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STABILIZATION OF CONFINED BEEF CATTLE MANURE: CHARACTERISTICS OF PRODUCED FERTILIZERS

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ABSTRACT: The growing demand for animal protein is directly related to the feedlot system of animals and their assumptions, such as the waste management. The characterization of the final products becomes an important factor in decision making by one or by other process. The objective was highlight characteristics that fertilizers present due to the used of stabilization process, by the principal component analysis. For the manure stabilization we realized three aerobic processes, composting, vermicomposting and natural decomposition, and one anaerobic, the anaerobic digestion. These processes produced the compost, the vermicompost, the decomposed manure and the biofertilizer. Fertilizers produced were analyzed by means of seventeen chemical and physic-chemical parameters. The main differences are related to stability and organic matter content. The compost is more stable fertilizer and decomposed manure is the worst. The vermicompost is presented as the best option to adsorb cadmium and lead. The biofertilizer has the lowest values of pH, CEC and adsorptive capacity of heavy metals (Cd and Pb). The decomposed manure in presence of precipitation, and the vermicompost, with significant irrigation, generates fertilizers with smaller source of potassium.

KEYWORDS: biofertilizer, cattle manure, compost, vermicompost, stability.

INTRODUCTION

In recent decades the animal husbandry became to employ the increased population of animals. This is due to the models of production and the need to increase the profitability of the systems, as is the case of cattle confinements.

By concentrating cattle in confinement and enhance their food have occurred intrinsic and inevitable consequences as the largest generation and concentration of high pollution potential waste into smaller areas (ORRICO JUNIOR et al., 2012). Intense and concentrated livestock industry activity generates vast quantities of biodegradable waste which must be managed under the appropriate practices to avoid negative impacts on the environment (BERNAL et al., 2009; LUO et al., 2014).

There are two fundamental assumptions regarding waste management and its use as a fertilizer, do not dispose waste in its original form and not dispose on the ground without any criteria. Therefore, care is required to use organic waste as fertilizer (FIGUEIREDO & TANAMATI, 2010).

The composting technique as waste management strategy shows interesting as suitable option for the production of fertilizers with economic and environmental gains (BERNAL et al., 2009; LUO et al., 2014). There is great interest in composting as means of waste management generated in confinements (HE et al., 2013).

LAZCANO et al. (2008) recommend composting and vermicomposting process to reduce the potential for pollution and waste stabilization of confined beef cattle. The worms used in the vermicompost contribute to the degradation and stabilization due to fragmentation of waste, allowing greater surface area exposed to attack by microorganisms (DORES-SILVA et al., 2011; FORNES et al., 2012).

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Unlike aerobic processes, anaerobic digestion is a stabilization process that occurs in the absence of oxygen. The use of anaerobic digestion using biodigesters contributes to integration and sustainability of agricultural activities, converting the manure into two energy sources, biogas and biofertilizer (QUADROS et al., 2010; ORRICO JUNIOR et al., 2012).

The quality of the organic fertilizer produced by the stabilization processes can be established in terms of stabilization, maturation and potential of agronomic use (BERNAL et al., 2009). QUIRÓS et al. (2014) comment on the importance of establishing parameters that guarantee stability and quality of stabilized fertilizers. The evaluation of humification level of the organic matter is an agronomic criterion for final quality product.

The value of an organic compost increases when increases the ratio HA / FA (COSTA et al., 2015) and CESTONARO et al. (2015) found that there is better quality in biofertilizers when the ratio HA / FA increases. CESTONARO et al. (2015) comment that although polymerization index (HA/FA) is most commonly used in composting studies, the results of this index are in agreement with the observations made by other authors who used spectroscopic techniques to evaluate the transformations of organic matter during anaerobic digestion.

Although several parameters are already suggested as indicators of stability of the compost or vermicompost, and some are widely employed, it is not easy to establish the stability of organic fertilizers based on only one parameter (COSTA et al., 2015). Accordingly, an integrated approach between the parameters is recommended by the authors to better approach the determination of stability and maturation of the compost produced.

