On-Farm Composting of Cattle Mortalities

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Introduction

Livestock mortalities are a fact of life for livestock producers. In the past few years, the industry has seen changes in what are considered to be acceptable solutions for carcass disposal. BSE cases in North America have effectively closed the market for rendered meat products. In a survey of Ontario producers conducted by Fleming et al. (2003), several farmers reported that the cost of sending a carcass off the farm quadrupled after May of 2003, when BSE was found in an animal in Canada. The study included 316 producers, of which 92 were beef producers. Eleven of the beef farmers used composting, though mostly for small animals. The number relying on burial was 39%, while 67% used licensed dead stock services. Of course, several farmers used more than one method of disposal. Interest in composting was higher in poultry and swine (41% and 37% respectively) than in dairy and beef.

Currently in Ontario, regulations under the Dead Animal Disposal Act govern the disposal of livestock mortalities. If and when the current standards are reviewed, one potential impact on livestock producers may be to tighten up standards on burial, since this practice has the greatest potential to impact the environment (Freedman and Fleming, 2003). Composting may emerge as the preferred option in the near future.

Carcass composting is less capital intensive than incineration and rendering, a better alternative to burial in areas with shallow water tables, and provides for quick removal and isolation of farm mortalities (Kalbasi et al., 2005). The process begins with an initial heating phase characterized by high oxygen consumption, thermophilic temperatures (55^{o}C), rapid reductions in bio-degradable volatile solids, and odour potential. This is followed by a phase where temperatures are not as high, reactions are slower and aeration is no longer a limiting factor. Bacteria flourish in the early stages, and fungi and actinomycetes become more important near the end (Kalbasi et al., 2005).

For the most part, the interest in composting has been in either of two areas: a) what to do with routine livestock mortalities; and b) what to do when a disease outbreak or other catastrophic loss occurs and large numbers of carcasses must be dealt with at one time. For disease-related carcass composting, special considerations apply. The composting process should produce high temperatures to help reduce pathogen numbers. The compost mass must be able to retain liquids, minimizing the release of contaminated leachate. In addition, turning of the compost should be avoided to reduce risks of air-borne contaminant release (Glanville et al., 2006; Goldstein, 2004).

Glanville et al. (2006) found that turkey litter, corn silage, oat straw, and alfalfa hay were all suitable materials for composting where disease control was important. They also found that ground cornstalks, wood shavings, sawdust and soybean straw were suitable materials for composting routine mortalities or any other not caused by disease. Other researchers have found the following additional materials to also be appropriate for the composting of mortalities: poultry litter, ground corncobs, semi-dried screened manure, paper, leaves, peat, rice and peanut hulls, cotton gin trash, low nitrogen yard wastes, vermiculite, spent horse bedding, tree trimmings and a variety of waste materials like matured compost (Kalbasi et al., 2005).

Carcass composting options include windrow composting, bin composting, mechanized carcass composting, grinding and mixing, rotating vessels and aerated synthetic tubes. Bin composting allows higher stacking, better use of floor space, elimination of weather problems when a roof is used, containment of odours, and better temperature control than windrows. In emergency situations, however, windrows are preferred to bins (Kalbasi et al., 2005).

For Ontario livestock farms, Koebel et al. (2003) recommend starting with a base of substrate that is 0.6 m deep. A layer of mortalities should then be placed on this base, staying at least 0.3 m from the edges of the bin. This is followed with at least 0.6 m of substrate, to top off the bin. The bin is left to sit for up to six months, depending on carcass size, then should be mixed. It may take a year to completely compost a 200 kg carcass. Koebel et al. (2003) also caution that if a mortality is frozen (e.g. during winter months), it should be thawed before placing in the composting bin.

While some proponents have found benefits in opening up the body cavity (e.g. Cody 2002), others prefer to keep the process as simple as possible and add carcasses whole (Koebel et al., 2003).

Objectives

Given that composting of cattle mortalities was not widely used in Ontario and that it potentially offered advantages to other disposal methods, the following objectives were adopted:

1. To determine the efficiency and suitability of using sawdust, corn silage and solid manure (three readily-available materials) as media for composting cattle mortalities, in an on-farm study.
2. To determine costs of carcass composting and compare these to other methods of carcass disposal.
3. To document management practices associated with successful carcass composting on operating beef feedlots.

