

WASTES solutions treatments opportunities IV

Editors:

Cândida Vilarinho, Fernando Castro & Margarida J. Quina



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WASTES: SOLUTIONS, TREATMENTS AND OPPORTUNITIES IV

WASTES: Solutions, Treatments and Opportunities IV contains selected papers presented at the 6th edition of the International Conference Wastes: Solutions, Treatments and Opportunities, that took place on 6-8 September 2023, in Coimbra, Portugal. The Wastes conference, which takes place biennially, is a prime forum for sharing innovations, technological developments and sustainable solutions for waste management and recycling sectors worldwide, with the participation of experts from academia and industry. The papers included in this book cover a wide range of topics, including:

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Valorization of water hyacinth waste through composting

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ABSTRACT: Water hyacinth composts can be used in agriculture to improve soil fertility and crop yield, reducing the dependence on synthetic fertilizers. This study aimed to monitor physicochemical parameters of the composting of water hyacinth waste blended with other organic wastes. Two composting piles were assembled using different organic materials: water hyacinth waste, potato residue, olive pomace and dairy cow manure (pile 1) or rice straw (pile 2). Composting pile 1 ran for 251 days and pile 2 lasted 244 days. Both piles registered temperatures above 55 °C for several weeks, whereas moisture and pH values were found within adequate intervals, ensuring good conditions for sanitation and microbial activity. The C/N ratio decreased during the composting period, stabilizing in values close to those that are commonly referred as adequate (12.6, pile 1; 10.9, pile 2). Measured quality parameters indicate that the final organic compost is very suitable for agricultural use.

1 INTRODUCTION

Water hyacinth [*Eichhornia crassipes* (Mart.) Solms] is an aquatic and floating plant, which develops very well in hot weather regions. It presents an accelerated development in eutrophic watercourses, a situation provided by the pollution of urban, agricultural and industrial effluents. Water hyacinth can grow 1.9% daily, 0.3 to 0.5 m in length (Tibebe, 2022). In Portugal, water hyacinth is considered an invasive alien species by the Decree-Law nº 92/2019 (Presidência do Conselho de Ministros, 2019) and it is present in almost all mainland regions (Pádua et al., 2022). It is also one of the 41 invasive alien species of concern of the European Union (European Union, 2014). Water hyacinth development has been devastating in several aquatic ecosystems. The dense mats of water hyacinth can interfere with water use for irrigation and livestock, navigation and recreation activities and, not least, the blockage of canals and rivers can cause flooding (Singh and Kalamdhad, 2015). In addition, this species originates large masses of decomposing material, interfering with the development of native species. Every year, the Portuguese local authorities have high costs with its annual control. However, the efforts of these entities have not been entirely effective in controlling the spread of water hyacinth or in reducing the economic, social and ecological consequences.

The R&DT project BioComp_2.0 is investigating transforming water hyacinth waste into organic compost for agricultural applications. So far in Portugal, there was no attempt to compost water hyacinth waste, valorizing its biomass as organic fertilizer. Therefore, use of the water hyacinth waste for this purpose is one of the possible solutions for reducing the problems associated with water hyacinth. The composting process is a controlled aerobic decomposition of organic matter by microorganisms into a stable, humus-like soil amendment. It can be divided into two principal periods: degradation and humification. In the first period, there is vigorous microbial activity during which readily degradable materials are decomposed. In the second period, there is a lower level of microbial activity and further decomposition of the products of the

first period (USDA, 2010). In order to the composting period progresses satisfactorily, some physicochemical parameters must be at an adequate level, allowing favorable conditions to transform the organic matter into a soil amendment.

Therefore, the aim of this study was to analyse the evolution of some physicochemical parameters during composting of water hyacinth waste in combination with other exceeding organic materials in the region, with a view to obtain high quality composts for agriculture.

