Efficacy of the compost tumbler as a tool in organic waste management in households in Trinidad and Tobago

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Abstract

In Trinidad and Tobago, organic material comprises a large component of municipal waste, accounting for twenty-seven percent (27%) of waste at national landfills, according to a 2010 waste characterization study. In 2019, the twin island country which is located in the Caribbean was designated as having the second highest fossil CO_2 emissions per capita in Latin America (Alves, 2021). In recognition of home composting as a potential solution to the issue, Central Pathfinders Environmental Foundation (CPEF) posited that an urbanized composting unit (UCU) could ultimately serve as an alternative for organic waste landfilling. CPEF thus commenced a UNDP Global Environment Facility Small Grants Programme-funded project in October 2020 with the design, construction, installation and beta-testing of twelve (12) UCUs, in six (6) households. The objective of this paper is to document the efficacy and efficiency of a locally-produced UCU as a tool for disrupting the flow of organic waste directed to the landfill. Data on the inputs of high nitrogen and carbon materials were analyzed along with temperature, humidity, pH and odour readings. Pre-evaluation survey as well as in-situ feedback was completed in order to collect feedback on the impact of the UCUs on the participating households.

The findings revealed that participating households took on average 17 days to fill the UCU, and a further 59 days to generate mature compost, compared to documented heap composting cases which ranged from 18 days to a year (Raabe, n.d.). Participating households expressed an increased interest in composting at the end of the evaluation period and anticipated that the UCUs would continue to be utilized, given its convenience. The results of the case study indicated that each UCU can potentially remove up to about or 37.12 kg per household per year, from the municipal waste stream and produce compost with a moderate level of efficiency. Households with multiple (5) UCUs can remove as much as 168kg/year. This country generates approximately 189,000 tonnes of organic waste per year based on a 2010 waste characterization study (SWMCOL, 2015). Thus based on these figures, if each household in this country were to implement UCUs, this would significantly reduce organic waste in our landfills.

Keywords: landfill alternative; compost tumbler; composting; Trinidad and Tobago; waste management; NGO

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Introduction

Home composting has the potential to simultaneously disrupt the flow of organic waste to landfill sites and provide a valuable household resource with environmental and economic benefits. An efficient composting process aims to produce a stable organic soil amendment through a controlled decomposition process (Ayilara *et al*., 2020). Composting could reduce the volume of organic waste at landfills, reduce methane emissions and compress the spread of disease, especially due to the illegal dumping. The diversion of organic waste from landfills is also beneficial from a national economic standpoint as it would reduce the cost of waste disposal by authorities (Harir *et al*., 2015; Vásquez and Soto, 2016) and was shown to create more employment opportunities when formulated as a component of a green economy (Tellus Institute, 2010).

The composting process includes the controlled integration of oxygen, water, microorganisms and a ratio of materials containing nitrogen and carbon. Materials that are high in nitrogen, referred to as “brown materials”, include dried leaves, wood chips and saw-dust whereas materials high in carbon, referred to as “green materials,” include manure, food scraps, vegetables and fruits. Most microorganisms require a ratio of 25 - 30 parts carbon to 1 part nitrogen, taking into consideration the C:N ratio within the components used, however, is equivalent to about 1 - 2 parts brown materials to 1 part green by volume. It is also recommended that oxygen concentration be at least five percent (5%), moisture content between 30 - 65% and with a temperature ranging from 43%. The recommendation for particle size was 5 - 30cm (Meena et al, 2021; Vásquez and Soto, 2017).

According to literature (Ayilara *et al*., 2020; Richard, 2005), compost has proven to improve soil structure, provide nutrients to enhance plant growth and increase soil biodiversity. Accordingly, fields with compost have been shown to have high yields (FAO, 2010). Further, the amelioration of soil may encourage home and community gardening, which can ultimately build stronger food systems and improve the existing supply chain, if adequately managed. The use of compost instead of, or in addition to, synthetic fertilizers could reduce household expenditure dedicated to fertilizers and store-bought produce. It is postulated that home composting could reduce the flow of organic waste to landfills and thus, it becomes necessary to quantify the organic waste processed by home composting (Vásquez and Soto, 2016).

