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## ORIGINAL RESEARCH

### Investigating the role of stirring in composting of goat manure with application of corncob biochar

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#### Abstract

**Purpose:** The abundance of corncob waste has not been optimally utilized and tends to be thrown away and left to decompose. The utilization of corncobs processed into biochar in the composting process is a topic that needs to be explored. In addition, dependence on external bio-activators in the composting process can be reduced with the application of biochar as an indigenous material. In this context, the objective of this study was to know the effect of corncob biochar application and stirring on the quality of goat manure organic fertilizer.

**Method:** A randomized Complete Block Design with the first factor of no application and application of 10% biochar based on weight of goat manure and the second factor of being without stirring or with weekly stirring was tested, and each treatment was repeated five times. The observed variables were pH, temperature, humidity, water content, and chemical characteristics viz. C-organic, N, P<sub>2</sub>O<sub>5</sub>, and K<sub>2</sub>O.

**Results:** The addition of corncob biochar with or without stirring to the manure of goats produced better-quality organic fertilizer with the low relative humidity, and high contents in C-organic, N, and K.

**Conclusion:** composting using corncob biochar with or without stirring resulted in better-quality composting by using corncob biochar with or without stirring resulted in a better-quality organic fertilizer compared to composting without biochar application based on regional and national standards supported by WHO such as those in Canada, USA and Europe.

**Keywords:** Compost quality, Crop residue, Livestock waste, Sustainable agriculture, Zero waste management  
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## 1. Introduction

Waste is unused leftover material from human activities or natural processes that has no economic value and has a negative impact on the environment. Various wastes are found around us, such as livestock and agricultural waste, which are increasing in quantity as time goes by. Waste left without further treatment can pollute the environment, disrupt the surrounding community's health, and reduce aesthetic and comfort values (Sudharmaidevi et al., 2017).



Many livestock waste, such as feces, urine, and leftover feed, are not reprocessed, so they can make the environment smelly and become a breeding ground for disease. There is lots of livestock waste around us, one of which is goat manure. According to Orskov et al. (2014), one goat can produce 1.5 kg of manure/feces per day on average. Many agricultural wastes are also left to pile up, one of which is corncobs. So far, people have tended to process corncobs into animal feed or just throw them away. Therefore, appropriate waste processing measures are needed to avoid environmental pollution and benefit the environment and society (Khan et al., 2024).

Waste processing can be done in many ways, one of which is by making it into compost. Composting is the process of making compost or the process of biological decomposition of organic materials by microorganisms that utilize organic materials as an energy source (Begum et al., 2023). Composting tends to take a long time, so efforts are needed to speed up the composting of organic materials. One effort can be made to choose the ingredients that makeup compost. Compost can be made from a mixture of livestock waste and agricultural waste. Goat manure can be used as an organic material to make compost because it has a relatively high nutrient content. Goat manure is mixed with urine, which also contains nutrients (Rizkiyah et al., 2024). Fresh goat manure has hot properties because it has a high ammonia content with evidence of a low C/N ratio, so it needs to be composted (Navianti & Priyadi, 2023).

Composting goat manure commonly takes a long time and requires much energy. When composting goat manure, it needs to be stirred to increase aeration and reduce heat in the compost pile (Hong-li and Yan, 2011). Aeration during the composting process is essential because it supplies the oxygen required for aerobic microorganisms to efficiently and rapidly decompose organic matter and simultaneously controlling foul odors and balancing moisture content (Guo et al., 2012; Wang et al., 2021). Stirring compost, which is carried out regularly, especially when making large quantities of compost, requires special attention, time, and energy to achieve the desired quality of compost. Optimized stirring or turning frequency during composting is crucial for maintaining an adequate oxygen supply to fuel the aerobic microbes, which accelerate the decomposition rate, sustains the necessary high temperatures, prevents anaerobic odor development, and ensures a uniform mix of materials for faster maturation (Jiang-ming, 2017; Zhang et al., 2019). Therefore, a solution is needed, such as using additional compost ingredients, which are thought to optimize the composting process.

