Nutrient content and greenhouse gas emissions of goat manure compost processed without and with decomposer

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Abstract. Processing of livestock manure into compost needs to be done to increase its nutrient availability and reduce greenhouse gas emissions. The objective of the study was to evaluate the compost of goat manure processed without and with decomposer on nutrients content and greenhouse gas emissions. Three treatments were Control = 100% manure; C-Dec1 = 85% manure + 15% sawdust + 0.25% urea + 0.25% TSP + 0.25% Decomposer1; C-Dec2 = 85% manure + 15% sawdust + 0.25% urea + 0.25% TSP + 0.25% Decomposer2. The experiment was conducted in a completely randomized design with 5 replications. The results showed that application of the two decomposers significantly affected fermentation temperature. The methane emitted from C-Dec1 and C-Dec2 compost were 341 and 340 ppm, which were less than control being 623 ppm. However, there was no difference on methane gas emissions between C-Dec1 and C-Dec2 groups. The usage of both decomposers did not significantly affect the N2O gas emissions, compost nutrients contents, and ratio C/N. From this study it can be concluded that goat manure compost processed using decomposer produced less methane gas emissions, while the nutrients content of composts produced from the three groups were similar.

1. Introduction
Urine and feces are by-product from livestock farming which is usually left as it is in the barn area and as it is. This could cause environment pollution and health problem to the society. On the other hand, livestock manure can be used as fertilizer due to its nutrient content such as nitrogen (N), phosphorous (P), potassium (K), and other micronutrients that are needed by plants and to increase soil fertility. Composting process is needed to make the nutrients in available form for plant. Principle of composting is reducing C/N ratio value to be ≤ 25 which is near to soil C/N ratio [1-3].

The composting process occurred in anaerobic fermentation which resulted in methane (CH₄) and di-nitro oxide (N₂O) emission as components of greenhouse gas. The production and emission of N₂O during composting was a complex process affected by many factors, such as different materials, additives, and the aeration rate [4]. N₂O was emitted as a result of the continuous consumption of carbon by microbes during the denitrification process [5]. Different materials to be composted produce different methane gas emissions. The total carbon content of the composted material shows a positive correlation with CH₄ emissions mainly because of this direct participation of carbon sources in CH₄ production [6]. Fermentation process in traditional composting takes a longer time and resulted in higher methane and di-nitro oxide production. Methane production of composting cattle dung increased with increasing time of incubation [7]. At the beginning of incubation methane emission was very low (<6.5 x 10⁻⁶ %), the emission increase with increasing duration time of incubation, at 6 hours
incubation the methane emission increased 100 times, and continue increased up to 100,000 times after 24 hours incubation. Greenhouse gases such as N₂O, CO₂, CH₄ and NH₃ emitted into the atmosphere during composting which could contribute to global warming [8].

To accelerate the composting process, decomposer addition can reduce negative impact occurred during composting process. Organic matter decomposition requires microbes as bio decomposers and also require an appropriate environment to speed up the composting process. Faster decomposition will be resulted no negative impact on social, aesthetic, health, and environment [7]. There are many types of commercial decomposers including Decomposer1 and Decomposer2. Decomposer1 is a mixture of bacteria that is formulated to accelerate decomposing organic waste so it can be used in composting process. Decomposer1 contains photosynthetic bacteria, lactic acid bacteria, actinomycetes, yeast, and fermenting bacteria [9]. Decomposer2 is a decomposer containing several microorganisms such as Aspergillus sp., Trichoderma harzianum DT 38, Trichoderma harzianum DT 39, etc. [10]. Duration of composting process depends on the characteristics of composted material, composting method used, and with or without adding decomposer. On the other hand, composting manure using certain additives and microbial decomposers can accelerate decomposition process, and resulted in low CH₄ and N₂O production. Bio decomposers utilization results in lower gas production than without decomposers [7].

Manure composting technology has become the most popular form of manure management [11]. The process of organic matter decomposition is different between traditional process and decomposer addition. Therefore, it is necessary to evaluate the composting process to obtain compost with optimal nutrient content and the lowest CH₄ and N₂O gas emissions. This study aimed to evaluate the effect of composting goat manure with or without decomposer addition on nutrient content and greenhouse gas emissions.