2 MATERIALS AND METHODS

2.1 Feedstock materials

The organic materials selected for the composting study were: i) water hyacinth waste, ii) potato residue, iii) olive pomace, iv) dairy cow manure and v) rice straw (Fig. 1). These organic materials were used for the preparation of two different piles for the composting process. Water hyacinth was collected from a watercourse and potato residue was obtained from an industrial facility, both from municipality of Montemor-o-Velho. Olive pomace was purchased from a company of olive biomass production in the municipality of Coimbra. Dairy cow manure was obtained from a dairy farm in the municipality of Figueira da Foz. Rice straw was obtained from a farmer in the same location as dairy farm. All organic materials were collected in the district of Coimbra, Portugal and were not submitted to any processing before composting.

Before the composting process, each organic material was previously analysed for moisture content, carbon (C) and total nitrogen (N). Different combinations of four organic materials were established, taking into account their properties (moisture, C and N content) so that the mixture would present values close to those commonly used as a standard, 30 for the C/N ratio and 60% for moisture. For this approach, the moisture content and the C/N ratio of the mixtures were calculated, considering the quantities included in the mixture, according to the following equations (1)-(2):

$$M = \frac{(m_1 \cdot M_1 + m_2 \cdot M_2 + m_3 \cdot M_3 + m_4 \cdot M_4)}{(m_1 + m_2 + m_3 + m_4)} \quad (1)$$

where M=mixture moisture, m_1 =mass of organic material 1, M_1 =moisture of organic material 1.

$$C/N \text{ mixture} = \frac{m_1 \cdot C_1 \cdot (100 - M_1) + m_2 \cdot C_2 \cdot (100 - M_2) + m_3 \cdot C_3 \cdot (100 - M_3) + m_4 \cdot C_4 \cdot (100 - M_4)}{m_1 \cdot N_1 \cdot (100 - M_1) + m_2 \cdot N_2 \cdot (100 - M_2) + m_3 \cdot N_3 \cdot (100 - M_3) + m_4 \cdot N_4 \cdot (100 - M_4)} \quad (2)$$

where C_1 = carbon content of organic material 1 and N_1 = nitrogen content of organic material 1.

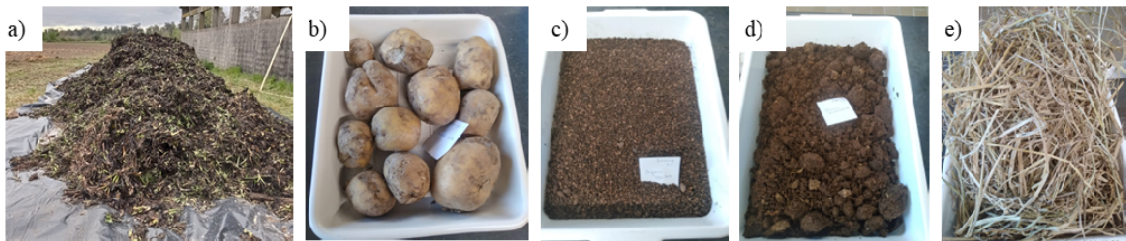


Figure 1. Organic materials used in the composting study: a) water hyacinth waste, b) potato residue, c) olive pomace, d) dairy cow manure, and e) rice straw.

2.2 Construction of composting piles and monitoring

The composting study was performed from April to December 2022. Two different waste combinations were composted by assembling piles, with length of 6 m and width of 3 m. Each pile was assembled by alternating different layers of each organic material. Table 1 shows the composition of each composting pile.

During the composting period, temperature and moisture content were monitored three times per week, at 50 cm depth, in eight different locations of the pile, by a moisture and temperature

meter (Schaller, humimeter FL2, Austria). When necessary, the piles were watered and/or aerated, in order to maintain a moisture content of around 60% and to control the temperature values. About 100 g of samples were collected from the eight different locations on days 34, 48, 62, 83, 104, 125, 146, 168, 188, 209, 230 and 251 in pile 1 and 27, 41, 55, 76, 97, 118, 139, 160, 181, 202, 223 and 244 in pile 2, to measure the pH and electrical conductivity. At the end of the composting, the composts obtained from piles 1 and 2 were analysed for pH, electrical conductivity, C, N and C/N ratio.

