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WAGENINGEN UNIVERSITY & RESEARCH

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Summary UK The aim of this study was to evaluate effects of composting different ratios of fresh dairy cow feces and amendment material on the composition and the cost price of compost. To this end, mass balance, nutrients losses and the costs of composting were analysed in two composting trials with different ratios of cattle feces to dry amendment (‘postal’, i.e. broiler manure mixed with bedding material) in a practical farm and experimental farm in Lembang Sub-District, West Java, Indonesia. Results showed that composting reduced the weight of input materials and increased the dry matter content, thereby increasing the concentration of nutrients (total nitrogen (N) and phosphate (P)) in the final compost product compared to the initial mixture. Much N was lost during composting, particularly mineral N. Extending the composting period to eight weeks further increased the DM content and resulted in a more stable compost. Using more amendment material (postal) in the initial mixture or extending the composting period, however, led to a higher cost price of compost. It was concluded that reducing the amount of amendment material (postal) and shortening the length of the composting period can reduce the cost price of compost, but may affect the quality of the final compost product. Results showed larger differences between farms than between ratios of cow feces and amendment material, suggesting that compost management practices play an important role.

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Summary (English)

On dairy farms in Lembang Sub-District in West-Java, Indonesia, part of the cattle manure is disposed into the environment. This is causing nuisance, pollution of ground and surface waters, increased greenhouse gas emissions, and loss of valuable nutrients and organic matter. One of the main reasons for not utilizing manure is the difficulty of handling and transporting of cattle manure, because of its high moisture content. Farms have no or little land close to the barn and if applied on small areas of land, this will lead to overfertilization. Collection of the feces and composting it, is considered as a promising solution because of mass and moisture reduction, manure stabilisation, and reduction of pathogen levels. Amendments for composting are expensive, however, which influences the profitability of composting. Therefore, amendments need to be used in an optimal ratio so that the desired quality of compost is obtained, nutrient losses are minimized, and economic benefits are maximized. This study aimed at evaluating the effect of composting different ratios of fresh cow feces and amendment material on i) the dry matter (DM) content, nutrients (N and P) content and organic matter (OM) content in the final compost product, and ii) on the cost price of producing compost.

Two composting trials (trial 1 and trial 2) were executed on two dairy farms: i) an experimental dairy farm of the local dairy cooperative KPSBU in Lembang with four brick composting units, and ii) a practical dairy farm with four bamboo compost boxes. Treatments consisted of distinct ratios of fresh cow feces (CF) and so-called ‘postal’ (PS) (broiler manure consisting of dry chicken manure and rice husk) as amendment material, ranging from 3:1 to 9:1 (CF:PS). Trial 1 consisted of four treatments (CF:PS ratio of 1:3 to 1:7) and trial 2 consisted of three treatments (ratios of 1:5 to 1:9). In 3 treatments of the second trial, the four-week composting period was extended to eight weeks in total.

Results showed that composting reduced the total weight of input materials by 68,5% to 73,8% of the initial mass, due to the loss of moisture and dry matter. Composting increased the dry matter content from 23.6-32.8% in the initial mixture to 33.3%-68.8% in the final compost. A longer composting period (eight weeks) increased the DM content of the final compost product in trial 2. Losses of organic matter and nutrients (on average) were higher in the practical farm than in the experimental farm. With regard to the effect of different ratios of cows feces and postal, results showed that the dry postal amendment compensated the low DM content and low C:N ratio of the fresh cow feces. DM content of the final compost product was higher when more postal was used in the initial mixture (i.e. low CF:PS ratio). The loss of OM was found proportionate to dry mass loss and to a larger extent in extended treatments. Results also showed that composting, regardless of the amount of postal used, caused significant N losses ranging from 37% to 60%. Despite the nutrient losses, concentrations of total N and P were higher in the final compost product than in the initial mixture due to the loss of moisture. Nutrient concentrations were higher when more postal was used in the initial mixture (i.e. low CF:PS ratio). In the practical farm, dry weight loss, N loss and OM loss were relatively higher than in the experimental farm. This could likely be attributed to the better management of composting practices in the experimental farm in terms of the size and material of compost units and boxes, ventilation and turning practices. The results of the temperature profile showed that some treatments ended in above-ambient temperature at week 4, indicating that the compost was not yet stable and mature. Extending the composting process to 8 weeks allowed compost to reach ambient temperatures. In some treatments with high postal use (DM contents of more than 30%), temperature rose above 70°C, which increases the risk of catching fire and can negatively affect the organic matter content of compost.

The cost-accounting analysis showed that the cost price of compost was correlated with the ratio of fresh cow feces to postal amendment, because postal is purchased. The cost price of compost was lowest at the highest CF:PS ratios (i.e. 7:1 in Trial 1 and 9:1 in Trial 2, equalling a cost price of 320-490 and IDR kg^{-1} compost and 258-294 IDR kg^{-1} compost, respectively, including labour costs).

Extension of composting period resulted in higher costs due to additional labour requirements (538 IDR kg^{-1} compost with a ratio of 9:1).
It was concluded that using more amendment material (postal) or extending the composting period can increase the quality of compost, but leads to a higher cost price of compost. A higher quality of compost, therefore, should be rewarded with a higher price to compensate for higher production costs. Results showed larger differences between farms than between ratios of cow feces and amendment material, suggesting that compost management practices play an important role.

Summary (Bahasa)

Peternakan sapi perah di Kecamatan Lembang, Provinsi Jawa Barat, membuang sebagian limbah peternakan ke lingkungan sekitar. Hal ini menimbulkan gangguan, pencemaran perairan, meningkatkan gas rumah kaca dan hilangnya nutrien dan bahan organik. Salah satu alasan tidak termanfaatkannya limbah dari peternakan sapi perah adalah tingginya kandungan kadar air, sehingga sulit dalam hal penanganan dan pengangkutan. Peternak sapi perah umumnya tidak memiliki lahan atau memiliki sedikit lahan yang dekat dengan kandang, dan jika mengaplikasikan seluruh limbah ternak pada lahan yang terbatas tersebut akan menyebabkan terjadinya *overfertilization (*kelebihan pemupukan*).* Mengumpulkan feses dan melakukan pengomposan dapat menjadi sebagai sebuah solusi dalam menangani masalah limbah peternakan sapi perah, karena proses pengomposan mengurangi masa dan kadar air, menstabilkan limbah, dan mengurangi jumlah bakteri patogen. Usaha memodifikasi komposisi bahan yang digunakan pada proses pengomposan membutuhkan biaya yang tinggi, yang akan mempengaruhi keuntungan pengomposan. Oleh sebab itu, modifikasi komposisi bahan yang digunakan pada saat pengomposan membutuhkan rasio yang optimal, sehingga menghasilkan kualitas kompos yang diinginkan, meminimalkan kehilangan nutrien dan mendapatkan keuntungan ekonomi yang maksimal. Tujuan dari penelitian ini adalah mengevaluasi efek dari pengomposan dengan penggunaan rasio feses segar dan modifikasi komposisi bahan pengomposan yang berbeda. Parameter yang diamati pada produk kompos antara lain (i) komposisi bahan kering (DM), komposisi nutrien (N dan P) dan komposisi bahan organik (OM), dan (ii) biaya produksi kompos.

