ผลของตัวกลางถ่ายโอนความร้อนที่มีผลต่อไบโอออยล์จากใบอ้อย

Effects of Heat Transfer Media on Bio-Oil Yield from Sugarcane Leaves

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บทคัดย่อ

วัตถุประสงค์ของงานวิจัยนี้เป็นการศึกษาผลของอัตราการไหลของแก๊สไนโตรเจนร้อน และผลของตัวกลางในการถ่ายโอนความร้อนที่มีต่อผลได้ไบโอออยล์จากใบอ้อยโดยใช้กระบวนการไพโรไลซีสแบบเร็ว ผลการทดลองพบว่าอัตราการไหลของแก๊สไนโตรเจนร้อนและวัสดุที่ใช้เป็นตัวกลางในการถ่ายโอนความร้อนที่เหมาะสมอยู่ที่ 7 ลิตรต่อนาที และทราย ตามลำดับ ซึ่งได้ปริมาณไบโอออยล์สูงสุดร้อยละ 53.83 โดยน้ำหนัก และอัตราการไหลของไนโตรเจนร้อนที่ต่ำและสูงเกินไปจะมีผลต่อผลได้ไบโอออยล์ คุณสมบัติของไบโอออยล์ที่ทำการวิเคราะห์ ได้แก่ ปริมาณของแข็ง ความหนาแน่น ความเป็นกรด-เบส และเถ้า จากผลการวิเคราะห์พบว่าปริมาณของแข็งในไบโอออยล์ที่ใช้ทรายเป็นวัสดุในการถ่ายโอนความร้อนจะให้ค่าต่ำกว่าชนิดอื่น ซึ่งจะสอดคล้องกับปริมาณเถ้าที่ได้

คำสำคัญ : ไบโอออยล์ ใบอ้อย ตัวกลางถ่ายโอนความร้อน ไพโรไลซีสแบบเร็ว

Abstract

The objective of this research was to investigate the effects of hot nitrogen flow rate and heat transfer media on bio-oil yield from sugarcane leaves using fast pyrolysis process. Results showed that the optimum hot nitrogen flow rate and heat transfer medium were 7 L/min and sand, respectively, which gave a maximum bio-oil yield of 53.83% by weight and also showed that too high or too low rates of the nitrogen flow influenced the bio-oil yield. The properties of bio-oil studied were solids content, density, pH and ash content. The solid content of the bio-oil obtained with sand as a heat transfer medium was lowest. This is corresponding to the ash content.

Keywords : bio-oil, sugarcane leaves, heat transfer media, fast pyrolysis

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Introduction

Currently, petroleum, natural gas, and coal are in limited quantity and it is likely to be used up due to highly usage demand. Also, the use by combustion these fossil fuels caused pollution to the environment that affected global warming and changes in the Earth's atmosphere (Oppenheimer, 1998). To solve such problems, the use of renewable energy that is more environmentally friendly can be one way to provide the better solution (Huber *et al*., 2006). Biomass is a renewable energy that can be processed into fuel (Zakzeski *et al*., 2010). The popular processes in changing chemical composition of biomass were mainly involved two methods: biochemical and heat energy. However, the process of changing chemical composition of biomass using heat energy can be classified into three sub-processes: combustion, pyrolysis, and gasification (Bridgwater, 2012). The pyrolysis process is considered appropriate and effective for biomass processing in order to produce liquid fuel called bio-oil (Zhang *et al*., 2005).

Thailand is one of the countries possessing extensive amount of biomass but the use is very limited. Many researchers found that wastes being disposed from farming could be used to produce bio-oil by fast pyrolysis process using fluidized bed reactor. For example, Jung *et al*. (2008) found that the perfect temperature for producing bio-oil from rice straw was at 440-500 ^{O}C and 405-450 ^{O}C. In the case of bamboo sawdust, the highest derived bio-oil yield was 70% by the product weight. Heo *et al*. (2010) investigated producing bio-oil from sawdust as the waste from furniture manufacturing. It was found that the use of gas as media evolved fluidizing which increased the yield of bio-oil production and generated the highest yield of bio-oil at 65% by weight. The appropriate temperature was at 525 ^{O}C. Zheng (2007) studied producing bio-oil from rice husk and found that the highest derived bio-oil yield was 50% by weight at the temperature of 465 ^{O}C. Therefore, this research aims to use the waste from sugarcane farming (sugarcane leaves) which is abundant in the northeastern part of Thailand to produce bio-oil by fast pyrolysis process using sand, perlite, and dolomite as heat transfer media. This study also aims to investigate the flow ratio of hot nitrogen that affects yields and properties of derived bio-oil.

