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Addition of cattle manure to sheep bedding allows vermicomposting process and improves vermicompost quality

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ABSTRACT

Animal waste is usually a good substrate for vermicomposting. However, numerous animal husbandry systems use bedding that consists primarily of lignocellulosic substrates, which hinders earthworm and microorganism's development and thus, the entire bioconversion process. One possible solution is to mix the used bedding with other waste materials that are more amenable to earthworm ingestion and can provide better conditions for earthworm population growth. Here, we have aimed to examine the effectiveness of such procedure by mixing rice-husk-based sheep bedding with cattle manure in different proportions (0%, 25%, 50%, 75% and 100%). We have carried out vermicomposting experiments in benchtop vermireactors inoculated with 0.88 kg of dry matter (sheep bedding + cattle manure). Data used in the Principal Component Analysis were the multiple vermicomposting variables (i.e., EC; pH; HA/FA and C/N ratios; P, K, cellulose, and hemicellulose content). The effect of the treatment on earthworm count was analyzed with ANOVA. We have observed that the addition of at least 25% of cattle manure to sheep bedding allows vermicomposting process but it is necessary 148 days to obtain a stabilized vermicompost. However, increasing the proportion of cattle manure to sheep bedding, the vermicomposting time decreases proportionally to 94 days. We concluded that vermicomposting can be considered a bioprocess to stabilize rice husk after being used as sheep bedding.

1. Introduction

The use of water for cleaning the animal houses is increasingly criticized, making it necessary only in situations where there is risk of contamination as lactating cows (Rowbotham and Ruegg, 2015) or maternity sectors (Meadows et al., 2015). In the case of animals in feedlot finishing phase, the scraping of the wastes is preferable, and considering the possibility of bedding use, which allows to accumulate the manure for more than one fattening cycle.

The use of bedding in sheep production systems brings benefits such as welfare (Teixeira et al., 2015a), reduction of problems with copper toxicity (Day et al., 2006), the best growth performance and the quality of the meat produced (Aguayo-Ulloa et al., 2014; Teixeira et al., 2015b). The factors mentioned above are considered the most important to making decisions on the choice of the material to be used as bedding not considering the degradability characteristics of the material upon its submission to the stabilization bioprocesses to be adopted later.

In sheep husbandry, the use of rice husk as bedding is becoming increasingly common, especially in regions where rice husk is a major byproduct of agricultural practices, with little other practical use, such as in southern Brazil (Corrêa et al., 2009). Rice husks and other plant-based bedding materials (e.g., sawdust or wood shavings) offer several advantages, including ready absorption of manure (Honeyman and Harmon, 2003; Borhan et al., 2014), low risk of pathogen spread (Waltemyer et al., 2014; Fávero et al., 2015), and particularly in the case of rice husks, ease of acquisition (Wolf et al., 2010; Teixeira et al., 2013). Unfortunately, the rice husk also presents a considerable disadvantage in being resistant to degradation considering the stabilization process after the removal from the animal husbandry. This recalcitrance is the result of generally high lignocellulose content in plant-based bedding (DeAngelis et al., 2011; Loow et al., 2015, 2016), as well as the additional presence of silica in rice husks (Corrêa et al., 2009). Previous studies on bio-processes for stabilization of sheep bedding by Costa et al. (2015) and Cestonaro et al. (2015) have reported that adding 50% or more cattle manure to composting and anaerobic co-digestion

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improves the quality of the final product (compost, biogas and biofertilizer, respectively). However, the machinery required for frequent turnings in the composting process and the cost of the digester in the anaerobic co-digestion process could be a limitation for these technologies adoption. In this sense, vermicomposting could be a third option for stabilization of this material.

Vermicomposting has been proposed as a viable and cost-effective method to bioconvert rice-husk when mixed and blended with easily degradable substrates such as market refused fruit (Lim et al., 2012) and cow manure (Antoniolli et al., 2009; Shak et al., 2014). However, it is not common to find information about the performance of the vermicomposting process of rice-husk after its use as bedding in animal husbandry. In this situation some characteristics of the animal bedding such as sheep bedding can limit the development, quantity, and decomposition action of the earthworm (*Eisenia fetida*), such as its high electrical conductivity (Molina et al., 2013) and the emission of toxic gases, such as ammonia (Suthar, 2007, 2010). Thus, sheep bedding requiring a pre-treatment before its submission to the vermicomposting process (Garg et al., 2005; Coulibaly and Bi, 2010).

In the present study, we have aimed to evaluate the efficiency of sheep bedding vermicomposting process using *Eisenia fetida* earthworms and the quality of vermicompost when blended with cattle manure in different proportions. To do so, we assessed both vermicompost quality and earthworm development through a wide range of variables using multivariate statistical techniques such as principal component analysis (PCA). Our results are expected to contribute to more efficient treatment and disposal of used livestock bedding, thus improving animal husbandry practices.

