Composting Paunch Manure with Solid Cattle Manure

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FINAL REPORT
Date:
December 2004

Ridgetown College
UNIVERSITY of GUELPH
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Introduction

Paunch manure, the contents of the rumen of cattle at slaughter, has been largely landfilled in Ontario in recent years. Very few other options have been available for dealing with this material. With the increased costs of landfilling and with pressure to divert materials from landfills, it is important to find alternative means of disposal or use. Because paunch manure has characteristics similar to livestock manure, it should be an ideal material for composting.

Previous studies have looked at both anaerobic digestion and composting as means of processing paunch manure. Composting can be a practical, environmentally friendly method to handle this material. Composting offers several environmental benefits. Typically, compost represents an excellent source of nutrients for plant growth, it is free of pathogens and weed seeds and it is free of offensive odours. A trial was carried out in 2004 at Ridgetown College, University of Guelph, to assess the potential to compost paunch manure in a farm scale in-vessel composter. Paunch manure was mixed with solid cattle manure and composted. The composting system is covered and has forced aeration and mechanical turning.

Literature Review

Research has been carried out at Olds College, Alberta, on composting paunch manure (Chaw 1997). The system consisted of open windrows. One focus of this research was to monitor the amount of leachate formed. The following recipe was used:

3 parts paunch manure
1 part pen cleaning manure
2 parts wood shavings
1 part switches

Two windrows were formed initially. After one month, they were combined. The tails and ears caused the windrow turner to seize, and were therefore removed. The temperature, oxygen levels and moisture content inside the windrows were measured during the trial. Testing showed that the optimal moisture content was between 50 and 60%. Too much moisture inhibited the microbial activity. However, high moisture rates did not necessarily produce leachate, perhaps because of the high absorbency of the sawdust. During the process of composting, no malodours were observed, and the final product did not have an offensive smell (Chaw 1997).

A study at Ridgetown College, University of Guelph looked at the potential to compost liquid hog manure using various carbon sources (Fleming and MacAlpine 2002). Test materials included wheat straw, corn cobs, corn stover, tree leaves, shredded slab wood, paper mill sludge and shredded tree limbs. This project proved to be quite successful, producing a nutrient-rich compost that was odour-free and pathogen-free, with a reduced volume and mass.

Various studies have been performed on the composting of livestock mortalities. Composting in static piles is now an accepted option for disposing of whole carcasses in many jurisdictions (Fleming et al 2003).

Objectives

A study was carried out at Ridgetown College, University of Guelph in 2004 to assess the following:

1. the ability to compost paunch manure in combination with solid cattle manure
2. the potential for composting to produce a stable organic fertilizer
3. the potential for composting to provide an environmentally friendly alternative for handling paunch manure - by eliminating odours and destroying pathogens

Project Setup

Composter

The study was run as a single batch in a single channel in the Ridgetown College composter. The in-vessel, forced aeration composter is covered to exclude all precipitation and consists of three adjacent channels. Each channel is 2.2 m wide, 1.8 m deep and 15.2 m long. The walls separating the three channels are of reinforced concrete. The compost turner is a prototype - the MARVEL, built by Global Earth Products, Utopia, Ontario. The turner is hydraulically operated, powered by a 15 kW electric motor driving a hydraulic pump. This powers a 15 kW hydraulic motor to operate the apron and also powers the hydraulic cylinders needed to lift the apron. A 2.25 kW electric motor drives a second hydraulic pump that powers four hydraulic motors operating the drive wheels. The control panel includes a PLC controller to operate the turner. The turner travels down each channel on steel tracks and can be moved from one channel to the next at one end on a steel transfer cart.

One aeration fan is provided for each of the three channels. The fans are Airstream Inline Centrifugal Fans (Model # ILC-318, 2.25 kW electric). They are rated at 1650 L/sec at a static pressure of 100 mm. The fans force outside air through a transition plenum to two 250 mm PVC pipes and then to the individual aeration floors. In each of these ducts is a pressure transducer (Omega Canada Inc., model PX154-025D1). These three devices are connected to the data-logger and record the static pressures.