Dua percobaan pengomposan dilakukan (percobaan 1 dan percobaan 2) pada dua lokasi kandang peternakan sapi perah:i) Kandang percobaan KPSBU Lembang dengan empat unit pengomposan yang terbuat dari batu bata, dan ii) kandang peternak percontohan dengan empat unit pengomposan yang terbuat dari bambu. Perlakuan terdiri dari rasio kotoran sapi segar (CF) dan postal (PS) (kotoran ayam yang terdiri dari kotoran ayam kering dan sekam) yang berbeda dengan rentang 3:1 hingga 9:1 (CF:PS). Percobaan 1 terdiri dari empat perlakuan (rasio CF:PS adalah 1:3 hingga 1:7), dan percobaan 2 terdiri dari tiga perlakuan (rasio 1:5 hingga 1:9). Pada perlakuan 3 dalam percobaan 2, periode pengomposan empat minggu diperpanjang hingga total periode menjadi delapan minggu.

Hasil penelitian menunjukkan bahwa proses pengomposan mengurangi berat total bahan awal sebesar 68,5% hingga 73,8%, dan hal ini terkait dengan hilangnya kadar air dan bahan kering. Pengomposan meningkatkan komposisi campuran bahan kering: dari 23.6-32.8% pada pencampuran bahan awal menjadi 33.3-68.8% pada produk akhir. Pada periode pengomposan yang lebih panjang (delapan minggu), terjadi peningkatan kandungan bahan kering pada produk akhir di percobaan 2. Rata-rata kehilangan bahan organik dan nutrien lebih tinggi pada kandang peternak percontohan dibandingkan kandang percobaan KPSBU. Penelitian ini mengamati efek perbedaan rasio kotoran segar dan postal, dan hasil penelitian menunjukkan modifikasi bahan pengomposan menggunakan postal kering mengkompensasi rendahnya kandungan DM dan rasio C:N pada kotoran segar. Kandungan DM pada produk akhir kompos lebih tinggi ketika lebih banyak postal digunakan pada pencampuran bahan awal (rendahnya rasio CF:PS). Kehilangan bahan organik terjadi seiring dengan hilangnya bahan kering dan terjadi pada percobaan yang periode pengomposannya lebih panjang.

Hasil penelitian juga menunjukkan bahwa proses pengomposan tanpa menggunakan postal dapat mengakibatkan pengurangan N sebanyak 37% hingga 60%. Disamping adanya kehilangan nutrien, komposisi total N dan P lebih tinggi pada produk akhir kompos dari pada komposis N dan P pada campuran bahan awal, dan hal ini terkait dengan hilangnya kadar air. Konsentrasi nutrien lebih tinggi ketika lebih banyak postal yang digunakan dalam pencampuran awal (rendahnya rasio CF:PS). Pada kandang peternak percontohan, kehilangan bahan kering, N dan OM relatif lebih tinggi dibandingkan dengan kandang percobaan KPSBU. Hal ini dapat dikaitkan dengan pengelolaan pengomposan yang lebih baik di kandang percobaan KPSBU dibandingan kandang peternak percontohan, dalam hal ukuran, material bahan kotak pengomposan, ventilasi dan metode pengadukan kompos. Hasil

pengamatan suhu menujukkan bahwa beberapa perlakuan menghasilan suhu diatas suhu udara *(ambient temperature)* pada minggu ke 4, dan hal ini mengindikasikan bahwa kompos belum stabil dan matang. Memperpanjang proses pengomposan hingga delapan minggu membuat suhu kompos mencapai suhu udara. Pada beberapa perlakuan dengan tingginya penggunaan postal (kandungan DM lebih dari 30%), suhu dapat mencapai 70°C dan dapat meningkatkan resiko munculnya percikan api dan berpengaruh secara negatif terhadap kandungan bahan organik pada kompos.

Hasil analisa biaya menunjukkan bahwa harga biaya kompos berkorelasi dengan rasio penggunaan kotoran segar dan postal, hal ini karena postal perlu dibeli. Harga kompos yang paling rendah ditemukan pada rasio CF:PS yang paling tinggi (7:1 pada percobaan 1 setara dengan Rp. 320-490 per kg kompos dan 9:1 pada percobaan 2, Rp. 258-294 per kg compost, dan biaya ini meliputi upah tenaga kerja). Memperpanjang periode pengomposan berdampak pada tingginya biaya pengomposan yang lebih tinggi karena terkait dengan tambahan kebutuhan tenaga kerja (Rp. 538 per kg kompos dengan rasio 9:1).

Penelitian menyimpulkan bahwa modifikasi komposisi bahan pengomposan menggunakan postal yang lebih banyak atau memperpanjang periode pengomposan dapat meningkatkan kualitas kompos, tetapi meningkatkan biaya pengomposan. Kualitas kompos yang lebih tinggi harus mendapatkan harga yang lebih tinggi untuk mengkompensasi biaya produksi. Hasil penelitian menunjukkan adanya perbedaan kualitas kompos antara kandang percobaan KPSBU dan kandang peternak percontohan, serta rasio penggunaan feses dan modifikasi komposisi bahan pengomposan, dan hal ini mengindikasikan pentingnya melakukan pengelolaan kompos yang baik.

1 Introduction

Dairy farms in Lembang Sub-District, West-Java, are zero-grazing small-scale farms typically owning 3-5 cows per farm in tied barns with very limited land for production of fodder or food crops. Part of the cattle manure is disposed into the environment on most of the farms, and only few farms use manure for fertilization of fodder or food crops (de Vries and Wouters, 2017). In many farms too much manure is applied on land near the cow barn, leading to overfertilization. Current practices of discharging cattle manure and overfertilization of agricultural land are causing nuisance, pollution of ground and surface waters, increased greenhouse gas (GHG) emissions, and loss of valuable nutrients and organic matter. 'Cattle manure' consists for about half of semi-solid feces that can be collected and transported, particularly when it is dried. The other half, liquid urine, is more difficult to handle and transport.

This situation of manure management in dairy farms of Lembang Sub-District demands new solutions to alleviate the negative environmental impacts. One of the main reasons of not utilizing manure is the difficulty of handling and transporting of cattle manure, because of its high moisture content. Composting is considered as a promising solution because of mass and moisture reduction, manure stabilisation, and reduction of pathogen levels. The costs of the process can be offset by the added-value of the compost product in terms of enhancing soil fertility, increasing crop yields, and reducing diseases (Dick and McCoy, 1992; Changa et al., 2003). Furthermore, composted manure compared to untreated manure and synthetic fertilizers can reduce nutrient leaching when applied to arable lands (Pecchia, 1996).

