

## Torrefaction study of Indonesian crop residues subject to open burning

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### Abstract:

Forty-five million tonne of Indonesian crop residues representing 21% of total crop residues are openly burned annually. Giving added value to the residues was one of the solutions to reduce open burning activities and consequently mitigate the emissions. Torrefaction is one of the pretreatment processes for improving biomass properties. In this work, fast and slow torrefaction experiments (300°C-5 minutes and 250°C-45 minutes) of Indonesian rice straw, corncob and cassava stalk were conducted using static and rotating tubular reactors. The result shows that fast torrefaction gave superior solid product properties to the slow counterpart for both reactors. Furthermore, the static tubular reactor showed better performance. Blending samples did not have a significant impact on the product properties. However, blending method can help to distribute the crop residues for the whole year due to the lack of availability on seasonal time.

**Keywords:** Torrefaction; Crop residues; Blending; Indonesia

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## 1. Introduction

Andini et al. (2016) reported that about 45 million tonnes of rice, corn, cassava and sugarcane residues was subject to open burning on annual basis in Indonesia. Even though farmer used crop residues as composting, animal feed, roof thatching and fuel for domestic use, but many of the crop residues still left on the field and were openly burned. It is due to the lack of labor as well as money to remove the crops residues. In the modern days, some of the residues which originally used for fuel return to the field, because farmers prefer to use commercial fuel. This activity added the number of crop residues subject to open burning (Oahn et al., 2011). Giving added value to biomass residues could have a positive consequence on open burning reduction. But there are some major problems encountered during biomass processing. Biomass needs to be pretreated to make it easier to process (Basu, 2010; Knoef, 2005). Torrefaction is a thermal pretreatment process of carbonaceous material which is carried out at 200-300°C under inert condition. To investigate the potential of this technical option on agricultural residues, the selected biomass materials was investigated at the laboratory then a parametric study was performed for individual and blended biomass.

## 2. Material and Methods

Three selected biomass samples i.e. rice straw, corncob and cassava stalk, which are mostly subject to open burning and present the highest potential to becoming biofuel, had been distributed from Lampung province, Indonesia. The samples were blended into two and three components following some default composition. Thus, there were nine samples consisted of three original samples, four blend samples of two components and two blend samples of three components as shown in Table 1. Two types of reactors were chosen including static tubular reactor and rotating tubular reactor. Two different conditions (slow and fast torrefaction) had been prepared. The slow torrefaction was operated at 250°C for 45 minutes, while 300°C for 5 minutes was for fast torrefaction.

**Table 1** Default composition of samples blend

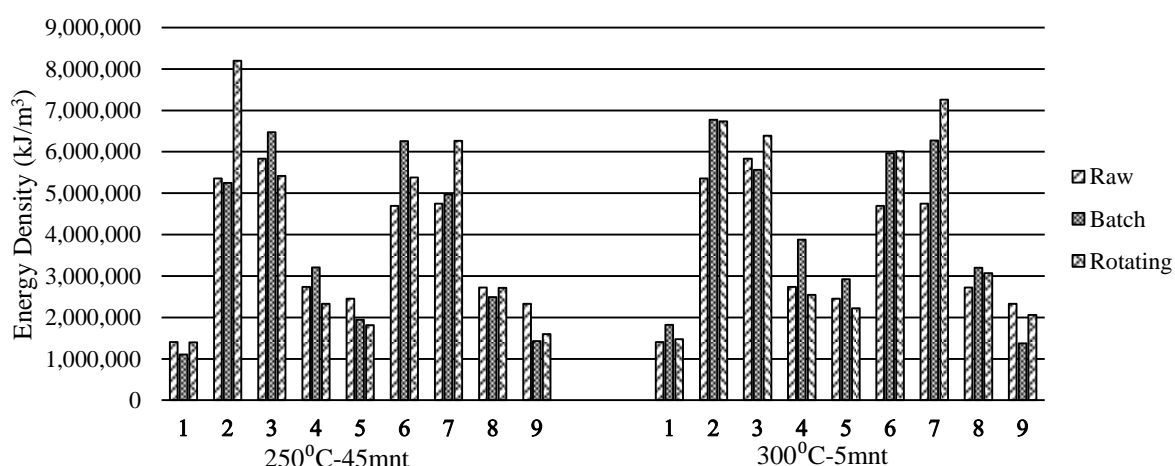
Crop residues \ Samples	1	2	3	4	5	6	7	8	9
<b>Rice Straw (RS)</b>	100	-	-	30	50	-	-	30	70
<b>Corn cob (CC)</b>	-	100	-	70	50	30	50	35	25
<b>Cassava stalk (CS)</b>	-	-	100	-	-	70	50	35	5

