Physical and chemical characterization of sewage sludge with different proportions of diatomaceous earth[1]

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ABSTRACT

The use of residues for agricultural production is an alternative for the achievement of sustainability. When mixed with diatomaceous earth (DE) from biofuel filtration, sewage sludge (SS) plays an important role as soil conditioning agent. As a result, the objective of this work was to make a DE vermicompost at different proportions: 0; 7.53; 15.06; 22.59 and 30.12% v/v in relation to a SS pre-compost (PC) and gardening pruning residues. The experiment was carried out in 100-L containers in a randomized block design, with 5 treatments and 5 replications, in which *Eisenia foetida* earthworms were used in the pre-composting and vermicomposting processes. After four months, the physical characteristics of the vermicompost were analyzed. It was verified that the diatomaceous earth can be vermicomposted, even when soaked in biofuel oil, at amounts of up to 30.12% v/v, with no visible physical damage to earthworms and plants, and this proportion of DE reduced the concentration of nutrients, but improved the physical properties of the vermicompost, making it an excellent physical conditioner for use as a substrate of plants and fertilization of soils.

Keywords: biosolid; residue recycling; substrate for plants.

INTRODUCTION

As a final product of sewage treatment plants, a by-product called sewage sludge (SS) is generated. This by-product is considered of great agricultural potential due to its physical and chemical attributes (Caldeira *et al*., 2013). Despite its favorable characteristics for agricultural use, it may present pathogens and high levels of heavy metals and toxic organic substances, as well as a characteristic odor, among others (Paredes Filho, 2011).

Vermicomposting is only one of several techniques that can be used to stabilize the SS and provide its use in agriculture. This technique is able to reduce the amount of viable eggs of helminths, using the enzymes and other mechanisms of the digestive process of the earthworms, which confers a result with excellent efficiency (Nascimento *et al*., 2013). In addition to the attempts to make SS feasible in agriculture, CONAMA Resolution 375 indicates criteria and methodologies for the use of this residue, by means of maximum limits and other precautions that must be followed for its correct use (Brasil, 2006).

For the purpose of agricultural use, sewage sludge can be a compost or a vermicompost combined with other wastes, such as diatomaceous earth (DE), which is used in the biofuel filtration process. It is of sedimentary origin, friable and porous with fine granulometry, besides presenting a high capacity to absorb its weight in water, it displays peculiar characteristics that can help in enhancing the physical conditions of a substrate. Although it contains other impurities, its major composition is silica (Souza, 2011). Due to these physical characteristics, it has been widely used in the filtration of biofuels, in which an organic residue soaked in oil is generated by the factories.

To obtain benefits from the well-known applications of sewage sludge in agriculture, the intention was to mix these two residues in order to form a good quality substrate and

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at the same time to contribute to the reuse of these two residues. Therefore, the objective of this work was to evaluate the physical quality of vermicompost obtained from the mixture of sewage sludge, garden pruning residues and different proportions of diatomaceous earth.

MATERIAL AND METHODS

Pre-composting was carried out for seven weeks from September to November in 2014 in a shed in Instituto de Ciências Agrárias (Institute of Agricultural Sciences) at Universidade Federal de Minas Gerais (ICA/UFMG) in Montes Claros, from the sewage sludge originated in Copasa Treatment Plant in the city of Montes Claros, state of Minas Gerais and from plant residues of the University Campus at proportion of 3: 1 v/v, with weekly revolving.

After that, vermicomposting was performed for 5 months, from November 2014 to April 2015, in 100-L plastic containers. The experiment was a complete randomized block design with 5 treatments and 5 replicates, in which different proportions of the diatomaceous earth residue, produced by the filtration of biofuel in Petrobras S/A of Montes Claros, to the pre-compound formed, in the following % v/v ratio: T1 = 0/100; T2 = 7.53 / 92.47; T3 = 15.06/84.94; T4 = 22.59 / 77.41; T5 = 30.12 / 69.88. The mixture with the final volume of the substrate amounted to 80 L. The pot was laid slightly inclined so that excess of water was collected by a container and returned to the substrate.

