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Autonomous Home Composting Units for Urban Areas in Greece: The Case Study of the Municipality of Rhodes

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Abstract: A significant issue is reducing the amount of biological waste that is disposed of in landfills, particularly in high-density residential areas. The Wastes Framework Directive (98/2008), in particular, sets forward the legal requirements for source separation in the European Union's (EU) environmental legislation. The directive sets a target for separate collection of 10% of the organic waste produced in each municipality by 2030, especially with regard to organic waste. The pilot experience of an integrated biowaste management system that supports source separation and urban composting in an Autonomous Composting Unit (ACU) was presented in this study. The Municipality of Rhodes installed five ACUs in various locations. Used food and green waste are the two types of waste that are deposited in the ACUs. The development of a system for the collection of produced biowaste and its treatment at the source, without producing a nuisance, within an urban area, is the goal of this innovation. Since landfilling of mixed municipal solid waste has long been a common practice on the island of Rhodes, as well as in many other locations of insular and mainland Greece, this technique was introduced as a novel implementation and innovation for the region. The results showed that biowaste source separation was successfully carried out by citizens, resulting in high-purity feed. All ACUs produce compost that is of a standard quality. In accordance with the principles of the circular economy, this study showed that ACUs are a sustainable solution for taking a closed unit approach to the biowaste management problem in urban areas.

Keywords: Autonomous Composting Units; biowaste; urban waste; green waste

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1. Introduction

New national planning, in the context of the ambitious environmental policy followed by Greece, has set a primary goal of reducing the landfill of municipal solid waste (MSW), the lowest level of management in the waste hierarchy pyramid, to a rate of less than 10% in 2030, achieving this target five years earlier than required by EU guidelines, which foresee a maximum burial rate of 10% in 2035. In order to achieve this percentage, especially in urban municipalities, major changes need to be made in MSW and especially biowaste management, entailing a significant financial burden.

In Greece, source separation scheme (SSS) recycling increased slightly from 790,000 tn (15.0%) to 913,000 tn (16.5%) from 2015 to 2018. Biowaste rose correspondingly from 109,000 tn (4.7%) in 2015 to 139,000 tn (5.7% by weight of produced biowaste) in 2018 [1] The sustainability of the urban environment may be threatened by the rapid changes in lifestyle that are occurring among urban residents all over the world. However, reducing food waste (FW) is a key objective of waste prevention. Waste prevention includes all actions taken before a product or item becomes waste, reducing waste production, harmful effects on the environment and human health, and toxic substance content [2]. The major amount of biowaste produced is made up of food waste, particularly in metropolitan areas and large urban centers where the generation of green waste is constrained. Biowaste has been identified as a global environmental and social problem that requires attention. Other nations, like Greece, have an almost complete knowledge gap regarding the compositional and physicochemical characteristics of municipal biowaste, despite the fact that it represents the single largest fraction of MSW, accounting for about 35% w/w. This is despite the fact that several countries, at the EU and international level, have recently carried out studies searching for additional data on municipal biowaste characterization [3].

Food waste has historically received less attention than other biodegradable waste fractions, despite the fact that it has been a significant source of methane emission in landfills and is the waste stream most likely to contaminate other waste fractions. Due to public perception issues and health concerns regarding the spread of disease, composting and other biological treatment technologies—which are not new—have not been frequently used to treat food waste [4]. The complex proteins and carbohydrates in dead organic matter are broken down into simpler nutrients that plants may absorb during the natural biological process of composting. You might think of it as simply recycling organic waste to create a conditioner or substitute for soil that can be used to grow new crops. FW diversion into composting represents a form of environmental waste management, where organic material is biologically broken down [5].

Composting can be further categorized into aerobic and anaerobic. Aerobic composting can be done in the open, as in the aerated pile and windrow processes, or in closed in-vessel or container systems [6]. Composting is recommended because it is environmentally friendly, economical, and converts waste into products with value added without endangering the environment. Additionally, the result can be utilized as organic fertilizer, a soil stabilizer, and a crop development promoter [7]. Microorganisms are crucial to the composting process because they help turn organic matter into stable material through a variety of biochemical reactions, creating humus that is fiber-rich, carbon-containing, and rich in organics like nitrogen and phosphorus [8].

