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Physical and Chemical Quality of Cow Feces Organic Fertilizer Produced by the Addition of Different Starters

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ABSTRACT

The study aimed to know the effect of different starters on the quality production of organic fertilizer. Three kinds of starters, EM-4 (P1), BM-4 (P2), and Petroganic (P3), were used in this study. The quality of organic fertilizer with a starter for the 28th day of composting was evaluated by physical and chemical parameters in triplicates. Based on the results, we showed the physical parameters of treatment compost P1, P2, and P3 are blackish brown, didn't smell of stool, and are crumbly textured. The chemical parameters showed the content of C-organic from the treatments was 42.51%, 39.19%, and 35.74%, respectively, at the end of the composting process, while total nitrogen content was 4.71%, 9.47%, and 5.77%. The C/N ratio of the treatments, P1, P2, and P3, were 9.02, 4.17, and 6.20, while the total phosphor contents were 0.092%, 0.15%, and 0.13%, respectively. Next, the total potassium contents were 0.69%, 0.79%, and 0.77%, respectively, at the end of the composting process. The addition of different types of starters did not affect physical and chemical quality. In conclusion, EM-4, BM-4, and Petroganik can be used as alternative starters in producing organic fertilizer.

Keywords: Organic fertilizer, EM-4, BM-4, Petroganik

INTRODUCTION

Composting is used for the biological treatment of solid organic wastes and to manage organic waste stability. Various microorganisms, including bacteria and fungi, recycle organic waste as microbial decomposers (Haynes and Zhou, 2016). The productivity in cattle farming owned by farmers can be optimized by utilizing feces and waste as organic fertilizer, which crops need for better growing because cattle-rearing systems in developing countries are generally integrated with agriculture. The use of the microbial starter will affect the fertilizer production quality. Starter contains cellulolytic bacteria, proteolytic bacteria, fungi, and actinomycetes (Cahyono *et al.,* 2014; Hansgate *et al.*, 2005). Cellulolytic bacteria and fungi will play a role in changing cellulose-based materials, whereas proteolytic bacteria focus on changing proteins in materials. The basic principle of composting is to decrease the ratio of C/N. Thus, its ratio will be as close as the C/N of soil. The steps of composting process generally include the mesophyll step, thermophile step, concoction step, and cooling step.

Each step of processing fertilizer has its optimum activity bacteria. Organic fertilizer is a decomposition of organic matter from organic waste such as feces and agricultural waste that was fermented for several weeks to stabilise the organic matter and used as fertilizer for cropping activity (Belda *et al.*, 2013). Cattle farm production has an animal side product in solid, liquid or gas waste. However, solid waste such as feces at the farm were buried on the ground and lived there for a long time. Deposition of cattle feces has the potential for air pollution, and it also causes nitrate pollution in rainwater that would lead to acid rain (Patterson and Adrizal, 2005). Significant environmental pollution caused by farm activity was from the ammonia (NH3) content accumulated in feces. In the case of high humidity and low-temperature conditions, ammonia synthesis increased and was emitted from manure (Patterson et al., 2008).

Some microbes have been reported that could oxidize organic existing in the environment, which caused odor to the air and can be used as a treatment process for reducing ammonia from cattle feces (Ye and Thomas, 2001). The principle of animal feces processing is to manage the ammonia to become a nitrite or nitrate, which is safe for the environment and can be considered for organic fertilizer processing (Burrell *et al.,* 2001). Moreover, organic fertiliser production is to make it environmentally friendly. It can use commercial bacteria such as EM_4 (Swayne *et al.,* 2010) to help fertiliser production by oxidizing NH_3 from feces. Organic fertilizer is more effective than chemical fertilizer and has become an important issue (Zai *et al.,* 2008) in many countries that cover most of the land. In this study, we aim to investigate the use of three kinds of starters in terms of the effect on organic fertiliser's physical and chemical quality and to know the optimal commercial starter used as a bacteria starter in compost production.