The channel used for this study has a concrete floor with a central concrete plenum 200 mm wide and 150 mm deep. This plenum is covered by a metal plate with regularly spaced holes to allow air to enter the compost in the center of the channel. Temperatures in the channel are measured using up to six thermocouples (shielded thermocouple cable type T 24-AWG), connected to a data-logger (Campbell Scientific CR10). Thermocouples are also set up to measure outside air temperatures and the temperature of air inside the building.

The data logger reads the temperatures and operates the aeration fans. A base level of aeration is maintained (three minutes on in each hour) until any one of the thermocouples in a channel exceeds 66^{o} C. Then a second level of aeration is initiated - i.e. two minutes on for every 10 minutes, until the temperature drops below 60^{o} C. This helps prevent excessive heating and maintains aerobic conditions within the channel. The data logger also monitors times of the fan operation and static pressure as well as several other parameters.

Unlike many commercial systems, this is operated as a batch system. This was chosen to allow the flexibility to experiment with turning frequencies, etc. and to develop the best recipe without having to regularly remove small amounts of "finished" compost. For an on-farm system, it offers the advantage of dealing with an entire batch every few weeks rather than having to deal with relatively small amounts every day or two.

Compost Blend

A mix of paunch manure and solid cattle manure was selected. There were three reasons for choosing this mix: a) it was somewhat similar to the recipe tested in the Olds study; b) the straw in the manure provided a way to bulk up the compost, thus allowing for better aeration within the pile; and c) it was deemed to reflect the most likely mix to be used in the future, based on materials available. A more comprehensive study of several other blends was considered but was not performed due to budget restrictions.

The paunch manure originated at Better Beef, Guelph, a beef slaughtering facility. The material was partially de-watered before being loaded onto a Blaemar Ltd truck for delivery to the composter, on June 9, 2004. The paunch manure was immediately blended with solid beef manure at a ratio of:

3 parts paunch manure, to
1 part solid cattle manure (by volume).

This was equal to a ratio of about four to one, by weight. The mixture was placed in the composter channel using a tractor and front end loader - i.e. three buckets of paunch manure to one bucket of solid beef manure. Once the channel was filled, the compost turner mixed the ingredients, producing a relatively uniform blend.

Data Collection, Sampling and Analysis

The raw materials (paunch manure and solid beef manure) and the compost at various stages were tested for certain physical characteristics and for levels of a variety of nutrients and bacteria. The samples were tested for: N, P, K, NH_4-N, NO_3-N, Total Carbon, Organic Carbon, Inorganic Carbon, Ash, pH, % Dry Matter, *E. coli* and *Salmonella*. Initial samples and compost samples were taken on the following days:

June 9, 2004	Day 0	(both raw materials)
July 7	Day 28	(at 4 weeks)
July 29	Day 50	(at approx. 7 weeks)

August 25 Day 77 (at 11 weeks)
September 22 Day 105 (at 15 weeks)

The final volume and bulk density measurements were made on Day 117 (more than 16 weeks since beginning the study).

Each time, two representative composite samples were taken using sanitized equipment and placed in sterile plastic bags for delivery to the lab. Delivery was made the same day in a cooler chilled to about 4^{o} C.

Volumes of the raw materials, the initial volume in the composting vessel and volumes throughout the study period were measured, to track the volume reduction. The bulk densities of the raw materials were measured and bulk densities were taken throughout the study period to help track changes in the compost mass. Bulk densities were measured by first placing the material into a plastic pail. The pail was then dropped twice from “waist” height, in order to pack the material. Mass and volume were then measured.

As mentioned earlier, temperatures were measured constantly during the in-vessel treatment (June 9, 2004 to July 12, 2004) using up to six thermocouples connected to a data logger. Ventilation rates, static pressure and times of fan operation were also recorded during this in-vessel stage. When compost was removed to a curing stack, the temperature was measured at regular intervals using an analog compost temperature probe - until the study was completed on September 22, 2004.

