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Implementing Composting and Awareness Campaigns in a Higher Education Institution to Promote Circularity

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Abstract

Sustainable waste management is essential for environmental protection and climate change mitigation. In mainland Portugal, 59% of municipal waste was sent to landfills in 2023, while only 8% underwent organic valorization. Domestic composting offers low-cost, local solutions to reduce landfill dependency and promote a circular economy. When produced with quality, compost can be used in parks and gardens, improving soil structure, supplying nutrients for plants, and promoting water retention. This study describes the implementation of a composting program at a Higher Education Institution in Lisbon, focusing on community engagement, awareness-raising actions, process monitoring, and challenges faced. The training sessions increased the participants' knowledge, who reported personal constraints in urban areas, such as limited space and slow composting rates. The results from the composting assays showed that the temperature and the pH followed the expected patterns, with the pH ranging from 4 to 9. Although the composting process progressed satisfactorily, the maximum temperature reached was approximately 45 °C, a value that can occur in home composting systems. The compost analysis showed a mature compost with pH values around 8, a dark color, and an earthy smell, proper for use. Nonetheless, challenges remain, including contaminants found in some composters and the need for increased community participation and awareness to fully engage all stakeholders.

Keywords: composting; HEI campus; sustainability; circular economy; waste management improvement; biowaste

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1. Introduction

Sustainable waste management is a powerful tool for both environmental protection and climate change mitigation. Worldwide, waste production has increased, and if no significant changes are made, climate change will be worse, with a consequent degradation in the quality of life.

Sustainable waste management encompasses a holistic approach aimed at minimizing environmental impacts while promoting resource efficiency and social well-being. It integrates waste reduction, reuse, recycling, and recovery strategies within the framework of a circular economy, which seeks to maintain the value of materials and resources for as long as possible, thereby reducing the need for new resource extraction and minimizing waste generation.

The increase in waste production significantly contributes to climate change and the degradation of quality of life through multiple pathways. According to the waste hierarchy, the least preferable treatment option is disposing in landfills due to the pollution caused, such as gaseous emissions (e.g., CO_2 and CH_4) and liquid emissions. Despite the possible electricity and heat production by incineration treatment, there are several environmental problems, namely gaseous emissions (e.g., dioxins, furans, and CO_2). Due to these facts, landfill disposing and incineration methods contribute to the emission of greenhouse gases (GHGs) and consequently to climate change.

The energy consumption and emissions associated with waste collection, transport, and treatment further exacerbate GHG emissions.

Beyond the climate impacts, the improper management of waste leads to soil and water contamination through leachate generation, affects biodiversity by polluting habitats, and poses human health risks due to the spread of pathogens and toxic substances. These factors cumulatively contribute to the degradation of ecosystem services and the overall quality of life.

Addressing these challenges requires a systems approach that considers the connections between the environmental, social, and economic dimensions of waste management. By adopting such an integrated perspective, sustainable waste management can contribute to climate change mitigation, resource conservation, and the promotion of healthy and resilient communities.

Municipal waste (MW) production, one of the most significant waste streams in the world, is estimated to grow from 2.1 billion t in 2023 to 3.8 billion t by 2050, corresponding to an increase of 70%. There has been an evolution in the treatments applied to wastes, but in 2023, only 48% of MW in the EU was recycled (material recycling and composting), with the remainder being sent to incinerators or landfills, leading to significant environmental impacts [1].

Despite efforts to reduce the production of MW in the EU, its amount has increased over the last fifteen years, although since 2020, some stabilization in production was observed. In Portugal, the per capita waste generation rose from 439 kg in 2013 to 505 kg in 2023 [1].

According to the Mayor of Lisbon in a statement to the media in 2024, more than 900 t of waste are produced daily in Lisbon [2]. With a resident population of 547,733 inhabitants, this results in at least 599.7 kg of MW per capita (2024) in the city of Lisbon.

In Portugal, MW is composed of different fractions: 10.5% is plastic, 9.0% is paper/cardboard, 8.9% is sanitary textiles, and 6.9% is glass, with the largest fraction represented by 37.7% of biowaste. In 2023, it was reported that in mainland Portugal, 59% of MW was sent to landfills, while organic valorization (anaerobic/composting) accounted for just 8%, and recycling stood at 14%, as shown in Figure 1. In terms of collection type, in the unsorting collection of MW, biowaste constitutes the largest fraction, representing around 47% of the total [3].

According to European legislation, specifically the Waste Framework Directive, Portugal is required to improve biowaste treatment by 2030. This includes ensuring the separate collection of biowaste or its recycling at the source by 31 December 2023.

To promote recycling at the source, local treatments such as domestic composting must be implemented. Decentralized biowaste treatment solutions have numerous advantages comparing to industrial organic valorization, including reducing transport costs and environmental impacts [4,5]. Currently, domestic composting can be divided into home composting and community composting [6].

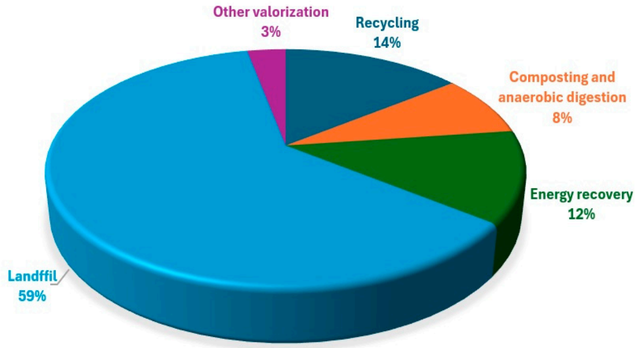


Figure 1. Final destinations of MW produced in mainland Portugal in 2023, adapted from [3].

Composting is a traditional biologic treatment for organic waste that occurs in the presence of oxygen (aerobic conditions). This process converts organic matter from several waste sources, such as animal and plant residues, livestock manure, food waste, and sewage sludge, into compost [7,8]. This process represents a key strategy for promoting a circular economy through the application of the composting product (compost) as an organic fertilizer in agriculture [9], as well as in the maintenance of parks and gardens, with several advantages.

The compost produced through composting has a very positive effect on soil structure, increasing the amount of organic matter present, making it more cohesive and stable, enhancing water infiltration, reducing surface water runoff, and minimizing soil erosion [10,11]. Moreover, the increase in organic matter in the soil contributes to carbon sequestration [10] and provides essential nutrients for plant growth [12]. Nevertheless, the compost quality depends on the waste subjected to composting, which also influences the efficiency or speed of the composting process [8].

Despite the advantages presented by composting, there are also challenges, as it is a time-consuming process that requires specific knowledge and care, such as maintaining the carbon-to-nitrogen (C/N) ratio, which necessitates adding brown (carbon-rich) and green (nitrogen-rich) waste in the correct proportions. Periodic aeration of the waste pile and moisture control are also essential, as these factors influence the quality of the final compost [13].

The composting process typically consists of four phases: heating, high temperature, cooling, and maturation [14]. These phases can also be called mesophilic, thermophilic, mesophilic and maturation, as described below.

1. Mesophilic Phase: In this phase, the decomposition of easily biodegradable organic compounds occurs by bacteria and fungi. The energy released in the form of heat is partially retained in the composting mass.
2. Thermophilic Phase (55 to 60 °C): In this stage, the organic fraction of the waste is almost completely degraded, with the partial exception of cellulose and lignin. The destruction of a high percentage of pathogenic microorganisms and other constituents (weed seeds, parasite eggs, and insect larvae) occurs, but is only possible if a high temperature is maintained for a few days.
3. Mesophilic Phase: In the second mesophilic phase, when the most accessible carbon sources are exhausted, there is a decrease in the microbiological activity with a consequent decrease in the temperature values. Colonization occurs by populations of microorganisms capable of attacking the compounds that are more difficult to degrade.
4. Maturation Phase (at ambient temperature): In this phase, the degradation of the most resistant substances and the formation of humic acids and humin continues

(mature compost—humidity 20% and C/N 10:1). Of the four phases, this is usually the longest.