One kilogram of California red earthworms (*Eisenia foetida*) were added to each container, covered with shade cloth to prevent excessive evaporation, drying of the substrate, and to protect the earthworms from predators in addition to preventing their escape.

The largest proportions of DE (22.59% and 30.12%) caused initial stress in the earthworms because their skin respiration was impaired by the oil contained in the biofuel residue. To lessen this effect and to facilitate the adaptation of the earthworms, a 1-cm layer of the initial pre-compound was added over all experimental units in order to reduce the direct contact of the mixture containing DE soaked in oil with the worms. However, the added layer was counted in the calculation of the ratio between volumes, justifying the fractional values of the treatments. As soon as the pre-compost was added, the worms adapted quickly to it.

The local humidity was measured daily with regular water replenishment in order to provide a suitable environment for vermicomposting so that to maintain humidity close to the water retention capacity indicated by Ricci (1996), in which all excess of drained water returned to the vermicompost. Once a month, this material was manually turned over to prevent damage to the earthworms and to avoid compaction, which hinders aeration and drainage.

After 4 months, a sample of the substrate of each experimental unit was taken to Laboratório de Análises de Resíduos para Aproveitamento Agrícola (Laboratory of Analysis of Residues for Agricultural Utilization) of the UFMG Campus in Montes Claros for the analyzes of water retention curve, through the Richards extractor, at the pressures of 0.0; 0.1; 0.33; 0.5; 0.1; 1; 5 and 15 bar, and analyzes of the organic matter content (OM), total mineral residue, soluble and insoluble mineral were performed by the methodologies proposed by Alcarde (2009). For the apparent density, pH and electrical conductivity, the methods proposed by Tedesco *et al*., (1995) were used. The phytotoxicity of the substrate produced was tested by an experiment similar to the vermicompost experiment in which seeds of cucumber (*Cucumis sativus*) were sown and the visible changes in the aerial part and root growth were evaluated. Table 1 presents the physical and chemical characteristics of the sewage sludge, pre-compost and diatomaceous earth used for the execution of the experiment.

The results achieved in this experiment were submitted to analysis of variance and regression equations were adjusted by testing the significance of the coefficients up to 10% of probability by the test F.

RESULTS AND DISCUSSION

The organic matter content of the substrate decreased by 6.34 dag kg^{-1} as the addition of DE to sewage sludge and pruning residues to vermicompost was increased (Table 2). This reduction can be attributed to a greater decomposition of vegetable oil present in DE. According to Dores-Silva *et al*., (2011), the degree of humification and the chemical nature of the substrates directly influence the speed and intensity of the transformations in the organic matter fraction. Neverthless, the values of organic matter exceeded the minimum threshold of 30 dag kg^{-1}, considered adequate for a vermicompost (Kiehl, 1985).

From Table 2, it can be inferred that the increment in DE in the vermicompost provided an increase in the total mineral residue of the substrate, which varied from 58.83 to

Table 1: Physical characteristics of sewage sludge (SS), pre-compost (PC) and diatomaceous earth (DE)

Parameters[1]	S S	PC	DE
OM (dag kg^{-1})	43,60	43,14	49,56
TMR (dag kg^{-1})	56,39	56,85	50,44
IMR (dag kg^{-1})	35,53	36,67	49,98
SMR (dag kg^{-1})	20,87	20,18	0,46
EC (dS m^{-1})	3,41	4,58	3,28
AD (g cm^{-3})	0,57	0,53	0,68

[1]OM = Organic matter, TMR = Total mineral residue, IMR = Insoluble mineral residue, SMR = Soluble mineral residue, EC = Electrical conductivity, AD = Apparent density.

65.18 dag kg^{-1}. In addition, there was a reduction of the soluble mineral residue from 19.90 to 12.68 dag kg^{-1} and an increase of the insoluble mineral residue from 38.92 to 52.34 dag kg^{-1}. As a result, it was evident that the earthworms had great affinity and fed strongly on DE oil, which accelerated the decomposition and provided the use of some of this carbon in the constitution of its biomass. Furthermore, because it is rich in silica compounds of low solubility in water, DE contributed to the increase of the insoluble mineral residue of the substrate.