The additional material used in this research is biochar. Biochar is charcoal made from plant residues and is made by burning it in conditions of limited or even no oxygen (Jindo et al., 2014). Biochar primarily functions as a porous bulking agent and microbial habitat, significantly accelerating the organic solid composting process by improving aeration, regulating moisture, and stabilizing the pH of the pile. Its high surface area and cation exchange capacity enable it to retain valuable nutrients, resulting in a higher quality, more stable final compost product (Xiao et al., 2017).

One of the plant residues that can be used as raw material for biochar is corncobs. Biochar has porous properties because it has many pores, thereby allowing increased aeration in the composting process (Liu et al., 2017). The use of biochar can also trigger an increase in biomass, activity, and composition of microorganisms so that it can optimize the composting process (Tripathi et al., 2016; Czekala et al., 2019). Therefore, the objective of this study was to know the effect of biochar application through stirring on the goat manure composting process and the quality of the compost.

## 2. Materials and method

### 2.1. Study area

The research was carried out in Singasari Village, Karanglewas District, Banyumas Regency, for composting activities, and the Soil and Land Resources Laboratory, Faculty of Agriculture, Universitas Jenderal Soedirman, for compost-quality testing activities from March to July 2024.

### 2.2. Methodology

A randomized complete block design consisting of two factors was implemented. The first factor is without and with the addition of 10% biochar, and the second factor is the absence or presence of weekly stirring. Goat manure was the primary material in this study. Goat manure of 30 kg was placed in a 40



kg compost bag, and then 1 kg of dolomite and molasses 2 L (3 mL/L) was while biochar of 3 kg (10% manure-based) was added according to the treatment.

## 2.3. Observed variables and analysis

The variables observed and calculated in this study were divided into two stages, i.e., the composting stage and the compost quality stage. During the composting stage, the temperature and moisture were monitored weekly. Compost temperature and moisture were observed by sticking the tip of the thermo-hygrometer sensor at a depth of 30 cm in the compost in the middle. The degree of acidity (pH) was measured weekly by putting a soil pH and moisture meter into the compost pile in the middle at a depth of 30 cm.

In the compost quality stage, water content, pH, and the level of organic C, Nitrogen, Phosphor, and Potassium of the compost were measured. Water content measurements were carried out by employing gravimetric method. The compost sample was weighed then dried in the oven at 105 °C for 16 hours. The dried sample was weighed then the difference of weight was calculated to determine water content. The acidity (pH) was measured using glass electrode method. The fine compost sample was weighed at 3 g, then put into a bottle, and 15 mL of distilled water was added. The bottle was closed tightly and homogenized with a shaking machine for 30 minutes. Then, it was measured with a pH meter that was calibrated using a buffer solution of pH 4.01 and pH 6.86.

C-organic analysis was done by using the Walkley-Black method. The working procedure for this measurement was a 0.05 g sample of compost put into a 100 mL measuring flask to add 5 mL of 2 N  $K_2Cr_2O_7$  solution. The solution was shaken, and 7.5 mL of  $H_2SO_4$  was added. 98% then left for 30 minutes, then given distilled water until the solution volume became 100 mL and shaken back until homogeneous. The standard solution used was a 5000 ppm C standard solution. A standard containing 250 ppm C was made by inserting 5 mL of a standard solution of 5000 ppm C into a 100 mL measuring flask. The solution was added with 5 mL of  $H_2SO_4$  and 7.5 mL of 2 N  $K_2Cr_2O_7$  and shake within 30 minutes. The blank solution uses a standard of 0 ppm C. The standard and blank solutions were diluted with ion-free water, and the volume was adjusted to the 100 mL mark after cooling. The solution was shaken back and forth until homogeneous. The sample, standard, and blank solutions were put into a cuvette, and the absorbance was measured using a spectrophotometer with a wavelength of 587 nm.

