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The Effect of Adding Vinasse for Biochar Production from Bagasse by Pyrolysis Method

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ABSTRACT

The increasing industrial waste was caused problems for the environment. Bagasse is a solid waste produced from the sugar industry. Vinasse is bioethanol industry liquid waste from molasses which contains much nutrients. The vinasse and bagasse in this study was developed into biochar. This study aimed to determine the effect of vinasse addition on biochar characteristics. The yield and characteristics of the biochar were then compared. Based on gravimetric, pH, and SEM-EDX analysis, the result indicated that adding vinasse to the biochar was increasing yield, water content and ash content, lowering pH, and tend to increase nutrient levels (carbon, nitrogen, and potassium). The biochar produced from bagasse and vinasse by pyrolysis had a yield of 6.682-9.406%; water content of 7.0-8.2%; ash content of 4.8-13.6%; at pH 8.4-88; carbon content (C) of 65.07-80.88%; nitrogen (N) content of 2.06-8.66%; and potassium (K) levels of 0.00-2.15%, while phosphorus (P) levels were not detected in SEM-EDX analysis. Based on the consideration of the highest levels of nitrogen and potassium elements needed by plants, the optimum biochar was obtained from bagasse with a vinasse of 7.5%.

***Keywords*:** biochar, bagasse, pyrolysis, vinasse.

1. INTRODUCTION

Biochar is a solid material that has pores which obtained from the carbonization process of biomass. The biochar can be used in the fields of catalyst, energy storage, soil enrichment, and adsorbent. In the field of soil fertilization, the biochar improves soil fertility and quality and increases carbon sequestration [1]. The biochar can improve soil chemical properties that support for increased agricultural productivity [2,3]. Soil containing biochar can provide a habitat for bacteria that can be permeated nutrients. So that nutrients can be optimally absorbed by plants [4-6]. The biochar is more effective in retaining nutrients for plants and lasts longer in the soil than compost and manure [7]. According to the Indonesian National Standard (SNI), the biochar has an ash content of 15.2-16.8%, water content of 2.3-2.4%, pH value of 8.0-9.0, and carbon value of 48.0 - 45.2% [7]. The biochar can be produced from biomass such as rice husks, bagasse, wood, sawdust, and corn cobs [2,8]. The bagasse is a by-product of the sugarcane extraction process which contains 48-52% water. It contains lignocellulose with fiber length is 1.7-2 mm and diameter is about 20 microns [9]. The bagasse fiber is insoluble in water and consists of cellulose (35.01%), hemicellulose (25.24%), lignin (6.4%), and silicate (9.35%) [10]. Therefore, the bagasse is used as biomass source for biochar at this research.

Production of biochar can be done using pyrolysis, carbonization, gasification, hydrothermal, torrefaction, and flash carbonization methods [1]. The pyrolysis is an incomplete combustion process at high temperatures of 250-900 °C to produces carbon called biochar. The process usually use a closed reactor made of steel and run at 4-7 hours [7]. Slow pyrolysis process produced higher yields of biochar than fast pyrolysis process [11,12]. The biochar from bagasse pyrolysis has a yield of 40.2-59.6%; pH 8.8-9.2; carbon content 60.8-68.2%; nitrogen content 1.7-1.8%; water content 1.7-

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2.9%; ash content 32.2-48.8% [12]. This shown that nutrients of biochar from bagasse have low element levels. The nutrients are important elements needed by plants, but the produced biochar at prior research have low nutrient content. Therefore, the biochar needs to be given additional ingredients that contain nutrients, so that nutrient levels can increase. In this research bagasse mixed with vinasse was used as raw material for biochar to increase nutrient levels.

Vinasse is liquid waste generated by the bioethanol industry from molasses [13]. In the production process, 1 liter of ethanol product produces 13 liters of vinasse [14]. The vinasse contains a lot of organic matters, elements of nitrogen and potassium [15]. The mineral content in 100 grams of vinasse is 6.36-7.2% potassium, 1.58-1.84% sodium, and 0.24-0.28% phosphorus [16].

Therefore, vinasse must be further processed into a more useful product. Vinasse in this study used as a source of potassium in biochar. Nutrient contents in biochar were analyzed using scanning electron microscopy – energy dispersive x-ray spectroscopy (SEM-EDX) [17]. The aim of this study was to evaluate the characteristics of biochar from the utilization of a mixture of bagasse and vinasse waste by pyrolysis method using a pyrolysis reactor with variations in vinasse mass percentage.

