International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 21, Issue 4 (April 2025), PP 20-24

The Effect of Variation of Agent Gas Flow Rate on Hydrogen Production in Biomass Gasification Process

Rudy Sutanto[1], I Gede Bawa Susana[2]
[1,2]*Department of Mechanical Engineering, Faculty of Engineering Mataram University, Mataram, Indonesia.*
[1]*Corresponding Author*

ABSTRACT: *Gasification is a thermochemical process that converts solid fuels into gas through combustion with a limited air supply. This process consists of four main stages, namely drying, pyrolysis, oxidation, and reduction. Drying, pyrolysis, and reduction are endothermic processes that require energy, while oxidation is exothermic and acts as a heat source for the other three stages. This study examines the biomass gasification process using horse manure as raw material and oxygen as a gasification agent. The gasification reactor used has a diameter of 600 mm and a height of 1500 mm. The study was conducted using the thermal decomposition method, where the flow rate of the oxygen gas agent was varied at 10, 15, 20, and 30 L/min. This study aims to analyze the effect of variations in the flow rate of the gas agent on the composition of the gas produced in the gasification process. The results showed that increasing the flow rate of the oxygen gas agent caused an increase in hydrogen gas levels of 8.5%, an increase in oxygen gas of 16.7%, and an increase in hydrogen sulfide gas of 7.3%.*

***Keywords**: gasification, syngas, oxygen, hydrogen, flow rate*

Date of Submission: 23-03-2025 Date of acceptance: 04-04-2025

I. INTRODUCTION

Global energy needs continue to increase along with population growth and industrial development. However, dependence on fossil fuels causes various environmental problems, such as greenhouse gas emissions and air pollution [1]. Therefore, the development of more environmentally friendly alternative energy is very important. One promising method is biomass gasification, which can convert organic waste into gas fuels that have high calorific value [2].

Gasification is a thermochemical process that converts solid fuels into synthesis gas (syngas) through reactions with gasification agents, such as air, oxygen, or water vapor. This process consists of several main stages, namely drying, pyrolysis, oxidation, and reduction {3]. Biomass as a raw material for gasification has great potential because of its abundant availability and renewable nature. One type of biomass that can be utilized is horse manure, which is a livestock waste with a high enough carbon content to support the gasification process [4].

An important factor affecting gasification efficiency is the flow rate of the gasification agent. The oxygen flow rate, for example, can affect the reactor temperature and the reactant ratio, which ultimately affects the composition of the gas produced [5]. Therefore, this study aims to analyze the effect of variations in oxygen flow rates on the composition of syngas produced from horse manure gasification. Horse manure (feces) has various shapes and sizes as well as fine grain sizes. In addition, horse manure also has a high water content. As a gasification feed, if used directly, horse manure will be difficult to process and can interfere with gasification performance. Therefore, initial processing of horse manure needs to be done. The initial processing is in the form of reducing the water content of horse manure. While the ratio of horse manure (feces) waste production reaches 5.5 tons/year/head with an energy conversion coefficient of 14.9 Gjoule/ton [6].

The coconut shell gasification process using an updraft gasifier produces combustible gas CO = 13.32%; CH_4 = 1.52%; H_2 = 4.68%; N_2 = 37.09% and CO_2 = 38.21% [7]. Research on coconut shell gasification using an updraft gasifier was also conducted by Yuono [8] at an AFR of 15%, the composition of the syngas produced was H_2 = 2.67%; CO = 40.70%; CH_4 = 1.7% and LHV of 5.53 MJ / m3. Therefore, the resulting calorific value can be used as a substitute for conventional fuels. Research on the gasification process of coconut shells and palm oil shells using a downdraft fixed bed reactor with variations in material size found that the composition of syngas at a material size of 11 mm with a combustion temperature of up to 900 ° C in coconut shells was H_2 = 13.3%; CO = 17.4%; CO_2=16.7% and CH_4=4.23% [9].