Odours were monitored and assessed subjectively to rate the odour offensiveness and to estimate the effectiveness of composting at reducing or eliminating odours. Odours of the raw materials were assessed as well as the composting paunch and beef manure. Assessment was based on intensity and character. This was done during each visit to the compost building, during turning as well as during curing. The character descriptors were those used by the wastewater treatment industry - shown in Figure 1.

Sample Analysis

Samples were delivered to the Laboratory Services Division and the Food Microbiology Lab, University of Guelph, on the day of sampling. Between the time of sampling and delivery, samples were stored in a refrigerated cooler (at approximately 4^{o}C). As mentioned, all samples were tested for *Salmonella* and *E. coli*, as well as N, P, K, NH_4-N, NO_3-N, Total Carbon, Organic Carbon, Inorganic Carbon, Ash, Dry Matter, and pH. The following is a brief description of the test procedures:

- Dry Matter: samples weighed wet, dried in 80^{o}C oven for 24h, weighed dry, dry matter calculated
- K: modified Kjeldahl digestion, digestate analyzed by atomic absorption
- N: modified Kjeldahl digestion, digestate analyzed using colorimetric method
- NH_4-N: KCl extraction, extract analyzed using colorimetric method
- P: modified Kjeldahl digestion, digestate analyzed using colorimetric analysis
- pH: saturated paste method using pH electrode
- NO_3-N: KCl extraction, extract analyzed using colorimetric method

- LOI (% Ash): muffle furnace at 480^{o} C, before and after weights taken

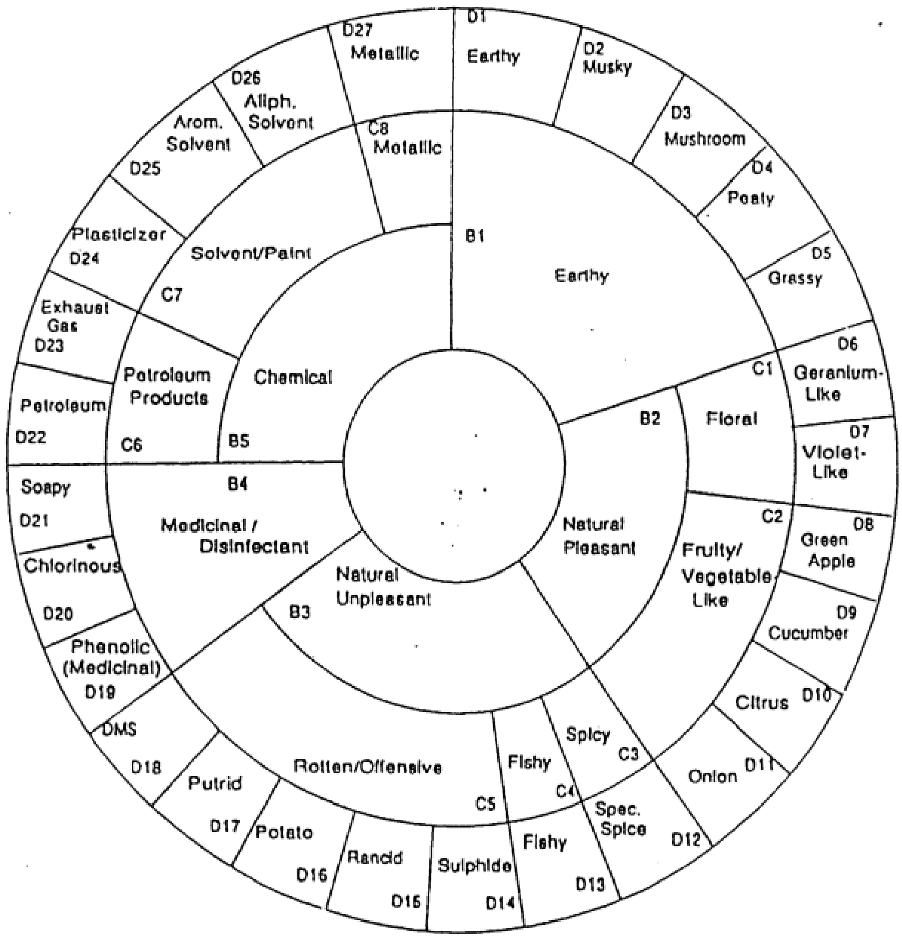

Figure 2 Odour character descriptors used by the wastewater treatment industry

- Total C, Inorganic C, Organic C: combustion method (Leco C analyzer)