In practice composting on the small-scale dairy farms in Indonesia is hindered by limited knowledge about good composting practices, such as the amount of amendment material required. Dairy cow feces have a high moisture content, therefore addition of amendments to improve the composting process is essential. For composting, dry matter contents of 35-40% and C:N ratios of 25:1 to 30:1 of the input material are generally thought to be optimal (Rynk et al., 1992; Haug, 2018). These amendments are often expensive and may influence the profitability of composting (de Vries, 2020). Therefore, amendments need to be used in an optimal ratio so that the desired dry matter content is obtained for the composting process, minimum nutrients are lost, and maximum economic benefit is gained. Nitrogen losses during composting are inevitable and increase with the amount of nitrogen added by amendments (Van Faassen and Van Dijk, 1979). High losses of total-N during composting are mainly due to NH_3-volatilization. C:N ratio has been noted to affect the degree of N loss through ammonia volatilization (Bishop, 1983). To minimize the nitrogen loss during dairy cattle manure composting, it has been advised to prepare composts with adequate C:N ratios between 25:1 and 35:1 (Van der Wurff et al., 2016; Michel Jr et al., 2004).

To help farmers with better understanding of the composting process and designing more optimal composting management in order to reduce the need for amendments, enhance nutrients conservation and improve the cost-effectiveness of composting, the following goals are defined for the current study.

1.1 Aim

The objectives of this study were to determine the effects of using different ratios of cattle feces and amendment material (postal) on the dry matter (DM) content, nutrient (N and P) content, organic matter content, and mass loss in the final compost product and to evaluate the cost effectiveness of composting mixtures with different ratios of fresh cow feces to postal amendment.

2 Material and Methods

2.1 Description of composting procedure and location

Composting processes were examined in two different locations in Lembang Sub-District, West Java (Figure 2.1), including:
- An experimental farm (farm 1) located on the premises of the experimental farm of the dairy cooperative KPSBU at Manoko village in Lembang sub-district. In this composting unit cow feces was used from 13 milking cows on the experimental farm. The composting unit had four compartments of each about 3 m^3 (dimensions: 185×150×120 cm) which were open to the front side and with walls made of stone bricks with ventilation perforations, and partly open pallet floors (see Figure 2.1-left); ventilation thus occurred from all sides. Composting activities were executed by farm staff.
- A practical dairy farm (farm 2): on this small-scale dairy farm cow feces from 6 milking cows were collected and composted. This farm had 4 composting boxes of 1 m^3 each (dimensions: 105×105×116 cm). The boxes were made of bamboo with ventilation from all sides (see Figure 2.1-right). Composting activities were executed by the farmer.

Figure 2.1 *Composting compartments in two farms. Left: farm 1 and right: farm 2.*

The best available amendment as dry material for composting in Lembang Sub-District is "postal" (local term), which is a dry mixture of chicken manure and rice husks (bedding) from broiler farms. In this report, fresh cow feces and postal will be referred to as CF and PS, respectively. In each farm, two composting trials were conducted. Within each trial, different ratios of CF:PS were tested, i.e. 'treatments'.
In all treatments, the composting process took four weeks to make a final compost product. The mixture stayed in each composting compartment for one week and was mixed and moved to a next compartment after each week. After four weeks, the compost was weighted and put in bags. Table 1 shows the detailed characteristics of each trial. In this report, treatments are named with numbers (1 and 2) and letters (A-D and E). The first numeric index refers to the trial, the second one refers to the farm number. In trial 2, the name associated with replicated treatments are repeated (AA, BB and CC) and the extended treatments are shown with letter E.

Table 1 *Treatment (T) characteristics of trial 1 and trial 2.*

Farm	Treatments	Ratio (CF:PS)	Mass of CF (kg)	Mass of PS (kg)	Input material (kg)	Date formed	Date harvested
Trial 1							
Farm 1	A11	3:1	565	200	765	28/06/2019	26/07/2019
	B11	5:1	565	120	685	05/07/2019	02/08/2019
	C11	7:1	565	85	650	12/07/2019	08/08/2019
	D11	4:1	565	150	715	19/07/2019	16/08/2019
Farm 2	A12	3:1	600	200	800	02/07/2019	30/07/2019
	B12	5:1	600	120	720	09/07/2019	06/08/2019
	C12	7:1	600	85	685	16/07/2019	13/08/2019
	D12	4:1	600	150	750	27/07/2019	23/08/2019
Trial 2							
Farm 1	A21	5:1	750	150	900	06/09/2019	04/10/2019
	B21	7:1	788	112	900	13/09/2019	11/10/2019
	C21	9:1	810	90	900	20/09/2019	18/10/2019
	CC21	9:1	810	90	900	11/10/2019	08/11/2019
	AA21	5:1	750	150	900	27/09/2019	25/10/2019
	BB21	7:1	788	112	900	04/10/2019	31/10/2019
	AA21-E	-	-	-	305	25/10/2019	22/11/2019
	BB21-E	-	-	-	328	31/10/2019	29/11/2019
	C21-E	-	-	-	350	18/10/2019	15/11/2019

The main differences of these two trials are as follows:

1. Trial 1 was conducted in the period July-August 2019, and trial 2 was conducted in the period September-December 2019.
2. Trial 1 consisted of four treatments, and trial 2 consisted of three treatments.
3. Trial 1 was executed on both farms while trial 2 was only performed in farm 1.
4. Ratios of CF:PS varied from 3:1 to 7:1 in trial 1, and from 5:1 to 9:1 in trial 2 (Table 1).
5. Trial 2 started with equal amounts of composting mixtures whilst in trial 1, different amounts of composting mixtures were tested at the start of the composting process (See Table 1).
6. Treatments of trial 1 were not repeated during the composting process, whereas treatments of trial 2 were repeated once and some treatments were extended to eight weeks to assess the effect of composting prolongation.
7. During trial 2, cow feces were collected daily during one week and then transported to the composting boxes; therefore one week of “pre-drying” was applied before the composting process started, whilst it was not the case in trial 1.

2.2 Measurements

Quantities of input materials (collected fresh cattle feces and purchased postal) and of the final compost product were measured at the start and at the end of the process. Samples were taken from each mixture at the start of each treatment and at the end of composting process and analysed on the dry matter content, total N content, mineral N content, P content and ash/organic matter. The same sampling was performed for both trials.
In trial 2, all treatments were started with 900 kg of input material and resulted in different masses of compost. As it was described, fresh manure was pre-dried for one week, however, the effect of pre-drying on feces properties were not directly measured in this study since the samples were taken from the pre-dried mixture.
During the process of composting, temperatures in each compartment were measured at 5 sampling points and three times in a week: beginning of the week, middle of the week and end of each week (before moving to the next compartment).

Organic matter (OM) content was estimated by subtracting ash from the dry matter content. Losses of nutrients during composting were calculated from the initial and the final contents (DM basis) according to the Equation (1):

$$Loss\ of\ nutrients\ (\%\ of\ initial) = \frac{initial\ mass_{nutrients}\ - final\ mass_{nutrients}}{initial\ mass_{nutrients}} \times 100 \qquad \text{Equation (1)}$$

Ash content of manure was estimated by measuring the loss of weight following combustion of a sample at 550° C. To estimate the carbon content, it was assumed to be equal to half of OM content (Bianchi et al., 2008).

2.3 Cost accounting analysis

The cost accounting analysis of the different treatments, including the costs of postal amendment, labour and the break-even point of profit was carried out based on variable costs and considering two scenarios: with and without labour costs. Assumed prices of postal and labour used for the cost analysis are listed in Table 2.

Table 2 *Assumed price of inputs and output during composting process.*

Parameters	Unit[1]	Value
Postal price	IDR kg^{-1}	500
Labour price	IDR h^{-1}	16.250
Labour demand-farm 1	h (per round)	2,8
Labour demand-farm 2	h (per round)	3,9

[1] Weights on wet basis.