MATERIALS AND METHODS

Cattle feces collection. The feces were collected from the cattle barns in the Faculty of Animal Science, Universitas Gadjah Mada. The feces were three days old and had 60% of water content. Beef cattle feces of Peranakan Ongole (PO), rice straw, ash, and dolomite were used in this study. The composition of materials used was feces 90%, rice straw 7%, ash 1%, lime 1%, and the additional 1% starter. Three types of starters have added the mixture of organic matter for composting; EM-4 (P1), BM-4 (P2), and Petroganik (P3) as the treatment used in this study.

Composting organic fertilizer. The feces were mixed with the other materials and was added by 1% of starter bacteria. The mixed materials were fermented for 28 days, and aeration was carried out weekly. Organic fertilizer was composted in Turi, Sleman, and Yogyakarta.

Physical analysis. Colour and texture of physical parameter analysis were carried out once a week, and temperature, environmental temperature, and pH observation were done daily during composting. The temperature of composting the organic fertilizer was measured by putting the thermometer into the compost pile for 30 seconds, and then the temperature was recorded. Temperature measurement was carried out every day during composting process of 28th days.

Chemical analysis. The chemical analysis includes a total ratio of the C-organic test, total phosphor applying spectrophotometer UV visual method, a ratio of N-total using the Kjedahl method, and K total used the *Atomic Absorption Spectrophotometer* (AAS) method. Sampling was done in the first (M0), second (M2), and fourth (M4) weeks. The N total was determined by taking a 5 g sample of organic fertilizer, and then a sample was mixed with 20 ml H_2SO_4 and put into a destruction tube. The sample will be destroyed for an hour, and if the colour of the sample becomes clear, the destruction will stop. The P total was measured by oxidation with HNO_3 and $HClO_4$. The first extract was put into a beaker glass, added with distilled water, and diluted ten times. The sample for P total was measured by spectrophotometer UV-1601 PC Shimadzu with a wavelength of 600 nm and then recorded to the results. The K total was measured by wet oxidation with HNO_3 and $HClO_4$. The sample for K total was measured using a flame photometer.

Statistical analysis. The data were analyzed by analysis of variance one-way ANOVA with significance using 5% ($P<0.05$), and next, the mean differences were tested by Duncan's Multiple Range Test (DMRT) methods. The treatments were conducted in triplicates for homogeneity data.

RESULTS AND DISCUSSION

The physical observation in organic fertilizer

We observed the physical parameter of fertilizer consisted of colour, smell, and texture after 28 days of the composting process. The physical observation can be seen in Table 1.

Table 1. Physical parameter observation of compost fertilizer

Treatment	Colour	Smell	Texture
P1.1	Black	Odorless	Crumbly
P1.2	Black	Odorless	Crumbly
P1.3	Black	Odorless	Crumbly
P1.4	Black	Odorless	Crumbly
P1.5	Black	Odorless	Crumbly
P2.1	Black	Odorless	Crumbly
P2.2	Black	Odorless	Crumbly
P2.3	Black	Odorless	Crumbly
P2.4	Black	Odorless	Crumbly
P2.5	Black	Odorless	Crumbly
P3.1	Black	Odorless	Crumbly
P3.2	Black	Odorless	Crumbly
P3.3	Black	Odorless	A little rough
P3.4	Black	Odorless	A little rough
P3.5	Black	Odorless	Crumbly

The physical observation of fertilizer in either P1, P2, or P3 showed the same black and odourless colour, whereas the crumble level of P1 and P2 is better than P3, where there was still a little rough compost in P3. Moreover, the difference in texture was caused by the temperature factor, and the increase of heat was affected by the height of the compost stack and would affect the evaporation thus, it affected the water levels. When the water levels were still high, the materials would be hard to destroy, producing granola or a little rough in the shape of fertilizer texture. The criteria of compost are indicated by having the same temperature as the environment temperature, blackish in colour, odourless, no fungi, and crumbly textured.