2. Materials and methods

2.1. Materials

The study used dairy goat manure from Saanen x Peranakan Etawah crossbred collected from dropping manure under the pen after 1-3 days of dropping. The commercial decomposer used were Decomposer1 containing photosynthetic bacteria, lactic acid bacteria, actinomycetes, yeast, and fermenting bacteria [9] and Decomposer2 containing Aspergillus sp, Trichoderma harzianum DT 38, Trichoderma harzianum DT 39, etc. [10]. The Composting process was done at Balitnak (Indonesian Research Institute for Animal Production) Experimental Farm in Bogor.

2.2. Methods

Composting process was conducted by fermented manure with and without decomposer. Three treatment were: Control = 100% goat manure; C-Dec1 = 85% goat manure + 15% sawdust + 0.25% urea + 0.25% TSP + 0.25% Decomposer1; C-Dec2 = 85% goat manure + 15% sawdust + 0.25% urea + 0.25% TSP + 0.25% Decomposer2. This research activity was carried out in a completely randomized design with 5 replications.

Composting process using decomposer was done by mixing 102 kg goat manure, 18 kg Albizia falcata wood sawdust, 300 g urea, 300 g TSP. This mixture was then added with 300 ml Decomposer1 for treatment C-Dec1, while for treatment C-Dec2 was done by adding the mixture with 300 g Decomposer2. All ingredients were mixed thoroughly until homogenous and stored in a thick plastic bag. Whereas, in control treatment was done by storing 102 kg fresh goat manure in a plastic bag. All the filled bags were kept under the shed to prevent from rain and sunlight. To allow aeration during composting, holes were made on side of the bags. The composting process was carried out for 60 and 30 days each for control and for those using decomposer treatments. Composting process in control was done to imitate the process conducting in the field condition in which after 2 months of piling up the manure then was used as fertilizer.
During composting process, the compost was measured its temperature with a thermometer at various sides (top, middle, and bottom) of the bag. Gas produced during composting process was sampled by putting a gas chamber on top of the bag. The gas chamber used was a cylindrical chamber with a dimension of 40 cm in height and 18 cm in diameter, which was equipped with gas sampler and thermometer. Gas samples were collected using a syringe from gas sampler in the chamber. Temperature measurements and gas sampling were carried out every 3 days in the morning (06-07 am) and afternoon (03-04 pm). Gas samples collected then were stored in bottles covered with rubber and metal seals. Gas samples collected were analyzed for CH₄ and N₂O content in the Laboratory of Agricultural Environment Research Institute, Jakenan Pati. At the end of composting period, composts were sampled and analyzed for their nutrient content. Nutrient analysis was carried out in the Laboratory of Bogor Soil Research Institute. The data obtained were analyzed of variance, differences, and the mean value using Duncan multiple range test using SAS program version 9 [12].

3. Results and discussion

3.1. Temperature and gas emission of compost

Manure accumulation in near the pen will decomposed naturally, while the use of decomposer is to accelerate the decomposition process of organic matter. During the process of organic matter decomposition, the compost temperature changed due to microbiological fermentation activity. The average compost temperature during composting process was presented in table 1. The temperature measured in the morning, noon, and average temperature of morning and afternoon measurements during 30 days of composting shows no significant difference (P>0.05) among composting treatment C-Dec1, C-Dec2 and Control. However, the average temperature during 30 days of composting period in C-Dec1 and C-Dec2 treatments compared to 60 days of composting in Control showed a significant difference (P<0.05), which was control one had lower temperature than other treatment.

| Table 1. The temperature of compost processed with and without decomposer. |
|---------------------------|-------------------|-----------------|------------------|-----------------|
| Treatment | Temperature (°C) | | | |
| 30 days | Control | C-Dec1 | C-Dec2 | CV (%) | |
| 06-07am | 39.31ᵃ | 40.48ᵃ | 39.88ᵃ | 3.73 |
| 03-04pm | 39.27ᵃ | 41.23ᵃ | 40.65ᵃ | 3.62 |
| Average | 39.29ᵃ | 40.86ᵃ | 40.27ᵃ | 3.63 |
| 60 vs 30 days | | | | |
| 06-07am | 36.54ᵇ | 40.48ᵃ | 39.88ᵃ | 3.02 |
| 03-04pm | 36.54ᵇ | 41.23ᵃ | 40.65ᵃ | 3.07 |
| Average | 36.59ᵇ | 40.86ᵃ | 40.27ᵃ | 3.00 |

Control = without decomposer; C-Dec1 = use Decomposer1; C-Dec2 = use Decomposer2.
Values with different superscript in the same column shows significant difference (P<0.05).

