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Biomass conversion of tamarind waste to syngas through gasification process on downdraft gasifier

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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 tamarind. Tamarinds produce waste tamarind shells. These wastes can be treated with gasification technology to produce syngas. The gasification model used in this research is downdraft gasifier equipped with a cyclone to separate gas with solid or liquid gasification process. The more dry waste of Javanese tamarind, the more syngas produced during the gasification process. And the more dry waste of Javanese tamarind, then the longer the expenditure time of syngas. In syngas analysis known at 5 ml syngas contain 3,046% of CH₄, 14,337% CO and 9,031% H₂.

1. 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 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. Tamarind (*Tamarindus indica*) is one of the sources of biomass waste which generates tamarind waste.

Sugarcane is one type of plant that can only be planted in tropical climate areas. The total area of sugarcane 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 [1].

Sugarcane obtained from plantations is generally processed into sugar in sugar factories. A bagasse 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), bagasse of 32% was generated from the weight of sugarcane. However, 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, which is a process to convert raw solid biomass into fuel gas (syngas).

Sugarcane is the residual waste juice, 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 [2], which are presented in Table 1. Coronel and Feungchan et. al. [3] also described the composition of tamarind fruit which is shown in Table 2.

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

Table 2. Composition of tamarind fruit

Constituents	Amount (per 100 gm)
Water	17.8-35.8 g
Protein	2-3 g
Fat	0.6 g
Carbohydrates	41.1-61.4 g
Fibre	2.9 g
Ash	2.6-3.9 g
Calcium	34-94 mg
Phosphorous	34-78 mg
Iron	0.2-0.9 mg
Thiamine	0.33 mg
Riboflavin	0.1 mg
Niacin	1.0 g
Vitamin C	44 mg

The utilization of sugarcane residues has been studied for various purposes. The cane cane has been made into charcoal and used for the collection of iron (Fe) and manganese (Mn) from water [4], as well as for the tri-chloropenol collection [5]. In addition, sugarcane residues are also used for chrome adsorption [6]. Tsai et al. [7] have conducted pyrolysis of sugarcane residues that produced bio-oil and charcoal.

Trends in the use of biomass as energy sources are increasing, as happened in India [8]. 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 [9]. Patel et al. [10] has 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 [11]. 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 [11], [12].

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 gasified coal uses this configuration [12], [13]. 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 [12].

Gasification of biomass has been widely conducted. Adeyemi et al. [14] conducted a gasification comparison between coal and construction waste wood. Gasification of wood waste and efforts to reduce tar levels have also been done [15]. Anukam et al. [16] reviewed the potential utilization of waste bagasse as a energy source through gasification. However, researches on gasification of bagasse is still limited. This reports the gasification of bagasse using downdraft gasification system.

2. Method

2.1. Materials

Material needed for this research was tamarind waste which was collected from imogiri.

2.2. Conversion of Tamarind Waste to Syngas

This research was started with preparing raw materials. Tamarind waste was dried under the sunshine, and then followed by the reduction of tamarind waste size into 2 to 4 cm. The next step was to weigh biomass using a digital balance. Gasification was started by feeding tamarind waste feedstock into the gasifier. The blower was turned on for flowing the air into the gasifier and ignited the biomass through the burning hole, then temperature changes was recorded every minute during the gasification process. The final result of gasification was the resultant gas coming out of the blower, the tar which accommodated 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. The sample of syngas was taken to check the gas content by using gas chromatographic analysis.

3. Results and Discussion

3.1. Effect of Tamarind Waste 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, we will get data of effect of feed weight to syngas production. Data of effect of tamarind waste weight on syngas weight is presented in Figure 1.