Methods

Biomass feedstock

Biomass used in the experiment is sugarcane leaves derived from farmers in northeastern part of Thailand by drying, grinding, and separating at the size of 250 - 425 μm. After that, biomass underwent drying before performing the experiment and proximate analysis on quantity of moisture, volatile matter, fixed carbon and ash contents.

Fast pyrolysis apparatus

Fast pyrolysis of biomass sample was performed in a fluidized bed reactor with diameter of 50 mm. and height 450 mm. in conjunction with other equipment including cyclone, condenser, and bio-oil storage as shown in Figure 1. Installed inside the reactor were sand, perlite, and dolomite which were used as heat transfer media while nitrogen gas was used as media for fluidized bed, and cyclone served as device collecting charcoal particles coming with pyrolysis vapor before being condensed with coolant. Some uncondensed vapor was recondensed by dry ice, while the uncondensed gas was filtered by cotton wool before being released out.

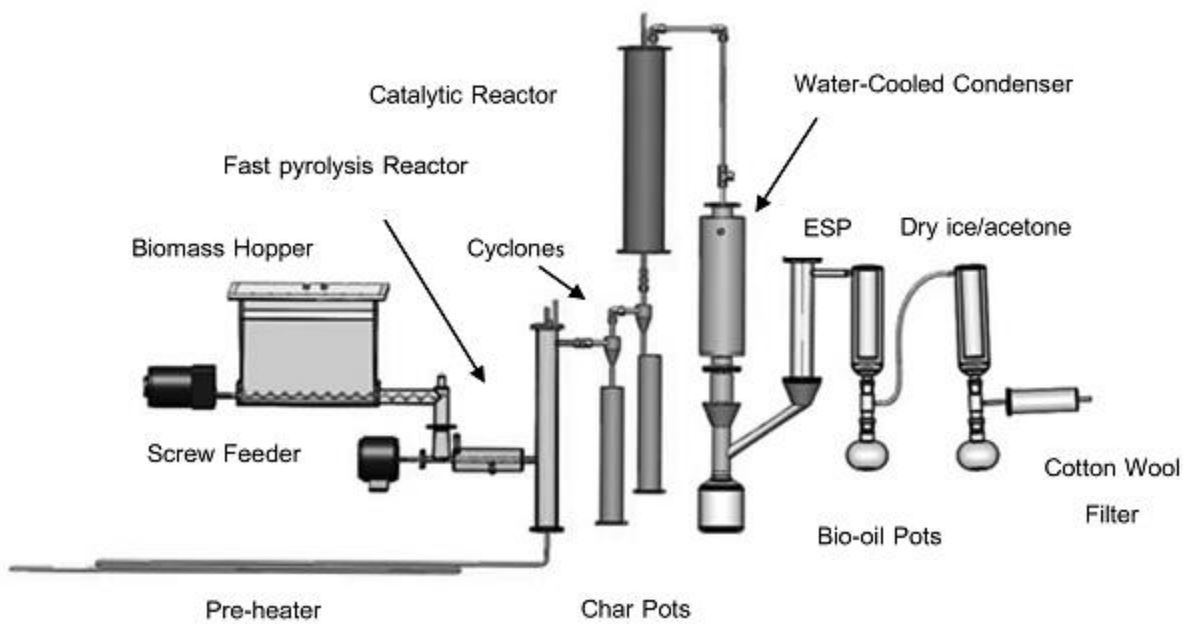

Figure 1 Schematic diagram of the fast pyrolysis unit.

Mass balance calculation

The main products from fast pyrolysis are liquid bio-oil, solid char and gases. The yields of each product were calculated by weighing all parts of the fast pyrolysis system – biomass hopper, media, fluidized bed reactor, cyclone separators, hot filter and product collection unit – before and after each experiment. The bio-oil yields were the combined weight of the liquid from the product collection unit. The char yields were the combined weight of the solid from the reactor, the cyclones, the hot filter, transfer line and the solids in bio-oil. The gas yields were calculated by difference.

This experiment was the study on flow ratio of hot nitrogen and types of heat transfer media that affected bio-oil derived from sugarcane leaves pyrolysis as outlined in Table 1.

Table 1 Pyrolysis conditions of sugarcane leaves.

Parameters	Run				
	1	2	3	4	5
Pyrolysis temperature (^{O}C)	425				
Flow rate of hot nitrogen (L/min)	5	7	9	7	7
Thermal Conductivity (k ; W/m-K)	Sand 2 – 4 [a]			Perlite 0.031 [a]	Dolomite 3.9 [b]
Biomass size (μm.)	250 - 425				
Biomass feed rate (g/hr)	200 - 300				

[a] www.engineeringtoolbox.com [b] www.geophysica.de

Analysis of pyrolysis products

The properties of bio-oil for analysis were solid content, density, ash content, and pH while each of the properties would be reanalyzed 3 times, and the analysis was performed at the Laboratory Equipment Center, Mahasarakham University, Thailand.