Measurement of the total nitrogen content of compost was carried out based on the total nitrogen content using the Kjeldahl method. This method consists of destruction, distillation, and titration. The stages of nitrogen content were determined by determining N-organic,  $N-NH_4^+$ , and  $N-NO_3^-$ . Determination of  $P_2O_5$  content by dye-generating reagent. Phosphate levels were measured with a spectrophotometer at a wavelength of 889 nm, and the absorbance value was recorded.  $K_2O$  content was analyzed using a flame photometer with a standard series as a comparison. The standard series was taken from the parent standard solution K 1000 ppm in water. The C/N ratio is an important indicator in determining compost maturity. The C/N ratio measurement was obtained from the C-organic content compared to the total nitrogen content in the compost. The calculation of the C/N ratio value was based on the comparison of organic C content (%) / total N content (%).

## 2.4. Statistical analysis

The data obtained were analyzed statistically using variance tests at a level of significance  $p < 0.05$ . The treatment showed a significant effect, then tested the real difference with Duncan's Multiple Range Test (DMRT) at 5% level.

## 3. Results and Discussion

### 3.1. Temperature, Relative humidity, pH and water content during composting

The weekly stirring treatment had no significant effect on the composting temperature within eight weeks. However, the composting temperature in the first week showed that corncob biochar application had a very significant effect. The addition of corncob biochar increased the temperature of the composting process up to



44.1 °C while composting without the addition of corncob biochar had a temperature of 41.9 °C. But, in the second week, the temperature of both treatments was relatively the same as at the end of the composting process. In the third and fourth weeks, the temperature of the compost with corncob biochar showed a significant difference. Composting with corncob biochar treatment had a lower temperature (36.3 °C and 33.3 °C) compared to the treatment without biochar corncob (37.7 °C and 34.4 °C). This indicated that compost with the addition of corncob biochar has a faster temperature reduction. The compost temperature during 5 to 8 weeks did not show any significant differences; each treatment had a relatively similar and stable temperature. This stable temperature indicated that the composting process for each treatment had entered the maturation phase. The combination treatment of adding corncob biochar and weekly stirring did not show a significant temperature difference each week (Fig. 1).

Weekly stirring significantly affected the average humidity from 0 to 8 weeks. Composting without stirring has an average humidity of 62.72% while composting with stirring has an average humidity of 60.02%. The average compost moisture showed a significant difference with the addition of corncob biochar. Composting with the addition of corncob biochar has lower average humidity than composting without the addition of corncob biochar. Adding the corncob biochar to the composting process had a lower average relative humidity (Fig. 2).