2. Materials and methods

2.1. Earthworms, sheep bedding, and cattle manure

Adult earthworms (*Eisenia fetida*) were obtained from a vermicomposting farm located in Boa Vista da Aparecida, Parana, Brazil. Sheep bedding used for approximately 45 days was taken from a feedlot located in Cascavel, Parana, Brazil. The used bedding basically consisted of rice husks mixed with sheep dung and urine. Cattle manure was obtained from a feedlot located in Cafelândia, Parana, Brazil. Detailed characteristics of the sheep bedding and the cattle manure are shown in Table 1.

Table 1
Chemical characteristics of the sheep bedding and the cattle manure used in the vermicomposting process.

Parameters	Sheep bedding (feeding I)*	Sheep bedding (feeding II)**	Cattle manure
pH	8.82	8.76	8.74
EC (dS m^{-1})	3.57	0.84	1.31
Carbon (%)	40.6	42.1	33.2
TKN (%)	2.00	2.42	2.70
Potassium (g kg^{-1})	6.88	3.32	6.00
Phosphorus (g kg^{-1})	7.39	8.03	6.24
Ash (%)	24.2	25.7	39.3
Cellulose (%)	25.3	18.6	11.3
Hemicellulose (%)	22.2	20.7	23.8
HA/FA	0.98	1.29	1.52
C/N	20.0	17.0	12.0

EC, electrical conductivity; TKN, total Kjeldahl Nitrogen; HA/FA, humic acids/fulvic acids ratio.
C/N, carbon/nitrogen ratio.
* Sheep bedding after pre-composting.
** Sheep bedding after being washed.

2.2. Experimental set-up

We constructed 20 horizontal bench vermireactors ($0.15 \times 0.28 \times 0.40$ m; height $\times$ width $\times$ length) from OSB (Oriented Strand Board). Vermireactors had perforated flooring, covered with a fine nylon mesh. The experiment consisted of five treatments, each comprising 0.88 kg of waste materials that differed in sheep bedding to cattle manure ratios: 0:100 (CM_{100}), 25:75 (CM_{75}), 50:50 (CM_{50}), 75:25 (CM_{25}), and 100:0 (CM_0). The top of the vermireactors was covered with another fine mesh screen to prevent the worms from escaping, and the entire apparatus was suspended 0.05 m above the bench to enhance gas exchange.

Sheep bedding and cattle manure were pre-composted in separated windrows for 25 days, with temperature and moisture checks and frequent turnings before being fed to the vermireactors in two stages (feedings I and II). In feeding I, 50% of the waste material (0.44 kg) and 15 earthworms were deposited per vermireactor. Feeding II occurred 40 days later, when the other 0.44 kg were deposited without adding any earthworms.

After feeding I, cattle manure was frozen to maintain its characteristics. However, having noticed that there was 100% earthworm mortality in the CM_0 treatment, we decided to wash the pre-composted sheep bedding before using it in feeding II. Therefore, the pre-composted sheep bedding was placed on a suspended bench with a perforated bottom in order to leach the soluble salts. Throughout the experimental period, waste materials were dampened to maintain 75% moisture content. The vermicomposting process was monitored until the wastes were stabilized (ash $\geqslant$ 45%) as described by Singh et al. (2004) or when the ash content were stabilized.

2.3. Chemical analysis and earthworm count

We collected homogenized samples from both feedings on day 0 (when earthworms were added) and at the end of the treatment.

Electrical conductivity (EC) and pH were determined from samples suspended in distilled water at a proportion of 1:10 (m/w). Ash content was determined following APHA et al. (2012). Samples were burned in a muffle furnace for 12 h at 550 °C to determine carbon (C) content, following the methods of Cunha-Queda et al. (2003). Chemical fractionation of organic matter and calculations of the humic acid (HA)/fulvic acid (FA) ratio were performed according to Benites et al. (2003). We then used a Kjeldahl distiller to determine the total Kjeldahl nitrogen (TKN) concentration, following Malavolta et al. (1997). The contents of C and TKN were then used to determine sample C/N ratios. Cellulose and hemicellulose concentrations were obtained from neutral detergent fiber and acid detergent fiber content, determined by the previously described sequential method (Campos et al., 2004). The dry-extraction method (Alcarde, 2009) was used for obtaining phosphorus (P) and potassium (K). Subsequently, P content was determined with a model 700 Plus spectrophotometer (Femto, Brazil), following previously described procedures (Malavolta et al., 1997), and K was determined using flame photometry in a model DM-62 photometer (Digimed, Brazil).

Earthworms were counted once at day 60 and again at the end of the treatment. Counts were conducted by depositing vermireactor contents onto a plastic tray and removing the worms of each treatment.

2.4. Experimental design and statistical analysis

The experimental design was completely randomized, with five treatments and four replications per treatment, totaling 20 experimental units.