Description of Study

Farm Location

The cattle mortalities were composted at two beef cattle feedlots in southwestern Ontario, near Sarnia. The mortalities originated on the farms in question, representing “normal” livestock deaths. These beef feedlots were in the size range of 1000 to 1500 finishing cattle. The livestock producers agreed to compost all of their mortalities as they occurred. Composting would include a variety of substrate materials, including materials readily available on the farm. Compost bins would be built using farm materials.

Experimental Design

The intent was to monitor up to 12 compost bins (i.e. six per farm). This would depend on the actual rate of mortalities. Each bin would contain two carcasses. Each bin would be left to sit for six months, then mixed and left for a further six months. At the 12 month mark, the material would be examined again, to ensure the composting process truly was finished. A protocol for carrying out the project was designed, in the hopes that the farm operators would be able to follow it fairly closely. However, there was an understanding that practical considerations at each farm (e.g. availability of substrate, convenience of timing of animal death, weather conditions, etc.) would require a certain amount of flexibility in the ongoing management of the compost bins. This would still yield useful information, as it is the farmers who ultimately must embrace the system to ensure its success.

At least three substrate materials would be evaluated: sawdust, corn silage and solid manure (containing straw). Sawdust was selected due to its popularity in past composting projects. It represented a material with a proven record of performance, but with a higher price than the alternatives. Corn silage is readily available on most feedlot operations in Ontario. This availability and the desirable nutrient characteristics make it an appropriate choice. Solid manure is readily available on most feedlots. The manure at the feedlots in the study contained straw as a bedding material.

Composting Bins

The composting was located in an area that was not highly visible from off the property. The land had a slight slope to avoid any ponding of surface water in the area. Construction of each compost bin (six in total per site) began by constructing walls of wheat straw or bean straw bales. Bins were constructed by the farmers when time permitted, but preferably and in most cases when the animal died and before it had either frozen or started to decay.

The bins walls consisted of large square bales measuring typically 76 cm by 120 cm by 250 cm, stacked two high. This gave a bin size of approximately 150 cm deep by 240 cm by 240 cm. The holding capacity of each bin was therefore approximately 8.6 m^3, deemed to be appropriate for composting two cattle carcasses. As more animals died, additional bins were constructed. Not all bins were of these exact dimensions, nor were there always just two carcasses placed in each bin. As each new bin was constructed a different substrate was used. Bins were typically adjacent so there was a common wall between bins.

A base of substrate material (one selected per pile – sawdust, corn silage, manure, wheat straw) was then laid down (30 to 60 cm depth). Each carcass was placed on top of the base, on its side. A 10 to 15 cm thick layer of substrate was then placed over the carcass. When the second carcass was available, it was placed on top, and a final 60 cm layer of substrate was placed on top. The final compost pile was approximately 1.8 meters deep and the design loading rate was 150 kg of animal/m^3 of compost mixture.

When compost turning occurred at the six-month stage, it was done in the original bin (i.e. not moved from one bin to another). Turning was done by the farmer using a loader tractor or pay-loader. The compost was mixed either by lifting and rolling the material together, or by removing the compost from the bin and then placing it back into the bin. Once the compost was well-mixed and placed in the bin, it was re-capped with a fresh substrate about 60 cm deep.

Temperatures

Two thermocouple probes were placed in each bin, at a depth of one meter, to monitor the internal compost temperatures. These were connected to a data logger (Spectrum Technologies Watchdog model 125 - ambient temperature plus a temperature probe). The temperatures were recorded every 15 minutes.

Measurements and sampling

At the establishment of each compost bin, the volumes of all inputs and the carcass weights were estimated by the farmers. During the first farm visit of the research team, samples of all substrate materials were collected and tested for nutrient levels and bacteria. The volume of the composting materials was measured.

At the three-month stage for each bin, six samples were taken from each pile for nutrient analysis. A visual inspection was made to estimate the degree of composting and bone disintegration. Two samples per bin were taken for a bacteria analysis (E*. coli,* and *Salmonella*).