The evaluated biochar characteristics are yield, pH value, moisture content, ash content, carbon, nitrogen, and potassium content. The yield, moisture content, and ash content were analyzed by gravimetric analysis. The nutrient content (carbon, nitrogen, and potassium levels) were analyzed by SEM-EDX.

2. MATERIAL AND METHOD

2.1 Material

The bagasse materials were collected from solid waste of Kebonagung Sugar Factory, Malang Regency, Indonesia. The vinasse materials were collected from liquid waste of bioethanol industry PT Energi Agro Nusantara, Mojokerto Regency, Indonesia.

2.2 Biochar Production from Bagasse and Vinasse Waste by Pyrolysis Method

Total mass of 1000 grams mixture of the vinasse and bagasse was dehydrated first in the sun for 3 h. The vinasse was added at various in mass (0; 2.5; 5; 7.5; 10) % wt/wt. The pyrolysis reactor shown at Figure 1, which divided into three compartments: drying, pyrolysis, and fire initiation chamber (Figure 2). The mixture was fed into the drying chamber in Figure 2 (1) next to the screen bulkhead at pyrolysis reactor. Drying process used heat flue gas from pyrolysis chamber as energy.

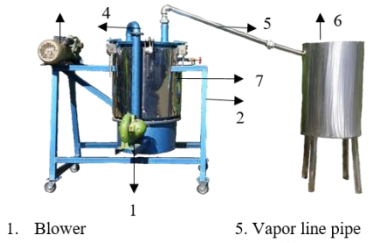

Figure 1. The pyrolysis reactor equipment [18]

The dried mixture of bagasse and vinasse feed is fed into the pyrolysis chamber in Figure 2 (3). Airflow with a limited flow rate 5.10 L/m was passed through the air path. The ignition is done at the fire initiation chamber in Figure 2 (4) to start the pyrolysis. During the process, the temperature is measured by observing the thermocouple. After pyrolysis and the temperature dropped to 40 °C, the reactor was opened and biochar was taken from the pyrolysis chamber for sample analysis. The tar formed during the process, is condensing and stored in the tar tank.

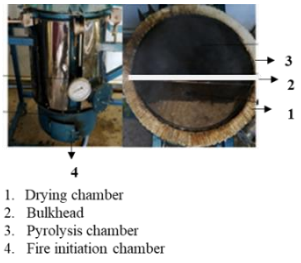

Figure 2. The pyrolysis reactor compartments

2.3 Characteristic Analysis of Biochar from the Pyrolysis of Bagasse and Vinasse Mixture

Yield Analysis (%). Based on the results of weighing biochar and raw material mixture of bagasse and vinasse. Yield is calculated using the Equation 1:

$$\text{Yield percentage } (\%) = \frac{m_2}{m_1} \text{ x } 100\% \quad (1)$$

Where:
m_1 = initial sample weight (g)
m_2 = weight of biochar formed (g)

Ash content analysis (%). For analyzing ash content, one gram of the sample was heated in a furnace (Nabertherm B170) at a temperature of 815 °C to form ash for 1 h. The sample was cooled in a desiccator for 15 min. The ash content is calculated using the Equation 2:

$$\text{Ash content } (\%) = \frac{m_2}{m_1} \text{ x } 100\% \quad (2)$$

Where:
m_1 = initial sample weight (g)
m_2 = weight of ash formed (g)

Water content analysis (%). For analyzing the water content, one gram of sample was put in a porcelain dish and was heated in the oven (Memmert Universal Oven UN55) at temperature of 110 °C for 1 h. The sample was cooled in a desiccator for 15 min. The water content is calculated using the Equation 3:

$$\text{Water content } (\%) = \frac{m_2 - m_3}{m_2 - m_1} \text{ x } 100\% \quad (3)$$

Where:
m_1 = weight of empty dish (g)
m_2 = dish weight + content before oven (g)
m_3 = dish weight + content after being in the oven (g)

Morphology and elemental analysis. The morphology and elemental analysis (potassium, nitrogen, and carbon**)** for produced-biochar was performed by using scanning electron microscopy-energy dispersive x-ray spectroscopy (SEM-EDX) in 20 kV and 50 μm magnitude.

