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The Effects of Raw Material Ratio and Calorific Value on Gasification Rate from Co-Gasification of Coal and Biomass (Bagasse)

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Abstract

To reduce greenhouse gas pollution by 29% in 2030 and actively fight climate change, Indonesia uses biomass as an alternative energy which can be combined with coal. Bagasse is a relatively abundant biomass that has not been effectively utilized. Bagasse can be used as a more effective alternative energy source if it is processed with co-gasification, which is the conversion of solid fuel into gas from two different fuel materials at the same time to produce syngas. The characteristics of biomass and coal co-gasification are closely linked to reactor type and gasification parameters such as temperature, gasifying agent, and mass ratio. The composition of the produced syngas changes depending on the calorific value of the coal used and the raw material ratio. The amount of syngas produced rises in direct proportion to the amount of biomass, and the quantity of air supplied causes complete combustion, so the syngas content decreases. The impact of the calorific value of the coal used, as well as variations in the ratio of the composition of coal and bagasse, on the supply of oxygen in downdraft type gasification equipment is investigated in this study. Bagasse characteristics identified by proximate and ultimate analysis indicate that this biomass can be used as an alternative source of renewable energy. The co-gasification process with 100% coal raw material has the highest temperature and the longest time; the co-gasification process with 100% sugarcane bagasse raw material has the lowest temperature and the shortest time; and the duration of the flame produced in syngas ranges from 5-6 minutes. The 25% bagasse and 75% coal ratio provided the fastest high temperature in this testing, making it more efficient. The calorific value of coal and biomass determines combustion efficiency, with 5300 cal/gr coal producing heat that lasts longer than 3800 cal/gr and 4500 cal/gr.

INTRODUCTION

Economic growth and human population both contribute to the ongoing rise in energy requirements. In the next thirty years, it is anticipated that its utilization will rise by approximately 56 percent (Inayat et al., 2019). The Presidential Regulation of the Republic of Indonesia no. 22 of 2017 concerning the National Energy General Plan (RUEN) outlines the approach that the government will take to the organizing of the nation's energy infrastructure. In order to accomplish energy independence and national energy security in order to support sustainable national development, RUEN acts as a guide to provide direction for national energy management (Afifah & Sopiany, 2017)

The pledge made by Indonesia to cut its greenhouse gas emissions by 29% by the year 2030 encourages the government to continue to increase the role of new and sustainable energy sources as part of efforts to maintain energy security and independence. According to PP No. 79 of 2014 concerning the National Energy Policy, the goal for the proportion of new and renewable sources of energy in the total amount in the year 2025 is at least 23 percent, and 31 percent is the objective for

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the year 2050 (Kementerian Energi dan Sumber Daya Mineral, 2020).

One of the attempts that the government of Indonesia is making to reduce the use of fossil fuels, particularly coal, which is still the predominant source of energy, and to stimulate the achievement of new targets for a balance of renewable and conventional sources of energy. In addition to coal, biomass is yet another type of fuel that has the potential to be converted into a usable form of alternative energy. The possibility for the production of biomass in Indonesia, which is primarily an agricultural nation, is enormous. Bagasse biomass is one of the many kinds of agricultural and forestry waste that can be used as a source of energy. Despite its abundance, bagasse biomass has not been utilized to its full potential up until this point. To this day, the bagasse that is generated from sugar cane is primarily put to use as fodder, as a raw material for the production of fertilizer, pulp, and particle board, and it is also put to use as fuel for the boilers in sugar factories (Yuliwati et al., 2022). When it comes to the development of technologies that can make use of biomass energy sources, this is undoubtedly a challenge for researchers.

The co-gasification technique is the technology that is utilized in the process of converting energy sources such as coal and biomass. The process of converting solid fuel into gas by using two different fuel materials at the same time is called co-gasification, and it is done in order to decrease the emissions that result from the burning of fossil fuels. The co-gasification of bioenergy and coal each have their own unique characteristics that make them fascinating to investigate. While coal is not combustible due to its high level of fixed carbon content, biomass is highly combustible due to its high level of volatile matter content. Biomass can be readily converted into gas. A reduction in emissions as well as the quantity of contaminants that are produced by fossil fuels is brought about by the co-gasification of biomass and coal. The process of gasification actually results in the lowest amounts of air emissions, solid waste, and waste while also producing superior gas products (syngas) (Bow et al., 2022).