The quality of the compost produced will be influenced by the type of composting method used, process control variables [9], and the nature and composition of the input material [10]. One benefit of domestic composting is that costs associated with collection, transportation, technological processing, and potential commercial usage of the output are kept as low as possible. When performed correctly, household composting can offer excellent stability [11]. Other options for FW processing exist with the use of automatic home composters. Currently, these are also used in hotels, restaurants, and catering [12]. Due to its physical and chemical characteristics, a separate composting of FW is highly challenging. Its unsuitable C/N ratio, high moisture content and compact structure can have an impact on the process itself, as well as attributes (phytotoxicity). This avoids using FW as the only raw material for composting. Because of this, it is advised to compost FW with the addition of bulking agents such as urban green biomass and agricultural waste biomass [13].

In-vessel composting produces fewer greenhouse gas (GHG) emissions than windrow and aerated pile composting due to its enclosed form, but consumes more diesel and energy due to using a compressor, mechanical turning, and the heating/cooling system [14]. This technique accelerates the decomposition process, particularly the thermophilic phase, because it is very controlled and it generates humus-poor but mineral-rich compost in a short amount of time (only a few weeks). All types of waste products, including manure, biosolids, meat, and more, can be decomposed using this technique. In comparison to other methods, this procedure is particularly efficient since the conditions for composting are better controlled. Due to the high cost of the equipment required for this procedure, it is mostly utilized by large food processing factories and other industries. This process uses a small amount of area and emits minimal odors [15].

For compost to mature, the majority of composting systems require a significant amount of space. An important advantage of an in-vessel system is the rapid initial phase of composting, which leads to early homogenization of the feedstock and significant volume reduction. This makes it a particularly attractive method for managing organic putrescible waste, especially when combined with the advantages of a closed system in terms of avoiding vermin and birds [16]. As a substitute for the current centralized composting system, the in-vessel composting method is chosen. Compared to windrow composting, in-vessel composting provides a higher level of control over the process's operation and makes it much easier to manage unfavorable gaseous emissions and odors [17].

Given the above, this study aims to present the methodology developed for implementing an integrated biowaste management system developed on the island of Rhodes, Greece, which promotes source separation and urban composting with the use of Autonomous Composting Units (ACUs). Additionally, it comes within the scope of the current work to provide the outcomes of composting in ACUs in the Rhodes Island case study region and to contrast these outcomes with those of other nations and case studies. An in-depth assessment of composting in urban ACUs is necessary due to the growing need to divert biowaste from landfills and the current policy that encourages its separate collection and treatment. The outcomes of this case study can inspire the use of ACUs in large FW producers, such as urban residential areas, and can encourage the development of on-site composting technology in urban areas.

2. Materials & Methods

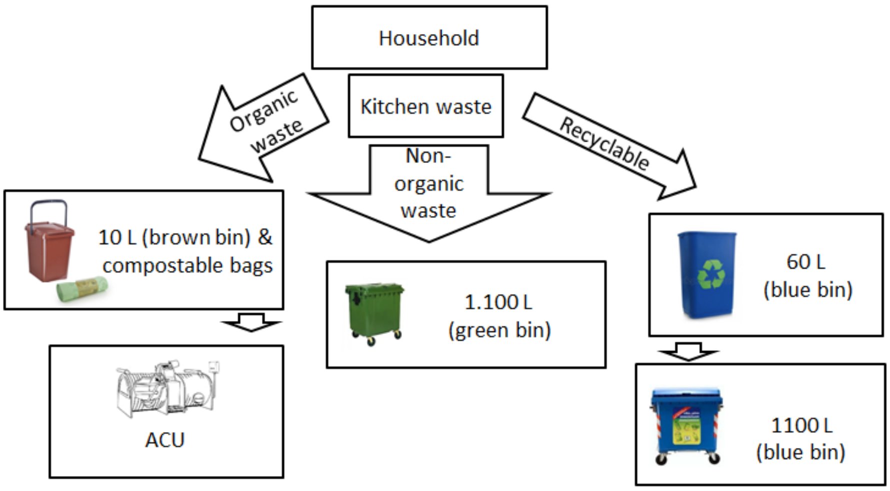
2.1. Case Study and Source Separation in the Municipality of Rhodes

Five Autonomous Composting Units (ACUs), installed in the Municipality of Rhodes, Greece in the framework of the Autonomous Composting Units for Urban Areas (ACUA) project, were chosen as a case study. The five ACUS were installed in urban areas to receive the biowaste produced directly without the need to collect it. Two ACUs of 1.49 m^3 were placed, one in the nursery garden (105 citizens) and one in the common meal area (100 persons), and three ACUs of 2.27 m^3, one in the Army apartments (175 persons), one in the general hospital (140 equivalent persons) and one in the central vegetable market (140 equivalent persons). Each 1.49 m^3 ACU is capable of processing almost 40 kg/day of FW, while each 2.27 m^3 ACU can process 60 kg/day. The ACUS convert the FW into compost which is then used in the municipal parks.

