Characterization of the physical, chemical and biological properties of the organic material produced by the Food Cycler (DRAFT)

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Executive Summary

Food Cycle Science provides on-site organic food waste recycling solutions to the food service industry through the distribution and sale of the Food Cycler unit. The Food Cycler process accelerates the decomposition of food waste converting it into a humus-rich, high-carbon organic matter with potential for use as a soil amendment. Food Cycle Science is investigating the requirements necessary to develop the material produced by the Food Cycler unit into a soil amendment for sale on the Ontario and Canadian Markets. Accordingly the St. Lawrence River Institute of Environmental Sciences has undertaken initial characterization of the physical, chemical and biological properties of the organic material produced by the Food Cycler unit located at the Cornwall Community Hospital. The preliminary results indicate that the Food Cycler material meets most of the requirements for metals, pathogens and maturity for AA compost in Ontario. This report provides a summary of the analytical results.

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Purpose

This document summarizes the preliminary characterization of the physical, chemical and biological properties of the organic material produced by the Food Cycler. For comparison purposes, the characteristics of the material produced by the Food Cycler units were compared to those of AA grade compost. The *Ontario Compost Quality Standards*[1] were not written for the application of the Food Cycler technology and/or the use of the end product it generates as a soil amendment; however, these standards serve as a guideline for material that is currently being sold and land applied in Ontario.

Current Scope

Food Cycle Science provides organic food waste recycling solutions for a wide variety of industries. The Food Cycler is a multi-phase, onsite organic food waste recycling machine that dehydrates and converts food waste into a humus-rich, high-carbon organic matter with potential for use as a soil amendment. Food Cycle Science would like to develop the residue produced by the Food Cycler into a soil amendment that can be packaged and sold on the Ontario and Canadian markets.

Description of the methods

1. Industrial Unit

Two baseline, 2-3 L composite samples of material were collected from the Cornwall Community Hospital (CCH) Food cycler unit immediately following completion of the Food Cycler process and sent out for analysis by A&L Canada Laboratories Inc., London Ontario.

[1] Ontario Ministry of the Environment, Waste Management Policy Branch. *Ontario Compost Quality Standards.*(PIBS 8412). (2012). Retrieved from: http://www.ene.gov.on.ca/environment/en/resources/STDPROD_099820.html

A trial compost pile (1 m wide X 0.5 m high X 1 m length) was created at the Food Cycle Science storage facility with fresh material collected from the CCH Site. The material pile was contained in a plywood box and covered with a tarp to prevent moisture loss, and placed on a skid to insulate it from conductive heat loss to the cement floor. Upon completion of pile construction the temperature at the center of the pile was continuously measured and logged using a ThermoWorks temperature data logger (TW-USB-1). Ambient air temperature and internal pile temperature at 10 random points within the pile were measured daily (Monday to Friday) for a period of 21 days. The pile was turned manually on a daily basis (Monday to Friday) to properly aerate the material. Following the 21 day monitoring period, two composite samples (2 – 3 L each) were collected and sent for analysis of the following parameters:

- % Organic matter and % moisture
- Major nutrients: Total Nitrogen and % water insoluble nitrogen, total phosphoric acid (P_2O_5) and available phosphoric acid (P_2O_5) and soluble potash K_2O
- Metals: Arsenic, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, lead, selenium, zinc.
- Nutrients (Elements): Calcium, Magnesium, Sulfur, Boron, Copper, Iron, Manganese, Molybdenum, Chloride
- pH
- Sodium (Na)
- Physical contaminants/Foreign matter & Sharp Foreign Matter
- Pathogens: Escherichia coli and Salmonella
- Maturity

2. Home Unit

Food Cycle Science was interested in determining the sodium concentration of the organic material produce by Food Cycler home units. Food waste was collected over a 28 day period for processing by the Food Cycler home unit. High salt and highly processed foods were collected from the St. Lawrence College (Cornwall campus) cafeteria and processed using the home unit to create a 2 – 3 L high sodium (High Na) composite sample. Food waste consisting of raw vegetable and fruit material as well as homemade, lightly seasoned meals was also collected from at the River Institute. This material was also processed with the home unit to create a 2-3 L low sodium (Low Na) composite sample. The two composite samples were then analyzed for the above list of parameters.