3. RESULTS AND DISCUSSION

3.1 Biochar Characteristics from the Pyrolysis of Bagasse and Vinasse Mixture

In this research, characterization is focused on the characteristics of biochar from a mixture of bagasse and vinasse pyrolysis. The produced biochar is used to improve soil chemical properties that support increased agricultural productivity. The addition of vinasse can increase the nutrients needed by plants in biochar.

Soil containing biochar can provide a habitat for bacteria that can be permeated nutrients. So that nutrients can be optimally absorbed by plants. Parameter of pH, ash content dan C level of bagasse biochar (BV0, Table 1) has met the biochar characteristic SNI standards. The addition of vinasse to bagasse for producing biochar can increase ash content, nutrients C, N and K.

For phosphorus content levels were not detected in the biochar produced in this study. This caused by phosphorus content in vinasse is also low. This is supported by [16] which state that phosphorus levels in vinasse are only 0.24-0.28%. For the appearance of the obtained biochar results are shown in Figure 3 and 4. While the results of the obtained biochar characterization are shown in Table 1.

Table 1. Biochar characteristics from the pyrolysis of bagasse and vinasse mixture at variations in the mass percent of vinasse

Biochar	Mass percent vinasse of mix	Measured Parameter						
		% yield	pH	Water content (%)	Ash content (%)	K level (%)	N level (%)	C level (%)
BV0	0%	6.68	8.8	7.0	4.8	*0.36*	2.06	*74.38*
BV2.5	2.5%	8.20	8.8	7.7	9.0	0.00	2.84	78.86
BV5	5%	8.49	8.5	7.7	9.7	1.03	1.84	80.88
BV7.5	7.5%	9.13	8.4	7.9	10.8	2.15	8.66	65.07
BV10	10%	9.41	8.4	8.2	13.6	0.23	3.69	70.52
Standard *	-	-	8.0-9.8	2.4	15.2-16.8	-	-	48.0-45.2

Figure 3. Biochar yield from bagasse and vinasse mixture by pyrolysis method with variations in the mass percent of vinasse: (a) 0%; (b) 2.5%; (c) 5%; (d) 7.5%; and (e) 10%