Recorded labour activities on these farms included: collecting cow feces, purchase and transport of postal, mixing raw materials, moving the mixture from one compartment to other compartments (4 times in one round of composting process), harvesting, weighing and taking samples, and putting the compost into bags. The cost price of compost (break-even point of profit) was calculated using the following equation. In case of labour excluded scenarios, labour costs were considered as zero.

$$Cost\ price\ of\ compost\ (IDR\ kg^{-1}\ compost) = \frac{postal\ cost\ (IDR) - labour\ cost\ (IDR)}{compost\ mass\ (kg, wet\ basis)} \qquad \text{Equation (2)}$$

3 Results

3.1 Temperature profile during composting

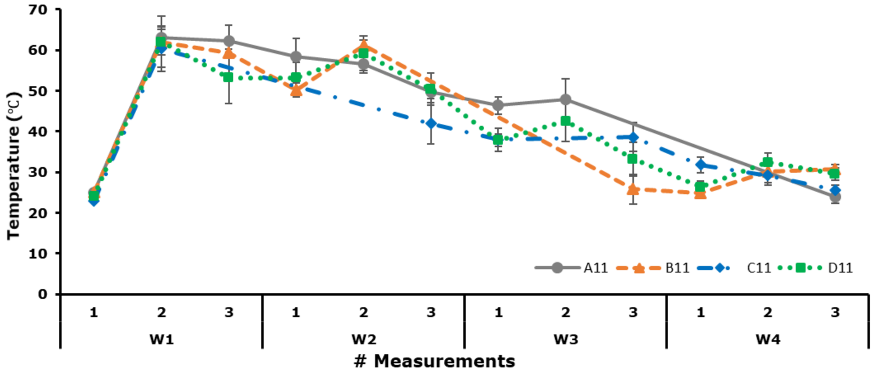
Results of trial 1

Pattern of temperature change during composting processes in two trials and for different treatments are depicted in Figure 3.1 and 3.2. All composts were characterised by an initial increase in temperature to >60 °C in less than 5 days. This rapid increase in temperature can be explained by the relatively fast increase of microbial organisms, adapted to the aerobic conditions (Van Faassen and Van Dijk, 1979; Sommer, 2001).

Temperature profiles differed mainly between farm 1 and 2, and between trial 1 and trial 2, but not consistently between ratios of CF:PS (amount of postal; Figure 3.1). In farm 2, the initial temperature increased to around 70 °C in treatments A and D, which could have been caused by the high amount of postal (CF:PS ratios 3:1 and 4:1) and the higher air ventilation in farm 2, which has possibly accelerated the composting process. However, such a high temperature is not desirable since it affects the biological quality of the compost (losses of organic matter were higher in farm 2; see section 3.2) and increases the fire risks. In general, composting in farm 1 peaked at 60 °C faster and then dropped gradually to ambient levels, implying that the composting process went faster from decomposition phase to the maturation phase.

As shown in the temperature graph (Figure 3.1), temperatures fluctuated much more in farm 2 than in farm 1 and in farm 1, slightly larger fluctuations of temperature were found in treatments B, C and D than in treatment A. In addition to fluctuations, composting in farm 2 terminated with higher temperatures at the end of process (week 4) which implies an unfinished composting process (unstable compost product) and a slower rate of composting compared to farm 1.

The temperature variations of composting over time suggest that CF:PS ratios have less effect on temperature profiles than management practices. In contrast, adding much dry amendment (such as in treatment A and D) caused very temperatures over the composting process, potentially increasing the risk of catching fire and affecting the organic matter content of compost.



(a)

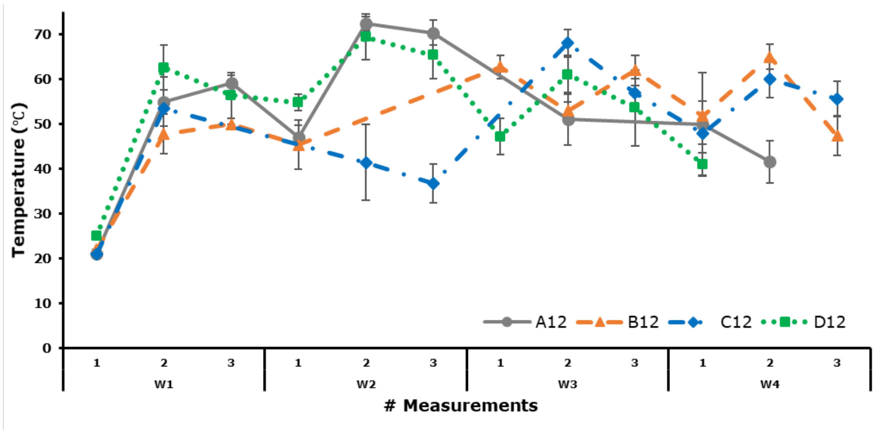


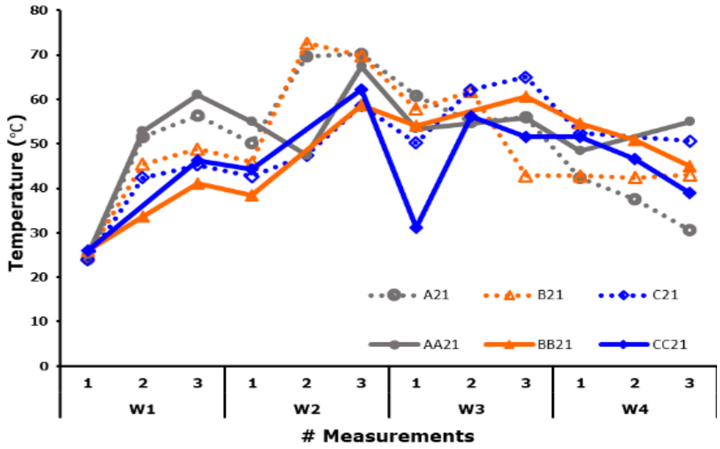
Figure 3.1 *Temperature profile of composting in two farms during trial 1 (a): farm 1 and (b): farm 2. Data points represent an average of 15 measurements. Error bars represent plus and minus standard deviation.*

Results of trial 2

The temperature profile of trial 2 is depicted in Figure 3.2. The first graph (a) displays the composting process after four weeks with repeated treatments and the second graph (b) shows the temperature changes over the eight weeks composting period (in time extended treatments). The first four weeks of graph (b) is depicting the same treatments as in graph (a) followed by the extended treatments. The results revealed that not all of the treatments of trial 2 reached high temperatures (60°C) in a few days after starting the composting except for treatment A and its replication (AA) comprising of a lower CF:PS ratio (more postal). Treatments B and C reached the maximum temperature later in week 2 and the rise in temperature was slower in their repeated treatments (BB21 and CC21) (Figure 3.2. (a)). This effect was not seen in Trial 1 (farm 1), however, where the temperature increase in the first week was the same for all treatments.