The problem of organic waste in Trinidad and Tobago

According to the National Recycling Policy (2015), a 2010 waste characterization study in Trinidad and Tobago concluded that about 27% of all wastes directed to national landfills were organic in nature. Organic waste comprised the highest percentage of waste at the Beetham and Guanapo Landfills at 32% and 22% respectively, with paper categorized separately. Locally, there has been a significant reduction in the capacity of landfills and furthermore, organic waste in a landfill undergoes decomposition under

anaerobic conditions, thereby producing methane gas, a contributor to climate change that is a more potent greenhouse gas than CO_2 (UNECE, 2021). It must be remembered that Trinidad and Tobago is the second largest per capita producer of carbon emissions and hence, any attempts to reduce greenhouse gases will contribute to national objectives on the National Determined Contributions (NDCs). To address such issues, it would be prudent to provide an alternative channel for the reduction of organic wastes to national landfills. Solid waste management has to compete with other pressing national matters (Riquelme, Mendex and Smith, 2016) and in the absence of policy tools and national infrastructure, such as organic waste bans and composting facilities, innovative ways to reduce the amount of organic waste proceeding to the landfill should be bolstered at the household level.

The role of CPEF

The Central Pathfinders Environmental Foundation (CPEF), is a non-governmental organization that aims to promote ecological conservation through sustainable environmental and agricultural awareness and development. In recognition of home composting as a probable partial solution to the waste management issue in Trinidad and Tobago, CPEF posited that the application of an easy-to-use and compact urbanized composting unit (UCU) could encourage home composting and ultimately serve as an alternative to the disposal of organic wastes in the landfills. The UCU, entitled “Captain Turner”, was designed to be enclosed, lightweight, compact, thereby alleviating composting challenges such as offensive odours, pests, high labour intensity and lengthy time for compost maturation and featured a tumbling action to reduce manual labour required for mixing materials. As a result, CPEF embarked on a United Nations Development Programme (UNDP) Global Environment Facility Small Grants Programme-funded (GEF SGP) project to design and beta-test the efficiency of an urbanized composting unit for proof of concept and procedural optimization. The objective of this paper is to document the efficacy and efficiency of a locally-produced UCU as a tool for disrupting the flow of organic waste directed to the landfill.

Materials and methods

Selection of participants

Volunteer sampling was utilized for this project. Six (6) households were selected based on their willingness to voluntarily participate in the programme and having indicated a desire to be more environmentally friendly and an interest in composting. A total of twelve (12) compost tumblers were distributed to six (6) households.

A survey was used to determine the following demographics of the participating households:

- All participants were within the 35 - 60 age group.

- Participant households were located in the communities of Cunupia, Carlsen Field, Freeport, San Fernando and Point Fortin, on the island of Trinidad, as seen in Figure 1.
- There was an equal percentage of male and female participants.
- The average size of the households was three (3) persons, with one household containing four (4) and another household containing seven (7) persons.
- Five (5) households contained meat-eaters whereas one household had only vegetarians.
- Two (3) of the six (6) households actively practiced heap composting.
- None of the participating households previously practiced container composting.

Figure 1: Map showing the location of participating households in Trinidad

Programme of evaluation and operation of the compost tumbler

The project commenced in October 2020 with the design and construction of twelve (12) Urbanized Composting Units (UCU), an example of which is shown in Figure 2. Each participating household was provided with two (2) UCUs so that when one (1) was filled and its content maturing, the other could be used for a new cycle. Notably, Covid-19 impacted the number of participating households as planned participants were no longer willing to interact with individuals unnecessarily. Participants were encouraged to test the compost tumblers for the period of five months, April to August, 2021. This period gave the participants enough time to complete at least one (1) cycle in each UCU and harvest mature composted material. Prior to the commencement of the testing phase, all participants were trained in the composting process using a blended approach, that is, via the Zoom platform as this was conducted during the Covid-19 pandemic and in-person training upon delivery.