When six months had elapsed, similar samples were collected for nutrient and bacteria testing. An inspection of each pile for the degree of composting was conducted. At this stage, the bin was opened up and turned. The compost was returned to the bin and (if needed) additional substrate was added to cap it off - to ensure any carcass parts were covered.

The final visit to the bins was at the 12-month stage. Once again, nutrient and bacteria testing was carried out. An inspection of each pile for the degree of composting was conducted.

In all cases, samples were collected using sterile disposable gloves (new gloves for each bacteria sample and also for the nutrient samples for each bin). Samples were grab samples. At the three-month stage, four to six holes were dug into each bin to a depth of at least 30 cm. The samples were retrieved from the bottom of the holes. At the six-month stage, the samples were taken from all parts of the bin as the compost was mixed. The samples were placed in sterile plastic bags and placed in a cooler for transportation. They were delivered to the University of Guelph Laboratory Services for testing, usually within 24 hours of collection. The same procedure was used for the one-year sampling, collecting samples as the bins were opened up.

Each time the bins were opened up for sampling, an assessment was made of the effectiveness of the composting process. These were subjective assessments and included observations of the presence of carcass tissue, hide and bones and the condition of each of these. Bones were examined to gauge the degree of disintegration. If bones remained solid after a year of composting, this was considered to represent ineffective composting.

Samples were delivered to the Laboratory Services Division and the Food Microbiology Lab, University of Guelph, in a refrigerated cooler (at approximately 4^oC). Bacteria test samples were delivered within 24 hours of sampling. Samples for nutrient analysis (if not delivered within 24 hours) were stored in a refrigerator (at approximately 4^oC) until delivery to the lab. All nutrient samples were tested for N, P, K, NH_4-N, NO_3-N, Total Carbon, Organic Carbon, Inorganic Carbon, Ash/organic matter, Dry Matter, and pH. Bacteria samples were tested for *Salmonella* and *E. coli*. The following is a brief description of the test procedures:

- Dry Matter: samples weighed wet, dried in 80^oC 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 to calculate Loss on Ignition
- Total C, Inorganic C, Organic C: combustion method (Leco C analyzer)
- *E. coli*: 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.
- *Salmonella* : first step was 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”. If a sample tested positive it would go on to 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).

Other observations

Subjective observations of odours were made at each visit to the sites. Odour character descriptors were those used by the Wastewater Treatment Industry.

The labour needed to manage the piles was recorded by the farm operators, as were cost estimates of all inputs, in order to establish the economic impact of composting.

Results and Discussion

Site Descriptions

For the purposes of this discussion, the two farms will simply be referred to as Site 1 and Site 2. The beef operation at each of Site 1 and Site 2 consisted of a partially covered feedlot with a covered bedded area for the cattle to rest. There was an open concrete area for feeding and exercise. The feed bunkers (mangers) were located along the perimeter. Cattle were bedded with straw. The open area was scraped regularly to keep it clean and there was a runoff storage to capture any escaping liquids. The bedding pack was removed several times per year and field-applied. The compost bins were located next to a straw storage shed behind the cattle feedlot. At Site 1, all compost bins were made using big square bean straw bales. At Site 2, all compost bins were built out of big square wheat straw bales.

General Observations

The study began in November, 2004. The first bin was constructed on November 3 on Site 1 and on November 17 at Site 2. The initial visit to set up the monitoring system, collect samples, take pictures and confirm the experimental protocol was made to both sites on November 23, 2004. Both farmers had used large square bales to construct bins big enough for two cattle carcasses. Site 1 used bean straw, while at Site 2, wheat straw was used. The last of the bins (for this study) was constructed in July, 2005.

The sites were visited for monitoring, sampling and data collection on December 17, 2004, January 10, February 2, March 3, March 31, May 4, June 6, June 9, July 7, August 3, September 15, October 20, November 23, and December 20, 2005, and January 26, March 1, and April 11, 2006 (final). Each bin was sampled at the visit that corresponded most closely to three months after the establishment of that bin. Bins were mixed at the six-month stage, and mixed (and considered finished) at the 12-month stage. A summary of the start dates and other relevant compost age data is shown in Table 1. It was not always possible to stick to exactly the three, six and 12-month schedule, but the times are fairly close (averages are 3.3, 6.4 and 12.3 months). Table 1 demonstrates that composting was done continuously throughout the year, including through a winter that was colder than normal for the area.