The temperature of composting during the fertilizer production process

The temperature during composting process showed a similar phase in each treatment (Figure 1). The increasing temperature at the beginning of the composting process showed an effect of bacteria growth from the treatments (EM-4, BM-4, Petroganik) and would play a role in organic matter decomposition. The highest temperature on each treatment (P1, P2, P3), based on observation of composting temperature of organic fertilizer for 28 days, was between the 14th to 15th day, which was 42,13°C; 42,79°C; and 37,93°C respectively, which indicated the beginning of thermophilic bacteria activity with high temperature, and it could suppress the pathogenic microorganism growth (Le Goff *et al.,* 2010; Tiquia *et al.,* 2002). The temperature will keep decreasing until it nearly reaches the environment temperature. The existing microbes in this phase were thermophilic microbes that lived in temperatures between 45°C to 70°C (Canganella and Wiegel, 2014). The quickly increasing temperature in the early days of the composting process was due to the high microbial activity (Haynes and Zhou, 2016) in degrading the substance containing nitrogen (N) in the form of ammonium (NH_4^+) that is contained in feces.

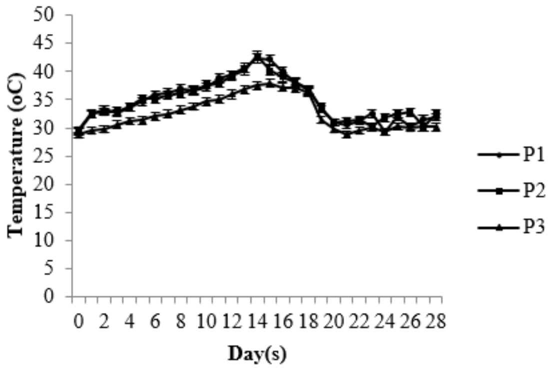

Figure 1. Temperature changes during the composting process.

The composting temperature decreased on the 8th day and continuously decreased day by day until the 28th day. After a week of composting, starting on the 8th day, the decreasing temperature reached 40°C degrees; this condition was the mesophyll phase that lasted for a week. The final temperature on the day of harvesting the compost fertilizer (day 28th) were respectively 31.86°C, 32.46°C, and 30.13°C (Fig. 1). Organic matter which was decomposed could produce a heat exotherm (Haynes and Zhou, 2016). The nitrification process, forming ammonium to nitrite (NO_2^-) and nitrate (NO_3^-) by nitrifying microbes, produces a heat exotherm. The more ammonium content in feces leads to the higher the temperature released.

pH measurement during composting process of organic fertilizer

Next, we showed the pH condition from the beginning until the last processing of compost fertilizer. The pH measurement of the composting process is provided in Figure 2. pH at the beginning of composting is started by the base condition because there is an effect of dolomite addition and because of containing the N-protein of feces itself (Haynes and Zhou, 2016). Dolomite character ($CaCO_2$) is a medium base and reacts well towards acid compounds. pH decreased at the beginning of the composting process because there was a change reaction in organic material, which produced organic acid compounds. The increase of pH in the middle of the composting process occurs because protein decomposition produces ammonium (NH4+) (Dimkpa et al., 2020), and the release of ion OH^- affects the increase of pH.

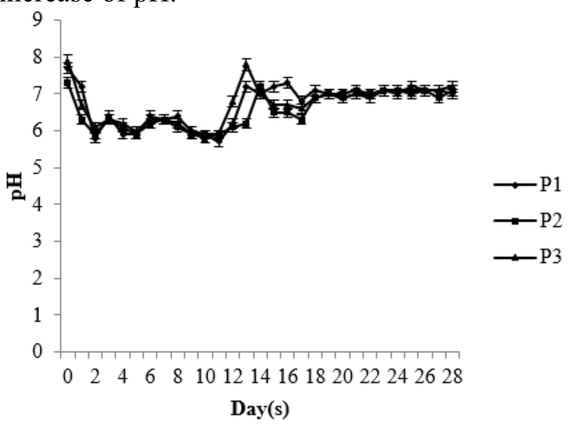

Figure 2. pH measuring during the composting process.

