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PYROLYSIS OF CORN COB BIOMASS TOWARD GASEOUS PRODUCTS ON SMALL CAPACITY REACTOR

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Abstract

Corn waste is the result of agricultural production that can be further utilized and get additional economic for the community. Waste Corn cab is one of Indonesia abundant biomass apart from. The utilization of biomass by implementing pyrolysis process can be viable solution. This study aims to observe the determination corn cab pyrolysis using HCL-bentonite activation and without bentonite towards syngas product (CH_4-H_2-CO-CO_2). Updraft reactor was utilized for 30 minutes pyrolysis process. We used MQ4, MQ8, MQ7 coupled with Arduino UNO for measuring CH_4, H_2, CO_2 and CO in ppm unit. Compared without bentonite, the result showed that methane (CH_4) gas production increased. In addition, we found also that hydrogen (H_2) gas increased respectively. Not mention, the content of CO increased.

***Keywords**: Pyrolysis, Biomass, Corn Cab, Syngas, Bentonite*

1. INTRODUCTION

Due to the need for renewable energy sources caused by global population expansion, economic development, and climate change, reaction energy demand has surged recently. In addition to increasing greenhouse gases that harm the environment [1]. Then, it contributes to global warming, the demand for energy, which is primarily derived from fossil fuels and other restricted fossil sources, is causing an energy crisis. As a result, it is essential to have a concrete manifestation in the pursuit of renewable energy sources that might lessen reliance on decreasing fossil fuels.

The fourth most popular renewable energy source, biomass energy, has vast reserves and low carbon emissions [2]. Biomass energy may significantly improve energy security, ease the current power crisis, lessen climate change brought on by excessive carbon emissions [3], and contribute to sustainable social development [4]. Many academics in worldwide have recently done studies on agricultural biomass energy, including those concerning the suitability of biomass energy development, motivated by the carbon neutrality aim.

There are several example of biomass in Indonesia as an agricultural country. By data, Indonesia comprises 188.20 million hectares of land area with various soil and climate types in terms of land use. Agricultural farming of different of kinds of valuable commodities is possible, including bioenergy plants such as palm oil [5], sugarcane, cassava and other. There is a lot of potential for biomass usage since, according to [6], 76.4 million hectares are ideal for cultivating these valued crops. Rice husk, coconut shell, corn cob, and kernel shell [7] are a few examples of Indonesia's biomass.

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Pyrolysis is the process of thermally converting biomass into more valuable products while utilizing inert gas. A catalyst can be added to the pyrolysis process to hasten the reaction and improve the yield of biofuel. We frequently come across catalysts such as bentonite and zeolite [8].

Bentonite is a type of clay that can be utilized as a catalyst. Bentonite can be activated using acid solutions or alkaline solutions in a variety of ways, making it suitable for use as a catalyst. Bentonite is used in the pyrolysis process to increase the pyrolysis and gasification process's product output [9]. The effects of employing bentonite that has been chemically activated with HCL, H_2SO_4, and H_3PO_4 on the hydrocarbons produced during the pyrolysis process. When bentonite is used as a catalyst in the pyrolysis process, HCL solution increases the content of BTX (Benzene Toulene Xylene), whereas H_2SO_4 acid solution increases the content of mono aromatic hydrocarbons.

Pyrolysis is an exothermic reaction that releases energy as a gas product, namely carbon monoxide (CO), hydrogen (H_2), methane (CH_4), carbon dioxide (CO_2) and water vapor. Furthermore, H_2 and CH_4 can be used as fuel to generate energy. Observation of those gaseous is essential to determine the amount of usable energy for further application. Due to its numerous components and complex reaction conditions, biomass pyrolysis is considered to be a complicated process.

There are several example of biomass energy generation in world such as the rural electrification programs, with small scale pyrolysis technology, carried out to increase energy services. Small scale reactor has ease maintenance and low cost in terms of replication. Therefore, it can be implemented at household scale to reduce waste volumetric. Therefore, in this study we conduct corn cob pyrolysis with and without adding HCL bentonite. Moreover, three gaseous products namely CH_4, H_2, CO_2 is later examined to give additional insight of biomass utilization using catalyst and without catalyst using experimental method.

