Aerobic Food Waste Composting: Measurement of Green House Gases

Chung An Li Justina, ISF academy, Hong Kong
0612002@student.isf.edu.hk

Background

The Independent Schools Foundation Academy is a private independent school in Hong Kong with approximately 1500 students. Each academic year, the school produces 27 metric tonnes of food waste. In November 2013, the school installed an aerobic food waste composting system.

The composting process employs two machines:

- The Dehydra
  - It reduces the mass of the food waste by grinding the food waste into a uniform size and removing excessive water.
- A900 Rocket (See fig. 1)
  - A composter made by Tidy Planet, processes food waste into compost in 14 days. This machine runs in an aerobic process, in which oxygen is required and will emit carbon dioxide

Fig. 1 A picture of the A900 Rocket

Over the past 3 years, various improvements, such as installing a bio-filter to reduce the smell of the compost, have been made to the composting process. Meanwhile the compost is used by the primary students, as part of their experiential learning curriculum and organic farming projects.

As a school, we are committed to reduce the amount of waste we send to the landfill and also reducing our carbon footprint.

Research Objective

While composting can reduce the amount of waste being sent to the landfills, aerobic composting processes also produce greenhouse gases which in turn contribute to global warming. (EPA)

This research studied different composting systems' GHG emissions for four major GHGs: carbon dioxide, methane, nitrous oxide and ammonia.

Gas Collection Method

Equipment used (See Fig. 2):

1) Siphon pump 2)Tedlar bags

Method:

- The suction pipe was inserted 5cm into the compost. Then, the output pipe was connected to the opening valve of the Tedlar bag.
- Around 1000cm^3 of gas was collected at each compost site.


Fig. 2 An picture of the pump and the Tedlar sampling bag

System Model

In October 2016, ISF Academy acquired a Gasmet DX 4015, a Fourier transform infrared spectroscopy (FTIR) multi gas analyzer. This equipment measures the concentration (ppm) of the GHGs and the data is presented through the Calcmet Analysis software. (See Fig. 3.1 and 3.2)


Fig. 3.1 A setup image of the Gasmet DX 4015

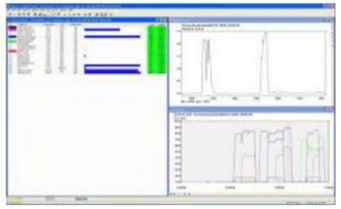


Fig. 3.2 A screenshot of the software

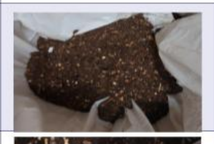
Raw data

Sample No.	CO_2 (ppm)	CH_4 (ppm)	N_2O (ppm)	NH_3 (ppm)
1	7377.42	16.20	0.92	0.39
2	1312.17	12.16	0.29	0.55
3	2501.13	36.96	0.61	0.55
4	1398.27	10.37	1.19	40.97
5	1138.00	1.00	0.18	0.70

Data processing

1) 400 ppm, the background CO_2 level on earth, was subtracted from each CO_2 measurements before the ratios were calculated. (EPA)
2) Each GHGs data was divided by the corresponding CO_2 reading, which is to find the ratio of CO_2 to the other GHGs. The ratios are shown below in scientific notation. This ratio normalized the data because the sample of gas collected in the Tedlar sampling bag was not exactly the same for each sample.

Ratio of Greenhouse Gases *vs.* CO_2

Sample No.	Description and type of composting	Picture of the compost	$[CH_4]/[CO_2]$	$[N_2O]/[CO_2]$	$[NH_3]/[CO_2]$
1	A 4 month compost pile, which is regularly turned and aerated.		2.3×10^{-3}	1.3×10^{-4}	5.6×10^{-5}
2	Same as above, but it is a 2 month pile.		1.3×10^{-2}	3.2×10^{-4}	6.0×10^{-4}
3	Vermicomposting, using earthworms to decompose food waste and generate humus in 2 months time		1.8×10^{-2}	2.9×10^{-4}	2.6×10^{-4}
4	Compost generated by a machine called AEL Food Waste Composter.		1.0×10^{-2}	1.2×10^{-3}	4.1×10^{-2}
5	Compost produced by the A900 Rocket at ISF Academy		1.4×10^{-3}	2.4×10^{-4}	1.0×10^{-3}