Results and Discussion

Temperature

The trial compost pile was created to observe whether or not the material generated from the industrial food cycler unit would have any thermogenic activity when composted. An active aerated static compost pile should maintain a minimum temperature of 55^{o}C for a period of at least 3 consecutive days to ensure that potential pathogenic bacteria are killed. Increases in core pile temperature also indicate the breakdown of the organic matter in the compost pile by microorganisms. No substantial temperature increases were observed during the 21 day period. During the 21 day composting trial temperature at the center of the pile fluctuated with the ambient air temperature (Figure 1). The internal temperature of the pile mimicked that of the ambient air temperature. The size of the pile may have limited the ability of the material to hold any heat being produced through microbial activity. Therefore no conclusions can be made at this point on whether or not the material would successfully compost.

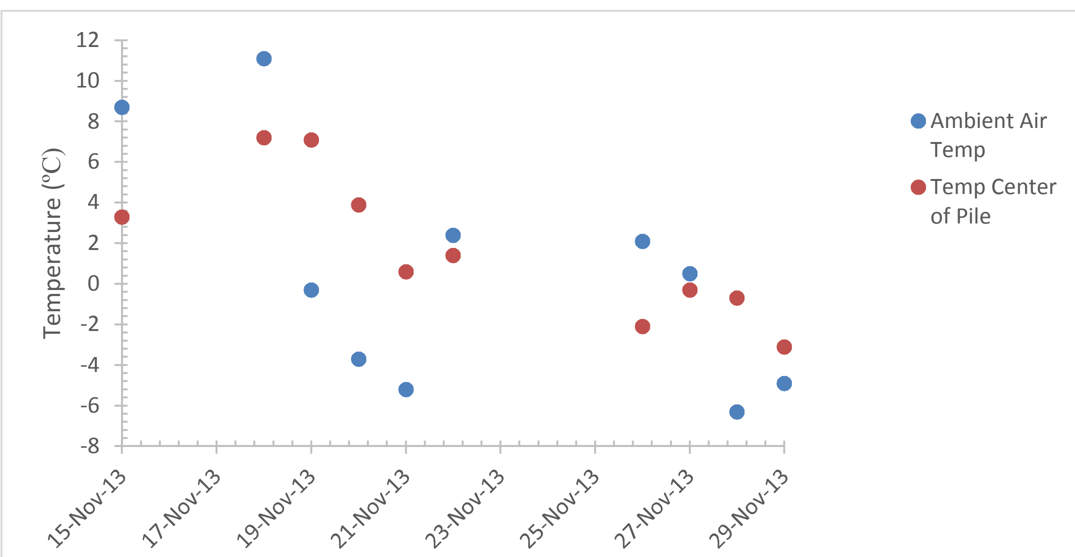

Figure 1. Comparison of the ambient air temperature and the temperature at the center of the trial compost pile.

Nutrients

In order to determine the suitability of the material produced by the Food Cycler for use as a soil amendment, we compared nitrogen, phosphorus and potassium concentrations to average nutrient levels found in materials that are currently applied to agricultural land. The nutrient levels present in the processed food waste collected from the CCH site are reasonably similar to material that is currently being land applied (Table 1). The nutrient levels in the material produced by the Food Cycler suggests that there is the potential to develop this material into a soil amendment. The preliminary analysis (A&L Canadian Laboratories Inc. in London Ontario) indicated that all samples analyzed were rich in available potassium, calcium and zinc which would make Food Cycler material ideal for landscaping and amendment purposes.

The Food Cycler reduced the volume of food waste material and breakdown of the organic material through a process of agitating and heating the material to 82^{o}C. This process is very different from the process of microbial breakdown of organic material that occurs during composting. Therefore further studies are needed to characterize the nutrient availability in the material generated by the industrial Food Cycler units.

Table 1: Comparison of the Available Nutrients of various land applied materials to the material produced by the Industrial Food Cycler Unit located at CCH.