2. MATERIALS AND METHODS

This research was carried out by using experimental-observation method. This study is conduct to get the amount of syngas from biomass heating by using updraft furnace type. For measuring temperature, k type thermocouple is installed. this study, corn cob is used as biomass. Besides, to reduce the amount of tar, the corncob mixed with catalyst. Furthermore, catalyst that used in this study is HCl-Bentonite that classified as chemical activation. To get a homogenous mixture of HCl and Bentonite, magnetic stirrer was used. To find out the effect of catalyst addition in biomass, we conduct corn cob pyrolysis without catalyst as a comparison. Then, we mixed 10% HCl-Bentonite from biomass total mass with corncob to be processed. The size of bentonite which used in that process is #400.

A B C

Figure 1. (A) corn cab 1 (B) Bentonite (C) magnetic stirrer

Furthermore, the placement of the biomass and the mixture of biomass and catalyst is in-situ. This study is based on experimental method. Initially corn cab was dried by using microwave 360 minutes. The reason behind this is reducing moisture content as conducted also by [10] et al, [11] et al. Then we set the biomass (corn cob) mass as much as 100 grams. The selected biomass was inputted into pyrolysis reactor and ignited. Raw material (corn cob) was presented in fig 1 A, bentonite in fig 1 B while the reactor of this study was presented in fig 1.B.

For visualizing the mechanism, we used Avogadro coupled with Pubchem repository. We used four database of cellulose, hemicellulose, lignin and bentonite. ID for models lignin, hemicellulose, cellulose, bentonites were 175855, 72941614, 16211032, and 24847856. Those model were obtained at SDF file then imported into Avogadro software to create 3D model. While carbon dioxide, carbon monoxide, hydrogen and water are generated without database model. All models were generalized with optimize geometry option (UFF 10000 step and 10e-7 convergence) and visualized separately.

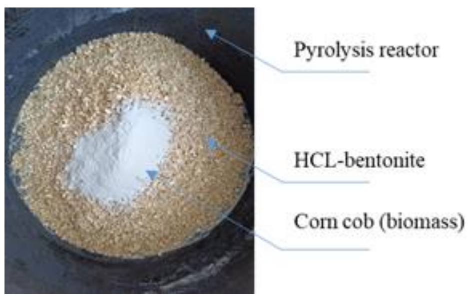

Fig. 2 position materials before pyrolysis process

Generally, pyrolysis process referred to [12] is:

$$biomass + heat \rightarrow gases\ (H_2, +CO + CO_2 + H_2O + CH_4) + tar + char \quad (1)$$

While our study using corn cob then, it can be written as:

$$CC\ (corn\ cob) + heat \rightarrow gases\ (H_2, +CO + CO_2 + H_2O + CH_4) + tar + char \quad (2)$$

Generated gaseous are examined by four types of sensor. We used MQ4, MQ8, MQ7, MQ32 coupled with microcontroller Arduino UNO for measuring CH_4, H_2, CO and CO_2 in ppm unit. The microcontroller is used for an interface to send data temperature and gaseous products into the computer. In detail, schematic our experiment can be seen in fig 3. Label at right side of the fig 3 shows more detailed about used instrument in this study.

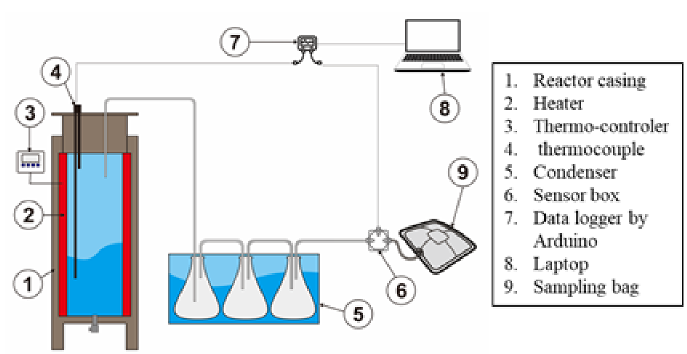

Figure 3. Schematic sensor installation

We used water as coolant at condenser that pointed by number 5. Then the generated gaseous products were contained at sampling bag. After pyrolysis, the reactor was cooled until reaching ambient temperature. All residues left was cleaned before conducting next experiment. In detail, we present flowchart of this study at Fig 4.