The experimental procedure was set as follow. Firstly, samples were loaded and then placed in the middle of the tube which had lied on the furnace and stay there for some time according to the required residence time. Both ends of the tube were sealed with silicon bed. At the rotating tubular reactor, both ends of the tube, which connected to the rotating motor, were sealed with a flange. After that, Nitrogen was purged into the tube at the flow rate of 100 ml/min to create the inert atmosphere for the whole process. After 10 min purging, the reactor was heated to the required temperature as well as started the rotating motor at the rotating tubular reactor.

During torrefaction, the temperature inside the reactor was measured using a thermocouple. The temperature, residence time and the heating rate of 10°C/min were controlled by a controller. Volatiles and gas flowed through the outline port along the process. When the default temperature reached, residence time was started to count. During the residence time, the hot gas was captured into a gas bag and then immediately injected into gas chromatography to analyze the gaseous products. After cooling down, the torrefied samples were analyzed for ultimate, proximate, calorific values, densities and lignocellulosic composition.

### 3. Results and Discussion

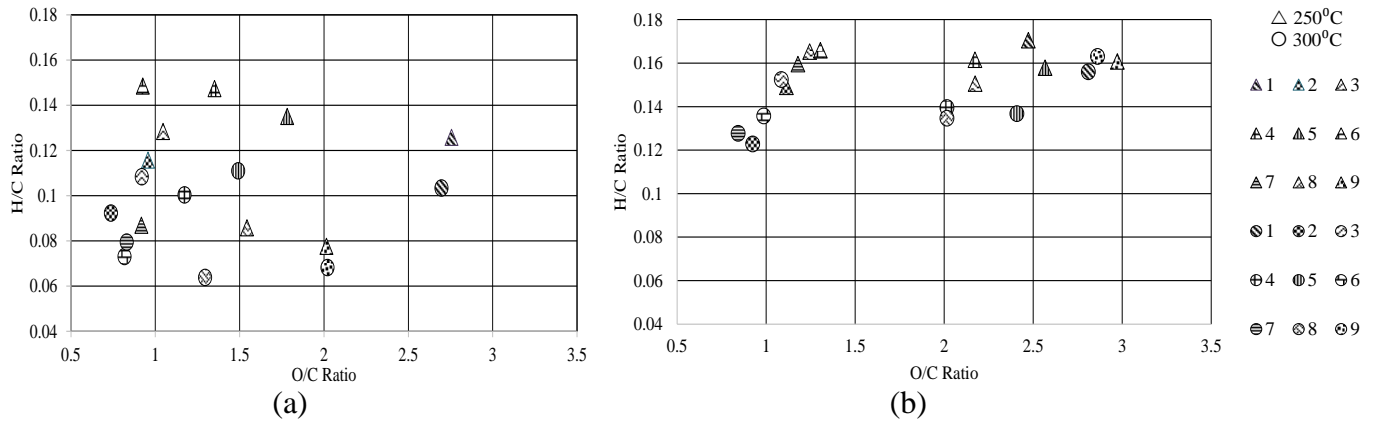
In terms of mass and energy yields, both reactors indicated that the temperature was the major factor affecting the yield. This result was in line with the Chen et al. (2015) which stated that higher temperature gives lower mass and energy yields but higher energy density because the fixed carbon content increased as shown in Fig. 1. The result was supported by its Van Krevelen diagram for both reactors in Fig. 2. It indicated that higher temperature can produce higher heating value, which clearly shown that rice straw had lower heating value compared to other crop residues either in original form or in blending form. The figure also showed that the samples on the static tubular reactor have better properties rather than the rotating tubular reactor.