Material	Available Nutrients				Total Nutrient Content (as-is basis)				
	Ave. DM	Usable N[1]	P_2O_5	K_2O	Total N	NH_4-N		P	K
	%	lb/ton			%	ppm	%	%	%
Solid manure Beef	31.4	4.9	6.1	14.3	0.92	1778	0.18	0.33	0.66
Solid manure Dairy	25.9	4	3.7	13.2	0.72	1505	0.15	0.20	0.61
Composted Cattle	38.3	5.6	5.2	23.8	0.86	543	0.05	0.28	1.1
Compost: all types	46.4	7.3	6.3	17.9	1.09	877	0.09	0.34	0.83
Biosolids (dewatered)	32.1	25.7	24.1	2.4	3.76	3443	0.34	1.31	0.11
Food Cycle Science									
B1	87.5	N/A	14.5	19.8	3.21	395	N/A	0.31	0.82
B2	87.5	N/A	13.7	20.5	3.18	449	N/A	0.30	0.85
E1	88.2	N/A	16.7	23.4	3.48	450	N/A	0.36	0.97
E2	88.1	N/A	14.4	21.1	3.7	478	N/A	0.30	0.90

DM = Dry Mater

[1] Useable N = amount of nitrogen available in the year of application assuming spring application incorporated within 24hr.

* This table has been modified from; Brown, C. Ministry of Agriculture and Food, Ministry of Rural Affairs. (2013). *Available nutrients and value for manure from various livestock types* (Order No. 13-043). Toronto, ON: Queen's Printer for Ontario.

Metals

Preliminary analysis indicates that the material generated by the Food Cycler at the CCH location meets metal requirements for land application. All of the samples analyzed were compliant with metal requirements for Category AA compost (Table 2 & 3).

Table 2: Comparison of the metal concentrations in the material produced by the Industrial Food Cycler unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Metals	CCH unit				Detection Limit	Category AA compost (ppm)
	Baseline T(0)		T(21) Days			
	B1	B2	E1	E2		
	ppm					
Aluminum (Al)	28.9	50.8	24.1	50.9		N/A
Arsenic (As)	BDL	BDL	BDL	BDL	1.00	13
Cadmium (Cd)	BDL	BDL	BDL	BDL	1.00	3
Cobalt (Co)	BDL	BDL	BDL	BDL	1.00	34
Chromium (Cr)	1.31	1.46	BDL	BDL	1.00	210
Copper (Cu)	3.83	3.7	BDL	29.5	1.00	100
Mercury (Hg)	BDL	BDL	BDL	BDL	0.10	0.8
Molybdenum (Mo)	BDL	BDL	BDL	BDL	2.00	5
Nickel (Ni)	BDL	BDL	BDL	BDL	1.00	62
Lead (Pb)	6.43	5.78	2.2	BDL	1.00	150
Selenium (Se)	BDL	BDL	BDL	BDL	1.00	2
Zinc (Zn)	22.66	23.19	12.09	18.68	1.00	500

Table 3: Comparison of the metal concentrations in the material produced by the Food Cycler Home unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Metals	Home Unit		Detection Limit	Category AA compost (ppm)
	Low Na	High Na		
	ppm			
Aluminum (Al)	99.9	4		N/A
Arsenic (As)	BDL	BDL	1.00	13
Cadmium (Cd)	BDL	BDL	1.00	3
Cobalt (Co)	BDL	BDL	1.00	34
Chromium (Cr)	BDL	BDL	1.00	210
Copper (Cu)	6.04	3.2	1.00	100
Mercury (Hg)	BDL	BDL	0.10	0.8
Molybdenum (Mo)	BDL	BDL	2.00	5
Nickel (Ni)	BDL	BDL	1.00	62
Lead (Pb)	BDL	BDL	1.00	150
Selenium (Se)	BDL	BDL	1.00	2
Zinc (Zn)	23.19	26.13	1.00	500

Pathogens

The following criteria must be met in order to ensure that there is no risk of adverse health effects from pathogens present in the compost material. *The Ontario Compost Quality Standards* states that:

a. Compost shall meet specified temperature requirements
    - Windrow composting method: the material shall maintain a minimum temperature of 55°C for a period of at least 15 consecutive days and during the high temperature period the windrow will shall be turned at least 5 times.
    - Aerated Static pile: the material shall maintain a minimum temperature of 55°C for a period of at least 3 consecutive days. The pile shall be covered with an insulating layer of material to ensure that all areas of the feed material are maintained at the required temperature.

b. Compost shall meet the following pathogen reduction requirements
    - Must not exceed 1000 colony forming units (CFU) *Escherichia coli* or most probable number (MPN)/gram total solids (on a dry weight basis), and
    - Must not exceed 3 MPN *Salmonella*/4 grams total solids (on a dry weight basis, based on an analysis of the entire 4g samples).

