In-Vessel Food Residual Composting

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Introduction

A study of food waste composting was conducted at Brown Creek Correctional Institution, Polkton, NC. Brown Creek Correctional Institute houses an average of 852 inmates and has 362 employees. Funding was provided, in part, through a grant from the North Carolina Division of Pollution Prevention and Environmental Assistance, Department of Environmental and Natural Resources. RKB Enterprises, Inc. of Norfolk, VA, was the selected grant recipient to provide the equipment and conduct the study, assisted by Brown Creek Correctional Institute staff. Although this was not a university-supported study, Dr. Don Cawthon of Texas A&M University-Commerce and Dr. Alan Heyworth, teg Environmental, plc, England, contributed a significant amount of their expertise and time for consultation.

The nine-month project set out to collect data testing the appropriateness of in-vessel composting, in particular, the GREENDRUM in-vessel system, for safe and efficient composting of institutional food waste. Pre-determined objectives focused on the collection of data pertaining to:

- quantity and characteristics of waste generated
- GREENDRUM operating capacity
- operating cost
- transferability of the technology
- cost savings
- analysis of resulting compost

Before beginning the trial, it was necessary to determine daily food waste from the average prisoner. Assumptions as to the size of the daily waste stream were based on existing survey figures from the EPA document, “Waste Assessment Reference Manual.” Under section 4, “Conversion Charts and Figures,” in cafeteria-style dining each meal produces 1 pound. of waste per person. Interpolating this figure to the prison situation where the total waste figure per inmate is assessed as 4.5 lbs. per day, it becomes evident that food residuals are more than 50% of the total waste per inmate daily. As Brown Creek food preparation conscientiously attempts to minimize food waste, we anticipated receiving between 1,000 lbs. and 3,000 lbs. of food waste residuals daily; in addition, the prison uses paper towels at a rate of about 12 pounds daily.

This daily waste prediction prompted a request to change the contract to allow RKB Enterprises to provide at larger GREENDRUM, Type 616, in order to run a pilot program with an operating capacity closer to the maximum needed to handle Brown Creek. Based on trials by Texas A&M, Type 616 is estimated to handle 900 lb. of food residuals daily, plus amendment.

General Project Description

The GREENDRUM in-vessel composter is a continuous feed system using an insulated drum. The drum is mounted on an all-steel frame and rests on all-steel rotor casters and it rotated every 20 minutes using a chain-drive unit powered by an electric motor.

The Greendrum in-vessel process ensures that the health and environmental requirements set forth by the NC Solid Waste Composting Rules are more easily satisfied. This long-term trial of food residuals composting studied the GREENDRUM in-vessel process by rigidly applying those rules to see if the Greendrum performed to those standards. Potential problems with site location are solved through system design. All waste is isolated from the environment until after the time and temperature requirements to “further reduce pathogens” (Rule 1406 para. 12C) is accomplished. That rule requires, “temperatures in the compost piles shall be maintained at a minimal temperature of 131 deg. F for at least 3 days”. Analysis confirmed pathogen requirements were attained. After removal from the drum, compost is stacked for curing.

The objective was to compost a waste stream made up entirely of all food waste. This is a more complex process than adding food waste as a minor part of an existing yard waste, leaf, or other similar waste stream. The critical mix characteristics to achieve required thermophilic temperatures are all interrelated. These are pH, moisture content, porosity, and oxygen. C:N ratio is irrelevant to the process when the primary waste is institutional food waste because nitrogen is readily available and immediately released in food waste, while the carbon in wood chips and bark amendment takes longer to breakdown. Therefore the C:N ratio in a drum filled with food waste and a carbon amendment will always be effectively lower than lab analysis indicates. C:N ratio will, of course, effect the nutrient value of the end result -- compost. Locally available bark/sawdust from sawmill, and poultry litter cake was added to reduce moisture and improve porosity. Hydrated lime was added to control pH.

The Daily Process

The availability of labor at Brown Creek allowed Warden Rick Jackson to choose a manual mixing process over purchasing additional mixing equipment. Initially, a PATZ chopper was installed to chop the food prior to mixing. Use of the chopper was discontinued as it did not improve the consistency of the mix nor did it improve the process. The PATZ chopper is designed as a hay bale chopper, not a food-waste chopper. It proved to be noisy and allowed food to drop through the grid.

The Brown Creek staff devised amore effective method of mixing. A discarded 600-gallon cylindrical drum was recycled. The staff cut it longitudinally in half and welded wheels at the corners making it an efficient mobile mixing chamber. Food waste is trucked about ½ mile from the prison kitchens to the site in 35-gallon plastic bins. Additional 35-gallon bins are used to measure the amendment to achieve an accurate mix by volume. Two inmates mix the amendments and food manually with pitchforks. The mixing chamber is then wheeled next to the input screw conveyor, and the mix is transferred to the screw-conveyor hopper that loads the drum. At the other end of the drum, the three sliding-door exit ports unload pre-cured compost completing the continuous process. Residence time is 4 to 5 days. The volume of material removed is equivalent to approximately 75% of the daily intake. Allowing for volume reduction during the process, this keeps the same mass of material in the drum. Compost drops onto a belt conveyor and then into a dump truck. Curing is accomplished static piles.