The study was conducted to compare coconut shell and oil palm frond biomass fuels in terms of flammability and tar content. The fuel was burned in an updraft type gasification reactor until syngas was produced. The results of the study showed that the flammability of coconut shell biomass lasted for 43 minutes

14 seconds while oil palm frond biomass lasted for 10 minutes 26 seconds. The dry tar weight from the gasification process weighed using a digital scale on coconut shell biomass was 8.99 grams, while on oil palm frond biomass was 4.62 grams. The mass of tar in each liter of gas sample of Coconut Shell Biomass was 0.064 grams/liter while Oil Palm Frond Biomass was 0.034 grams/liter [10].

Numerical simulation of biomass steam gasification (oil palm empty bunches) using a thermodynamic equilibrium model. From the simulation, it can be seen that hydrogen production increases with increasing temperature. At low temperatures, hydrogen production is low and increases with increasing temperature until it reaches a peak and then hydrogen production decreases again [11]

The composition of syngas varies depending on the biomass raw material, but on average it can produce syngas with H2 content of 18-20%, CO of 18-20%, CH_4 of 2-3%, CO_2 of 12%, H_2O of 2.5% and the rest N2, with a gas calorific value of around 4.7 - 5 MJ / m^3 [12]. The gasification that we have known so far is gasification with coal and agricultural waste feed, but gasification with livestock waste feed, especially horse manure (biomass) has never been done, even though horse manure has great potential to be developed as a gasification raw material. In this study, the use of horse manure will be developed as a feed material in the gasification process by considering the fine grain size, carbohydrate content, fat and crude fiber which are quite high so that it can increase carbon production which will indirectly increase the production of methane and carbon monoxide gas.

II. MATERIAL AND METHODS

The research method that will be used to achieve the research objectives is to test the potential of horse manure as a feed material in a gasification reactor using the thermal decomposition method with oxygen as a gas agent, then test the composition of syngas.

In this study, the variables used are:

Fixed variables

- Syngas composition consisting of a mixture of H_2, O_2, H_2S gases
- Updraft type gasification reactor

Changing Variables

- agent gas flow rate: 10 lt/minute (fuel A); 15 lt/minute (fuel B); 20 lt/minute (fuel C); 30 lt/minute (fuel D)
- agent gas: oxygen

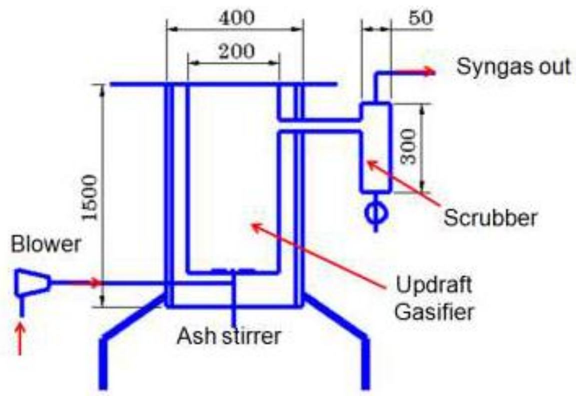

Figure 1: Gasification reactor test installation

The gasifier used in this study has a reactor diameter of 600 mm, and a reactor height of 1500 mm (figure 1). The main material needed in this study is horse manure, horse manure has a high water content. As a gasification feed, if used directly, horse manure will be difficult to process and can interfere with gasification performance. Initial processing of horse manure needs to be done through a drying process first. The study was continued with the process of making syngas with horse manure as feed material, in this case an updraft type gasification reactor was used and using a thermal decomposition method with a gas agent media in the form of oxygen and flowed using a compressor. The gas agent flow rate was varied at 10, 15, 20 and 30 lt/minute respectively. Furthermore, the composition of the resulting syngas will be studied.