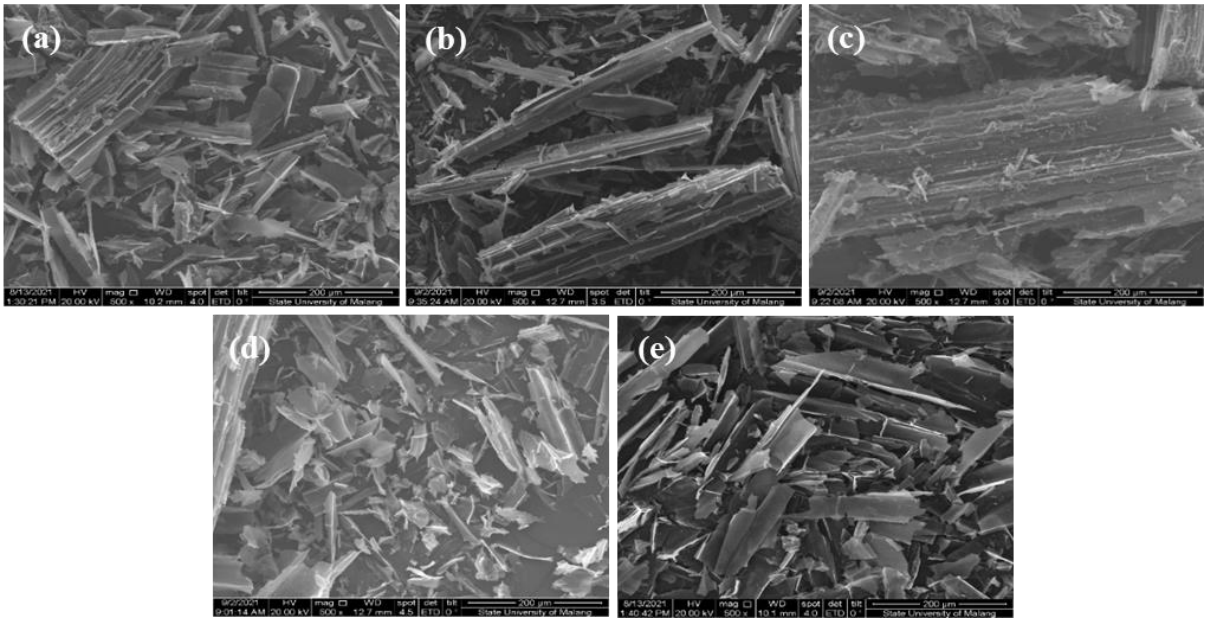

Figure 4. SEM image on biochar from bagasse and vinasse mixture by pyrolysis method with variations in mass percent of vinasse: (a) 0%; (b) 2.5%; (c) 5%; (d) 7.5%; and (e) 10%

3.2 Effect of Adding Vinasse to Biochar Yield Percentage

Based on the gravimetric analysis shown in Figure 5 and Table 1, the more percent of vinasse added to bagasse, the more yield of biochar obtained, because vinasse is in liquid form which increases the moisture of bagasse, thus affecting the pyrolysis process. The yield of biochar produced has a percentage yield of 6.68 - 9.41%. The highest

percentage yield was found in biochar which was made with 10% vinasse mass percentage.

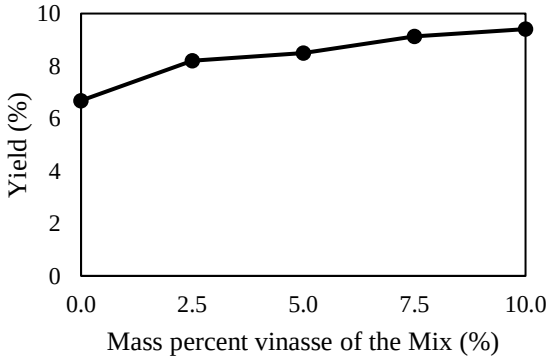

Figure 5. Percentage yield of biochar from the pyrolysis of bagasse and vinasse mixture

3.3 Effect of Adding Vinasse to Biochar pH

Based on the pH measurements shown in Figure 6 and Table 1, the more percent of vinasse added to bagasse, the lower the pH of the biochar produced tends to be. This is because vinasse is acidic as suggested [15] so that it affects the pH yield of biochar produced. The results of produced biochar have pH of 8.4-8.8, meets the Indonesian National Standard which range from 8.0 to 8.9.

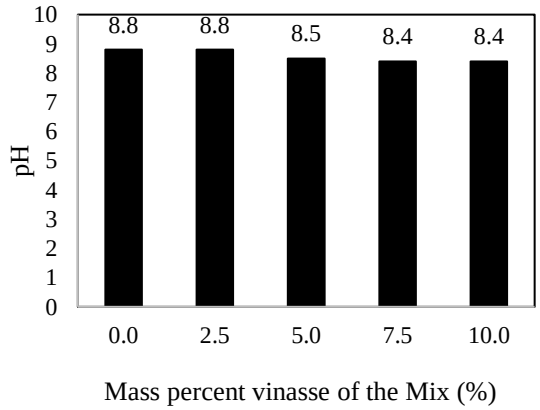

Figure 6. pH of the biochar from the pyrolysis of bagasse and vinasse mixture

3.4 Effect of Adding Vinasse to Biochar Water Content

Based on the gravimetric analysis shown in Figure 7 and Table 1, the more percent of vinasse added to bagasse, the higher water content of the biochar produced. This is because vinasse has high water content, thereby increasing the water content of biochar. The produced biochar has a water content of 7.0-8.2%. The highest water content is found in biochar made with 10% vinasse mass. This shows that the water content in biochar is higher than the Indonesian National Standard which is 2.4%.

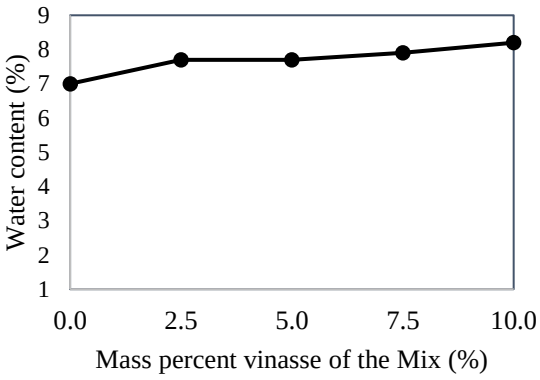

Figure 7. Water content in biochar from the pyrolysis of bagasse and vinasse mixture

3.5 Effect of Adding Vinasse to Biochar Ash Content

Based on the gravimetric analysis shown in Figure 8 and Table 1, the more percent of vinasse added to bagasse, the higher ash content of biochar produced. This is because vinasse has high ash content of 34 % [19], thus increasing the ash content in produced biochar. The results of the produced biochar have ash content of 4.8-13.6%. The highest ash content in biochar is made with 10% vinasse mass. This shows that the ash content in biochar does not meet the Indonesian National Standard, which range from 15.2 to 16.8%.