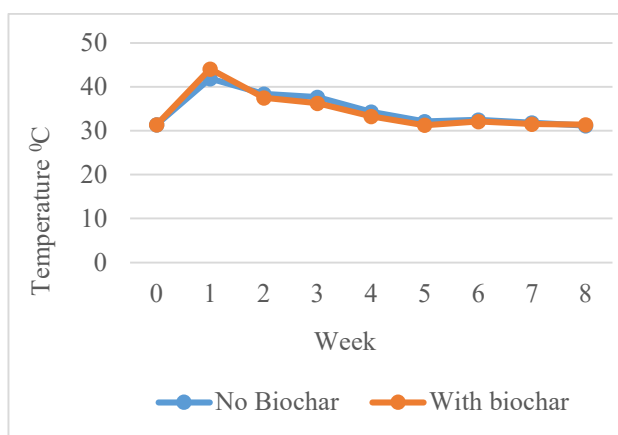


Fig. 1. Temperature during the composting process

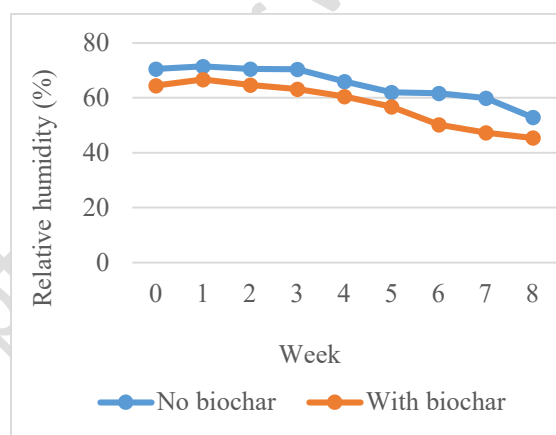


Fig. 2. Relative humidity during the composting

The weekly stirring and biochar added had no significant effect on the average pH of the compost. Composting with and without stirring had an average pH of 4.97 and 5.06, respectively, and with and without the addition of corncob biochar had an average pH of 5.06 and 4.97, respectively (Fig. 3).

The weekly stirring did not show any significant difference in the moisture content of the compost, but there was a significant effect due to the application of corncob biochar. The water content of compost with and without the addition of corncob biochar was 46.2% and 55.28%, respectively. This indicated that compost with the addition of corncob biochar could decrease water content compared to compost without adding corncob biochar (Fig. 4).



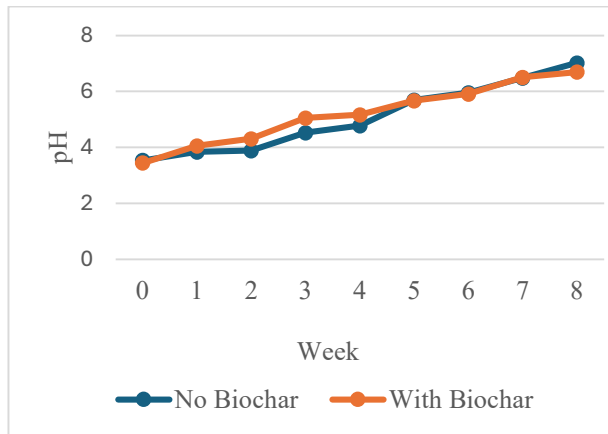


Fig. 3. pH during the composting process.

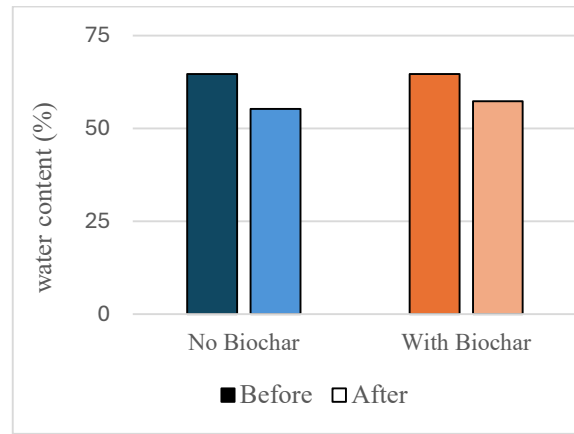


Fig. 4. Water content in the composting process

Composting is the process of breaking down organic materials into humus-like forms with the help of microorganisms. Organic materials are composted until they show signs of compost maturity. Compost maturity parameters can be determined based on physical, chemical, and biological properties. The physical properties of compost include temperature, humidity, pH, water content reduction, weight loss, and volume reduction.

Temperature is an important parameter in composting. Temperature shows the activity of microorganisms in decomposing organic materials. According to Miyatake and Iwabuchi (2005), temperature is a direct control of the activity of microorganisms in degrading organic carbon available in compost raw materials. Microorganisms in compost decompose organic materials into CO<sub>2</sub> gas, water vapor, and heat. Fan et al. (2021) stated that high composting temperatures can help accelerate the breakdown of proteins, fats, and complex carbohydrates such as cellulose and hemicellulose. The composting temperature will decrease over time because microorganisms have decomposed the carbon content in the compost. A stable temperature in the compost indicates that the compost is ripening.

