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Pilot-scale organic solid waste composting yard: A technical and economic feasibility study

Vanderson Urbaiti Giménez[1], Jacira Lima da Graça[2], Maria Aparecida Lopes da Costa[3], Dawilson Menna Junior[4], José Martins de Oliveira Júnior[5], Valquíria Miwa Hanai-Yoshida[6].

INTRODUCTION

Waste management in Brazil is guided by the National Solid Waste Policy (PNRS). The PNRS provides for the extinction of landfills and the disposal of municipal solid waste (MSW) in landfills only when there is no potential for reuse, including recycling and reverse logistics. Organic solid waste (SR) can be turned into fertilizer, and improper disposal can cause sanitary and environmental problems. MSW is classified by Law No. 12,305/2010 into household waste (RDO) and public waste (UPR). In this study, SRs were classified as wet household solid waste (RSDU) and UPR, according to the SNIS. Composting, a natural process of degradation of organic matter, is currently used to manage organic SR, using techniques to accelerate decomposition and produce organic compounds of social interest. This study hypothesized that the implementation of a composting yard at the University of Sorocaba is feasible, both technically and economically, to manage part of the SR generated at the Cidade Universitária Prof. Aldo Vannucchi Campus. The objective was to develop an operational pilot project of an organic RS composting yard for the university, identifying sources of organic RS (RSDU and RPU), adapting a methodology for composting, determining performance indicators and performing a project cost analysis. (IBAMA, 2022) (BONJARDIM; PEREIRA; GUARDABASSIO, 2018, p. 315) (ARAÚJO; CERQUEIRO; CARNEIRO, 2020) (HECK et al., 2013) (BRASIL, 2010) (2022) (CRIVELARO; MOREIRA; DA SILVA, 2018, p. 91)

MATERIALS AND METHODS

For the collection of the RSDU, two 200 L containers were used, and the collection of only 100 L daily from Mondays to Fridays was defined to facilitate the transport and disposal of waste in the composting windrows. Three types of compost windrows (n=3) were constructed for the production of samples, following the parameters established by the research team and shown in Table 1.

[1] University of Sorocaba – São Paulo
[2] University of Sorocaba – São Paulo
[3] University of Sorocaba – São Paulo
[4] University of Sorocaba – São Paulo
[5] University of Sorocaba – São Paulo
[6] University of Sorocaba – São Paulo

Table 1 - Characteristics of compost windrows for testing

Design of the experiment									
Parameters	**Compost windrow**								
	1	2	3	4	5	6	7	8	9
Dimension(m2)	2			2			2		
Soil waterproofing	No			Plastic tarpaulin			Masonry structure with Gravity drainage		
Biofertilizer collection Liquid (chorume)	No			No			Yes		
Coverage	No			Plastic tarpaulin			Plastic tarpaulin		
Disposition	Directly on the ground			About Plastic Tarpaulin			About the structure		