The type of reactor and gasification parameters such as temperature, gasifying agent, and raw material mass ratio are closely connected to the characteristics of biomass and coal co-gasification (Chang et al., 2020). There are three different kinds of gasifiers: downdraft, updraft, and cross draft. In general, the distinction between these types of gasifiers depends on the direction which air and oxygen flow through the unit (Thummar & Darji, 2020). Variations in the composition of the coal and biomass mixture that occur during the gasification process will cause an increase or decrease in the amount of combustible gas (CO) and CO_2 gas that is converted into syngas. The composition ratio plays an important part in the syngas product that results from the gasification process (Wijaya & Winaya, 2017). In addition, the selection of gasification agents will have a significant impact on the quality of the syngas that is generated. Gasification agents come in a variety of forms, including air, oxygen, steam, and carbon dioxide, among others (Pinto et al., 2016). The kind of coal that is ignited also has an impact on the chemical make-up of the syngas that is produced; for example, lignite coal has a greater proportion of hydrogen gas than bituminous or anthracite coal does (Riza et al., 2017).

In this study, the updates made were on the use of biomass raw materials in the form of bagasse with several different types of coal / calorific value, variations in the ratio of bagasse and coal composition, with oxygen gasification agents. The effect of the ratio of the composition of biomass in the form of bagasse and coal based on the calorific value as a fuel for the co-gasification process on the syngas produced is reviewed at the temperature distribution along the gasifier will be discussed in this research.

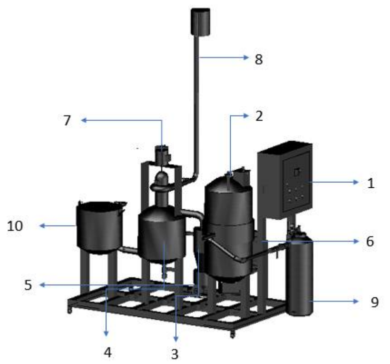
MATERIALS AND METHODS

Materials Preparation

Coal and bagasse were the two types of basic materials that were used in this experiment. Prior to their use, both of these materials were crushed and dried at room temperature (Erwin et al., 2022). Waste bagasse originated from a sugarcane ice seller in Indralaya, South Sumatra. In order to prevent contamination, dry raw materials are placed inside of airtight plastic containers. In addition, it will be examined at PT. Carsurin through proximate and ultimate analysis.

Gasification

In this research, the coal gasification process was carried out using a downdraft system reactor. The technique for the experiment was



Remarks
1. Panel control
2. Reactor
3. Cyclone
4. Separator
5. Cooler Pump
6. Condenser
7. Blower
8. Flare stack
9. Oxygen Bottle
10. Adsorber

Figure 1. Downdraft Co-gasification.

Table 1. Proximate and ultimate analysis result of materials used.

Parameters	Unit	Method	Result			
			Bagasse	BB1	BB2	BB3
Proximate Analysis						
Moisture	%	ASTM D 3173-17a	6.89	9.04	9.00	9.15
Ash Content	%	ASTM D 3174-12	1.89	7.26	7.17	7.25
Volatile Matter	%	ASTM D 3175-18	76.50	43.75	43.87	44.24
Fixed Carbon	%	ASTM D 3172-13	14.72	39.95	39.96	39.36
Ultimate Analysis						
Carbon (C)	%	ASTM D 5373-21	40.72	44.76	54.19	58.96
Hydrogen (H)	%	ASTM D 5373-21	7.32	6.00	6.46	5.95
Nitrogen (N)	%	ASTM D 5373-21	0.32	0.50	1.04	0.83
Sulfur (S)	%	ASTM D 4239-18e1	0.22	0.21	0.23	0.35
Oxygen (O)	%	ASTM D 3176-15	42.64	31.23	21.91	17.54

derived from one that Yohandri had previously carried out (Bow et al., 2022; Yopianita et al., 2022) and it was modified so that it would fit the parameters of the device's design. As a source of fuel, coal and bagasse can be utilized in a variety of mixtures, including 100%-0%, 25%-75%, 50%-50%, 75%-25%, and 0%-100.0%. The temperature of the gasification reactor was monitored and noted throughout the course of the investigation. Figure 1 shows a downdraft reactor in its application.