Composting with and without biochar gained the highest temperature of 44.1 °C and 41.9 °C, respectively. This higher temperature indicated that the activity of microorganisms in composting with biochar was greater than without biochar. Jindo et al. (2012) mentioned that biochar can help create an ideal space for microorganisms so that the activity of microorganisms breaking down organic material increases. A similar statement was also explained by López-Cano et al. (2016); the addition of biochar was able to support the activation of the composting process, thereby showing a faster temperature increase compared to treatment without biochar.

The composting temperature in the third and fourth weeks showed that the composting with biochar compared to without biochar resulted in a faster temperature decrease. The faster decline in temperature was due to the porous nature of biochar, which increases aeration in the compost. Parra-Orobio et al. (2023) reported that biochar can increase aeration in compost because it can prevent the formation of compost material.

Applying biochar results in lower relative humidity compared to composting without biochar. However, adding biochar in the composting process did not significantly affect humidity according to the activity of microorganisms, with the evidence that compost moisture was under optimal requirements in both conditions. Melo et al., (2020) stated that humidity will affect the performance of microorganisms in decomposing organic material.

The pH of composting increased every week. The increase in compost pH occurs due to the increase in the number of basic cations, such as potassium, calcium, and magnesium, as well as the destruction of proteins and the release of ammonia. The activity of microorganisms increases pH because microorganisms convert organic compounds that have been formed previously and finally stabilize at neutral pH (Wang et al., 2018). The pH in the composting process without biochar in the fifth week showed a more significant increase than the pH with the biochar. Meanwhile, the increase in pH of compost with biochar tended to be slightly stable. The pH stability of composting is due to biochar having a high buffering capacity. The pore structure absorbs and retains hydrogen ions (H<sup>+</sup>) and other acidic compounds, thereby reducing pH fluctuations (Antonangelo et al., 2021).



Composting pH needs to be maintained in accordance with the optimal requirements for microorganisms in the range of 5.5 – 8.0. Under conditions too acidic or too alkaline, it can inhibit the decomposition process because the activity of microorganisms is not optimal (Yang et al., 2019). This pH is also not much different from a similar study conducted by (Chung et al., 2021), with the pH obtained in the range of 7.53-7.81. The stable pH of compost is due to the role of dolomite, which is added at the beginning of composting. According to Cahyono et al. (2020), dolomite can increase the pH in compost stably.

Composting with corncob biochar had a very significant effect on the moisture content of the compost. The moisture content of the compost with and without biochar was 46.2% and 55.28%, respectively. The lower moisture content of the compost with biochar was due to the fact that biochar absorbs water and increases aeration within the compost. Microorganism activity also affects the water content in the compost. Microorganisms that had greater activity cause hotter temperatures, thereby increasing evaporation in the compost. The evaporation causes the water content in the compost to decrease more quickly (Jia et al., 2016).

### 3.2. C-Organic, N total, C/N ratio, P<sub>2</sub>O<sub>5</sub>, K<sub>2</sub>O contents in organic fertilizer

Compost C-Organic content with weekly stirring did not show a significant difference. Meanwhile, there were differences in significance due to the corncob biochar on C-Organic content. The addition of corncob biochar to compost had a higher C-Organic content of 26.29% than without the addition of corncob biochar of 21.69%. This data showed that compost with the addition of corncob biochar improved C-Organic content compared to compost without corncob biochar treatment (Fig. 5).

The weekly stirring treatment did not significantly differ in the N-Total content of the compost. However, the addition of corncob biochar showed a significantly different effect on the N-Total content of the compost. Fig. 6 showed that compost with corncob biochar resulted in a total N content of 1.052%, while compost without corncob biochar obtained a total N content of 0.955%. Therefore, adding corncob biochar increased the N-Total content of compost.

The weekly stirring did not show a significant difference in the compost's C/N ratio. Compost with and without stirring had a C/N ratio of 23.73 and 24.01, respectively (Fig. 7). The addition of corncob biochar also did not make a significant difference. Compost with and without the addition of corncob biochar had a C/N ratio of 24.98 and 22.76, respectively.