Tables 2 and 3 show summary information on the establishment of the various bins at Sites 1 and 2, respectively. In general, the farmer at Site 1 used less substrate per carcass than was used at Site 2. At Site 1, the initial base was 25 to 30 cm thick, compared to 45 cm at Site 2. The substrate layer over the first animals was not as thick at Site 1, though the top cover was similar in thickness.

Table 1 - Start dates for each compost bin and ages of compost at various stages of the study

Site	**Bin**	**Start Date**	**First sampling (Months since start)**	**First Mixing (Months since start)**	**Final Mixing (Months since start)**
1	1	Nov 3, 2004	3.0	6.1	12.8
1	2	Nov 18, 2004	3.5	6.7	12.3
1	3	Feb 9, 2005	2.8	5.9	14.2
1	4	Apr16, 2005	3.7	6.2	12.0
1	5	May 30, 2005	3.6	5.9	10.5
1	6	July 1, 2005	NA	NA	9.5*
2	1	Nov 17, 2004	3.5	6.7	12.4
2	2	Dec 3, 2004	3.0	6.2	11.8
2	3	Jan 29, 2005	3.2	6.2	14.6
2	4	Feb 9, 2005	3.9	7.3	14.2
2	5	Apr 20, 2005	3.5	6.1	11.9
2	6	May 3, 2005	3.1	6.8	11.4
Average			**3.3**	**6.4**	**12.3**

Note: *April 11, 2006 represented the end of the study period, whether the compost was 12 months old or not.

Tables 2 and 3 show the differences in numbers of mortalities from one bin to another and from one site to the other. At Site 1, 21 carcasses were processed in six bins. At Site 2, 12 carcasses were composted in six bins. Average weights of mortalities were 486 kg at Site 1 and 522 kg at Site 2. These were, therefore, large animals that were close to market weight. Weights are based on estimates of the livestock producers (the carcasses were not weighed). Note that at Site 1, there were several cases where slaughter waste was added instead of the entire carcass. This slaughter waste consisted mainly of offal, bones and paunch manure.

Table 2 – Material inputs into the 6 bins at Site 1

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
Compost Substrate	corn silage/ straw	wood chips	solid manure base/ sawdust cap	sawdust	sawdust	wood chips and sawdust
Depth of Substrate Base (cm)	30	30	25	25	25	25
Approx. Weight of First Animal(s) (kg)	544 635	680 680	680 275	680 680	680 680	680
Depth of Substrate Layer (cm)	0	0	0 to 15	0 to 15	0 to 15	0 to 15
Approx. Weight of Next Animal(s) (kg)	295* 295	295 295	275	295 295	295 295	680
Thickness of top Substrate (cm)	60	60	40 to 60	40 to 60	40 to 60	40 to 60

* all those listed as 295 kg consisted of slaughter wastes (offal and bones)

Table 3 - Material inputs into the 6 bins at Site 2

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
Compost Substrate	solid beef manure	Corn silage	solid beef manure	Corn silage	sawdust	Corn silage
Depth of Substrate Base (cm)	45	45	45	45	45	45
Approx. Weight of First Animal(s) (kg)	635	545	454	590	635	635
Depth of Substrate Layer (cm)	45	45	30	45	45	45
Approx. Weight of Next Animal(s) (kg)	454	454	590	360	454	454
Thickness of top Substrate (cm)	45	45	45	45	45	45

Visual Appraisal

Composting appeared to be very efficient at breaking down the carcasses. Almost all soft tissue disappeared over the 12 months. Most bones disappeared during this time. Any bones that remained were brittle and easily broken. It appeared that the rate of decomposition was influenced by bin loading rates and the amount of substrate used. In two instances, carcasses did not break down as well as expected. One of these was a case where the carcass had had a chance to freeze before being placed in the bin. The bin then only served to insulate it, so composting did not really begin until after the material was mixed. In the other case, it was felt that the carcasses did not have enough substrate cover to allow for efficient composting.

