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Home-Composting – A Study on the Simplicity of the System in the Application toward the Effectiveness and Feasibility in Spreading in Vietnam

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In 2018, the landfill in Danang city (DNC) received a significant amount of 1,073 t/d of waste, of which 54 % are bio-degradable waste, this lead to the overloaded of DNC landfill. It also shows the huge potential of composting using organic waste is being overlooked. This study aims at introducing a biowaste treatment with a conventional aerobic composting method, the T-COM V2.0 system. The model is a horizontal rotary drum with the same operating principle as the in-vessel composting system, with a capacity of 200 L, equivalent to 10 kg/d. Four models are alternately operated at DNC primary school for kitchen waste treatment, with the combination of effective microorganisms to improve decomposition efficiency and reduce odor. The Compost showed positive results with organic matter 2.5 times higher than the Vietnamese standard on organic fertilizer, odorless, non-contaminated by heavy metal, and can be applied for cultivation or improving soil condition. Within three months of operation, the system had shown efficiency impact with more than 1 t of organic waste treated and is possible to replicate at households, restaurants, hotels with outstanding features like technical assurance, economic optimization, operational simplification, and ease of application. Thus, this system can benefit the DNC waste management system by reducing the quantity of organic waste generation at source.

1. Introduction

Worldwide, biodegradable waste accounted for a large proportion of municipal solid waste. In developed countries, one of the most important policies is reducing organic waste, which accounted for 60 % of urban waste (Katinas et al., 2019). Whist, in middle-income countries, although municipal solid waste contains a significant amount of biodegradable waste (50%), which releases undesirable odor upon decomposing, minimize organic waste was not considered. Composting is the most common option for organic waste treatment of solid waste management (SWM) due to its cost-efficiency, nutrient-rich material product (Manu et al., 2019). Besides, composting and compost production can enhance the soil condition (Abu et al., 2019). While the SWM system is facing the challenge of waste segregation at source and overloading landfills, home-composting can reduce a significant amount of biowaste and cut off the cost of classifying. The advantages of home-composting including (1) in combination with waste collection at source, improve the overloading waste situation; (2) can be operated by appropriate technology, and cost-efficiency in operation; (3) allow reuse of organic waste ay source, reducing the waste quantity to be transported as well as increasing waste recycling; (4) small scale of home-composting is possible to be set up for households, even in the urban area. (Bhave and Kulkarni, 2019).
Currently, a variety of composting systems with different mechanisms are being used, from aerobic to anaerobic, from natural decomposition to combined with microorganism components. For high-income countries, large-scale composting systems are more common (Baere and Mattheeuws, 2012), while small anaerobic digesting systems are preferred in middle-income countries (Kalemelawa et al., 2012) and (Hoang et al., 2019). Table 1 shows standard in-vessel systems that are being used worldwide. In general, using biodegradable waste as raw materials for composting is not a new method. However, the application and replication of home-composting systems are not accessible.

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Table 1: In-vessel systems

Country	Type	Mode	Aeration	Turning	Duration (d)
Denmark (Andersen et al., 2010)	Recycled PE Cone; 320 L	Continuous	Holes at the bottom	-	250 – 300
Spain (Colón et al., 2010)	HDPE rectangular box; 500 L		Holes on the rear	Once a week	90
Bangladesh	Steel barrel; 197 L	Batch	Holes on the rear	-	40
Thailand (Karnchanawong and Suriyanon, 2011)	PE cylindrical bins; 200 L	Continuous	Rectangular hole on the rear	-	80 – 90
France (Adhikari et al., 2013)	Wooden and plastic rectangular bin: 392 L	Batch	Holes on the rear	Once a week	40 – 50
Italy (Tatàno et al., 2015)	Polypropylene truncated conical bin: 310 L	Continuous	channels and slits at the bottom	-	150
Spain (Storino et al., 2016)	Plastic trapezoidal system: 320 L	Continuous	Vents	Irregular turning	180
Malaysia (Fan et al., 2018)	Plastic bin: 13 L	Batch	Mesh on the periphery	Once a week	50
Vietnam	PP Plastic bin: 50 L	Continuous	Holes on the rear	-	20 – 30

