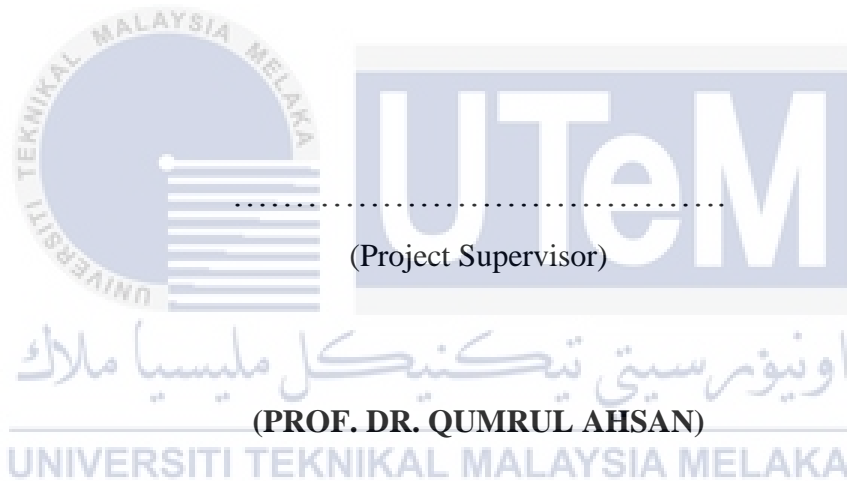
اونيورسيتي تیکنیکل ملیسیا ملاک

---

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Manufacturing Engineering (Engineering Materials) (Hons.). The member of the supervisory committee is as follow:



## ABSTRAK

Kajian ini memberi tumpuan kepada sifat penyerapan bunyi komposit mengandungi sisa daun teh bertujuan untuk penyerapan bunyi. Sisa daun teh (STL) adalah bahan buangan dari kilang pemprosesan teh dan merupakan sumber semula jadi baru untuk bahan penyerapan bunyi daripada komposit polypropylene. Tujuan kajian ini adalah untuk menghasilkan, mencirikan dan mengkaji sifat penyerapan bunyi komposit polypropylene mengandungi sisa daun teh. Tiga gred STL yang digunakan dalam kajian ini adalah BHE-SW (serat halus), BHE-BM (serat sederhana) dan SPE-SW (serat kasar) dari tangkai pokok teh. Sebahagian daripada STL dirawat dengan alkali. Komposit yang dihasilkan telah menjalani FTIR spektroskopi, ujian tiub impedans dan kajian mikroskopik. Dapatan kajian penyerapan bunyi telah menunjukkan bahawa saiz serat dan rawatan kimia memberi kesan pada sifat penyerapan bunyi. Dari segi saiz serat, komposit serat halus adalah penyerap bunyi yang baik pada frekuensi sederhana (1000 – 2500 Hz), manakala komposit serat sederhana dan kasar adalah lebih baik dalam menyerap bunyi frekuensi tinggi (2500 – 4500 Hz). Dari segi rawatan kimia, komposit serat yang tidak dirawat adalah penyerap bunyi yang baik pada frekuensi sederhana, manakala komposit serat yang dirawat adalah lebih baik dalam menyerap bunyi frekuensi tinggi. Oleh itu, komposit polypropylene mengandungi sisa daun teh boleh digunakan mengikut keperluan aplikasi.

## ABSTRACT

This research focuses on the sound absorption properties of spent tea leaves composites materials for sound absorption. Spent tea leaves (STL) are waste materials from tea processing plants, and are considered as new natural resources for sound absorbing polypropylene composite materials. The aims of this research are to synthesize, characterize and study the sound absorption properties of spent tea leaves filled polypropylene composites. Three grades of STL are used in this research, which are BHE-SW (fine fiber), BHE-BM (medium fiber) and SPE-SW (coarse fiber) from the stalk of the tea plant. Portions of STL are subjected to alkalization treatment. The fabricated composites are subjected to FTIR spectroscopy, impedance tube test and microscopic examination. From this research, the sound absorption results have shown that fiber size and treatment conditions have pronounced effects on the sound absorption properties. In term of fiber size, fine fiber composites are good sound absorbers at medium frequency range (1000 – 2500 Hz), while medium and coarse fibers composites are good at absorbing high frequency sound (2500 – 4500 Hz). In term of treatment conditions, untreated fiber composites are good sound absorbers at medium frequency range, while treated fiber composites are good at absorbing high frequency sound. Thus, spent tea leaves filled polypropylene composites can be employed according to the demands of the application.