The characteristics of produced fertilizer from cattle beef manure may differ due to the type of stabilization process, with more or less stability or agronomic potential. In addition to the characterization of the final product, become an important factor in decision making by one or other stabilization process. In this sense, it is aimed, through the ACP multivariate technique, demonstrates the characteristics that produced fertilizers present according to the employed stabilization process.

MATERIAL AND METHODS

Origin and description of manure

Waste used in the production of four fertilizers was the manure (dung and urine) of cattle raised in *loose housing* confinement system located in Santa Tereza do Oeste - PR. This system performs management with scraping the manure to the external side of the pickets, where the waste was obtained. The animals' diet consists 60% of roughage from whole corn plant silage, and 40% of concentrate, containing grain bran and mineral supplement.

Compost production

The compost was obtained from the composting process. Five windrows were conducted in a composting area with waterproof floor and coverage. Each windrow consisted of 500 kg of cattle manure in fresh matter (FM) or 150 kg of dry matter (DM).

The turning and moistening, maintained at 60% in the composting windrows were performed weekly. The temperature of the windrows and the environment was measured every day until the end of the composting process, when they equaled the two temperatures at 126 days. Initially the thermophilic phase was obtained and ensures efficiency in conducting the composting process (BERNAL et al., 2009; KIEHL, 2010).

Manure decomposed production

The decomposed manure was obtained from the natural process of decomposition. Five windrows of manure were installed in a composting area with waterproofed floor without coverage, or susceptible to rainfall. Each windrow consisted of 500 kg (FM) or 157 kg of DM. During 126 days of decomposition process, there was no management intervention in the windrows. In this situation, the manure found huddled together, simulating a practice commonly adopted by cattle farmer in the region.

Production of vermicompost

The vermicompost was produced in the vermicomposting process. For installation of this process were made wooden horizontal reactors with dimensions of 0.15 x 0.28 x 0.40 meters of height, width and length, respectively. Five reactors were supplied with 1.85 kg of cattle manure (FM) or 0.44 kg (DM). For the inoculation of earthworms, bags made of black polyethylene screen with opening of 5 mm filled with 0.3 kg (FM) of stabilized vermicompost were used as a refuge. This way allowed the 15 earthworms of the species *Eisenia fetida* stayed sheltered in the refuge until the conditions of the waste permitted their survival and development.

After the worms have left the refuge, this was removed with all the contained within material. The humidity of the manure was maintained at 70% throughout the process of vermicomposting. At the end of the process, at 90 days, it was found, on average, 175 earthworms, between adults and juveniles, and 86 eggs per reactor. These characteristics showed the proliferation and activity of earthworms in manure, producing vermicompost.

Biofertilizers production

The biofertilizer was obtained after the process of anaerobic digestion in batch feed system. Each of the five digesters consisted of three PVC cylinders of the same height (500 mm). The two cylinders attached to the base expanded PVC have a diameter of 250 and 150 mm. The loose cylinder capsized inside the biodigester is the gasometer; this is sealed with PVC cap and has a metal register coupled to the burning of biogas. The gasometer of 200 mm floats on the water seal, outside the anaerobic chamber storing the produced gas (Figure 1).

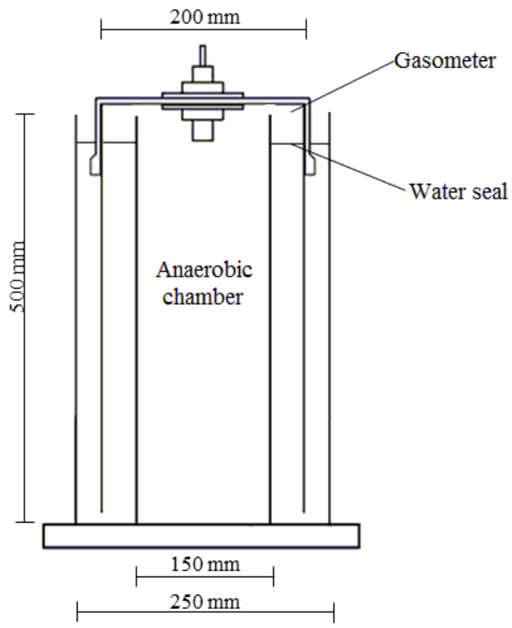

FIGURE 1. Schematic sketch of the biodigester used in the anaerobic digestion test.