The temperature changes during composting process of goat manure are illustrated in figure 1. An increase in compost temperature indicates the occurrence of microbial activity to decompose organic matter. Based on figure 1, compost temperature peaks were reached on days 11-13 then they gradually decreased. The temperatures measured during 30 days of composting process in treatments C-Dec1 and C-Dec2 (with decomposer group) were comparable with those measured in control (control group). The average temperature recorded in this study was slightly lower than the previous study. Composting waste temperatures increased to 50.55°C on the 13th day of composting with C-Dec1 treatment, and to 48.78°C on the 10th day with C-Dec2 treatment [13]. Further reports explained that
increasing in temperature during composting period occurred in the first 10 days and then gradually decreased until the end of composting period [4]. The temperature averages in C-Dec1 and C-Dec2 treatments were higher resulted in a shorter composting process (30 days) than control (60 days). An increasing in temperature indicates that the decomposition process is progressing rapidly. The composting process for the first 30 days showed that the process of decomposing organic matter was relatively similar, since the compost temperature was not significantly different. After 30 days of decomposition process of organic matter, compost temperature decreased slowly, and the control group produced the lowest temperature.

![Temperature of composting goat manure](image)

**Figure 1.** The temperature of composting goat manure.

In addition to increase in composting temperature, gas is also produced by decomposer microbes during decomposition process. Only N₂O and CH₄ were considered for the calculation of GHG emissions due to their high global warming potential [14]. In this study, N₂O and CH₄ gases were measured for 30 days of composting for C-Dec1 and C-Dec2 and Control, in addition, gas collection was continued up to 60 days for control. The average N₂O and CH₄ gases produced during the composting process are presented in table 2. All treatments had similar (P> 0.05) N₂O gas production both for 30 and 60 days of composting with average values in the range of 14,870 - 17,736 ppb. The accumulation of N₂O gas will occur due to an increase in temperature [15]. In this study, the accumulation of N₂O didn’t occurred, due to similar recorded temperature during the process of composting among the three treatments.

Fermentation process produce CH₄ gas due to anaerobic conditions, the presence of methanogenic bacteria in the feces, and breakdown of C component in feces producing CH₄ gas [1,16,17]. Compost in treatment C-Dec1 and C-Dec2 had lower average of CH₄ gas emission concentration (P<0.05) compared to control. There were 32.3 and 32.5% emission reduction when C-Dec1 and C-Dec2 was added at making goat manure compost. Methane gas emission in cow dung incubation increases drastically along with the incubation period [7]. The high concentration of CH₄ gas in the control treatment followed by doubling duration of composting process resulted in high amount of CH₄ emissions as well. On the other hand, addition of decomposer in composting process resulted in lower concentration of CH₄ gas emissions. With a shorter period of composting process, the accumulation amount of CH₄ gas was also low. It is illustrated in figure 2 that CH₄ gas emission in Control treatment was higher with longer composting time. Thus, the use of decomposer is beneficial to reduce CH₄ levels through reduction of produced gas and shorter composting time.
CH₄ gas is emitted in early stages of organic matter decomposition during composting process [18,19]. CH₄ gas emissions increase due to anaerobic environment, high temperatures, and the availability of carbon sources for methanogenic bacteria [15]. Substrate content and incubation time affect the gas production. Gas production increases along with increasing incubation time.

**Table 2.** Concentration of N₂O and CH₄ gases during composting goat manure.

| Treatment | Control | C-Dec1 | C-Dec2 | CV (%) |
|-----------|---------|--------|--------|--------|
| **30 days** |         |        |        |        |
| Gas N₂O (ppb) | 15,843ᵃ | 17,736ᵃ | 14,870ᵃ | 48.57 |
| Gas CH₄ (ppm) | 504ᵃ | 341ᵇ | 340ᵇ | 54.16 |
| **60 vs 30 days** |         |        |        |        |
| Gas N₂O (ppb) | 16,301ᵃ | 17,736ᵃ | 14,870ᵃ | 52.81 |
| Gas CH₄ (ppm) | 623ᵃ | 341ᵇ | 340ᵇ | 73.18 |

Control = without decomposer; C-Dec1 = use Decomposer1; C-Dec2 = use Decomposer2. Values with different superscript in the same column shows significant different (P<0.05).

