

**TORREFACTION AND PELLETIZATION OF OIL PALM WASTE AND
FORESTRY RESIDUE**

NUR NABIHAH BINTI RAMLI

**BACHELOR OF CHEMICAL ENGINEERING
UNIVERSITI MALAYSIA PAHANG**

**TORREFACTION AND PELLETIZATION OF OIL PALM WASTE AND
FORESTRY RESIDUE**

NUR NABIHAH BINTI RAMLI

Thesis submitted in partial fulfilment of the requirements
for the award of the degree of
Bachelor of Chemical Engineering

**Faculty of Chemical & Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG**

MAY 2017

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering.

Signature :
Name of main supervisor : SURİYATI BINTI SALEH
Position : SENIOR LECTURER
Date : 25 MAY 2017

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree

Signature :

Name : NUR NABIHAH BINTI RAMLI

ID Number : KE13037

Date : MAY 2017

Dedicated to my family, supervisor and friends.

ACKNOWLEDGEMENT

I would like to express my special appreciation and thanks to my supervisor, Dr. Suriyati binti Saleh. You have been a brilliant mentor for me. I would like to thank you for your never ending support during my tenure as research student under your guidance, for giving insightful comments and suggestions of which without it, my research path would be a difficult one. Your advice on my research has been valuable. I would also like to thank Miss Huda who is one of Dr Suriyati master students for all her guidance during my research.

A special thanks to my family. Words cannot express how grateful I am to my mother, father, sisters and brothers for the love and support throughout these years. Your prayer for me was what sustained me thus far.

I am also indebted to the Ministry of Higher Education and Universiti Malaysia Pahang for funding my study.

I would also like to thank all of my friends especially Mira, Rahsya and Izzma who supported me in writing, and motivate me to strive towards my goal. I am sincerely grateful to the staffs of Chemical Engineering and Natural Resources Faculty who helped me in many ways and made my stay in UMP pleasant and unforgettable.

TABLE OF CONTENTS

	Page
SUPERVISOR’S DECLARATION	ii
STUDENT’S DECLARATION	iii
ACKNOWLEDGEMENT	v
ABSTRACT	vi
ABSTRAK	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF SYMBOLS	xiii
LIST OF ABBREVIATIONS	xiv
CHAPTER 1 INTRODUCTION	1
1.1 Background of the Study	1
1.2 Motivation	3
1.3 Problem Statement	3
1.4 Objectives	4
1.5 Scopes of this research	4
CHAPTER 2 LITERATURE REVIEW	5
2.1 Overview	5
2.2 Biomass	5
2.3 Forestry biomass	7
2.4 Oil palm biomass	8
2.4.1 Chemical composition of oil palm biomass	9
2.5 Torrefaction	13
2.5.1 Torrefaction of oil palm wastes	14
2.6 Pelletization	15
CHAPTER 3 METHODOLOGY	17
3.1 Overview	17
3.2 Materials	17
3.2.1 Raw material	17
3.2.2 Gases	18
3.2.3 Binding agent	18
3.3 Methods	18
3.3.1 Pre-treatment of PKS and Kulim wood	18

3.3.2	Torrefaction process	19
3.3.3	Pelletization process	20
3.4	Measurements	21
3.4.1	Calorific Value Determination	21
3.4.2	Mass and energy yield	23
3.4.3	Scanning Electron Microscopy (SEM)	23
3.4.4	Strength of pellet	24
CHAPTER 4 RESULTS AND DISCUSSION		26
4.1	Introduction	26
4.2	Effect of temperature on mass yield, energy yield and Higher Heating Value (HHV)	26
4.2.1	Mass yield	26
4.2.2	Energy yield	29
4.2.3	Higher Heating Value (HHV)	31
4.3	Effect of Particle Size Distribution on mass yield, energy yield and HHV	34
4.3.1	Mass yield	35
4.3.2	Energy yield	37
4.3.3	Higher Heating Value	39
4.4	Characterization of Scanning Electron Microscopy (SEM analysis)	40
4.5	Strength of pellet	43
4.5.1	Effect of Temperature on Compression Strength of Pellet	43
4.5.2	Effect of Size Distribution on Compression Strength of Pellet	44
CHAPTER 5 CONCLUSION AND RECOMMENDATION		46
5.1	Conclusion	46
1.	Temperature effect gave the biggest impact to characterization of torrefaction product compare to size particles.	46
5.2	Recommendation	46
REFERENCES		48
Appendix		52