Weekly stirring showed no significant difference in K<sub>2</sub>O content. Fig. 9 showed that compost with corncob biochar had a K<sub>2</sub>O content of 6.068%, while compost without stirring had a K<sub>2</sub>O content of 4.786%. This indicated that compost with corncob biochar resulted in higher K<sub>2</sub>O content than compost without stirring.

P<sub>2</sub>O<sub>5</sub> content was not significantly different from the weekly stirring. Based on Fig. 8, compost with and without stirring had a P<sub>2</sub>O<sub>5</sub> content of 0.224% and 0.213%, respectively. Corncob biochar also did not have significant differences with and without corncob biochar obtained P<sub>2</sub>O<sub>5</sub> content of 0.225% and 0.212%, respectively (Fig. 8).

Biochar is a material with high levels of organic carbon. According to Setiani et al. (2021), corncob biochar has a C-Organic content of 53.2%. Based on the data presented in Fig. 5, compost with biochar showed a very significant difference compared to compost without biochar. The C-organic content of compost with biochar was more than 25% higher than compost without biochar. Both treatments have met the minimum standard for the C-organic content of solid organic fertilizer, in accordance with the Indonesian National Standard, at a minimum of 25% (Widowati et al., 2024).



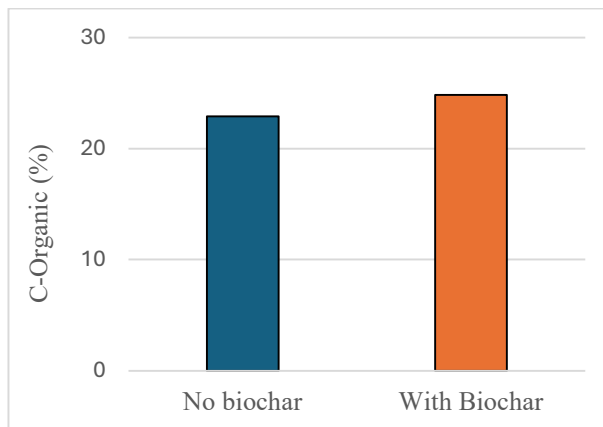


Fig. 5. C-organic content in organic fertilizer due to biochar.