The useful volume in the chamber of anaerobic biodigester is six liters. For each biodigester, were added 0.36 kg (DM) or 1.2 kg (FM) of manure and added 4.8 L of water, totaling six liters of substrate. With these ratios, it was obtained 6% total solids in supply.

The biogas burning was carried out since when the combustion was possible. This indicates the prevalence burning of methane gas, ensuring the occurrence of anaerobic digestion. The diminution of biogas production, even with the ambient temperature around 25 °C, was used to stop the hydraulic retention time, that is the duration of the process. Biofertilizer was sampled after 126 days of the anaerobic process.

Analytical methods

The compound samples were taken from each experimental unit stored in refrigerator (- 4 ° C) in order to maintain the original characteristics. The determination of pH and electrical conductivity (EC) of the solid fertilizers, compost, decomposed manure and vermicompost were determined in the aqueous extract at a ratio of 1:5 (0.01 kg of sample to 0.05 L of water) according to the methodology proposed by TEDESCO et al. (1995). For biofertilizer, pH and EC were determined in crude liquid sample, undiluted (APHA, 2012).

With the exception of samples used for the determination of pH and EC all the others were dried at 50° C in a forced air circulation oven to constant mass and grounded in a mill to the determinations. All results were corrected, and expressed on dry matter (105° C).

The total organic carbon (TOC) was calculated according to Equation 1. By the method of ignition in a muffle furnace at 550 °C was determined by gravimetric, the volatile solids (SV), and ash, as described by CARMO & SILVA (2012). The C/N ratio was calculated from the ratio between the TOC and TKN.

$$TOC(\%) = SV(\%)/\ 1.8 \quad (1)$$

where,

SV= volatile solids = organic matter

The bio oxidizable carbon (Cox) was determined by WALKLEY and BLACK method. The method offers the advantage that only oxidizes the organic compostable fraction of the organic matter (KIEHL, 2010).

The cation exchange capacity (CEC) was determined by titration of the calcium acetate solution with activated carbon using the methodology described by EMBRAPA (2009). The CEC/C ratio was determined between CEC ($mmol_c.kg^{-1}$) and TOC content (%) according to ALCARDE & RODELLA (1994).

Cadmium (q Cd) and lead (q Pb) adsorption capacity were performed on dry samples of fertilizer. Aliquot parts of 0.5 g were immersed for 12 hours in pH = 7 solutions with known concentrations of Cd and Pb. Solutions with and without samples, after filtration, were subjected to detection of Cd and Pb by atomic absorption spectrometry (EMBRAPA, 2009). The difference concentration between the solutions (with and without sample) influence on the adsorption capacity (q) of each produced compost.

The fractions carbon content of humid acids (HA) and fulvic acids (FA) were determined by quantitative method of extraction and fractionation of humid substances described by BENITES et al. (2003). With the concentration of each fraction was possible to determine the ratio HA / FA.

For the determination of Total Kjeldahl Nitrogen (TKN) was used the Kjeldahl distiller after the sulfuric acid digestion of the samples, according to the methodology proposed by MALAVOLTA et al. (1997). For the determination of total phosphorus (P) and potassium (K) was performed digestion in nitro-perchloric acid with external heat source. P was detected on spectrophotometer and K by flame photometry (MALAVOLTA et al., 1997).

Experimental design and statistical analysis

The four produced fertilizers, the compost, the vermicompost, the decomposed manure and the biofertilizer, compose the treatments of this experiment. The five repetitions on each stabilization process composed 20 experimental units.

Principal Component Analysis (PCA) was performed for the interpretation of the relationships between variables, seventeen parameters analyzed, between treatments, four produced fertilizers, and between variables and treatments. The Principal Components (PCs) were extracted from the correlation matrix of the original variables and the standardization of observations with zero mean and variance equal to one. This prevents interference from analyzed parameter units. On selection criteria of PCs was used the percentage explanation of the total variance higher than 70% (FERREIRA, 2011) and the Broken-Stick method when the component eigenvalue is higher than the randomized eigenvalue and generated by the method (JACKSON, 1993).