LIST OF TABLES

Table No.	Title	Page
Table 2-1	Chemical composition of EFB (Abdul Khalil et al., 2012)	11
Table 2-2	Chemical composition of PMF (Saka et al., 2008)	12
Table 2-3	Chemical composition of OPF (Abdul Khalil et al., 2012)	12
Table 2-4	Percentage of mass and energy yield for different samples at different temperature	15
Table 2-5	Strength and density of pellet for different type of samples	16
Table 4-1	Effect of temperature on mass yield of PKS	27
Table 4-2	Effect of temperature on mass yield of Kulim sawdust	28
Table 4-3	Effect of temperature on energy yield of PKS	30
Table 4-4	Effect of temperature on energy yield of Kulim sawdust	31
Table 4-5	Effect of temperature on HHV of PKS	32
Table 4-6	Effect of temperature on HHV of Kulim sawdust	33
Table 4-7	Effect of particle size on mass yield of PKS	35
Table 4-8	Effect of particle size on mass yield of Kulim sawdust	36
Table 4-9	Effect of particle size on energy yield of PKS	37
Table 4-10	Effect of particle size on energy yield of Kulim sawdust	38
Table 4-11	Effect of particle size on HHV of PKS	39
Table 4-12	Effect of particle size on HHV of Kulim sawdust	40
Table 4-13	Effect of temperature on compression strength of pellet for different biomass	43
Table 4-14	Effect of different size distribution on compression strength of pellet for different biomass	45

LIST OF FIGURES

Figure No.	Title	Page
Figure 2-1:	Availability of dry weight oil palm biomass in Malaysia in 2009 (Mn/T=Million tonnes) Awalludin et al. (2013)	9
Figure 2-2:	Empty fruit bunch (EFB)	10
Figure 2-3:	Palm mesocarp fibre (PMF)	11
Figure 2-4	Oil palm frond (OPF)	12
Figure 3-1	Oil palm waste collected from palm oil plantation in Felda Hilir Lepar Gambang, Pahang	18
Figure 3-4	Hot press machine that used in pelletization process	21
Figure 3-5:	Illustration of Bomb calorimeter	22
Figure 3-6	Scanning electron microscope (LEO EVO 50 SEM, Carl Zeiss, Germany)	24
Figure 3-7	Universal tensile strength testing machine with computer	25
Figure 4-1	Effect of temperature on mass yield of PKS	28
Figure 4-2	Effect of temperature on mass yield of Kulim sawdust	29
Figure 4-3	Effect of temperature on energy yield of PKS	30
Figure 4-4	Effect of temperature on energy yield of Kulim sawdust	31
Figure 4-5	Effect of temperature on HHV of PKS	33
Figure 4-6	Effect of temperature on HHV of Kulim sawdust	34
Figure 4-7	Effect of particle size on mass yield of PKS	36
Figure 4-8	Effect of particle size on mass yield of Kulim sawdust	37
Figure 4-9	Effect of particle size on energy yield of PKS	38
Figure 4-10	Effect of particle size on energy yield of Kulim sawdust	38
Figure 4-11	Effect of particle size on HHV of PKS	39
Figure 4-12	Effect of particle size on HHV of Kulim sawdust	40
Figure 4-13	200x, 500x, 1000x magnification of a pellet fracture surface for PKS (a-c) and PKS torrefied at 270°C (d-f).	42
Figure 4-14	200x, 500x, 1000x magnification of a pellet fracture surface for Kulim sawdust (a-c) and Kulim sawdust torrefied at 270°C.	42
Figure 4-16	Effect of temperature on compression strength of pellet for different biomass	44

Figure 4-17 Effect of different size distribution on compression strength of pellet for different biomass

LIST OF SYMBOLS

mm	millimetre
cm	centimetre
°C	Celcius
L	Litre
min	minute
MPa	Mega pascal
g	gram
Hg	Heat of combustion
t	temperature rise
W	Watt
e ₃	correction in calories for heat of combustion of fuse wire
m	mass
M _{torrefied}	mass of torrefied sample at certain temperature
M _{raw}	mass of dry sample
HHV _{torrefied}	high heating value of torrefied sample
HHV _{raw}	high heating value of dry sample
%	percentage
wt	weight
µm	micrometre
kN	kiloNewton
kg	kilogram
MJ	megajoules
Mn/T	Million tonnes

LIST OF ABBREVIATIONS

CO ₂	Carbon dioxide
EFB	Empty fruit bunch
OH	Hydroxyl group
OPF	Oil palm frond
OPT	Oil palm trunk
PKS	Palm kernel shell
PMF	Palm mesocarp fibre
POME	Palm oil Mill effluent
SEM	Scanning Electron microscopy