In Vietnam, the rapid growth of MSW, ineffectively waste management system, and low waste management practice at source caused the overloading of waste in urban areas and at the landfills (Pham Phu et al., 2020). Besides, Vietnam is an agricultural country, and even with the high urbanization rate, many parts of the country rely on cultivation and livestock as life-maintaining, organic waste took up a large proportion of 56 - 77 % (MONRE, 2019). The most common way to treat organic waste is landfill and anaerobic digestion, which can lead to environmental and health issues (Nguyen et al., 2013). A huge potential of composting using biodegradable waste had been overlooked. This study aims at creating an advanced home-composting model with simplifying manufacturing and optimizing operation, evaluating the system's efficiency through the quantity of organic waste that can be treated as well as the quality of the compost. Therefrom, creating a premise for replicating the model in the future, contributing to the solid waste management plan in the area of Da Nang city.

2. Study site

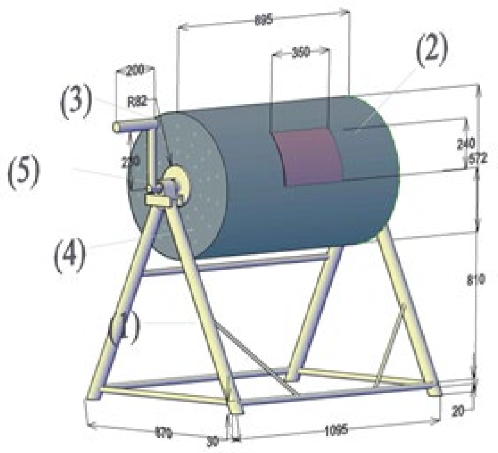
Da Nang city (DNC) is one of the five biggest cities in Vietnam. Over the last decade, there has been dramatic development of economy and population growth in this metropolitan city. DNC has a diverse economy, including industry, agriculture, services, tourism, and commerce, in which services and tourism account for a large proportion of the city's economic structure. This led to a significant increase in the municipal solid waste generation in this area. As a result, optimization of the existing municipal SWM towards sustainability is becoming severe for ensuring the prosperous development of DNC, Vietnam. However, the study on solid waste in DNC is still limited and is not keeping pace with the changes in the city.

DNC municipal solid waste (MSW) has been generating greatly with an increasing rate of 9 % annually. In 2018, the amount of MSW daily was 1,073 t, in which Hai Chau accounted for the most percentage (24.9 %), and Thanh Khe has the highest density of waste (17.56 t/km^2). Notably, the vast majority of DNC solid waste was biodegradable waste (54 %), including 48 % of food waste (Pham Phu et al., 2021). Although MSW in DNC is increasing, the city’s solid waste management planning is not consistent and isn’t suitable for the actual situation. A scientific-based solution for reducing waste-to-landfill is required to overcome the current obstacles (Hoang et al., 2020).

3. Methodology

3.1 Establishing the Home-Composter T-COM V2.0

Figure 1 shows the model of Home-Composter T-COM V2.0 with the capacity of 20 kg/d, corresponding to the organic waste amount from a primary school (semi-boarding), small hotels or villa, and a restaurant, which are objects that can apply this model.
The reaction tank is a horizontal rotary drum with the same operating principle as the in-vessel composting system. The rotary drum is made of stainless steel and can be reused from used drums. The volume of the drum is 55 gallons (an equivalent of 208 L) with dimensions of diameter and length are 584 and 876 mm. Material loading and unloading door is designed in the middle of the drum with dimensions of 350 x 210 mm. This is also a checking door to monitor during the composting process with a lid and latched.



(1) Iron frame.
(2) Door for raw materials and finished products.
(3) Handwheel.
(4) Air vents.
(5) Spindle – Rotary impeller.