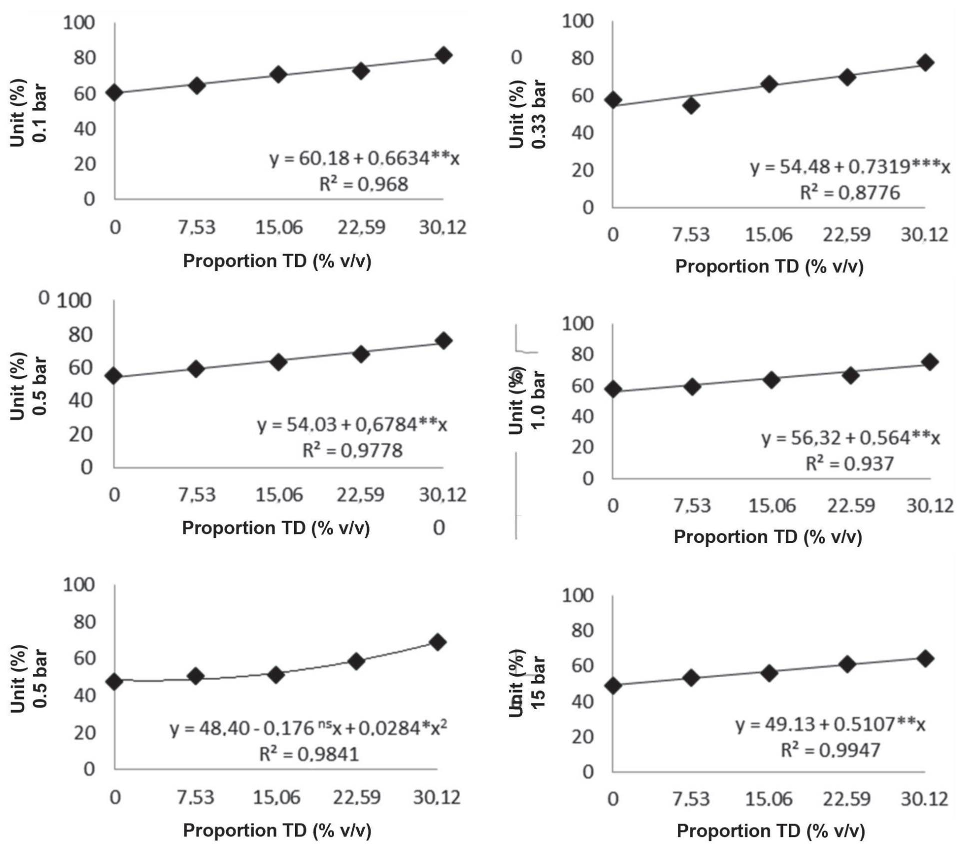
The electrical conductivity (EC) of the substrate decreased from 4.92 to 3.30 dS m^{-1} with the increment by 30.12% v/v in DE in the vermicompost (Table 2). Zibetti *et al*., (2015) state that the rise in the electrical conductivity indicates the mineralization of salts of the organic compounds during the vermicompost process. In this case, as there is a smaller number of elements to be mineralized in TD, the expected indication is that the EC of the formed vermicompost is also reduced. EC values less than 4.0 dS m^{-1} are recommended for plant cultivation with the intention

Table 2: Regression equation adjusted for chemical and physical attributes analyzed in the vermicomposed after addition of different proportions of diatomaceous earth

Attribute[1]	Adjusted regression equations [1]	R^2	CV (%)	VA
OM (dag kg^{-1})	$\hat{y} = 41{,}17 - 0{,}0974^{ns}x - 0{,}0179^{*}x^2 + 0{,}00047^{**}x^3$	0,99	1,51	34,83
TMR (dag kg^{-1})	$\hat{y} = 58{,}83 + 0{,}0975^{ns}x + 0{,}01792^{*}x^2 - 0{,}00047^{**}x^3$	0,99	0,91	65,18
SMR (dag kg^{-1})	$\hat{y} = 19{,}90 - 0{,}0891^{***}x - 0{,}014852^{ns}x^2 + 0{,}000327^{*}x^3$	0,99	1,20	12,68
IMR (dag kg^{-1})	$\hat{y} = 38{,}92 + 0{,}1863^{***}x + 0{,}0327^{\circ}x^2 - 0{,}0008^{*}x^3$	0,99	1,40	52,34
EC (d*S* m^{-1})	$\hat{y} = 4{,}92 - 0{,}0539^{*}x$	0,96	15,90	3,30
AD (g cm^{-3})	$\hat{y} = 0{,}55 - 0{,}0034^{***}x$	0,98	2,80	0,45

