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Article

Effect of Different Cover Materials in Household Vermicomposting Process

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RESUMO

A gestão adequada dos resíduos sólidos urbanos (RSU) requer mecanismos de controle e fiscalização eficazes devido ao crescente aumento da sua geração. No Brasil, mais da metade dos RSU são do tipo orgânicos. Desta forma, avaliar as possibilidades de tratamento existentes para estes tipos de resíduos (compostagem e vermicompostagem) é de extrema importância, seja do ponto de vista físico, químico, econômico-social e ambiental. Assim, objetiva-se com este artigo a determinação e quantificação de parâmetros físico-químicos do composto orgânico gerado (líquido e sólido) sob diferentes coberturas (serragem, folhas de serapilheira e solo), utilizando composteiras domésticas. Os resultados mostraram que os vermicompostos gerados (líquido e sólido) não sofreram influência significativa da granulometria das partículas de resíduos orgânicos de preenchimento e diferentes tipos de cobertura com relação aos macro e micronutrientes, metais pesados e pH, porém, os mesmos apresentaram características próximas das satisfatórias para uso em adubação.

Palavras-chave: resíduos sólidos; compostagem; composto orgânico; biofertilizante.

ABSTRACT

The management of municipal solid waste (MSW) requires an effective system of control and supervision because of its increasing generation. In Brazil, more than half of the MSW are organic. Thus, evaluating treatment possibilities (composting and vermicomposting) for this waste compound, it is of extreme importance from of the physical, chemical, socioeconomic and environmental point of view. So, the objective of this paper is to quantify physical-chemical parameters of the compost (liquid and solid) in different covers (sawdust,

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leaves and soil), using in the household composting. The results showed that the obtained vermicompost (liquid and solid) did not suffer significant effects of the used particles for filling and different types of cover related to macro and micronutrients, heavy metals and pH, however, those showed satisfactory features for the use in soil fertilization.
Keywords: solid waste; composting; organic waste; biofertilizer.

1. Introduction

As a result of accelerated population growth throughout the world, the huge amount of municipal solid waste (MSW) generated in the urban environment can make more troubles in the management of such waste, since it results in a series of environmental problems (air, water and soil pollution) affecting the health and well being of the population, beyond economic losses.

According to IPEA (2012), in Brazil, more than 50% of the MSW generated are organic materials, which enables the use of the composting technique in order to reduce improper disposal of these wastes, be these domestic, industrial or agricultural, which according to Nunes (2009), allows the stabilization and humification of organic matter in a short time.

There is a technique of composting only with the use of organic waste and in most cases the use of vegetable toppings, known for vermicomposting, which is most widely used for household composting, because the earthworms act in accelerating the process of decomposition of organic waste. They are producers of organic compound called vermicompost or earthworm humus, that second Ricci (1996), serves as a fertilizer for various activities, for example; horticulture, nurseries, fruit and others. This manure, when added to the soil, contributes to the development and plant nutrition and conservation of soil fertility.

The processes of composting and vermicomposting can use both material of vegetable and animal origin, however, so that the compost generated is quality, it is important to use waste rich in carbon and nitrogen, so that when applied to the soil, improve the physical-chemical and biological features. Thus, in order to verify the quality of the organic compost generated, one must be attentive to the quality standards established by Normative Instruction nº 46 of the Ministry of Agriculture Livestock and Supply (MAPA, 2011).

Such processes can be made and used in the own source, for example, in households, known as home composting, being a sustainable action, therefore, decreases the amount of waste that are generated and collected in homes, increasing the useful life of landfills.

About the types of vegetable coverages used in the process of vermicomposting, there are no major studies on their influences to the organic compost generated, which justifies the need to assess its origin, granulometry, quantity and the carbon/nitrogen ratio.

Initial studies on the effect of different types of cover used in the composting and vermicomposting process and chemical evaluation of the biofertilizers generated, especially organic matter are presented by Hervas et al. (1989), Fornes et al. (2012) and Hanc and Dreslova (2016), however, different materials were employed compared to those of this study.

The recycling of household waste is an alternative to the issue of environmental degradation, as well as the production of organic inputs for agriculture, as well as the low contamination by heavy metals and persistent organic pollutants.

Thus, the objective of this article is to determine and quantify the physical parameters (temperature and humidity) and chemical (pH, organic matter and heavy metals) of organic compost produced in households of vermicomposting kind (liquid and solid) evaluating the influence of different vegetation covers (sawdust, leaves and soil).

2. Theoretical Foundation

The accelerated growth of cities, according to Oliveira (2010), as well as industrialization and the capitalist development, is leading the society to a consumption in large scale, generating numerous consequences such as the increase in the generation of MSW without proper control or concern with the environment.

Thus, Maia et al. (2015) affirm that the lack of management of the MSW brings consequences to the environment and to the population, such as, soil and water pollution, in addition to the proliferation of macro and micro vectors of diseases.