Figure 2: Photo of UCU

The participants were advised to only use kitchen scraps as their “green” material and were all provided with sawdust to be used as their “brown” material. Participants were provided with covered buckets and a scale so as to apply 1 - 2 parts brown materials to 1 part green materials by volume. Sawdust was provided to the participants to maintain a level of consistency in the brown materials, though an ideal

brown material mix would likely include other materials such as dried grass clippings. Dried grass and hard leaves were not recommended for the UCU as it would take a longer period to decompose. CPEF monitored the progress of the testing participants via weekly communication, and site visits in June and August, 2021, that is, during the middle and end of the evaluation period. Please refer to the Appendix for photos of the UCU and items used in the process.

Determination of the efficacy of the compost tumbler

The efficacy of the units for home composting was evaluated based on the amount and kinds of organic material the participants were able to separate from their kitchen waste and divert to the UCUs as opposed to the landfill. The participating households were required to weigh and record the mass of organic waste each time they added material to the UCU. Each participating household was provided with a digital scale and hygrometer to enable them to record the temperature and humidity within the tumblers. Once per week for the duration of the composting period, the participants were asked to record temperature and humidity readings as well as observe and record changes in colour and odour of the composting material.

To evaluate the time taken to produce mature compost, the tumblers were marked with a "fill line"; the participants were advised to stop adding fresh material to the UCU once the material reached the fill line. At this point, the participants were to rotate the UCU twice weekly and continue recording the parameters identified for observation. Participants were advised to open a tap at the base of the UCU in the event of leachate buildup and upon collection, use it to water their plants. The leachate could also be used as an inoculant to 'kick-start' another UCU. When the material was judged to be mature, a pH value was recorded, the material was emptied from the tumblers, weighed, and then spread evenly to air dry. CPEF members advised the participants on compost maturity based on changes in colour, particle size and changes in volume. Compost is considered mature when the raw feedstocks are no longer actively decomposing and thus, volume changes halt, particle size is fine and the colour is dark and no longer red. When completely dried, participants were instructed to again weigh the material and sift through soil sieves that were provided. ANOVAs were used to compare the results of the twelve (12) tumblers to ensure consistency in efficiency.

Results and Discussion

Efficacy of the urbanised composting unit

In theory, the organic waste used as feedstock in the composting process represented waste that was destined for the landfill and is a key aspect in determining the role of the UCU in waste diversion. Table 1 shows the input of green and brown materials by the sample households.

Table 1: Green and Brown material inputs into each UCU for the testing period of April - August, 2021

Household	HH1		HH2		HH3		HH4		HH5		HH6		Total	Av.
Unit#	1	2	3	4	5	6	7	8	9	10	11	12		
Greens (kg)	6.20	6.78	9.16	6.58	6.20	4.96	3.88	11.00	7.40	12.35	6.54	12.85	93.90	7.83
Browns (kg)	3.51	3.80	3.15	2.07	2.14	4.17	0.70	3.64	1.52	3.96	2.49	3.95	35.10	2.93
Total (kg)	9.71	10.58	12.31	8.65	8.34	9.13	4.58	14.64	8.92	16.31	9.03	16.80	129.00	10.75

Source: Authors' compilation

Table 1 shows that through the use of the UCU, 6 households successfully diverted a total of 129.00 kg of organic waste from the landfill over a 5-month period, of which 93.90kg was attributed to kitchen waste. The remainder comprised brown materials, as participants were instructed to weigh brown materials amounting to the equivalent of 1 - 2 times the **volume** of the green materials used. On average, the UCU successfully utilized 10.75kg of organic waste, including 7.83kg of kitchen scraps with a range of 4.58kg to 16.8kg among the participating households. The final volumes varied due to the type of materials added as lighter voluminous materials would fill units faster than denser and more compacted materials. The water content of the green materials would also be a contributor to weight. Of the total number of additions (42), participants reported that vegetable and fruit peels were used in all additions, whereas 33.33% of the total number of additions contained leftover food scraps, 30.95% contained eggshells and 11.91% contained tea and coffee grounds. The figures were not mutually exclusive. ANOVA analysis comparing the twelve (12) units showed no significant difference in their performance (P = 0.91).

