Development of Kinetics Model for Torrefaction of Logging Residue and Palm Oil Waste

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ABSTRACT: Torrefaction is a mild thermal (200-300°C) pretreatment in an inert atmosphere used to upgrade the fuel properties of biomass. During torrefaction process, biomass is thermally decomposed at a lower rate which leads to an anhydrous weight loss (AWL) of biomass. Considering the properties of torrefied biomass usually depending on the AWL, hence a model to estimate the AWL is then become necessary in order to produce the desired properties of torrefied biomass in the torrefaction process. Therefore the objective of this work is to examine two step reaction in series model that can be used to predict the AWL for two different types of biomass. Two types of biomasses used are sawdust from logging residue and empty fruit bunch (EFB) which is a type of palm oil wastes. In this work, a two step reaction in series model developed by Di Blasi and Lanzetta is examined to model the AWL of logging residue and palm oil waste. In this proposed model, kinetics of all reactions is assumed to follow an Arrhenius law with two parameters namely activation energy and kinetic rate constant. These parameters are adjusted in order to fit the predicted AWL to the experimental AWL using nonlinear optimization 'lsqcurvefit' routine in Matlab. Here the sets of experimental data of AWL for sawdust and EFB are based on the different temperature at 240, 270 and 300°C at 10°C/min of heating rate which are obtained from thermogravimetric analysis (TGA). The results show the kinetic parameters estimated using two step reaction in series model give a good agreement in terms of the coefficient determination (R^2) for both palm oil and logging residue and thus can be employed to optimize the torrefaction process in the pilot and industrial scales.

Keywords: Torrefaction; Biomass; Kinetics; Modelling

1 Introduction

Currently, world still depends on fossil fuels as the prime source to generate electricity. Among this fossil fuels, oil is dominant for energy conversion followed by coal and natural gasses. However, with the increasing global population, the energy demand by the world also increases. This situation leads to depletion of reserved fossil fuels, severe pollution problems, high carbon emission as well as contributing to economic risks. Because of that, renewable and alternative energy sources are becoming more favorable. Recent years, numerous studies on the development of renewable energy have been conducted all over the world. Most of countries in the world have taken steps to increase the usage of renewable energy. In Malaysia tenth plan, a new target was set to generate 985 MW electricity from renewable energy sources in 2015. Among the available renewable energy sources, biomass holds most promising source for increasing use in the next few years. Biomass in particular palm oil and logging residue is the largest source of renewable energy in Malaysia. Usually biomass can be converted into energy via thermo chemical conversions, biochemical conversions or using extraction approach from oil bearing seeds. However, because of its unfavourable characteristics such as low energy value, high moisture content, low heating value, hygroscopic nature and poor grindability that possibly lead to low conversion and difficulties in grinding, storage and transportation, thus biomass needs to be pretreated before it can be converted into high-value-added products (Chen *et al*., 2015). One of the widely used methods that can be applied as a pre-treatment step to improve biomass properties before undergoing thermo chemical or biochemical conversions is torrefaction (Chew and Doshi, 2011).

Torrefaction is a technique for biomass upgrading which involves the heating of biomass to moderate temperatures typically between 200 and 300°C in the absence of oxygen and under atmospheric pressure (Shang *et al*., 2014). During torrefaction, biomass is thermally decomposed as its three main structure (cellulose, hemicellulose and lignin) start to break down due to the heating process. As part of the reaction, biomass will release torrefaction gas together with moisture. Thereby, biomass becomes brittle and its energy density is increases. Moreover, torrefaction can reduce oxygen and increase carbon content of biomass. That is the reason the torrefied biomass contains lower O/C ratios compared to raw biomass (Chen *et al*., 2015). Besides, during the torrefaction, the structure of the torrefied biomass is changed to be more brittle and hydrophobic resulted in decreasing of moisture content in biomass thus promoting low energy loss (Chen *et al*., 2015). Previous studies conducted on torrefaction proved that the properties of torrefied biomass is highly depending on the anhydrous