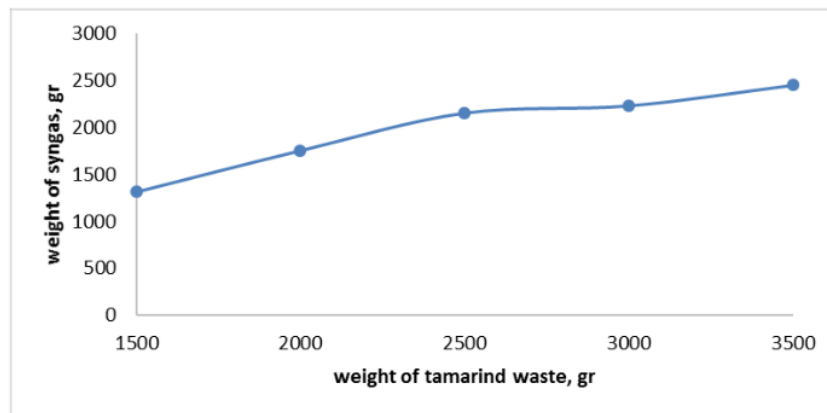


Figure 1. Weight of syngas for various weight of tamarind waste

Figure 1 shows the effect of weight of tamarind waste on syngas weight. The syngas weight increases with the increase of weight of tamarind waste that fed into the gasification unit. It can be seen that the more amount of tamarind waste produces more amount syngas. It is due to the higher cellulose content that results in a higher conversion of syngas.

3.2. Effect of Weight of Tamarind Waste on Duration of Syngas Combustion

The duration or time of syngas combustion/discharge were recorded. The results are presented in Figure 2. The syngas performs an easily burned characteristic when exposed to fire.

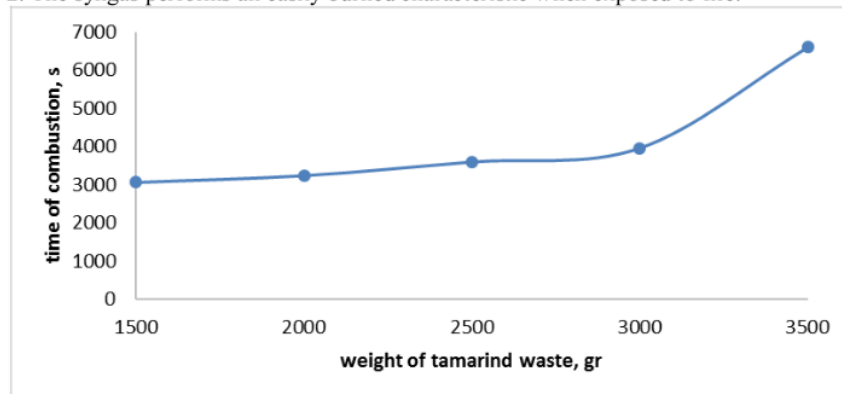


Figure 2. Syngas combustion time for various weight of tamarind waste

Figure 2 reveals that the time of syngas combustion increases proportionally with the increase of weight of tamarind waste. The syngas combustion time proportionally relates to amount of syngas. Data show that the weight of tamarind waste of 3.500 gram produced syngas with the longest time of combustion of 6.600 s or 110 minutes.

3.3. 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 3.

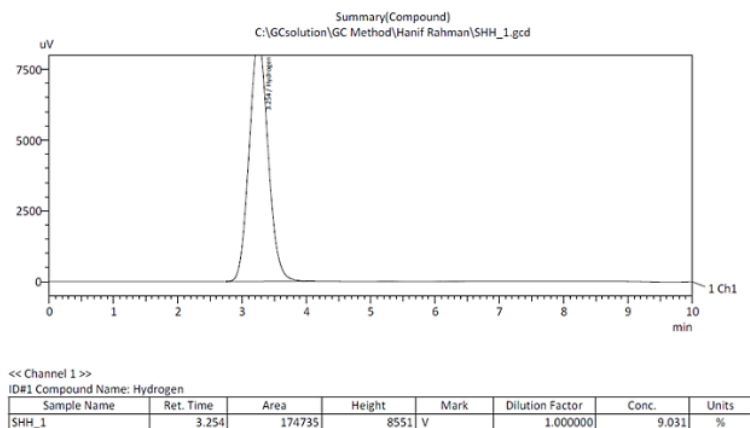


Figure 3. Chromatogram of syngas of tamarind waste

12 The results of syngas analysis are summarized in Table 3.:

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

No.	Composition	concentration (% volume syngas)
1.	CO	14,337
2.	CH ₄	3,046
3.	H ₂	9,031

As shown in Table 3, CO had the highest concentration of 14,337% in syngas gasification. In other words, CO had the biggest role on production of burning gas or syngas. The H₂ content of 9,031% and the CH₄ content of 3,046% in syngas.

2 Conclusion

The increase of tamarind waste, increases the amount of syngas by the gasification process. Carbon monoxide is the greatest content of syngas. In other words, syngas from tamarind waste gasification can be utilized as alternative energy or cheap alternative energy, since it is derived from waste.

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