Table 1. Composition of the two composting piles.*

	Pile 1	Pile 2
Composition	Water hyacinth waste Potato residue Olive pomace Dairy cow manure	Water hyacinth waste Potato residue Olive pomace Rice straw
Volume	16 m ³	15 m ³

*The percentage of each organic material used in piles 1 and 2 cannot be provided due to confidentiality issues.

2.3 Analytical methods

The pH and electrical conductivity of the samples collected during the composting process were determined in suspension or supernatant, respectively, from fresh samples after shaking for 1h, according to the EN 13037:2009 and EN 13038:2011, respectively.

The organic C of organic materials and of composts obtained from piles 1 and 2 was determined by dry combustion at 590 °C (EN 15936-2012). Total N was measured by a Kjeldahl method (Bremner, 1979).

3 RESULTS AND DISCUSSION

3.1 Characterization of feedstock materials used for the composting study

The characterization of the organic materials is displayed in Table 2. The adequate moisture content for a composting process is around 60% (USDA, 2010). Analyzing the values obtained, it is noticed that the moisture content of all organic materials is not within the recommended range. However, the piles were set up with different percentages of each organic matter in order to balance the C/N ratio and moisture to near optimal values: pile 1 started with moisture of 65.9% and a C/N ratio of 28.0, and pile 2 started with moisture of 64.8% and C/N ratio of 38.5.

Carbon contents varied between 42.7% in water hyacinth waste and 55.4% in olive pomace. Regarding the N content, rice straw showed the lowest value (0.60%), followed by olive pomace and potato residue. The material with the highest concentration of N was dairy cow manure, reaching 2.68%. These values indicate that rice straw is the less biodegradable organic material while water hyacinth waste and dairy cow manure are the most biodegradable materials. Therefore, rice straw presents a very high C/N ratio and the water hyacinth and dairy cow manure wastes present the lowest values. From the set of organic wastes available, the type and quantity of wastes that were chosen to combine with the water hyacinth waste, allowed to obtain mixtures with values close to the ideal for the start of the composting process.

Table 2. Initial characterization of organic materials used for the composting study.

Organic material	Moisture content (%)	C %	N %	C/N ratio
Dairy cow manure	65.4	45.25	2.68	16.87
Olive pomace	66.8	55.40	1.36	40.89
Potato residue	70.2	52.65	1.86	28.26
Rice straw	8.2	51.46	0.60	86.49
Water hyacinth waste	90.6	42.72	2.30	18.54

3.2 Composting monitoring

3.2.1 Temperature

The composting period of pile 1 was 251 days and of pile 2 was 244 days. The temperatures ranged from 28.9 ± 1.9 °C to 73.6 ± 0.9 °C in pile 1 and 20.4 ± 0.6 °C to 72.8 ± 1.9 °C in pile 2 (Fig. 2). During the first month, the evolution of temperatures was not substantial in both piles, probably because the organic material was just laid out in layers without turning the pile. After the first turning in the composting piles, temperatures increased very fast, revealing the good conditions for microbial activity created by the aeration. After this period, both composting piles registered temperatures above 55 °C for several consecutive weeks and even above 60 °C for 6.5 weeks in total in pile 1 and 9 weeks in total in pile 2. The temperature peak occurred on day 81 in pile 1 and on day 76 in pile 2 (after the third pile turned). These high temperatures were kept constant for one week. The dairy cow manure present in pile 2 may have boosted the composting process by providing easily available carbon to the microorganisms present in the composting biomass (Singh & Kalamdhad, 2015). In both piles, it was observed temperatures above 40 °C for several months indicating an extensive thermophilic phase. Afterward, it was noted a gradual cooling of materials in composting. The abrupt reduction in temperature observed several times in Figure 2 was due to the turning of composting piles (each pile was turned 10 times).