Beyond its technical and environmental benefits, composting also holds strong educational value, especially within Higher Education Institutions (HEIs). As centers of knowledge generation and innovation, HEIs are uniquely positioned to model sustainable practices, serving as catalysts for behavioral change, and to promote systems thinking among future professionals. Implementing composting on campuses not only contributes to a reduction in the waste sent to industrial treatment and to climate change mitigation but also serves as a living laboratory for students and staff, integrating practical experience with academic content. In this context, promoting knowledge and awareness around biowaste composting becomes a strategic tool for embedding sustainability into the institutional culture and the daily practices of the academic community, bridging the gap between theory and practice and equipping students and staff with the skills and the mindset needed for sustainable waste management. Furthermore, it serves as a means of disseminating good practices that can later be implemented in other contexts, such as companies and local communities, with students acting as ambassadors for sustainability and agents of change. Therefore, promoting knowledge on biowaste composting within academic communities is not merely complementary to technical implementation, it is an essential component of a system-based approach to sustainability.

Several studies have been conducted at HEIs, as these environments, as already mentioned, are well suited for promoting knowledge on biowaste composting, while also being sources of biowaste themselves, particularly from gardens and canteens [5,15,16]. Also, domestic composting, when implemented at HEIs, contributes to sustainable waste management, promotes circularity practices, closing the biowaste loop, addresses legal requirements, promotes the Sustainable Development Goals and, last but not least, reduces the carbon footprint of HEIs.

In the last years, composting at HEIs has gained increasing relevance as institutions face significant challenges related to resource consumption, such as energy, water, food, paper, and other resources. Implementing composting programs at HEIs not only reduces the amount of biowaste sent to industrial valorization sites and landfills but also helps raise community awareness of the need to transition from a linear economy model ("take-make-waste") to a circular economy model that promotes sustainable waste management and environmentally responsible practices [17].

To implement a successful composting process, proper source separation is essential across all waste categories, particularly for organic waste, when the goal is to produce high-quality compost [4,18].

To understand the factors behind students' behaviors regarding sustainable food waste practices, the University of Portland conducted a survey of the community. The survey was carried out both in-person and online, targeting those using the dining facilities. The results showed that a large portion of food waste occurred because the participants disliked the taste of the food or underestimated the portion sizes. However, most of the participants demonstrated environmental awareness, adopting food waste reduction practices and expressing interest in and support for the composting project [19].

A study conducted at a university in Texas assessed the economic benefits of composting and the measures needed for its implementation by the community. Awareness campaigns were conducted to ensure proper waste separation, with supervision to avoid contamination. The economic analysis considered the implementation costs, including awareness, equipment, signage, collection, transport, and processing, all subsidized by donations. The project showed a positive economic balance, significantly reducing waste collection costs and generating profit from the compost sale [20].

Similarly, Keng et al. [21] conducted a study at a university in Malaysia that demonstrated a positive economic evaluation when comparing the implementation costs with the profits from the compost value/quality and the waste transport and treatment fees.

In Portugal, several HEIs have been incorporating sustainable campus principles into their sustainability plans, covering several important topics, including decentralized organic waste management.

The University of Minho lead a European project funded by the EU with over two million euros entitled, "RES_2VALHUM–Valorization of Organic Waste: Production of Humic Substances". The project aimed to reduce the amount of waste sent to landfills in the cross-border region of northern Portugal and Galicia, focusing on composting as a means of waste management. The organization has partnered with two urban waste management entities (LIPOR, Braval), the Galician Society for the Environment, the University of Santiago de Compostela, and the Environmental Valorization Center of the North [22].

The Faculty of Sciences at the University of Lisbon has implemented a composting project aimed at turning its waste from gardens, bars, and cafeterias into high-quality compost, reducing the environmental impact of waste transport and the reliance on external fertilizer sources. The established composting process includes the transport, reception, sorting, pre-treatment, and creation and maintenance of compost piles, resulting in compost and leachates. The compost, rich in nutrients, is applied to the university's gardens and orchards, benefiting the soil, the plants, and the environment [23].

The University of Porto developed a project in partnership with Fraunhofer Portugal and LIPOR with the purpose to create "ConPosting", a technological solution to digitize home composting. The system includes sensors, a mobile app, and a web portal, enabling citizens to participate in composting. The goal is to simplify the monitoring of composters through adapted sensors that collect data such as temperature and humidity. Participants receive a composter and training, and they can monitor the process via the mobile app and the web portal [24].

The School of Biotechnology at the Catholic University of Portugal created the Composting Demonstration Center in 1996 to treat cafeteria and garden organic waste and to raise awareness about the impact of waste production. The Center has eight outdoor composters in operation and four vermicomposters in a covered campus space. The project is open to visitors who wish to observe the different phases of domestic composting and is organized to be as automated as possible. The compost piles are only turned, and the water, nitrogen, and carbon contents are adjusted when the pile height stabilizes, or when unpleasant odors emerge. The temperature is also monitored to ensure the compost is sanitized. The compost produced is applied to the university's gardens or distributed in training actions [25].

Although some case studies on composting initiatives at HEIs have been reported, such as the above mentioned and others, such as those by Torrijos et al. [5], Jakimiuk et al. [26], and Rodríguez-Guerreiro et al. [27], there remains a gap in studies that integrate the technical monitoring of the composting processes with awareness campaigns targeting behavior change and community engagement. This work contributes to filling this gap, drawing on concepts from circular economy, sustainability education, and participatory environmental governance.

At Instituto Superior de Engenharia de Lisboa (ISEL), an HEI in Lisbon, Portugal and an Eco-school since 2020 and an Eco-campus since 2022, various initiatives have been promoted to raise awareness about environmental impacts, circular economy, and climate change. As a part of this initiative, the institution joined the *Lisbon Composting Program*, promoted by the Lisbon City Council, with the dual aim of reducing the organic waste generated on campus and diverted to landfills while producing compost to enrich campus soil, support existing green infrastructure, and enhance biodiversity. This approach reduces the need for chemical fertilizers and strengthens the transition towards a circular economy. The work carried out in this area also aimed to raise awareness within the community about the importance of proper waste separation, reducing landfill-bound waste, and promoting the benefits of food and garden waste composting.

This study is based on the hypothesis that implementing a composting system within an HEI, combined with awareness-raising actions, can effectively promote sustainable biowaste management practices while fostering environmental literacy and behavioral change.

The main goal of this study is to present and evaluate a case of institutional composting implementation within an HEI, focusing both on the technical monitoring of the process and on the outreach activities designed to engage the academic community. Specifically, this study aims to undertake the following: (i) implement and monitor a composting system in a campus setting; (ii) assess key parameters (temperature, pH, solids) during the composting process; (iii) carry out awareness campaigns targeting students, professors, and staff; and (iv) discuss the potential of such combined approaches in contributing to circular economy goals and climate change mitigation, and in addition, address the main challenges faced.

The originality of this study lies in its integrative approach, which combines scientific monitoring of a low-tech and low-cost composting process with educational and community-engagement components. This dual focus reflects the potential of alternative conceptual approaches—such as systems thinking, circular economy, and transformative learning—to drive sustainability transitions in academic environments.

2. Materials and Methods

2.1. Installation of Composters on Campus

Under the *Lisbon Composting Program*, promoted by the Municipality of Lisbon, eight domestic composters (each with around 320 L of capacity) were installed in four distinct locations on campus (two composters were placed in each location), as presented in Figure 2. Figure 3, shows the food waste composters installation with the participation of students, professors, and staff. The locations chosen for the installation of the composters were selected based on their proximity to the waste food production areas on campus (Section 2.5), in order to promote the proximity of waste production and facilitate its disposal, encouraging (through proximity) the continuation of the process. In addition, the locations chosen considered the need for the composters to be protected from direct sunlight and rain. Thus, the composters have the following identifications:

- C1—near the student residence;
- C2—near the student bar;
- C3—near Polytechnic University of Lisbon Social Action Services Canteen;
- C4—near the restaurant "By Chef" (temporarily inactive due to building renovation works).

In addition, a garden waste composter (G1), shown in Figure 2, was built, with a capacity of approximately 4 m^3, using recycled wooden pallets (Figure 4). The results of the assays carried out with this composter were already published [28].

This set of composters has been used to deposit some biowaste from food consumed on campus, as well as garden waste such as leaves, branches, and grass. The compost produced is later distributed across various green areas to promote soil regeneration and nourish the plants in the institution's gardens, contributing to improving biodiversity and promoting the circular economy.