Discussion

- Sample No.1 is a 4-month-old compost pile. While it has the lowest CH_4 to CO_2 ratio, its CO_2 concentration is the highest among the 5 samples and more than 6 times of the lowest one.
- Sample No. 2 had the same process as No. 1, but with only two months piling. As a result, both the CH_4 to CO_2 ratio and NH_3 to CO_2 ratios of No. 2 are 10 times higher than No. 1.
- Sample No. 3 is a product of vermicomposting, leading to 37 ppm of CH_4 which is the highest reading and double the second highest sample generated by an aerobic composting system.
- The NH_3 to CO_2 ratio of Sample No. 4 is 40 times more than the second highest reading. Through smell test, its strong odor was evident that the ammonia was significantly higher, which might be caused by an imbalance of the composting formula.
- Lastly, gas sample No. 5 collected from the A900 Rocket at ISF with enriched nitrogen from coffee grounds has the lowest concentration of CO_2, CH_4 and N_2O as measured by ppm.

Conclusion

The gas sample collected from the ISF compost machine has the lowest emission of GHGs among all 5 samples. According to the Gasmet readings, the low concentration of methane (1 ppm) suggests that the food waste composting process in ISF is mostly aerobic, however when compared by evaluating the GHG ratios, it is apparent that nitrogen levels are higher than the other types of composting.

Next Steps in Research

- Since there was only one gas sample collected at each composting site, further research will include more trials to show the reliability and statistical validity of the results.
- The ammonia and nitrous oxide gases could be reduced by "fine tuning" the amount of nitrogen added to the compost mix.
- More accurate calculation of the background CO_2 concentrations at the time and location of the sampling.

Acknowledgements

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Research on Optimal Bulking Agent for Aerobic School Food Waste Composter

ISF 弘立書院
THE INDEPENDENT SCHOOLS FOUNDATION ACADEMY

Sabrina Chann (0107008@student.isf.edu.hk)

Abstract

Introduction

One third of Hong Kong's solid waste is food waste, thus reducing food waste has become crucial (Food Waste). The ISF Academy installed a A900 Rocket Food Composter in 2013, hoping to reduce its carbon footprint and reduce the amount of solid waste going to the landfill. Currently, the academy produces 27 metric tons of food waste annually, most of which is churned in the composter and reused as fertilizer for a primary school gardening project which has 500+ children participating.

The school is continuously improving the composter. Previously, we have made improvements by revamping the odor control system, increasing the nitrogen content and the installation of an improved grease trap. This study looks specifically at changing the bulking agent in the compost. By comparing and analysing data of different bulking agents, we hope to find a reliable, affordable and suitable alternative to wood shavings, the current agent being used.

Objective

The aim of this study is to determine an alternative bulking agent to wood shavings which passes the regulations for "general agricultural use" of a compost, is reliable, effective and suitable for use in a school setting.

Food Composting Method

1. Food waste is dehydrated and macerated.
2. Ground coffee, existing compost and the bulking agent are then incorporated into the macerated food before being introduced into the Rocket Composter.
3. Refer to figures 1&2 for process diagrams.

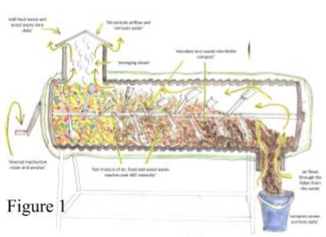

Figure 1

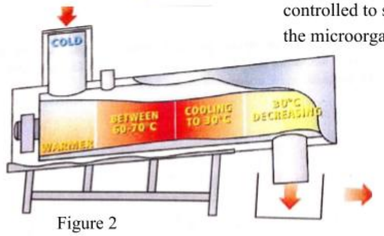

Figure 2

The composter has a capacity of 5,250 litres per week (A900 Rocket). The process takes a total of 14 days. In the composter, aeration, moisture and temperature are controlled to sustain the microorganisms.