The Food Cycler process does not meet the requirement that the material maintain a minimum of 55°C over a number of number of days. The Food Cycler agitates and heats the material to 82°C, which significantly reduces the volume of the material through dewatering and minimal decomposition, as well as achieving destruction of potentially pathogenic bacteria. All samples tested meet the requirements for AA compost in Ontario (Table 4 & 5).

Table 4: Comparison of pathogen levels in the material produced by the Industrial Food Cycler unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Pathogens	CCH Unit				Units	Category AA compost
	Baseline T(0)		T(21) Days			
	B1	B2	E1	E2		
E. coli	<3	<3	<3	<3	MPN/g dry	1000 (MPN)/g dry
Fecal coliform	<3	<3	<3	<3	MPN/g dry	1000 (MPN)/g dry
Salmonella spp.	Neg.	Neg.	Neg.	Neg.	P-A/25.0g(ml)	3 MPN *Salmonella*/4g dry

Table 5: Comparison of pathogen levels in the material produced by the Food Cycler Home unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Pathogens	Home Unit		Units	Category AA compost
	Low Na	High Na		
E. coli	<3	<3	MPN/g dry	1000 (MPN)/g dry
Fecal coliform	<3	<3	MPN/g dry	1000 (MPN)/g dry
Salmonella spp.	Neg.	Neg.	P-A/25.0g(ml)	3 MPN *Salmonella*/4g dry

Foreign Matter

The material generated by the Food Cycler was characterized as a medium-fine textured material, primarily ¼ in. particle size. All samples analyzed are compliant with the current Ontario type AA compost standards for foreign matter (table 6 & 7).

Table 6: Comparison of foreign matter in the material produced by the Industrial Food Cycler unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Foreign Matter	CCH Unit				Unit	Detection Limit	Category AA Compost
	Baseline T(0)		T(21) Days				
	B1	B2	E1	E2			
Total FM > 8 mesh	BDL	BDL	0.06	BDL	%	0.01	Total foreign matter > 3 mm shall not exceed 1.0% (dry weight)
Total FM > 2.8 mm	BDL	BDL	0.06	BDL	%	0.01	
Total FM > 25 mm	BDL	BDL	0.05	BDL	%	0.01	
Total FM > 25 mm	BDL	BDL	1	BDL	pieces/500ml		Shall not contain foreign matter > 25 mm per 500 ml
Total Plastics > 8 mesh	BDL	BDL	0.06	BDL	%	0.01	Shall not exceed 0.5% (dry weight)
Total plastics > 2.8 mm	BDL	BDL	0.06	BDL	%	0.01	
Total sharps > 12.5 mm	BDL	BDL	BDL	BDL	pieces/500ml		Shall contain no material of a size or shape that can reasonably cause human or animal injury
Total sharps > 2.8 mm	BDL	BDL	BDL	BDL	pieces/500ml		
Total sharps > 2.36 mm	BDL	BDL	BDL	BDL	pieces/500ml		

Table 7: Comparison of foreign matter in the material produced by the Food Cycler Home unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Foreign Matter	Home Unit		Unit	Detection Limit	Category AA Compost
	Low Na	High Na			
Total FM > 8 mesh Total FM > 2.8 mm Total FM > 25 mm	BDL BDL BDL	BDL BDL BDL	% % %	0.01 0.01 0.01	Total foreign matter > 3 mm shall not exceed 1.0% (dry weight)
Total FM > 25 mm	BDL	BDL	pieces/500ml		Shall not contain foreign matter > 25 mm per 500 ml
Total Plastics > 8 mesh Total plastics > 2.8 mm	BDL BDL	BDL BDL	% %	0.01 0.01	Shall not exceed 0.5% (dry weight)
Total sharps > 12.5 mm Total sharps > 2.8 mm Total sharps > 2.36 mm	BDL BDL BDL	BDL BDL BDL	pieces/500ml pieces/500ml pieces/500ml		Shall contain no material of a size or shape that can reasonably cause human or animal injury