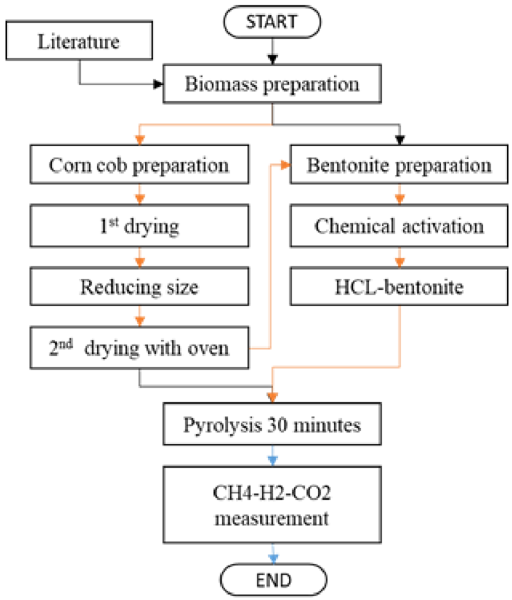

Figure 4. Flowchart of this study

3. RESULTS

Pyrolysis of corn cob was conducted. We present the result of gaseous products into several types namely methane (CH_4), carbon monoxide (CO), Hydrogen (H_2), carbon dioxide (CO_2) and temperature toward period of pyrolysis temperature in Celsius (ºC). 100 gram of corn cob after being proceed into pyrolysis, the residual mass is 45 grams. Fig 5 present measured residual mass of corn cab.