## DEDICATION

*Dedicated to  
my beloved father, Wong Kong Kiong  
my treasured mother, Thien Nyet Mee  
and my adored siblings, Wong Hui Shan and Wong Yung Zhi  
for giving me advice, understanding, encouragement and also moral support.*





## ACKNOWLEDGEMENT

First and foremost, I would like to express my utmost gratitude to my beloved supervisor, Prof. Dr. Qumrul Ahsan for his guidance, valuable information and knowledge sharing, which helped me in completing the Final Year Project as scheduled and fulfilled the requirements.

Besides, I would like to show my deepest appreciation to my beloved parents for their advice, understanding, encouragement and moral support throughout the entire project.

Last but not least, I would like to thank friends who helped and guided me during moments of difficulty. Their cooperation and encouragement during the project period were highly appreciated.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# TABLE OF CONTENTS

Abstrak	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of Contents	v
List of Tables	viii
List of Figures	ix
List of Abbreviations	xiii
List of Symbols	xv
<b>CHAPTER 1: INTRODUCTION</b>	
1.1 Background of Study	1
1.2 Problem Statement	3
1.3 Objectives	4
1.4 Scope	5
<b>CHAPTER 2: LITERATURE REVIEW</b>	
2.1 Natural Sound Absorbing Material	6
2.1.1 Tea leaf	7
2.1.2 Fibrous porous sound absorbing material	10
2.2 Synthetic Sound Absorbing Material	11
2.2.1 Polypropylene	12
2.2.2 Granular porous sound absorbing material	13
2.3 Acoustical Material	13
2.3.1 Sound absorbing material	14
2.3.2 Porous absorbing material	16
2.4 Modification on Fiber Surface and Matrix	17

2.4.1	Alkaline treatment	17
2.4.2	Maleic anhydride grafted polypropylene	19
2.5	Fabrication of Natural Fiber Composite	20
2.5.1	Compounding	21
2.5.2	Compression molding	22
2.6	Testing and Characterization	23
2.6.1	Impedance tube method	23
2.6.2	Fourier transform infrared spectroscopy	24
2.6.3	Scanning electron microscopy	26
2.7	Previous Work on Sound Absorption	29
2.7.1	Natural fiber absorption material	29
2.7.2	Synthetic absorption material	32
2.7.3	Summary on previous researches	35
2.8	Conclusion	35
<b>CHAPTER 3: METHODOLOGY</b>		
3.1	Overview of Methodology	37
3.2	Raw Materials	39
3.2.1	Spent tea leaves	39
3.2.2	Polypropylene	40
3.2.3	Maleic anhydride grafted polypropylene	40
3.2.4	Sodium hydroxide	41
3.3	Sample Fabrication	41
3.3.1	Preparation of spent tea leaves	41
3.3.2	Compounding of spent tea leaves/polypropylene blends	42
3.3.3	Hot compression molding	43
3.3.4	Sample preparation	44
3.4	Testing	46
3.4.1	Impedance tube measurement	46
3.5	Characterization	48
3.5.1	Optical microscopy	48

3.5.2	Fourier transform infrared spectroscopy	49
3.5.3	Scanning electron microscopy	50
<b>CHAPTER 4: RESULTS AND DISCUSSIONS</b>		
4.1	Dimensional Measurement	51
4.2	Fourier Transform Infrared Spectroscopy	53
4.3	Impedance Tube Measurement	63
4.3.1	Effect of fiber type on sound absorption with rigid backing	67
4.3.2	Effect of treatment condition on sound absorption with rigid backing	70
4.4	Scanning Electron Microscopy	73
<b>CHAPTER 5: CONCLUSION AND RECOMMENDATION</b>		
5.1	Conclusion	80
5.2	Recommendation	81
5.3	Sustainable Elements	81
<b>REFERENCES</b>		<b>83</b>
<b>GANTT CHART PSM 1</b>		<b>92</b>
<b>GANTT CHART PSM 2</b>		<b>93</b>

