Macronutrient content of compost produced by earthworm in the utilization of livestock waste using vermicomposting method

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Abstract. The development of livestock should be focusing on increasing productivity and maximizing profit and the environmental issue that happens around it. The produced waste can be managed by minimizing the waste generated by turning it into something valuable or re-utilizing it. One way to do it is by utilizing the waste as organic fertilizer (vermicompost). The vermicomposting process resulted in two products that are useful for agriculture; there are earthworm and vermicompost itself. Using the generated waste as growth media for the worm will result in an increased worm population, and the waste will be turned into vermicompost. The earthworm species that will be used in this study is Pheretima sp. This study purpose is to reduce the contamination by the waste generated by livestock, and other purposes are to find out whether the nutrient content in the waste is up to standard and the roles of the earthworm used. The samples were collected on days 30, 45, and 60. The result shows that the only nutrient that can meet the standard is potassium (> 0.2%), while carbon is slightly below standard and nitrogen and phosphor content are way below the standard. From the resulted nutrient content, it can be concluded that the role of Pheretima sp in the vermicomposting process was not optimal resulted in compost that below the Indonesian National Standard for compost.

1. Introduction
The livestock breeding sector has a big prospect due to the high demand for livestock products. As with other industries, livestock produce wastes, which can be a source of pollution such as greenhouse gases, ammonia, water pollution, and so on. The amount of waste generated from livestock activities depends on the livestock species, the size of the business, the type of business, and the cage floor [1].

The produced fertilizer is organic fertilizer, which is beneficial for agricultural production, increasing the quality and quantity of the harvest, reducing environmental pollution, and improving land quality in a sustainable condition [2]. The content of livestock waste is dominated by cellulose, which is why producing organic fertilizer takes time; it is because the structure of cellulose is difficult to be directly degraded by composting microbes [3].

Vermicomposting is a process of bio-oxidation and stabilization of organic matter that involves cooperation between earthworms and microorganisms [4]. The vermicomposting method makes compost from biodegradable waste into high-quality fertilizer with earthworms' help [5]. The vermicomposting process resulted in two kinds of products, earthworms and worm feces/vermicompost.
Earthworms can improve soil fertility by changing soil structure and can even be used as a base ingredient for food, medicine, and cosmetics [6]. With the nutrient contained in the wastes, organic decomposing microbes will continue to grow and decompose organic matter quicker.

Therefore, it can increase soil fertility [7]. This combination of earthworm and microbe method was chosen based on its effectiveness in a relatively short composting time compared to composting methods that only rely on decomposing microbes. Also, by utilizing this method, it will tackle the waste problem by turning it into fertilizer and provide an abundant amount of earthworm, which can then be cultivated for further use. This study aims to find out and analyze the nutrient content of the vermicomposting produced livestock waste and measure it to the established standards and identify the capability of the earthworm used to produce vermicompost that can meet the standards.

2. Methods
Field research was conducted from April to June 2017 in a greenhouse belonging to Environmental Engineering, Islamic University of Indonesia. This research was carried out to determine the vermicomposting process and observe the compost's maturity. Laboratory research was carried out from July to September at Water Quality Laboratory, Faculty of Civil Engineering and Planning, Islamic University of Indonesia. This research was conducted to analyze the vermicompost content that has been produced.

Primary data was collected from field observations and laboratory analysis of the nutrient content of vermicompost. Field observation was carried out until the vermicompost produced was mature and had prime quality. A good and matured vermicompost characteristic is brownish-black to black in color, odorless, crumb-textured, and has a ratio of C/N <20 (Mashur, 2001). The species of earthworm used is *Pheretima* sp. feed with livestock waste and as a comparison, a mixture of livestock waste with straw. The age vermicompost was also analyzed with time variations of 30th, 45th, and 60th days. According to Sulistyawati [8], compost matures around the 30th day. This is the base for determining the analysis time for vermicompost's best nutrient content according to the characteristics previously mentioned. There are 2 steps in this research: making vermicompost through the vermicomposting method and analyzing the produced vermicompost. Vermicompost content was analyzed at the Water Quality Laboratory of the Faculty of Civil Engineering and Planning, Islamic University of Indonesia.

There are 2 kinds of vermicomposts produced: from pure livestock waste and the second from a mixture of livestock waste and rice straw. The tool used in making the vermicompost is a worm reactor. The species of worms used in this study were *Pheretima* sp. Sulistiyono and Sumartini [9], inside the reactor, the worms feed on the waste and excrete its feces (vermicompost). The worm reactor used has specifications; in the form of a cylindrical tube with three supporting legs to stand upright, the tube diameter is about 45-75 cm with a height around 70-400 cm reactor was made from bamboo.

