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PROOF OF CONCEPT OF AN AUTOMATED SYSTEM USED FOR PRE–COMPOSTING ORGANIC WASTE

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Abstract: A wide range of novel waste management machinery have been researched recently, due to the growing interest in composting technologies. Applying novel processing technologies for organic wastes has 2 major benefits: size and volume reduction and production of a natural fertilizer that can improve the soil quality and reestablish the properties of the soil where is needed. Due to the generation in high quantities of the organic waste, a rapid, viable solution is needed. The goal of this study was to provide a proof of concept for an urban pre–composting equipment. The advantage of using a bioreactor for the decentralized organic waste treatment is the considerable reduction of the total volume of the waste, allowing a higher quantity of processed material, in safe working conditions for both the environment and human health.
Keywords: automated composting system, organic waste management

INTRODUCTION

Food losses and food waste has become a global concern and a priority, in order to achieve the Sustainable Development Goals Target. Over the last years the interest into the food losses and food waste increased, especially due to some major management problems, which generates challenges to the environment, food security and natural resources.

At the global level the political agenda includes the reduction of the food losses and food waste. Therefore, the European Union, United States, the African Union have been taken actions to work towards the targets established of reducing food waste by 50% by 2025–2030, (Cabeza et. al. 2013; Hanson et al., 2016).

According to the Food and Agriculture Organization (FAO) of the United Nations, one third of the food production, which was meant for human consumption, is being wasted. This means a loss of USD 750 billion (FAO, 2013; Gustavsson et al., 2011). The studies revealed that the European Union generate 100 million tons of food waste and food loss every year, 45% coming especially from households (FUSIONS, 2015).

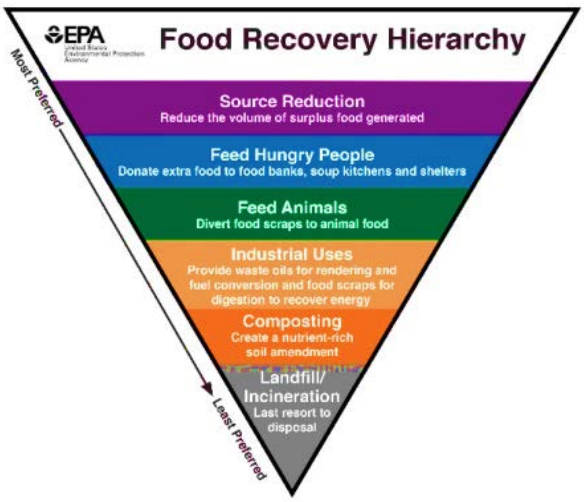

Figure 1. Food Recovery Hierarchy (epa.gov/sustainable–management–food)

The European Commission funded several projects focused towards a more resource efficient Europe focused on reducing the waste and improve the valorization of the food resources throughout the entire supply chain (Östergen et al., 2014, FUSIONS, 2016). According to the Food Recovery Hierarchy, each tier focuses on different management strategies and prioritizes actions to prevent and divert food waste and food loss.

Composting has been adopted mainly by cities in order to divert organic waste materials from landfills and create a new product which can be used for agricultural purposes at low cost. (Hargreaves, et al., 2008).

This direction of composting has attributes into the environmental factors and economic factors. Landfill capacity can decrease and also all the costs involved like transportation and materials, using the compost into the agriculture as fertilizer decreases the rate of artificial fertilizers, and the most important aspect is that the process increases the capacity of households for recycling (He et al., 1992; Otten 2001; Hansen et al., 2006; Zhang et al., 2006).

In order to obtain a good fertilizer during a short period of time through the composting process, different types of equipment emerged.

Feasible alternatives to door–to–door collection, are currently implemented in a number of European countries (Austria, Switzerland, Germany, UK, Belgium, Netherlands, Sweden and Norway) (Siebert et al., 2015). According to Sundberg et al., (2011), when organic waste is collected in classical containers, it undergoes an uncontrolled breakdown through anaerobic fermentation, resulting in odor issues and the production of leachate. While this method has no detrimental impacts on the anaerobic digestion, due to the compaction, it releases moisture in the waste, and resultant low porosity.

Sakarika et al., (2019), assessed a pre–composting technology that had the role of controlling the breakdown of organic matter, reducing time and space requirements at the final main composting stage.

Composting is the process of reducing organic substances from vast volumes of decomposable materials to smaller volumes of relatively stable decomposable materials. The carbon–to–other–element ratio is brought into equilibrium in this process, preventing temporary nutrient immobilization.

The classic method of composting was to pile organic materials and let them stand for a year, but the method is very long, valuable nutrients are lost during the process, and organisms, some weeds, weed seeds and insects are not properly controlled (Raabe, 2015).