In order to check the difference between the produced fertilizers in each variable, the average of the analyzed parameters were subjected to the analysis of variance (ANOVA) after the model assumptions to be satisfied, comparison of averages was carried out using the Tukey test at the level of 5% and 1% error probability.

RESULTS AND DISCUSSION

The principal component analysis selected the first two components, PC1 and PC2, which are able to explain 83.6% of the variance data. Fertilizers produced from cattle manure, have taken different positions in Cartesian biplot graph (Figure 2). The graphical interpretation biplot, PC1 and PC2, revealed that the characteristics of the produced fertilizer showed differently on a set of 17 parameters, according to the employed stabilization process.

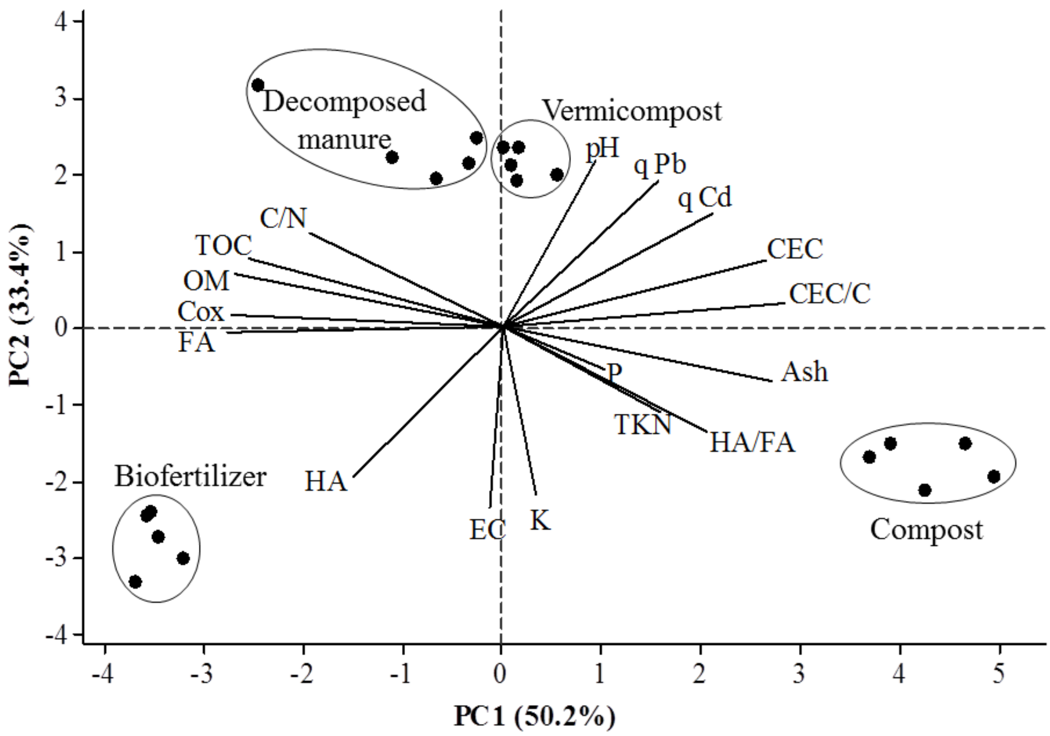

FIGURE 2. Biplot graph extracted from principal component analysis (PCA). Cadmium (q Cd) and lead (q Pb) adsorption capacity, cation exchange capacity (CEC), CEC/C ratio, phosphorus (P), Total Kjeldahl Nitrogen (TKN), HA/FA ratio, potassium (K) , electrical conductivity (EC), humic acid (HA), folic acid (FA), oxidized carbon (Cox), organic matter (OM), total organic carbon (TOC), C / N ratio.

Among the 17 analyzed parameters in the produced fertilizers, 10 were main and composed the first component. The PC1 component is responsible for half (50.2%) of percentage of explanation. From the eigenvector (data not shown) it can be checked the influence of each analyzed parameter in the main components (FERREIRA, 2011).