Efficiency of compost generation

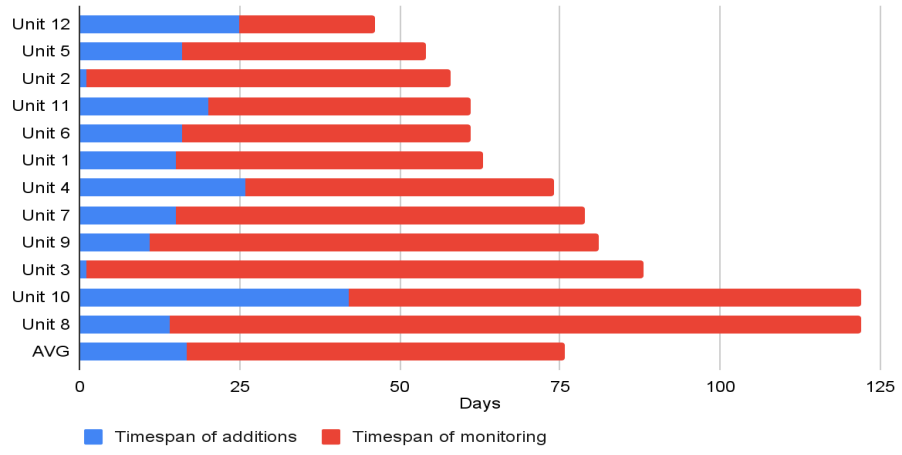

Figure 3: Time taken for additions and maturity and total time per UCU

As seen in Figure 3, the time taken to fill the UCUs was highly variable, ranging from 1 day, in the case of family gatherings, to 42 days, averaging 17 days. Typically, the time taken to fill the UCU would be

dependent on the number of persons in the household as well as lifestyle factors such as diet (be it heavily plant-based for example), the number of times per week of home cooking and quantity of leftovers thrown out. Subsequent to the addition of green materials, the time taken for compost maturity ranged from 21 days to 108 days, averaging 60 days. Further data gathering is required from additional testers for validity purposes and to ensure representative data gathering. During the evaluation period, 2 UCUs experienced problems; the contents of UCU #3 become dormant whereas UCU #8 became severely waterlogged. Troubleshooting was required and prolonged the time taken for compost maturation.

If one (1) household were to have only one (1) UCU, then in a 77-day timeframe, the UCU would utilize 7.83kg of kitchen waste, which can be extrapolated to 37.12kg per year, if the household data is representative. However, if households were to have 5 UCUs at their disposal, then one (1) UCU can be used every 17 days to capture all kitchen waste in that household, which would amount to 168kg/year. This country generates 700,000 tonnes of waste every year (SWMCOL 2015; EGARR and Associates, 2013) with organic waste accounting for approximately 189,000 tonnes. Thus based on these figures, if each household in this country were to implement UCUs, this would significantly reduce organic waste in our landfills.

Compost generation

Figure 3 below showcases the output of the urbanized composting tumblers by weight. Wet compost generation per unit is presented below, though individuals were encouraged to fully dry their compost before its final storage or utilization.