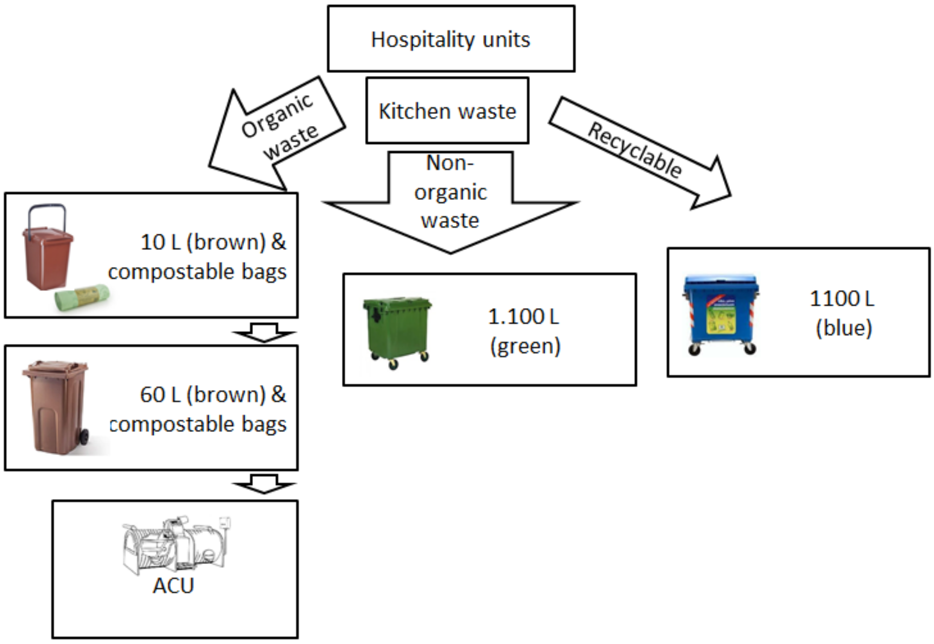
Based on the project study, a citizen publicity and education scheme was adopted. Citizens were shown how to separate kitchen waste from organic waste (FW), non-organic waste and recyclable waste. Households were provided with a small 10 lt brown bin for indoor use with a small compostable bag. The citizens then discarded the compostable bags in the ACUs. Green 1100 lt plastic bins were used for non-compostable waste, while 60 lt blue bins were used for the recyclable material. The hospitality units were also provided with a 60 lt brown bin. The details of the source separation scheme are shown in Figure 1. The ACUA project flow chart is illustrated in Figure 2.

The development of a system for the collection of produced biowaste and its treatment at source, without generating a nuisance, within an urban area, is the goal of this innovation. Since landfilling of mixed municipal solid waste has long been a common practice on the island of Rhodes as well as in many other regions of insular and mainland Greece, this technique was presented as a novel implementation and innovation for the region.

Hospitality units and households separated the organic material and disposed of it in compostable bags with a personalized card in the ACUs. We removed the compost after three to four months. The no composting waste was placed in a green bin and the recyclable waste in a blue bin. Therefore, we had a reduction of waste going to landfill. Composting would help the government achieve its goals of reducing the quantity of biodegradable waste transported to landfills as required by EU environmental legislation, specifically the Wastes Framework Directive (98/2008), contributing to an effective reduction in greenhouse gas emissions.



(**a**)



(**b**)

Figure 1. Source separation scheme of (**a**) households and (**b**) hospitality units.

2.2. Composting Field Trial at the General Hospital

Autonomous Composting Units (ACUs) are an updated form of domestic composting, in the sense that they can be placed near the points where biowaste (food and plant residues) is produced, but with no restrictions on the type of food waste they can receive (meat, fish, cooked and non-food items). They are essentially a complete, compact composting unit, as there is no drainage leakage or odor release, which can be found in both simple composting units and central open composting units. A key idea of ACUs is to serve areas with sophisticated sorting systems at the source (where biowaste is separated from mixed waste), as well as sites with significant biowaste production and urban areas.

In this paper, the composting trials were carried out at the General Hospital of Rhodes, as an example of the numerous institutions that have issues with the treatment of food waste, such as nursing homes, schools, universities, highway rest places, army bases, hotels, airports, medium and large corporate canteens, etc. The General Hospital serves approximately 1000 meals a day and produces 3 tn of food waste per week. The installed ACU only served the kitchen residues. The system used is shown schematically in Figure 3.

Figure 2. The ACUA project flow chart.