At the end of the composting process, pH measurement showed movement closing in neutral pH conditions. It occurred because the effect of temperature decreases, which caused the growth of nitrification bacteria changing ammonia to nitrate so that pH would close to neutral. The higher pH in cattle feces organic fertilizer from all different starter treatments was associated with less NO_3^--N accumulation. Nitrification is an acidifying process with two moles of H^+ being produced per mole of NH_4^+ converted to NO_3^- (Bolan and Hedley 2005), while a high concentration of cations in soil solution results in a more significant displacement of exchangeable H^+ into soil solution and a lower measured pH (Haynes and Zhou, 2016).

C-organic content in compost fertilizer

The chemical analysis content was observed in C-organic as a representative of organic matter. The C-organic content measured every two weeks of compost from three treatments is shown in Figure 3. The addition of different starters did not show a significant difference in the C-organic content of compost fertilizer, whereas C-organic content in P1, P2, and P3 was 42.51%, 39.18%, and 35.74%, respectively at the end of the composting process. The initial measurement of C-organic content at the beginning of the composting process (M0 and M2) showed non-significant differences among the treatments.

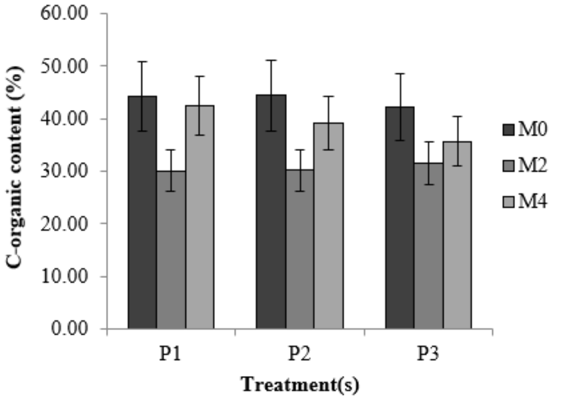

Figure 3. C-organic content in compost fertilizer for 28th days composting process with the addition of starters.

Organic material in waste was available for bacteria and was used as a nutrient for growth. The bacteria starter activity used in this study has digested the organic matter. In the case of the high organic matter contained in compost during the composting process, it caused the low C-organic content in composts. The high intensity of microbial activity resulted in C compound as CO_2 (Haynes and Zhou, 2016). The more significant loss of C in composts had the effect of concentrating other substances present in the feedstock so that composts had higher concentrations of extractable N, P, K, and a lower C/N ratio. Some previous studies have noted a lower C-organic content and a greater soluble salt content in composts (Fornes *et al.,* 2012; Belda *et al.,* 2013). During the process of organic materials decomposition, the content of the C-organic ratio undergoes fluctuation. C-organic ratio fluctuation is caused by evaporation and carbon release (Sucipta, 2015). Ratio of C-organic depends on deceased bacteria during the composting process. Automatically, those bacteria did not degrade the organic materials, but it is measured as organic, thus causing high organic compound content.

N total content in compost fertilizer

Next, we measured the Nitrogen (N) total as chemical content in the compost fertilizer. Nitrogen total content with the addition of different starters (P1, P2, and P3) was presented in Figure 4. The addition of different starters, P1, P2, and P3, showed a significant difference ($p<0.05$) in N total content of compost fertilizer, which was 4.71%, 9.47%, and 5.77%, respectively, at the end of the composting process. The N total content was higher with starter BM-4 (P2) at the end of composting compared to the beginning process and other treatments. A reduction in the ammonium content resulted in a change in the amount of NH_4-N.

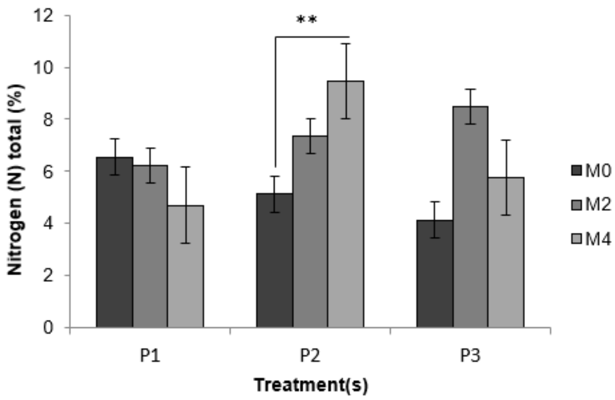

Figure 4. Nitrogen (N) total content in compost fertilizer for 28th days composting process with the addition of starters. **P<0.05.