## LIST OF TABLES

2.1	Chemical constituents, moisture content, and microfibrillar angle of natural fibers	7
2.2	Composition of fresh tea flush (% dry weight)	9
2.3	Average fiber diameter of natural and synthetic fibers	11
2.4	Properties of polypropylene	13
2.5	Sound absorption coefficients of different natural fibers	32
2.6	Constituents of recycled materials	33
2.7	Sound absorption coefficients of various samples	33
3.1	Average diameter for spent tea leaves	39
3.2	The formulation and ratio of compound ingredients	42
4.1	Minimum diameter, maximum diameter, average diameter and standard deviation values of three different grades of spent tea leaves	53
4.2	Summary of FTIR characteristic bands of spent tea leaves	54

## LIST OF FIGURES

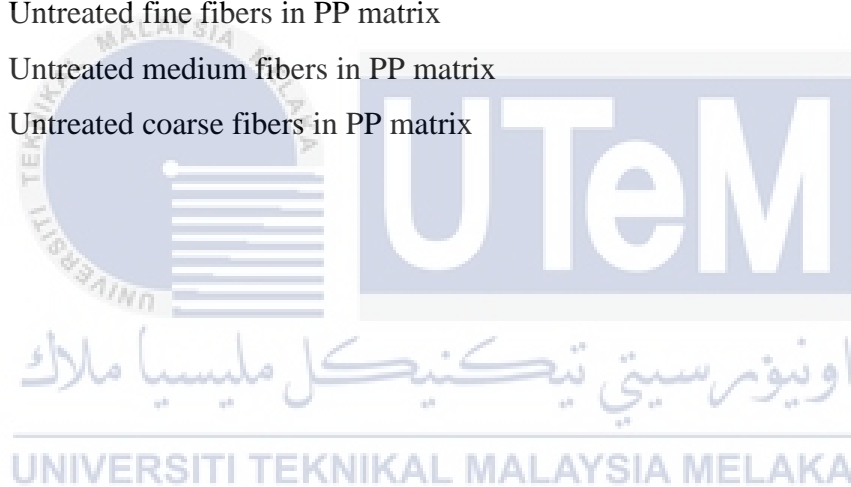
2.1	Camellia sinensis tea leaves	8
2.2	Sound absorption of the tea leaves material	10
2.3	Chemical formula of polypropylene	13
2.4	Sound travels through acoustical material	14
2.5	Sound absorption coefficient versus frequency for various types of sound absorbing materials	15
2.6	Schematic cross-section of a porous solid material	16
2.7	Reaction between MAPP and natural fiber	20
2.8	The press platens are heated and pressure is applied onto the mold	22
2.9	Schematic representation of two-microphone setup to determine acoustic impedance	24
2.10a	FTIR spectra of untreated sisal fibers	26
2.10b	FTIR spectra of treated sisal fibers	26
2.11	Schematic diagram of scanning electron microscope	27
2.12	Schematic diagram of signals generated by the impinging electrons	28
2.13a	Microstructures of rice straw fibers reinforced polypropylene composites under SEM: untreated	28
2.13b	Microstructures of rice straw fibers reinforced polypropylene composites under SEM: alkaline MAPP treated	28
2.14	Sound absorption coefficient vs. frequency for flax fiber (FE), glass fiber (GE) and glass/flax fiber (GFE) filled epoxy samples	31
2.15	Sound absorption coefficient of brick and its composite boards	34
3.1	Process flowchart	38
3.2a	Spent tea leaves grade BHE-SW	39
3.2b	Spent tea leaves grade BHE-BM	39
3.2c	Spent tea leaves grade SPE-SW	39

3.3	Polypropylene granules	40
3.4	Maleic anhydride grafted polypropylene granules	40
3.5	Internal mixer	43
3.6a	Hot compression molding by using hot press machine	44
3.6b	Hot compression molding by using mild steel mold	44
3.6c	Hot compression molding by using aluminium plunger	44
3.7a	Sound absorbing samples of pure PP	45
3.7b	Sound absorbing samples of untreated STL grade BHE-SW filled PP composite	45
3.7c	Sound absorbing samples of untreated STL grade BHE-BM filled PP composite	45
3.7d	Sound absorbing samples of untreated STL grade SPE-SW filled PP composite	45
3.7e	Sound absorbing samples of treated STL grade BHE-SW filled PP composite	45
3.7f	Sound absorbing samples of treated STL grade BHE-BM filled PP composite	45
3.7g	Sound absorbing samples of treated STL grade SPE-SW filled PP composite	45
3.7h	Sound absorbing samples of treated STL grade BHE-SW filled MAPP composite	45
3.7i	Sound absorbing samples of treated STL grade BHE-BM filled MAPP composite	45
3.7j	Sound absorbing samples of treated STL grade SPE-SW filled MAPP composite	45
3.8	Impedance tube type 4206	47
3.9	Optical microscope	49
3.10	FTIR spectrometer	50
3.11	Scanning electron microscope	50
4.1a	Optical micrographs of BHE-SW grade of spent tea leaves	52

