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Mineral-enriched Animal Waste as Solid Organic Fertilizer

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Organic fertilizer has complete nutrient content and various organic compounds that are needed by the plants. However, organic fertilizer is hard to be decomposed, so that it needs quite a long time in providing nutrient for the plant compared to the inorganic/chemical fertilizer. The alternative solution is by making solid organic fertilizer formulation which is enriched by several mineral materials. The purpose of this research is to characterize solid organic fertilizer which is enriched by several mineral materials. The research was conducted in the Soil Laboratory of Agriculture Faculty, University of Jember from May to July 2018. We used laboratory analysis of several organic fertilizer samples that were enriched with mineral materials, and results were compared with the Indonesian Organic Fertilizer Standard of 2011, which is called SNI-2011.The result of the research showed that solid organic fertilizer based on animal manure-enriched with several mineral materials had the character that was comparable with SNI-2011, except for moisture content that was still higher than the standard. The solid organic fertilizer also has macronutrient content available (N, P, and K) higher than non-enriched organic fertilizer.

In recent times application of organic fertilizers to crops has increased considerably in order to produce quality agriculture products that are safe for consumption, and support the conservation of soil and environment. It also supports healthy lifestyle with "back to nature" slogan, which is now a global trend. People are increasingly being aware of the negative effects of synthetic fertilizers, chemical pesticides, and growth regulators on human health and the environment (Roidah, 2013).

Organic fertilizers are partly or wholly derived from plants and/or animals that have been decomposed, can be solid or liquid and can supply organic materials to improve the physical, chemical and biological properties of the soil (Alamtani, 2015). Solid organic fertilizer from animal waste has near-complete nutrients and its decomposition process is faster than the organic fertilizer from plant materials (legume plants and vegetable waste). On an average, a ton of organic fertilizer from animal waste contains 5kg N, 3kg P_2O5, and 5kg K_2O, and other essential elements in relatively small amounts (Hardjowigeno, 2003).

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Every type of animal waste contains specific nutrients. However, the animal waste in general contains macro nutrients, such as Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sulfur (S). Chicken manure contains higher N and P than other animal wastes, whereas goat manure contains higher K than other animal manures. The cow manure also has macro- and micronutrients needed by plants (Roidah, 2013). As a single cow can produce more manure (around 24 kg/day) than a chicken ora goat it has higher potential to be used as an organic fertilizer (Neltriana, 2015). The preparation of organic manures from the three types of animal wastes is expected to provide higher amounts of macronutrients (N, P, and K) and thus meet the nutritional needs of cultivated plants. However, nutrients in organic manures are difficult to decompose into a form that is readily "available" for plants, so it takes a longer time to provide nutrients to plants compared to inorganic/chemical fertilizers. Previous research shows that organic manures from animal waste (chicken + goat + cow) have a relatively low proportion of macronutrients (N, P, and K) based on SNI-2011 Organic Fertilizer Standard (Arifandi *et al*., 2017). SNI- 2011 Organic Fertilizer Standard was the standard quality of organic fertilizers in Indonesia as determined by the Indonesian Minister of Agriculture in 2011 (the latest regulation of organic fertilizers standard). Therefore, efforts are needed to enrich the available macronutrient content, especially N, P, and K in organic manures from animal waste.

Solid organic manures can be enriched for macronutrients by adding mineral materials rich in N, P, and K, such as fish meal for N supplement (Syukron, 2018), rock phosphate for P (Batubara *et al*., 2014), and leucite rock (potassium aluminosilicate) for K (WKA *et al*., 2010). These enriched solid organic fertilizers are expected to have better nutrient content to comply with SNI-2011 Organic Fertilizer Standards. Therefore, this study was conducted with the objective of evaluating organic animal manures enriched by macronutrient containing minerals, using SNI-2011 Solid Organic Fertilizer criteria.

This research was conducted during May - July 2018, at the Soil Science Laboratory, Faculty of Agriculture, Jember University, East Java, Indonesia. Organic manures used in this study were prepared from chicken manure, goat manure, and cow dung and the supplements included fish meal, rock phosphate, and leucite rock. The manures were prepared through fermentation or composting for 7 days. The fermentation process was carried out by adding a bio-activator from the cow's rumen fluid (Zuhro *et al*., 2018).

The analysis of nutrient content in enriched-organic manures included macro nutrients (N, P, K), micronutrients (Fe, Mn, Zn), percentage of carbon (%C), C/N ratio, water content, and pH. Additional analyses for heavy metal Cadmium (Cd), functional microbial analysis (N-fastening and P solvent), and microbial contaminants (*Eschericia coli* and *Salmonella spp*.) were also carried out.