Dry matter content at the start has likely influenced the speed of composting in this trial since the DM content of mixture is lower due to the higher CF:PS ratios (see section 3.3, Table 6). In addition, temperature of all repeated treatments fluctuated greatly throughout the composting period (24–72°C). A sudden drop of temperature in CC21 could be due to turning practices or measurement errors however temperature was decreased for all other treatments during the third week when mixtures moved to the third compartment.

The extended treatments had a gradual decreasing temperature trend, shown as week 5 to week 8 in Figure 3.2 (b). In trial 2, nearly all treatments (ratios) ended in above ambient temperature at week 4, except for A21. Extension in time of composting process modified this trend to ultimately reach to ambient temperatures, which implies a stable and mature compost.



(a)

(b)

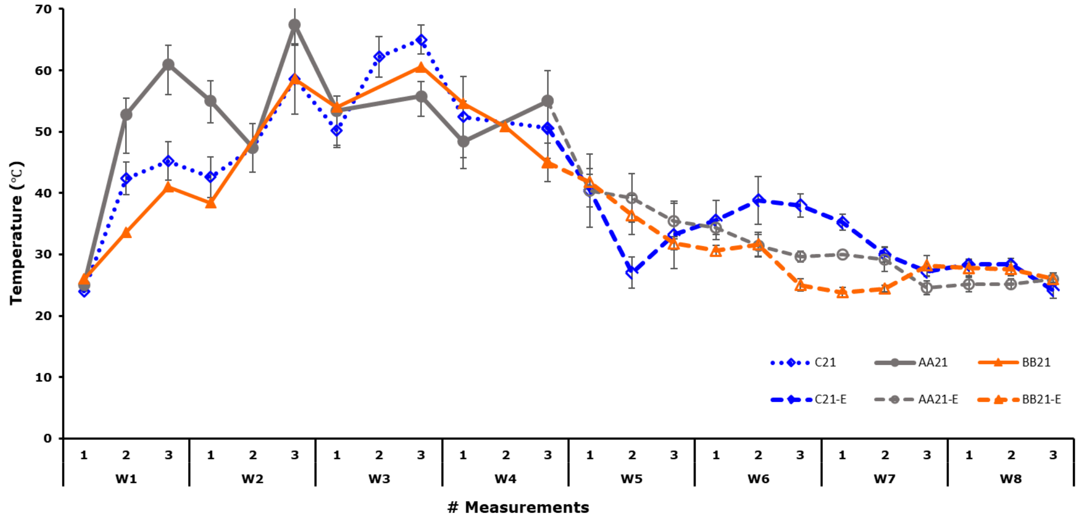


Figure 3.2 *Temperature profile of trial 2: (a) 4-week treatments and (b) 8-week (extended) treatments. The solid lines and dashed lines shows repeated and extended treatments, respectively. Data points represent an average of 15 measurements. Error bars represent plus and minus standard deviation.*

3.2 Initial material and final compost properties and losses

Results of trial 1

The mean properties of the initial (CF and PS), mixture (CF+PS) and the final compost product (CP) including mass, nutrient content, OM content and C:N ratio are shown in Tables 3 (farm 1) and 4 (farm 2). The results of the losses occurred during trial 1 are shown in Table 5.
The average mass of final compost in farm 1 and farm 2 were 201,3 kg and 321,5 kg. During composting, the total weight of the compost decreased by 68,5% to 73,8% of the initial mass in all treatments and both farms (Table 5). The decrease in weight during the composting process was caused by loss of moisture and organic matter, and was comparable to other studies e.g. Tiquia et al. (2002); Michel Jr et al. (2004).

__Table 3__ Mean properties of fresh cattle feces, postal and final compost product in farm 1 with 4 treatments. Values reported are mean of two samples and on wet basis.

INITIAL MATERIAL

Treatment ID	Date formed	Material	Initial mass (kg)	DM (%)	N-total (g kg^{-1})	N-min	P	OM	C:N
A11	28/6/2019	CF	565	13,8	4,3	1,0	1,7	761,4	10,0
		PS	200	86,4	31,1	2,7	5,4	743,2	
		CF+PS	765	32,8	11,3	1,4	2,7	748,9	
B11	5/7/2019	CF	565	14,2	6,6	1,3	1,8	758,1	7,1
		PS	120	85,5	36,8	2,4	4,8	756,2	
		CF+PS	685	26,7	11,9	1,5	2,3	757,0	
C11	12/7/2019	CF	565	13,8	4,3	0,9	1,4	771,0	10,7
		PS	85	88,4	26,0	1,8	4,1	755,0	
		CF+PS	650	23,6	7,2	1,0	1,8	762,9	
D11	19/7/2019	CF	565	15,6	5,6	1,0	1,8	786,0	9,2
		PS	150	74,2	28,9	1,8	3,1	762,0	
		CF+PS	715	27,9	10,5	1,2	2,1	772,3	

FINAL COMPOST PRODUCT

Treatment ID	Date Harvested	Material	Final mass (kg)	DM (%)	N-total (g kg-1)	N-min	P	OM	C:N
A11	26/7/2019	CP	210	68,8	23,7	1,1	5,7	684,7	8,5
B11	2/8/2019	CP	190	61,9	19,4	0,8	4,8	678,7	9,3
C11	9/8/2019	CP	180	50,7	15,1	0,7	4,2	667,3	9,6
D11	16/8/2019	CP	225	48,7	17,3	1,0	3,7	696	8,4

CF: Cattle feces, PS: Postal, CP: Compost product.

For the initial materials, the average DM content of the CF varied little (14,9±1%) in all treatments of trial 1. The average DM content of PS was 84,9±4,5%. Mixing dairy cattle feces with the postal in different ratios resulted in a dry matter content ranging from 23,6 to 33,2%. As expected, the mixture with the highest PS amount (treatment A) had the highest DM content. Accordingly, the DM content of the final compost product from this mixture was the highest (68,8%), although the relative mass and moisture loss was similar to treatments B and C (Table 5). In terms of CF:PS ratio, lower DM contents were obtained by increasing this ratio. In this respect, treatment C had the lowest DM content at the start and in the final compost product.

Table 4 *Mean properties of fresh cattle feces made with postal and final compost product in farm 2 with 4 treatments. Values reported are mean of two samples and on wet basis.*

INITIAL MATERIAL

Treatment ID	Date formed	Material	Initial mass	DM	N-total	N-min	P	OM	C:N
			(kg)	(%)	(g kg^{-1})				
A12	2/7/2019	CF	600	15,0	4,2	1,0	1,1	708,5	10,6
		PS	200	87,8	28,1	2,1	4,2	752,4	
		CF+PS	800	33,2	10,2	1,3	1,9	737,5	
B12	9/7/2019	CF	600	14,5	3,7	0,8	1,0	701,2	11,1
		PS	120	86,1	34,8	2,1	4,7	742,2	
		CF+PS	720	26,4	8,9	1,0	1,6	723,5	
C12	16/7/2019	CF	600	16,3	4,4	0,8	0,8	713,4	10,9
		PS	86	85,7	34	2,4	4,6	745,6	
		CF+PS	686	25,0	8,1	1,0	1,3	727,2	
D12	27/7/2019	CF	600	16,3	4,3	0,9	1,1	716,6	11,1
		PS	150	85,7	3,3	1,8	4,7	749,8	
		CF+PS	750	30,2	10,0	1,1	1,8	735,5	

FINAL COMPOST PRODUCT

Treatment ID	Date Harvested	Material	Final mass	DM	N-total	N-min	P	OM	C:N
			(kg)	(%)	(g kg-1)				
A12	30/7/2019	CP	320	46,4	16,3	0,9	5,5	656,6	8,0
B12	6/8/2019	CP	331	39,1	12,5	1,0	3,3	641,1	8,6
C12	13/8/2019	CP	335	33,3	10,0	0,6	3,8	637,9	9,2
D12	23/8/2019	CP	300	44,9	16,5	0,7	5,8	665,8	7,8

CF: Cattle feces, PS: Postal, CP: Compost product.