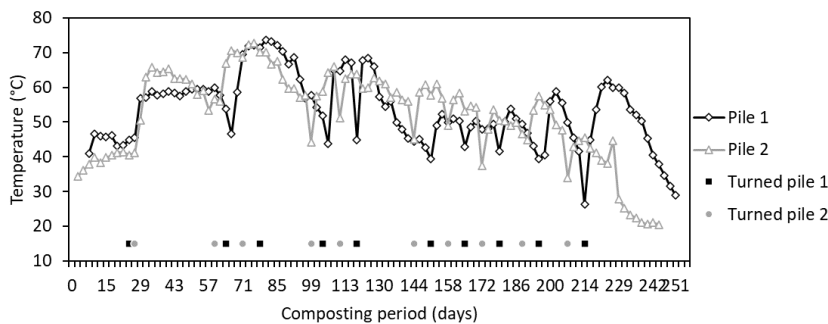


Figure 2. Variation of temperature (°C) during composting process.

3.2.2 Moisture content

Figure 3 shows the variation in moisture content during the composting process. According to Brito (2003), optimum moisture content values for the beginning of composting are around 50-60 %. At the beginning of the process, the moisture content was above the recommended value ($67.2 \pm 3.4\%$ in pile 1 – day 8, and $71.0 \pm 1.9\%$ in pile 2 – day 4), probably due to the measurements being done in a layer of organic material with high moisture content. Soon after the first pile turning, the moisture content values were $61.8 \pm 1.0\%$ in pile 1 and $56.7 \pm 3.0\%$ in pile 2. Afterward, there was a reduction in moisture content in both piles, due to the great increase of temperatures (Figure 2). Singh and Kalamdhad (2015) referred that during the composting process, the moisture loss can be viewed as an index of decomposition rate, since heat generation which accompanies decomposition drives vaporization or moisture losses. In order to increase the moisture content, it was added water to the composting piles. Water addition was carried out every time the moisture values were below the recommended ones.

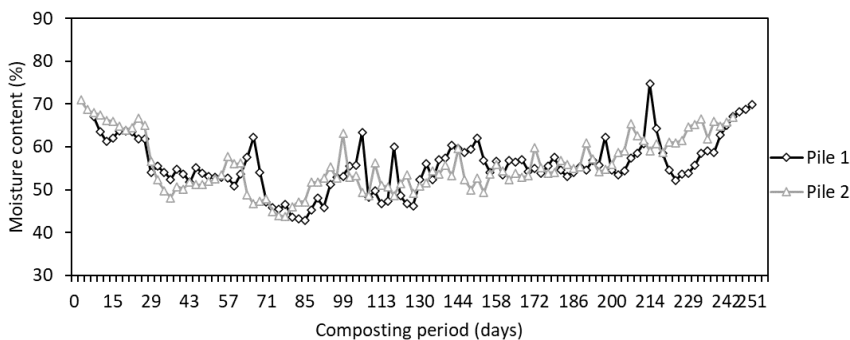


Figure 3. Variation of moisture content (%) during composting process.

3.2.3 pH and electrical conductivity

The behaviour of pH during composting process is shown in Figure 4a. The compost pH depends on the source materials and varies in each phase of the process (4.50 to 8.50) (Tibebe et al., 2022). In the present study, the pH measurements ranged from 7.3 ± 0.9 (day 34) to 9.5 ± 0.04 (day 251) in pile 1 and 7.5 ± 0.5 (day 27) to 9.0 ± 0.1 (day 223) in pile 2 (Fig. 4a). The initial pH was adequate for microbial degradation, being in the upper limit range for bacteria development, which is the most important decomposer during the most active phase of the composting process (Singh and Kalamdhad, 2015). Afterwards, the pH greatly increased to 9.0 ± 0.5 in pile 1 and 8.6 ± 0.3 in pile 2, which matches the beginning of the thermophilic phase of the composting process. Then, pH practically remained constant until the end of the composting process.