The *Salmonella* test involved a “presence/absence” screening step. The method used was the Health Protection Branch (Health Canada) method MFHPB-20, April 1998 - “Isolation and Identification of Salmonella from Foods”. Only those samples testing positive were examined further. The next step for the positives was an enumeration using a “Most Probable Number” (MPN) analysis. This test was the Laboratory Services Division Method MID-149 - Most Probable Number Method for the Enumeration of Salmonella in Poultry - Revision No. 0 (2001/01/31).

E. coli numbers were measured using Laboratory Services Division Method MID-104 - Enumeration of Coliforms and *Escherichia coli* using the Most Probable Number Method - Revision No. 1 (98/09/01). Samples were prepared using the procedures designed to measure *E. coli* in compost samples.

Results and Discussion

Mass and Volume

The changes in mass and volume of the compost between initial and final values (at Day 117) are shown in Table 1. Final mass was estimated using the bulk density, which was measured as described earlier. Using this method, the final mass of compost represented 38.6% of the starting mass, which is in line with values measured for manure composting. Typically most of the loss of mass during composting is represented by a loss of both water and carbon (i.e. as carbon dioxide).

The final volume was reduced to 25% of the initial volume, which is also a typical value. The bulk density of the paunch manure at the start of the study was 795 kg/m^3 (the cattle manure was less dense). At Day 117, the compost had a bulk density of 780 kg/m^3.

Table 1 - Changes in Mass and Volume between start and end of study

	Mass (kg)	Volume (m^3)
Initial (at Day 0)	17,188	35
Final (at Day 117)	6630	8.5
Final, as % of Initial	38.6	24

Nutrients

Tables 2 and 3 summarize the results of the nutrient sampling. Both tables show changes in concentrations over time. Table 2 reports the concentrations on a "dry weight" basis. Table 3 gives corresponding values of selected parameters on a "wet weight" or "as is" basis, which many find more familiar. These numbers were used, along with the mass numbers reported earlier, to calculate a nutrient balance for the process. Unfortunately, the results of this analysis pointed out inaccuracies in the procedure. It showed overall decreases in nutrients but on a scale that was much higher than expected. In other areas it showed net increases, which were not physically possible.

An alternate approach was attempted. It was based on the conservation of ash - the assumption that the total amount of ash was a constant - there should not be losses or gains of ash, only organic matter and water. Assuming the initial mass of materials was representative, the conservation of ash approach still did not yield reasonable results. It showed a net gain in the mass of most nutrients. A refinement of this approach using the total ash based on the Day 28 sampling (where the material would be more homogeneous) still did not adequately address the nutrient balance issues. Future studies will need to either include more samples (to reduce the variability) or to accurately measure the mass of at least all inputs. The variability is, of course, the greatest at the start of the process. The more the material is mixed, the more uniform it becomes.

Table 2 - Average nutrient concentrations of raw materials and compost - dry weight basis - based on 2 composite samples for each sampling time

Material	NH_4-N mg/kg Dry Weight	NO_3-N mg/kg Dry Weight	% N Dry Weight	% P Dry Weight	% K Dry Weight	Dry Matter %	% Ash Dry Weight	pH	% C Dry Weight	C:N ratio by weight
Raw Materials										
Paunch Manure	1908	9.36	2.03	0.60	0.43	19.5	93.5	5.2	46.2	22.7
Solid Cattle Manure	2235	7.98	2.74	0.72	1.98	29.6	88.7	8.4	43.9	16.5
Compost										
July 7	2112	9.51	2.30	0.91	0.87	24.9	89.8	8.6	42.6	18.6
July 28	2777	10.78	2.57	1.36	1.32	23.8	83.4	8.3	40.6	15.8
Aug 25	564	2.16	2.63	1.15	1.43	32.8	75.0	8.8	36.5	13.9
Sept 22	784	3.02	2.61	0.96	1.18	30.1	79.8	8.9	41.9	16.3