Thus, it was found that PC1 is composed of two groups of parameters, CEC, CEC/C, Ash, HA/FA and q Cd (positively correlated) and TOC, OM, Cox, FA and C/N (correlated on negative way). The first group mainly gathered parameters of stability and maturity, the second, grouped parameters related to organic matter content.

The graph shows that biplot groups of stability and organic matter parameters go in opposite directions from the center axes (Figure 2). In this sense, COSTA et al. (2015) found that groups of variables containing Ash and HA/FA show opposite directions to TOC, by the PCA in manure composting studies.

The PC1 separated the analyzed fertilizers in three groups. Group 1 is formed by the compost, located on the right end of the PC1 axis having the highest values related to stability and maturity and the lower in organic matter.

Group 2 consists of two products, vermicompost and decomposed manure located in the central area of the PC1 axis. The vermicompost stood on the right side of the axis closer to the stability variables of the decomposed manure which is closer to the parameters related to the organic matter (Figure 2).

Group 3 consists of biofertilizer and is located at the left end of the PC1, opposite to the compost in this axis. That is, while the compost possessed lower values of TOC, OM, Cox, FA and C/N, the biofertilizer showed higher ($p < 0.05$) values in the group of parameters (Table 1). This indicates that the carbon conversion occurred more intensively in the composting process when compared to anaerobic digestion.

TABLE 1. Influential parameters in each principal component extracted by PCA.

Component	Parameters		Compost	Vermicompost	DM	Biofertilizer	Signif.
PC1 50,2%	CEC	$cmol_c.kg^{-1}$	86.4 a	80.7 b	75.8 c	61.8 d	***
	CTC/C	-	24.5 a	20.8 b	19.2 c	15.7 d	***
	Ash	%	36.5 a	30.1 b	28.8 b	28.2 b	***
	HA/FA	-	2.30 a	1.72 b	1.47 c	1.76 b	***
	q Cd	$mg. g^{-1}$	7.02 b	8.26 a	5.46 c	0.71 d	***
	TOC	%	35.3 b	38.8 a	39.6 a	39.4 a	***
	Cox	%	25.5 c	28.8 b	29.7 b	31.1 a	***
	OM	%	63.5 b	69.9 a	71.2 a	71.8 a	***
	FA	$mg. g^{-1}$	23.5 d	29.7 c	33.9 b	37.9 a	***
	C/N	-	12.2 b	16.4 a	15.7 a	15.3 a	**
PC2 33,4%	K	$g.kg^{-1}$	3.31 a	2.56 b	2.35 b	3.31 a	***
	EC	$mS.cm^{-1}$	10.6 b	5.1 c	4.0 d	12.6 a	***
	HA	$mg.g^{-1}$	54.1 b	50.9 bc	49.6 c	66.4 a	***
	q Pb	$mg.g^{-1}$	5.08 b	6.27 a	5.69 b	2.10 c	***
	pH	-	8.6 c	9.2 b	9.6 a	7.6 d	***
PC3	N	%	2.91 a	2.37 b	2.6 ab	2.58 ab	**
	P	$g.kg^{-1}$	11.4 a	9.44 b	11.3 a	10.4 b	***

DM: Decomposed manure. Equal lowercase letters do not differ among them, in line, by the average univariate Tukey test. Significance: *** indicates $p < 0.01$ and ** $p < 0.05$. All parameters expressed in dry matter (105 °C), except pH and EC.

In the process of stabilization of organic matter, part of the initial carbon is metabolized by microorganisms reducing to the simplest forms, CO_2 (DORES-SILVA et al., 2013) or $CH_4 + CO_2$ (SILVA et al., 2012), depending on the means of stabilization, aerobic and anaerobic respectively. The four fertilizers produced, the content of organic matter depended on the means of stabilization. The more supply of oxygen in the manure promoted by turning of the compost, the lower were the TOC content, OM and Cox ($p < 0.01$).

Waste-stabilization processes under two metabolic via, aerobic and anaerobic there were further reductions of carbon and organic matter under aerobic conditions (KALEMELAWA et al., 2012).