(1) Solid content of bio-oil was determined by vacumm filtration. The solids in bio-oil were defined as ethanol insoluble. About 2-3 g of bio-oil was dissolved in ethanol and filtered through a pre-dried and pre-weighed 6 μm mean pore size qualitative filter paper (Whatman No.3). The liquid was then washed with excess of ethanol until the filtrate was clear to ensure that there was no organic liquid left on the paper. The filter paper with the solids was air-dried for approximately 15 min and further dried in an oven at 105 ^{O}C for 30 min. Then the paper was cooled in a desiccator and weighed. This method was suggested by Oasmaa *et al*. (2009).

(2) The density of bio-oil was measured using a density bottle at room temperature (about 30 ^{O}C).

(3) Ash content of bio-oil was determined as the amount of residue when heating bio-oil to 775 ^{O}C in an oxygen atmosphere. Direct heating of bio-oil would result in foaming and splashing due to the high water contents. Thus, the first controlled evaporation of water at 105 ^{O}C is needed before rapid heating to 775 ^{O}C (Oasmaa *et al*., 2009).

(4) The pH value of bio-oil was measured with a pH metre (COMBI pH/mV/Temp Bench Metre) at room temperature. Before the measurement, the instrument was calibrated with liquid calibration standards of pH 4 and 7.

Results and Discussion

The samples of biomass were undergone proximate analysis on moisture, evaporated substance, stable carbon, and ash as analysis results shown in Table 2. Biomass analysis results indicated that sugarcane leaves contained evaporated substance in higher quantity than that of the rice straw (Xiao *et al*., 2010) but generated low ash quantity; so, this showed that sugarcane leaves pyrolysis yielded higher quantity of bi o-oil than rice straw pyrolysis.

Table 2 Characteristics of sugarcane leaves

Analysis Proximate (wt.%, dry basis)	Sugarcane Leaves	Rice Straw (Xiao *et al*., 2010)
Moisture	2.97	Not available
Volatile matter	78.47	71.70
Fixed carbon*	14.23	18.58
Ash	7.3	9.72

*Calculate from difference.

Effect of hot nitrogen flow rate on the product distribution

The flow ratio of hot nitrogen used in the experiment was 5, 7, and 9 L/min by selecting pyrolysis temperature at 425 ^{O}C and using sand particle size at 250 - 425 μm for heat transfer media as shown in Figure 2. The experiment results showed that the perfect appropriate flow ratio of nitrogen was 7 L/min which could yield bio-oil quantity at 53.83% by weight (dry basis). The low level of hot nitrogen flow would generate low yield of bio-oil due to incomprehensive diffusion of heat transfer which caused ineffective heat transfer. Nevertheless, the high of heat transfer resulted in fast mobility of pyrolysis and that caused incomplete condensation of pyrolysis vapor and therefore affected low yield of bio-oil.

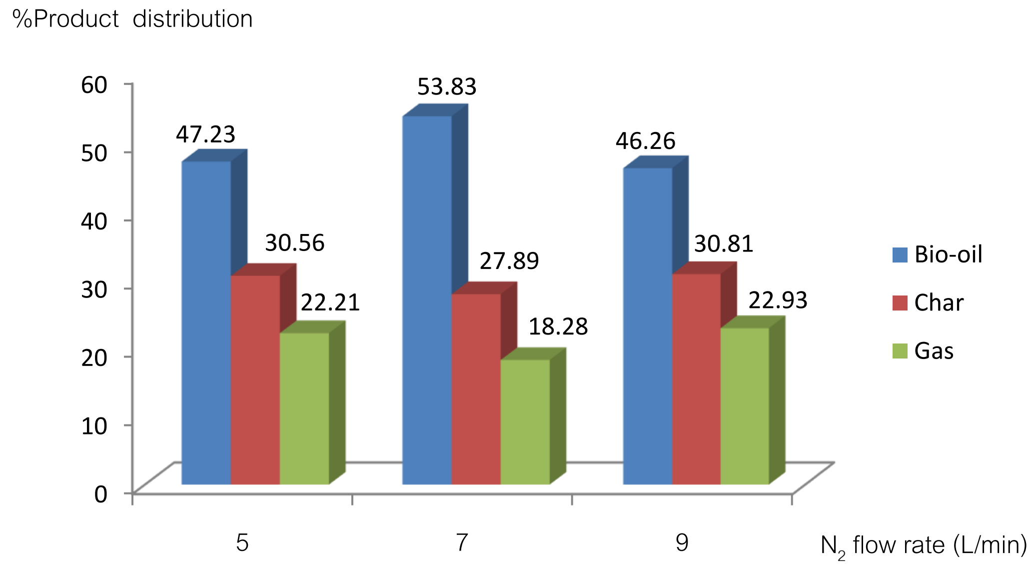

Figure 2 Effect of hot nitrogen flow rate on the product distribution.