By comparing two farms, a much larger difference in loss of OM was found between both farms, which was likely due to the differences between composting practices and management methods. The average loss of OM in farm 2 (65,4%) was about 20% higher than in farm 1 (45,6%) which was proportionate to the dry mass loss (61,1% *vs.* 39,6%) (Table 5).

By comparing the results of different ratios, in farm 1 the loss of OM was higher for mixtures of lower CF:PS ratios (treatments A and D) in comparison to treatments with higher ratios (B and C), although an effect of ratio was not clearly observed in farm 2.

When it comes to the effect of applying different composting ratios, it was observed that the initial mixture of treatment C had the lowest concentration of nutrients since lower postal amounts were mixed with fresh feces, both in farm 1 and 2.

From Tables 3 and 4, it is obvious that the initial postal had substantially higher N and P concentrations than the fresh cow feces. Due to the loss of moisture, total N and P concentrations increased in the final compost product compared to the initial mixture, despite N loss during composting. On average total N increased from 10.2 g/kg in the initial mixture to 18.9 g/kg in the final compost in farm 1 and from 9.3 g/kg to 13.8 g/kg in the final compost in farm 2 (Table 3 and 4). Mineral N content decreased, however, particularly in farm 2.

The average C:N ratio of CF and PS in farm 1 and farm 2 were respectively 10,4±1,6 and 8,8±1,2. Mixing dairy cattle feces with the postal in different ratios as amendment resulted in C:N ratio ranging from 7,1 to 11,1 at the start of the composting process. The average C:N ratio of the final compost in farm 1 and farm 2 were 8,9±0,6 and 8,4±0,6 respectively. The C:N ratio decreases during the composting process because part of the carbon is lost as CO_2 gas from microbial respiration, while most of N is retained in the system (Ryckeboer et al., 2003).

The percentage of N loss ranged from 42,5-67,8% of the initial N (wet basis). The losses of N was lowest in treatments with lowest CF:PS ratios (A and D) while treatment C had the highest loss of N, both in farm 1 and 2. Average N loss was about 10% higher in farm 2 than in farm 1 (59.7 vs 50.1%). Phosphorus loss ranged from 3,9% to 45,3% of the initial P between treatments, whereas the P content increased in all treatments due to moisture loss. The high P loss in this study could be a result of errors in sampling and laboratory analysis as well.

Table 5 *Mass, moisture, organic matter, and nutrient losses (% of initial) during trial 1 in two farms (1/2) and 4 treatments (A/B/C/D).*

Treatment ID	Total mass loss	Dry weight loss	Moisture loss	N loss	P loss	OM loss
A11	72,5	42,4	87,3	42,6	41,4	47,3
A12	73,8	63,3	78,9	58,0	22,6	67,3
B11	72,3	35,6	85,6	54,7	43,2	42,3
B12	73,6	61,0	78,2	62,8	45,3	65,4
C11	72,3	35,6	85,6	54,7	43,2	42,3
C12	73,8	65,1	76,7	67,8	24,2	69,4
D11	68,5	45,1	77,6	48,2	43,2	50,6
D12	70,0	55,3	76,3	50,3	4,0	59,6

Values reported are losses as a percent of the initial quantity and were calculated using total weight and measured concentrations.
The first numeric index indicates trial 1 and the second number shows the farm number.

Results of trial 2

The properties of fresh cow feces, postal and the final compost product for the repeated and extended treatments of trial 2 are shown in Table 6. Contrary to trial 1, DM content did not differ systematically between CF:PS ratios, neither in initial mixtures, nor in the final compost. The DM content of the final compost in the second repeated treatment (AA21, BB21 and CC21) was higher than in the first repeated treatment (A21, B21 and C21), despite similar DM content of the initial mixtures. The average DM content of the initial mixture in trial 2 was 22,0±1,9% which was lower than those of trial 1 (28,2±3,5%). The lower initial DM content of the mixture in trial 2 (22,0±1,9%) than trial 1 (28,2±3,5%) was due to the lower DM content of the postal in trial 2 compared to trial 1. Accordingly, the final compost after 4 weeks had a lower DM content in trial 2 than trial 1 (31,8%±5,2 *vs.* 49,2±11,5%). Extending some treatments with four more weeks increased the DM content of the compost to an average of 45,1%±3,4%.

Table 6 *Mean properties of fresh cattle feces made with postal, initial mixture and final compost product in 3 treatments. Values reported are mean of two samples and on wet basis.*

INITIAL MATERIAL

Treatment ID	Date formed	Material	Initial mass	DM	N-total	N-min	P	OM	C:N
			(kg)	(%)	(g kg^{-1})				
A21	6/9/2019	CF	750	16,6	2,7	1,0	2,0	752,2	20,3
		PS	150	55,7	7,7	1,9	2,8	727,4	
		CF+PS	900	23,1	3,5	1,1	2,2	742,2	
AA21	27/9/2019	CF	750	17,8	2,7	0,8	2,4	755,6	22,4
		PS	150	52,2	5,7	1,5	3,4	717,8	
		CF+PS	900	23,5	3,2	1,0	2,5	741,7	
B21	13/9/2019	CF	788	15,0	2,3	0,9	2,9	736,5	19,9
		PS	112	54,4	9,5	2,0	4,4	705,6	
		CF+PS	900	19,9	3,2	1,0	3,0	726,0	
BB21	4/10/2019	CF	788	20,4	3,7	0,7	2,4	758,9	18,9
		PS	112	51,7	6,2	1,8	3,3	702,8	
		CF+PS	900	24,3	4,0	0,8	2,5	744,1	
C21	20/9/2019	CF	810	16,3	2,6	0,7	1,9	771,2	21,1
		PS	90	56,9	8,2	2,0	2,8	712,3	
		CF+PS	900	20,3	3,1	0,8	2	754,8	
CC21	11/10/2019	CF	810	16,8	2,6	0,6	1,8	769,6	21,8
		PS	90	55,9	7,7	2,5	2,9	729,0	
		CF+PS	900	20,7	3,1	0,7	1,9	758,6	

