



Conversion of Biomass of Bagasse to Syngas through Downdraft Gasification

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Abstract

National energy demand has been fulfilled by non-renewable energy sources, such as natural gas, petroleum, coal and so on. However, non-renewable energy reserves deplete increasingly which can cause an energy crisis. Conversion of biomass into energy becomes one of the solutions to overcome it. Indonesia has an enormous biomass potential especially from sugarcane plantation. Sugarcane plantations produce waste of bagasse abundantly. Commonly bagasse is utilized as energy source by conventional combustion. This research studies the utilization of bagasse as energy source by gasification technology to produce gas fuel. The gasification model used in this research is downdraft gasifier equipped with cyclone to separate gas with solid or liquid gasification products. The result has shown that gasification of bagasse has produced flammable syngas. The increase of bagasse weight increases the amount of syngas of gasification process. Carbon monoxide is the greatest content of syngas, while a few amount of H₂, CH₄ are also detected. Bagasse through gasification process is very potential source of alternative energy, since it is derived from waste and a cheap material.

INTRODUCTION

The economic growth, population, development and national development causes the increase of energy demand from year to year in all sectors. During this time the national energy needs are met by non-renewable energy resources, such as natural gas, petroleum, coal and so on. However, fossil energy reserves deplete increasingly which can cause an energy crisis. The depletion of this energy reserve forces the Indonesian government and society to seek other alternatives as a source of energy. The hunt, development, and exploration of alternative energy sources must consider the main factors, such as energy, economy and ecology, in other words the developed system must be able to produce energy in large quantities, with low cost and have minimal environmental impact.

One of the alternative energy resources that developed intensively is biomass. Biomass is a

material that can be obtained from plants either directly or indirectly and used as a large amount of energy or material. The resource base covers hundreds and thousands of species of land and oceans, various agricultural resources, forestry, and waste residues and industrial processes, waste and animal waste. Biomass is a renewable energy resource. Indonesia is one of the tropical countries, so it has a very large biomass potential. Agricultural and plantation industries such as oil palm plantations, coconut plantations, cane plantations, industrial plantation forests, and other species, produce a large amount of biomass waste. Sugarcane plantation (*Saccharumofficinarum* L.) is one of the big sources of biomass waste which generates sugarcane waste (bagasse).

Sugarcane is one type of plant that can only be planted in tropical climate areas. The total area of sugar cane in Indonesia is 344 thousand hectares with the main contribution is in East Java (43.29%),

Central Java (10.07%), West Java (5.87%) and Lampung (25.71%). In the last five years, the whole area of sugarcane in Indonesia has stagnated in the range of about 340 thousand hectares. From all of sugarcane plantations in Indonesia, 50% of them are smallholder plantations, 30% private plantations, and only 20% of state plantations. In 2004, sugar production in Indonesia attained 2,051,000 tons of crystal (Goenadi et al., 2007). Recently, sugar production increases to 2,200,000 tons or 2.2 million tons (Wright & Meylinah, 2017).

Sugarcane obtained from plantations is generally processed into sugar in factories. Fiber of sugarcane or commonly called a bagasse, is a by-product of the sugar cane extraction process. Based on data from the Indonesian Sugar Plantation Research Center (P3GI), about 32 % of sugarcane weight was remained as bagasse. Approximately 60% of the bagasse is utilized as fuel, raw materials for paper, raw materials of brake canvas industry, mushroom industry, and others by sugar factories. Therefore, 45% of the bagasse is estimated not utilized. With the large potential of bagasse, the biomass of bagasse will be able to meet the current energy needs. One of the treatment methods that can be used to treat biomass is a gasification process which convert solid biomass into fuel gas (syngas).

Bagasse is the residual waste of sugarcane juice extraction, which generally contains 31 - 34% part of the sugarcane. The composition of 50% of bagasse is 47% of fibrous and 3% of residual sugars and other dissolved solids (Moeksin et al., 2009), which are presented in Table 1. Andaka (2011) also described the composition of bagasse which is shown in Table 2. The composition of bagasse is slightly different with that which has been reported by Erlich & Fransson (2011).

Table 1. Chemical composition of Bagasse

Composition	%
Ash	0.79
Lignin	12.70
Pentose	27.90
Core (alcohol, benzene)	2.00
Cellulose	44.80
Solubility in hot water	3.70

The utilization of bagasse has been studied for various purposes. The cane has been made into charcoal and used for the collection of iron (Fe) and manganese (Mn) from water (Dalai et al., 2015), as well as for the tri-chloro-phenol collection (Mubarik et al., 2016). In addition, sugarcane residues are

also used for chrome adsorption (Ullah et al., 2013). Tsai et al. (2006) have conducted pyrolysis of sugarcane residues that produced bio-oil and charcoal.