![Figure 1. Worm reactor model](image)

The produced vermicompost was then taken to the laboratory to be tested for its nutrient content. The tested content was the elements C (Carbon), N (Nitrogen), P (Phosphorus), and K (Potassium) because plants need these nutrients. The test method used in vermicompost nutrient research can be seen in Table 1.
Table 1. Analytical methods for measuring vermicompost nutrients

| No | Parameter   | Test Method          |
|----|-------------|----------------------|
| 1  | Carbon (C)  | SNI 01-3554-2006     |
| 2  | Nitrogen (N)| SNI 2803-2010        |
| 3  | Phosphor (P)| SNI 2803-2010        |
| 4  | Potassium (K)| SNI 2803-2010       |

3. Result and Discussion

Vermicomposting has two benefits, the first is worm biomass, and the second is vermicompost. An increase in biomass could increase worm weight and in the number of worms. Meanwhile, vermicompost is a fertilizer excreted by worms from the decomposition of organic matter.

Figure 2. Worm reactor containing livestock waste (left) and the mixture of livestock waste with rice straw (right)

This study’s bamboo reactor was based on the latest technological innovations in processing waste into compost, the first in Indonesia. Using bamboo as a reactor building material has an advantage. It can make it easier to breed earthworms and process organic waste without stirring and reversing earthworm breeding media and organic waste piles [9]. This study refers to SNI 19-7030-2004 regarding Compost Specifications from Domestic Organic Waste to determine the quality of macronutrients from the produced vermicomposting.

3.1. Macronutrient content

3.1.1. Organic carbon

Organic carbon content was tested using the UV-VIS spectrophotometric method with a wavelength of 561 nm. The 6 samples from two reactors, each containing different raw materials with varying ages from day 30, 45, and 60 were tested. The test results are presented in the following Table 2.

Referring to the standard specifications for the quality of compost of SNI 19-7030-2004, the minimum carbon content is 9.8%, while the maximum is 32%. The results show that the carbon content of each sample did not fulfill the SNI 19-7030-2004 criteria. In the reactor containing pure cow manure, the data shows that on days 30, 45, and 60 the carbon contents are 7.8473%; 8.6387%; and 6.6072%; while the reactor containing a mixture of cow manure and straw have around 8.7038%; 8.0595%; and 8.0604% of carbon content. The data shows that the sample with the highest carbon content is in the sample with cow manure and straw mixture and an incubation time of 30 days numbering in 8.7038%. The sample that had the lowest carbon content is the pure manure sample and 60 days incubation period, numbering in 6.6072%.
Table 2. Organic carbon content in the samples

| Days | Cow Manure | Cow Manure Mixed with Straw | SNI 19-7030-2004 |
|------|------------|----------------------------|------------------|
| 30   | 7.8473     | 8.7038                     | Min 9.8          |
| 45   | 8.6387     | 8.0595                     | Max 32           |
| 60   | 6.6072     | 8.0604                     |                  |

From the table above, it can be seen that during the vermicomposting process, the sample with pure cow manure experienced an increase in carbon content from day 30 to day 45, around 7.8473% to 8.6387%, but from day 45 to day 60, the carbon content significant decreasing to 6.6072%. On cow manure and straw mixture sample, the carbon content from day 30 to day 45 decrease from 8.7038 to 8.0595%, and from day 45 to day 60, the number increase slightly to 8.0604%.

The decrease in carbon content shown in the graph above is due to the raw material's fermentation. In the vermicomposting process, there are respiration and assimilation by microorganisms and earthworms. The number of dead earthworms or the absence of worms in the reactor, making the mineralization process incomplete, caused an increase in the carbon content in pure cow manure raw sample on the 45th sampling day. Bagus Setya [10], an increase in carbon content also occurs when there is an increase in the volume of the bulking agent or the main composting ingredient.

3.1.2. Nitrogen Content

The nitrogen content was measured using the spectrophotometric with a wavelength of 636 nm. 6 samples from two reactors, each containing different raw materials with varying ages from day 30, 45, and 60 were tested. The results from each reactor obtained data are presented in the following table 3.