Table 2: Compost generated by each UCU for the testing period of April - August, 2021

Household	**HH1**		**HH2**		**HH3**		**HH4**		**HH5**		**HH6**		**Total**	**Avg.**
Unit#	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**		
Feedstock (kg)	9.71	10.58	12.31	8.65	8.34	9.13	4.58	14.64	8.92	16.31	9.03	16.80	129.00	10.75
Wet compost (kg)	7.81	8.68	7.35	6.75	7.43	6.72	4.02	7.94	6.63	14.02	7.65	14.43	99.43	8.29

Source: Author's compilation

Literature indicates that the time frame for compost maturation is variable, based upon conditions, the type of composting process as well as inputs (Raabe, n.d). Compost is considered mature when the raw feedstocks are no longer actively decomposing and are biologically and chemically stable. Generally however, the Berkeley method generates compost in a 18 - 30 day period whereas passive composting generates composting in 130 days and more. In this regard, the efficiency of generation of compost from the urbanized composting unit in 56 days can be classed as **moderate.**

In the event that the compost is not mature, decomposition will continue to occur thus reducing the availability of nutrients for plant growth and potentially damaging plants via root rot. Another effect of using immature compost is the release of compounds such as carbonic acids and sulfides which could compromise root systems. The chemical components responsible for the lower pH values such as carbon dioxide and the associated carbonic acid are depleted naturally once metabolic activity ceases, which indicates the completion of composting. The theoretical pH range for finished compost is above 7, which was attained by all participants upon completion of the composting process. It should be noted that the pH of materials also affects the composting rate and varies as the compost approaches maturity.

Participants used their generated compost as potting soil and as soil amendments. Most participants gave positive feedback in terms of being able to produce their own compost as well as the quality of the compost, which resulted in positive growth of their plants and seedlings.

Potential and resulting considerations

Participants expressed positive feedback on the initial Zoom training, rating their new knowledge as useful and very useful. Moreover, through interviews, it was found that testers had an continued interest in composting given the convenience and ease of use of the UCU. Based on interview responses, the participants were particularly pleased that the UCU was enclosed and did not encourage pests. However, participants stated that problems faced were unpleasant odours and leachate issues. Observations indicated that waterlogging appeared to be the major problem, which then led to lowered temperatures and prolonged compost generation times; participants were advised to leave the leachate drain open and open the cover periodically as a solution. All participants expressed interest in continuing to use the UCU at the end of the evaluation period, thereby indicating a reduction of organic wastes from 6 households being directed towards the landfill. The response that participants would continue to use the UCU was promising as it signified that the easy-to-use and compact design could result in behavioural change as it relates to organic wastes. Notwithstanding, further research into this aspect is required.

Pending further data collection, through an increase in number of users over a longer period of time, the community and/or national benefit can be obtained on an annual basis by multiplying the estimated number of households by the quantity of organic waste utilized by time frame ratio (to obtain an annual rate).

Composting process characteristics

Given that specific ranges of temperatures and humidities are recommended as optimal, Figures 4 and 5 represent the recorded values during the period by the participating households. A mixed microbial community is integral to composting, involving aerobic mesophilic organisms which dominate the initial

and final stages of composting that represent the lower temperature stages and thermophilic organisms which produce the highest temperatures.