Moisture Content (%) of Wet Compost (*prior to going through composter*) Test Method

Compost formula

Bulking Agent	*Formula*
Cardboard	*15 litres of cardboard + 15 litres of food waste + 5 litres of compost + 2 litres of coffee*
Wood Shavings	*22 litres of wood shavings + 15 litres of food waste + 7 litres of compost + 2 litres of coffee*

Figure 3
Cardboard compost (left) Wood shavings compost (right) prior to drying

Moisture Content Test

Measure out 10 g of compost (3 samples)

1. Place compost samples into oven set at 100ºC for 24 hours to dry and remove moisture
2. Reweigh the samples and calculate moisture content using the following formulae:

"$M_n = ((W_w - W_d)/W_w) \times 100$

in which:

M_n = moisture content (%) of material n

W_W = weight of wet compost sample

W_d = weight of compost sample after drying.

(Trautmann 2016)

Optimal moisture level for compost: 50-60%

Figure 4
Rocket Composter on campus

Processed Data

Moisture Content (%) of Wet Compost

Optimal moisture level: 50-60%

	Moisture content %	
Trial #	Wood Shavings	Cardboard
1	60.8066	63.7670
2	59.6865	56.6774
3	67.0972	55.1531
Average	62.5301	58.5325

Figure 5
Oven used to dry compost samples

Analytical Chemical Analysis			Compost Standards	
	Shredded Cardboard	Wood Shavings	General Agricultural Use	Organic Farming
EA002: pH value	7.2	7.8	5.5 – 8.5	5.5-8.5
EA035B: % Organic matter (at 550ºC)	96.7	96.4	>20	>20
EA055A: Moisture Content (dried at 70ºC)	16.4	20.3	25 – 35	25-35
EK055: Ammonia as N 7664-41-7	2,460	646	<700	< =700
NPK value (as %DW)	N/A	4.332	>4	>4
EA162: Carbon to Nitrogen Ratio	17	15.2	<=25	<=25
EP045: Volatile Acids as Acetic Acid	1,400	1360	Unknown	Unknown
EM102C: Escherichia coli	NOT DETECTED	NOT DETECTED	<1000	<=1000
EM107C: Salmonella	NOT DETECTED	NOT DETECTED	<3	<=3
ET011: Seed Germination Index	100	100	>80	>=80

Results and Analysis

Moisture Content Test

Optimal moisture content for organic waste before composting is 50-60%, any variation from this range may cause the process to become anaerobic.

From the results of the moisture content test it can be reasoned that the cardboard based compost is more efficient and cost-effective compared to the wood shaving compost. The moisture content (%) of the cardboard compost was 3.9976% lower than that of the wood shaving compost even though less bulking agent was used and more food waste was added. As shown, by using cardboard as the bulking agent:

1. Food waste capacity increased (more efficient)
2. Less bulking agent used (cost effective)
3. Lower chance of compost becoming anaerobic (lower moisture content)
4. Approximately 20% more food waste can be processed by using shredded cardboard as the bulking agent. (With an increasing student population, being able to recycle more waste is required.)

Compost Test Comparison

Analytical chemical analysis was performed by a certified lab in Hong Kong, ALS Laboratory Group. All compost used for food production must be certified.All testing procedures used by ALS are approved by the Hong Kong government.

1. Escherichia coli and Salmonella levels are low standards
Safe for children
2. All heavy metals values were well below compost standards
Data not shown but includes: Cadmium, Zinc, Lead, Mercury and Chromium
Safe for growing vegetation
3. Acceptable levels of volatile acids and ammonia
Ensures that aerobic compost system remains healthy; however, the values for the shredded cardboard are slightly higher than the wood shavings.
4. High levels of organic matter
Compost is rich in carbon, good for growing plants and vegetation
5. 100% seed germination index
Indicates that plants will grow.

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