III. RESULTS AND DISCUSSION

The results of the research that has been conducted show that during the gasification process, an endothermic chemical reaction occurs. This reaction requires external heat during the process. The temperature that occurs in the gasification reactor increases along with the increasing rate of oxygen flow to the gasifier. Increasing the air flow rate increases the temperature in the reactor, gas composition, gas flow rate and gasification efficiency. High temperatures of around 900ºC will result in the combustion process of horse manure biomass in the gasifier becoming more perfect [13]. Figure 2 shows the relationship between the flow rate of the gas agent (oxygen) and the percentage of hydrogen gas (H_2) content produced in the gasification process. It can be seen that the higher the oxygen flow rate (from 10 to 30 L/min), the percentage of H_2 in the gasification gas increases. At a flow rate of 10 L/min, the H_2 content is in the range of 16%, then increases gradually to reach around 21% at 30 L/min. This pattern shows that increasing oxygen supply can increase the gasification reaction that produces hydrogen, possibly due to optimization of the reduction reaction that breaks down carbon compounds more effectively. However, this increase may have a certain limit before reaching the saturation point or conditions that are no longer favorable for H_2 production. The greater the flow rate of the gas agent, the more hydrogen gas (H_2) produced. The increase that occurs is around an average of 8.5%.

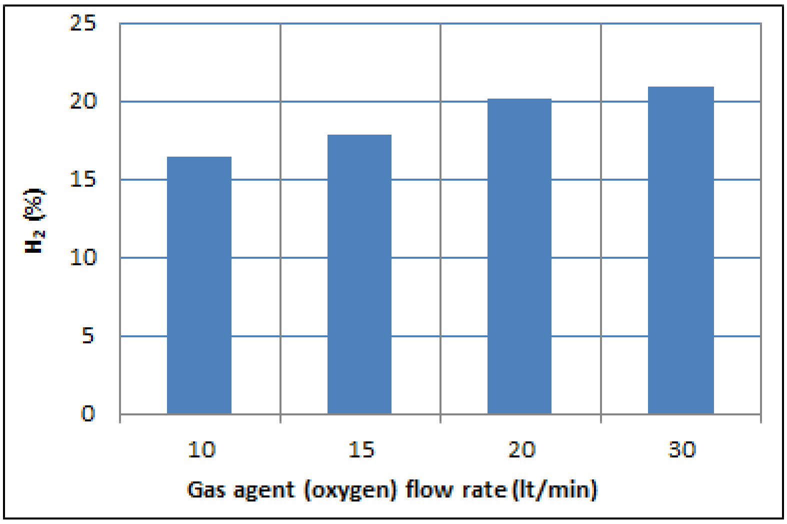

Figure 2: Relationship between gas agent flow rate and hydrogen gas composition (H_2)