For a proper management of the MSW, Poli et al. (2014) reported the importance of consideration of collection, treatment and final disposal of waste, in accordance with the Federal Law nº 12,305 (BRAZIL, 2010), establishing the National Solid Waste Policy (NSWP).

As there is a great generation of organic waste from industrial, house, among others, Loureiro et al. (2007) reported that these residues are sent to landfills, incinerated or disposed, and are not only great concern of municipalities, related to environmental sanitation, as well as waste of nutrients. Thus, the Law nº. 12,305 of NSWP, considers the composting as an environmentally suitable for final disposal of organic waste.

Resolution nº 481 of the National Council of Environment (CONAMA), defines composting as "controlled biological decomposition of organic waste, performed by a diverse population of organisms, in aerobic and thermophilic conditions, resulting in material stabilized, with properties and characteristics different from those that gave origin" (BRAZIL, 2017).

To Dores-Silva et al. (2013) there are two processes for stabilization of organic materials: composting, performed exclusively by microorganisms, and the vermicomposting, performed by the symbiosis between earthworms and microorganisms that live in your digestive system.

On the composting, Russo (2003) says that the microorganisms are responsible for biochemical transformations in the mass of residues and humus. The biochemical reactions occur in the maturation phase, which lasts approximately 25 to 30 days, and the humification phase occurs between 30 and 60 days, depending on the temperature, moisture, organic matter composition and conditions of aeration. According to the author, composting is an effective process of recycling organic matter, possessing economic advantages, because the compost generated is applicable in agriculture, great for the containment of slopes and erosion control, among others.

Ferreira et al. (2013) affirm that the manure generated in the composting process, is essential to the soil, because it improves its structure and fertility, as well as increase your productivity. According to Nord (2013), this process allows the use of organic waste, but are needed some knowledge about the method, to ensure a stable and a good quality product, which provide properly nutrients and condition to the soil in order to not to harm the development of the plants.

To better understand this process, Bidone (2001) reports that the speed in composting varies in accordance with the molecular structure of the material used, for instance, the materials rich in carbon (sawdust, straws among others) degrade more slowly than the domestic wet waste, then the deficiency in nitrogen should be compensated for that process to occur more rapidly.

In composting, second Dores-Silva et al. (2013), the determination of the carbon nitrogen ratio (C/N) is one of the methods to assess the capacity of assimilation of nitrogen by plants in an organic waste, and the relationship between CECef/TOC (cation exchange capacity/total organic carbon) provides an indication of the cation exchange capacity of the matrices and the stabilization process. Resolution nº 481 of the CONAMA (BRAZIL, 2017) says that the C/N ratio in the compost must be less than or equal to 20:1.

This process, according to Teixeira et al. (2002), should be conducted in aerated environment, since the microorganisms require oxygen, in addition to avoiding the bad smell and the proliferation of flies. The handling also contributes to the homogenization of the mass of decomposition, mixing organic waste rich in nitrogen with materials (sawdust, dried leaves among others) rich in carbon.

For the organic compost produced be used in agriculture, its quality must follow the standards recommended by MAPA (2011), referring to the maximum limits of contaminants allowed in organic compounds.

According to Bidone (2001), the evaluation of organic fertilizer, in relation to the heavy metals should be strict so that it is available to plants not taking the high concentration of these metals. As the temperature in the composting process, the ideal range control is a result by agitation of the material, irrigation, or by both. Other factors that may lead to the increase of temperature are materials rich in protein and with a low C/N ratio.

Thus, the composting is affected, according to Valente et al. (2009), by interdependence and inter-relationship of moisture, oxygen, C/N ratio, granulometry and porosity of the material to be composted. Therefore, to try to balance the relationship between these factors, it is necessary to mixture various types of organic waste.

The process of composting and vermicomposting are quite similar, the difference is that in the vermicomposting, conforming to Ricci (1996) and Bidone (2001), when the earthworms digest the organic waste, a mucus is released which facilitates the work of the microorganisms decomposers, speeding up the process of humus and increasing the population of microorganisms, improving the quality of vermicompost when compared to traditional composting process, beyond improving the aeration and drainage of the material in the maturation phase.

According to Dores-Silva (2011), the vermicomposting is the process of transformation of little degraded organic matter, which occurs through the action of earthworms with the flora that live in your digestive. What occurs is a mechanical process, composed by agitation and aeration of the compound, as well as the grinding of organic particles that pass through the digestive system of earthworms. Thus, they are capable of generating waste richer in nutrients that can be assimilated by plants.

However, also an important factor, conforming to Valente et al. (2011), is the use of materials rich in carbon, for example dry grass and/or sawdust, are important to achieve the desired characteristics for the development of composting, helping in the maintenance of moisture and improving the carbon/nitrogen ratio.