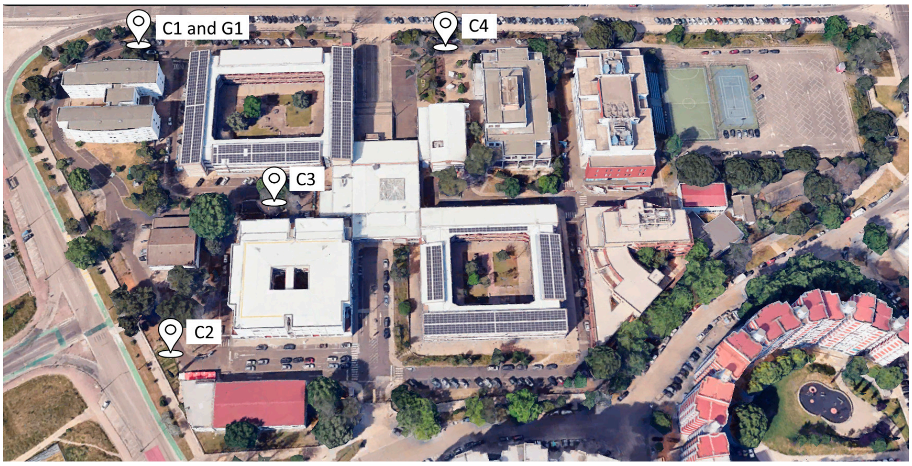
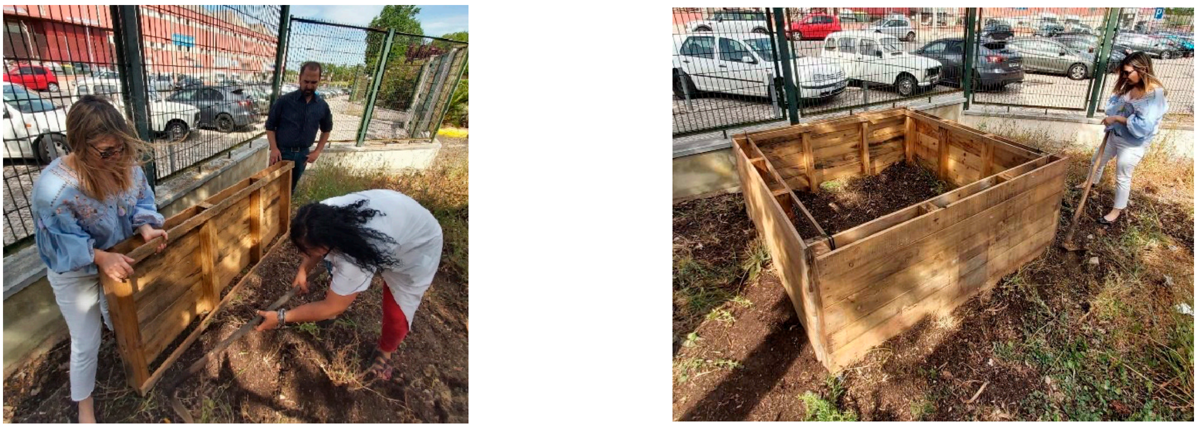


Figure 2. Location of composters on ISEL campus.

(**a**) (**b**)

Figure 3. Food waste composters installation at ISEL campus with the participation of the community: (**a**) initial structure assembly; (**b**) final composter installed.



(**a**) (**b**)

Figure 4. Garden waste composter construction: (**a**) initial structure assembly; (**b**) final composter installed.

Alongside the installation of the composters, training sessions about the composting process were conducted and informational posters were displayed near the composter's vicinity to guide users and to promote user engagement.

2.2. Training Actions

The training actions, conducted as part of the composting program at ISEL, had the primary goal of educating the academic community on the importance of properly separating wastes, the selective collection of biowaste, and the composting process.

The training actions consisted of two online webinars in which people from waste management entities, municipal councils, and waste consultancy companies participated as speakers. Two workshops were also carried out, in which participants were given theoretical knowledge about waste, biowaste, unsorted and selective collections, and composting. In the laboratory, participants analyzed some of the characteristics of biowaste, such as pH, solids, and particle size. They then sorted the biowaste for disposal in the composters installed on the ISEL campus.

These sessions targeted students, faculty, and staff, and they were scheduled at different times to maximize participation. The training covered the following topics:

- The importance of efficient waste management for sustainability;
- The importance of waste separation at the source and identifying compostable materials;
- The environmental impact of composting compared to other waste management methods (such as incineration and landfilling);
- The composting process and its phases;
- The use of compost as an organic fertilizer on campus and its benefits for biodiversity.

Informational materials, such as pamphlets and practical guides, were distributed to complement the training sessions and allow participants access to resources after the classes. Additionally, the training incorporated hands-on demonstrations of the composting process and examples of best practices.

2.3. Community Awareness

In addition to the training actions, it was crucial to carry out awareness-raising activities to ensure the community's engagement with the composting program. Several approaches were implemented to increase the program's visibility and encourage active participation, namely:

- Creation of a home composting manual: A manual containing detailed information on how to carry out and monitor domestic composting was distributed and placed at the various biowaste production sites.
- Creation of posters: Informative posters were placed near the composters and other high-traffic areas on campus. The posters highlighted the importance of waste separation, the environmental benefits of composting, and clear instructions on what could be placed in the composters.
- Carrying out awareness campaigns: Periodic campaigns were held to reinforce the benefits of composting and correct waste separation practices. These campaigns included the distribution of educational materials, the organization of open lectures, and scientific gatherings during sustainability events for all members of the academic community.

2.4. Community Survey

To assess the effectiveness of the awareness and training actions, a survey was conducted within the academic community.

To conduct the survey, the initial plan was to include the entire ISEL community, but due to technical difficulties, this was not possible. A representative sample of the community was chosen, namely members of the bachelor's degree in Municipal Technologies and Management and the master's degree in Quality and Environmental Engineering, where courses related to waste management and sustainability are taught. This sample included students, professors, and staff. The survey was distributed during training events and in classes. The survey was completed using a Google form and using an online link. The participants were completely voluntary, and the survey was completely anonymous.

The survey consisted of twelve questions, divided into three sections: demographics (three questions about age, gender, and education), sustainable development (three questions about participants' knowledge about climate change and sustainable development), and biowaste production and treatment (six questions about current composting practices and barriers faced). The average time to complete the survey was approximately three minutes.

The questions made focused on the following:

- Prior knowledge of composting and recycling: Evaluating participants' initial perception of composting and their usual waste separation practices;
- Participation in the program: Asking participants how often they used the ISEL composters and whether they were aware of their locations;
- Impact of awareness campaigns: Evaluating the effectiveness of the awareness campaigns, including whether they increased the willingness to participate in the composting program;
- Challenges encountered: Identifying barriers or difficulties faced by participants, such as time constraints, lack of knowledge about procedures, or difficulty in separating compostable waste.

2.5. Biowaste Characterization and Composting Monitorization Assays

Prior to the composting assays, some individual biowaste (food and green wastes) were selected in order to obtain the biowaste characterization in terms of pH and solids determination.

Food waste used in the composting assays came from three sources: the student residence, the student bar, and the Polytechnic University of Lisbon Social Action Services Canteen. As mentioned in Section 2.1, food waste from the "By Chef" restaurant was not used in this project. Food waste was mainly produced as a result of meal preparation, including fruit and vegetable peels, legumes, and eggshells. There was also a small quantity of food waste from individual production of fruit and vegetable peels that were also placed in the composters.

The green waste came from the maintenance of green spaces and consisted mainly of grass, dry leaves, small branches, and roots.

The composting process analysis was carried out in two assays to ensure a systematic and efficient approach and to evaluate and optimize the implementation process, as presented in Table 1.

Table 1. Description of composting assays and analyses performed.

Assay	Description	Parameters Obtained
1st	Preliminary composting assay	Moisture content, pH, temperature, solids, and contaminates.
2nd	Second composting assay	Moisture content, pH, temperature, solids, and contaminates.
	Compost quality	Color, texture, odor, pH, and moisture content.

The first composting assay (preliminary assay) lasted six months, from March to September (spring and summer in Portugal), and served as a preparation assay to assess the composting equipment and to observe the behavior of the ISEL community regarding the practice of home composting. In this preliminary assay, pH and temperature (T) were determined monthly, with a specific sample being taken from the contents of the composter to determine total solids (TS), fixed solids (FS), and volatile solids (VS).