Figure 1: Model of T-COM V2.0 system

The inside of the drum is composed of a system of mixing blades, evenly distributed throughout the volume of the barrel, ensuring the mixing of materials when rotating at a slow speed of about 20 rpm. The natural ventilation is located on either side of the rotating drum with multiple holes 5 mm in diameter and 50 mm apart. These positions ensure natural ventilation, do not spill materials during mixing and shield water from rain. The rotating drum is driven by a rotary arm that is indirectly connected to the rotating drum, which transmits force to the rotating drum through a threaded gear unit. The length of the swing arm is equal to the drum radius (280 mm). The reaction drum is fixed at the height of 500 mm by the iron frame.

3.2 Measurement method

Moisture content: The moisture of samples was determined at 105 ± 5 °C by Drying Oven DY300 – YAMATO machine in 24 h and calculated by the Eq(1):

$$M\ (\%) = \frac{m_1 - m_2}{m_1} \times 100\ \% \qquad (1)$$

In which, M is the moisture of compost in the module, m_1 is the weight of the sample and m_2 is the dry weight of the sample after drying at 105 ºC in 48 h.
The temperature content of the compost was measured daily by temperature sensor.

3.3 Operation and application:

Organic waste from the kitchen is cut into 2-3 cm and mixed with sawdust at the mixing rate of 1:2. All raw materials were put into the reactor and added 200 mL microbiota including Streptomyces, Phizobium, Lactic, Bacilus, Photosynthetic bacterias, and Yeast. Mixing the reactor by rotation every two days in one minute. The moisture was also checked after mixing. Whereby water is added to control the moisture from 40 to 60 %. The duration was three weeks based on the previous studies.
T-COM V2.0 was applied for the treatment of kitchen waste at a primary school in DNC. The average amount of organic waste from the kitchen and garden of this school was around 10 kg/d. So, Composting system was designed and set up with four modules (Figure 2a). The capacity of a module is around 100 kg for one week.

The composter module was operated alternatively, with the retention time is three weeks. After composting, 2/3 of the Compost was be taken out for the stabilization process. The remaining 1/3 of the product as a primer was continuously mixed with the raw materials (organic waste) to the new batch without adding microorganisms.
The T-COM V2.0 system will be operated by the food court staff of the school (Figure 2b) after training. The moisture is manually measured by squeezing the incubation product after mixing. The suitable moisture is that there is no water coming out of the compost and is not breaking after pressing. Compost will be stored in a plastic tank for gardening.

Figure 2: T-COM V2.0 system (a) is operated by food court staff (b) at a primary school.

4. Results and discussion

4.1 Operation and application assessment

In this study, the composting process is operated normally. The novelty in this study is the combination of high-speed organic-degrading aerobic microorganisms with in-vessel composting, T-COM V2.0 system, to treat organic waste at source. Microorganisms are added only once during system startup, and the microorganisms in Compost are reused as a primer for the next batch. This helps to save operating costs. Secondly, the system is naturally ventilated by air supply holes and manual mixing, providing enough oxygen during the composting process, making the composting process completely aerobic, ensuring the progress of organic matter decomposition.
Minimalist design for construction from available recycled materials is advantageous in investment and saving installation costs. The simple operation, easy access, and process control are the advantages of the system when reaching out to the community, to schools, or to businesses, where the people directly operating are mostly cleaning staff. The unique characteristics of the T-COM V2.0 system bring positive values in practical applications, eliminating concerns about contamination in treatment, reducing cost barriers in investment and operation, optimizing the participation of stakeholders and source owners. This is the favorable condition for spreading and replicating the home-composting model to recycle organic at source, reduce waste generation and minimize waste to the landfill site.
A T-COM V2.0 system (four modules) was piloted at a primary school with student boarding activities in this study. All kitchen waste and garden waste are collected daily for composting. The T-COM V2.0 has been operating continuously for three months with an average capacity of around 10 $kg.day^{-1}$. It means that about 1.020 t of organic waste will be reduced at the schools in DNC if this model is spread and replicated to primary schools. Like accommodation facilities, restaurants, condominiums, or apartments, a significant amount of organic waste is recycled and reduced before moving to a landfill. For the municipal waste management system, this issue brings many positive values, such as reducing waste generation, decreasing the collection route, increasing the heating value of municipal waste for incineration, and optimizing the economics of waste. For each waste source, home-composting can reduce waste generation and minimize tipping fees. Compost might be used for gardening and land reclamation.