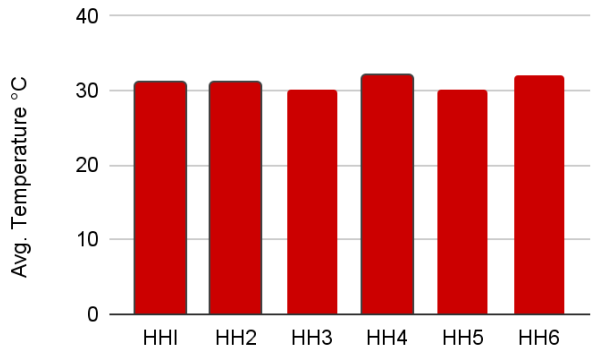

Figure 4: Avg. UCU temperature per household

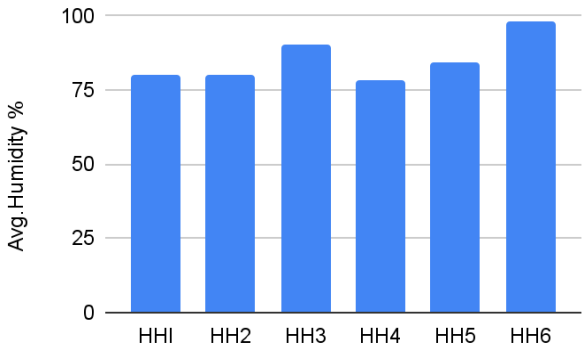

Figure 5: Avg. UCU humidity per household

The temperatures in Figure 4 were measured at the surface, not internally and ranged from 28℃ - 36.2℃. Internal temperature readings were taken periodically with a compost thermometer and confirmed that internal temperatures were higher than that of the surface temperatures. A consistent programme of internal monitoring was difficult to adhere to based on limited site visits due to Covid-19 considerations, however, provided a range of temperatures from 37℃ - 43℃.

Nonetheless, the surface temperatures recorded were no higher than 32℃. Vásquez and Soto (2017) proposed that the moisture content in a home composting unit constrained the temperature of the compost itself. From the experimental data gathered and experience in household compost heap maintenance, the size and shape of a compost heap is better suited for drainage whereas it is possible that the size and shape of the UCU dissipated heat more readily, leading to a stable mesophilic phase of composting. The relative humidity of the UCUs were over 75%, likely due to respiration by microorganisms and limited drainage. Waterlogging may occur from excessive additions of water, low amounts of dried brown materials and the emergence of water from moisture rich foodstuff.

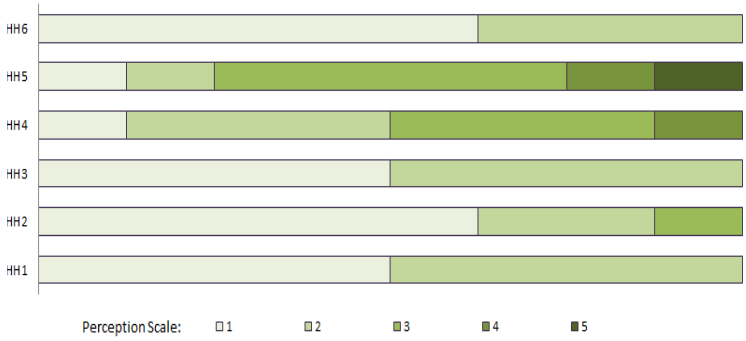

Figure 6: UCU odour perception per household

Odour rating was set to a subjective 1 - 5 scale: 1 being relatively odourless and 5 being a highly offensive scent. Odours are an indication that the decomposition has moved from aerobic to anaerobic

(Colon *et al*, 2010). During aerobic composting the main gases produced are carbon dioxide and water vapour with trace amounts of other gases. Anaerobic composting generates malodorous compounds such as hydrogen sulfide and ammonia, along with odourless greenhouse gases such as methane, carbon monoxide and nitrogen dioxide. The subjective detection of the malodorous compounds indicated that the tumbler was possibly waterlogged and required immediate attention. As seen in Figure 6, households 4 and 5 witnessed the emergence of malodorous gases and a possible shift to anaerobic composting whereas the remaining households had low to no odours.

Challenges and Limitations

Limitations of the evaluation process are as follows:

- Covid-19 regulations limited regular in-person interactions which would have been useful to make more frequent site visits to the testers to verify their internal temperature and humidity readings. Also to monitor the state of the UCUs with respect to waterlogging and or microbial inactivity to thereby better advise the testers on corrective actions.
- Data gathering on the efficacy and efficiency of the UCU is required from additional testers for validity purposes and to also determine further adherence issues as well as problems which require troubleshooting.