New composting technologies have recently been developed that address some of the issues associated with traditional composting. Compost can be generated in 2 to 3 weeks using this method. Extra effort on the part of the composter is necessary in exchange for the time savings, but the effort is justified for people who desire big amounts of compost or who want to transform items that would otherwise be wasted into usable compost.

To achieve the correct C/N ratios, it is necessary to identify the food waste composition and define the proportion of different food waste categories before beginning the composting process. Following the assessment of physico–chemical parameters, regression analysis can be successfully utilized to determine the quantities of each type of waste in order to attain the appropriate C/N ratio.

Compostable materials should have a carbon to nitrogen ratio of 25–30 to 1 for the composting process to be most effective. This is difficult to quantify, but blending equal volumes of green plant material with equivalent volumes of naturally dried plant material, produces a carbon to nitrogen (C/N) ratio of around 30/1. Grass clippings, old flowers, green pruning, weeds, fresh rubbish, and fruit and vegetable wastes are all examples of green materials. Dead, fallen leaves, dried grass, straw, and moderately woody materials are all examples of dry material.

Salla (2016) evaluated on–farm composting of vegetable organic waste, under cold climate conditions of Eastern Canada, using bark or straw as bulking material. Feedstock was added at two–week intervals for the first six weeks, and the compost readjusted the quantities in order to have 65% water content and a C/N ratio of 30. He concluded that the mature composts have been obtained after several weeks of composting, and the analysis showed adequate physicochemical properties, being also free of E. coli. He also emphasized the importance of screening the row material in order to eliminate foreign matter before their use as soil organic matter amendment.

It's difficult to use fruit and vegetable waste as the only compost feedstock, since their moisture content is above 80% and their porosity is rapidly depleted (Sundberg et al., 2013; Chang and Chen, 2010).

Inside the composting equipment fruits and vegetables are crushed by their own weight in a short time, and the plant cells that provide structural strength and rigidity are damaged, allowing water to fill the pores of the composting mass. Plant cells decompose quickly due to microbial action in these conditions, and the pH drops, hindering the well–functioning composting microorganisms and lowering composting effectiveness (Sundberg et al., 2012). To overcome these constraints, the physical properties of composting recipes must be adjusted (Awasthi et al., 2014).

Bhave and Kulkarni (2019) researched the influence of active and passive aeration on composting of household biodegradable wastes. Their main results confirmed that both types aeration systems performed well under continuous loading, however the maturation period required for actively aerated reactor was 37.30% less efficient than the naturally aerated system.

The present paper assesses a small equipment for organic waste processing, an intelligent composting machine that can convert the organic waste into compost in a shorter period of time. The process is obtained by using a consortium of thermopile bacteria (Ecoman, Foodie user manual).

MATERIAL AND METHOD

The biological process of the FOODIE is using microorganism to transform the organic waste. By maintaining the temperature, air flow and moisture, allows the bacteria to break down the organic waste into compost within 24 hours, and reduce the volume by 85%. The tests were performed on an automatic composting equipment for organic waste management Ecoman – Foodie, and the operational mode was customized according to the type and nature of the waste (Figure 2).

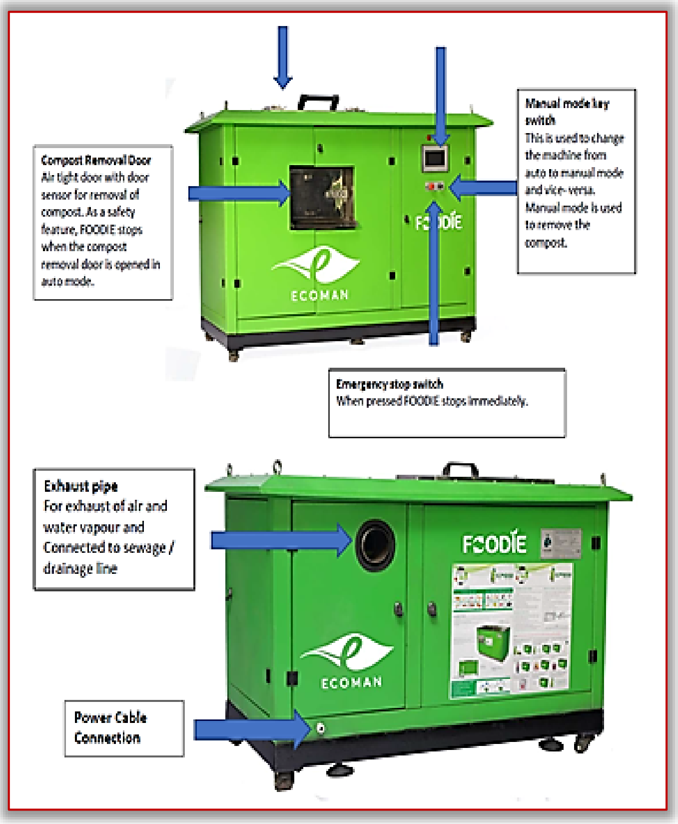

Figure 2. ECOMAN FOODIE composting equipment (Ecoman Foodie Manual, 2021)

The equipment is formed by a composting tank, with a humidity sensor, heater, mixing blades and exhaust system. Food waste from a supermarket chain was introduced into the equipment. Previously, the waste was separated so that there was no plastic, metal and other contaminants in the mixture (Figure 3). The waste is then mixed using mixing blades, according to a predetermined schedule, depending on the nature of the introduced waste, as seen in Figure 4.