Table 3. Nitrogen content in samples

| Day | Cow Manure | Cow Manure Mixed with Straw | SNI 19-7030-2004 |
|-----|------------|----------------------------|------------------|
| 30  | 0.0178     | 0.0226                     | Min 0.40         |
| 45  | 0.0128     | 0.0171                     |                  |
| 60  | 0.0120     | 0.0351                     |                  |

Referring to the standard specifications for the quality of compost of SNI 19-7030-2004, the minimum nitrogen content is 9.8%. The results show that the nitrogen content of each sample did not fulfill the SNI 19-7030-2004 criteria. In the reactor containing pure cow manure, the data shows that on days 30, 45, and 60 the nitrogen contents are 0.178%; 0.0128%; and 0.012%, while the reactor containing a mixture of cow manure and straw have around 0.0226%; 0.0171%; and 0.0351% of nitrogen content.

It can be seen in the table 3 that the nitrogen content in sample pure cow manure keeps decreasing with each passing day, from 0.0178% on day 30 to 0.0128% on day 45, finally to 0.0120% on day 60. On cow manure and straw mixture sample, the nitrogen content decreased, from day 30 to day 45, numbering from 0.0226% to 0.0171%, and after that, the nitrogen gradually increased until the 60th day to 0.0351%

Microorganisms need nitrogen as a food source for the growth of their cells. According to Setyorini et al. [11], reported the results from research on making compost from animal manure in Japan show that 10-25% of the nitrogen in the compost material will be lost as NH₃ during the composting process. Saiful [12], the higher the nitrogen content in the composting base material, the easier the decomposition process will be, and it will produce a high level of nitrogen as well. Damayanti [13], nitrogen content decreases because nitrogen compounds were utilized for microorganisms to maintain their body cells in the vermicomposting process. There was a possibility that the nitrogen was consumed by worms then converted into protein. The increases occurred in the sample mixture of cow manure and straw on the
60th sampling day. According to Windyasrama [14], this increase is due to the excretions of microorganisms and worms, which then resulted in a greater amount of nitrogen than the nitrogen used by microorganisms.

3.1.3. Phosphorus Content

The phosphorus content was measured using the UV – VIS spectrophotometric with a wavelength of 889 nm. 6 samples from two reactors, each of which contained different raw materials with varying ages from day 30, 45, and 60 were tested. The results from each reactor obtained data are presented in the following table 4.

Table 4. Phosphorus content in samples

| Day | Cow Manure (%) | Cow Manure Mixed with Straw (%) | SNI 19-7030-2004 |
|-----|----------------|-------------------------------|------------------|
| 30  | 0.0436         | 0.0103                        | Min 0.10         |
| 45  | 0.0374         | 0.0111                        |                  |
| 60  | 0.0275         | 0.0091                        |                  |

Referring to the standard specifications for the quality of compost of SNI 19-7030-2004, the minimum phosphorus content is 0.1%. The results show that the phosphorus content of each sample did not fulfill the SNI 19-7030-2004 criteria. In the reactor containing pure cow manure, the data shows that on days 30, 45, and 60 the phosphorus contents are 0.0436%; 0.0374%; and 0.0275%, respectively, while the reactor containing a mixture of cow manure and straw have around 0.0103%; 0.0111%; and 0.0091% of phosphorus content.

It can be seen in table 4 during the vermicomposting, the phosphorus content in the sample of pure cow manure experience a decreased from 0.0436% on day 30 to 0.374% on day 45, and then to 0.0275% on day 60. On cow manure and straw mixture sample, the phosphorus content increased a little at the beginning from day 30 to day 45, numbering in 0.0103% to 0.0111%, and then the content decreased until the 60th day to 0.0351%

The higher the nitrogen content, the number of microorganisms that break down the phosphorus will also increase; this increases the amount of phosphorus content in the compost material and vice versa [12]. According to Arthawidya [15], the increase in phosphorus content that occurs in samples of cow manure and straw mixtures occurs due to the mineralization process by microorganisms and is carried out by worm metabolism and worm excretion. The decrease that occurs is due to the phosphorus content in the substrate used by microorganisms to build their cells.

3.1.4. Potassium Content

The potassium content was measured using SSA equipment. 6 samples from two reactors, each containing different raw materials with varying ages from day 30, 45, and 60 were tested. The results from each reactor obtained data are presented in the following table 5.

