

HIGH ENERGY DENSITY SOLID BIOFUEL FROM OIL PALM BIOMASS

Chin Kit Ling and H'ng Paik San*

Introduction

Biomass is a primary source of renewable carbon that can be utilized as a feedstock for biofuels production in order to achieve energy independence. As one of the largest producers and exporters of palm oil, Malaysia has abundant availability of oil palm biomass (oil palm trunk and empty fruit bunch) as a promising source of lignocellulosic raw material. In nature, lignocellulosic biomass has high moisture content, low bulk energy density and is difficult to transport, handle, store and feed into existing combustion systems without pretreatments. When lignocellulosic biomass is employed for bioenergy, pretreatments of lignocellulosic biomass are essential procedures for achieving higher efficiencies of fuel production or consumption [2]. For example, moisture content from the lignocellulosic biomass was driven off to enhance the combustion efficiency and prevent microbial degradation during storage [3]. While, in liquid biofuel production, acid pretreatments have been adopted widely to facilitate the conversion of hemicelluloses and cellulose into soluble sugars for lignocellulosic ethanol production [4,5,6].

In addition to the aforementioned methods, torrefaction of biomass is another notable pretreatment method that enables energy densification of biomass and biomass homogenization [7,8]. This pretreatment has been recommended as an efficient way to enhance solid biofuel properties by water removal, reduction of the hygroscopic range, and increased grindability. Torrefaction is a thermal pretreatment process by subjecting wood to temperature levels between 200 °C and 300 °C in the absence of oxygen. During this process, the cell walls are degraded and the nature of the resulting product lies between that of wood and

charcoal. The residual product is in solid form, which is referred to as torrefied biomass. Torrefaction is influenced by many parameters including the composition and physical properties of the biomass and operating condition [8].

Torrefaction Pretreatment on Oil Palm Biomass

Without appropriate treatment, oil palm trunk (OPT) and empty fruit bunch (EFB) are not suitable to be fed into existing combustion systems because of its high moisture content, low bulk energy density and difficulties in transport, handling and storage. Biomass can be upgraded and used as a fuel by torrefaction process. The torrefied biomass is more suitable than raw biomass in terms of HHV, physical and chemical properties. The optimum conditions for the torrefaction of oil palm biomass were investigated with respect to the reaction temperature (Temp) and time (RT). The primary goal of torrefaction is to refine raw biomass to an upgraded solid fuel, of improved handling qualities and enhanced combustible properties comparable to those of the fossil coal. Regarding fuel efficiency, it is necessary to increase the energy density (HHV yield) of the biomass, requiring a growth of the ratio between HHV and mass. The HHV yield per raw material indicates the total energy conserved in the torrefied biomass. The HHV yield was calculated from the weight loss and HHV using Eq. 1 and expressed as a percentage of the HHV of untreated lignocellulosic biomass: HHV_f is HHV of lignocellulosic biomass after torrefaction and HHV_i is HHV of lignocellulosic biomass before torrefaction.

$$HHV \text{ yield (\%)} = (100 - \text{Weight loss}) \times (HHV_f / HHV_i) \quad (\text{Eq. 1})$$

Our results clearly demonstrated an increased degradation of the material due to the combined effects of temperature and treatment time. While the reaction temperature had a strong impact on the HHV yield of torrefied oil palm biomass, the effect of reaction time was considerably lesser. As a whole, the torrefaction at 200°C just degraded a small amount of holocellulose and gave a mediocre effect on improving the energy properties. When biomass underwent the torrefaction at temperatures above 250°C, large amount of hemicelluloses and cellulose were degraded which

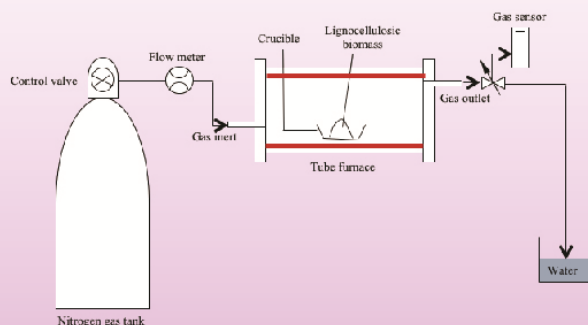


Figure 1: Schematic diagram of torrefaction experimental setup

contributed to the increment of acid-insoluble material. Weight loss and HHV vary for different biomass types at the same operating conditions as the polymeric composition and reactivity differ. In consequence, each biomass type has its own set of operating conditions to achieve a high density solid biofuel. The torrefied biomass occurred more suitable than raw biomass in

terms of calorific value, physical and chemical properties. The results of this study could be used as a guide for the production of high density solid biofuel from oil palm biomass available in large amounts in Malaysia.