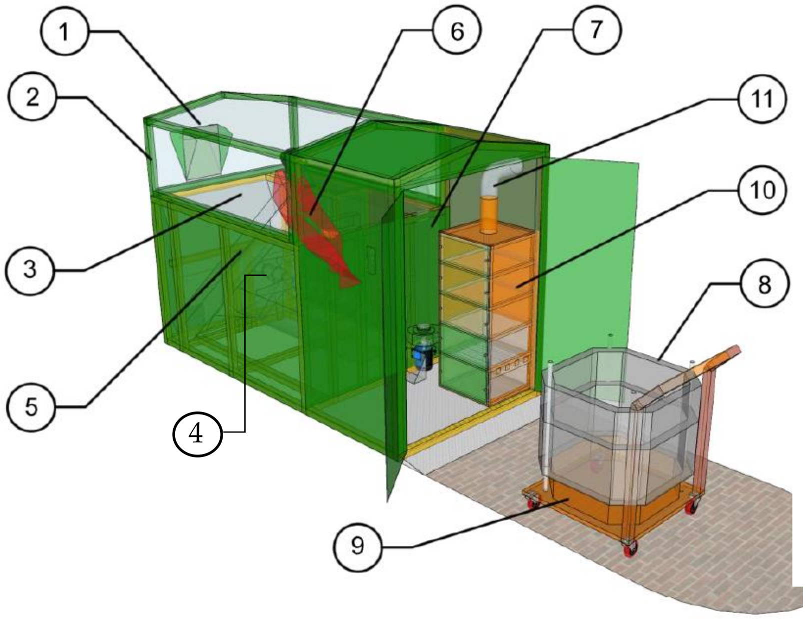


Figure 3. Solar mechanical composter (Incotech Model SMEC-3).

A solar mechanical composter (Incotech Model SMEC-3) was used in the trial to treat the kitchen waste of the General Hospital. This composter (length 3.77 m, width 1.76 m and height 2.42 m) consists of a horizontal intermittent screw with a screw conveyor lift and a biofilter.

Biowaste is introduced into the composting unit via the inlet (1), on the front side for the unit and on the greenhouse cover (2). Biowaste is fed into the composting tank (3) where the composting of the biowaste takes place (thermophilic phase). The turning and movement of the material within the fermentation tank takes place using a horizontal intermittent screw (4). Parallel to the composting tank there is a screw conveyor lift (5) through which the material circulates from the front to the back of the composting tank. A diversion gate (6) regulates whether the material will return to the composting tank or pass into the visiting chamber (7) where maturation can be carried out. The maturation area consists of a fast composting system (8) on top of a conveyor platform (9). Composting odors are treated using a deodorizing ventilation system (10) which carries air through a biofilter with compost filler. The deodorizer absorbs the odors of the composter before they are released to the atmosphere through a chimney (11). The mechanical operations of the unit are controlled by 2 control panels; one on the outside of the unit and one on the inspection chamber. The composter can accept a maximum load of 60 kg per day, and has an energy consumption of 1.24 kWh per day.

In addition to biowaste, the Municipality added bulking material to the ACU at a predetermined time. The use of additives such as shredded green waste consists in their aqueous absorption capacity (regulation of mixture moisture), in ensuring the necessary structure and porosity in the mixture, while they are also a source of carbon to regulate the C/N ratio in the original substrate [18–21]. The bulking materials were provided by the Municipality. For compost production, the appropriate 1:2 ratio of bulking material to biowaste was used and the average minimum time in the composting tank was 4 weeks.

After remaining in the ACU for up to 3 weeks, the semi-mature compost was extracted through the diversion valve. The compost was fed into the composting system, consisting of 72.5 L individual stackable rings, in order to mature. The optimal compost curing period must be identified in order to characterize the compost; samples were taken for analysis from the maturation and storage bins at regular intervals.

2.3. Process of Composting Monitoring

Along with temperature, pH, and the substrate's moisture content, daily measurements of the input bulking materials' weights and the output, compost, were made.

During the composting process, the temperature and moisture of the mix was measured by sensors installed at appropriate points in the unit. These sensors updated the system on the conditions of both the material and the surrounding environment. The system activated the appropriate functions to maintain these values within the specified limits. The ventilation function was also activated at predetermined intervals to remove the odors naturally produced during the composting process. Once daily, temperature readings were taken along the composter's length (at 2 sampling points). For all analyses, sampling was performed immediately after agitation of the materials, at three different points along the ACU. These samples were combined and placed in a large bag. Analyses of the fresh samples were performed to determine pH and electrical conductivity. All other analyses were performed after sample preparation, which included drying the material in an oven at 105 °C until its weight stabilized and grinding in a mill. Sampling was carried out throughout the project. To examine and identify the ideal curing time before the compost could be used, monthly samples were gathered from each maturation bin.