FINAL COMPOST PRODUCT

Treatment ID	Date harvested	Material	Final mass	DM	N-total	N-min	P	OM	C:N
			(kg)	(%)		(g kg^{-1})			
A21	4/10/2019	CP	303	29,9	4,6	0,5	3,5	650,3	18,0
AA21	25/10/2019	CP	328	39,4	6,0	0,5	3,5	657,0	18,4
AA21-E	22/11/2019	CP	229	46,7	7,6	0,5	4,2	650,0	17,1
B21	11/10/2019	CP	305	26,9	4,1	0,6	3,6	625,7	17,6
BB21	31/10/2019	CP	350	28,5	4,4	0,8	3,8	658,6	18,3
BB21-E	29/11/019	CP	179	47,3	7,9	0,5	1,8	660,1	16,9
C21	18/10/2019	CP	372	28,8	4,8	0,7	5,9	659,2	16,9
CC21	8/11/2019	CP	307	37,4	6,6	0,4	3,9	662,0	16,1
C21-E	15/11/2019	CP	198	41,1	7,2	0,3	7,8	630,0	15,4

Losses that occurred in trial 2 are shown in Table 7. The higher mass loss of treatment A21 and AA21 (lower CF:PS ratio) at the start ended in a higher DM content of the final compost. When treatments were extended, more total mass was lost and likewise, more OM was lost.
Similar to trial 1, the N content of CF (2,8±0,04 g kg^{-1}) was lower than PS (7,5±0,1 g kg^{-1}) and for the final compost product was measured between 5,1±0,1 g kg^{-1} and 7,6±0,03 g kg^{-1} on wet basis. Consequently, N mineral in initial mixture was higher in the treatments with more postal (lower CF:PS ratios) in both trials. However, the mineral N in the final compost was not consistently higher in lower CF:PS ratios, showing no consistent pattern.
Phosphorus loss varied from 11% to 53% of the initial P between treatments, whereas the P content increased in all treatments due to moisture loss. The high P loss in this study could be a result of errors in sampling and laboratory analysis as well.
The fresh cow feces had an initial C:N ratio of 20,4±1,3 whereas those of postal was 22,8±3,7. After mixing two materials, the average C:N ratio was 20,7±1,3. The average C:N ratio of the final compost in trial 2 was found to be lower than those of trial 1 (17,5±0,9 and 8,7±0,6 respectively).
In respect to C:N ratio, N loss was lowest in treatments with the highest C:N ratio (AA21 and CC21). Extending some treatments with four more weeks increased the C:N ratio of the compost to an average of 16,5±1,0.

Table 7 *Mass, moisture, organic matter, and nutrient losses (% of initial) during trial 2 in one farms and 3 treatments.*

Treatment ID	Total mass loss	Dry Weight loss	Moisture loss	N loss	P loss	OM loss
A21	66	56	69	56	46	62
AA21	66	43	73	36	53	50
AA21-E	75	49	82	42	11	56
B21	59	44	62	47	51	52
BB21	64	57	66	60	46	62
BB21-E	80	61	86	62	31	66
C21	61	45	65	40	23	52
CC21	66	38	73	27	29	46
C21-E	78	56	84	55	16	63

3.3 Cost accounting analysis

Results of trial 1

A cost accounting analysis was performed for the examined composting processes and the results from trial 1 are shown in Table 8. It should be noted that, the calculations were based on kg of compost product (wet basis).
Postal and labour costs were calculated based on the current price of the studied region. An average wage was assumed for labourers in the studied region (Table 2). Labours requirements were different in two farms and therefore, the total cost of labour was estimated for two farms differently (45.229 *vs.* 64.187 IDR). Postal price was the same in both farms. Cost price was calculated based on Eq. 2 for two scenarios representing the break-even point for profit.
The cost price of compost in the scenario where labour costs were included was much higher than the ones without labour costs. In scenario without labour costs, cost price was determined by the amount of postal used. In this case, the cost of amendment (postal) compensated most of the variable costs. It should be noted that the variable cost of labour was relatively low in treatments of higher CF:PS ratio (with less postal).
By comparing treatments it can be concluded that higher CF:PS ratios (less postal) results in lower cost prices of compost which implies the higher profits can be expected in these treatments (treatment C). When labour costs were excluded from the total costs, the same results were derived for treatments. The minimum price of compost (without labour costs) to make composting profitable in farm 1 and farm 2 were 236 and 128 IDR kg^{-1} of wet compost, respectively.

Table 8 *Cost accounting and cost price of compost product in treatments of trial 1 (wet basis).*

Treatment ID	CF:PS	Postal cost (IDR)	Labour cost (IDR)	Compost mass (kg)	Cost price- with labour costs (per kg CP)	Cost price- without labour costs (per kg CP)
Farm 1						
A11	3:1	100.000	45229	210	692	476
B11	5:1	60.000	45229	190	554	316
C11	7:1	43.000	45229	180	490	239
D11	4:1	75.000	45229	225	534	333
Farm 2						
A12	3:1	100.000	64187	320	513	312
B12	5:1	60.000	64187	331	375	181
C12	7:1	43.000	64187	335	320	128
D12	4:1	75.000	64187	300	464	250

Results of trial 2

The results of cost accounting analysis for trial 2 are presented in Table 9. The same method was used to calculate the costs of labour, postal and the cost price of compost in two scenarios. For scenarios extended in time of composting, calculations were conducted for the whole composting period (eight weeks); therefore, as it is obvious from Table 9, the same costs of postal and additional labour costs were computed.
In general, by increasing the CF:PS ratio (from 5:1 to 9:1), i.e. less postal, the cost price was prone to decrease (e.g. 247, 150 and 129 IDR kg^{-1} CP respectively for A21, B21 and C21). This result is evident from the columns of Table 9, showing cost price of compost in two different scenarios (with and without labour costs).
When labour costs were included and composting duration was shorter (four weeks), treatment C and its replication (CC) with CF:PS ratio of 9:1 resulted in the lowest cost-price of compost (129 and 147 IDR kg^{-1} CP, without labour costs) implying that with a low addition of postal, the cost price can be kept low. As labour costs were included, the same result cost price of composting was increased.

The most remarkable result of cost accounting analysis is that in case the treatments were extended, more labour costs were made due to additional moving of mixture from compartment 1 to 4 and therefore the cost price increased (i.e. 596, 656 and 538 IDR kg^{-1} CP). A consequence of extension in time of composting is the higher cost-effectiveness of treatments with higher CF:PS ratio in terms of a lower cost price of compost product.

Table 9 *Cost accounting and cost price of compost product in treatments of trial 2 (wet basis).*

Treatment ID	CF:PS	Postal cost (IDR)	Labour cost (IDR)	Compost mass (kg)	Cost price- with labour costs (IDR per kg CP)	Cost price- without labour costs (IDR per kg CP)
A21	5:1	75.000	45229	303	397	247
AA21		75.000	45229	305	394	246
AA21-E		75.000	61479	229	596	327
B21	7:1	56.000	45229	372	272	150
BB21		56.000	45229	328	309	171
BB21-E		56.000	61479	179	656	313
C21	9:1	45.000	45229	350	258	129
CC21		45.000	45229	307	294	147
C21-E		45.000	61479	198	538	227

4 Discussion

Dairy cattle feces collected in the tied barns on small-scale dairy farms in Indonesia have a high moisture content and are difficult to handle and transport for other purposes than direct application on land close to the cow barn. Turning these feces into compost increases ease of handling and transport, and the feasibility to sell it to vegetable farms or to other customers at a longer distance from the farm.