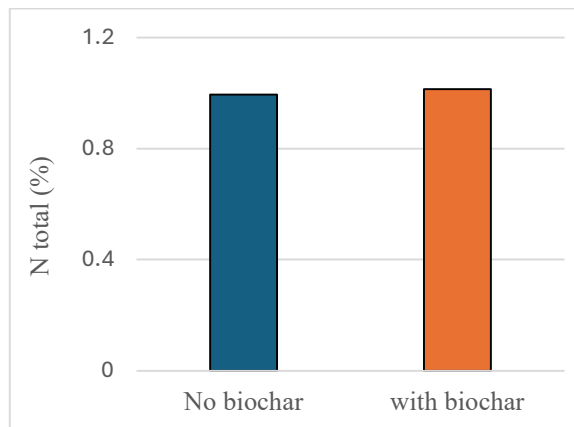


Fig. 6. N total content in organic fertilizer due to biochar

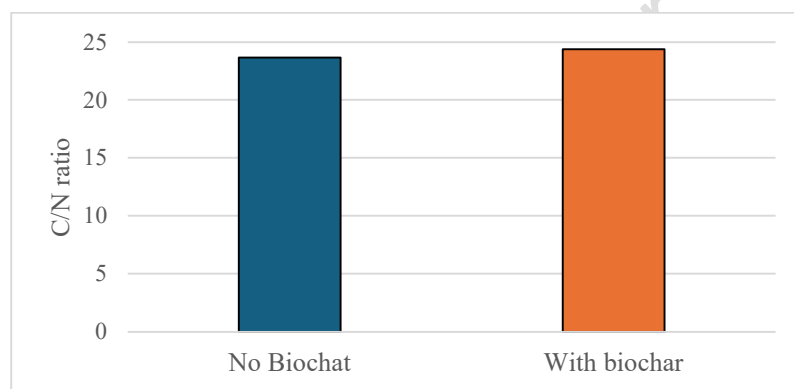


Fig. 7. C/N ratio in organic fertilizer due to biochar

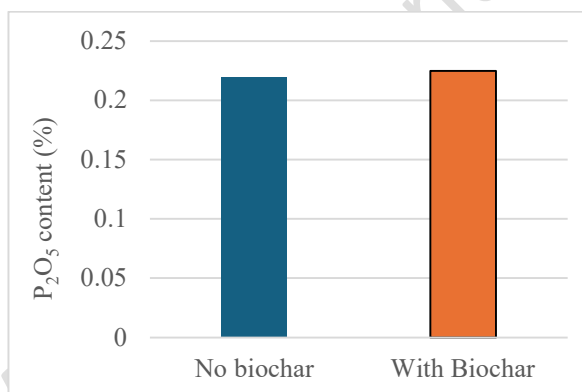


Fig. 8. Phosphate content in organic fertilizer due to biochar

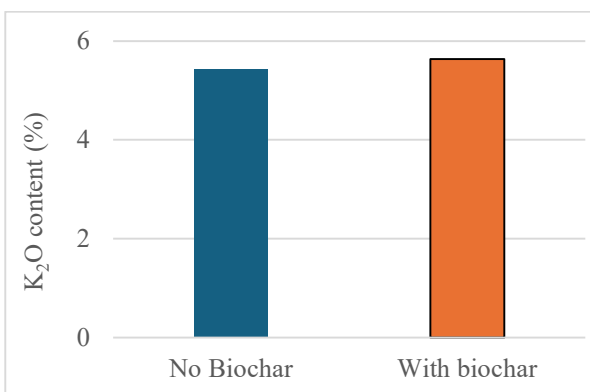


Fig. 9. Potassium content in organic fertilizer due to biochar.

The C-organic content of compost with biochar was higher due to the stable nature of biochar, so the C-organic content of compost was not lost in large quantities. The loss of organic carbon is caused by microorganisms using carbon as an energy source. Antonangelo et al. (2021) stated that decomposition of organic materials by microorganisms produces carbon dioxide (CO<sub>2</sub>), with biochar can reduce CO<sub>2</sub> emissions, and carbon is absorbed and stored for a long time. This statement is also supported by Zhang et al. (2016), who state that the more biochar content in compost material, the higher the organic carbon content will be. This is due to the high



absorption capacity of biochar, thereby increasing the persistence of organic materials. The use of corncob biochar in composting can increase the activity of microorganisms in breaking down organic material.

N-total compost with biochar was a little bit higher compared to compost without biochar. The difference in N-total values was due to the influence of microorganism activity. Biochar provides an optimal environment for microorganisms, thereby increasing the activity of nitrifying microorganisms. The greater the activity of microorganisms, the greater the total N-level in the compost. This is because when decomposing organic materials, microorganisms produce ammonia ( $\text{NH}_3$ ) (Wang et al., 2013). The ammonia can be lost and cause an unpleasant odor, thereby reducing the quality of the compost. The characteristics of biochar are that it can withstand  $\text{NH}_3$  emissions so that nitrogen remains retained in the compost. According to Chung et al. (2023), biochar can reduce evaporation and suppress ammonia emissions, thereby preventing nitrogen loss. El Ouassif et al. (2023) also reported that biochar has more potential to adsorb ammonia when processed in a higher temperature.

The C/N ratio is one of the compost ripening parameters. According to the Indonesian Minister of Agriculture, the maximum content is 25. The application of biochar in compost had a C/N ratio of 24.98, while the C/N ratio of compost without biochar was 22.76. The C/N ratio values of both treatments were in accordance with quality standards. The C/N ratio value of compost with biochar was higher; it could be due to a high C-organic content, as mentioned by Khan et al. (2014). According to Zhang et al. (2016), the greater the amount of biochar added as compost material, the higher the C/N ratio.