In order to initiate the gasification process, 2.5 to 5 kilograms of a coal and bagasse combination with a predetermined ratio is initially put into the reactor. The pipe system valve on the gasification apparatus is opened, and a flame igniter is used to light the raw material mixture that has been prepared. Beginning at the beginning of the process and continuing throughout the co-gasification process, data on the temperature of the reactor is collected every ten minutes

In order to initiate the gasification process, 2.5 to 5 kilograms of a coal and bagasse with three different calorific values (3800 cal/gr, 4500 cal/gr, and 5300 cal/gr) was combined with bagasse containing a calorific value of 2651 cal/gr. The ratios used for the composition are 0%, 25%, 50%, 75%, and 100% put into the reactor. The pipe system valve on the gasification apparatus is opened, and a flame igniter is used to light the raw material mixture that has been prepared. Beginning at the beginning of the process and continuing throughout the co-gasification process, data on the temperature of the reactor is collected every ten minutes, from minute 0 to minute 120.

RESULTS AND DISCUSSION

Ultimate and Proximate Analysis

Both proximate and ultimate analysis can be used to determine the characteristics, physical properties, and chemical properties of a raw material. These properties can be determined by examining the substance (Rusdianasari et al., 2022). Both proximate and ultimate analyses were carried out on the basic materials comprising the bagasse and the coal. Table 1 shows the results of the proximate and ultimate analyses performed on bagasse and coal.

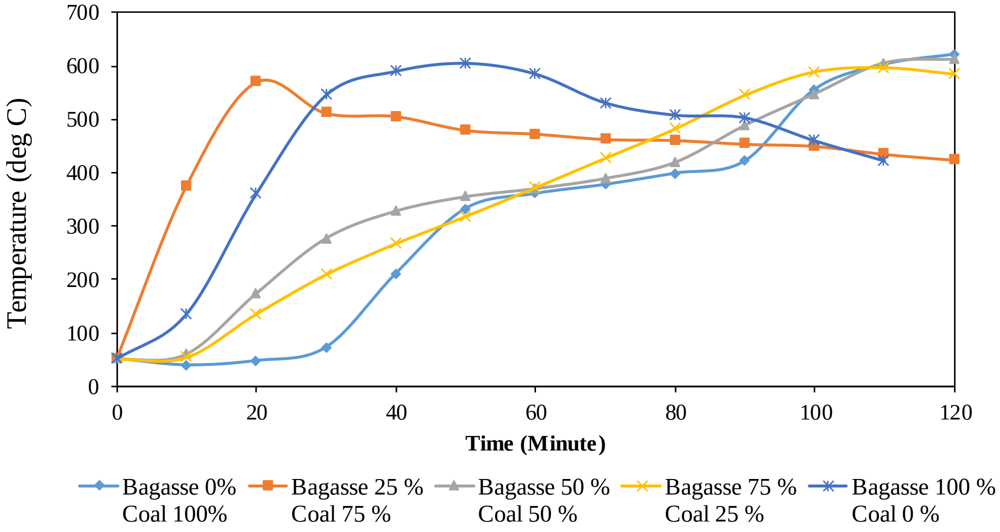


Figure 2. Temperature (°C) Vs time (minute) of coal 3800 cal/gr and bagasse co-gasification.

The bagasse used in this study had a relatively low moisture content of 6.89% when compared to other studies (Chen et al., 2019) (Erlinawati et al., 2022). Whereas, if the water content is high enough, the drying procedure in the gasification reactor will also be prolonged. It has a volatile matter content of 76.5% and an ash content of 1.89%, which is acceptable when compared to other journals because the high volatile matter content will influence the speed of the initial combustion process and the low ash content will not cause equipment fouling (Sutrisno, 2019).

The final analysis of bagasse reveals that it has a carbon value of 42.64%, indicating that it is a biomass with promise as an alternative to renewable energy. Bagasse's low sulfur content also indicates that it will not have a negative effect on the environment or the resulting exhaust emissions when used in the co-gasification process (Sutrisno, 2019; Syarif et al., 2018)

Proximate and ultimate coal analysis is used to identify coal classification. The American Society for Testing Materials (ASTM) divides coal into four types depending on C and H_2O, namely anthracite, bituminous, sub-bituminous, lignite, and peat (Lesmana et al., 2021). The results in Table 2 indicate the type of coal included in the sub-bituminous coal category.