There appeared to be a difference in the substrate materials used, both in their effectiveness at composting and in the presence of rats. Rats were most evident in bins that used sawdust as the carbon source. None of the bins appeared to have problems with dogs or wild animals digging in the bins (to feed on the carcasses). The wood chips did not perform as well as hoped. It failed to yield the same quality of finished compost. However, this material was already well decomposed before arrival at the site.

The big square bales used to construct the bins differed in their performance. As the study progressed, it was obvious that the bean straw did not hold up as well as the wheat straw. The bean straw started to break down over time, and by the end of the study the bales had completely fallen apart.

At all times of the year, the composting process was started as soon as carcasses were available. There was no effort, when there were winter deaths, to hold carcasses until warmer weather. Time of year appeared to have little impact on the composting process, as long as the carcasses were not allowed to freeze before being placed into a compost bin.

One of the concerns with composting is the breakdown of bones. Ideally, there should be no bones left when the compost is eventually spread onto the land. In the 12 month period involved, the breakdown of bones appeared to be better at Site 2. This was most likely due to a greater amount of substrate used in the bins at Site 2.

Two case studies are described, to show the variation in approach from one farm to the other. These also help to illustrate the various steps involved in the composting process.

Case Study #1 – Site 1, Bin 1

This bin was started on November 3, 2004. The base consisted of spoiled corn silage. Silage was also used between the carcasses. Finally, the bin was topped with spoiled straw. The bin dimensions were: 2.4 m x 2.4 m x 1.5 m. Two mortalities and the waste from two slaughtered animals were added to the bin, for a total animal weight of 1770 kg. During the site visit on November 23, no odours were noticeable. Temperatures inside the pile were in the range of 35^{o} to 45^{o}C. At that point the surface of the bin had already sunk by about 30 cm.

On December 17, no odours were detected. Inside temperatures averaged 30°C and the ambient temperature was -6.0°C. By January 10, 2005, the surface of the pile had settled to a total depth of 1 m. The air temperature was 1°C and the average pile temperature was 22°C. On February 2, samples were collected. Much of the soft tissue was gone, but many bones remained intact. The bin was mixed on May 4. When the bin was opened up, some vapour was released indicating it was still quite warm. The compost smelled like spoiled silage. At that point, some hide and bones were still intact. Very little tissue was found. One carcass had been placed near the edge and did not have the recommended amount of cover. More tissue remained, though in small pieces. The bones from this carcass had not undergone much deterioration at this point.

The bin was turned with a large loader tractor, lifting the compost and then dropping it. There was some difficulty reaching the back of the bin since the compost was left in the bin and not removed. Once the bin was suitably mixed it was leveled out and a bucket of corn silage was placed on top to keep it covered.

Temperatures for the next several months were higher (over 30°C). On November 23, 2005, the bin was opened up for the 12 month observations and sampling. The resulting compost had several bones still intact and even some tissue that not broken down. It appeared as though the bin contained too much carcass weight for the amount of substrate used. In fact the bin contained more than twice the weight of animal recommended for the amount of substrate. After this second mixing, it appeared that the bin should continue to compost and perhaps finish the breakdown process over an additional six months.

Case Study #2 – Site 2, Bin 2

This bin was started on December 3, 2004. As in the previous example, the base consisted of spoiled corn silage. Silage was also used between the carcasses and to cap the bin. The dimensions of this bin were 2.4 m x 2.4 m x 1.8 m. Two carcasses were added, totaling 1090 kg. One of the steers had died in November. There wasn't enough time to properly construct the bin at that time, so the carcass was placed on a concrete pad and covered with corn silage. A week later, the carcass had decomposed to the point it couldn't be lifted with the loader – material slipped through the forks. This carcass was therefore already well along the composting process when it was added to the bin on December 3.

By January 10, 2005, there were no odours, and temperatures in the bin ranged from 20° to 66°C (air temperature was 1°C). The material had settled to a depth of 1.1 m. Temperatures over the next several months remained in the desired range. The compost was mixed on June 6 (six months). The material had settled to a depth of 0.75 m. The bin was mixed using a pay-loader. The volume of compost was small enough that the compost could be turned in the bin without removing it. Some small pieces of flesh were still present. Also, the paunch manure had still not broken down. Several bones were still present, but most were gone.