The decomposition of organic matter by starter bacteria in this study determined the changes in the NH_3 emission between different ammonium levels after the first composting day. This suggested that a decrease in the applied ammonium amount from feces will increase the relative NH_3 that influences the N total content of fertilizer, and affects the emissions because most of the NH_3 volatilization took place during the first day (Gericke *et al.,* 2012). The fluctuation result of the total Nitrogen ratio happens because the N compound became a nutrient for bacteria to grow during fermentation, thus decreasing N total content.

The increase of N total results from N as a product of protein decomposition. In the beginning, the N total content was similar among the treatments at the first and second weeks. Moreover, the increase in the N total ratio at the end of composting process was also caused by the ammonification process, which was the ammonium-forming process from oxidized nitrate (Gericke *et al.,* 2012).

C/N Ratio during the composting process

The C/N ratio was acquired by comparing the C ratio to the N ratio. The ratio of C/N in the compost fertilizer with the addition of three starters (P1, P2, and P3) is presented in Figure 5. Result analysis of P1, P2, and P3 on C/N ratio showed non-significantly differences, which was P1, P2, and P3 was 9.02, 4.17, and 6.20, respectively. P1, P2, P3 treatment on C/N ratio of compost was below the standard (Standar Nasional Indonesia, 2004), which has already been set by Arifandi *et al.* (2017), the C/N ratio of fertilizer to be a standard dense organic is 10 to 20. It is because the nitrogen compound in organic materials is too high, which causes denitrification (Mapanda *et al.,* 2011). The C/N ratio is one of the most important aspects of the balance of the total base compound. Microorganism needs carbon and nitrogen to live.

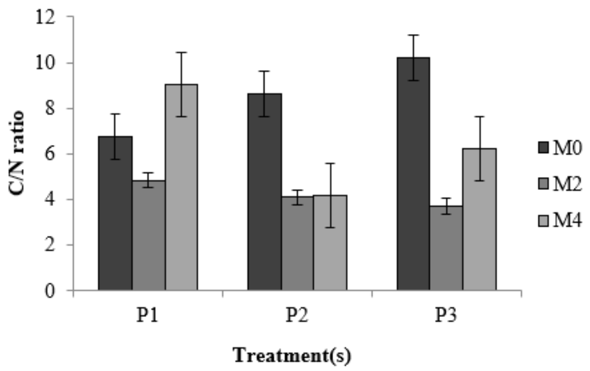

Figure 5. C/N ratio of compost fertilizer for 28th days composting process.

When the C/N ratio is too high, it will decrease microorganism biological activity. This will affect the degradation of organic matter, which needs a more extended period. Furthermore, when C/N ratio is too low, it is caused by an excess of unused nitrogen ratio for microorganisms thus, it cannot be assimilated and go through volatilization as ammonia or denitrification (Mapanda *et al.,* 2011; Haynes and Zhou, 2016).

Phosphor total content in the compost fertilizer

The chemical test results on P total contained in compost fertilizer at different starters addition were presented in Figure 6. The analysis of phosphor content in compost fertilizer showed no significant difference between the treatments (P1, P2, or P3). The phosphor content of each treatment, P1, P2, or P3, was qualified for the National Standard of Indonesia (Standar Nasional Indonesia, 2004), which is the minimum fertiliser content as many as 0,10% (Arifandi *et al.,* 2017). The phosphor ratio of P1, P2, and P3 showed mixed results. The variety was caused during the composting process by the bacteria starter. It occurred due to starter microorganisms, such as Aspergillus and Pennicilin, in EM-4 or BM-4, which triggered N-protein decomposition. Degrading of organic materials will produce organic acids of volatile or easily evaporate. When the degrading process occurs, the phosphor base compound content will decrease, and when this microorganism passes through, it will cause an increasing phosphor content in compost fertilizer (Dimkpa *et al.,* 2020).