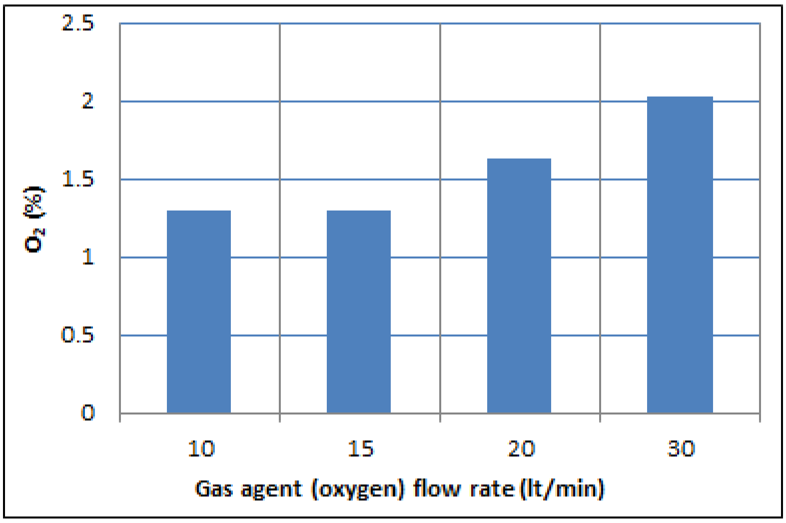

Figure 3: Relationship between gas agent flow rate and CO2 gas composition

Figure 3 shows the relationship between the flow rate of the gas agent (oxygen) and the percentage of oxygen content (O_2) in the gasification gas. From the figure, it can be seen that the higher the oxygen flow rate (from 10 to 30 L/min), the O_2 content in the gasification gas also increases. At a flow rate of 10 L/min, the O_2 content is around 1.2%, then increases gradually to more than 2% at 30 L/min. This increase indicates that some of the oxygen injected into the system does not fully react with the raw material, so it remains in the product gas. This may indicate that at higher oxygen flow rates, there is an increase in the amount of unconverted oxygen in the gasification reaction, which can affect the overall process efficiency, an increase in oxygen gas by 16.7%. This result is consistent with the results of research [14]. They said that high air velocity results in an increase in O2 gas content.

Relationship between gas agent (oxygen) flow rate and hydrogen sulfide (H_2S) content in gasification product gas (Figure 4). Increasing oxygen flow rate (from 10 to 30 L/min) causes an increase in H_2S concentration in the product gas. At a flow rate of 10 L/min, the H_2S content is around 420 ppm, then increases gradually to around 520 ppm at 30 L/min. The increase in hydrogen sulfide gas by 7.3% is due to the high availability of oxygen which accelerates the decomposition of sulfur compounds in the raw material, producing more H_2S. This shows that increasing oxygen flow rate not only increases the production of primary gas such as H_2, but can also increase the content of impurity compounds such as H_2S, which can affect the quality of syngas and require further cleaning process.

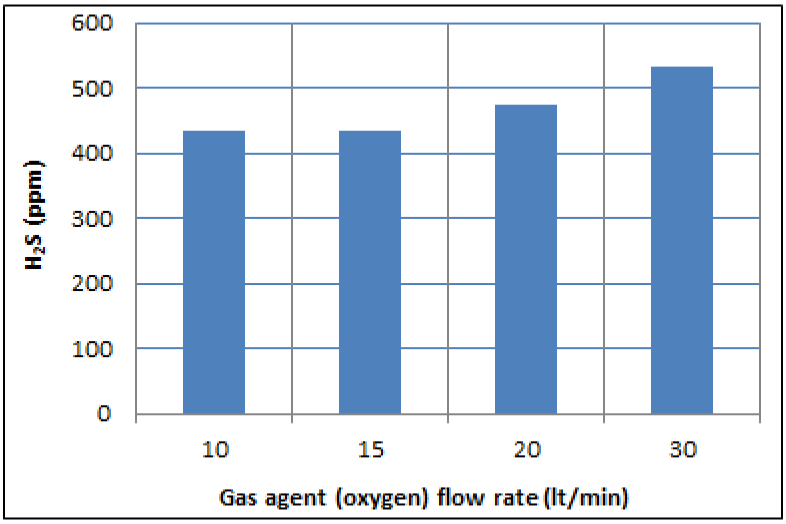

Figure 4: Relationship between gas agent flow rate and CH4 gas composition.

IV. DISCUSSION AND CONCLUSION

Based on the results of the study on the effect of variations in oxygen flow rates in the horse manure biomass gasification process, it can be concluded that increasing the oxygen flow rate has a significant effect on the composition of the gas produced. Increasing the oxygen flow rate from 10 to 30 L/min causes an increase in hydrogen gas (H_2) content of up to 8.5%, indicating that a higher oxygen supply can optimize the reduction reaction in gasification. In addition, the oxygen content (O_2) in the gasification gas also increases with increasing flow rate, indicating that there is oxygen that is not fully reacted in the process. However, increasing the oxygen flow rate also causes an increase in hydrogen sulfide (H_2S) levels in the product gas to 7.3%. This shows that in addition to increasing the production of primary gas, high oxygen flow can also increase the amount of impurities that have the potential to reduce the quality of syngas and require additional purification processes. Therefore, in optimizing the gasification process, it is necessary to consider the balance between increasing hydrogen production and the potential for increasing impurities in order to obtain more efficient and quality results.

