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Gasification Behavior Study of Torrefied Empty Corn Cobs

Krongkaew Laohalidanond[a,] *, Nithitorn Kongkaew[a], Somrat Kerdsuwan[a]

[a]*The Waste Incineration Research Center, Department of Mechanical and Aerospace Engineering, Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok,10800, Thailand*

Abstract

Nowadays raw empty corn cobs have been used as substitute fuel in conventional boilers in corn mills, in which the thermal efficiency is low because of its poor fuel properties. The fuel property of empty cobs can be improved by torrefaction process. This study focuses on the in-depth study of the gasification process using raw empty cobs and torrefied empty cobs as solid fuel. The gasification process was carried out in a batch-type laboratory scale downdraft gasifier at the air flow rate of 250 liters per minute for raw empty cobs, and 250, 300, and 350 liters per minute for torrefied empty cobs. The temperature distribution in each reaction zone, the producer gas composition, the heating value of the producer gas, and finally the cold gas efficiency obtained from the gasification of the raw empty cobs and terrified empty cobs were compared. The experimental results showed that the gasification of the torrefied empty cobs can provide better gasification behavior than raw empty cobs. The temperature in each reaction zone was higher for torrefied empty cobs, which ranged from 846.5°C to1,291.6°C in the combustion zone, and from 720.1°C to 838.8°C in the reduction zone, whereas the temperature in the combustion zone and reduction zone in the case of using raw empty cobs varied from 715.5°C to 909.7°C and 709.9°C to 814.5°C. Furthermore, the temperature distribution along the height of the gasifier was more stable for the torrefied empty cobs. The producer gas obtained from the gasification of the raw empty cobs contained more CO (18.20-27.79 %-vol.), H_2 (3.63-9.37 %-vol.) and CH_4 (0.17-0.33 %-vol.), but less CO_2, O_2, and N_2 than that obtained from the terrified empty cobs, which contained 5.72 %-vol. CO, 0.97 %-vol. H_2 and 0.03 %-vol. CH_4. The higher CO, H_2, and CH_4 led to a higher heating value for the producer gas and cold gas efficiency for the torrefied empty cobs. The producer gas heating value increased from 0.835 MJ/Nm^3 for the raw empty cobs to 2.84-4.25 MJ/Nm^3 for the torrefied empty cobs, and the cold gas efficiency increased from 31% for the raw empty cobs to 55-87% for the torrefied empty cobs.

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Keywords: Torrefaction process; Fuel property; Corn residues; Gasification

* Corresponding author. Tel.: +0-662-555-2000 ext. 8304; fax: +0-662-586-9541.
E-mail address: Krongkaew.l@eng.kmutnb.ac.th

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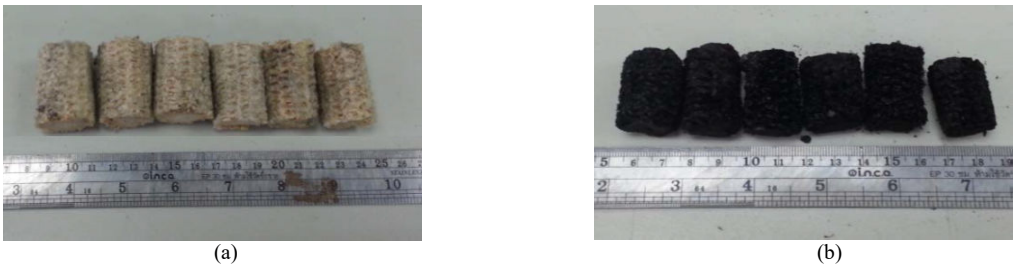
1. Introduction

As the key driver for the development of the industrial and energy sector, fossil fuel plays an important role as a primary energy source in many countries. In 2014, the share of oil, coal, and natural gas consumption in the world's total primary energy consumption was reported to be 32.65%, 30.04%, and 23.67%, respectively, and the proportion of this fossil fuel in the world's primary energy consumption in 2015 remained almost unchanged. In contrast to fossil fuel, the utilization of renewable energy was limited to only approximately 2.5% of the total primary energy consumption [1]. Relying significantly on fossil fuel however has resulted in the security of certain countries, especially for the countries whose primary energy sources are deficient. Hence, the world energy trend should switch to greater utilization of renewable energy than fossil fuel [2]. Thailand's energy trend has also shifted towards more renewable energy utilization for energy security, and for its economy and ecology. The Alternative Energy Development Plan (AEDP2015) has stated that the share of alternative energy for power production is targeted at 20% in 2036 [3]. Within this 20%, biomass from agricultural products and forestry is promoted to be the main renewable energy source. The residue from maize focused on in this study is empty cobs. Although empty cobs are mostly used as fuel in corn mills, their utilization is ineffective when used with old-fashioned boilers because they have low fuel properties. Compared to medium-grade lignite, raw empty cobs have high moisture content, high volatile matter, but low fixed carbon, consequently low heating value. Therefore fuel quality improvement is required. Much research has pointed out that the torrefaction process can improve the fuel properties of biomass [4-9]. Somrat et al. [10] conducted the experiments on the torrefaction of empty cobs at 250, 300, and 350 °C with the residence time of 30, 60 and 90 minutes. The results showed that the torrefied empty cobs had lower moisture content and volatile matter, but higher fixed carbon and heating value compared to raw empty cobs. This study will emphasize the investigation and comparison of gasification behavior when using raw and torrefied empty cobs.

2. Feedstock

The raw empty cobs were naturally dried and cut into a length of 5 cm before being placed into the gasification system. In order to prepare the torrefied empty cobs, the raw empty cobs were oven-dried and torrefied in the furnace at the torrefaction temperature of 300 °C for 30 minutes [10]. After that the torrefied empty cobs were cut into a length of 5 cm before being used as feedstock. Fig. 1. illustrates the feedstock used in this study and Table 1 presents the fuel properties of the feedstock.



(a) (b)

Fig. 1. Feedstock (a) raw empty cobs; (b) torrified empty cobs

Table 1. Fuel properties of feedstock

No.	Fuel properties	Raw empty cob	Torrified empty cob	No.		Raw empty cob	Torrified empty cob
Physical properties				Proximate analysis (%wt., dry basis)			
1	Apparent density (kg/m^3)	249.34	162.67	1	Moisture content*	49.88	7.63
2	Bulk density (kg/m^3)	94.14	78.45	2	Volatile matter	81.70	47.27
3	Higher heating value (kJ/kg)	18,791.31	27,161.59	3	Fixed carbon	16.13	47.80
*as received basis				4	Ash	2.17	4.93