Source: Prepared by the authors

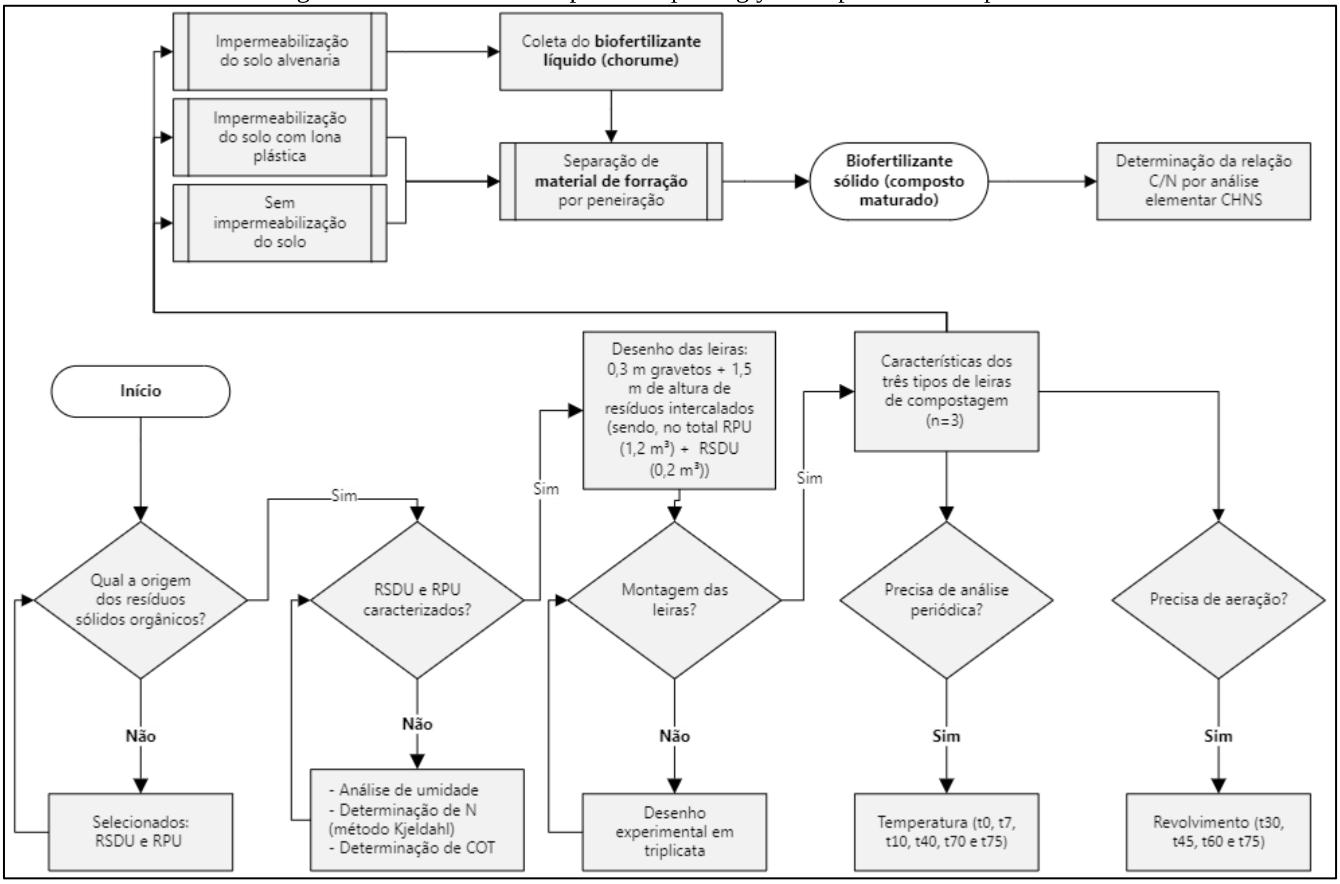
A cradle with 0.3 m high sticks was made for the disposal of organic waste (RSDU and UPR) in the windrows, to facilitate the entry of O2 into the material to go through the composting process. After the creation of this crib, a 0.3 m high UPR bed was arranged throughout the windrow, totaling 1.2 m³ (1200 L) of material, and 0.2 m³ of RSDU was inserted. This process was carried out until the windrows reached 1.5 m in height, with the exception of the cradle of sticks which was carried out only at the beginning of the work to facilitate the oxygenation of the windrows. The moisture content (%) (n=3) was calculated using Equation 1 with the aid of an analytical precision balance (SHIMADZU, ATX224).

$$\boldsymbol{moisture} = \frac{(m_i - m_f)}{m_i} \textbf{ x } \mathbf{100} \qquad \text{Equation 1}$$

where, it represents the initial mass and the final mass.$m_i m_f$

To determine the nitrogen content, the methodology proposed by Malavolta, Vitti and Oliveira was used. To determine the total organic carbon (TOC) content, the materials were dried at 105 °C in an oven with air circulation and renewal (Marconi, MAO35/S, Brazil), placed in a crucible previously weighed on an analytical balance (Tecnal, M214A, Brazil), and taken to the muffle furnace (QUIMIS, D21, Brazil), properly weighed and kept at a temperature of 580 °C for a period of 2 h. After cooling in desiccants, the material was weighed on an analytical balance with a precision of 0.0001 g, obtaining the TOC content by difference, according to the methodology of Cunha-Queda et al. .   (1997)   (2003) The CHNS elemental analysis was performed using the ThermoScientific® analyzer (FlashSmart, USA), available at CAQI-IQSC-USP. Temperature determination was performed at equal time intervals for the three types of windrows produced. Temperature was observed in the center of each windrow. The analyses were performed using a mercury thermometer at t0, t7, t10, t40, t70 and t75, where t represents time and the numeral the days after the beginning of the construction of each windrow. Figure 1 shows the flowchart of the process of implementing the pilot composting yard to visualize the methodology applied to the composting process.

Figure 1 - Flowchart of the pilot composting yard implementation process



Legend: wet household solid waste (RSDU) and public waste (UPR). Source: Prepared by the authors

RESULTS AND DISCUSSION

A documentary research at the University of Sorocaba (Uniso) identified that wet household solid waste (RSDU) is generated in practical classes and at the Famille University Restaurant, while public waste (UPR) comes from pruning and gardening on campus. Currently, Uniso hires a third-party service for the collection and transport of RSDU and UPR to landfills.

The moisture values for crude UPR and RSDU were 48 ± 3% and 89 ± 3%, respectively. The ratio of UPR:RSDU used was 1.2:0.2 m³, resulting in a moisture content of 54% at the beginning of the experiment. This justifies the absence of flies and rodents, as humidity values above 60% would make the environment anaerobic, attracting undesirable vectors (PEREIRA NETO, 2007). In the present study, no moisture corrections were performed and the matured compost was obtained in about 80 days. Technical Guideline No. 007/2021 - Dirtec (FEPAM, 2021) recommends that the moisture content be maintained between 40 and 60%, ideally 55%. (CRIVELARO; MOREIRA; DA SILVA, 2018)

The nitrogen concentration, determined by the Kjeldahl method, was 1.01 ± 0.05% for RSDU and 0.93 ± 0.04% for UPR. The total organic carbon (TOC) of the RSDU and UPR samples was 52.8 ± 0.5% and 45.3 ± 4.7%, respectively. These values are close to those obtained by Carmo e Silva (2012, p. 1218) and Ismael et al. (2013) for samples of plant origin.