Table 2. Composition of wet and dry bagasse

Component	Content (% Weight)
Wet Bagasse	
- Cellulose fiber	25-40
- Water	40-55
- Sugar	6-10
- Albuminoidal and Gum	0.1-0.15
Dry Bagasse	
- Hydrogen (H)	5.5-6.6
- Oxygen (O)	45-49
- Carbon (C)	43-47
- Ash	1.5-3.0

Trends in the use of biomass as energy sources are increasing, as happened in India (Kumar et al., 2010). Bagasse is a potential biomass waste to be used as an energy source. Bagasse in Indonesia has also been used as an energy source for sugar mill by conventional combustion. The value calorie of bagasse in net caloric value is about 7600 kJ/kg at water content of 50%. The calorie value is lower than the calorific value of wood, which is 11.715 kJ / kg at water content of 30%. However, bagasse is a potential energy source because it is available in large and renewable sugar factories. In just 12 months, each hectare of land can produce not less than 30 tons of sugar cane. While at the same time, wood production is less than half and it must wait 8 - 9 years to cut it down (Kurniawan & Yahya, 2009). Patel et al. (2011) have studied the quality improvement of bagasse as a fuel through the torrefaction process.

Gasification is a thermo-chemical conversion of a carbon-based solid or liquid material (feedstock) into a combustible gas product with the supply of a gas gasification auxiliary material (Belgiorno et al., 2003). Thermo-chemical conversion changes the chemical structure of biomass at high temperatures. Gasification auxiliaries encourage carbon-based materials to be rapidly converted into gases through various heterogeneous reactions (Belgiorno et al., 2003; Di Blasi, 2000).

The gasification unit consists of two types, i.e. updraft and downdraft. Updraft type that undergoes a counter-current flow between gas and solids, is more suitable for the conversion of less reactive char to gas. Nearly 90% of the world's

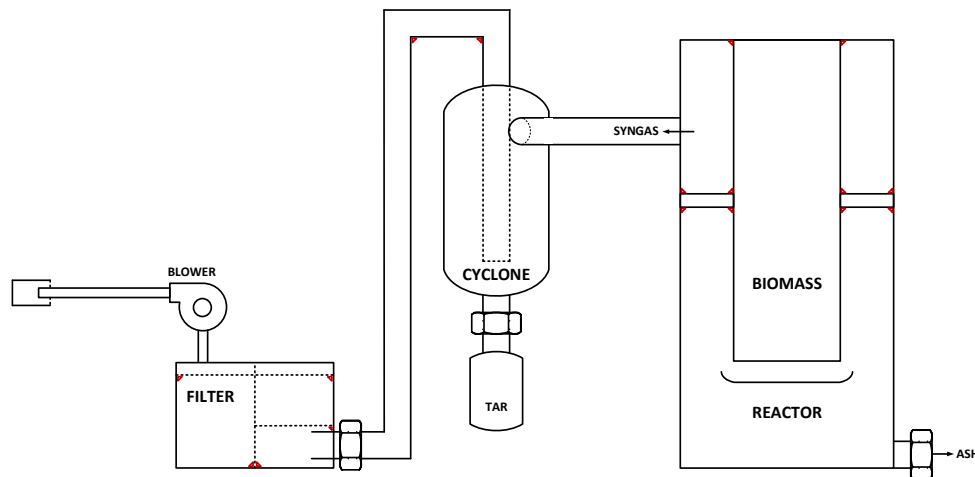


Figure 1. Configuration of downdraft gasifier for bagasse

gasified coal uses this configuration (Di Blasi, 2000; Hobbs et al., 1993). While the downdraft type undergoes a concurrent flow between the feedstock and gas, which is less flexible for water content and size. However, the downdraft type is preferred for small-scale processes because it provides a cleaner gas yield and results an uncomplicated cleaning or purification process (Di Blasi, 2000). Downdraft gasifier ensures that syngas contains only few amount of particulate and tar (Patra & Sheth, 2015).

Gasification of biomass has been widely conducted. Adeyemi et al. (2017) conducted a gasification, comparison between coal and construction waste wood. Gasification of wood waste and efforts to reduce tar levels have also been done (Park et al., 2016). Erlich & Fransson (2011), compared three different materials i.e. bagasse, wood and empty fruit bunch (EFB) of oil palm, in the form of pellets with a diameter of 6 mm and length of about 12 mm in downdraft gasifier. They found that fuel/pellet geometry took significant role in gasification process, rather than a chemical composition for varying materials of pellets.