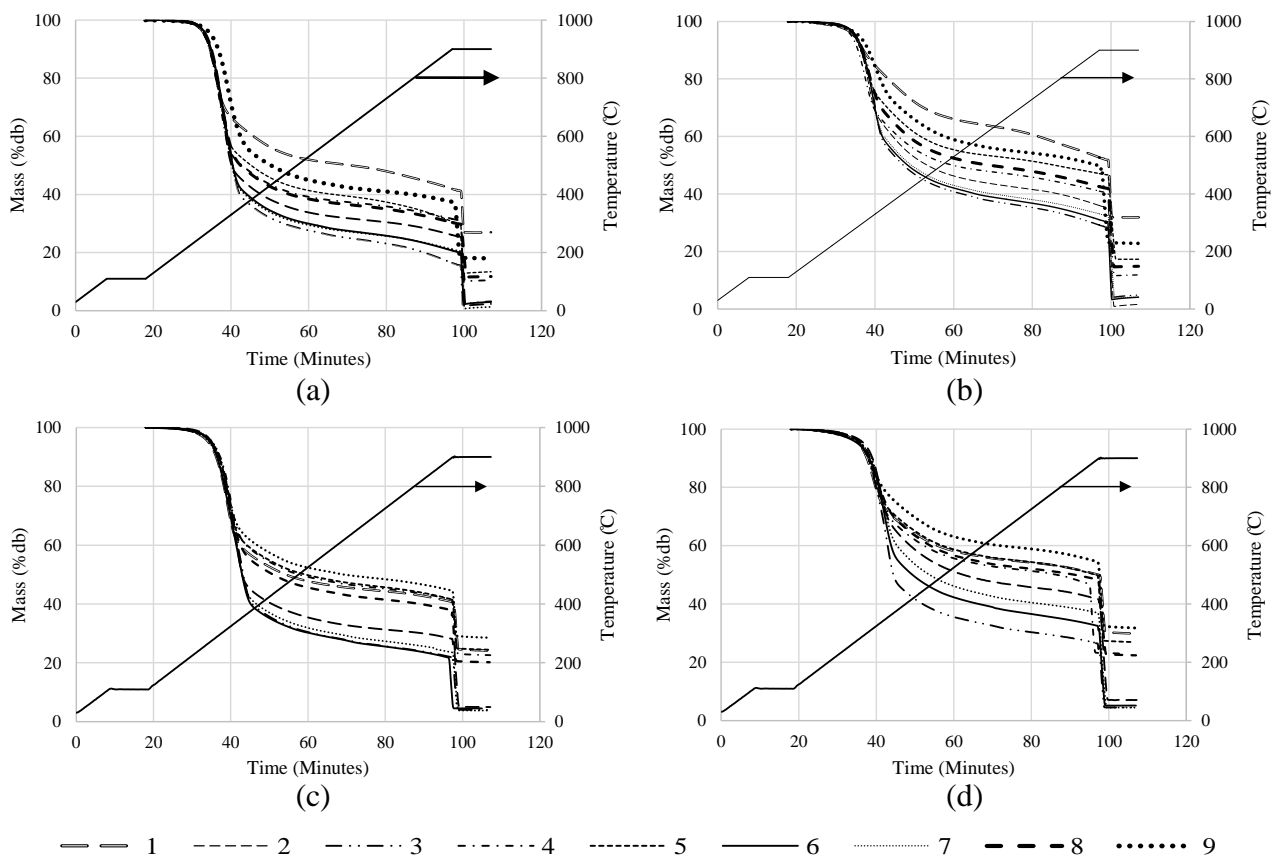
**Fig. 1** Energy density of raw and torrefied samples at 250°C and 300°C.