The quality of the vermicomposting product cannot be generalized mainlys because it depends on the waste used and the technique. In this context, we detail the methodology used in the next topic.

3. Materials and Methods

The whole research methodology used for quantification and evaluation of organic compost generated (liquid and solid) by the process of vermicomposting according different vegetative covers can be visualized in Figure 1.

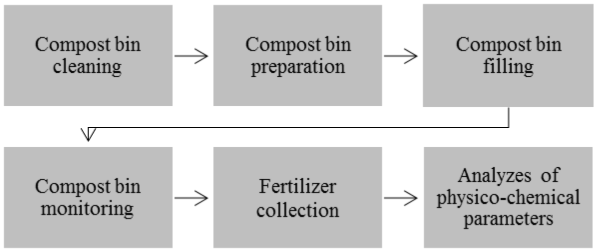

Figure 1. Methodological flowchart.

Were used three sets of compost bin for the study, one for each type of coverage used (sawdust, leaves and soil), starting with the cleanliness (performed with neutral detergent, water and exposure to sunlight for drying) and preparation.

The set of composting is composed by two plastic boxes, being the top called digester (60 liters), where it is produced the solid fertilizer, and the lower part called collector (40 liters), where it is stored liquid fertilizer generated in the process. Figure 2 shows the geometric characteristics of compost bins.

For the filling of the compost bins, initially was added 1kg of humus from the place where the earthworms are living, for ambiance, 141 g of Californian earthworms (approximately 300 units) (Figure 3a) and approximately 500 g of fresh organic waste (approximately 1 liters) for each set, along with the plant cover (sawdust, leaves and soil) in the ratio of 1:1, a volume of 1 liter of organic waste for 1 liter of plant cover (Figure 3b). As the ground cover, the ratio of 1:1 was not used, because, 500 g was enough to cover the organic waste added.

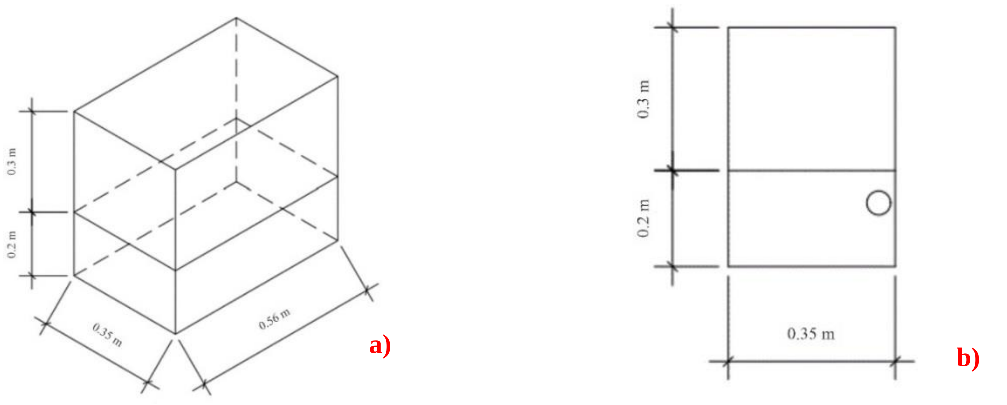

Figure 2. Geometry of compost bins: (a) perspective; (b) plan.

Figure 3. Technical details of the elements involved in the process of compost bins filling: (a) average size of earthworms; (b) vegetable toppings.

The amount of humus (1 kg) used in the process was only for the ambiance of earthworms, and about the number of Californian earthworms, was the one recommended by Ricci (1996), which is 1,0 to 1,2 kg for every square meter of the flowerbed.

About compost bins filling with organic waste, the amount adding 1 liter every three days (monday, wednesday and friday) tried to idealize the production of organic waste (behavior) of a family of 4 people, that performs some meals for lunch and dinner (including weekends) with little waste.

The compost bins filling with organic waste and vegetable toppings followed diagram shown in Figure 4. After the addition of humus for ambiance and earthworms, the addition of organic waste and covers (sawdust, leaves and soil) followed the stacks scheme, each day of filling was created a new stack with a total of 6 stacks and when finalized, there were created new layers above the existing stacks, always adding organic waste and above them, the plant cover.