After turning, temperatures moved to a range of 45° to 56° C for several months. The bin was emptied on November 23, 2005 (approximately one year). The volume of material had shrunk even further to about 1.8 m^3. There was no tissue remaining and virtually no bones. Any bones that remained could be crushed by stepping on them. This material had composted very well.

Odours

Odours were typically non-existent. Of course, the bins were located near the feedlots – feedlot odours were greater than any that may have been emitted by the compost bins. Odours were more apparent when the bins were opened up and mixed. At those times, odour intensities were slight to moderate, and odour character was rated "natural unpleasant - rotten/offensive".

Nutrient Analysis

At the beginning of each new bin, samples of the substrate material were collected and analyzed. As the study progressed, a total of 19 compost samples were examined per bin. Results of this analysis are summarized in Table 4. The test values are in line with expected values for the various materials. For sawdust, all but one result for N, P and K were below the sampling detection limit. This meant that a C:N ratio could not be calculated. It was assumed that the C:N would be in the order of 200 to 750:1 (NRAES 1992), which would make this material the richest source of carbon of those tested. Wood chips were used as part of the mix at Site 1. This material had been stockpiled off-site for some time and had undergone a considerable breakdown of organic material. As a result, it had a very low organic matter content. The C:N ratio of 26.8 was also lower than expected.

Table 4 – Selected chemical properties of initial substrate materials

	Units	Beef Manure	Sawdust	Wood Chips	Corn Silage	Straw
DM	% (as is)	28.6	41.7	37.8	20.4	51.6
N	% (as is)	0.795	ND	0.47	0.354	0.48
P	% (as is)	0.49	ND	0.13	0.073	0.045
K	% (as is)	1.39	ND	0.23	0.091	0.21
pH		8.25	6.025	7.6	7.6	7.6
C:N	% (as is)	13.7		14.5	28.0	46.3
Ash	% (DM basis)	28.5	0.46	73.2	12.0	10.7
Organic matter	% (DM basis)	71.5	99.5	26.8	88.0	89.3
Number samples		2	4	1	2	1

Analysis results for the compost samples are shown in Table 5. These are broken out into the three separate sampling times – i.e when the material had been in the bins for three, six and 12 months. There are many more sample results for the averages in Table 5, compared to Table 4. However, the variability in results was quite high. This was partly due to the variability in properties from one substrate to another. It also reflected the difficulty in obtaining a well-mixed, representative sample in this material. As time went on and the compost was mixed, it became more homogeneous, although some of the variability in results remained. As an illustration, the ash contents (dry matter basis) of all compost samples at three, six and 12 months were 18.9, 20.2 and 27.3%, respectively. Standard deviations were 22.0, 15.3 and 18.2, respectively.

Table 5 – Selected chemical properties of compost at different times – mean values of all samples, regardless of substrate used

	Units	3 Months	6 Months	1 year
DM	% (as is)	36.7	31.5	29.8
N	% (as is)	0.71	0.96	0.74
P	% (as is)	0.15	0.24	0.20
K	% (as is)	0.33	0.38	0.36
pH		7.68	7.57	7.39
C:N	% (as is)	37.6	46.0	25.4
Ash	% (DM basis)	18.9	20.2	27.3
Organic matter	% (DM basis)	81.1	79.8	72.7
Count		66	66	72

Bacteria

In total, seven samples from each bin were submitted for measurement of bacteria densities. The results of 82 analyses showed that none tested positive for *Salmonella.* There was a great deal of variability in the sample results for *E. coli*, presumably for the same reasons discussed earlier. The highest number was 2.4×10^6 and the geometric mean value was 5.8×10^1 MPN/g. In most cases, the first samples submitted for each bin had high numbers and the last samples had undetectable levels. This was expected, given the relatively high sustained temperatures in the compost mass.

Compost Temperatures

Two temperature loggers were placed in each bin. Two were needed in order to provide a backup in case one of the units should fail or be damaged (experience has shown that rats enjoy playing with them). As it was, on occasion, both loggers failed for various reasons. These failures may have been the result of cold and damp weather conditions and/or rodent activity. Rodents have climbed on the wires and pulled the thermocouple wires loose from the loggers.