Table 3 - Averages of selected nutrient concentrations of raw materials and compost - wet weight basis

Material	**NH_4-N mg/kg Wet Weight**	**% N Wet Weight**	**% P Wet Weight**	**% K Wet Weight**	**Dry Matter %**
Raw Materials					
Paunch Manure	368	0.40	0.12	0.08	19.5
Solid Cattle Manure	666	0.81	0.21	0.59	29.6
Compost					
July 7	529	0.57	0.23	0.22	24.9
July 28	662	0.61	0.33	0.31	23.8
Aug 25	184	0.87	0.37	0.47	32.8
Sept 22	236	0.78	0.29	0.35	30.1

Bacteria

The results from the bacteria testing:

- Initial levels of *E. coli* in the two samples of paunch manure were 1.49×10^4 and 4.27×10^5 MPN/g.
- Initial levels of *E. coli* in the two samples of solid cattle manure were 9.33×10^4 and 4.27×10^5 MPN/g.
- All subsequent samples for *E. coli* indicated levels below detection limits (i.e. <3.0 MPN/g for the samples in question) except for the two samples on August 25, when *E. coli* was measured as 2.3 and 0.36 MPN/g.
- *Salmonella* was not detected in the cattle manure but one sample of the paunch manure tested positive with 14.9 MPN/g.
- All subsequent samples for *Salmonella* tested negative.

It appeared that the high temperatures reached during the composting process were effective in killing these bacteria. At least in parts of the pile, temperatures reached 70 ^{o} C or more within 24 hours and remained above 55^o C until August 5, 57 days later. This far exceeds the composting guidelines of 55^o C for 3 days needed to ensure pathogen die off.

Odours

The in-vessel composter used for this study is located within 120 metres of a residential area. Because of the proximity to homes, no compost trials are considered to be totally successful if there are detectable offensive odours from the process.

The compost was continuously monitored for odour throughout the study period. Either one or two people specifically made observations of odour intensity and character in and near the composter (human nose method).

When the paunch manure arrived, it was fairly “fresh” - i.e. it arrived directly from the packing plant. It was light yellow/brown in colour, and contained recognizable quantities of whole corn, straw and hay. It was moist, with a small amount of leachate draining from it. Upon delivery, the paunch manure smelled similar to silage or fermenting grain. The odour was slightly sweet in character. There was also a slight odour that was similar to that of cattle manure. In all, however, there was surprisingly little odour and it was not offensive.

The solid cattle manure had an odour typical of solid manure - described as “natural/unpleasant”. This manure was bedded with straw and was quite dry.

When the materials were initially combined in the channel, no odour could be detected outside the compost building. Once the channel was initially filled, there was a small amount of solid cattle manure left over. It was placed in the west end of the channel. After the first day of composting, noticeable odours (“natural/offensive”), emanated from the small area containing the high concentration of solid cattle manure. These could only be detected a few metres from the composter. The remainder of the channel had virtually no odour. The aeration was turned on for 5 hours to ensure that the compost was aerobic. The compost turner was run on the third day to help maintain aerobic conditions.

By Day 6, no odours were detectable inside or outside the compost building. When the compost was turned, large amounts of vapour were released (due to the high temperatures). There appeared to be some odour associated with this vapour release. This odour was similar to that of silage. It dissipated quickly, but on one occasion could be detected up to 100 metres away. These odours would be considered non-offensive in a rural setting but would be a concern in an urban setting. Odours declined over time and, with the exception noted, were not detectable outside the compost building during virtually the entire testing period.