4.1b	Optical micrographs of BHE-BM grade of spent tea leaves	52
4.1c	Optical micrographs of SPE-SW grade of spent tea leaves	52
4.2	FTIR spectra of fine, medium and coarse fibers	56
4.3	FTIR spectra of untreated and treated fine fibers	58
4.4	FTIR spectra of untreated and treated medium fibers	58
4.5	FTIR spectra of untreated and treated coarse fibers	59
4.6	FTIR spectra of pure polypropylene, untreated and treated fine fibers composites	61
4.7	FTIR spectra of pure polypropylene, untreated and treated medium fibers composites	62
4.8	FTIR spectra of pure polypropylene, untreated and treated coarse fibers composites	62
4.9a	Absorption coefficient versus frequency of pure PP	63
4.9b	Absorption coefficient versus frequency of PPUF composite	63
4.9c	Absorption coefficient versus frequency of PPUM composite	63
4.9d	Absorption coefficient versus frequency of PPUC composite	63
4.9e	Absorption coefficient versus frequency of PPTF composite	64
4.9f	Absorption coefficient versus frequency of PPTM composite	64
4.9g	Absorption coefficient versus frequency of PPTC composite	64
4.9h	Absorption coefficient versus frequency of MPTF composite	64
4.9i	Absorption coefficient versus frequency of MPTM composite	64
4.9j	Absorption coefficient versus frequency of MPTC composite	64
4.10	Comparison of absorption coefficients versus frequency for different types of untreated fibers filled PP composites	67
4.11	Comparison of absorption coefficients versus frequency for different types of treated fibers filled PP composites	68
4.12	Comparison of absorption coefficients versus frequency for different types of treated fibers filled MAPP composites	69
4.13	Comparison of absorption coefficients versus frequency for untreated and treated fine fibers composites	70



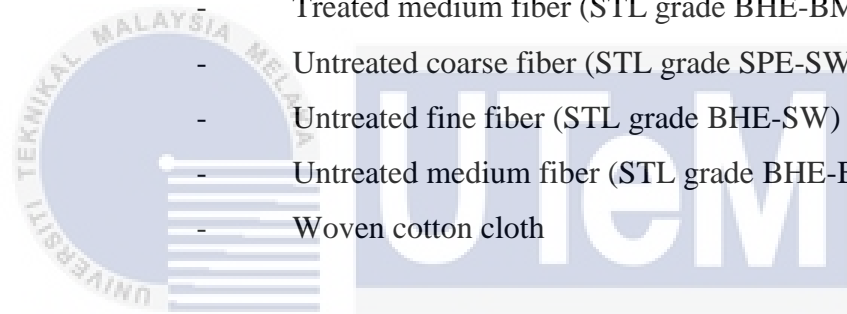
4.14	Comparison of absorption coefficients versus frequency for untreated and treated medium fibers composites	71
4.15	Comparison of absorption coefficients versus frequency for untreated and treated coarse fibers composites	72
4.16a	The distribution of untreated spent tea leaves of fine fibers in PP matrix	74
4.16b	The distribution of untreated spent tea leaves of medium fibers in PP matrix	74
4.16c	The distribution of untreated spent tea leaves of coarse fibers in PP matrix	74
4.17	Torque versus time for compounded materials of different types of fibers	75
4.18	Hollow lumen structure of untreated coarse spent tea leaves grade SPE-SW	76
4.19	Untreated fine fibers in PP matrix	77
4.20	Untreated medium fibers in PP matrix	78
4.21	Untreated coarse fibers in PP matrix	78



## LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
BHE-BM	-	Medium spent tea leaves grade
BHE-SW	-	Fine spent tea leaves grade
C	-	Coarse fiber (STL grade SPE-SW)
F	-	Fine fiber (STL grade BHE-SW)
FE	-	Flax fiber filled epoxy composite
FTIR	-	Fourier Transform Infrared Spectroscopy
GE	-	E-glass fiber filled epoxy composite
GFE	-	Flax/E-glass fiber filled epoxy composite
HDPE	-	High-density polyethylene
KBr	-	Potassium bromide
M	-	Medium fiber (STL grade BHE-BM)
MAPP	-	Maleic anhydride grafted polypropylene
MPTC	-	Treated coarse fiber filled maleic anhydride grafted polypropylene composite
MPTF	-	Treated fine fiber filled maleic anhydride grafted polypropylene composite
MPTM	-	Treated medium fiber filled maleic anhydride grafted polypropylene composite
NaOH	-	Sodium hydroxide
PE	-	Polyethylene
PET	-	Polyethylene terephthalate
PNF	-	Polypropylene based non-woven fiber
PP	-	Polypropylene
PPTC	-	Treated coarse fiber filled polypropylene composite
PPTF	-	Treated fine fiber filled polypropylene composite
PPTM	-	Treated medium fiber filled polypropylene composite

PPUC	-	Untreated coarse fiber filled polypropylene composite
PPUF	-	Untreated fine fiber filled polypropylene composite
PPUM	-	Untreated medium fiber filled polypropylene composite
PS	-	Polystyrene
SAC	-	Sound absorption coefficient
SEM	-	Scanning Electron Microscopy
SPE-SW	-	Coarse spent tea leaves grade
STL	-	Spent tea leaves
TC	-	Treated coarse fiber (STL grade SPE-SW)
TF	-	Treated fine fiber (STL grade BHE-SW)
TLF	-	Tea leaf fiber
TM	-	Treated medium fiber (STL grade BHE-BM)
UC	-	Untreated coarse fiber (STL grade SPE-SW)
UF	-	Untreated fine fiber (STL grade BHE-SW)
UM	-	Untreated medium fiber (STL grade BHE-BM)
WCC	-	Woven cotton cloth



اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## LIST OF SYMBOLS

%	-	percent
°	-	degree
°C	-	degree Celsius
μm	-	micrometer
cm	-	centimeter
cm <sup>-1</sup>	-	reciprocal of centimeter
g	-	gram
g/cm <sup>3</sup>	-	gram per cubic centimeter
g/mol	-	gram per mole
Hz	-	Hertz
kgf/cm <sup>2</sup>	-	kilogram-force per square centimeter
mg	-	milligram
ml	-	milliliter
mm	-	millimeter
MPa	-	mega Pascal
Pa	-	Pascal
wt%	-	weight percentage
X	-	times

# CHAPTER 1

## INTRODUCTION

This chapter describes the background of study, the problem statement, the objectives, and the scope of study.

### 1.1 Background of Study

Sound is a vibration that produces mechanical movement or wave which propagates through a medium such as air (Zhu *et al.*, 2013). To further explain, sound wave is a vibrational system in which the wave creates pressure during propagation as a result of the nature of fluctuation within a material (Fouladi *et al.*, 2013). Excessive sound beyond a certain limit will produce noise. Noise is an irregular and chaotic sound which disturbs people's works and causes health issues (Veerakumar and Selvakumar, 2012). Nowadays, noise pollution has become a critical issue with increasing urbanization (Fatima and Mohanty, 2011). According to Al-Rahman *et al.* (2012), some of the sources of unwanted noise are the sound emitted from factories, heavy machineries and vehicles. Long-term exposure to continuous noises can cause discomfort which may lead to various health problems such as nerve weakness, heart problems, high blood pressure, and even hearing loss. In worse scenarios, the noise-induced stress develops tension within an individual and contributes to mental illness (Yuhazri *et al.*, 2010).

Therefore, sound absorbing material is needed to reduce noise emission which can cause adverse effects on human health. Nowadays, sound absorption application is considered an important requirement for human comfort. Sound absorbing material or sound absorber is used to absorb as much sound energy as possible and to reflect very little. Various categories of sound absorber are available up-to-date, these include porous absorber, membrane absorber and resonator absorber (Jacobsen *et al.*, 2011). Basically, the porous absorber is good at absorbing high-frequency sound in which the sound absorption coefficient enhances with the increased material thickness. On the other hand, the membrane absorber performs efficiently in low-frequency sound absorption, while the resonator absorber best absorbs sound at narrow mid-frequency range. According to Jayamani *et al.* (2015), sound absorption occurs by converting sound energy that travels through a material into heat energy, yielding a reduction in sound pressure.