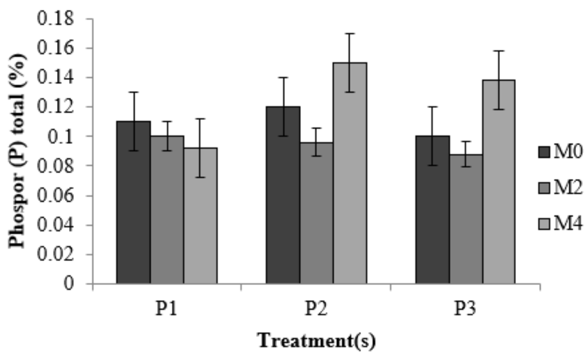

Figure 6. Phosphor (P) total content in compost fertilizer for 28th days composting process with the addition of starters.

The average content of P total in compost fertilizer after 28th days of fermentation with the addition of starter EM-4(P1), BM-4(P2), and Petroganik(P3) were 0.0092%, 0.15%, and 0.138%, respectively. In the beginning, the P total content was also similar to the treatments at the first and second weeks of composting because the manure was in dry matter (Tagoe *et al.,* 2008).

Potassium (K) content in the compost fertilizer

Finally, we examined the test of potassium (K) total in fertilizer produced by the addition of EM-4(P1), BM-4(P2), and Petroganik(P3). The K total content from the final product of compost fertilizer is presented in Figure 7. Potassium is one of the macro elements needed by plants. Test results of potassium content did not show a significant difference among the treatments. Microorganism starters use potassium in substrate material as the catalyst. The increase in potassium ratio was affected by the existence of bacteria. Potassium is then tied and kept in a cell by bacteria and fungi; when it is degraded, it will be available again. *Saccharomyces*, *Lactobacillus* and *Cellulomonas* help in the decomposition process producing potassium elements (Arifandi *et al.*, 2017).

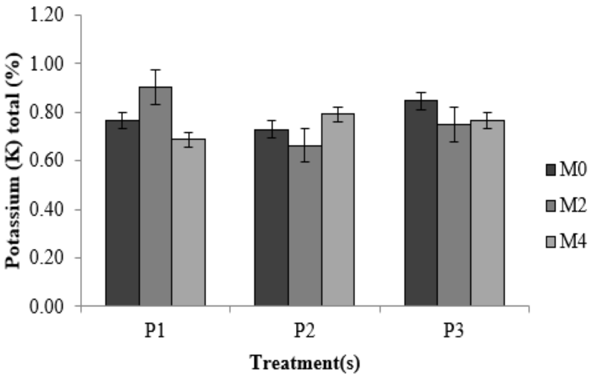

Figure 7. Potassium (K) total content in compost fertilizer for 28th days composting process with the addition of starters.

At the initial processing of compost fermentation using several starters as a treatment, the resulting test of P total content was similar in the first week and second week (Figure 7). The average content of K total observed in compost fertilizer was 0.69%, 0.79%, and 0.77%, respectively. The potassium content did not show a significant result between the treatments. The cow manure used in this study has been dried before, and the dry matter of manure has a concentration of K total of 0.23% (Tagoe *et al.,* 2008) to 2.06% (Zai et al., 2008). This indicated that the K total in the compost fertilizer was affected by the water content condition of the feces.

CONCLUSION

The addition of different starter types, EM-4(P1), BM-4(P2), and Petroganik(P3), can improve the physical and chemical quality of compost fertilizer for plants to have good growth. EM-4, BM-4, and Petroganik starters can be used as alternatives to produce compost fertilizer.

REFERENCES

Arifandi, N., F. Zuhro., dan HU Hasanah. 2017. Karakterisasi kandungan unsur hara pupuk organik hewani sesuai dengan SNI-2011. Prosiding Seminar Nasional SIMBIOSIS II, pp 165-177.

Belda RM., D. Mendoza-Hernandez, and F. Fornes. 2013. Nutrient-rich compost versus nutrient-poor vermicompost as growth media for ornamental-plant production. J Plant Nutr Soil Sci, 176: 827–835.