Figure 5. Residual mass of corn cob

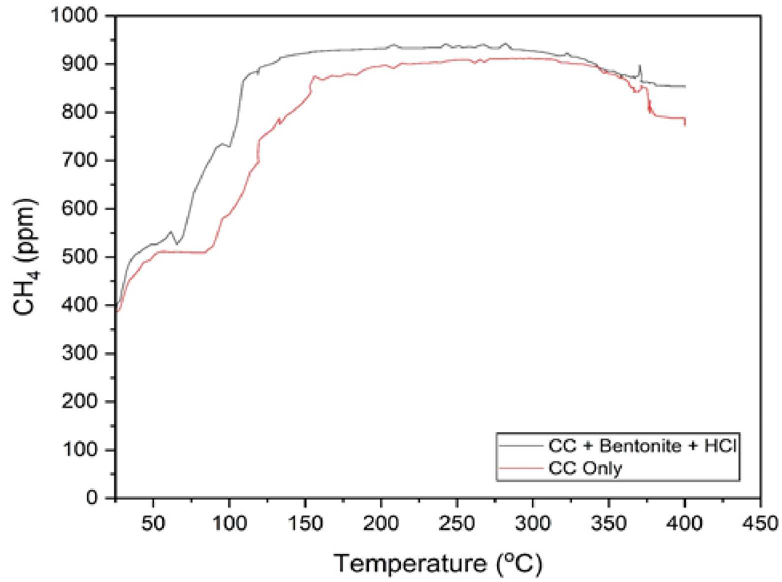

Figure 6. (a) methane formation towards temperature

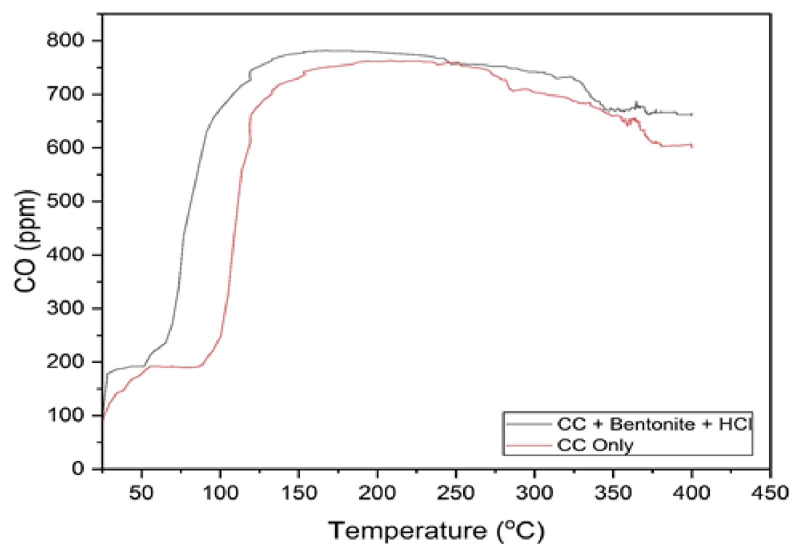

Figure 7. (b) CO formation towards temperature

Methane (CH_4) is one of the product from pyrolysis process. Fig. 6.a present methane content in ppm unit towards temperature. Initially when temperature started from ambient temperature up to 200 ºC the CH_4 content was ranging from 400 ppm up to 450 ppm. Corn cob pyrolysis without bentonite is slower. It can be seen the increase trend (corn cob with bentonite) up to 900 ppm at 225 ºC, while without bentonite reach similar level at 275 ºC. It shows that reaction rate faster if we applied catalyst (bentonite). Biomass without catalyst is showed steady trend while with catalyst still have slightly increase up to 400 oC. Then, after exceeding 400 ºC, CC with and without bentonite shows reduction trends. After examining methane gas, we move into carbon monoxide. Carbon monoxide (CO) is one of the product from pyrolysis process. Fig. 6.b present carbon monoxide content in ppm unit towards temperature. Below 150 ºC, biomass with catalyst is started to produce CO higher than without bentonite. Between range of 150-250 ºC, biomass without catalyst showed slower reaction which indicated by differ inclination (m=y/x) . Then, after exceeding 250 ºC, CC combined with bentonite showed CO formation more stable compared to without catalyst.

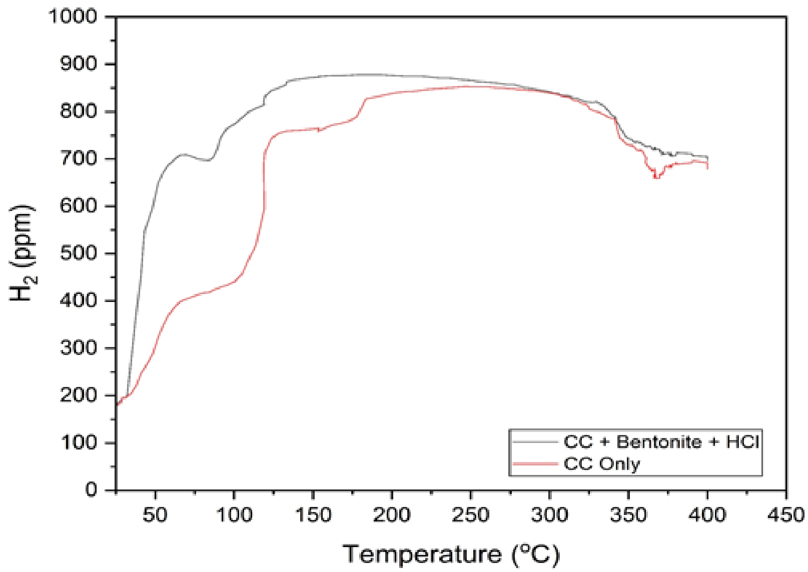

Figure 8. (a) hydrogen formation towards temperature

from pyrolysis process. Fig 7.a present Hydrogen content in ppm unit towards time. Below 250 ºC, CC with bentonite showed rapid incline while without catalyst tend to be slower. Next, between 250 ºC up to 400 ºC CC with catalyst faster to reach stable trend than biomass only. After exceeding 400 ºC, both variations showed decreasing trend. Lastly, we also measure CO_2 as the more stable product compared to CO. Fig 7.b showed carbon dioxide formation towards thermal function. It can be seen that below 200 ºC, CC combined bentonite showed parabolic line, with the highest point 300 ppm while without bentonite, slightly fluctuated and then increased. Then from 250 ºC up to 400 ºC, it can be seen stable trend for biomass only, while around 350 ºC the CC+ catalyst showed a slightly decrease then increased again. After exceeding 400 ºC, similar with other pyrolysis products, trend tend to decrease.