4.2 Evaluation of Compost

The composting process of each module finished after every three weeks, resulting in a dark brown, moist, soft foam, and no odor compost (Figure 3). The compost will be sent to the DNC Quality Assurance and Testing

Centre 2 for criteria measurement on nutrient, organic matter, and heavy metal index. The chemical characterization of Compost in Table 2 shows that Compost is an environmentally friendly product with high humus content.

Figure 3: The compost resulted after 3 weeks (a) and closeup of the product (b)

Table 2: The quality of Compost after three weeks

No.	Criteria	Unit	Compost	Vietnamese Standard of Organic fertilizer (7185:2002)
1	Total N	%	0.95	> 2.5
2	Available P	%	0.076	> 2.5
3	Available K	%	1.02	> 1.5
4	Organic matter	%	56.8	> 22
5	Cr (on dry matter)	mg/kg	16	< 200
6	Ni (on dry matter)	mg/kg	3.55	< 100
7	Pb (on dry matter)	mg/kg	1.86	< 200
8	Cd (on dry matter)	mg/kg	0.53	< 2.5
9	Hg (on dry matter)	mg/kg	< 0.05	< 2

From Table 2, a preliminary assessment of the Compost is that it has low nutrient content and is not considered as an organic fertilizer. This is due to the biodegrading process, nutrients have not been added, only substances available in the waste, so the N, P, K criteria of the product are unsatisfactory.

The organic matter content of the product is 2.5 times higher than the standard; organic content accounts for 56.8 % of the product, showing the high efficiency of the decomposition process. Soil organic matter is an essential factor in determining soil quality; the higher the organic matter content of the soil, the better it is (Manson, 2018). Organic matter had shown positive effects on the soil condition in cultivating and forest areas, such as improving soil physical properties (Kubotera, 2020). soil fertility (Iwasaki et al., 2017), and increasing the mobility of radiocesium (Nakamaru et al., 2007). The heavy metal factor in the Compost is low, meaning the product is not contaminated and can be used in mass quantity.

Vietnam faces the risk of land degradation on a large scale; in DNC only, there is 616 ha of alkaline soil. Thus, the Compost can improve soil quality material, especially in areas with poor conditions such as saline soil, alkaline soil, or even basalt soil and island soil. Because of its none-toxicity, it can be used in combination with other biological methods such as worm farms and bacteria. In the end, the output of this Compost is unrestricted.

5. Conclusion

This study successfully introduced and deployed an effective aerobic composting model for organic waste treatment at a school of DNC. The T-COM V.2.0 proves its feasibility with advantages such as simple operation, easy access, and process control. The T-COM V2.0 had treated a significant amount of kitchen waste, with an average of 15kg/d. After three months of operation, more than 1 tonne of organic waste from the DNC primary school had been reduced. The product also shows positive results with 60% organic matter, a very low heavy metal index proving that it's non-contaminated and can be applied for gardening and land reclamation. If this model can be spread to other accommodation facilities, restaurants, condominiums, or apartments, a significant amount of organic waste will be recycled and reduced before moving to the landfill. This model might bring many benefits to the MSW system, such as minimizing cost, enhancing the waste management practice at source, and mitigating emission. This study had also provided the baseline for future research on system automation and mechanization.

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References

Adhikari B. K., Trémier A., Barrington S., Martinez J., Daumoin M., 2013, Gas Emissions as influenced by Home Composting System Configuration, Journal of Environmental Management, 116, 163-171.

Andersen J.K., Boldrin A., Christensen T.H., Scheutz C., 2010, Greenhouse Gas Emissions from Home Composting of Organic Household Waste, Waste Management, 30(12), 2475–2482.