Smaller amounts of carbon observed in the compost provided the smaller C/N ratio ($p < 0.05$) (Table 1). The most intense carbon conversion also reflected in the smaller content of the FA fraction ($p < 0.01$) (Table 1). FA fractions reduce due to degradation of simple organic compost such as sugars, fats and carbohydrates, which can easily be metabolized by microorganisms (BERNAL et al., 2009; LÜ et al., 2013).

Biofertilizer showed lower values of CEC and CEC/C ($p < 0.01$) (Table 1). BERNAL et al. (2009) state that increased oxidation of organic matter leads to an increase of the CEC. In this case, the reducing atmosphere, not oxidative of anaerobic digestion gave smaller values of CEC and CEC/C ($p < 0.01$) (Table 1).

Among the stabilization processes, composting stood out due to weekly turning, resulting in greater injection of oxygen in the manure, which promoted higher oxidation. Thus, the compost has the highest CEC, compared to other organic fertilizers ($P < 0.01$) (Table 1).

This feature suggests that the organic colloids of this fertilizer have greater ability to adsorb cations and may give them away or make changes (DORES-SILVA et al., 2013). This ability brings interest to agricultural soils as enhances the adsorption and release of nutrients.

The CEC/C is indicative of stability degree and maturity of organic fertilizer produced (DORES-SILVA et al., 2011). This relationship is more appropriate than the C/N to indicate the degree of stability on organic materials (DORES-SILVA et al., 2011). In this sense, the compost has greater stability and maturation because the composting produced fertilizer with the highest ratio CEC/C ($p < 0.01$).

Researchers suggest maturation indexes based on monitoring of humic substances, HA and FA. Among the proper rates, the ratio HA/FA is one of the best parameters to determine the degree of maturation (KULIKOWSKA & KLIMIUK, 2011). The authors considered that the value of the ratio HA/FA higher than 1.6 indicates a good level of maturation of composts, including animal manure.

It has been found that the final relationships HA/FA of the compost, biofertilizer and vermicompost, 2.30; 1.72; 1.76 respectively attended the minimum value (1.6) to be referred to as matured. The product generated by the decomposition process, decomposed manure presented relation less than the limit, ranking as immature.

By the biplot graph (Figure 2) we verify that the vermicompost is positioned closer to the variable q Pb and q Cd. The higher adsorptive capacity, both cadmium (q Cd) and lead (q Pb), were found in the vermicompost ($p < 0.01$) (Table 1). The end products of the vermicomposting process had the highest capacity to retain these metals in their organizational structures. These features are appreciated when it aims to use these products as metals retention filter in environmental depollution processes.

The PC2 separated four fertilizers into two groups. The first group is formed by biofertilizer and compost, located in the negative region of the axis PC2. These fertilizers showed higher values of K and EC. Group 2 is formed by the two other fertilizers, manure decomposed and vermicompost, located in the positive region of the PC2 axis. This group behaves unlike the group 1, that is, have the smallest values of the variables K and EC.

The smallest value of K and EC was found in the vermicompost and decomposed manure ($p < 0.01$) (Table 1).Vermicomposting process with accentuated watering, as the decomposition, exposit to precipitation provided losses by dragging soluble salts, reducing K and EC of the fertilizers (FORNES et al., 2012). In contrast, fertilizers stabilized in the absence of precipitation, the compost and the biofertilizer showed higher values of K and EC ($p < 0.01$).

The TKN and P were not included in the two principal components (PC1 and PC2). The eigenvectors of TKN and P (data not shown) showed that these variables are in the third and fourth explanation component, PC3 and PC4 respectively. The PCs is not related with the percentage of explanation or the BROKEN-STICK test in the principal component analysis.

CONCLUSIONS

The main differences between the fertilizers produced from confined beef cattle manure are related to stability and contents of organic matter.

The compost is more stable fertilizer and decomposed manure is the worst.

Vermicompost is presented as the best option to adsorption cadmium and lead.

The biofertilizer has the lowest values of pH, CEC and adsorptive capacity of heavy metals (Cd and Pb).

The decomposed manure in presence of precipitation, and the vermicompost, with significant irrigation, generates fertilizers with smaller source of potassium.

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