Daily Operation

The original plan was to rotate the drum continuously. In doing this, however, we were not able to achieve the required temperature. As a result, we adopted an intermittent rotation routine running the drum only during loading and unloading or about 4 hours each day. This frequency of turning incorporates sufficient oxygen into the mix to achieve accelerated composting while preventing the mix from dropping in temperature. A ventilation port was added at the unloading end, which, after further trials, may allow us to discontinue use of the small blower currently in operation. The permanent solution will either be the ventilation port or a combination of the port and a blower.

Prison food waste includes a high percentage of cooked material -- much higher than other types of institutional food waste, and less food is discarded for aesthetic reasons. Fermentation starts immediately when most cooked food waste is placed in a garbage bin. A dramatic drop in pH results, often causing pH readings of less than 3. Fermentation microbes eliminate aerobic microbes in these highly acidic conditions. The addition of hydrated lime during mixing with a porous amendment prior to loading limited the drop in pH to about 5.5, as would normally be expected during the initial stages of aerobic decomposition. It is also possible that fermentation microbes, which are mostly single cell organisms, survived more easily than the more complex aerobic microbes and fungi, in a continuously rotating drum. This contributed to our decision to run the drum intermittently.

Initially the weight of food waste composted was limited to 900 lbs. per day plus amendment; the maximum daily loading rate, recommended by Texas A&M University. As the problems resulting from low drum temperatures were resolved, the daily loading rate was increased to include all of the food waste from the kitchens, plus paper towels. The full amount of waste averaged 1615 lbs. of food and 12 lbs. of towels that were mixed with amendment and loaded each day.

Laboratory analysis by Prism Laboratories, Inc. showed no evidence of pathogens. A series of analysis conducted by NCDA Agronomic Division and A&L Laboratories, Inc. of Richmond, VA characterized the waste, amendment, and compost.

Blending Materials to Desired Moisture Content

To produce compost from food waste, an amendment material is essential. This amendment adds structure (porosity) and absorbs moisture in order to reduce the moisture content to 55% plus or minus about 5%. A sawmill about 3 miles from Brown Creek was a source of suitable amendment material -- bark chips. This proved to be an excellent source for porosity, but because it was “green” the moisture content was higher than desirable for food waste, which starts out as approximately 80 percent moisture. From trials completed at two Texas prisons, we determined the best mix for composting institutional food waste, assuming an abundance of dry amendment, is as follows:

By Volume:
2 part wood chips
1 part sawdust
2 part food waste

Initial Mix Calculation:

The target moisture content for blend of food waste and amendment is 55% moisture.

Assumptions:
weight of water = total weight x moisture content
weight of dry matter = total weight – weight of water

1 pound of mixed food waste contains:

water	1 pound x 0.77	= 0.77 pounds
dry matter	1 pound – 0.77	= 0.23 pounds

1 pound of mixed amendment contains:

water	1 pound x 0.20	= 0.20 pounds
dry matter	1 pound x 0.80	= 0.80 pounds

Formulae:

$$\text{Moisture Content (MC)} = \frac{\text{weight of water in food + weight of water in amendment}}{\text{Total weight}}$$

$$55\% = MC = 0.55 = \frac{0.77 + (0.20 \times A)}{1 + A}$$

Where A is the weight of amendment required:

$$0.55\,(1 + A) = 0.77 + 0.2A$$

$$\mathbf{A = 0.63}$$

Therefore, by weight, 0.63 pounds of amendment is needed for every 1 pound of food,

BUT the mix is achieved by volume not by weight:

Ratio of volume to weight of food waste to amendment is:

270 : 60 = 4.5 : 1

Therefore mix ratio by volume is:

1 : 0.63 x 4.5 = 2.835

1 part food waste : 3 amendment (approximately) by volume

In reality, experience with the locally available amendment will determine the mix to achieve the correct moisture content. At this moisture percentage, leachate will not be released. If the mix is too wet, leachate can be collected in a container situated in the unloading hopper. Variations in food waste would need a waste audit to define. The greatest variable is moisture content, which can vary from very wet --- in excess of 85% moisture, to relatively dry – 65% moisture. As the staff and inmates gained experience, variations in moisture content were countered by adding amendment in the same proportion as the general mix. The practical field-test for moisture content remains the best; hand squeeze after the waste and amendment has been mixed. Experience will lead to appropriate action.

For Brown Creek, a second amendment source of poultry litter with a low moisture content and potentially good porosity properties was located. The final mix was adjusted to the following:

By Volume:
1 part food waste
1.5 parts poultry litter (used to reduce the moisture content)
1.5 parts (green) wood bark (for porosity)

Note: Also 15 lb. per cubic yard of hydrated lime to control the pH

Unanticipated Situations

A design change intended to reduce the time spent loading the drum by fitting a U-trough screw conveyor compounded difficulties producing the ideal mix. A new U-trough conveyor allowed for a reduction in the size of the access port, increasing the usable capacity of the system. This helped achieve two objectives; faster loading and greater capacity. Excellent! However, the new U-trough conveyor caused a reduction in air entering the drum, which was a more significant factor than expected producing an oxygen deficiency within the drum. This, in effect, caused the microbes to be smothered, which in hindsight, should have been detected sooner. When a smaller Type 408 GREENDRUM was used to test the mix, the extent of the oxygen deficiency became clear.