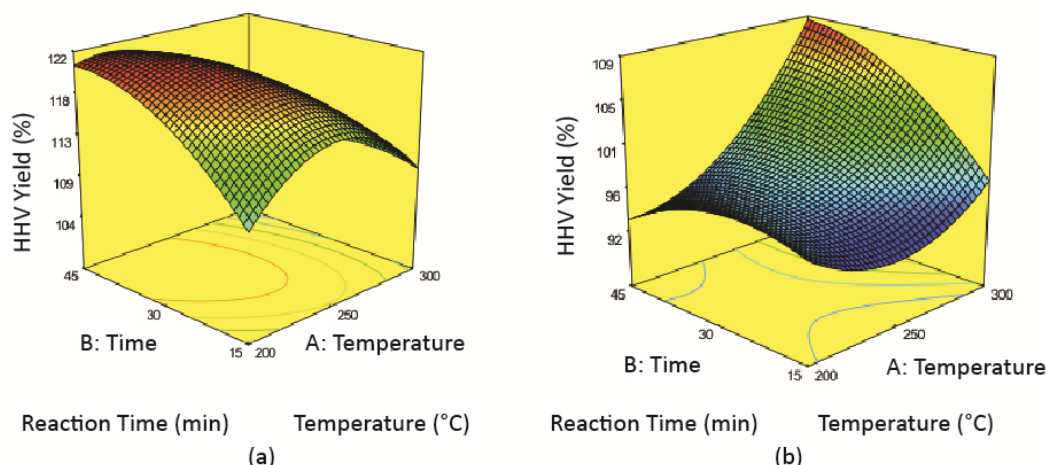


Figure 2: Response surface and contour plot of torrefaction temperature vs. reaction time on the HHV yield for; (a) EFB and (b) OPT.

Temp (°C)	Untreated	200			250			300		
RT (min)		15	30	45	15	30	45	15	30	45
OPT										
EFB										

References

- [1] Sims REH, Hastings A, Schlamadinger B, Taylor G, Smith P. Energy crops: current status and future prospects. *Glob Change Biol* 2006;12:2054–76.
- [2] Tabil L, Adapa P, Kashaninejad M. Biomass Feedstock Pre-Processing-Part 1: Pre-Treatment. In: Aurélio Marco dos Santos Bernardes, editors. *Biofuel's Engineering Process Technology*, Croatia: InTech; 2011, p. 411–38.
- [3] Chin KL, H'ng PS, Chai EW, Tey BT, Chin MJ, Paridah MT, Luqman AC, Maminski M. Fuel characteristics of solid biofuel derived from Oil Palm biomass and fast growing timber species in Malaysia. *Bioenerg Res* 2012; published online 3 July 2012.
- [4] Chin KL, H'ng PS, Wong LJ, Tey BT, Paridah MT. Optimization study of ethanolic fermentation from oil palm trunk, rubberwood and mixed hardwood hydrolysates using *Saccharomyces cerevisiae*. *Bioresource Technol* 2010;101(9):3287–91.
- [5] Chin KL, H'ng PS, Wong LJ, Tey BT, Paridah MT. Production of glucose from oil palm trunk and sawdust of rubberwood and mixed hardwood. *Appl Energ* 2011;88: 4222–8.
- [6] Lloyd TA, Wyman CE. Combined sugar yields for dilute sulfuric acid pretreatment of corn stover followed by enzymatic hydrolysis of the remaining solids. *Bioresource Technol* 2005;96:1967–77.
- [7] Yan W, Acharjee TC, Coronella CJ, Vásquez VR. Thermal pretreatment of lignocellulosic biomass. *Environ Prog Sustain Energ* 2009;28(3):435–40.
- [8] Arias B, Pevida C, Feroso J, Plaza MG, Rubiera F, Pis JJ. Influence of torrefaction on the grindability and reactivity of woody biomass. *Fuel Process Technol* 2008;89:169–75.

Laboratory of Biopolymer and Derivatives
Institute of Tropical Forestry and Forest Products,
Universiti Putra Malaysia,
43400 UPM Serdang, Selangor, Malaysia.
*Corresponding author: dwinackl@gmail.com