Effect of heat transfer media on the product distribution

Heat transfer media used in the experiment were sand, perlite, and dolomite by using the flow ratio of nitrogen at 7 L/min, pyrolysis temperature at 425 ^{O}C, and heat transfer media particle size at 250 - 425 µm. According to Figure 3, it could be seen that the best performing heat transfer media in this experiment was sand due to the fact that sand held better heat transfer properties than other substance, so sand provided good heat distribution on biomass particles that resulted in complete combustion and generated high yield of bio-oil.

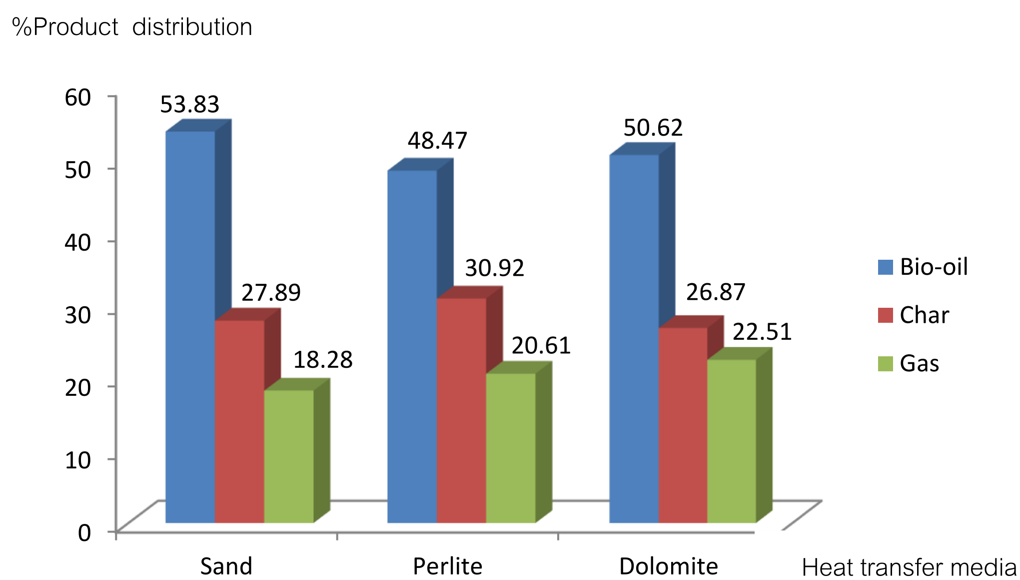

Figure 3 Effect of heat transfer media on the product distribution.

Bio-oil Analysis

Quantity of solid content in bio-oil was a vital component in bio-oil utilization because it directly affected engine fuel injection system. The solid content yield in this experiment was found at 1-3% by weight. The experiment results showed that high level of nitrogen flow generated high yield of solid content due to the fact that nitrogen carried along solid content mixed in pyrolysis vapor into the condensantion. The solid content evolved in this process was unable to be collected by cyclone; however, this can be fixed by improving the more effective charcoal collection system.

The density of bio-oil was at 1.01-1.21 g/mL and some portion of bio-oil contained high level of water that affected low level of density which was close to the density of water.

Ash yield of bio-oil was found at 0.35-0.60% by weight. The comparison results on ash yield derived from sugarcane leaves pyrolysis that used different types of media, it was found that bio-oil derived from using sand as heat transfer media generated the lowest ash yield due to effective heat transfer of sand onto biomass particles that caused complete burning and therefore resulted in clean pyrolysis and also corresponded with solid content yield in bio-oil.

pH of bio-oil was found at 2.7-3.8 which concurred with other studies in this area (Xiao *et al*., 2010).

Conclusions

Fast pyrolysis of sugarcane leaves was investigated using a fluidized-bed reactor at different flow rate of hot nitrogen. Bio-oils as the main product were characterized for their basic properties such as solid content, density, ash content and pH. Results showed that the optimum pyrolysis flow rate of hot nitrogen was 7 L/min with sand which gave maximum bio-oil yield of 53.83 wt% on dry biomass basis. The solid content, density, ash content and pH of the bio-oil were 1-3 wt%, 1.01-1.21 g/mL, 0.35-0.60 wt% and 2.7-3.8, respectively.

Acknowledgements

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