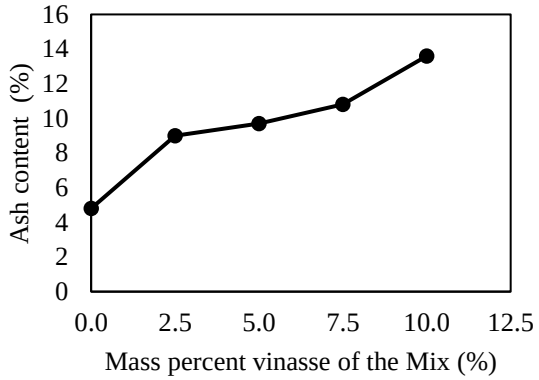

Figure 8. Ash content of biochar from the pyrolysis of bagasse and vinasse mixture

3.6 Effect of Adding Vinasse to Biochar Carbon Content

Based on the SEM-EDX analysis shown in Figure 9 and Table 1, the more percent of vinasse added to bagasse, the higher carbon content of produced biochar. This is because vinasse has 11-15% carbon content [20], thus increasing the carbon content produced in biochar.

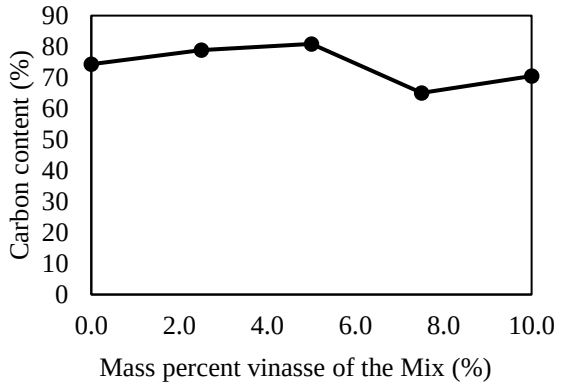

Figure 9. Carbon content in biochar from the pyrolysis of bagasse and vinasse mixture

The results obtained biochar has a carbon content of 65.07-80.88%. The highest carbon content is found in biochar made with 5% vinasse mass. This shows that the carbon content in biochar is higher than the Indonesian National Standard which range from 48.0 to 45.2%.

3.7 Effect of Adding Vinasse to Nitrogen and Potassium Levels of Biochar

Based on the SEM-EDX analysis shown in Figure 10 and Table 1, the increase in the addition of mass percent vinasse to bagasse tends to increase the levels of nitrogen and potassium elements in the biochar produced. The obtained biochar has a nitrogen content of 2.06-8.66%. Biochar results obtained have potassium levels at 0.00-2.15%.

The optimum yield of mass percent vinasse was obtained at 7.5% with a nitrogen content of 8.66% and a potassium content of 2.15%. When compared between biochar from bagasse without the addition of vinasse and biochar from bagasse with the addition of vinasse, show that vinasse could increase nitrogen and potassium levels. This is supported by previous studies [14] and [15] which stated that vinasse contains a lot of nitrogen and potassium elements. The optimum yield in this study had a higher nitrogen content value and a lower potassium content value than the biochar produced by [21] which 1.5% and 4.10%.

