Journal of Environmental Management 181 (2016) 443–448

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Performance of four stabilization bioprocesses of beef cattle feedlot manure

Mônica Sarolli Silva de Mendonça Costa*, Higor E.Francisconi Lorin, Luiz Antonio de Mendonça Costa, Taiana Cestonaro, Dercio C. Pereira, Francieli H. Bernardi

Research Group on Water Resources and Environmental Sanitation, Western Parana State University, Agricultural Engineering Graduate Program, Rua Universitária, 2069, Jardim Universitário, 85.819-110, Cascavel, Paraná, Brazil

ARTICLE INFO

Article history:
Received 1 September 2015
Received in revised form
14 May 2016
Accepted 1 July 2016

Keywords:
Composting
Vermicomposting
Anaerobic digestion
Static windows

ABSTRACT

The biological stabilization of beef cattle manure is crucial for promoting sanitation in feedlot pens. This study compared the performance of composting, vermicomposting, static windrows, and anaerobic digestion for stabilization of beef cattle feedlot manure based on the degradation of organic matter, nutrient retention, and stability of the final product in each process using uni- and multivariate analysis. The cluster analysis showed that composting and vermicomposting were the most similar processes. The principal component analysis showed that the more oxidative processes (composting and vermicomposting) degraded beef cattle feedlot manure more effectively (up to 45%) than static windrows and anaerobic digestion. Stabilization processes did not affect the amount of phosphorus, whereas potassium losses ranged from 3% (anaerobic digestion) to 30% (static windrow) and differed significantly across processes. Electrical conductivity decreased only in static windrow (30%). A decrease in the C/N ratio were observed in all processes, but the reduction was smaller in static windrow (5%). Larger reductions in C/N ratio were associated with greater increases in the humic to fulvic acid ratio. Composting and vermicomposting processes more effectively degraded beef cattle manure and produced stable organic fertilizers. Anaerobic digestion more effectively retained macronutrients (N and K) and converted organic N to ammonium. The use of static windrows is the least effective bioprocess for the stabilization of beef cattle feedlot manure.

1. Introduction

The biological stabilization of beef cattle manure is crucial for promoting sanitation in feedlot pens. The selection of the appropriate stabilization process depends on several factors, including economic considerations, farm characteristics, and the equipment available for each method. Our purpose with this research is to insert other criteria for the decision taking based on the degradation of organic carbon, the retention of nutrients, and the quality of the final product for selecting the most appropriate stabilization process.

The main biological stabilization processes of beef cattle feedlot manure include composting (COM) (Larney and Hao, 2007; Costa et al., 2015), vermicomposting (VER) (Lazcano et al., 2008), and anaerobic digestion (AD) (White et al., 2011; Costa et al.,2013; Costa JR. et al., 2015). Nevertheless, manure is usually stacked by feedlot cattle breeders in open fields for an extended period of time for subsequent spreading. In this procedure, called static windrow (SW), waste is exposed to weather and degradation occurs in an uncontrolled manner, usually attracting vectors and promoting slurry formation (Riaño et al., 2011). Thus, the final product has low nutrient content due to leaching and may be unstable depending on exposure time (Lazcano et al., 2008).

In aerobic processes (COM and VER), the degradation of organic matter is facilitated by temperature (COM) and earthworm activity (VER). Thus, carbon losses are higher and the physicochemical properties of the final product (compost or vermicompost) such as cation exchange capacity (CEC), adsorption capacity (q), and humic acid/fulvic acid (HA/FA) ratio are improved, resulting in a stable fertilizer. Thus, compost and vermicompost are excellent soil conditioners that improve the physical and biological properties of soil (Mohee and Soobhany, 2014).

* Corresponding author.
E-mail address: monicasarollisilva@gmail.com (M.S.S.M. Costa).

http://dx.doi.org/10.1016/j.jenvman.2016.07.003
0301-4797/

In the anaerobic digestion (AD) process, degradation of organic matter occurs in the absence of oxygen. Thus, the intensity of organic matter degradation is lower in AD than in oxidative processes (Kalemelawa et al., 2012). Conversely, the main advantages of AD include the conversion of organic nitrogen to ammonium ion and because it is an in-vessel process, greater nutrient retention (Tambone et al., 2010). Thus, fertilizers produced by AD are an interesting source of readily available nutrients to plants, mainly N.

Because many converging factors influence the choice of method for the stabilization of beef cattle feedlot manure, multivariate tools such as cluster analysis and principal component analysis are useful to obtain a more conclusive answer.

Submitting at the same time the beef cattle feedlot manure to four stabilization bioprocesses, we intend to compare their performance in transforming a pollutant raw material into a high quality organic matter. In recent literature it is commonly found papers that demonstrate the advantages of each process isolated or that evaluate two processes at the same time, mainly composting followed or not by vermicomposting (Fornes et al., 2012; Soobhany et al., 2015; Hanc and Dreslova, 2016).