Anukam et al. (2016) have reviewed the potential utilization of waste bagasse as an energy source through gasification. However, researches on gasification of bagasse is still limited. This paper reports the gasification of bagasse in natural form with the size of 20-40 mm using downdraft gasification system.

RESEARCH METHODOLOGY

Materials

Material needed for this research was bagasse which was collected from a sugar industry, PG Madukismo, Yogyakarta, Indonesia.

Conversion of Bagasse to Syngas

This research was started with preparing raw materials (bagasse). Bagasse was dried under the sunshine, and then followed by the reduction of bagasse size into 2 to 4 cm. The next step was to weigh biomass using a digital balance. The variables of weight of bagasse were 1000, 1250, 1500, 1750 and 2000 grams. Gasification process was started by feeding bagasse feedstock into the gasifier. Configuration of gasifier unit is presented in Figure 1. The blower was turned on for flowing the air into the gasifier and ignited the biomass through the burning hole. The temperature changes was recorded every minute during the gasification process. The sample of syngas was taken to check the gas content by using gas chromatographic analysis. Sample of syngas was taken using. The final result of gasification was the resultant gas coming out of the blower, the tar which collected under the cyclone and ash mixed with the charcoal retained under the gasification reactor. The mixture of ash and charcoal was sieved using a 2 mm diameter sieve and the smooth ash could be separated from the charcoal which is then weighed and recorded.

RESULTS AND DISCUSSION

Effect of Bagasse Weight on Syngas Weight

Cellulose content in bagasse is about 20-40%. Cellulose will be converted to syngas. Some data i.e. the weight of ash or residue and tar, were taken in the research to determine the amount of syngas production. From these two data, data of effect of feed weight to syngas production was obtained. Data of effect of bagasse weight on syngas weight is presented in Figure 2.

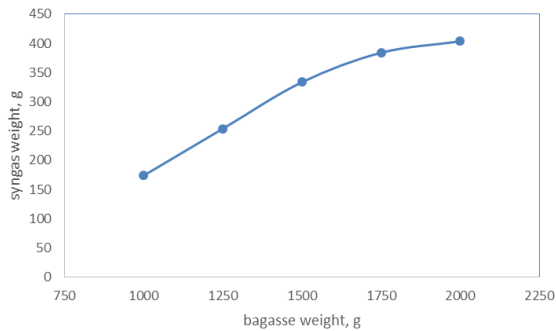


Figure 2. Weight of syngas for various weight of bagasse

Figure 2 shows the effect of bagasse weight on syngas weight. The syngas weight increases with the increase of bagasse weight that fed into the gasification unit. It can be seen that the more amount of bagasse produces more amount syngas. It is due to the higher cellulose content that results in a higher conversion of syngas.

Generally, weight of syngas is proportional to weight of bagasse or fuel consumption. The product syngas in this research is smaller than the result which reported previously by Erlich & Fransson (2011), who have studied gasification of wood, EFB and bagasse. They reported that sugarcane bagasse could produce syngas about 1.6-1.8 m³/kg-bagasse. It could be due to different treatment and condition of material i.e. water content that result in different conversion during gasification process.

Effect of Bagasse Weight on Duration of Syngas Combustion

In addition to the weight of ash and tar, other data taken during this study is the time in which syngas are burning when triggered by fire. Duration of syngas combustion relates to the amount of syngas produced. The effect of bagasse weight on duration of syngas combustion or discharge is presented in Figure 3.

The syngas performs an easily burned characteristic when exposed to fire. Figure 3 reveals that the time of syngas combustion increases proportionally with the increase of bagasse weight. The syngas combustion time proportionally relates to amount of syngas. Data show that the bagasse weight of 2000 gram produced syngas with the longest time of combustion, 1009 s or 16.82 minutes.

In continuous downdraft gasification of bagasse, the duration of 5-7 minutes is needed to only make a stable combustion of syngas (Erlich &

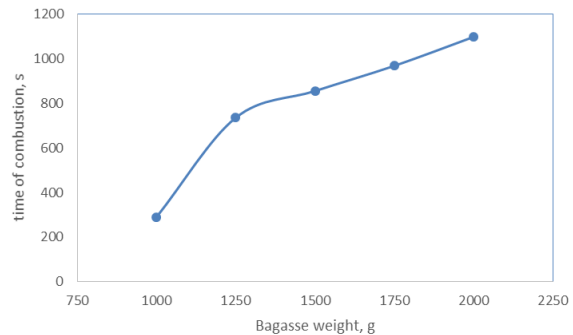


Figure 3. Syngas combustion time for various bagasse weight

Fransson, 2011). In this study, batch gasification is utilized, it takes time to reach a stable combustion. The recorded duration of combustion is shorter than the real combustion time.