The second composting assay took place from January to July (winter to summer in Portugal). The food waste composters were fed weekly, which allowed the microorganisms to be continuously supplied with organic matter (substrate). The addition of new waste was measured in order to balance carbon-rich materials (such as dried leaves) and with nitrogen-rich materials (such as food scraps), maintaining the appropriate carbon/nitrogen ratio.

The condition of the compost pile was checked weekly to determine the temperature, the humidity, the presence of unpleasant odors, and the presence of contaminants and pests. Supervision helped to identify problems early and take corrective measures when necessary.

In order to ensure adequate aeration to provide oxygen to the microorganisms involved in the decomposition of the waste, the compost pile was turned over using a shovel. This procedure helped to prevent/correct unpleasant odors associated with the compaction of waste and ensured adequate mixing of the waste in the pile.

For process analysis, samples from the composters were collected over 180 days, 1 to 2 times per week, and were analyzed in the laboratory to measure pH and TS, FS, and VS.

Temperature was also measured in the composters. This parameter was determined by instantaneous measurement read directly from a thermometer (1 to 2 times per week) and by continuous measurement (with sensors placed in the compost pile and connected to a PC). The thermometer was inserted into the compost pile to a depth of approximately 50 cm until the temperature reading stabilized. Measurements made with the thermometer were taken at five points: four points along the sides and one central point (T1 to T5) inside the composter, as shown in Figure 5. These points were selected based on previous temperature measurements that showed insignificant variations between points and given the reduced volume of the composters (around 320 L). The temperature in the three composters and the ambient temperature were measured over a period of 180 days. The ambient temperature was also measured near the composters.

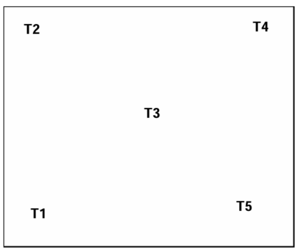


Figure 5. Indication of temperature measuring points inside the composters (plant view).

The assessment of the moisture content of the compost piles was carried out using a method known as the "sponge test". This method involves manually handling a quantity of material and squeezing it to check its moisture content. If the hand feels damp, this indicates that the moisture content is adequate. However, if water drips out, this indicates that the moisture content is excessive. On the other hand, if the hand feels dry, this indicates that water needs to be added to the waste pile in order to maintain adequate moisture. Thus, when a very dry composter pile was detected, water was added. Conversely, in the case of excess moisture, correction was carried out by adding dry materials, such as dry leaves or soil. The "sponge test" was also carried out for assessing compost quality.

Determining the height of the biowaste pile in the composters during the composting assays is essential to ensure an environment conducive to efficient decomposition. The average height of the pile was monitored over time using a tape measure. The measurement was taken from the base of the domestic compost to the top of the waste. The dates of supervision and the photographic record of the composters were recorded weekly.

The assessment of contaminants in the composters was conducted through visual inspection to identify the presence of non-biowaste materials, such as plastics, metals, and cigarette butts.

The presence of pests was also controlled by monitoring the presence of insects or rodents. In cases where the presence of pests, such as ants and mosquitoes, was detected, a layer of soil was added, and the compost lid was closed to keep weeds away.

The compost produced during the composting process was analyzed in terms of moisture content, pH, color, texture, and odor, and it was subsequently applied to the campus gardens.

The analytic methods performed in the laboratory for determining each parameter performed are described below.

pH measurement was performed according to EPA Method 9045D [29], and TS, VS, and FS were determined according to Standard Method 2540G [30].

The laboratory analysis of the compost piles was an essential component of the process, allowing the monitoring of the composting process and evaluating the composting effectiveness. During the monitoring period, samples were regularly collected and analyzed according to established standards.

The main parameters analyzed in composting assays included the following:

- pH: The pH was measured to check if the composter pile was within the ideal range for composting (usually between 6 and 8).
- Temperature: Temperature was monitored to evaluate whether the composting process was occurring correctly, with temperatures reaching high enough levels to promote decomposition (usually between 45 °C and 70 °C for the thermophilic stage).
- Total, fixed, and volatile solids: The measurement of volatile and fixed solids allowed the evaluation of the organic and inorganic matters in the pile and the stage of decomposition.

In order to ensure adequate analysis of the parameters, the sampling process was carried out according to the following steps:

- Type and quantity of sample: The samples taken from the composters were of composite type, comprising fractions collected from multiple points across the uppermost layer of the composters, totaling approximately 200 g.
- Bag identification: All bags were duly identified with the collection date and identification of the composter from which the sample was taken.
- Sample conservation: Samples were kept refrigerated until analysis.
- Removal of contaminants: Before collection, the detected contaminants were identified and removed.
- Sample representativeness: In order to guarantee the representativeness of the sample, the quartile method was used.

For the individual biowaste characterization and compost quality assessment, pH and solids were determined in a similar way to the composting pile.

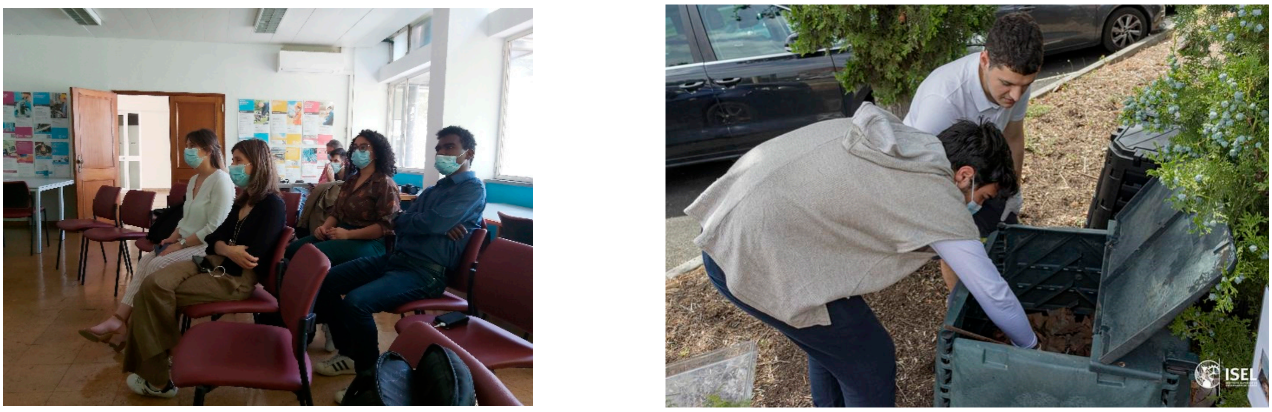
All parameters were performed at least in duplicates, to have concordant values, and the results correspond to the average of the two concordant measurements.

3. Results

3.1. Training Actions Results

The training sessions proved to be an important tool for increasing the academic community's knowledge about composting. Most of the participants demonstrated a good understanding of the concepts presented, and many expressed an increased interest in adopting composting practices at home. Some composting experiences and several difficulties encountered were also shared among the participants, namely the lack of space for having a composter in urban areas and the slowness of home composting.

However, the participation in the training was not as high as expected (Figure 6a), which could have been influenced by time constraints or a lack of prior knowledge about the event. Organizing more interactive training sessions with a practical component (Figure 6b) could help increase engagement.



(**a**) (**b**)

Figure 6. Training sessions about the composting process: (**a**) theoretical activity; (**b**) practical activity.

These activities contributed to an increase in awareness and participation, although the continuous promotion of the program is necessary to maximize the results.

3.2. Community Awareness Actions Results

Although the awareness campaigns were successful in terms of visibility, they still need more consistency and presence to ensure the community continues to engage with the program. The use of posters (Figure 7), made with the participation of the students and using informational materials, such as the composting manual (Figure 8), were effective and promoted engagement, but the ongoing integration of information through social media and regular events would help maintain interest and motivation among the participants.