Longer duration of incubation process (90 days) increased CH₄ gas from 5.3% to 31.3% with an average temperature of 15-20°C [20]. However, with higher temperature compost and increased incubation time to 30-90 days gas production declined into 10.9%. Higher fermentation temperatures reduce methane gas production [21]. In line with previous study, this research indicated that the higher composting temperature recorded in the C-Dec1 and C-Dec2 treatments (table 1) resulted lower CH₄ gas emitted compared to those in control (table 2). In composting process, the increase number of porous space reduced CH₄ gas emissions due to less anaerobic conditions [4]. Addition of biochar changed the environment from anaerobic to aerobic, which will increase the oxygen consumption from the decomposition of organic matter [4]. Comparable with those results, application of C-Dec1 and C-Dec2 with addition of sawdust produced compost with more porous and more aerobic conditions, resulting in lower CH₄ gas emissions. These results explained the role of sawdust in changing the porosity and specific surface area of the composted material.

**Figure 2.** Di-nitro oxide and methane emission during composting process.

### 3.2. Quality of goat manure compost

Compost quality is indicated by the nutrient composition contained based on quality standards. Quality standards are the parameters set by the National Standardization Agency of Indonesia in the form of...
Indonesian National Standard (SNI). This quality standard also stated by the Minister of Agriculture in the form of Minimum Technical Requirements [2]. Fresh goat manure used in this study had a nutrient composition of 41.33% C; 1.53% N; 2.81% P2O5; 1.09% K2O and C/N 27.0. Compost composition produced by C-Dec1 and C-Dec2 treatments compared to control is presented in table 3.

Results from statistical analysis on the compost nutrient composition showed that the use of decomposers did not (P> 0.05) cause differences in the composition of C, N, P2O5, K2O, and C/N ratio. If calculated from goat manure before processing, there was a decrease in element C by 13.4% (from 17.8% in control compost to 11.2% in compost with decomposers). On the other hand, there was an increase in N-element content by 15.3% (18.15% for Control and 13.07% for decomposers’ compost) so that the C/N ratio decreased by 23.7% (30.2% for control compost and 20.5% for decomposers’ ones). The C/N ratio decreased faster (compost ripens quickly) on compost made from basal materials containing sufficient nitrogen or receiving additional nitrogen [22]. The control treatment with only goat manure had a higher nitrogen content (1.53%) than the C-Dec1 and C-Dec2 treatments (1.46%). Addition of 0.25% urea in the two treatment groups could not increase the N content of the composts to reach similar nitrogen content of compost in control group. This could be due to the nitrogen content of sawdust wood which was added to C-Dec1 and C-Dec2 treatments, was low (0.29%). Results of this experiment indicated that even though the materials used in the composting process of the two treatment groups contained less nitrogen compared to those control group, the compost produced among the three groups had similar main nutrients composition. In a shorter incubation time, decomposers Dec1 and Dec2 were able to decompose organic matter in the compost to produce nutrients that were relatively similar with those compost without decomposer (control). To achieve similar amount of nutrients as two treatments group, composts in control group require a longer time of incubation period. All the composts produced from the three groups in this study contained nutrient composition in accordance with the quality standards in the Regulation of the Minister of Agriculture Number: 261/KPTS/SR.310/M/4/2019 concerning Minimum Technical Requirements for Organic Fertilizer, Biological Fertilizer and Soil Improvement, namely C at least 15%, total N, P2O5 and K2O at least 2% and C/N ratio ≤25 [2].

| Table 3. Nutrients composition of three different composts made from goat manure. |
|----------------------------------|--------|--------|--------|--------|
| Treatments                      | Control | C-Dec1 | C-Dec2 | CV (%) |
| Dry Matter (%)                  | 62.02   | 57.88  | 62.98  | 15.59  |
| C (%)                           | 33.97   | 36.27  | 37.11  | 9.86   |
| N (%)                           | 1.82    | 1.7    | 1.77   | 11.18  |
| P2O5 (%)                        | 2.89    | 2.7    | 2.69   | 29.03  |
| K2O (%)                         | 3.04    | 2.81   | 2.74   | 10.02  |
| C/N                             | 18.84   | 21.51  | 21.41  | 17.86  |

Control = without decomposer; C-Dec1 = use Decomposer1; C-Dec2 = use Decomposer2.

4. Conclusions
Addition of Decomposer1 and Decomposer2 in goat manure composting process produced less methane gas emissions and produced compost with relatively the same nutrients contents as the control compost but the composting time was faster.

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