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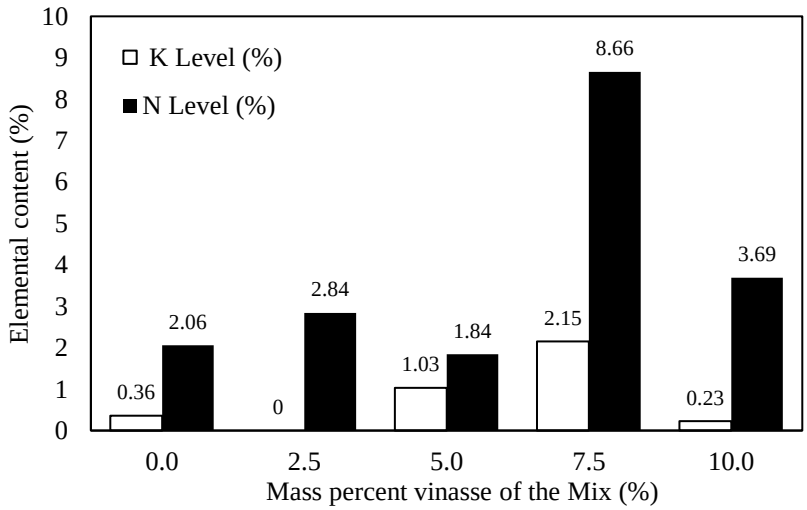

Figure 10. Potassium and Nitrogen levels in biochar from the pyrolysis of bagasse and vinasse mixture

4. CONCLUSION

The biochar derived from bagasse added with vinasse has higher nitrogen and potassium levels than biochar derived from bagasse without the addition of vinasse. The adding of vinasse increases the water and ash content, lower the pH, and tend to increase the levels of nutrients (carbon, nitrogen, and potassium). Biochar produced from bagasse with a mass percent variation of vinasse has yield of 6.68-9.41%; water content of 7.0-8.2%; ash content of 4.8-13.6%; at pH 8.4-88; carbon content (C) of 65.07-80.88%; nitrogen (N) content of 2.06-8.66%; and potassium (K) levels of 0.00-2.15%, while phosphorus (P) levels were not detected in SEM-EDX analysis. Based on the consideration of the highest levels of nitrogen and potassium, the optimum biochar was produced from bagasse with the vinasse addition of 7.5%, which resulted in yield of 9.13 %; pH of 8.4; water content 7.9%; ash content 10.8%; potassium content of 2.15%; nitrogen content 8.66%; and carbon content of 65.07%.

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REFERENCES

[1] P. R. Yaashikaa, P. S. Kumar, S. Varjani, A. Saravanan, A critical review on the biochar production techniques, characterization, stability and applications for circular bioeconomy, *Biotechnol. Reports*, vol. 28, pp. 1-15, 2020.

[2] S. Wijitkosum, Biochar derived from agricultural wastes and wood residues for sustainable agricultural and environmental applications, *Int. Soil Water Conserv. Res.*, vol. 10, pp. 335-341, 2022.

[3] X. Liu, Y. Ye, Y. Liu, A. Zhang, X. Zhang, L. Li, G. Pan, G. W. Kibue, J. Zheng, J. Zheng, Sustainable biochar effects for low carbon crop production: A 5-crop season field experiment on a low fertility soil from Central China, *Agric. Syst.*, vol. 129, pp. 22–29, 2014.

[4] A. Kurniawan, B. Haryono, M. Baskara, S. Y. Tyasmoro, Pengaruh penggunaan biochar pada media tanam terhadap pertumbuhan bibit tanaman tebu (Saccharum officinarum L), *J. Produksi Tanam.*, vol. 4, no. 2, pp. 153–160, 2016.

[5] R. Sarfraz, A. Hussain, A. Sabir, I. Ben Fekih, A. Ditta, S. Xing, Role of biochar and plant growth promoting rhizobacteria to enhance soil carbon sequestration—a review, *Environ. Monit. Assess.*, vol. 191, no. 251, pp. 1-13, 2019.

[6] J. Lehmann, M. C. Rillig, J. Thies, C. A. Masiello, W. C. Hockaday, D. Crowley, Biochar effects on soil biota – A review, *Soil Biol. Biochem.*, vol. 43, no. 9, pp. 1812–1836, 2011.

[7] D. Asyifa, A. Gani, R. F. I. Rahmayani, Karakteristik biochar hasil pirolisis ampas tebu (Sacharum officanarum, linn) dan aplikasinya pada tanaman seledri (Apium graveolens L), *J. IPA Pembelajaran IPA*, vol. 3, no. 1, pp. 15–20, 2019.

[8] A. E.-E. A. Z. Amin, Impact of corn cob biochar on potassium status and wheat growth in a calcareous sandy soil, *Commun. Soil Sci. Plant Anal.*, vol. 47, no. 17, pp. 2026–2033, 2016.