(**a**) (**b**)

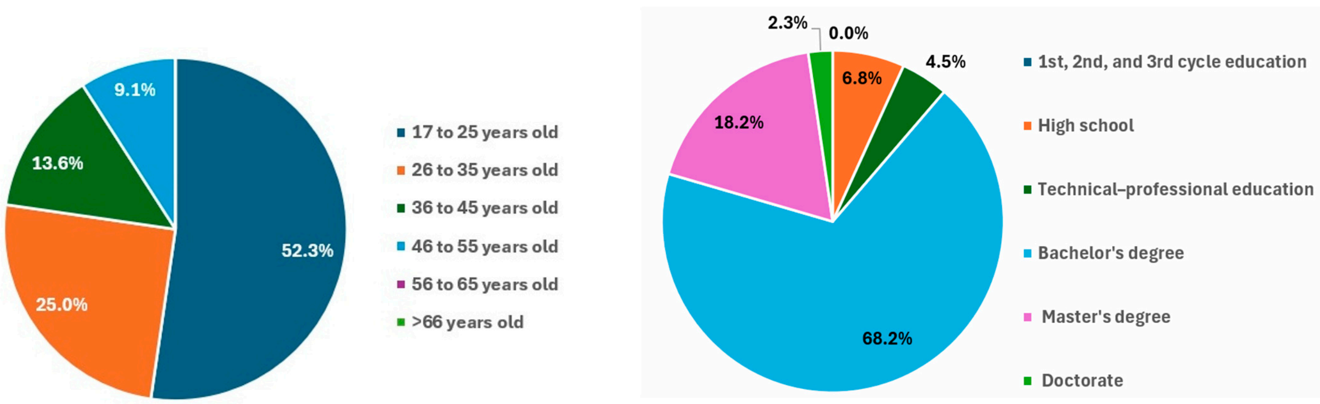
Figure 7. Examples of posters, installed on the campus, produced by students: (**a**) poster about home composting process; (**b**) poster about waste suitable for composting.

Figure 8. Example of a composting manual distributed at the institution (the manual is in Portuguese due to the fact that it was distributed at a Portuguese institution).

3.3. Community Survey Results

A comprehensive survey was conducted at the institution to assess the implementation of the composting practices and the community engagement. Of the 57 surveys distributed, 44 responses were received (77.2% response rate), which is identical to the value obtained by Campbell et al. [31] in a community compost study. Usually, the response rate varies significantly depending on the method of approaching the participants. Indirect methods have very low rates (<40%) [32], while direct methods, such as face-to-face interviews, can have response rates of 100% [33].

The survey included students, faculty, and staff members with diverse educational backgrounds and ages. The characterization of the participants in the composting survey is presented in Figure 9.



(**a**) (**b**)

Figure 9. Characterization of the participants on the composting survey: (**a**) age distribution; (**b**) educational qualifications.

The age distribution shows that 52.3% of the respondents were from the student population (17–25 years old), demonstrating a higher availability to participate in the survey (Figure 9a). The oldest age group (46 to 55 years old) is probably composed of teachers and staff.

Regarding the literacy of the participants (Figure 9b), it is observed that the majority of the respondents (86.4%) were ISEL students, with 68.2% holding bachelor's degrees and 18.2% holding master's degrees.

The results regarding the questions related to climate change concerns are presented in Figure 10.

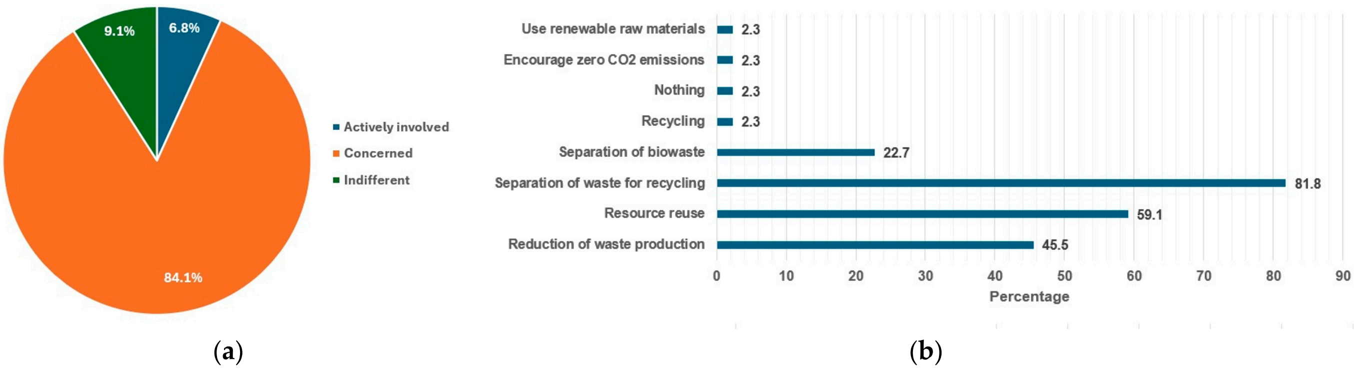


Figure 10. Survey results regarding climate change opinions and involvement: (**a**) level of community concern; (**b**) community practices for mitigation.

In Figure 10a, it can be observed that 84.1% of the respondents expressed concern about climate change issues; however, only 6.8% were actively involved in climate action initiatives. Although the majority showed some concern, the bulk of the respondents are still not fully aware of the importance of individual actions (notably composting) to combat this scourge and 9.1% of the participants showed indifference to climate change issues.

Regarding the practices developed in the daily lives of the participants that aim to combat climate change, and as shown in Figure 10b, it can be seen that a high percentage of the survey participants separate waste for recycling (81.8%), with just 22.7% separating biowaste. Other important measures in terms of resource sustainability are also adopted by a significant portion of the respondents; however, a small percentage (2.3%) of the respondents do nothing, which raises concerns regarding the fact that nowadays there are still people who are not concerned with adopting practices that ensure resource sustainability.

Concerning knowledge about the waste suitable for domestic composting (Figure 11), 29.5% of the respondents still believe that it is possible to put any biowaste in a domestic composter. Thus, they are not considering the impact that meat or fish scraps will have on the composting process, as mentioned in the training actions (Section 3.1). On the other hand, it is encouraging to see that a high percentage of the interviewees are properly informed about the type of waste that can be placed in a domestic composter.

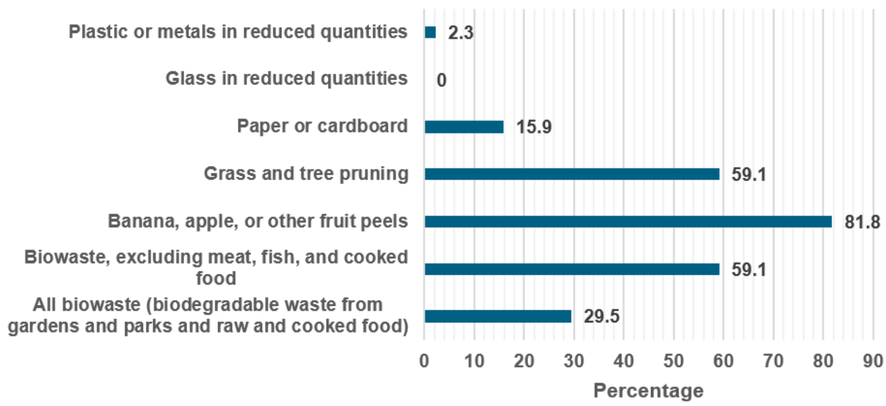


Figure 11. Survey results regarding knowledge about waste suitable for domestic composting.

In Figure 12, it can be seen that 81% of the survey participants produce fruit peels and 16.7% produce salad leftovers (without dressing). These wastes are valid for placement in the home composters present at ISEL, although, in terms of volume, they constitute a small fraction of the total volume admissible by the food waste composter.

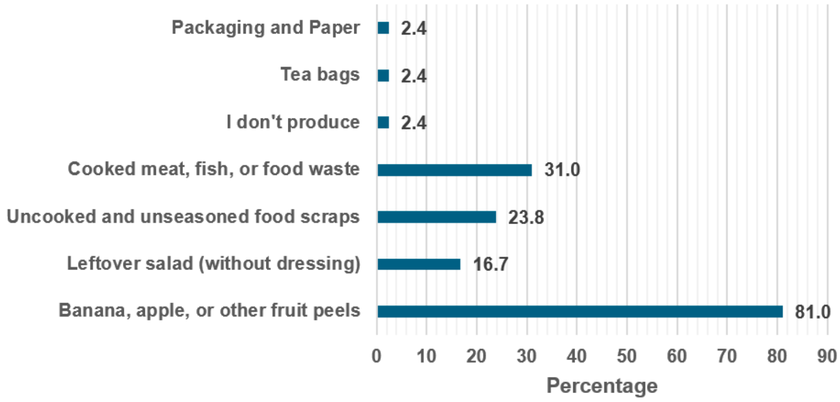


Figure 12. Survey results showing the types of biowaste generated by respondents on the ISEL campus.

The results of the remaining survey questions are presented in the following paragraphs.