Syngas Composition

The concentration and content of compounds in syngas were determined by using gas chromatography. The analysis result of syngas is shown in Figure 4. The results of syngas analysis are summarized in Table 3.

As shown in Table 3, CO had the highest concentration of 7.891% in syngas gasification. In other words, CO had the biggest role on production of burning gas or syngas. Ahmed and Gupta (2012) also reported that the important content of syngas was CO. They presented the CO/CO₂ ratio at different temperatures of gasification.

The other gas are also detected in the syngas i.e. H₂, CH₄. The H₂ content of 0.882% and the absence of CH₄ content in syngas. Based on CH₄ analysis on retention time of 3.468 minutes could be seen an existence of CH₄ on syngas, however the concentration is too small. It is similar with previous reports that composition of syngas are N₂, CO, H₂, CH₄, and CO₂ (Erlich & Fransson, 2011; Osada et al., 2012). It is also similar with the result of pyrolysis of sugarcane bagasse which syngas contains CO, H₂, CH₄, and CO₂ (Daniyanto et al., 2016). The torrefaction process has been applied to bagasse prior to pyrolysis-gasification process, so the water content has been reduced during pyrolysis and gasification process.

However, the gasification of bagasse in this study has shown a good result, even though bagasse is only treated by sun-drying pre-treatment. Pre-treatment may have a significant effect on quality of syngas. As mentioned above, the result of previous reports has shown more amount of

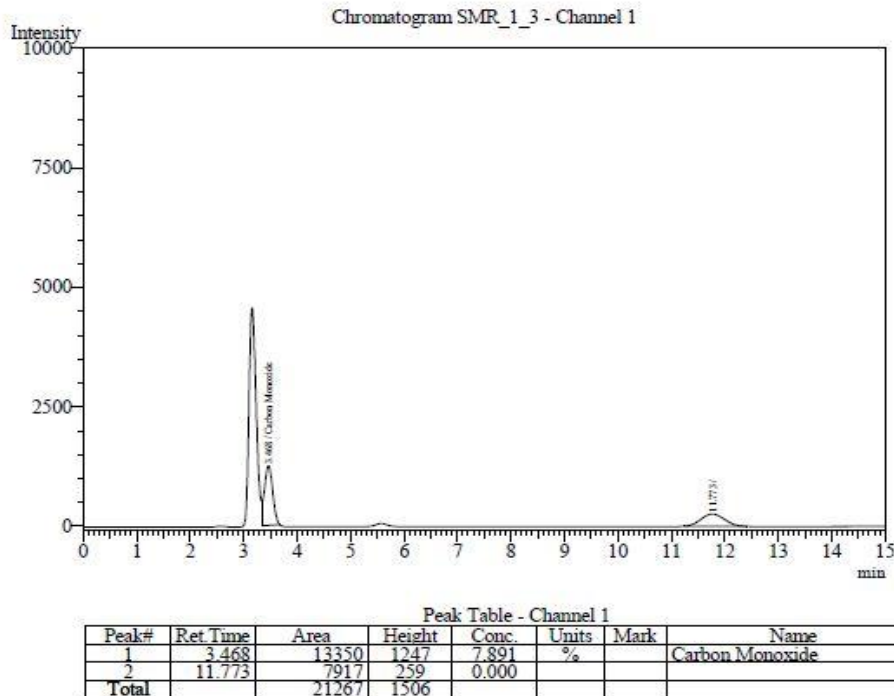


Figure 4. Chromatogram of syngas of bagasse

Table 3. Concentration of CO, CH₄, and H₂ in Syngas

No.	Composition	concentration (%volume syngas)
1.	CO	7.891
2.	CH ₄	0.000
3.	H ₂	0.882

product that it may due to different pre-treatment process, and also different size of raw material.

CONCLUSION

Gasification of bagasse has produced flammable syngas. The increase of bagasse weight increases the amount of syngas of gasification process. Carbon monoxide is the greatest content of syngas, while a few amount of H₂, CH₄ are also detected. The quality of syngas of bagasse could be improved by additional treatment of bagasse such as torrefaction, oven-drying prior to gasification process. Bagasse through gasification process is very potential source of alternative energy, since it is derived from waste and a cheap material.

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