The moisture content, total organic matter (TOM), pH, EC, volatile solids (VS), total organic carbon (TOC) and total nitrogen (TN) were measured in the composting raw waste and discharge. Temperature was recorded using the installed sensors.

By calculating the sample's weight loss following 105 °C drying, the percentage of moisture was calculated [22]. In a 1/1.5 solid/liquid aqueous extract, the pH and electrical conductivity (EC) were determined (extraction time equal to 24 h). The elements were extracted from solid samples and measured using the same method as for liquid samples in order to determine total phosphorus (TP). Specifically, acidic digestion with HNO_3 brought the TP to a solution. A solid sample module was used for TOC analysis (SSM-5000A, Shimadzu). The average of three comparable measurements was used to calculate each value.

To determine the end product's phytotoxicity, a germination test was performed. For the test, a mixture of 10 g of sample and 1:10 (w/v) deionized water was used. As a result, 20 lettuce (*Lactuca sativa*) seeds were placed onto a Petri plate along with 2 mL of extract. Each dish's number of seeds that germinated and the lengths of its root radicals were measured after two days of incubation at 25 °C in the dark. The following equation [23] was used to determine the germination index (GI): GI (%) = 100 × (average number of seed germination × average length of treatment's roots) (average number of seed germination × average of root length of control).

Salmonella spp. was assessed in accordance with the USEPs Class A, and *E. coli* was determined by plating onto the Eosin-methylene-blue (EMB) selective substrate (1998). In EMB substrate, Escherichia coli strains were isolated and identified by morphological (gram bacilli) and biochemical characteristics (Api 20E, BIOMERIEUX). The National Committee for Clinical Laboratory Standards' disc diffusion method was used to screen these bacteria for antibiotic susceptibility (NCCLS).

The statistical analysis of the data and the results of this study (analysis of average values, variance and standards deviation) were performed using Origin 9 (OriginLab, USA). Significant differences were analyzed utilizing analysis of variance (ANOVA) as a statistical technique.

3. Results and Discussion

3.1. The Composting Process

According to Zhao et al. (2016) [24], the temperature of the substrate during composting controls the rate of biological processes and is crucial for the population of microorganisms' evolution and succession. The temperature levels observed in ACUs are typical of the composting process. This is confirmed by the transition of the substrate from the thermophilic phase; then, after the readily available organic compounds have been consumed, the substrate shifts to mesophilic levels.

The ACUs of the Municipality of Rhodes started operating on February of 2020. Unfortunately, their operation was suspended from April to June 2020 due to COVID-19 restrictions. In a 48 weeks (1 year) trial of composting of food waste by all ACUs in the Municipality of Rhodes, approximately 50 tn of food waste was treated with 10.5 tn of bulking material (Figure 4). Contrary to composter recommendations, it was discovered that a 5:1 ratio of biowaste to bulking material was best for boosting the C/N ratio in the system. The final compost produced had a mass decrease from food waste to final product of more than 40%, and it weighed 30 tn.