Related to the identification of practices on the ISEL campus by its users, 50% identified the presence of composters on the campus. The results also indicated that a significant number of the survey participants are aware of the sustainability initiatives implemented at the Institute.

The main reason given by the survey participants for their lack of interest or participation in composting at ISEL was the lack of time or availability, reported by 90% of the respondents. This may be due to the perception that composting is a time-consuming activity that requires a significant commitment.

At the time of the survey, 82% of the respondents reported never having deposited biowaste in the campus composters. It is hoped that this initiative will help change that reality.

Half of the interviewees reported never having found any composters at ISEL, and only 9% had confirmed the existence of the eight composters on campus. This fact is possibly due to the need to place the composters in places protected from adverse weather conditions, which in some cases means that they are not perfectly visible to the ISEL population in general. In this sense, placing identification signs or even posting signs near the composters could represent a solution to the problem.

The survey also revealed that although many of the participants were aware of the importance of composting, a significant number still failed to separate waste correctly. Furthermore, a lack of clarity about what materials are compostable was identified as a key barrier.

The survey results provided valuable data on community acceptance and challenges faced, allowing for adjustments in future awareness and training actions.

3.4. Biowaste Characterization and Composting Monitorization Assays Results

Some individual biowaste materials were characterized in terms of pH and solids, namely pine needles, plantain leaves, grass, rubber tree leaves, cabbage, watermelon rind, banana peel, tomato, red apple, yellow plum, and zucchini. The characterization of each waste type, in terms of pH and solids content, was carried out under the same project (Projeto IPL/2022/BioCompost_ISEL) and is presented in Table 2 [28].

Table 2. Individual biowaste characterization [28].

Biowaste	pH	ST (%)	SV (%)	SF (%)
Red apple	4.5	14.4	14.1	0.3
Banana peel	5.0	22.6	18.8	3.8
Watermelon rind	4.3	7.2	6.6	0.6
Cabbage	7.0	12.2	10.8	1.4
Yellow plum	3.3	10.6	10.3	0.3
Zucchini	6.4	4.7	4.1	0.6
Tomate	5.2	4.5	4.0	0.5
Pine needle	4.5	90.9	86.1	4.8
Plantain leaves	4.8	85.0	79.4	5.6
Rubber tree leaves	7.0	80.8	70.0	10.8
Grass	7.0	39.1	30.4	8.7

The results indicate that the pH of the waste materials ranged from 3.3 (yellow plum) to 7.0 (cabbage, grass, and rubber tree leaves). Banana peels showed a lower pH (5.0) than the 6.7 reported in [34]. As the optimal pH range for composting is 7–8, lower-pH wastes should be combined with higher-pH materials to achieve a balanced mixture.

Solid content varied significantly, with leaves showing higher TS (80–85%) and VS (70–80%) values. In contrast, fruit and vegetable wastes had lower TS (4–23%) and VS (4.0–19%) contents, which is consistent with previously reported ranges [35].

Concerning the composting assays, the height of the compost pile varied, reflecting the different stages of the decomposition process. In general, the height of the compost pile was observed to increase over time, with some variation between the different composters. In the first assay (preliminary assay), the height of the composter's piles varied by 10 cm for the first 40 days and reached maximum heights of 60 to 70 cm after 100 days. In the second assay, carried out over 180 days, the evolution of heights was similar, reaching maximums of 60 to 80 cm.

The moisture conditions during the assays varied from "very wet with runoff" to "very dry with no apparent activity". Overall, the moisture was adequate; however, in the warmer months, it was necessary to add water occasionally, and in the wetter months, it was necessary to mix dry soil in order to avoid problems such as excessive compaction, the formation of anaerobic zones, and the loss of essential nutrients.

The compost pile temperatures represent the average of the five measurements made for each composter (Section 2.5). The temperature evolution during the second assay for composters C1, C2, and C3, and the ambient temperature, is presented in Figure 13.

According to the average temperature profile (Figure 13) for the three composters, a temperature increase is observed on the seventh day, and it is more pronounced for composters C1 and C3. The existence of small peaks in temperature is confirmed throughout the assay, as a result of the weekly feeding of the composter. The second composting assay began in January (winter time), with an average ambient temperature of 15 °C, and ended in June (summer time), with an average ambient temperature of approximately 25 °C. Composter C2 presents a temperature similar to the ambient temperature until day 110 of composting, possibly related to the type of biowaste added to the composter, such as cabbage stems and roots, which contain compounds that are more difficult for microorganisms to degrade (e.g., lignite).

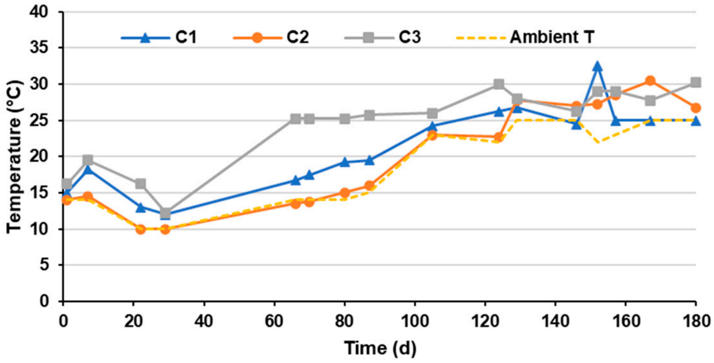


Figure 13. Average temperature profile recorded in composters C1, C2, and C3 (2nd composting assay).

In Figure 13, it can be observed that composter C3 presented higher temperatures, probably due to the larger amount of waste deposited, consequently providing a greater quantity of organic matter available for biodegradation reactions. However, none of the composters reached the temperature characteristic of the thermophilic phase of the composting process. No temperatures higher than 45 °C were recorded in any of the assays. Usually, it is necessary to maintain a temperature of 55 °C for 3 to 5 days to ensure the reduction of pathogens [36]. This was likely due to two main factors: the small volume of waste deposited that made up the pile and the fact that only plant wastes were placed in the composters [37,38]. On the other hand, the ambient temperature was relatively low due to the fact that the monitorizations were done in winter and spring (January to June), which contributed to a lower temperature in the outer layers of the waste piles inside the composters, thus influencing the average temperatures recorded. The composters analysis revealed that, although the temperature did not reach the necessary temperature to destroy the pathogenic microorganisms (thermophilic phase), the composting process progressed satisfactorily.

The pH evolution for the composters C1, C2, and C3 is presented in Figure 14.

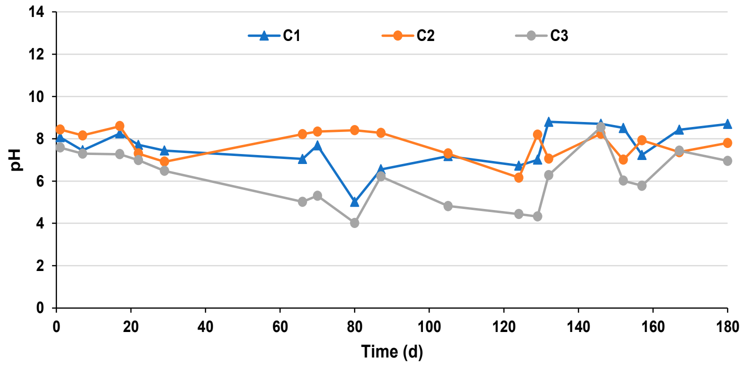


Figure 14. pH profile obtained in composters C1, C2, and C3 (2nd composting assay).

The pH profile for composter C1 remained relatively constant until 60 days of composting (Figure 14). From this point on, there was a slight increase in pH, followed by a considerable decrease to around 5 units.

The three composters showed a tendency to lower the initial pH in the first days of the assay (Figure 14), which is characteristic of the beginning of the composting process due to the action of acid-forming bacteria that decompose the organic matter. Due to the continuous feeding of the composters, there are several peaks in the pH profile throughout the 180 days of the composting assay, which are characteristic of the composting process.

Regarding pH, it is observed in Figure 14 that composter C3 has a lower pH profile, which aligns with the temperature profile observed and the higher amount of organic matter. All the composters showed a pH between 4 and 9, which is the typical range for the composting process.

With respect to the TS and VS content measured during the second composting assay, these parameters exhibited considerable variation among the composters, reflecting the differences in the quantity and the variety of biowaste introduced into each.