$\text{P}_2\text{O}_5$  levels in compost with biochar were slightly higher than in compost without biochar. The increase in phosphate content in compost with biochar was due to the phosphate absorbed by the biochar. The phosphate content during composting decreases due to phosphate mineralization and consumption by microorganisms. According to Zhang et al. (2016), the phosphate content in compost with biochar increased by 22-28% compared to compost without biochar during composting. This is because biochar retains phosphate from mineralization. Compared to compost without biochar, the  $\text{K}_2\text{O}$  content of compost with biochar was higher at 37.18%. The increase in potassium content is due to the increased retention of potassium ( $\text{K}^+$ ) by the negative charges on the biochar surface (Antonangelo et al., 2021). Gopal et al. (2024) reported that pyrolyzing rich-potassium waste produces high potassium content of biochar. Thus, Zhang et al. (2016) stated that compost with biochar can increase the  $\text{K}^+$  content by 14-59% compared to compost without biochar.

In terms of quality, the application or non-application of biochar produces organic fertilizer quality that meets the Indonesian National Standard (Widowati et al., 2024) (Table 1). The World Health Organization (WHO) has yet to create its own universal standards for compost quality. Nonetheless, it endorses regional and national efforts that formulate guidelines grounded in specific criteria to safeguard public health and the environment. Standards like those Canadian Council of Ministers of the Environment (CCME) in Canada (Public Works and Government Services of Canada, 2013), U.S. Environmental Protection Agency (EPA) in the USA (Brinton, 2000), and European Compost Network (ECN) in Europe (Prasad et al., 2012) differ based on intended use (e.g., general agriculture versus growing media) and frequently define limits along with specifications for nutrient levels, organic content, and moisture (Table 1). Above all, this information highlights the numerous differences apparent due to the diversity and scope of standards present in various nations.

Table 1. Parameters of compost quality in some countries

Parameter	INS (INDONESIA) <sup>1</sup>	CCME (CANADA) <sup>2</sup>	EPA (USA) <sup>3</sup>	ECN (EUROPEAN) <sup>4</sup>
Water content	< 25%	40-50%	40-50%	< 75%
C-organic	> 25%	50-60%	> 30%	> 20%
Nitrogen		2%	0.5-3%	
Phosphor	≥ 2%	< 0.5%	0.5-1.5%	≥ 4%
Potassium		1%	0.5-1%	
C/N ratio	10-20	15-20	25-40	10-30

<sup>1</sup>Widowati et al. (2024).

<sup>2</sup>Public Works and Government Services of Canada (2013).

<sup>3</sup>Brinton (2000).

<sup>4</sup>Prasad et al. (2012).



The important thing from this study is the ability of biochar to increase the nutrient content to support plant growth, which can be used as an alternative to reduce the use of synthetic fertilizers. However, efforts to develop organic fertilizers as a nutrient provider are interesting to study further to produce organic fertilizer that plays a dual role as a soil conditioner and nutrient provider for plants in supporting sustainable agriculture systems.

## 4. Conclusion

The application of corncob biochar, with or without stirring, increased the C-organic (21.21%), N (10.16%), and K (26.79%) contents in compost from goat manure. Generally, the composting process with the addition of biochar resulted in better quality of organic fertilizer based on the Indonesian National Standard and equal to the criteria in some countries, as supported by WHO, such as the Canadian Council of Ministers of the Environment (CCME), U.S. Environmental Protection Agency (EPA), and European Compost Network (ECN). Improvement of the composting process with the application of biochar could potentially be developed to support sustainable agricultural systems.

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**Authors contributions:** Conceptualization and design of the work, methodology, writing – original draft, YRA; Project administration, writing – review and editing, EM; Project administration, supervision, writing original draft, AF; formal analysis, investigation, NSL. All authors read and approved of the final manuscript.

### Conflict of interest statement

The authors declare that they are no conflict of interest associated with this study.

### Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

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