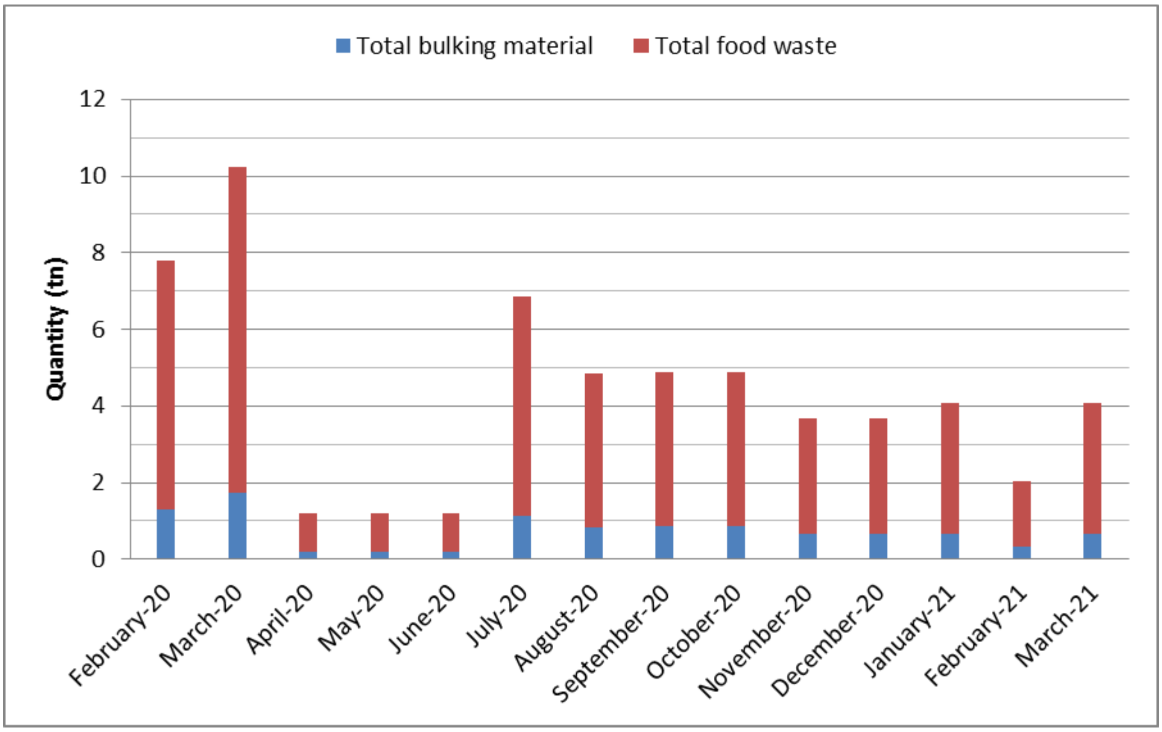


Figure 4. Total collected FW and bulking material in ACUs.

The temperature of the ACUs was monitored throughout the project. The evolution of temperature during the composting period is shown in Figure 5 for the ACU of the General Hospital. During the composting process it is necessary to maintain the temperature and moisture of the mix within certain limits. For this reason, sensors were installed at appropriate points in the unit. These sensors updated the system on the conditions of both the material and the surrounding environment. Figure 5 displays the materials' temperature and moisture content. The climatic conditions (air highest temperature and air highest relative humidity) observed during the composting process of food waste are presented in Figure 5. The moisture content of material gradually decreased from 64.2 ± 0.2% at the beginning of the process to 55.2 ± 2.5% after 10 days and finally to 42.9 ± 1.9% on the outlet of the ACU. According to Figure 5, the material's temperature increased over the period of three weeks, achieving a maximum of over 65 °C in the ACU. The temperature of the materials changes rapidly from the first week. This agreed with other studies [13]. By the end of the fourth week, the average temperature trend had stabilized, allowing the material to be extracted and transferred to the maturation units. Temperature measurements taken along the composter's length (Figure 5) indicate that the temperature was higher than what was needed to kill pathogens, staying at 60 °C for at least seven days during the thermophilic phase. According to Onwosi et al. (2017) [25], the material will be free of pathogens and weeds if the thermophilic temperature remains above 55 °C for three days. After 12 weeks, the composting study was concluded with a consistent product that had been heated to a level that ensured pathogenic depletion.