Fig. 3 showed the proximate analyses of each sample produced from both reactors. Both of the reactors showed the same trend line. At 300°C, the samples showed lower volatile matter than at 250°C, which have been lost because of the torrefaction process. However, the torrefaction process

increased the fixed carbon content of the samples. With regard to individual crop residues, rice straw had lowest volatile matter followed by corncob and cassava stalk. The same pattern also occurred on the blending sample, whenever rice straw appeared, the sample's volatile matter was decreased from its original form, resulting on corncob-cassava blend having higher volatile matter than the other blend samples.



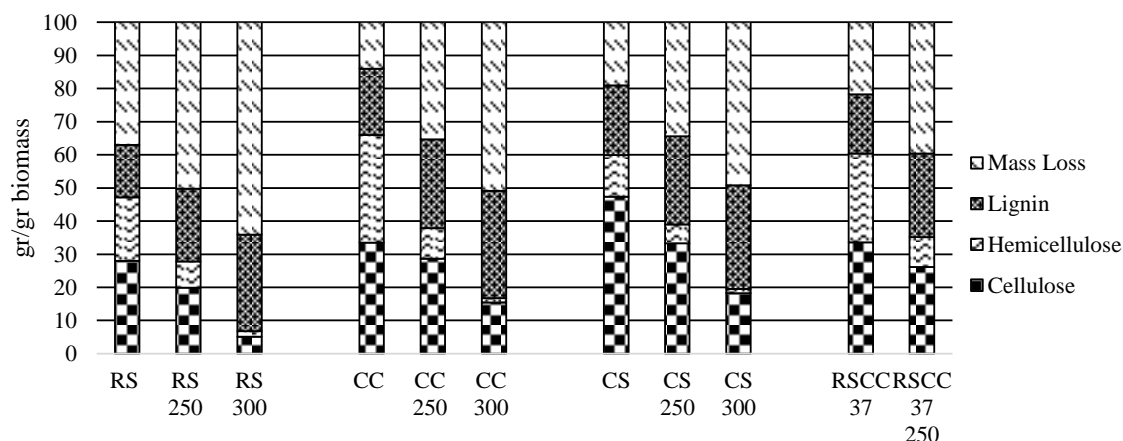
**Fig. 2** Van Krevelent diagram, (a) Static tubular reactor, (b) Rotating tubular reactor.



**Fig. 3** Proximate analyses a) 250°C and b) 300°C at Static tubular Reactor;  
c) 250°C and d) 300°C at Rotating tubular Reactor.

Eseltine et al. (2013) reported that torrefaction process at 300°C degraded hemicellulose and cellulose which clearly can be observed from Figure 4, whereas lower temperature caused the fewer hemicellulose and cellulose degradation. However, the lignin content was not affected by the torrefaction process. Furthermore, the exhaust gas analyses also showed the disadvantages of

higher temperature as it showed that higher temperature produced higher carbon dioxide (CO<sub>2</sub>) and carbon monoxide (CO). This is owing to the higher volatile matter being burned during torrefaction process. At 250°C, it was recorded that CO<sub>2</sub> and CO emissions were around 0.16-0.31 % volume and 0.05-0.23 % volume, respectively. Meanwhile, at 300°C, the emission increased to 5-7 % volume of CO<sub>2</sub> and 2-4 % volume of CO.



**Fig. 4** Ligno-cellulosic analyses of samples from static tubular reactor.

#### 4. Conclusion

This work demonstrates that fast torrefaction was better than the slow torrefaction in terms of heating value and energy density of the solid products. The static tubular reactor showed better performance compared to the rotating one. In addition, blending samples did not have any specific implication to the properties of solid products because it was obvious that original sample was better than blending sample. However, the blending aspect may have further benefit to the end user due to the lack of availability of crop residues for the whole year.

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