Figure 3. Adding a mixture of organic material to the composter consisting of fruits, vegetables, meat, and dairy

Figure 4. The operation of mixing and aerating the organic matter inside the equipment

When the composting tank is filled, the moisture sensor detects the humidity and the heating system starts. The parameters are controlled using a programmable logic controller, which also helps with process customization (Figure 5). The water content from the organic matter is evaporated and it is released as vapors. It is highly important the sorting stage before composting, otherwise may arise processing isues as seen in figure 6, where several small contaminants remained in the mass of processed organic matter.

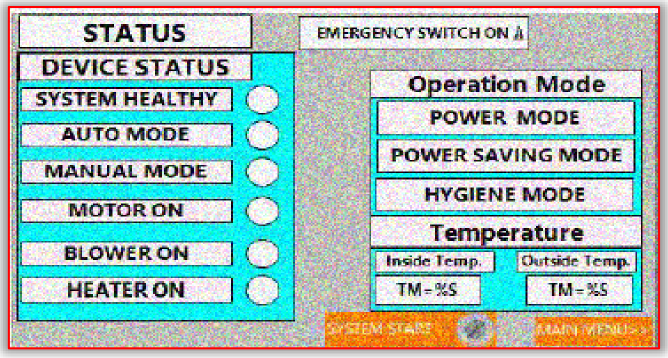

Figure 5. Parameter display and process customization

The remaining matter, after water content is released, starts to decomposed due to the microbial activity. The equipment does not emit loud or disturbing noises, as it does not use grinding or mechanical crushing processes, being equipped with internal blades that use exclusively the process of homogeneous mixing of waste. A mixture of sawdust and special cultures of microorganisms are used for organic matter decomposing. At the end of each compost extraction, a small ratio of compost ramains in the equipment to guarantee a continuity of the production of microorganisms. The equipment complies with both Romanian legislation and the European legislation, namely: REGULATION (EC) No 1069/2009 and REGULATION (EU) 142/2011.

Figure 6. Example of incorrect separation of plastic waste, leading to compost contamination

Electrical conductivity, moisture, pH, ash content are being measured every week, while nitrogen and carbon contents were determined at the beginning and the end of the composting period.

In order to kill any pathogens that could develop in the process, we introduced a sanitation phase, which involves maintaining a high temperature (70 degrees Celsius) for an hour. This stage of sanitization is necessary to ensure that there will be no pathogens at the end of the composting process (eg E–coli, Salmonella, etc.).

The composting equipment has been fed with oraganic waste for a period of 3 months. In this time it has been followed a recipe which includes: several types of organic waste such as fruits, vegetables, fruit and vegetable peels, eggs, eggshells, fish, chicken or fish bones, shells , dairy products, bakery products, meat or processed meat preparations, leaves or dried grass.

RESULTS

Samples of the compost have been tested by an authorized laboratory. Have been found that from the organic waste introduced, have been obtained 92.55% dried substance with a 4.4 pH, 93.05% and a total organic carbon of 45.62%. Also what is very important is that no Escherichia coli or salmonella spp. have been detected.

The tested working methodology envisaged a temperature increase continuously until reaching the value of 50 degrees celsius. The temperature is increased using a ceramic heater, which is mounted on the bottom of the equipment. After reaching this temperature, the heater stops, until the temperature drops below 40 degrees Celsius, then starts again. During this time, the other mixing and steam extraction functions work without being affected. The humidity extractor has been set for a 10 minute operation with a 5 minute break.

The variation of the mixture temperature, at the surface where the temperature is homogeneous, can be observed in the graph below, for a period of 24 hours. The moment the material is introduced in the equipment generates a sudden variation of the temperature, considering that the waste is cold and humid.