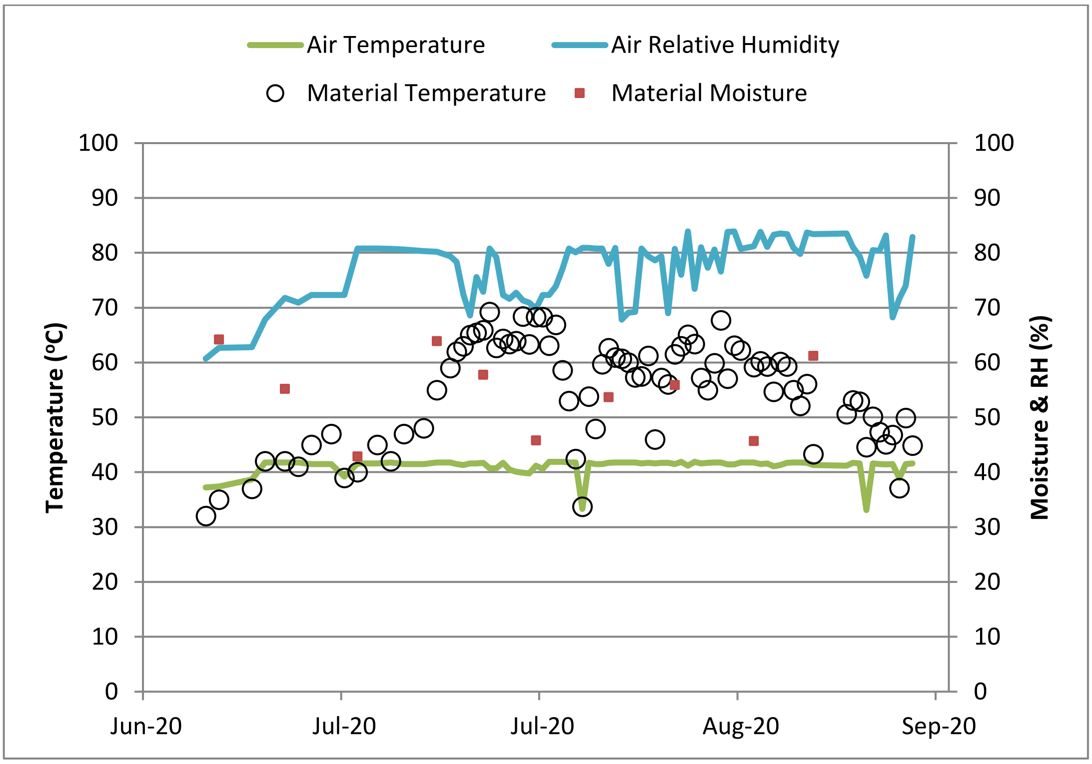


Figure 5. Temperature and moisture variation during composting experiment.

For the best growth of the bacteria participating in the biochemical activities, the ideal feedstock composition for the production of high-quality compost is (a) a C:N ratio of 25–30:1. and (b) around 60% water content. The pathogenic analysis in particular demonstrates consistency in the removal of *E. coli* and *Salmonella* to the levels needed by the standard, and the level of heavy metals in the compost is far lower than the threshold limits stated in the standard.

The results showed that, after 4 and 8 weeks in the in-vessel process and individual stackable rings for maturation, within three months the compost had reached its full maturity.

3.2. Feedstock and Compost Characteristics

Full analyses of the output compost and results of pathogen analyses are presented in Table 1. The final compost shows good plant germination and growth, and absence of pathogens.

Table 1. Analysis of feedstock and produced compost.

Parameter	Feedstock	Outlet of ACU	Compost
pH	5.0 ± 0.1	8.1 ± 0.1	7.7 ± 0.0
EC (mS/cm)	4.9 ± 0.2	3.8 ± 0.1	3.3 ± 0.2
VS (g/kg)	891 ± 1.5	680.5 ± 3.5	647.8 ± 2.3
TOC (mg/g)	553.1 ± 18.7	378 ± 25.2	377.2 ± 15.1
TN (%)	1.9 ± 0.0	2.1 ± 0.0	3.1 ± 0.0
TOC: TN	29.1 ± 1.0	18 ± 1.0	12.2 ± 1.0
Moisture (%)	64.2 ± 1.9	42.9 ± 3.6	36.8 ± 2.1
Organic matter (%)	89.3 ± 0.2	65.7 ± 0.1	52 ± 0.1
Ash (%)	10.7 ± 0.2	34.3 ± 0.2	48 ± 0.1
P (g/kg)	0.7 ± 0.2	1.0 ± 0.1	1.1 ± 0.1
Germination Index (%)	-	67 ± 0.5	113.6 ± 0.1
E. coli	-	-	Negative
Salmonella	-	-	Negative

Table 1 displays the final product's quality after composting. As a result of carbon losses caused by microbial activity during composting, the material has less organic carbon and more nitrogen than the original product.

Moisture content is very important in controlling the composting process [26]. To produce a favorable environment for microorganisms, it is crucial to adjust the moisture content to the necessary range. The optimum moisture content needed for composting, according to Angelica et al. (2020) [27], is between 50 and 60%. Additionally, less than 55% of the mature compost's moisture content should be present [28]. The initial moisture content was 64.2 ± 1.9%, which was within the literature range of 50–60% for promoting the composting process. The moisture content reduced gradually and was recorded as 42.9 ± 3.6% in the outlet of the ACU. It was further reduced in the final product (36.8 ± 2.1%) after 8 weeks which is less than 55%.

The pH also affects microbial activity in the composting process and is among the key elements of the composting process. According to various researchers, the initial pH level following the setup of the composting trials may range from approximately 6.0 to 6.5 [29]. The pH increased from 5.0 ± 0.1 to 7.7 ± 0.0, which was carried on by the efficient breakdown of organic acids [30]. In conjunction with this, the pH increased from acidic to weakly alkaline [31]. Guo et al. (2018) recorded the same range of beginning pH values. However, pH increased significantly after the fourth week of composting due to the microbial decomposition of organic matter, which resulted in the volatilization and consumption of organic acids at high temperatures as well as the formation and accumulation of NH^{+4} [32]. Wang et al. (2021) also noted the increase in pH. According to He et al. (2020) [33], the pH tends to rise during the first two to three weeks of composting as ammonia gas is formed from the breakdown of nitrogen, but falls later as organic acid breaks down into organic matter. These are in accordance with our results where pH decreased from 8.1 ± 0.1 to 7.7 ± 0.0. About 7.0 is the optimum pH for microorganisms to grow and reproduce [34].