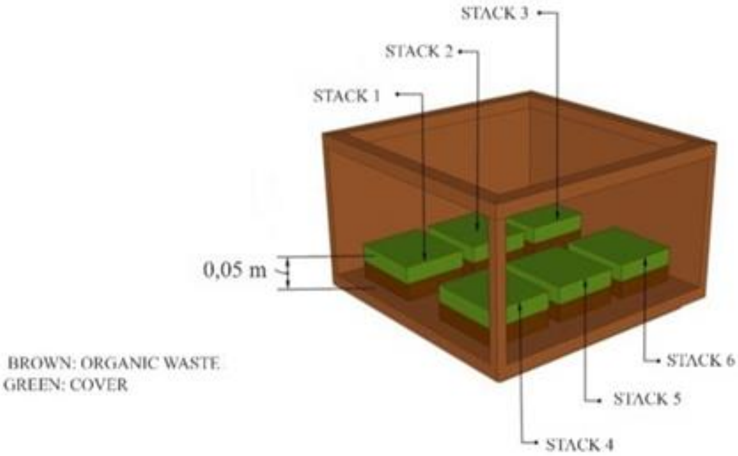

Figure 4. Diagram of sequential compost bins filling.

The organic waste used in the compost bins filling were generated in their own residence (place of study), in a fresh way. Figure 5 illustrates the control of entry (by mass) of organic waste (Figure 5a) and the beginning of the process of compost bins filling (Figure 5b). For the filling (organic waste and covers), they were placed in 1L container, and then weighed. About the coverages used, Figure 6 illustrates the number of compost bins and its type of coverage.

Figure 5. Control of entry and the beginning of the compost bins filling: (a) weighing of waste; (b) initiation of filled with humus and earthworms.

Figure 6. Compost bins and their respective covers.

The whole process of filling and generation of biofertilizer (liquid and solid) was carried out in two phases, each phase with different granulometry of organic waste and coverage. In the first phase, the organic waste used (Figure 7a) had on average 5 cm and the covers were used at the same size they were collected (Figure 8a). In the second phase (Figure 7b), was restarted the whole process of cleaning and new fill, as described previously, now with the organic waste into smaller sizes (approximately 2 cm) and coverage by half (Figure 8b).

For the filling, the sawdust used was from a company in Brazil without contamination and leaves and soil were collected in their own backyard. It is important that the sawdust is not of wood with paint, neither MDF (Medium Density Fiberboard) or plywood, must be of natural wood without chemical treatments.

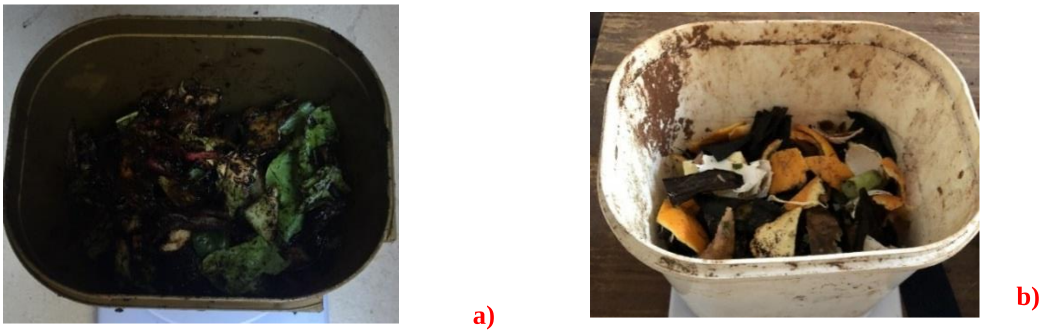

Figure 7. Organic wastes: (a) average size used in the first phase; (b) average size used in the second stage.

Figure 8. Covers: (a) average size of the first phase; b) average size of the second phase.

Similarly, a raw material used in the production of fertilizer should not include metals, glasses, oils, paints, dairy products, meat and fats. This means that the degradation of these materials alters the amount of oxygen essential for the decomposition of the raw material.

The temperature monitoring in the first stage was carried out every Monday of the week (day 07/05/18 to 16/07/18) inside (Figure 9a) and on the surface (Figure 9b) of the stacks (13:00 and 15:00), being also observed the moisture in a visual way, for example, the presence of water droplets inside the compost bins and cap. As the second phase was performed the same procedure of monitoring all mondays (09/17/18 to 26/11/18), at the same time of the previous step.

The equipment used are digital thermometer to evaluate the internal temperature of the stacks (Figure 9a), generally used in domestic kitchens and industries to measure temperature of foods , and the digital infrared thermometer (Figure 9b), used for measuring temperatures on the surface of objects without the need for physical contact. Table 1 illustrates the technical characteristics of the thermometers used.