[1]OM – Organic matter; EC – electrical conductivity; TMR – Total mineral residue, SMR – Solid mineral residue, IMR – Insoluble mineral residue; AD – Apparent density; VA – Value of the attribute in the vermicompost at the highest DE dose.

[1]ns – Not significant up to 0.10 of the probability by the t test; °, *, **, *** – Significant at 0.10, 0.05, 0.01, 0.001 of probability by the t test, respectively.



*, **, *** significant at 5, 1 and 0.1% of probability, respectively by the t test. ns = not significant.

Figure 1: Moisture retention capacity at 0.1 bar, 0.33 bar, 0.5 bar, 1 bar, 5 bar and 15 bar according to the proportion of diatomaceous earth (DE) added in the vermicompost.

Figure 2: Cucumber cultivation for evaluation of vermicompost phytoxicity produced by sewage sludge and diatomaceous earth.

of avoiding injury to plants. In this case, it is important to add at least 18% DE for EC reduction at a suitable level for plant cultivation. It can be found in the works by Oliveira *et al*., (2002) data evidencing that increasing applications of sewage sludge doses in the soil rise the electrical conductivity.

In relation to the apparent density of the substrate, it decreased from 0.55 to 0.45 g cm^{-3} as DE was incremented in the vermicompost. Therefore, it is observed that DE made the vermicompost a little more porous, favoring the dynamics and retention of water and the gas exchanges of the substrate. This fact may have benefited the biological activity of the substrate, which may also explain the larger reduction in the organic matter verified as he addition of this residue to the vermicompost was increased (Table 2).

However, even considering only the vermicompost of sewage sludge and pruning residues, the apparent density is 0.55 g cm^{-3}, which is considered low. Guerrini & Trigueiro (2004) attributed the reduction of density in substrate cultivated in eucalyptus seedlings containing sewage sludge to the organic matter content found in this residue. In the mixture of DE and vermicompost, the apparent density decreases further due to the even lower density of the former (Table 2).

Figure 1 shows the increase in water retention force by the substrate, which linearly increased as diatomaceous earth was increased in the vermicompost. The increases in water retention capacity were from 60.18 to 80.16% at 0.1 bar, from 54.48 to 76.53% at 0.33 bar, from 54.03 to 74.46% at 0.5 bar, 56.32 at 73.31% at 1 bar, from 48.40 at 68.86% at 5 bar and 49.13 at 64.51% at 15 bar. Thus, the increments in water retention of the vermicompost varied from 15.38 and 22.05% with the addition of 30.12% DE.

In that case, DE may have promoted the raise in microporosity of the substrate, which is the primary responsible for the increase in water retention of vermicompost and DE mixture. Therefore, the benefit of the addition of DE to the vermicompost has become evident, making it an important physical conditioner of the soil, besides an organic fertilizer, and it can also be used directly as a substrate for plant cultivation.

Substrate phytotoxicity was evaluated using the cultivation of cucumbers (*Cucumis sativus*), a plant species listed by the EPA as an important indicator of phytotoxicity (Grant, 1998). Figure 2 shows that none of the cucumber plants presented phytotoxicity, that is, they did not present any apparent damage, but a normal growth with healthy appearance, instead.

CONCLUSIONS

Even soaked in biofuel oil, diatomaceous earth can be vermicomposted with sewage sludge and garden pruning residues in amounts up to 30.12% w/w, with no visible physical damage to earthworms and plants.

The addition of up to 30.12% w/w of diatomaceous earth enhances the physical properties of the vermicompost, making it an excellent physical conditioner for being used as substrate of plants and for fertilization of the soils. In addition, it has been found that the resulting substrate is not phytotoxic at this higher proportion of TD of the produced vermicompost.

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