Challenges regarding the composting process included:

- The design of a cost-effective design for an enclosed leachate recovery process.
- The occurrence of waterlogging, which leads to a reduction in the diffusion of oxygen and in turn reduces the metabolic activities of the organisms appeared to be an issue. To counter the issue, instructions were changed so that participants would leave the drain-tap on the ‘on’ position, rather than vent when necessary.
- Maintenance of required temperatures. Further research and iterative design improvements may be required to ensure sufficient oxygenation and maintenance of the required temperatures.
- The UCU appeared to be functional for households of 4 individuals and under.
- Potential opportunities for further research to disrupt the flow or organic waste to the landfill include a larger composting unit. This would be especially useful and welcomed given the fast rate at which the designed UCU was filled.

Marketing Strategy

Upon completion of the beta-testing phase, CPEF embarked on a plan to market and sell the tumblers to the general public. Branded as ***“Captain Turner - the household compost tumbler”***, CPEF created an email address and pages on social media platforms, Facebook and Instagram, to provide information on this novel product and allow interested persons to place orders to purchase. Figure 7 showcases an

example of a published flyer. The product is priced at $500.00 - 600.00TTD. In Trinidad and Tobago, the average cost of a 45kg bag of compost is currently $60.00 - 75.00TTD; Captain Turner affords its owner the ability to produce compost indefinitely for less than the cost of 10 bags of commercial compost. CPEF provides an added value proposition to its customers, knowing that when they purchase Captain Turner they support a local non-governmental organization which has created an upcycled product, which can efficiently recycle their organic kitchen scraps into a medium they can use in their kitchen gardens and potted plants to add nutrients and improve soil structure. After-sales support is also a feature of the product as CPEF via text communication will provide troubleshooting advice to its customers.

Figure 7: Marketing flyer for the UCU

Recommendations and Conclusion

Based on the data collected on the beta-testing, the following can be concluded about the UCU:

1. The UCU is an effective method of reducing household organic waste and converting it into a viable household product (compost);
2. The UCU works well under the local climatic conditions and allows the production of mature compost within 60 days (2 months). This is a lower timeframe than other research on passive heap composting which can take as long as a year (Raabe, n.d.).
3. It is important that users of the UCU reduce the water content of the material going into it in order to reduce water logging and foul smells as well as allow leachate to drain as much as possible.
4. The produced compost has proven to be useful to the beta-testing participants who used it for their home gardens and potted plants.

The following recommendations are hereby suggested to aid the improvement of the UCU and the monitoring process:

- A programme of further research to gain additional data on the current process as well as mitigate challenges encountered. Research and observations would also serve to introduce information for other aspects such as the determination of an ideal brown material mix.

- More research is also required to determine the impact of wider-scale composting activities. For example, compost can retain excess water that may contribute to flash flooding and assist in conserving water to maintain larger-scale crop yield (Kirchhoff *et al*., 2003).
- It is especially acknowledged that public education campaigns are critical to inform households of the need to reduce their organic waste disposal and redirect it towards a beneficial resource in order to achieve large-scale behavioural change. Due to its compact size, the UCU tumblers can serve as an educational tool showing how the composting process is carried out.
- The expansion and replication of the use of the UCU in communities on a large-scale basis can culminate in a significant disruption of organic waste directed to landfills while promoting sound agricultural practices and improving environmental and human health.

In conclusion, home composting may be a viable solution to reduce a proportion of the organic waste stream that is directed to landfills in Trinidad and Tobago. CPEF continues to advocate for change in waste management locally by educating the public on the need to integrate home composting into their lifestyle and by promoting useful waste management tools and techniques, such as the UCU. The UCU has proven to be advantageous over the traditional method of compost for some individuals, due to its rate of compost generation, enclosed and compact design. The UCU was found to have a moderate efficiency and the potential to disrupt about 7.83kg of organic kitchen waste every 17 days and produce compost in a further 60 days. A shift in behaviour from dumping organic waste to the utility of a waste management tool, namely the UCU, may serve to improve environmental and human health.

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Appendix

Figure A1: Photos showing participants with UCUs

Figure A2: Photo showing some of the items that were distributed to participating households

Figure A3: Photo showing inside of a UCU in use, with humidity and temperature recorder

Figure A4: Photo showing matured compost