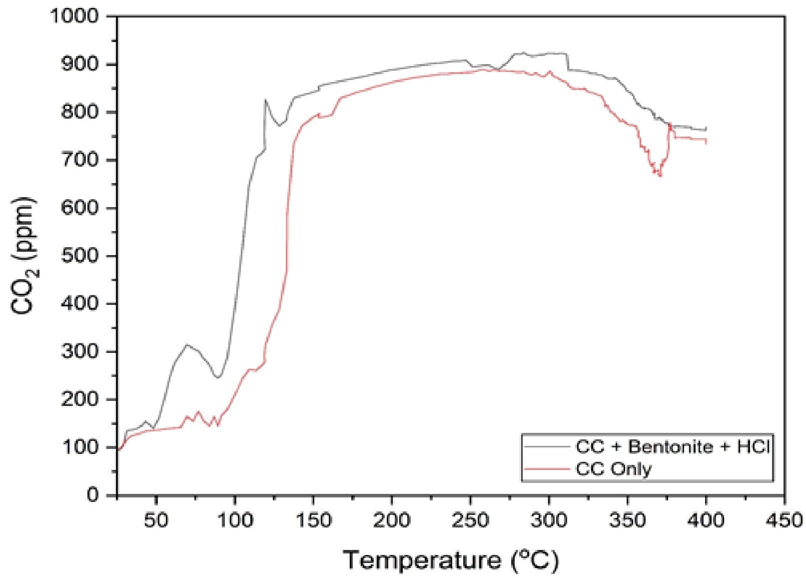

Figure 9. (b) CO_2 formation towards temperature

Apart from that explanation, we can imply that increment of overall gaseous product based on wider area below the line. Fig 6, Fig 7, Fig 8 and Fig 9 showed that methane, carbon monoxide, hydrogen, and carbon dioxide were increased compared to biomass without bentonite. Therefore, it can be seen that using such catalyst to enhance syngas production.

4. DISCUSSION

Corn cob pyrolysis, theoretically, is a thermochemical process that involves heating corn cobs in the absence of oxygen to break down into specific products (bio charsyngas and bio-oil). As it initiated with drying process to reduce their level of moisture. Removing moisture is essential because water vapor can interfere with the pyrolysis reaction. Then decomposition of organic matter processed and produced

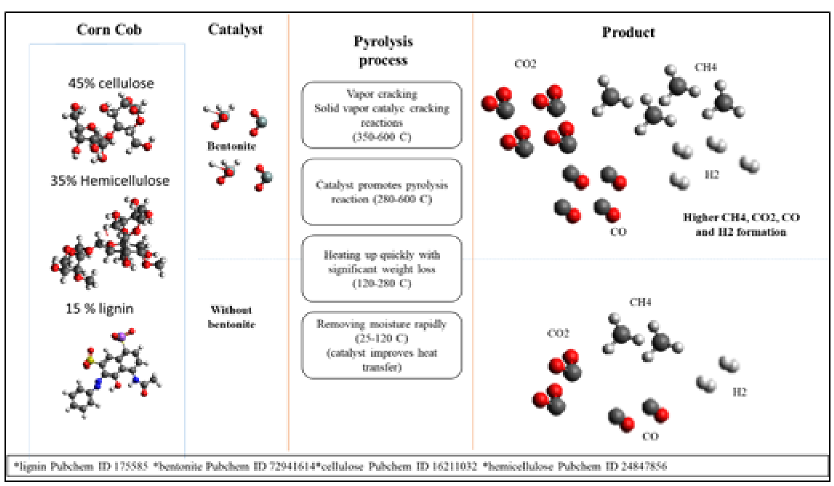

Figure 10. Schematic corncob-syngas formation using pyrolysis process.

Corn cob which consist of 45% celluloses, 35% hemicellulose, and 15% lignin [13] is degraded by different temperature range. Cellulose started decomposed at temperature started from 315 ºC-400 ºC. Hemicellulose is expected to be decomposed 220-315 ºC. Lignin is expected to be decomposed at temperature 300 ºC-900 ºC [14]. It can be seen based on temperature deformation, hemicellulose was started the process initially, followed by cellulose and ended by the lignin decomposition. Lignin, compared to other, become the hardest. By content, bentonite is consisted of SiO_2, Al_2O_3, Fe_2O_3, MgO, K_2O, Na_2O. Moreover, it provides Br\emptysetnsted (proton donor site) that can be promoting C_xH_y (hydrocarbon) yield and Lewis (electron accepting sites) [15] that can be catalyzing decarboxylation by promoting the formation of radical groups [16].

As previous section graphs showed that syngas production is overall increased. Therefore based on ppm parameter toward temperature, we can state that using bentonite as catalyst for corn cob pyrolysis is successfully enhanced the formation of CH_4, CO, CO_2 and H_2 respectively. However, it should be noted that our study still relies on four different sensors to measure the syngas products formation as preliminary examination. Further microscopic measurement is needed such as gas chromatography, XRD and FTIR.

5. CONCLUSIONS

The pyrolysis process of corn cab was conducted. Gaseous product of pyrolysis process already analyzed. Based on previous analyzation and discussion, it can be concluded that syngas formation (CH_4 and H_2) process is enhanced by combining biomass and catalyst. The indicator is increased area below the line of corn cob combined with catalyst compared with biomass only. Further research is required to examine different ratio of catalyst-biomass to determine optimum portion using pyrolysis method. In addition, altering the moisture can be beneficial insight to give more complete biomass energy map.

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