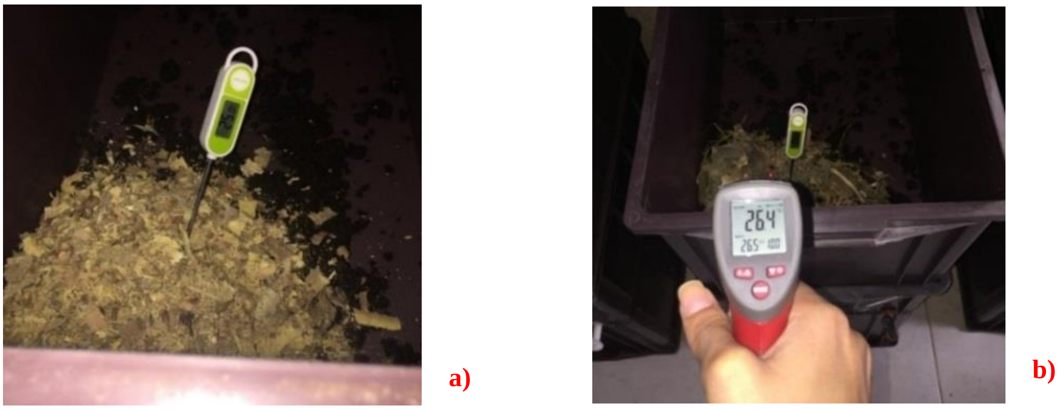

Figure 9. Temperature monitoring: (a) measurement inside the stack; (b) measurement on the surface of the stack.

Table 1. Technical features of thermometers.

	Type thermometer skewer	Digital infrared thermometer
Measurement Capability:	-50° to 300 °C	-40º to 550 ºC
Resolution:	0.1 °C	0.1 °C

The collection of organic compost generated was performed manually, collecting approximately 500 g of sample of each compost bins and withdrawal of earthworms (Figure 10a). The collection of the biofertilizer generated in the collector box was performed in pet bottles (Figure 10b), collecting approximately 500 mL of volume for the realization of laboratory analysis.

Figure 10. Collection of organic compound: (a) withdrawal of earthworms for sample storage; (b) collection of the biofertilizer.

About the physical-chemical analyzes, it was performed the analyzes of entry (humus) and the organic compost generated (solid, produced in the digester box, and liquid, which is the vermicompost produced in the collector box) within the period of 3 months after the end of the fill (incubation), in the first phase, and 2 months in the second phase.

4. Results and discussions

Initially, was collected and analyzed the humus of entry from the place where earthworms live to perform the ambiance to earthworms and analyzed in the laboratory 2 samples of 500 g, for knowledge of the characteristics of the humus of entry (Table 2).

The results presented in Table 2 shows that the initial humus can be used as organic fertilizer, because its characteristics adequate the minimum quantities required by the Normative Instruction SDA 25/2009 (Tables 4 and 5). The values of C/N ratio also meet the CONAMA (Environment company of Brazil) Resolution nº 481, establishing the ratio less than or equal to 20:1.

From the measurements temperature on a weekly basis inside and on the surface of 6 stacks to fill with the organic wastes and vegetation covers (Figure 11a and 11b), it was possible to determine the average temperature inside and of the surface (first and second phases) of all compost bins monitored (sawdust, leaves and soil), and compost bin 1 (sawdust), compost bin 2 (leaves) and compost bin 3 (soil).

Table 2. Analysis of the humus of ambience of compost bins.

Parameters	Sample 1	Sample 2
N (g kg^{-1})	19	26
P_2O_5 total (g kg^{-1})	12	11
K_2O (g kg^{-1})	29	29.5
OM (g kg^{-1})	240	240
Moisture (%)	65	64
Mineral matter (g kg^{-1})	110	120
C/N ratio	20.9	14.9
OM (Dry matter) (%)	68.6	66.7

The temperatures of the first phase were measured from month May to July, with average temperatures minimum of 22ºC and maximum of 29ºC (INMET, 2018), until its stabilization.

The lowest internal temperatures measured in the compost bins in the 7th week (06/18/18) of the first phase (Figure 11a) and 1st week (10/11/18) of the second phase (Figure 11b) are associated with the non-stabilization of the temperature of the organic compost before being used in the process of filling the compost bins, that is, pieces and peels of fruits and vegetables used that were cooled went directly to the compost bins.

This fact shows the importance of controlling, monitoring and waiting for the stabilization of the temperature of the organic compost used in the process of filling the compost bins so as not to negatively affect the vermicomposting process and, consequently, the action of earthworms. It can also be seen, for the two phases (Figures 11a and 11b), that the following week there is already a stabilization of the internal temperature of the compost bins, highlighting that the system has rebalanced itself without affecting the quality of the biofertilizer produced, emphasizing that the fact does not if repeated more than once.. The stabilization of the temperature of the compost bins' stacks began in the 8th week, two months after the beginning of the filling, both superficially (approximately 25ºC) and inside (approximately 27ºC), with the knowledge that the stabilization temperature inside of the stacks are always higher than the superficial due to the effect of the vegetal toppings.