When the compost was removed from the channel and placed in a curing stack, odours were non-detectable. At Day 105, the compost had an earthy smell, typical of other composts.

The system has the potential to release odours, at least during turning. For the most part, odours would be less offensive than a typical manure storage facility. They would be more in line with a farm composting operation where manure is composted - with a slight silage odour given off at times.

Aeration

The aeration rate for the in-vessel composter was set at three minutes per hour when the temperature of the compost did not exceed 66^{o} C. Once the compost exceeded 66^{o} C for one thermocouple and then did not fall below 60^{o} C, the aeration rate was set at two minutes on for every ten minutes. This gave an aeration rate of 12 minutes on per hour, to help cool the compost and keep it aerobic. During this study, the high aeration rate started within 24 hours of the startup and continued until the compost was removed from the channel. In other words, at least one of the thermocouples was reading above 66^{o} C for the almost entire time the compost was in the channel.

Turning Frequency

During previous manure compost studies, the compost was turned three times in a two-week period and then removed from the channel after 14 days. With the paunch manure, turning frequency was based on maintaining aerobic conditions, on odour control and on temperature control. The compost was turned a total of seven times: on Days 3, 7, 10, 14, 21, 24, and 28. The turning also helped mix the materials being composted, making it more homogeneous.

Curing

After 33 days in the channel, the compost was removed and stacked (open pile) for curing. It was left in the stack for an additional 72 days. During this period the compost was not turned, but was monitored for odours, nutrient levels, bacteria levels, volume, bulk density and appearance.

At the end of the study period, temperatures were still close to 40^{o} C (higher than the ambient temperature), indicating that the compost was not yet completely stabilized. The compost also had small areas that did not have the dark brown colour typical of finished compost. It appeared that the compost could have benefitted from turning (e.g. in a windrow) to further mixing and to speed up the process.

Temperatures

Temperatures were monitored using six thermocouples connected to a Campbell Scientific CR10 data logger while in the in-vessel composter. Once the material was removed and stacked, temperatures were monitored using a compost temperature probe.

The compost reached maximum temperatures of 70^{o} C within 24 hours and remained high while in the composter. At times the maximum temperatures recorded approached 80^{o} C.

Figure 3 gives a record of compost temperatures for four of the thermocouples. Two were located in the middle of the channel. These started off with temperatures of 50^{o} C to 77^{o} C. The temperatures declined after day 14 and values approached ambient temperatures by day 28. Two thermocouples were at the east end of the channel. These remained relatively low, in the 40^{o} C to 55^{o} C range, for the first 7 days. Temperatures then increased. The other two thermocouples are not shown, since they were not always in the compost (i.e. because the channel was not completely filled, the cables for TC 1 and TC 2 could not always extend far enough to reach the compost pile.