The analysis of N, P, K, Fe, Mn, Zn, and %C was determined by alkaline ignition method. C/N ratio was obtained by comparing the content of C to N. Water content was measured by gravimetric method and pH by a pH-meter. The amount of materials such as glass, plastic, and gravel were also determined. Heavy metal (Cd) was analyzed by metal determination method (Aji, 2018), while microbial analysis was carried out by microbial population determination method (Hidayati *et al*., 2013).

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Animal manure used in the preparation of both types of fertilizers was dried for several days, and bio-activators were used to accelerate the process of degradation of organic matter. The microbes in the bio-activator help breaking complex chemical bonds to hasten the process (Arisha *et al*., 2003).

The process of making enriched and non-enriched organic manures required the same time (7 days). Also, the physical appearance (colour, texture, odour, etc.) was also almost the same (Fig. 1) and indicated that both organic manures were well fermented and were ready for use. A

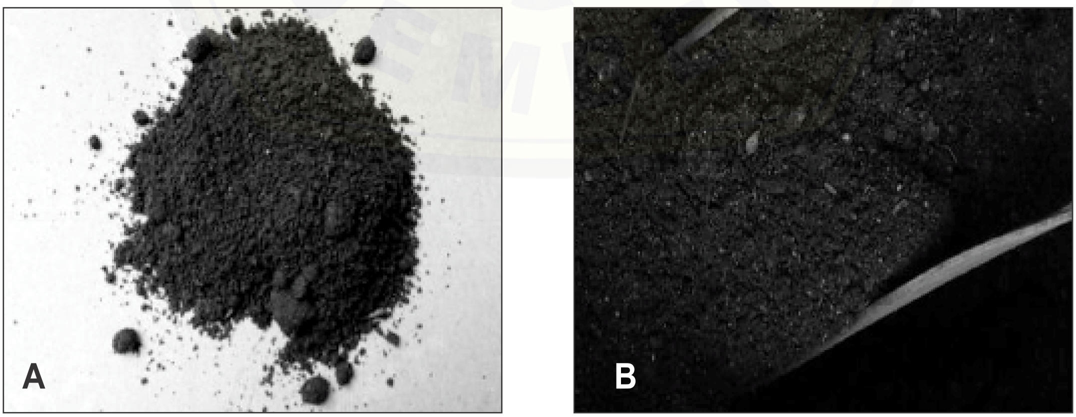

Figure 1. Non-enriched organic fertilizer (A), and mineral-enriched organic fertilizer (B).

comparison of solid organic manures from animal waste enriched and non-enriched with mineral contents is presented in table1.

Table1. Comparison of non-enriched and enriched-organicfertilizers based on Solid Organic Fertilizer Standard (SNI-2011).

Parameter	Non-enriched organic fertilizer	Enriched-organic fertilizer	SNI-2011
Follow-up Materials (plastics, glass, gravel) (%)	1	0.6	Max 2
Water Content (%)	29	57.5	15-25
pH	7	8.99	4-9
C-organic (%)	21	28.91	Min 15
C/N Ratio	15	16.28	15-25
Heavy Metals (Cd) (ppm)	2	2	Max 2
Macronutrient ($N + P_2O_5 + K_2O$) (%)			
- N total	1.4	1.78	Total
- P available	0.028	13.8	Min 4
- K available	0.013	0.77	
Micronutrient			
- Fe (ppm)	265	517	Max 500
- Mn (ppm)	894	35	Max 5000
- Zn (ppm)	479	580	Max 5000
Functional Microbes			
- N-fixing (cfu/g)	6.8×10^6	14.90×10^7	Min 10^3
- P-solubilizing (cfu/g)	6.8×10^6	4.27×10^7	Min 10^3
Contaminant Microbes			
- E. coli (MPN/g)	0	0	Max 10^2
- Salmonella spp. (MPN/g)	0	0	

Based on the physical quality, the enriched-organic fertilizer had a smaller amount of inert material than non-enriched organic fertilizer (Table 1). However, the nutrient content of both types of organic fertilizers was generally lower than the Solid Organic Fertilizer Standard (SNI-2011). However, relatively lesser amount of inert materials in organic fertilizers showed that these were of good quality.

Moisture contents in both the enriched-organic fertilizer (57.5%) and non-enriched organic fertilizers (29%) were higher than the SNI Standard of 15-25% (Isroi, 2015). Humidity has a very important role in the process of microbial metabolism and indirectly influences the supply of oxygen. At optimal humidity, microbial metabolism goes well, supporting the decomposition of organic matter in the organic fertilizer. Microorganisms can utilize organic material if it gets dissolved in water (Dewi and Tresnowati, 2012). Moisture content can be reduced by the drying process (Suriadikarta and Setyorini, 2012).