The logger data was downloaded to a laptop computer and then analyzed. One cycle (30 days) of lost data resulted from a problem with the serial cable.

Despite the problems described, a good deal of useful temperature data was recorded. The temperatures appeared to depend on three main factors: a) the positioning of the probes in the bin, b) the substrate used, and c) the amount of mixing in the bin.

Temperatures in many of the bins stayed over 55°C for extended periods of time. In certain cases, the temperature rose to these levels almost immediately, then gradually dropped over several months. In other cases, temperatures remained lower for the first six months, until mixing. The low temperatures may have been related to placement of the probes. Regardless, in several cases, the temperatures rose to temperatures over 50°C and stayed there for several months. Time of year made no difference to these values.

The lowest temperatures appeared to be in Bin 1 at Site 1, described in the earlier case study. This was the only bin where no temperatures over 50°C were measured.

Volume Changes

The volume of the compost reduced over the study period. The substrate used had an impact on how much the volume reduced. The bins where corn silage was used, on average, reduced in volume by 72% (3 bins). Other reductions were: sawdust - 47% (4 bins), solid cattle manure - 37% (3 bins), silage and sawdust - 37% (1bin) and wood chips - 0% (1 bin).

Economic Analysis

One of the reasons for carrying out this study on-farm was to assess the labour and economic viability of composting under real-life conditions. This meant giving up a certain amount of control over the study in order to give the system a realistic evaluation by typical end-users of the practice. Table 6 includes summary data for the two sites, including a calculation of the average amount of labour for composting. Labour included building and loading the bins, mixing at six months and removal at 12 months.

Table 6 – Summary of labour inputs by farm operators – Nov 2004 to April 2006

	Site 1	Site 2
Number of mortalities	21	12
Average weight of mortalities (kg)	486	522
Number of bins created	6	6
Labour per 1000 kg (operator + loader tractor) (min.)	55	88

In determining whether composting of mortalities is economically feasible on farms, it must be compared to the main alternative, licensed pick-up for delivery to a rendering plant. Table 7 summarizes the actual composting costs. In calculating costs, the following assumptions were made:

- Costs of constructing the compost bins and the materials used for composting were based on estimates provided by the farmers involved. Site 1 assumed \$15/bale, \$6/m^3 for sawdust, \$0/t for corn silage (spoiled), \$2.50/m^3 for manure; Site 2 assumed \$20/bale, \$25/t for sawdust, \$25/t for corn silage, \$2.30/m^3 for manure – in reality, most farms have a supply of spoiled silage or straw that can help reduce composting costs, and many farmers would not place a high value on solid manure as a substrate material (especially in light of the fact that the finished compost will likely be spread onto the land eventually).

- Labour costs were estimated at $12.00 per hour.
- The total cost of the loader tractor and operator was estimated at $50.00 per hour - which is the typical custom rate charged in the area.
- The time required to build the bins and place cattle into the bins was based on estimates of the farmers involved.
- Carcasses were assigned no value or cost to the composting project. Also, no value was assigned to the final compost.
- Costs for picking cattle up for rendering reflect the most recent range in costs these farms have paid.
- No additional costs for carcass pick-up were considered even though a certain amount of labour would be needed to move the carcass to a suitable place for the truck to access the carcass.

Table 7 - Average costs per bin for composting mortalities

Costs	Site 1	Site 2
Bales to form bins	$60.00	$86.67
Labour and Equipment to build bin	$9.72	$12.50
Substrates	$23.33	$89.17
Labour and Equipment to place carcasses into bin	$43.75	$35.42
Labour and Equipment to mix bin	$12.50	$12.50
Labour and Equipment to empty bin	$12.50	$12.50
Total Costs for bin	$161.80	$248.76
Number of Cattle per Bin	3.5	2
Costs per 1000 kg of Carcasses	$97.60	$239.70
Cost of pickup (@ $55.00 per animal)	$192.50	$110.00
Cost of pickup (@ $100.00 per animal)	$350.00	$200.00

Note: costs per bin were the average of all 6 bins from each farm.

Table 7 points out that management of the compost system has a significant impact on the total cost. The average cost per bin of composting carcasses at Site 1 was lower than the cost of pickup. At Site 2, the cost of pickup was lower than on-site composting. In part this is because different dollar values were given for the same materials used in the composting process. Also, at Site 1, more carcasses were placed into each bin, which significantly reduced the costs.