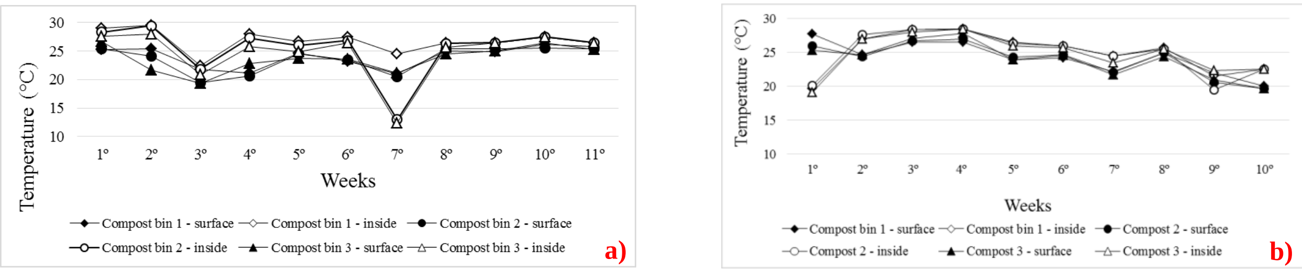

Figure 11. Average temperatures of compost bins' stacks: (a) first phase, diameters of organic waste and coverage of 5 cm; (b) second phase, diameters of organic waste and covers of 2 cm.

In the second stage of temperatures monitoring of the compost bins' stacks, measured in October and November, we can observe the gradual decrease, however, the temperature did not stabilize in the 10th week as occurred in the first phase. This fact may be related to the seasonality, since the second stage was held with regional temperatures mild and relative humidity higher (INMET, 2018).

According to Dal Bosco (2017), to do the process of vermicomposting, ideal temperatures are around 20 to 25ºC. Temperatures above 30ºC affect earthworms and can be lethal, while temperatures below 10ºC are also detrimental to vermicomposting process, because they reduce the digestive and reproductive activities of earthworms, causing consequences in vermicompost generated. Thus, the generation of the biofertilizer in household compost contemplated the temperature range specified by Dal Bosco (2017).

The vermicompost generated (biofertilizer liquid and solid) was submitted to physical-chemical analysis to verify its quality as regards macro and micronutrients and contaminants (Table 3 for larger diameters – 5 cm and Table 4 for smaller diameters – 2 cm), respectively.

Table 3. Results of vermicomposts generated in the first phase analyzes (diameters of 5.0 cm for organic waste and different covers) and studies and limits established by the IN 46/2011 and IN SDA 25/2009.

Parameter	Sawdust		Leaves		Soil		Galvão et al. (2017)*	Senesi et al. (1989)**	IN 46/2011 ($mg\ kg^{-1}$)*** (maximum)	IN SDA 25/2009 (%)**** (minimum)	
	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Solid		Solid	Liquid
N (%)	1.7	1.5	1.5	1.1	1.8	1.2	1.75	1.1	-	1.0	1.0
P_2O_5 (%)	0.47	0.22	0.46	0.36	0.46	0.24	0.306	0.4	-	1.0	1.0
K_2O (%)	2.66	1.33	2.66	1.17	0.99	0.99	2.33	0.9	-	1.0	1.0
Cu (%)	0.000 5	0.0004	0.000 4	0.005	-	0.005	0.0198	0.43	-	0.05	0.05
Ca (%)	2.45	0.15	2.12	0.18	2.04	0.2	4.94	11.5	-	1.0	0.5
S (%)	0.67	0.58	0.48	0.42	0.55	0.41	0.035	0.3	-	1.0	0.5
Fe (%)	0.009	0.018	0.01	0.019	0.01	0.026	16.69	12.85	-	0.2	0.1
Zn (%)	0.006	0.002	0.006	0.002	0.006	0.003	0.049	0.075	-	0.1	0.05
Mg (%)	0.31	0.03	0.18	0.04	0.23	0.05	0.36	0.6	-	1.0	0.5
Mn (%)	0.022	0.012	0.022	0.0118	0.022	0.012	0.184	0.665	-	0.05	0.05
OM (%)	76.9	86.8	72.6	96.4	17.4	94.7	-	24.0	-	15.0	8.0
Cd ($mg\ kg^{-1}$)	0.1	0.2	0.1	0.2	0.12	0.3	4.83	3.0	0.7	-	-
Pb ($mg\ kg^{-1}$)	10.0	1.0	10.0	1.1	11.0	1.0	5.33	193.0	45	-	-
Ni ($mg\ kg^{-1}$)	2.0	2.0	2.0	2.0	2.2	2.0	11.5	25.0	25	-	-
pH	7.1	7.12	6.86	5.8	6.96	6.12	8.22	6.9	-	6 to 6.5	6 to 6.5

*Average result from the analysis of 6 vermicomposts collected in Goiânia (Brazil city) with various toppings **average results from the analysis of vermicomposts with origin of municipal solid waste; ***IN 46/2011 (maximum permitted quantity of contaminants); ***IN SDA 25/2009 (minimum quantity required for organic fertilizer). Values in bold refer to parameters that were not met by existing standards.