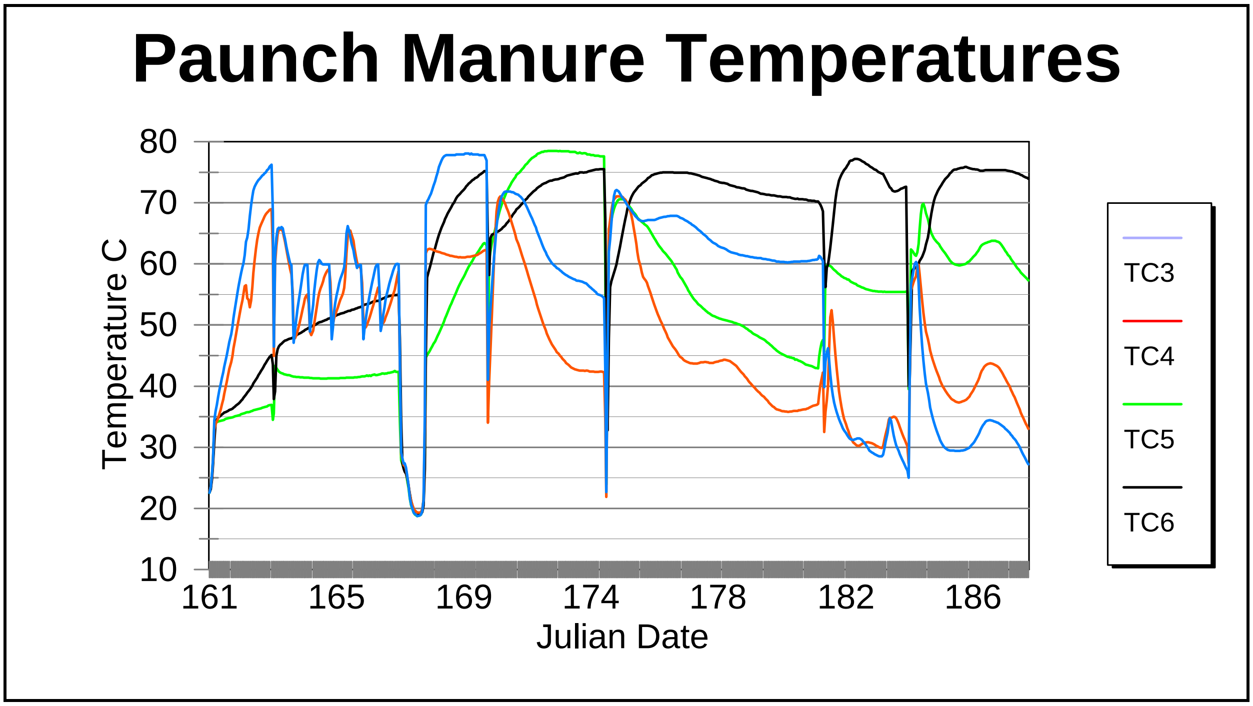

Figure 3 Four thermocouple temperatures (°C). The vessel was filled June 9 and compost turned June 11, 15, 18, 22, 29, July 2 and 6. Note temperature drops when probes were removed for turning, followed by spikes after turning.

Summary

In this study, a mixture of paunch manure and solid cattle manure was composted in a single batch in an in-vessel composting system. After about four weeks in the channel, the compost was moved to a static pile to continue composting and "curing". The study revealed the following:

1. A mixture of paunch manure and solid cattle manure was an excellent input for a composting system.
2. Composting of paunch manure can provide an environmentally friendly alternative to landfilling.
3. Composting paunch manure with cattle manure was effective in reducing pathogens to below detectable levels. The compost operation produced temperatures in excess of 55° C for more than 3 days, thus effectively killing pathogens. While there was variability in the temperatures, parts of the compost mass remained over 70° C for the entire time period in the channel and at least part remained above 55° C for 57 days while curing in a stack.
4. Composting paunch manure with cattle manure produced a nutrient-rich organic compost.

5. Composting these materials proved to be an effective way to reduce or eliminate odours.
6. The compost was turned 7 times in the 33 days it was in the channel. Once removed from the channel it was left in a stack for the remainder of time. When the compost was inspected at the end of the study it appeared the curing compost would have benefitted from being turned in a windrow to help it cure.

Testing for heavy metals in the finished compost should be done to make sure it meets composting guidelines. This was not part of the study, however. All other requirements are met with this compost including adequate temperatures to ensure pathogen die off. The finished compost appears to be an excellent product suitable for use as a household compost, landscaping, golf courses etc or application to farm land.

Only one mix was tested in this study. This represented one recipe possibility out of many. Judging by the nutrient analysis of the paunch manure, it may seem reasonable to assume that the paunch manure may have composted without the addition of cattle manure. The consistency was fine enough, however, that it appeared to benefit from being mixed with a more bulky material - thus aiding in aeration. Other materials could may have worked as well or better. The choice of materials will need to fit the raw materials on hand.

Acknowledgments

The authors would like to acknowledge the contributions to the study from:

- Blake Fisher, Blaemar Ltd., for funding the laboratory costs and supplying the paunch manure.
- the Ontario Ministry of Agriculture and Food and the University of Guelph for funding and overhead costs.

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