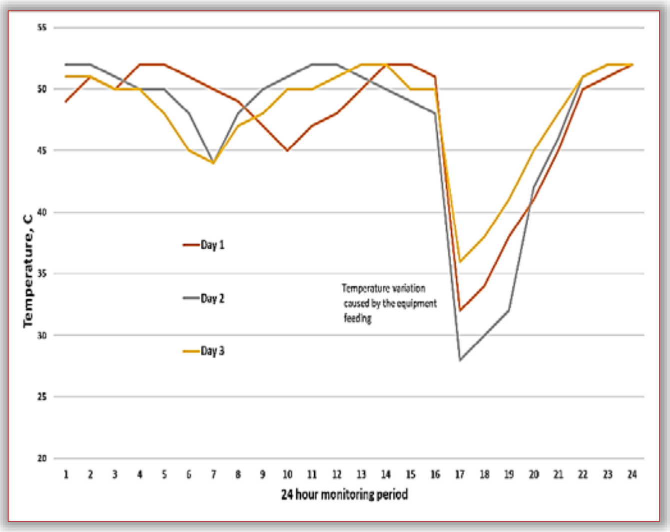

Figure 7. Temperature variation within 48 hours in the composting equipment

It can be seen that, although the upper temperature is set at 50°C, due to the heat inertia, it rises to 52°C. After the heater stops, the temperature drops gradually to 45°C, this being the temperature set for the heater to start again. At 4 pm (16^{00} on the graph), the daily supply of material takes place this explaining the sudden drop in temperature. The process then resumes, and in the period 16^{00}–19^{00} can see the increase in temperature, that returns in the range of 45–52 °C.

The temperature range was chosen this way because the main objective was to reduce the volume of raw material, in order to maximize the processed waste.

The correct decomposition of organic matter have been detected by the pleasant odor of the mixture, by the heat produced (naturaley by the process), by the growth of white fungi on the decomposing organic material, by a reduction of volume, and by the change in color of the materials to dark brown. Using the equipment using the proposed processing methodology, several quality indicators were obtained, no unpleasant odors were eliminated from the process, while the presence of bacteria and fungi indicated an efficient level of processing. The color of the material changed within 24 hours, and the material became homogeneous and crumbled (Figure 8).

Insects do not survive the composting process, therefore the equipment can be placed inside production halls without disturbing the activity due to the presence of the insects. In addition, most weeds and weed seeds are killed by processing. However, the ability of the equipment to destroy highly resistant weed seeds has not been tested.

Figure 8. Depicting of the compost characteristics during processing (continuous processing for 3 weeks, adding vegetable waste every day)

After processing, the mass of compost obtained was matured, in order to obtain a quality product, without mechanically intervening on it. Therefore, at the end of the composting process using Foodie equipment and after it has been matured for another two weeks, the compost looks like in figure 9.

Figure 9. Depicting of the compost characteristics during processing (continuous processing for 3 weeks, adding vegetable waste every day)

The colour is middle brown, no plant remains or seeds have been identified. Organic matter and elemental contents are determined on dry matter basis. The analytical results on dry matter basis are used for compost quality comparison. To determine the moisture content, compost samples are dried at 103°C until constant weight is achieved. Weight loss equals moisture loss, based on which moisture content or dry matter content of the compost is calculated. A moisture content of 38% was determined (the optimal range followed being 40–45%).

The organic matter or carbon content of compost is of high importance especially if it is used to enhance soil organic matter content. Low organic matter values in compost can result from the use of purely organic waste streams while a high level of organic matter can be an indicator of an unfinished composting process or unstable compost. Continutul de substanta organica opbinut in faza de procesare utilizand echipamentul a fost de 78%, iar in urma maturarii a fost determinat un coninut de 68% (50–60 % being the desirable values for most compost uses). Total organic carbon obatined, at a pH of 5.2, was determined to be 45,62%. Major and secondary nutrient content of compost is important, in order to estimate the fertilizer value and to know how much of the compost is preferably or can be legally applied for different types of soil. Repeated applications of compost rich in certain elements can be useful to overcome an imbalance of the nutrient status of the soil.

The total nitrogen value had a very good value of 2.76 % dr. subst., total phosphorus % dr. subst., calcium 13913 mg/kg dr. subst., potasiu 13931 mg/kg dr. subst., zinc 28.60 mg/kg dr. subst., the other parameters/heavy metals being in normal parameters.

CONCLUSIONS

This study showed that food waste from supermarkets and grocery stores could be composted on local sites using high–performance composting equipment, provided with a monitoring system and sensors to control the process. The proposed process and equipment can convert organic matter into quality compost in a short a time, ranging from 14 to 21 days.

Although the performance of the equipment is high, and it manages to speed up the composting process and kill pathogens, it is recommended to be used a maturation stage, to further reduce organic matter. The higher presence of organic matter is caused by the fact that the material is added daily, while the organic material added in the last 2 days did not have time to be fully processed.

Rapid composting have proved to kill all plant diseases and the the sanitization phase proved that it can destroy pathogenic germs from meat, by maintaining a high temperature (which can vary depending on the case from 60–70°C). The compost being produced on the site can be accepted by the farmer as a soil organic amendment. However, the row material needs to be verified before use to remove potentially foreign matter and contaminants such as plastics, labels, gloves, or elastic bands.

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