[9] A. Kurniasih, D. A. Pratiwi, M. Amin, Pemanfaatan ampas tebu sebagai arang aktif dengan aktivator larutan belimbing wuluh (Averrhoa bilimbi L), *J. Kesehat. Lingkung. Ruwa Jurai*,

vol. 14, no. 6, pp. 56–63, 2020.

[10] A. S. D. S. Hidayati, S. Kurniawan, N. W. Restu, B. Ismuyanto, Potensi ampas tebu sebagai alternatif bahan baku pembuatan karbon aktif, *Nat. B*, vol. 3, no. 4, pp. 311–317, 2016.

[11] S. Kloss, F. Zehetner, A. Dellantonio, R. Hamid, F. Ottner, V. Liedtke, M. Schwanninger, M. H. Gerzabek, G. Soja, Characterization of slow pyrolysis biochars: effects of feedstocks and pyrolysis temperature on biochar properties, *J. Environ. Qual.*, vol. 41, no. 4, pp. 990–1000, 2012.

[12] S. V. Novais, M. D. O. Zenero, J. Tronto, R. F. Conz, C. E. P. Cerri, Poultry manure and sugarcane straw biochars modified with $MgCl_2$ for phosphorus adsorption, *J. Environ. Manage.*, vol. 214, pp. 36–44, 2018.

[13] J. R. Amelia, U. Hasanudin, E. Suroso, Potensi biogas dari proses rekayasa aklimatisasi bioreaktor akibat perubahan substrat pada industri bioethanol, *J. Tek. Pertan. Lampung*, vol. 8, no. 2, pp. 224–233, 2019.

[14] R. S. Harjanti, Pupuk organik dari limbah pabrik gula madukismo dengan starter mikrobia pengurai untuk menambah kandungan N, P, K, *Chem. J. Tek. Kim.*, vol. 4, no. 1, pp. 1-7, 2017.

[15] M. Z. Arrodli, M. Muhartini, T. Taryono, Pemanfaatan vinasse - limbah industri alkohol- untuk perbaikan sifat fisik tanah dalam pengembangan tebu (Saccharum officinarum L) Di Lahan Pasir Pantai, *J. Sains &Teknologi Lingkung.*, vol. 3, no. 2, pp. 108–114, 2011.

[16] R. Ekawati, L. H. Saputri, Pengaruh cara pemberian pupuk organik cair vinasse terhadap pertumbuhan awal bawang dayak (Eleutherine palmifolia) T, *J. Kultiv.*, vol. 17, no. 3, pp. 760–765, 2018.

[17] X. Ma, B. Zhou, A. Budai, A. Jeng, X. Hao, D. Wei, Y. Zhang, D. Rasse, Study of Biochar Properties by Scanning Electron Microscope – Energy Dispersive X-Ray Spectroscopy (SEM-EDX), *Commun. Soil Sci. Plant Anal.*, vol. 47, no. 5, pp. 593–601, 2016.

[18] E. Naryono, S. Susanto, M. A. I. Iswara, R. Y. W. Ardhinantoro, G. R. Tiftazani, R. Basuki, The development of pyrolysis reactor unit for processing bagasse and vinasse mixture into biochar, in *ATASEC,* (*3rd Annual Technology, Applied Science and Engineering Conference), Malang Indonesia (online), Sept.* 2021.

[19] M. J. Dirbeba, A. Brink, M. Zevenhoven, N. DeMartini, D. Lindberg, L. Hupa, M. Hupa, Characterization of vinasse for thermochemical conversion—fuel fractionation, release of inorganics, and ash-melting behavior, *Energy & Fuels*, vol. 33, no. 7, pp. 5840–5848, 2019.

[20] V. Rajagopal, S. M. Paramjit, K. P. Suresh, S. Yogeswar, R. D. V. K. Nageshwar, N. Avinash, Significance of vinasses waste management in agriculture and environmental quality-Review, *African J. Agric. Res.*, vol. 9, no. 38, pp. 2862–2873, 2014.

[21] C. Prayogo, N. D. Lestari, K. S. Wicaksono, Karakteristik dan kualitas biochar dari pyrolysis biomassa tanaman bio-energi willow (Salix sp), *Buana Sains*, vol. 12, no. 2, pp. 9–18, 2012.