Figure 4b shows the evolution of electrical conductivity during the composting process. Singh and Kalamdhad (2015) refer to the importance of electrical conductivity measurements, since it reflects the salinity of the compost and its appropriateness for plant growth. In the current study, the mean electrical conductivity values ranged from 2.4 ± 0.1 (day 230) to 3.0 ± 0.1 mS/cm (day 251) in pile 1 and 1.6 ± 0.2 (day 41) to 2.6 ± 0.1 mS/cm (day 244) in pile 2 (Fig. 4b). These results are in accordance with the recommended values cited by Tibebe et al. (2022), which is below to 10 mS/cm. For the improvement of agricultural soils, the acceptable level of electrical conductivity in compost is < 4 mS/cm and pH should range between 5.5 to 9 for fertilizer or soil amendment (INIAV, 2022). Therefore, it is noticed that the obtained composts from piles 1 and 2 seem to be suitable for improving agricultural soil fertility.

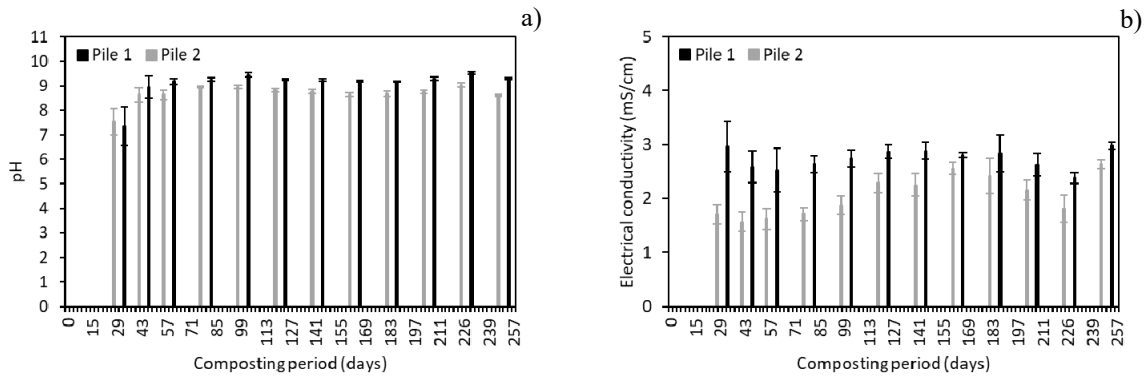


Figure 4. Variation of pH (a) and electrical conductivity (b) during composting process (error bars represent standard deviation).

3.2.4 Carbon/nitrogen ratio

Table 3 shows the C/N ratio of the initial mixture of organic materials and the composts obtained at the end of the composting process. According to USDA (2010), the C/N ratio recommended for rapid composting is between 20 to 40. In the present study, the C/N ratio of pile 1 was 28.0 and pile 2 was 38.5 revealing adequate to provide a good start of the composting process. As expected, during the composting process, there was a decrease in the C/N ratio; pile 1 registered a C/N ratio of 12.6 and pile 2 of 10.9. These values demonstrate that obtained composts show optimal conditions to be applied in soil, since the ideal range for C/N of compost is between 10 and 15 (FAO, 2015). Values higher than 20 may indicate that compost is not yet mature (Inácio & Miller, 2009).

Table 3. C/N ratio at the beginning and at the end of the composting process.

	At the beginning			At the end		
	C %	N %	C/N ratio	C %	N %	C/N ratio
Pile 1	51.45	1.84	28.01	36.82	2.35	12.56
Pile 2	52.22	1.36	38.50	25.59	2.93	10.88

4 CONCLUSIONS

Based on these findings, it is possible to conclude that both piles presented adequate physico-chemical parameters to provide good conditions for the composting process. The obtained composts showed good characteristics fitting the recommended values for soil application.

Thus, the composting process is revealed to be a possible effective process that can be used for water hyacinth waste valorization, since it transforms its biomass into organic fertilizer which has great applicability on soils.

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