UNIVERSITI TEKNOLOGI MARA

TORREFACTION OF OIL PALM FROND FOR ENHANCING SOLID FUEL PROPERTIES

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Thesis submitted in fulfillment
of the requirements for the degree of
Master of Science
(Chemical Engineering)

Faculty of Chemical Engineering

May 2019

ABSTRACT

Researches on potential utilization of lignocellulosic biomass from oil palm residues as energy feedstock has increased significantly due to depleting fossil fuel such as coal. However, due to undesired properties of lignocellulosic biomass such as high moisture content, low energy density and energy content, as well as high bulk density, researchers started to find alternative ways to pretreat them into a useful fuel. Torrefaction technology had been considered by researchers and is acknowledged to enhance the fuel properties of biomass towards an efficient renewable energy feedstock. This research investigates the physicochemical properties of oil palm frond (OPF) at torrefaction temperatures of 200°C, 225°C, 250°C, 275°C, and 300°C at 15, 30, 45, and 60 min holding time at a constant heating rate of 10°C/min. The solid torrefied products were characterized in terms of their chemical composition, heating value, mass and energy yield. The color appearances of the solid torrefied products were also reported. Thermogavimetric Analyser (TGA) and elemental analyser were used to determine the chemical composition as well as to investigate the degradation behaviour of the solid torrefied product. Bomb calorimeter was also used to measure the heating value to calculate energy yield of the torrefied products. As a result, OPF with original heating value of 17.8 MJ/kg was improved to 23.42 MJ/kg after subjected to torrefaction at 300°C. The solid yield decreased while the energy yield increased as torrefaction temperature and holding time increases. However, the effect of torrefaction temperature is much more significant while the effect of holding time becomes more prominent at low torrefaction temperature. The degradation behaviour of lignocellulosic constituents; cellulose, hemicellulose, lignin was discussed through TG and DTG analysis. This research also develops an optimum torrefaction parameters; temperature and holding time by using response surface methodology (RSM) based on central composite rotatable design (CCRD). A total of 13 experiments were conducted to optimize the combination effects of the variables. As a result, the regression coefficients of 98.3 and 85.5 for the solid yield and heating value were obtained, respectively. This proved that the RSM based on CCRD is efficiently applicable for the torrefaction study. The result shows that optimum production of solid fuel with enhanced heating value of oil palm frond is obtained at torrefaction temperature of 268°C; holding time of 15 minutes with predicted solid yield and heating value of 70.5% and 21.4 MJ/kg, respectively. This work concludes that a good torrefied OPF can be obtained at a torrefaction temperature higher than 250°C with a holding time 15 minutes.

ACKNOWLEDGEMENT

Firstly, I wish to thank God for giving me the opportunity to embark on my Master and for completing this long and challenging journey successfully. My gratitude and thanks go to my supervisor Prof. Dr. Norazah Abdul Rahman for providing the guidance and support throughout this project as well as spending a lot of her precious time for technical discussions and invaluable suggestions. A special thanks to Madam Sharmeela Matali and Dr. Siti Shawalliah Idris for their continuous guidance, motivations, patience, and constructive suggestions on research. They have also continuously giving me encouragements and carefully reading my reports and manuscripts. I am grateful to Prof. Dr. Norazah Abdul Rahman for giving me a chance to study in Universiti Teknologi Mara (UiTM). Honestly, it is such a wonderful journey.

Next, my appreciation goes to Mr. Attha and Tenaga National Berhad Research who provided us the samples. facilities and assistance during sampling. Special thanks to Universiti Teknologi Mara (UiTM) for providing us the facilities and kind assistance of their lab technicians. I owe many thanks to my colleagues and friends for helping me with this project and their contribution to a pleasant working environment.

Finally, this thesis is specially dedicated to my very dear father, Yaacob Bin Abdullah and my mother, for the vision, endless support and determination to educate me. Above all, special thanks to my dear husband for his unconditional love and constant support as well as to my lovely son for giving me a very good support to complete this challenging journey. This piece of victory is dedicated to all of you. Alhamdulillah.

TABLE OF CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Research Background

With the growing energy demand and emerging environmental issues owing to fossil fuel, biomass is categorized as renewable energy (RE) source and does not contribute to global warming [1]. The abundance of biomass has been used for years as it offers a tremendous opportunity to improve sustainability of energy production and consumption [2]. Biomass has a carbon neutral property where carbon dioxide released to the atmosphere during combustion is converted back to the plants. Moreover, use of biomass in power generation sector also offers an alternative way to waste disposal and saves landfill space. In addition, diversification of energy resources is critical to ensure that the country is not dependent only on a single source of energy such as coal [3]. In general, biomass can be burned directly as a solid fuel to boil water, later produces steam to run a turbine and generate electricity [4]. However, due to some drawbacks of the biomass properties such as tenacious and fibrous structure, high moisture content, low calorific value, hygroscopic in nature, and low bulk density results in low conversion efficiency thus leads to difficult in handling, transport and storage thus makes it less favourable for direct combustion [5].

Torrefaction treatment has been considered as an effective thermal pre-treatment to upgrade the properties of the biomass by successfully transformed the biomass into a harder biomass fuel that easier to be ground, longer shelf life, and easier handling for storage as compared to the raw biomass. [6]. In addition, the releases of moisture and volatile matter from the biomass improves the hydrophobicity of the biomass and eventually makes it less sensitive to degradation reaction. Recently, torrefaction studies on various types of biomass had growing drastically in worldwide. Torrefaction is defined as a mild pyrolysis process carried out in an inert condition with the absence of oxygen with an operating temperature typically ranging from 200-300°C and a holding time of less than one hour [7]. As biomass undergoes thermal decomposition, devolatilization occurs during the process. The solid product, namely torrefied biomass has a considerable potential as a solid fuel to replace the coal mainly in energy production [8], [9].