The simple solution took months of trials to uncover because there were multiple solution options. Initially, the basics of composting were addressed:

a. Moisture content
b. C:N ratio

Note: 1. Reasonable values of these two characteristics were quickly established. Since the desired temperatures were not achieved immediately, time was lost varying the moisture content in an attempt to produce higher temperatures.

2. The analyzed C:N ratio for the mix, at approx. 35:1, was reasonable but not likely to promote a highly active composting process. We believe our effective C:N ratio was lower as the nitrogen in the food waste was much more available than the carbon in our amendment. Having exhausted combinations of the above, we concentrated on the following:

c. pH
d. ammonia
e. oxygen

Daily variations in food waste complicate the problem. The key to solving the mix equation at Brown Creek was use of the portable 408 GREENDRUM. Unworkable mixes were quickly eliminated and small batches were used to refine the mix for maximum composting efficiency. The portable unit allows each site's waste to be tested quickly with the available amendment to ensure that a full-scale system will operate efficiently.

Things I would consider doing differently

The 616 GREENDRUM design has been changed to include a heavy-duty frame mount. It is now considered too heavy to be supported on a trailer. The absence of the trailer allows the drum to be lower on the pad, which makes it easier to load. Future GREENDRUM installations of type 616 or larger should be ordered without the trailer.

Productivity, working conditions, and the efficiency of the labor/system combination were examined. Actual situations should be observed. For example, when the time to mix a batch is measured, the circumstances and the labor resources should be taken into consideration. The Brown Creek project was planned as a morning activity allowing adequate time to complete each mix in 30 minutes. Several things here could alter productivity. These include a covered paved working area and paid non-inmate labor. Notwithstanding their circumstances, the inmate workers had an excellent attitude, were interested and took some pride in this project.
The PATZ chopper added time to the process without providing any tangible improvement in efficiency. The consistency of food waste delivered to the site meant it is not necessary to employ a chopper to prepare prison food waste for composting; an aesthetically pleasing product is produced without the use of a chopper. BW Organics has designed a chopper/mixer to work with this system; a low cost smaller capacity unit has not been found currently on the market. A mixer cuts preparation time before loading and would likely reduce total handling time by half.

Waste reduction impact

The following table shows the actual daily loading rates and the total tons of food waste diverted. During the first four months the daily the loading rate was limited to the expected maximum daily capacity of the GREENDRUM 616. The drum was not loaded on a regular routine as various trials were conducted. During the second half of the trial all the available food waste was loaded:

Month	Daily Loading Rate, lb./day	Monthly Total, Tons
July	896	5.8
August	955	6.7
September	954	11.0
October	973	1.9
November	1633	24.5
December	1727	25.1
January (thru 24th)	1486	17.8
TOTAL		92.8

Using the figures for the months when the GREENDRUM was working at full capacity, the average daily loading rate was 1615 lb., giving a projected annual diversion of 295 tons of food waste plus, 2 tons of paper napkins for a total of **297 tons annually**.

Considering only waste disposal cost, annual savings are $10,395.00. Not including the capital cost, operating costs projected over one year including lime, labor, electrical power, and amendment are $ 2,675.00 annually. The positive balance is $ 7,719.00.

Brown Creek will produce approximately 1,000 cubic yards of compost annually. In Charlotte, 50 miles to the west, this has a market value of about $ 20,000.00 when sold in bulk.

Changes at Brown Creek.

Food Preparation

The quantity of food wasted each day prompted Warden Rick Jackson and the Food Service Department to investigate. Two primary factors were uncovered. Often, more food than required is prepared. No procedure is in place to feed this excess food to inmates. The waste food becomes a disposal cost as it is currently going into the garbage bins. Also, for security reasons, there is no method for inmates to communicate with the servers, who fill the food trays in the kitchen. Currently, each tray is filled with an entire meal and then slid under the hatch. Brown Creek Enterprise Division is building a security screen through which the inmates will be able to request items be omitted from their tray, thus reducing wastage. Rick Jackson intends to further review the quantity of food prepared for each meal.

Project accomplishments

The GREENDRUM in-vessel system, with a delivered, set-up, and running price of less than $50,000 hands on average 1615 lbs. of food waste plus amendment every day seven days a week. If the prison system could market this waste stream as they do other recyclables, the combined cost savings plus income would come to about $25,000.

The Greendrum in-vessel composting process ensures that the health and environmental requirements set forth by the NC Solid Waste Composting Rules are satisfied. The system proved simple to operate and reliable technology that could easily be transferred to other institutions in NC where similar cost savings are possible.

Quality compost is available for Brown Creek's use on grounds and vegetable gardens. Surplus compost is available for use by other North Carolina State agencies.