The tests carried out on solid biofertilizers (matured compounds) resulted in C/N ratios of 11.4/1, 12.4/1 and 12.7/1 for windrows 1 to 3, 4 to 6 and 7 to 9, respectively, corroborating the findings of Gorgati and Lucas Júnior (2001) and below the values obtained by Melo (2016). The solid biofertilizers of windrows 7, 8 and 9 showed higher N values than those of windrows 1-3 and 4-6, probably due to the contamination of the compost with material from plastic sheeting and loss of liquid biofertilizer (leachate) (PEDROSA et al., 2013).

The windrows built of masonry, in addition to providing better yields, comply with Ordinance No. 52/2021 (BRASIL, 2021), which establishes criteria to avoid water and soil pollution and the proliferation of pests and disease vectors.

The validation of solid biofertilizer (compost) is done in accordance with Normative Instruction (IN) No. 25/2009, of the Ministry of Agriculture, Livestock and Supply (MAPA) (BRASIL, 2009), which defines rules for organic fertilizers of different types aimed at agriculture.

It can be observed that the temperature data obtained were similar for windrows from 1 to 9 at different times (t0, t7, t10, t40, t70 and t75), considering the mean values and their respective standard deviations. In addition, they varied regularly in all windrows at different sampling times, corroborating the values in the literature (.   (BRASIL. MMA, 2018, p. 26)

In this research, the composting of RSDU and UPR in static aerated windrows waterproofed by masonry was monitored. The mean initial temperature was 29.7 ± 0.9 °C, increasing to 50.9 ± 2.3 °C after 40 days and decreasing to 29.1 ± 0.2 °C after 75 days. The mesophilic phase, characterized by temperatures of up to 40 °C (SOUZA et al., 2020), was reached before t10. The active degradation phase, with temperatures between 45 and 65 °C (AZEVEDO; VILELA, 2019), was observed around t40, diverging from MPE-PR data (2011, p. 2). The humification phase occurred close to t70, with the compost presenting an appearance similar to that of vegetable soil and the presence of earthworms (Brazil. MMA, 2018), although earlier than described in the literature (BRASIL. MMA, 2018, p. 28). The difference may be related to the frequency of windrow turns. The temperatures observed in windrows from 1 to 9 on the 40th day ranged from 51ºC to 53.1ºC, ending the thermophilic phase. These results diverge from the work of Oliveira (2015), who reported higher temperatures and a longer thermophilic phase period with regular aeration and watering. In the present study, the first turning of the windrows occurred 30 days after the beginning of the composting process, without the addition of watering with water and humidity control. It is believed that the O2 in the windrows was sufficient for the microbiota, which released energy in the form of heat, resulting in the release of water from the waste. The compound was obtained in approximately 80 days.

Elias and Oziel (2014) studied aerated static windrows, where the mixture of waste is deposited on a network of perforated pipes that forces air to enter. The forced aeration technique can promote the excessive removal of moisture, decreasing the temperature of the windrows and increasing the time to obtain compost (6 to 7 months). In this research, the use of a bed of sticks for better aeration of the windrows accelerated the production of composting products (about 80 days of process).

The cost of inputs for the construction of three masonry composters, with a capacity for 1.2 m³ of organic solid waste, was R$ 1565.00. The cost for composting for a windrow, from the beginning to the end of solid biofertilizer production, for three months at Uniso's Pilot Yard, was R$ 1292.87, with values quoted on 12/01/2023. Considering the inputs used for the production of windrows, labor, personal protective equipment, expenses with waste transportation and depreciation of assets, the pilot composting yard proved to be viable. After the beginning of this work, no chemical fertilizers previously used for fertilizing the plantations and gardens of the University of Sorocaba - Professor Aldo Vannucchi Campus were purchased. In addition, there was a decrease in the number of dumpsters and transportation for the waste generated at the site, with 64.8 m³ of waste destined for the composting process in three months, equivalent to 54 dumpsters of 1.2 m³ each.

This work points to the targeted savings, the reduction of costs and a small step towards the resolution of environmental problems, such as soil and water pollution and a decrease in the useful life of landfills due to improper waste disposal.

FINAL THOUGHTS

A pilot composting yard was implemented at the University of Sorocaba, demonstrating the technical and economic feasibility of managing part of the solid waste on campus. Three types of windrows were tested, with masonry windrows proving to be superior in the uptake of liquid biofertilizer. Composting generated three products: solid and liquid biofertilizer and fodder material. The nitrogen-to-carbon (N/C) ratio of the waste is crucial to the process, with an ideal initial ratio of 30/1 and final ratio of 10/1. Once the composting process has been established, monitoring is not necessary as the microbiota regulates the environment. Regular aeration of the windrows is important to the process, and the high temperature of the process flushes the water from the waste, eliminating the need for watering. The study indicates that composting can be a cost-effective and environmentally friendly solution for waste management.

Keywords: Composting, Solid waste, National environmental policy.

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