Table 5. Potassium content in samples

| Day | Cow Manure (%) | Cow Manure Mixed with Straw (%) | SNI 19-7030-2004 |
|-----|----------------|-------------------------------|------------------|
| 30  | 0.392          | 0.5495                        | Min 0.20         |
| 45  | 0.4702         | 0.4959                        |                  |
| 60  | 0.3504         | 0.2073                        |                  |

Referring to the standard specifications for the quality of compost of SNI 19-7030-2004, the minimum potassium content is 0.2%. In the reactor containing pure cow manure, the data shows that on days 30, 45, and 60 the potassium contents are 0.392%; 0.47027%; and 0.3504%, while the reactor containing a mixture of cow manure and straw have around 0.5495%; 0.4959%; 0.2073% of potassium.
content. The data shows that the sample has the highest potassium content in the sample of cow manure and straw mixture at an incubation time of 30 days numbering in 0.5495%. The sample with the lowest potassium content is cow manure and straw mixture with 60 days incubation period, numbering in 0.2073%.

From table 5, it can be seen that during the vermicomposting process, the amount of potassium in the sample with pure cow manure increased from day 30 to day 45, around 0.392% to 0.4702%. However, from day 45 to day 60, the potassium content was decreasing to 0.3504%. On cow manure and straw mixture sample, the carbon content from day 30 to day 45 decrease from 0.5495% to 0.4959%, and from day 45 to day 60, the number increase slightly to 0.2073%. An increase in potassium levels in samples of pure cow manure is due to the activity of enzymes and microorganisms in the digestive tract of earthworms which process organic matter, which is then excreted by the worm, another source of potassium could be originated from the raw materials used [16]. According to Windyasmar [14], the potassium content in vermicompost depends on the material used. Arthawidhya [15], explains that the decrease in potassium content is due to the decomposition of bacteria from organic material into potassium. However, the produced potassium is no longer lasting because potassium itself is easily soluble in water and can easily bind with other compounds.

3.2. Earthworm roles in vermicomposting process
Earthworms break down organic matter into smaller compounds and ions whose substances are beneficial to plants and soil. The organic matter that is already broken down by the worm is then excreted as feces, known as vermicompost. Vermicompost contains many nutrients needed by plants in its vegetative phase.

In this research, the species of earthworm used was Pheretima sp. This type of worm is included in the phylum Annelida, Oligochaeta class, family of Megascolecidae and Pheretima genus. Usually, the preferred temperature for growth and reproduction is around 15-25° C. This species of worm prefers slightly acidic soil with acidity levels with a pH of around 6 - 7.2 which facilitates their growth [17].

![Figure 3. Pheretima sp worms used in vermicomposting](image)

The application of Pheretima sp worms in this study is because when compared to other research, this species of worm is under-utilized. According to Sinha et al. [18], Charles Darwin first stated the role of earthworms in solid organic waste management in 1881. Several studies have showcased earthworms’ ability to decompose various organic wastes such as animal feces, sludge from sewage channels, harvest, and agricultural waste [19]. The authors used these as a basis in considering the selection of worms used for this research.

Before employed it as a vermicompost medium, the organic material in the reactor is first fermented for two weeks. The purpose of fermentation of vermicomposting media is to provide a suitable environment for the worms to grow and breed, and it is because they cannot utilize fresh raw materials and they can die if the conditions are not suitable [9].
Data sampling was conducted three times, on a different variation of the time, day 30, day 45th, and day 60 after the worms were put into the reactor. The test results of vermicompost samples from worms with all samples’ carbon content parameters show results below the minimum standard of SNI 19-7030-2004. The results indicate that using earthworm *Pheretima* sp has a significant effect, mainly on the carbon content inside the vermicompost. This is because the amount of carbon will decrease over time as microbes need carbon as a source of energy, and earthworms appear to help the microbes function optimally. According to Rahmatullah [20], *Pheretima* worms are geophageal or predominantly soil eating and have a relatively low environmental pressure impact. Its life cycle includes burrowing in the soil by eating soil mass and organic matter and tends to leave or migrate.

![Pheretima worms trying to get out of the reactor](image)

**Figure 4.** *Pheretima* worms trying to get out of the reactor

The state of the media used during the vermicomposting process can deter the worm's ability to decompose organic matter. For example, when there is a lack of moisture, the worms' skin will be damaged, and they will try to hide underground for a while and will not looking for food until it eventually dies. On the other hand, if the conditions are too humid/wet, it will disturb their skin-breathing mechanism, and the *Pheretima* worms will move to other places [21].

### 4. Conclusion

This research concludes that nutrient content, such as while carbon, nitrogen, phosphor, was below the Indonesian National Standard criteria, only potassium can fulfill the standard with a value of 0.3504% for pure cow manure and 0.2073% for cow manure mixed with straw at 60-day incubation. The use of *Pheretima* sp worms in the vermicomposting process is still far from optimal. Due to *Pheretima* sp worms' tendency to leave the media, the role of worms in the vermicomposting process is less optimal.

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