Co-Gasification Temperature of Subituminous Coal and Bagasse

In this study, coal with three different calorific values (3800 cal/gr, 4500 cal/gr, and 5300 cal/gr) was combined with bagasse containing a calorific value of 2651 cal/gr. The ratios used for the composition are 0%, 25%, 50%, 75%, and 100%. Figure 2-4 shows the reactor temperature data for the duration of the gasification process for the ratio of coal with varying calorific values and bagasse from minute 0 to minute 120.

From Figure 2 it can be seen that the addition of coal affects the combustion temperature (Zulatama et al., 2021). If the average use of 100% bagasse is carried out in the co-gasification process, it has the lowest temperature where the maximum point is reached at 50 minutes with a temperature of 605°C in the following minute and continues to diminish until the 120th minute. When using 100% coal, the co-gasification process reaches a maximum temperature of 621°C; when the ratio of each ratio is 50%, the maximum temperature is 612°C; and when the ratio of coal and bagasse is 25% to 75%, the maximum temperature is 585 °C in 120 minutes. At a ratio of 75% to 25% coal to bagasse, there is temperature instability where the maximum temperature is formed in the 20th minute with a temperature of 570°C and continues to decrease until the 120th minute. This is because coal is too dominant compared to bagasse, causing combustion to occur more rapidly (Ismail & El-Salam, 2017; Tong et al., 2021).

From Figure 3, if the average is calculated in the same way as before, the same results are obtained: the use of 100% bagasse in the co-gasification process has the lowest temperature, with a maximal point at 50 minutes and a

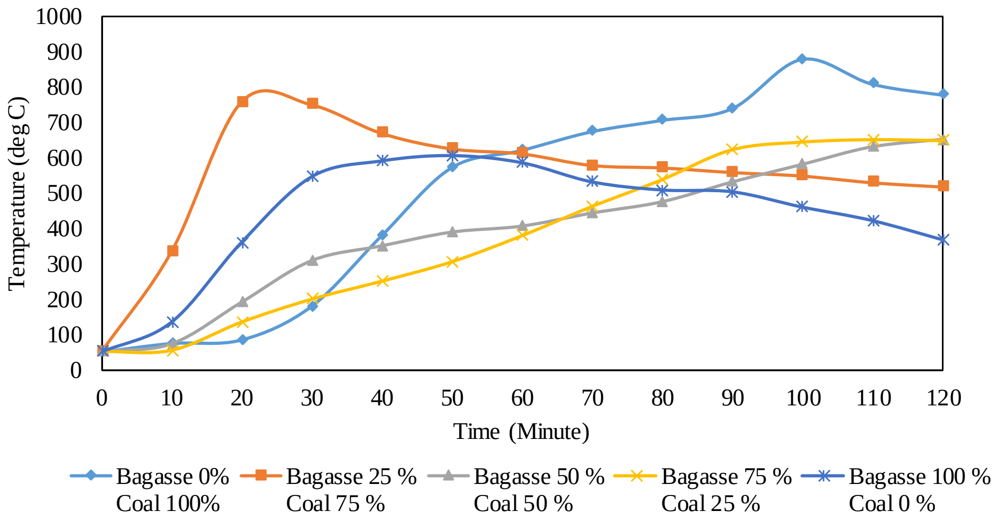


Figure 3. Temperature (°C) Vs Time (Minute) of Coal 4500 cal/gr and Bagasse Co-gasification