The composter C2, located near the student bar, with predominantly fibrous biowaste deposition from the campus vegetable garden maintenance, presented lower average TS values. The high concentration of woody material hindered rapid decomposition, resulting in a slower reduction of VS. On the other hand, C3, located near the canteen, stood out for the diversity of food waste. Initially, it recorded high VS values, characteristic of fresh organic matter, but over time, a progressive reduction was observed, suggesting active decomposition directly related to the nutritious nature of the food waste. C1, located near the student residence, presented an intermediate pattern. The mixture of biowaste resulted in more balanced values of TS and VS, with low variability, indicating a more controlled composting process.

Since the supervision was carried out simultaneously with the successive disposal of waste until the end of the process, there was no progressive decrease in TS and VS, but instead there were peaks after the addition of waste, followed by decreases resulting from microbial activity. Thus, VS values above 60% were observed, which are indicative of fresh, undegraded organic matter.

Several contaminants were occasionally identified in the composters, namely: plastic bags and nets, prepared food (fish bones), knives, and potato peelers (Figure 15). Most of the contaminants were found in C3, near the canteen facility, possibly related to the diversity of employees assigned to the canteen who prepare the meals.

Figure 15. Plastic contaminant found in the composter.

According to Rodríguez-Guerreio et al. [27], the compost quality necessary for soil application requires the separative collection of biowaste and a low level of contaminants. Therefore, the compost quality is correlated with the raw feedstock properties rather than the composting process. In the present work, the compost produced and used for soil application was only from the composters with less contamination, namely from composters C1 and C2.

In domestic composting, it is preferable to assess the compost maturity based on its physical characteristics, such as texture, smell, or color, rather than through laboratory tests, which involve inherent challenges in obtaining consistent and accurate results [39], as well as higher time and cost demands. Therefore, in the present work, the compost maturity was obtained by these physical characteristics, and only pH was measured. In addition, the moisture content was evaluated, and the results revealed a sufficient moisture content.

The compost produced during this work and applied to the campus soil was dark, crumbly, and earthy smelling, with no recognizable food scraps or other contaminants. The measured pH, a chemical indicator of the compost maturity, presented an average value of 7.8, consistent with other studies, which report pH values ranging from 7 to 9 [36].

4. Conclusions

The domestic composting program implemented at ISEL proved to be a promising initiative for biowaste management and promoting sustainable practices on campus.

The training sessions were effective in increasing the academic community's knowledge of composting. Most of the participants understood the concepts well and showed an interest in applying them at home, despite challenges such as limited urban space and the slow pace of composting. However, the attendance was lower than expected, possibly due to the time constraints or a lack of awareness. More interactive, hands-on sessions could help boost engagement.

The awareness campaigns were visible and engaging but needed more consistency. The posters and materials developed by the students were effective, but the continued use of social media and regular events is key to sustaining interest in domestic composting.

The survey showed that while 50% of the users recognize the presence of composters at ISEL and are aware of sustainability actions, 45% are unwilling to participate in the composting initiative—mainly due to a lack of time. Most (82%) had never used the composters, and many had not seen them, likely due to their poor visibility. Better signage and information could help. A lack of knowledge about compostable materials also remains a barrier.

The composting assays showed slight temperature increases, especially in composters C1 and C3, due to weekly feeding. C3 presented higher temperatures, probably due to more waste deposition, but none reached the thermophilic phase (>45 °C). The low temperatures were due to the small waste volumes, the use of only plant waste, and the cold weather during the winter and spring. C2 remained near ambient temperature, possibly due to the harder-to-degrade biowaste.

The pH in all the composters initially dropped, typical of early composting, then fluctuated due to regular feeding. Composter C1 showed a late sharp drop, while C3 had a consistently lower pH, matching its higher organic content. Overall, the pH ranged between 4 and 9, as expected for composting.

The composting process implemented on the ISEL campus has proven to be an asset (albeit on a small scale), promoting a circular economy and reducing the waste sent to industrial valorization units and landfills.

The compost produced was dark, crumbly, and had an earthy smell, with no visible food scraps or contaminants, indicating good quality. The average pH was around 8, which reflects compost maturity. This compost was applied to the campus gardens, leading to improvements in the soil quality. By enriching the soil organically in selected areas, it supported plant development and fostered local biodiversity.

Despite the successful production of compost, the composting initiative still faces challenges related to community engagement. These include waste contamination (such as fish bones, cutlery, napkins, and plastics) and the need to further raise awareness and educate the community. Furthermore, the process is relatively slow, typically requiring 5 to 6 months. It was concluded that periodic and frequent awareness campaigns are necessary to reach a larger number of people and raise their awareness on this issue.

The work developed aimed to contribute to the 17 Sustainable Development Goals (SDGs), namely, improving education on sustainable development for the school community (SDG 4), improving waste management and reducing the environmental impact of cities (SDG 11), promoting sustainable consumption and production, efficient use of natural resources, and reducing waste generation sent to landfills (SDG 12), and promoting climate action (SDG 13).

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Institutional Review Board Statement: Verbal informed consent was obtained from the participants. Verbal consent was obtained rather than written because the response to the survey was voluntary and all participants were fully informed that their anonymity would be guaranteed and about the relevance of the study in question. The survey did not involve the collection or analysis of sensitive personal data, but solely opinions and knowledge regarding waste management. As it was an opinion survey, without collection of sensitive personal data, entirely voluntary and anonymous, submission to the institution's ethics committee was not required.

Informed Consent Statement: Verbal informed consent was obtained from all participants. Written consent was not required, as participation was entirely voluntary and anonymous. The survey did not involve sensitive personal data, but only opinions and knowledge related to waste management and environmental sustainability. The only demographic information requested was age group (in intervals), gender, and education level. No identifying data, such as name or email, were collected. At the start of the survey, participants were presented with the following information (in Portuguese): "This survey is anonymous and confidential, and the data collected will be used exclusively for statistical purposes".

Data Availability Statement: Data are contained within the article.

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Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Eurostat. Municipal Waste Statistics. 2025. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Municipal_waste_statistics (accessed on 27 June 2025).
2. SAPO. Atualidade. 2024. Available online: https://www.sapo.pt/noticias/atualidade/artigos/carlos-moedas-lisboa-produz-mais-de-900-toneladas-de-lixo-por-dia-nao-pode-continuar-a-nao-ter-recolha-ao-domingo (accessed on 26 June 2025).
3. APA. Relatório Anual Resíduos Urbanos 2023. Agência Portuguesa do Ambiente. 2024. Available online: https://apambiente.pt/sites/default/files/_Residuos/Producao_Gest%C3%A3o_Residuos/Dados%20RU/2023/raru_2023.pdf (accessed on 27 June 2025).
4. Bruni, C.; Akyol, C.; Cipolletta, G.; Eusebi, A.L.; Caniani, D.; Masi, S.; Colon, J.; Fatone, F. Decentralized community composting: Past, present and future aspects of Italy. *Sustainability* **2020**, *12*, 3319. [CrossRef]
5. Torrijos, V.; Dopico, D.C.; Soto, M. Integration of food waste composting and vegetable gardens in a university campus. *J. Clean. Prod.* **2021**, *315*, 128175. [CrossRef]
6. Barrena, R.; Sánchez, A. HomeComposting: A Review of Scientific Advances. *Eng. Proc.* **2022**, *19*, 3–6.
7. Misslin, R.; Clivot, H.; Levavasseur, F.; Villerd, J.; Soulié, J.-C.; Houot, S.; Therond, O. Integrated assessment and modeling of regional recycling of organic waste. *J. Clean. Prod.* **2022**, *379*, 134725. [CrossRef]
8. Yin, J.; Xie, M.; Yu, X.; Feng, H.; Wang, M.; Zhang, Y.; Chen, T. A review of the definition, influencing factors, and mechanisms of rapid composting of organic waste. *Environ. Pollut.* **2024**, *342*, 123125. [CrossRef]
9. Awasthi, S.K.; Kumar, M.; Sarsaiya, S.; Ahluwalia, V.; Chen, H.; Kaur, G.; Sirohi, R.; Sindhu, R.; Binod, P.; Pandey, A.; et al. Multi-criteria research lines on livestock manure biorefinery development towards a circular economy: From the perspective of a life cycle assessment and business models strategies. *J. Clean. Prod.* **2022**, *341*, 130862. [CrossRef]
10. Sharma, B.; Vaish, B.; Monika; Singh, U.K.; Singh, P.; Singh, R.P. Recycling of organic wastes in agriculture: An environmental perspective. *Int. J. Environ. Res.* **2019**, *13*, 409–429. [CrossRef]