These costs do not consider the convenience that either method may provide at a specific location. Pickup of carcasses involves having to place the mortality at a convenient location (where there is access by the truck), likely involving similar time and effort to placing the carcasses into compost bins close to the feedlot.

While the costs were lower at Site 1, there would be more bones to deal with if this material was spread at the one-year mark. This may not be an issue for some people. If it were a concern, a simple solution would be to continue the compost process (after mixing) or to screen the material. Either option could increase the costs.

Other considerations: There may be bio-security risks having a truck drive onto the farm to pick up a carcass. Once the phone call is made, pickup may not be as quick as desired, perhaps depending on proximity to the trucking company.

Farmer Comments

Both cattle producers have chosen to continue composting mortalities on site. They had both attempted composting earlier, with limited success. During this study, they attempted to follow the recommended management practices. They now feel comfortable with composting. They both intend to field-apply the compost when it is completed. Also, they both feel the costs and effort needed to compost are less than or equivalent to having mortalities picked up for rendering.

Other comments:

- They liked the improved bio-security of handling the mortalities on site.
- They liked the absence of odours during the composting process.
- They liked the effectiveness of composting through the winter months.
- They were impressed at the effectiveness of composting when the process was done following the recommended procedures.
- They were pleased with the simplicity of composting and the relatively low labour needs.
- They liked being able to compost the carcasses close to the feedlot, minimizing travel time.
- Both recognized that there are ways to reduce costs – e.g. using spoiled silage and other waste materials.

Summary

This study provided an opportunity to carry out an on-farm evaluation of composting of livestock mortalities using large carcasses. Two beef feedlot operations participated and composted all mortalities for the duration of the study - November, 2004, to April, 2006. Management practices were different from one site to the other and final composting results were somewhat different. The following are the main findings of the study:

- Composting can be a practical and cost-effective way of dealing with routine cattle mortalities on the farm. Total costs are similar to those involved with licensed pickup for delivery to a rendering plant and there are opportunities to reduce actual costs.
- The labour needed to carry out composting (including an operator and a loader tractor) was 55 minutes per 1000 kg mortality at Site 1 and 88 minutes per 1000 kg at Site 2.
- The substrates used in this study performed well, except for the aged wood chips. Saw dust, corn silage and solid manure all produced desirable results. Straw was also used as part of a mix, though it was not used to cap a bin.
- The degree of breakdown of bones varied from bin to bin. In general, destruction of bones was very good at the 12 month point. As long as the bin is not overloaded and the proper amount of substrate cover is used, very few bones, if any, will remain at 12 months. The remaining bones appear to have most minerals leached out and are easily broken. Screening of bones or composting longer may be acceptable alternatives in cases where bones are an issue.
- The nutrients in the 12-month compost were not substantially different from the initial solid beef manure and thus would be as valuable a source of crop nutrients if land-applied.
- Temperatures in the bins exceeded 50^{o}C for weeks or months at a time (except in one bin where it was felt that overloading occurred).
- Volumes of material reduced by 37 to 72% over the 12 months of composting, depending on substrate used (corn silage was responsible for the greatest reduction). The exception was the bin using aged wood chips, where there was virtually no volume reduction.
- Odour control was very good – odours from the compost bins was never an issue.
- Rats appeared to be present and seemed to favour the bins using sawdust. The rats did not seem to create any serious problems. Dogs digging in the bins were never an issue.
- Bacteria numbers (*E. coli* and S*almonella*) were measured. No *Salmonella* were detected in any of the samples. *E coli* numbers were quite variable but demonstrated a considerable reduction (or in most cases, elimination) over the 12 months.
- Composting provides a certain amount of convenience and an added measure of biosecurity for the livestock producer. It avoids having trucks visit the farm that may carry diseases from other farms.
- Winter-time composting should proceed in a timely fashion, with the carcass added to the composter before it freezes.
- The composting process is rather robust. Even if ideal temperatures are not achieved, composting will still progress. To get the desired results (e.g. complete destruction of all bones) may simply take extra time.

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