The acidity (pH) factor also plays a role in the semi anaerobic decomposition process.

Both enriched and non-enriched organic fertilizers had pH values that are in accordance with SNI-2011 pH Standards, which is around 4-9. Microbes in organic fertilizer work well in neutral pH conditions. The optimum pH for the growth of autotrophic ammonia per-oxidation bacteria ranges from 7.5 to 8.5 (Agustiani *et al.*, 2004). During fermentation process, ammonia formation usually occurs from compounds containing N, resulting in an increased pH. In the next stage, the acid release results in a decrease of pH (Djuarnani *et al.*, 2005). A decrease of pH is an indicator of increasing levels of P in organic fertilizer. The increase in P levels is thought to be the result of bacterium *Lactobacillus* spp. in the fermentation process, which plays a role in converting glucose to lactic acid, which causes the medium to become acidic (Amanillah, 2001).

In this study, enriched-organic fertilizer had higher %C and higher C/N ratio than non-enriched organic manure, and both met the SNI-2011 Standards. Organic C content plays an important role in agriculture, because organic matter can regulate various soil properties (physical, chemical, and biological) and acts as a buffer for supply of nutrients to plants (Suhardjadinata and Dwi, 2016). The quality of organic materials greatly determines the speed of the decomposition and mineralization of organic matter. Meanwhile, the C/N ratio is one indicator of compost/organic manure maturity and can be used to predict the rate of mineralization of organic matter. Change in the C/N ratio during the fermentation process is caused by the use of C as a source of energy that escapes in the form of CO_2. Thus, longer fermentation decreases the C content (Graves *et al.*, 2000). The C/N ratio of 16.28 in enriched-organic fertilizer shows that organic manure is in a mature condition and can be used as a source of nutrients for plants. The C/N ratio of soil is 10-20, hence materials that have a value of such soil C/N ratio can be directly used as manures (Damanhuri and Padmi, 2007).

Another factor that determines the quality of organic manure is the presence of heavy metals. The lower the content of heavy metals in organic fertilizers, better is the quality and vice versa. Heavy metals have a negative impact on the physiological conditions of plants and livestock if their absorption exceeds the predetermined tolerance limit (Irwan *et al.*, 2015). Both enriched- and non-enriched organic fertilizers contained 2ppm of heavy metal Cadmium (Table 1), which is the maximum limit of heavy metal content allowed by SNI-2011 Solid Organic Fertilizer Standards (Isroi, 2015).

The most important characteristic of organic fertilizer is the content of macronutrients, especially N, P, and K because these elements are needed by plants in both of their vegetative and generative stages. The total macronutrient content of non-enriched organic fertilizer was below 4 (not in accordance with SNI-2011 Standards). However, it had increased significantly to 16.35 in the

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enriched organic fertilizer. Fish meal plays a role in increasing N content (Syukron, 2018), rock phosphate in increasing P content (Batubara *et al*., 2014), and leucite rocks in increasing nutrient K content (WKA *et al*., 2010) of organic fertilizer. The highest macronutrient contained in enriched organic fertilizer was 13.8% for P (Table 1). The high P content in organic fertilizer is thought to be affected by the high N content, which enhances the multiplication and increase of microorganisms that eventually leads to increased P content in the organic fertilizer (Yuli *et al*., 2011).

In addition to macronutrients, organic manures also contain several micronutrients that are needed by plants in small quantities, but they cannot grow optimally if there is a deficiency of any one of them (Adelia *et al*., 2013). In this study, organic fertilizers both enriched- and non-enriched had sufficient micronutrients (Fe, Mn, and Zn) that are in accordance with SNI-2011 Standards. At higher levels than what is needed by plants, micronutrients can actually inhibit plant growth.

Organic fertilizers also have biological characteristics that are indicated by

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functional microbial content. Functional microbes are microbes that have an important role in the decomposition of organic matter in fertilizer. These include N-fixing and P-solubilizing microbes that help in decomposition of organic matter (Sahwan, 2016). In this study, both the enriched- and non-enriched organic fertilizers had adequate populations of N-fixing and P-solubilizing microbes that are in accordance with SNI-2011 Standards (Table 1).

Besides containing functional microbes, there is also the possibility of microbial contaminants in organic manures. The commonly found contaminant microbes in organic fertilizers include *E. coli* and *Salmonella* spp. which can be pathogenic and their presence is used as a proxy parameter for other pathogenic bacteria. In this study, we did not record the presence of these microbial contaminants neither in enriched nor in non-enriched organic fertilizers.

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