REFERENCES

[1]. Smith, D., Johnson, L., & Williams, P. (2020). Environmental Impact of Fossil Fuels and the Role of Biomass Energy. *Journal of Cleaner Production*, 250, 119–132. https://doi.org/xxxx

[2]. Jones, M., & Brown, T. (2018). *Advances in Thermochemical Biomass Conversion*. Elsevier.

[3]. Rahman, A., Kumar, S., & Patel, B. (2019). Gasification Process and Its Application in Renewable Energy. *Energy Conversion and Management*, 180, 123–136. https://doi.org/xxxx

[4]. Anderson, J., & Lee, R. (2021). *Biomass Waste Utilization for Sustainable Energy Production*. Springer.

[5]. Chen, Y., Zhang, X., & Wang, L. (2022). Effect of Oxygen Flow Rate on Syngas Composition in Biomass Gasification. *Renewable Energy*, 185, 234–245. https://doi.org/xxxx

[6]. Hall, D. O, 1993, "Biomass for Energy : Supply Prospects", in: Renewable Energi, Johansson, T. B. eds., pp.594, Washington, Island Press.

[7]. Gunawan, I. G. H., Sucipta, M., & Winaya, I. N. S.(2015). Analisis Performansi Reaktor GasifikasiUpdraft Dengan Bahan Bakar TempurungKelapa. Jurnal METTEK, 1(2), 28–34.

[8]. Yuono, Y., Pertiwi, D. S., Farouk, A. Z., & Adlan, I. N. (2018). Pengaruh AFR Terhadap Karakteristik Gas Produser Hasil Gasifikasi Batok Kelapa. Seminar Nasional Itenas 2019, 1–5. http://eprints.itenas.ac.id/278/

[9]. Yahaya, A. Z., Somalu, M. R., Muchtar, A., Sulaiman, S. A., & Wan Daud, W. R. (2019). Effect of particle size and temperature on gasification performance of coconut and palm kernel shells in downdraft fixed-bed reactor. Energy, 175, 931–940. https://doi.org/10.1016/j.energy.2019.03.138

[10]. Abrar Ridwan and Budi Istana, 2018, " Analisis Pengaruh Variasi Bahan Bakar Biomassa Terhadap Ampu Nyala Dan Kandungan Tar Pada Reaktor Gasifikasi Tipe Updraft", Jurnal ENGINE Vol. 2 No. 1, pp no: 7-17.

[11]. Adjar Pratoto and Slamet Raharjo, 2008, "Gasifikasi-uap Biomassa untuk Menghasilkan Hidrogen – Simulasi dengan Model Keseimbangan", Seminar Nasional Tahunan Teknik Mesin (SNTTM) VII, Manado.

[12]. Haifa Wahyu, Imam Djunaedi, M. Affendi, Sugiyatno and Yusuf Suryo Utomo, 2011, "Perancangan dan Pengembangan Model Reaktor Circulating Fluidized Bed Untuk Gasifikasi Biomassa", Research Centre fo Physics, LIPI.

[13]. B. Sihotang, " Kandungan Senyawa Kimia Pada Pupuk Kandang Berdasarkan Jenis Binatangnya", Avaliable at r.yuwie.com/blog/ entry. Accession date: 29 November 2010.

[14]. T.R. Pacioni, D. Soares, M. Di Domenico, M.F. Rosa, R.P.M. Moreira, H.J. José, Bio-syngas production from agroindustrial biomass residues by vapor gasification, Waste Management, vol. 58, pp.221–229, 2016.