Bolan, N.S., and M. J Hedley. 2005. Role of carbon, nitrogen and sulfur cycles in soil acidification. In: Rengal Z (ed) Handbook of soil acidity. Marcel Dekker, New York, pp 29–56.

Burrell, P.C., C.M Phalen, and T. A. Hovanec. 2001. Identification of bacteria responsible for ammonia oxidation in freshwater aquaria. Applied Environ. Microbiol., 67: 5791-5800.

Cahyono, A., E. Faridah., D. Wulandari, dan B. H. Purwanto. 2014. Peran mikroba starter dalam dekomposisi kotoran ternak dan perbaikan kualitas pupuk kandang. Jurnal Manusia dan Lingkungan, vol. 21, no. 2: 179-187.

Dimkpa, C. O, J. Fugice, U. Singh, and T. D. Lewis. 2020. Development of fertilizers for enhanced nitrogen use efficiency–Trends and perspectives. Science of the Total Environment, 731: 139113.

Fornes F., D. Mendoza-Hernandez, R. Garcia-de-la-Fuente, M. Abad, RM Belda. 2012. Composting versus vermicomposting: a comparative study of organic matter evolution through straight and combined processes. Bioresour Technol 118: 296–305.

Gericke, D., L. Bornemann, H. Kage, and A. Pacholski. 2012. Modelling ammonia losses after field application of biogas slurry in energy crop rotations. Water Air Soil Pollut. 223(1): 29-47.

Hansgate, A. M., P. D. Schloss, A.G. Hay, and L.P. Walker. 2005. Molecular characterization of fungal community dynamics in the initial stages of composting. FEMS Microbiol. Ecol. 51: 209–214.

Haynes, R.J., and Y.F. Zhou. 2016. Comparison of the chemical, physical and microbial properties of composts produced by conventional composting or vermicomposting using the same feedstocks. Environ. Sci. Pollut. Res. 2(11): 10763-10772.

Le Goff, O., V. Bru-Adan, H. Bacheley, JJ Godon, and N. Wéry. 2010. The microbial signature of aerosols produced during the thermophilic phase of composting. Journal of applied microbiology, 108(1): 325-340.

Mapanda, F., M. Wuta, J. Nyamangara, and RM Rees. 2011. Effects of organic and mineral fertilizer nitrogen on greenhouse gas emissions and plant-captured carbon under maize cropping in Zimbabwe. Plant and soil, 343: 67-81.

Patterson, P. H., and A. Adrizal. 2005. Management strategies to reduce air emissions: Emphasis-dust and ammonia. J. Applied Poult. Res., 14: 638-650.

Patterson, P. H., A. Adrizal, R. M. Hulet, R. M. Bates, and C.A.B. Myers. 2008. Vegetative buffers for fan emissions from poultry farms: 1. Temperature and foliar nitrogen. J. Environ. Sci. Health Part B: Pestic. Food Contam. Agric. Wastes, 43: 199-204.

Ye, R.W., and S.M. Thomas, 2001. Microbial nitrogen cycles: Physiology, genomics and applications. Curr. Opin. Microbiol., 4: 307-312.

Swayne, D.A., W. Yang, A. A. Voinov, A. Rizzoli, and T. Filatova, 2010. Effective Microorganisms (EM) technology for water quality restoration and potential for sustainable water resources and management. Proceedings of the International Congress on Environmental Modelling and Software, July 5-8, 2010, Ottawa, Ontario, Canada.

Standar Nasional Indonesia. 2004. Spesifikasi Pupuk Kompos dari Sampah Organik Domestik. Badan Standarisasi Nasional.

Tagoe, S.O., T. Horiuchi, and T. Matsui. 2008. Effects of carbonized and dried chicken manures on the growth, yield, and N content of soybean. Plant Soil. 306 (1-2): 211-220.

Tiquia, S.M., H.C. Wan, and N. F. Tam. 2002. Microbial population dynamics and enzyme activities during composting. Compost Sci. Util. 10(2): 150-161.