The results presented by Galvão et al. (2017) are averages of samples collected in 6 household composts of the project Residence Zero Residue (RZR), both in the city of Goiania (central regions, northwest, north, west, south west and south), of matured vermicompost, obtaining relevant values of macro and micronutrients, however, high values of heavy metals (Tables 3 and 4).

About Senesi et al. (1989), a study was conducted in 6 different vermicomposts in Spain (animal manures, municipal solid waste, cow manure, sewage sludge and animal dung), which were submitted only the results about the vermicomposts with municipal solid waste origin (Tables 3 and 4).

It can be observed in Tables 3 and 4 that the nutrients present in the vermicompost generated (be they macro or micronutrients), most of the chemical elements did not meet the minimum amount required by the Normative Instruction SDA 25/2009 (MAPA, 2009) to be used as organic fertilizer, on the other side, the results of heavy metals did meet the limits established by Normative Instruction 46/2011 (MAPA, 2011).

Table 4. Results of vermicomposts generated in the second phase analysis (diameters of 2.0 cm for organic waste and different covers) and studies and limits established by the SDA IN 46/2011 and 25/2009.

Parameter	Sawdust		Leaves		Soil		Galvão et al. (2017)*	Senesi et al. (1989)**	IN 46/2011 (mg kg^{-1})*** (maximum)	IN SDA 25/2009 (%)**** (minimum)	
	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Solid		Solid	Liquid
N (%)	1.75	0.13	2.1	0.15	0.75	0.10	1.75	1.1	-	1.0	1.0
P_2O_5 (%)	0.34	0.08	0.89	0.05	0.3	0.05	0.306	0.4	-	1.0	1.0
K_2O (%)	0.25	0.64	0.365	0.47	1.1	0.30	2.33	0.9	-	1.0	1.0
Cu (%)	0.003	0.001	0.003	0.001	0.003	0.001	0.0198	0.43	-	0.05	0.05
Ca (%)	0.12	0.03	3.1	0.04	0.21	0.008	4.94	11.5	-	1.0	0.5
S (%)	0.18	0.06	0.21	0.05	-	0.05	0.035	0.3	-	1.0	0.5
Fe (%)	0.18	0.009	3.31	0.008	7.9	0.670	16.69	12.85	-	0.2	0.1
Zn (%)	0.003	0.001	0.006	0.002	0.003	0.001	0.049	0.075	-	0.1	0.05
Mg (%)	0.13	0.02	0.31	0.02	0.06	0.002	0.36	0.6	-	1.0	0.5
Mn (%)	0.005	0.002	0.025	0.003	0.018	0.003	0.184	0.665	-	0.05	0.05
OM (%)	25	60	13	62.5	22	1.3	-	24.0	-	15.0	8.0
Cd (mg kg^{-1})	0.03	0.01	0.03	0.02	0.03	0.01	4.83	3.0	0.7	-	-
Pb (mg kg^{-1})	0.02	0.01	0.10	0.01	0.01	0.01	5.33	193.0	45	-	-
Ni (mg kg^{-1})	0.50	0.04	2.0	0.15	0.20	0.02	11.5	25.0	25	-	-
pH	8.03	8.91	8.67	9.20	8.75	9.15	8.22	6.9	-	6 to 6.5	6 to 6.5

*Average result from the analysis of 6 vermicomposts collected in Goiânia (Brazil city) with various toppings; **average results from the analysis of vermicomposts with origin of municipal solid waste; ***IN 46/11 (maximum permitted quantity of contaminants); ***IN SDA 09/25 (minimum quantity required for organic fertilizer).Values in bold refer to parameters that were not met by existing standards.

All solid vermicomposts showed the vast majority of the physical-chemical parameters higher than liquid vermicomposts (Tables 3 and 4), with the exception of organic matter (OM) for the first phase (larger diameter for the organic waste and coverage - 5 cm). The solid vermicompost, generated by sawdust, presented macronutrients (Ca, Mg) together with OM interesting for use in agricultural fertilization.

It is noteworthy that the low value of OM detected in the liquid vermicompost that used the soil cover (1.3% - Table 4) may be associated with the low granulometry used (2.0 cm) and consequently, little volume to be transferred to the liquid vermicompost, leaving most of it is removed from the solid vermicompost.

About the contaminants (heavy metals), all the generated solid vermicompost showed high levels of lead (Pb), considering that this element also presents high toxicity in some concentrations, but still meets the regulatory limitations (46/2011), as well as the metals cadmium (Cd) and nickel (Ni) (Tables 3 and 4).

Comparing the level of contaminants (heavy metals) present in the vermicompost generated in this study with those of Senesi et al. (1989) and Galvão et al. (2017) it is easy to notice lower levels of toxicity, highlighting that the inputs used (covers and organic waste) were guaranteed origin, without contaminants entered (controlled environment by researchers).