In current market, the common sound insulation and absorption materials are usually made of synthetic materials that include foam, glass wool, mineral fibers and their composites. However, natural fibers including jute, coir and hemp are slowly replacing these synthetic fibers as sound absorbing materials (Fatima and Mohanty, 2011). The use of natural fibers including tea leaves is getting more attention due to their attractive benefits such as economic price, lightweight, adequate strength, biodegradability, renewability and abundant supply (Mohanty *et al.*, 2005). On the flip side, few major drawbacks are always present in natural fibers. One of the concerned issues is the inconsistency of fiber quality due to the existence of hydroxyl and polar groups, causing poor moisture resistance. In addition, the poor compatibility between the hydrophilic natural fibers and hydrophobic polymer causes a weak fiber-matrix interfacial adhesion (Thakur, 2014). Overall, the present study focuses on the sound absorption properties of chemically treated and untreated spent tea leaves in polypropylene.

## 1.2 Problem Statement

The existing scenario is that synthetic sound absorbing materials made of glass wool, rock wool, and polyurethane are basically petrochemicals-based, and are expensive to produce (Berardi and Iannace, 2015). Manufacturing of synthetic sound absorbing materials poses serious environmental issues. According to Arenas and Crocker (2010), the synthetic sound absorbing materials made from polymers and minerals are manufactured through high-temperature extrusion and industrial processes based on petrochemicals. The processing of synthetic chemicals leads to the emission of greenhouse gases such as carbon dioxide, nitrous oxide and methane from the manufacturing plant, posing a great impact on our environment. Therefore, it can be seen that synthetic sound absorption materials are high in cost and incur sustainability issue such as biodegradability problem. On the other hand, green materials are environmentally-friendly, involves less contamination and can be recycled.

Although natural fiber is an ideal filler material to be used in sound absorber, there is still one limitation in which the natural fiber possesses rotting characteristic upon making contact with water. They decay gradually by a natural process over time due to moisture absorption. Therefore, in this project, spent tea leaves are used instead. Tea leaves are superior to other natural fibers due to their excellent rot-retardant properties. They possess high resistance to fungus and termite (Shi *et al.*, 2006), high durability obtained from the polyphenols extract known as tannins (Yalinkilic *et al.*, 1998), and high resistance to fire (Dittenber and GangaRao, 2012). Besides, tea leaves have fresh scent that can eliminate unpleasant smell. These distinctive features of tea leaves, thus, are important in manufacturing a durable sound absorbing material which can last longer than other natural fiber sound absorption materials.

In addition, there is not much understanding on the distribution of spent tea leaves in polypropylene based on previous researches. Microscopic examination can be performed to evaluate the morphology of spent tea leaves-polypropylene composites,

especially the fiber distribution in the polymer matrix. Jayamani *et al.* (2015) had studied the morphology of rice straw stem fibers reinforced polypropylene composite to correlate the fiber-to-matrix adhesion to its sound absorption behaviour. They concluded that good sound absorption relied upon a proper adhesion between the natural fiber and polymer matrix. This was because proper fiber-to-matrix adhesion gave a good distribution of natural fibers in the matrix, which in turn improving the acoustic absorption properties. Therefore, further studies on the distribution of natural fibers in polymer and its effects on sound absorption properties are necessary.

From the above highlighted statements, it can be seen that spent tea leaves are highly competent materials to be used as sound absorbing materials as they can address the environmental and cost issues. Moreover, the superior properties of spent tea leaves help in enhancing the durability of sound absorbing materials manufactured. These superior properties may not be found in other natural fibers. Although there are studies conducted on the tea leaves materials for sound absorption, the distribution of tea leaves in polymer is seldom investigated. Considering all the stated problems, the main challenge of this project is the possibility of using spent tea leaves in polypropylene matrix as sound absorption materials.

### **1.3 Objectives**

The objectives of this research are:

- (a) To synthesize and characterize the sodium-hydroxide treated and untreated spent tea leaves in polypropylene (PP) and in maleic anhydride grafted polypropylene (MAPP) matrix.
- (b) To study the sound absorption properties of the spent tea leaves filled polypropylene composites through impedance tube method.