11. Diacono, M.; Montemurro, F. Long-term effects of organic amendments on soil fertility. A review. *Agron. Sustain. Dev.* **2010**, *30*, 401–422. [CrossRef]
12. Boldrin, A.; Andersen, J.K.; Møller, J.; Christensen, T.H.; Favoino, E. Composting and compost utilization: Accounting of greenhouse gases and global warming contributions. *Waste Manag. Res.* **2009**, *27*, 800–812. [CrossRef]
13. Hemidat, S.; Jaar, M.; Nassour, A.; Nelles, M. Monitoring of Composting Process Parameters: A Case Study in Jordan. *Waste Biomass Valori.* **2018**, *9*, 2257–2274. [CrossRef]
14. Qian, X.; Shen, G.; Wang, Z.; Guo, C.; Liu, Y.; Lei, Z.; Zhang, Z. Co-composting of livestock manure with rice straw: Characterization and establishment of maturity evaluation system. *Waste Manag.* **2014**, *34*, 530–535. [CrossRef]
15. Vázquez, M.A.; Plana, R.; Pérez, C.; Soto, M. Development of Technologies for Local Composting of Food Waste from Universities. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3153. [CrossRef]
16. Filho, W.L.; Ribeiro, P.C.C.; Setti, A.F.F.; Azam, F.M.S.; Abubakar, I.R.; Castillo-Apraiz, J.; Tamayo, U.; Özuyar, P.G.; Frizzo, K.; Borsari, B. Toward food waste reduction at universities. *Environ. Dev. Sustain.* **2023**, *26*, 16585–16606. [CrossRef]
17. Gallardo, A.; Edo-Alcón, N.; Carlos, M.; Renau, M. The determination of waste generation and composition as an essential tool to improve the waste management plan of a university. *Waste Manag.* **2016**, *53*, 3–11. [CrossRef] [PubMed]
18. European Environment Agency. Bio-Waste in Europe—Turning Challenges into Opportunities. Report No 04/2020 (Issue 04). Available online: https://www.eea.europa.eu/publications/bio-waste-in-europe (accessed on 26 June 2025).
19. Alattar, M.A.; Delaney, J.; Morse, J.L.; Nielsen-Pincus, M. Food waste knowledge, attitudes, and behavioral intentions among university students. *J. Agric. Food Syst. Community Dev.* **2020**, *9*, 109–124. [CrossRef]
20. Sanders, J.; Waliczek, T.M.; Gandonou, J.M. An economic analysis of a university educational cafeteria composting program—Bobcat Blend. *HortTechnology* **2011**, *21*, 639–646. [CrossRef]
21. Keng, Z.X.; Chong, S.; Ng, C.G.; Ridzuan, N.I.; Hanson, S.; Pan, G.T.; Lau P, L.; Supramaniam, C.V.; Singh, A.; Chin, C.F.; et al. Community scale composting for food waste: A life-cycle assessment-supported case study. *J. Clean. Produ.* **2020**, *261*, 121220. [CrossRef]
22. Universidade do Minho. UMinho Coordena Projeto Europeu de Valorização de Resíduos Orgânicos. 2017. Available online: https://alumni.uminho.pt/pt/news/Paginas/Not%C3%ADcias%202017/Residuos-org%C3%A2nicos-.aspx (accessed on 15 April 2024).
23. CiênciasULisboa. Como está Ciências a Melhorar a Gestão Dos Resíduos Orgânicos? 2017. Available online: https://ciencias.ulisboa.pt/pt/noticia/28-06-2017/como-est%C3%A1-ci%C3%AAncias-a-melhorar-a-gest%C3%A3o-dos-res%C3%ADduos-org%C3%A2nicos (accessed on 10 June 2025).
24. UPORTO. Fraunhofer Portugal e LIPOR Criam Tecnologia Para Facilitar Compostagem Caseira. 2021. Available online: https://noticias.up.pt/2021/05/21/fraunhofer-portugal-e-lipor-criam-tecnologia-para-facilitar-compostagem-caseira/ (accessed on 27 June 2025).
25. Almeida, C.; Teixeira, F.; Silva, M. Compostar para Educar O Papel de um Centro de Demonstração de Compostagem. In Proceedings of the XIV Encontro Nacional de Educação Ambiental, Parque Biológico de Gaia, Portugal, 3–5 October 2003.
26. Jakimiuk, A.; Matsui, Y.; Podlasek, A.; Koda, E.; Goli, V.S.N.S.; Voběrková, S.; Singh, D.N.; Vaverková, M.D. Closing the loop: A case study on pathways for promoting sustainable waste management on university campuses. *Sci. Total Environ.* **2023**, *892*, 164349. [CrossRef]
27. Rodríguez-Guerreiro, M.-J.; Torrijos, V.; Soto, M. A Review of Waste Management in Higher Education Institutions: The Road to Zero Waste and Sustainability. *Environments* **2024**, *11*, 293. [CrossRef]
28. Santos, M.T.; Freitas, F.; Lamego, P.; Teodoro, T. Sustainable composting of garden and food waste in higher education institution. In Proceedings of the 3rd International Conference on Challenges in Engineering, Medical, Economics and Education: Research & Solutions (CEMEERS-24a), Porto, Portugal, 7–8 March 2024.
29. United States Environmental Protection Agency. SW-846 Test Method 9045D: Soil Waste, p.H. 2004. Available online: https://www.epa.gov/sites/default/files/2015-12/documents/9045d.pdf (accessed on 15 April 2024).
30. APHA. *Standard Methods for the Examination of Water and Wastewater*, 23rd ed.; American Public Health Association, American Water Works Association: Washington, DC, USA, 2017.
31. Campbell, C.G.; Gusto, C.; Kelsey, K.D.; Haase, H.; Cohen, N.; Robertson, K.; Kiker, G.A.; Boz, Z. Household food waste behaviors of participants in a municipal community compost program. *J. Agric. Food Syst. Community Dev.* **2025**, *14*, 9–26. [CrossRef]
32. Madusanka, K.H.P.; Matsuto, T.; Tojo, Y.; Hwang, I. Questionnaire and onsite survey on municipal solid waste composting in Sri Lanka. *J. Mater. Cycles Waste Manag.* **2017**, *19*, 804–814. [CrossRef]
33. Sayara, T.; Hanoun, R.; Hamdan, Y. Survey on the factors and social perspectives to participate in home composting schemes in Palestine: Anabta case study. *AIMS Environ. Sci.* **2022**, *9*, 232–243. [CrossRef]
34. Islam, M.R.; Wang, Q.; Guo, Y.; Wang, W.; Sharmin, S.; Enyoh, C.E. Physico-Chemical Characterization of Food Wastes for Potential Soil Application. *Processes* **2023**, *11*, 250. [CrossRef]
35. Esparza, I.; Jiménez-Moreno, N.; Bimbela, F.; Ancín-Azpilicueta, C.; Gandía, L.M. Fruit and vegetable waste management: Conventional and emerging approaches. *J. Environ. Manag.* **2020**, *265*, 110510. [CrossRef]

36. Azim, K.; Soudi, B.; Boukhari, S.; Perissol, C.; Roussos, S.; Alami, I.T. Composting parameters and compost quality: A literature review. *Org. Agric.* **2018**, *8*, 141–158. [CrossRef]
37. Storino, F.; Arizmendiarrieta, J.S.; Irigoyen, I.; Muro, J.; Aparicio-Tejo, P.M. Meat waste as feedstock for home composting: Effects on the process and quality of compost. *Waste Manag.* **2016**, *56*, 53–62. [CrossRef] [PubMed]
38. Smith, S.R.; Jasim, S. Small-scale home composting of biodegradable household waste: Overview of key results from a 3-year research programme in West London. *Waste Manag. Res.* **2009**, *27*, 941–950. [CrossRef] [PubMed]
39. Ujj, A.; Percsi, K.; Beres, A.; Aleksza, L.; Fernanda Ramos Diaz, F.R.D.; Csaba Gyuricza, C.; Fogarassy, C. Analysis of Quality of Backyard Compost and Its Potential Utilization as a Circular Bio-Waste Source. *Appl. Sci.* **2021**, *11*, 4392. [CrossRef]