In the first phase, the results of macro and micronutrients, few of them were the parameters that met the Normative Instruction SDA 25/2009 (MAPA, 2009), they are: organic matter, nitrogen, potassium (generated by sawdust and leaves), calcium (solids compounds) and sulfur (liquid compound generated by sawdust). As the pH values, only the value obtained by liquid vermicompost generated by soil presented within the established by law. According to Oliveira (2008), the microorganisms present in the vermicomposting have a great development in a range of pH values between 6.5 to 8.0, low values of pH (below 5) indicates a problem in the maturation due to the duration of the process or occurrence of anaerobic processes inside the cells, which was not the case for this study.

In the second phase, the behavior was similar to the first stage, few parameters met the legislation, they are: nitrogen (solid compounds generated by sawdust and leaves), potassium (solid compound generated by soil), calcium (solid compound generated by leaves), iron (solid compound generated by leaves and compounds generated by soil), manganese (solid compound generated by sawdust) and organic matter in all compounds, except the liquid generated by soil.

About the volume of liquid biofertilizer generated in the first phase, where the granulometry of organic waste's particles and covers were higher (around 5 cm), we obtained higher volumes than in the second phase (smaller particle size - 2 cm), being 1 liter on compost bins 1 and 2 and 500 mL in compost bin 3, approximately. In the second step, the volumes were: 250 mL in compost bin 1, 500 mL in compost bin 3 and 1 liter in compost bin 2 (equal to the first phase).

In the first phase, the organic waste used for compost bins filling were more humid (coffee grounds, papaya, banana, eggs shell, vegetables, legumes) if compared to the second phase (fruit peels, leaves in general, such as lettuce and green onions), which may explain the difference in the amount generated of liquid biofertilizer, influenced by the type of organic waste from filling, food moisture and particles' size. The difference of organic waste used in the second stage, is related to the difficulty of waste storage generated in the residence, now being used organic waste from restaurants.

The volume of solid compound generated in the first phase (granulometry of 5 cm) was also higher, which may be related to the larger granulometry, i.e., lower speed of organic material degradation.

5. Conclusions

With the monitoring and results of vermicompost's analyzes generated by household compost (liquid and solid) with different diameters of organic waste particles and coverage of this study, we can conclude that:

- the vermicompost's temperatures ranged from 20 to 30 ºC, complying with the recommendations of the literature for the process of vermicomposting, which led the parameters of macro and micronutrients partially meet the legislation;
- still on the macro and micronutrients, few elements met the minimum limits established by Normative Instruction SDA 25/2009, and they include organic matter, nitrogen, potassium (generated by sawdust and leaves), calcium (solid compounds) and sulfur (liquid compound generated by sawdust), especially for the first phase (larger diameters – 5 cm). Thus, in spite of the vermicomposts generated in two phases are not considered fertilizers, it can be used as soil conditioners;
- the obtained values of heavy metals met the requirements permitted by IN 46/2011, emphasizing that they can be used in conventional fertilization as a condition of the soil;
- the pH, being an indicative of vermicompost's quality generated, and although the SDA Normative Instruction 25/2009 establishes that values must be between 6.0 and 6.5, the values found in the first phase were nearby, ranging from 5.8 to 7.12 considered pH stable and satisfactory. In the second phase, the pH values ranged from 8.03 to 9.20, more basic, which leads us to believe in the possibility of greater activation microbiological;
- still on the pH, considering the Cerrado (Brazilian biome) soil in its great majority is acidic, the vermicompost generated can be used as soil correction agents (pH balance);
- the quantity of organic matter generated in the vermicompost were satisfactory when compared to the limits that the SDA Normative Instruction 25/2009 points, the vermicompost generated are rich in organic matter, being an important characteristic to be used as fertilizer, mainly the one generated in the first stage (larger granulometry);
- the quantity (volume) of vermicompost, mainly the liquid, was influenced by the diameter of particles, in the first phase (larger particles) showed higher volumes generated, which may be related to more rapid evaporation of the liquid part of organic waste of the filling in the second phase (smaller particle diameters) by the greater surface area of contact;
- in general, the values of macro and micronutrients, organic matter, pH and contaminants of vermicompost generated in different compost bins analyzed vary very little even using different toppings and diameters of particles, in other words, there was little influence on the quality of vermicompost generated.

Can be pointed that existed difficulty in completing the household compost bins regarding the quantity and standardization of organic waste used, since they are the most diverse types, sizes and shapes, and define parameters for the population may discourage their use.

However, highlights the importance of the technique in sustainable production processes in the generation of fertilizers with less impact of saturation and soil contamination.

Finally, the research showed low influence of particle size on filling (organic) and coverage in the final quality of vermicompost generated, only differences (still considered low) in the final volume of the biofertilizer generated.

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Conflicts of Interest

No conflict of interest in research development.

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