EC decreased from 4.9 ± 0.2 mS/cm to 3.3 ± 0.2 mS/cm with the composting process, suitable for agricultural use [31]. The salt concentration, which reflects the ionic concentration of both organic and inorganic salts in the composting materials, is displayed by the electrical conductivity. The high concentration of salts in the raw materials presents a significant challenge because, after composting, the salts would be released into the final compost, and if it were used as fertilizer it might result in too much salt in the soil, which might prevent the soil from absorbing other salts [28]. The final product and the outlet of

ACU had almost similar EC. After the fourth week, the EC was lower than 4 mS/cm, which is beneficial for plant growth [33].

The reduction in organic matter (OM) was 23.6% after 4 weeks in the ACU, while OM further decreased in the final compost product (37.3%) after 8 weeks maturation. Microbial activity on the compost matrixes was the cause of the decline in organic matter levels [35]. Nutrients are progressively made available in the soil solution and taken up by plants while being protected from leaching by organic matter. As a result, since it can greatly enhance the physicochemical qualities of soil, compost's organic matter content is very crucial. The final product from the co-composting of FW and green waste contains a high proportion of organic matter (52 $\pm$ 0.1%), which is much more than the threshold quality requirements. Similar values for biowaste compost have been published in the literature by Mor et al. (2006) [36] and Malamis et al. (2017) [37].

TN concentration increased (from 1.9% to 3.1%); this was carried on by an organic mass reduction in the composting process. Composting resulted in a reduction in OM, an increase in TN, a decrease in the C/N ratio, and more stable, mature compost. Compared to other compost, the nitrogen content was found to be at a satisfactory level [38,39].

One of the crucial parameters used to determine the maturity and toxicity of the finished compost is the germination index (GI). The compost GI value was found to be 113.6% for 1:10 dilution ratios. Compost without phytotoxins is reported to have GI values above 50%, while compost with GI values below 50% may prevent seed germination and harm crops [40]. Pathogenic bacteria in composted biowaste are a hygienic quality need for the finished product's safe land application. Examining the final product for the aforementioned pathogenic bacteria reveals that it has been completely sanitized, proving that the temperature–time regime reached during aerobic biological treatment is sufficient to hygienize the substrate [37]. Considering the above, the final compost product presented brown with no odor and no detection of *E. coli* and *Salmonella* pathogens. As a result, the produced compost can be used to improve soil.

3.3. Economic Analysis

The reduction in landfill costs, the reduction of food waste collection costs, the elimination of food waste disposal administrative costs, and the elimination of the need to buy compost are the economic advantages of the ACU process. The cost of composters in the Municipality of Rhodes was €158,720.00 while the cost of bins and compostable bags was €5971.84, meaning that the total investment budget was €164,691.84. In the first year, due to the purchase of equipment, the operating cost was €15,082.11. The income of the Municipality of Rhodes per savings category (compost production, biowaste diversion and diversion of recyclables) for the first year was €5625.00, €2500.00 and €3750.00, respectively (€11,875.00 in total). It is ascertained that by applying the proposed SSS and ACU system, the Municipality of Rhodes presented minimal losses. It is important to note that the real gain of the action is environmental first and foremost. The operation of the ACUs of the ACUA project shows that the Municipality of Rhodes can establish an integrated source sorting system for its biowaste with relatively low investment and operating costs, which can divert a significant amount of biowaste with the possibility of expanding the ACU network, so that each Municipality meets national and European targets for biowaste diversion.

4. Conclusions

The current study examined technical and economic indicators of a pilot-scale case study of source separation and autonomous composting in the Municipality of Rhodes. Results show that after the 4 and 8 weeks in the in-vessel process and individual stackable rings for maturation, in just three months the compost reached its complete maturation. After the process, high quality compost was obtained with no odor and no detection of *E. coli* and *Salmonella* pathogens. The investigated system demonstrates that FW leads to high-quality compost when the temperature regime is acceptable. Additionally, the government's targets to minimize the quantity of biodegradable waste sent to landfills as mandated by EU environmental legislation, notably the Wastes Framework Directive (98/2008), could be met with the diversion of food waste from landfill to composting. Finally, autonomous composting has proven to be an effective method for managing food waste locally in urban areas that is both ecologically friendly and a nuisance-free solution.

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