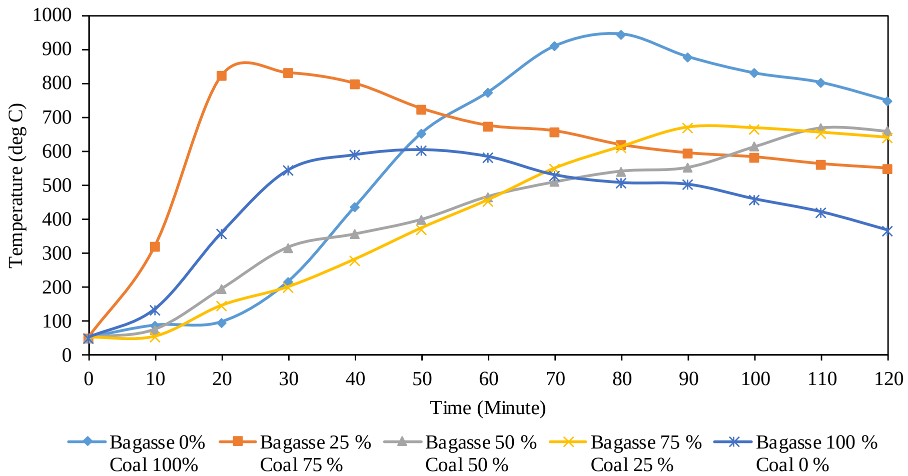


Figure 4. Temperature (°C) Vs time (minute) of coal 5300 cal/gr and bagasse co-gasification.

decreasing temperature of 605°C from the 51st minute to the 120th minute. Despite the fact that the utmost temperature in the co-gasification process when using 100% coal is also 779°C, the ratio of each ratio is 50%. The maximum temperature is 652°C, and the ratio of coal to bagasse is 25% to 75%; at minute 120, the maximum temperature is 649°C. At a ratio of 75% to 25% coal to bagasse, there is also instability at the temperature, where the optimum temperature of 760°C is reached in the 20th minute and continues to decrease until the 120th minute.

From Figure 4 the ratio is the same as the calorific value of 3800 cal/gr and 4500 cal/gr where the use of 100% bagasse in the co-gasification process has the lowest temperature with the highest point at 50 minutes with a temperature of 605° C and then decreasing to 120 minutes. While the highest temperature was also the same, namely in the co-gasification process when using 100% temperature coal but full coal, the maximum temperature was found in the 80th minute with a temperature of 946°C, after which it decreased until the 120th minute to 750°C, then the ratio of each ratio was 50% to a maximum temperature of 671°C in the 110th minute, while the 120th minute saw a decrease of 10°C to 671°C. Then, the ratio of coal to bagasse is 25% to 75%, and the temperature reaches a maximum of 670°C in 90 minutes. At a coal-to-bagasse ratio of 75% to 25%, there is also temperature instability, as the maximal temperature of 831°C is reached in the 30th minute and continues to decrease until the 120th minute. This research demonstrates that the addition of coal effects the burning time (Syarif et al., 2018). This happens because the contact area between coal and biomass decreases as more coal is added. Therefore, the biomass is more affected by coal itself (Mallick et al., 2020).

The ratio of 25% bagasse and 75% coal with calorific values of 3500 cal/gr, 4500 cal/gr, and 5300 cal/gr burns faster than a number of other ratios, as indicated by the three graphs above. This rapid combustion rate indicates an increase in the gasification reactor's temperature. Temperature increase causes an increase in both heterogeneous and homogeneous endothermic reactions, which can accelerate syngas production (Zhang et al., 2017). This is supported by research including a mixture of 25% bagasse and 75% coal, where the combustion temperature increased to 300°C in 10 minutes.

The calorific value of coal and biomass also determines the combustion rate's efficacy. The higher the calorific value, the longer the combustion lasts at high (Bow et al., 2022). Coal with a calorific value of 5300 cal/gr generates heat that lasts longer than those with calorific values of 3800 cal/gr and 4500cal/gr.

So of the three ratios with calorific values, all indicate that 100% use of coal has a fast and long burning value, but on the other hand, coal has a fairly high level of pollution if used continuously, and coal is a nonrenewable energy source whose availability is decreasing. However, Co-Gasification with a ratio still can be an option because the addition of coal to the bagasse co-gasification process can still increase the combustion of syngas produced.

CONCLUSION

The research shows that bagasse's proximate and ultimate properties make it a viable renewable energy source. The co-gasification process with 100% coal has the greatest temperature and takes the longest, whereas the one with 100% sugarcane bagasse has the lowest temperature and is the fastest. Coal-biomass ratio affects co-gasification syngas output. Endothermic processes increase syngas production with combustion rates. In this research, 25% bagasse and 75% coal produced the fastest high temperature. 5300cal/gr coal produces heat for longer than 3800cal/gr and 4500cal/gr biomass.

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