Maturity

Compost maturity is defined in the *Ontario Compost Quality Standards* as:

> "a condition of compost that results from the thorough decomposition of the feedstock materials, and as a result exhibits very little biological activity, which enables the compost to be stored and handled without adverse effect, including offensive odours, and used without risk to plants from residual phytotoxic compounds"

In order for a product to be considered Category AA compost it must meet the following maturity criteria as laid out in the *Ontario Compost Quality Standards*:

- Compost shall be maintained at ≥40% moisture during curing
- Compost must be cured for a minimum of 21 days
- Material must have a respiration rate that is
    - Less than or equal to, 400 milligrams of oxygen per kilogram of volatile solids (on a dry weight basis) per hour **OR**
    - Less than, or equal to, 4 milligrams of Carbon in the form of carbon dioxide per gram of organic matter (on a dry weight basis) per day.

The Food Cycler process dewaters the food waste and takes less than 24 hrs; therefore the material is not able to meet the moisture and curing requirements for AA compost. However all samples analyzed meet the respiration rate requirement of less than, or equal to, 4 milligrams of Carbon in the form of carbon dioxide per gram of organic matter (on a dry weight basis) per day (Table 8 & 9). The process of heating the material to 82°C kills most of the microorganisms present in the food waste thus eliminate the microbial activity in the material that would contribute to the respiration rate of the final product.

Table 8: Comparison of maturity index for the material produced by the Industrial Food Cycler unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Sample	Maturity Index	Category AA Compost
B1	8 (Slovita) 0.50 mg CO_2 C/g O.M./day	≤ 4.00 mg CO_2 C/g O.M./day
B2	8 (Slovita) 0.10 mg CO_2 C/g O.M./day	
E1	7 (Slovita) 3.30mg CO_2 C/g O.M./day	
E2	7 (Slovita) 3.00 mg CO_2 C/g O.M./day	

Table 9: Comparison of maturity index for the material produced by the Food Cycler Home unit to the requirements for Category AA compost as stated in the *Ontario Compost Quality Standards*.

Sample	Maturity Index	Category AA Compost
Low Na	8 (Slovita) 0.01 mg CO_2 C/g O.M./day	≤ 4.00 mg CO_2 C/g O.M./day
High Na	8 (Slovita) 0.01 mg CO_2 C/g O.M./day	

An additional requirement for maturity is that the material is able to be used without risk to plants from residual phytotoxic compounds. High levels of sodium are potentially toxic to many species of plants. Sodium interfere with nutrient and water uptake and competes with calcium and potassium uptake by the roots. Excessive soluble salts or high % base saturation for sodium in the final growth media (greater than 2%) is toxic to most plants. The percent sodium by mass in the material produced by the CCH Food Cycler unit is low. However, from a % base saturation standpoint (40 – 44%) it is rated very high (Table 10). Further studies are required to determine the best method to mitigate any potential negative impact of the high % base saturation for sodium in the final product to be developed as a soil amendment.

Table 10: Sodium levels, Soluble Slats and the Cation Exchange Capacity (CEC) of the composite samples collected analyzed from the Industrial Food Cycler unit at CCH.

Sample	Na^+			Soluble Salts	CEC
	% by mass	PPM	% base saturation	ms/cm	meq/100g
B1	0.92	3737	41.38	6.3	39.3
B2	0.91	4935	44.08	6.6	48.7
E1	0.85	4669	42.02	8.2	48.3
E2	0.80	4976	40.27	8	53.7

Recommendations and Next Steps

The following recommendations and next steps are intended to provide guidance to Food Cycle Science as they move forward with the development of a soil supplement that is intended to be sold on the Ontario and Canadian Markets.

- Characterize the feedstock material from several food waste generators currently using the Food Cycle Science technology. Currently there are 10 units in operation in the city of Hamilton, Ontario.
- Fully characterize the available nutrients and confirm the maturity of the final product.
- Determine if the material needs to be amended in any way to adjust the % base saturation of sodium in the final product.
- Develop an appropriate method to generate a consistent, marketable product with guaranteed minimum nutrient and mineral content to be sold on the Ontario and Canadian Market.
- Conduct growth trials to assess the benefits to plant growth and determine the desired application rates.
- Contact the CFIA and schedule a pre-submission consultation meeting.