This study aimed to compare the performance of composting, vermicomposting, static windrows, and anaerobic digestion for stabilization of beef cattle feedlot manure based on the degradation of organic matter, nutrient retention, and stability of the final product in each process.

2. Material and methods

2.1. Data treatment

Beef cattle feedlot manure was used to compare the performance of COM, VER, SW, and AD processes. The four stabilization processes were analyzed using mass balance or percentage of variation considering the difference between the beginning and end of the processes.

For the variables total organic carbon (TOC), oxidizable carbon (OxC), organic matter (OM), dry matter (DM), total Kjeldahl Nitrogen (TKN), ammonium ($N\text{-}NH_4^+$), nitrate ($N\text{-}NO_3^-$), Phosphorus (P) and potassium (K) we used the following equation:

$$Mass\ Balance(\%) = \frac{\left[\left(DM_{final} * C_{final}\right) - \left(DM_{initial} * C_{initial}\right)\right] \times 100}{\left(DM_{initial} * C_{initial}\right)} \quad (1)$$

In which:

DM_{inital}: Dry matter in the beginning of the process.
$C_{initial}$: Variable concentration in the beginning of the process.
DM_{final}: Dry matter at the end of the process.
C_{final}: Variable concentration at the end of the process.

For the variables electrical conductivity (EC), lead adsorption capacity (q Pb), cadmium adsorption capacity (q Cd), humic acids (HA), fulvic acids (FA), carbon/nitrogen ratio (C/N), humic acid/fulvic acid ratio (HA/FA), and cation exchange capacity/carbon ratio (CEC/C) we used the following equation:

$$Variation(\%) = \frac{\left(C_{final} - C_{initial}\right) \times 100}{C_{initial}} \quad (2)$$

In which:

$C_{initial}$: Variable concentration in the beginning of the process.
C_{final}: Variable concentration at the end of the process.

A positive (+) balance or variation indicates percentage increase, whereas a negative (−) balance or variation indicates percentage reduction in the variable during the stabilization process.

2.2. Origin and description of waste

The composting experiment was conducted using cattle manure (feces and urine) collected from a loose housing sheds located in Santa Tereza do Oeste, state of Paraná, Brazil. Manure management was conducted by scraping manure out of feedlot pens. Animal diets consisted of 60% forage (corn silage) and 40% concentrate (ground bran and mineral supplement).

2.3. Stabilization bioprocesses

COM was done on a covered, waterproof composting area. Five windrows were formed with an initial weight of 150 kg DM of manure. Turning and moistening were performed weekly and moisture content was kept at 60%. Windrow and ambient temperature were monitored daily until windrow temperature was equal to ambient temperature (126 d). The thermophilic phase was reached, which ensured the efficiency of the composting process (Bernal et al., 2009; Kiehl, 2010).

For the SW process, five windrows were formed on an uncovered (i.e., exposed to rainfall), waterproof composting area. Each windrow had an initial weight of 157 kg DM of manure. Windrows were not turned or mixed in the 126 stabilization days. In this stabilization process, manure was only raked, simulating a practice commonly adopted by cattle farmers in the region.

VER was conducted in five 0.15 × 0.28 × 0.40 m (height × width × length) horizontal wooden reactors supplied with 0.44 kg DM manure. For earthworm inoculation, 5-mm poly mesh bags filled with 0.3 kg natural matter of stable vermicompost were used as a refuge, which enabled 15 *Eisenia fetida* per reactor to remain sheltered until the conditions in the manure were favorable.

Poly mesh bags and their contents were removed from reactors after worms had left the refuge. Manure moisture content was kept at 70–80% during the vermicomposting process. At the end of the process (90 d), 175 worms (adults and juveniles) and 86 eggs were found per reactor on average, which indicates that worms multiplied and successfully produced vermicompost.

AD was performed in a batch system using five experimental-scale digesters. Digesters were supplied with 0.36 kg (DM) of manure and 4.8 L of water, totaling 6 L of substrate and 6% total solids.

The burning of biogas started after the biogas became available for combustion, which indicates the occurrence of anaerobic digestion with production of methane. The constant reduction in biogas production, even with an ambient temperature around 25 °C, was used to consider the end of the stabilization process (126 d).

2.4. Analytical methods

Compost samples were collected from each experimental unit and stored at −4 °C to preserve their original characteristics. EC and pH were determined in a suspension of sample in distilled water (1:5 m/v) for COM, VER, and SW samples, according to the methodology proposed by Tedesco et al. (1995), and in undiluted samples for AD samples (APHA, 2005).

Except for pH and EC, all samples were dried at 50 °C in a forced air oven up to constant mass and ground in a grinder for analysis. All results were corrected to dry basis (105 °C).

OM was determined by loss-on-ignition in a muffle furnace at 550 °C. TOC was estimated by dividing the volatile solid content by