Baere L.D., Mattheeuws B., 2012, Anaerobic digestion of the organic fraction of municipal solid waste in Europe - Status, experience and prospects, Waste Management, Recycling and Recovery, 3, 517-526.

Colón J., Martínez-Blanco J., Gabarrell X., Artola A., Sánchez A., Rieradevall J., Font X., 2010, Environmental Assessment of Home Composting, Resources, Conservation and Recycling, 54(11), 893–904.

Nguyen D.L., Hoang G.M, Bui X.T., Nguyen T.H., 2013 Challenges for municipal solid waste management practices in Vietnam, Waste Technology, 1(1), pp. 17–21.

Fan Y.V., Lee C.T., Klemeš J.J., Chua L.S., Sarmidi M.R., Leow C.W., 2018, Evaluation of Effective Microorganisms on Home Scale Organic Waste Composting. Journal of Environmental Management, 216, 41–48.

Hoang G.M., Pham Phu S.T., Fujuwara T., Pham D.V., 2020, Waste-to-Landfill Reduction: Assessment of Cost-Effective Solutions Using an Optimisation Model, Chemical Engineering Transactions, 78, 511–516.

Hoang H.A., Luu Q.H., Le P.T.K., Tran V.T., 2019, Enhancement of Pineapple Residue Composting by Food Waste Addition, Chemical Engineering Transactions, 72, 217–222.

Iwasaki S., Endo Y., Hatano R., 2017, The Effect of Organic Matter Application on Carbon Sequestration and Soil Fertility in Upland Fields of Different Types of Andosols, Soil Science and Plant Nutrition, 63(2), 200–220.

Kalemelawa F., Nishihara E., Endo T., Ahmad Z., Yeasmin R., Tenywa M.M., Yamamoto S., 2012, An Evaluation of Aerobic and Anaerobic Composting of Banana Peels Treated with Different Inoculums for Soil Nutrient Replenishment, Bioresource Technology, 126, 375–382.

Karnchanawong S., Suriyanon N., 2011, Household Organic Waste Composting Using Bins with Different Types of Passive Aeration, Resources, Conservation and Recycling, 55(5), 548–553.

Katinas V., Marciukatis M., Perednis E., Dzenajavičienė E.D., 2019, Analysis of Biodegradable Waste Use for Energy Generation in Lithuania, Renewable and Sustainable Energy Reviews, 101, 559–567.

Kubotera H., 2020, Analysis of Problems in Certain Soils of the Kyushu Okinawa Region for Suitable Management, Soil Science and Plant Nutrition 66(1), 15–20.

Manson A., 2018, Soil Organic Matter: Research & Technology Bulletin, KwaZulu-Natal Department of Agriculture & Rural Development, Pietermaritzburg, South Africa, 2018.

Nakamaru Y., Ishikawa N., Tagami K., Uchida S., 2007, Role of Soil Organic Matter in the Mobility of Radiocesium in Agricultural Soils Common in Japan, Colloids and Surfaces A: Physicochemical and Engineering Aspects 306(1-3), 111-117.

Pham Phu S.T, Fujiwara T., Akasaki N., Cuong L.D., Hoang G.M., Pham D.V., 2021, Analyzing The Characterization of Municipal Solid Waste in Da Nang City, Vietnam, Chemical Engineering Transactions 83, 241–246.

Pham Phu S.T., Fujiwara T., Akasaki N., Le D.C, Hoang G.M., Pham D.V., 2021, Analyzing The Characterization of Municipal Solid Waste in Da Nang City, Vietnam, Chemical Engineering Transactions, 83, 241–246.

Storino F., Arizmendiarrieta J.S., Irigoyen I., Muro J., Aparicio-Tejo P.M., 2016, Meat Waste as Feedstock for Home Composting: Effects on the Process and Quality of Compost, Waste Management 56, 53–62.

Tatàno F., Pagliaro G., Di Giovanni P., Floriani E., Mangani F., 2015, Biowaste Home Composting: Experimental Process Monitoring and Quality Control, Waste Management 38, 72–85.