The main principle of composting is the evaporation of moisture in combination with microbial processing of the organic matter. However turning dairy cattle feces into compost without adding dry amendments and by natural drying will take a long time and will result in a long turn over time, and will thus require a large storage area. The composting process can be accelerated by adding dry amendments to this wet dairy cattle feces resulting in a "hot" composting process with raised temperatures. In this study, the addition of "postal", a relatively dry and nitrogen rich manure product from the broiler industry was mixed with dairy cattle feces to increase the dry matter content, stimulating the "hot" composting process. This product is ample available and much used on vegetable farms for soil improvement, but it is relatively expensive.

In this study mixing of fresh cattle feces with postal showed that different mixing ratios of cattle feces and amendment (postal) when composting affect the quality and properties of the final composted material as well as the economic outcomes. The amendment used complemented the high moisture content and low C:N ratio of the fresh cow feces.

Studying the temperature pattern of composting treatments revealed the fact that in trial 1/farm 1, a much faster rate of composting took place possibly due to the lower ratios of CF:PS; however an unfinished composting process was observed in treatments executed in trial 1/farm 2 since the composting process finished above ambient temperature. Moreover, in the latter farm the initial temperature increased to a higher level. These high temperatures of 70°C or 80°C could have occurred due to more air ventilation (with sufficient oxygen and not enough moisture content). Besides, this high temperature (notably in treatment A) can be due also to the high N concentration of the starting mixture (lower C:N ratio) (Van der Wurff et al., 2016). The differences in management, location of the boxes and the construction of the compost box might explain the larger fluctuations of temperature in farm 2. The composting process on the experimental farm (farm 1) was more controlled than the practical farm (farm 2).

In trial 2 more fluctuations in temperature through the composting period was observed, which was likely caused by the higher CF:PS ratio used in trial 2 compared to trial 1. As a consequence, the pile temperature remained high at the end of process in week 4. The extension of composting period with four more weeks caused a further decrease of temperature, reaching a final temperature close to the ambient level.

Overall, temperature profiles of the executed treatments in trial 1 showed that if the addition of dry material is too little the process will take longer than four weeks to reach a stable and mature end product. If the addition of dry amendment is too much, reaching DM contents more than 30% at the start, the temperatures could rise during the composting process and higher losses of organic matter can occur.

In a practical situation where a small composting box of bamboo was used (farm 2), it appeared that dry weight loss, N loss and OM loss were relatively higher than in a composting unit with compartments (farm 1). This could likely be attributed to the better management of composting practices in farm 1 in terms of the size and material of compost units and boxes, ventilation and turning practices (Van der Wurff et al., 2016; Parkinson et al., 2004). Accordingly, the higher P loss in farm 1 compared to farm 2 could probably be due to the more frequent turning schedules in this farm (Parkinson et al., 2004). In this study, substantial losses of P could be attributed to sampling errors since P is not volatile and degradable. P losses ranged between 20% to 42% in the study of Tiquia et al. (2002) with similar mixture properties and composting temperature.

The reduction in moisture content showed that composting is a promising option for dairy farmers interested in reducing the weight and volume of raw cattle feces, and producing a low volume of stackable compost which is easier to handle and transport.

The dry weight losses were higher in farm 2 while the moisture loss was not proportionate to that during trial 1, which could be due to the higher losses of nutrients and ultimately led to a lower DM content of the final compost in farm 2.
The DM content of the initial mixture was higher in trial 2 than trial 1, which could be mainly attributed to the pre-drying treatment before the composting started. Consequently, moisture losses in trial 1 were slightly higher than trial 2.
Results showed that composting, regardless of mixing ratios, caused significant nutrient losses. The N loss found in this study was comparable to the N loss reported by Tiquia et al. (2002), which was ranging between 37% and 60% (with almost similar mixture properties). Moreover, the C:N ratio of the initial mixture ranged from 7:1 to 11:1. To minimize the nitrogen loss it has been advised to prepare composts with C:N ratios between 25:1 and 35:1 (Van der Wurff et al., 2016; Michel Jr et al., 2004).
The effect of higher ratios of CF:PS and extended time of composting was also examined in some treatments of trial 2. Higher losses of N and P were observed at the end of week 8 while the DM content increased. The average N losses in trial 2 were lower than in trial 1. Comparing the two trials in this study showed similar losses of organic matter (on average).
The study showed that the major variable costs of composting was related to the dry amendment and as a result the potential cost price is correlated with the ratio of CF:PS where postal was considered to be purchased at market prices. Overall, increasing the CF:PS ratio which means a lower postal input, resulted in lower cost prices of the compost. Extension of the composting process by increasing the composting time increased the labour costs and resulted in a higher cost price. On the other side, the improved quality of the final compost (in terms of the higher DM content) may increase the cost-effectiveness of extended treatments if the compost quality is important to compost buyers and when they are prepared to pay a higher price.
In general, these results suggest that reducing the amount of amendment material and diminishing the length of the composting period can reduce the cost price of compost, but may affect the quality of the final compost product. In addition, a higher quality of compost should be rewarded with a higher price to compensate for higher production costs. A further important implication is that the cost price in reality will be even higher than those we estimated in this study as no fixed costs like depreciation of the investments are taken into account. Moreover, in case of using family labour, the family will be paid the minimum wage. In this situation if farmers get a sale price that is equal or above the cost price for the end product, they could earn extra income.

5 Conclusions

This study showed that composting of cattle feces with amendment materials (postal) significantly reduced the volume, weights and moisture content of input materials, which resulted in a dry compost product that is easier to handle and transport. Composting also resulted in large losses of N and P, but due to the reduction in moisture, the nutrient content of the final compost was similar to the mixture of initial input materials.

Using a higher amount of amendment material (postal) relative to cattle feces was shown to result in a final drier compost product with higher nutrient contents, but with a higher cost price compared to the compost produced when using less amendment material.

When a short duration of composting is desired to get stable relatively dry compost (end product reaching ambient temperatures), use of more postal (lower ratios of cattle feces and postal mixture) is recommended. In this case, a mixture of cattle feces with postal in the ratio of 3:1 indicated the best performance. When composting for a longer time than 4 weeks is not a problem, prolongation of the composting time to eight weeks resulted in more stable compost when cattle feces is mixed with low amounts of postal. The amount of postal to be added to get stable compost after 4 weeks depends also on the moisture content of the postal. If the postal is very dry, less amount of postal needs to be added than when the postal is more moist.

From the results obtained, it is recommended to farmers to implement a sound operation management of composting process, extend the composting period to 7-8 weeks when low amounts of dry amendment is available and while taking into account the cost-effectiveness of composting due to additional labour costs.

One major disadvantage of composting only cattle feces is that liquid fraction is mostly discharged, causing major losses of mineral nitrogen and potassium.

For future studies, it is recommended to increase the number of treatments and replicates to get higher accuracy in determining the best optimal ratio. Besides, mixing of composting material is a critical factor so that the samples homogeneity is high and represents the actual mixture properties.

Regarding the economic analysis, it should be taken into account that only the cost price of compost is calculated based on variable costs. This cost price is very much determined by the costs of the dry amendment and labour costs. The profitability of composting will be much determined by the market price for the end products and the demands of the market regarding the quality and characteristics of the end product. If family labour is used and has no alternative earning options then composting of cattle feces can be profitable already at relatively low market prices for the compost.

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