Composting Blood (Slaughterhouse Waste) Mixed With Various Substrates

- Final Report -

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Introduction

The term “slaughterhouse waste” is used to refer to a number of byproducts of the cattle slaughter industry. These include paunch manure, offal and blood. This report deals specifically with blood. In the past, blood has been trucked to rendering plants where it was used to create such products as blood meal. In this way, the nutrients could be re-used. With demand for blood products waning in light of concerns regarding the potential for the spread of certain diseases, the industry must find alternate uses for blood. Because composting is becoming more and more popular as a disposal method for livestock mortalities on the farm, it seems reasonable to assume that it can be used to treat blood. It must first be mixed with a suitable substrate and that is the subject of this report.

This study took place at the Ridgetown College campus of the University of Guelph, located in Ridgetown, Ontario, Canada. Previous college research had worked out recipes for composting liquid swine manure, by mixing it with a variety of substrate materials. It seemed that blood should have similar characteristics to liquid swine manure, so should compost very well using similar techniques.

Objective

The study was designed to determine the feasibility of using blood in a composting process. The blood would form a part of a compost recipe, with the balance being materials readily available in rural Ontario.

Project Setup

General

The testing was carried out at the compost facility at Ridgetown College, University of Guelph. This system is a covered in-vessel system (three channels) with forced aeration and mechanical turning. A different carbon substrate was used in each of the three channels. Most of the nitrogen needed in the process was contained in the blood.

During the trials, there was a constant monitoring of the compost temperatures. Odour characteristics were assessed, and volume and mass reductions were measured. Samples were taken of the raw materials before composting and then at 4 week intervals. Monitoring was scheduled to continue for 16 weeks when the composting process was expected to be finished.

The management of the system was designed to be somewhat flexible, as it was unknown what problems may arise and what odours may be created. However, the original concept was as follows:

- for the first four weeks, representing the time of most active composting, the material will stay in the in-vessel channels
- during this period (mainly in the first two weeks), liquids (blood and liquid swine manure) will be applied
- compost will be turned when required - based on maintaining aerobic conditions in the compost
- increased odour levels will be used to indicate anaerobic conditions
- if odour levels become high, aeration rates may need to be increased
- if the levels become unacceptably high, the material may need to be removed from the channels and moved further from the nearby residences
- at the end of the fourth week, the compost will be moved to static piles to continue the curing process
- monitoring will continue during curing, for up to 16 weeks (or until the composting is complete)

Composter

The Ridgetown College composter is an in-vessel, forced aeration system. It 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. It 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. Air is forced upward through the compost. It then enters the building air space. The building has roll-up doors in the end walls which can be used to adjust the building ventilation rate.

Temperatures in the channels were measured using up to six thermocouples (shielded thermocouple cable type T 24-AWG), connected to a data-logger (Campbell Scientific CR10). Thermocouples were also set up to measure the outside air temperature and the temperature of air inside the building.

The data logger recorded the temperatures and operated the aeration fans. A base level of aeration was maintained (three minutes on in each hour) until any one of the thermocouples in a channel exceeded 66^o C. Then a second level of aeration was initiated - i.e. four minutes on for every 10 minutes, until the temperature dropped below 60^o C. The goal of this aeration rate increase was to prevent excessive heating and maintain aerobic conditions within the channel. The data logger also monitored 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 when the system was initially set up in 1998 - 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. 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.

Approvals/Safety

Prior to testing, it was the responsibility of Blake Fisher to get any appropriate approvals to allow for the testing of this material. According to their contacts within the Ontario Ministry of the Environment, no special permits were necessary as the material was deemed to be an agricultural by-product.

Measures were taken during the composting tests to ensure the health and safety of the operators and researchers. Precautions were taken similar to those needed for other composting - e.g. wearing a dust mask during turning operation, wearing latex gloves during sample collection. None of the materials used were regarded as posing any specific health or safety risk.

Experimental Design

As mentioned, the compost trial consisted of three batches, underway concurrently. Each batch started out in the in-vessel compost unit and was expected to have a maximum initial volume of up to 50 cubic metres. The proposed start date was October, 2004, with the projected finish by late March, 2005.

The expectation was that the blood would be in a concentrated form - possibly too thick for pumping with the Ridgetown College transfer equipment. In order to rectify this and to introduce a material with a proven track record, the blood would be mixed and stored with liquid swine manure. The three treatments were as follows:

- Treatment # 1 - Blood and liquid swine manure (mixed 50:50 and stored together) composted with solid cattle manure
- Treatment # 2 - Blood and liquid swine manure composted with tree leaves
- Treatment # 3 - Blood and liquid swine manure composted with wood fibre

Sample Collection and Analysis

The compost was tested monthly for the following nutrients: N, P, K, NH_4-N, NO_3-N, Total Carbon, Ash, Dry Matter, and pH. In addition, samples were analyzed for *E. coli* (indicator organism) and *Salmonella* bacteria to determine the potential for killing pathogens in the process.

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
- 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.

Temperatures were measured and recorded continuously throughout the compost process. Volumes and masses of material at various stages were measured or calculated, to show reductions in mass and volume and changes in density.

Odour Assessment

No formal protocol was used to accurately measure odours emitted during composting. Rather, observations were made and recorded regularly by the operator. These generally fell under the headings of odour intensity (i.e. how strong was the odour) and odour character (i.e. how objectionable was the odour). The aim was to get a feel for the odours that the compost operator could expect and the odours that the neighbours might encounter from time to time.

Results and Discussion

General Management of Composter

In preparation for receiving the blood and starting the trial, the carbon materials were added to the channels. On November 10, 2004, Channel 1 was filled with wood fibre consisting of shredded tree limbs. On the same day, Channel 2 was filled with tree leaves. On November 19, Channel 3 was filled with fresh solid beef manure. The channels were not filled to capacity. The amount of material used was based on the ability of the mechanical turner to operate and on the expected ability to maintain aerobic conditions in the composting material.

By November 22, these materials were beginning to compost on their own, especially the solid manure, which had a more desirable C:N ratio and moisture content. The building began to fill with vapour.

Before the blood arrived, the liquid holding tank at the site contained just under 6000 L of liquid swine manure. On December 9 (Day 1), 19,500 L of fresh blood (and wash water) from the Better Beef slaughter facility, near Guelph, was delivered and dumped into the liquid holding tank (delivered by Blaemar Ltd). Because this blood had not been concentrated, there appeared to be no need to dilute it 50:50 with liquid swine manure. The blood was still warm (38^{o}C) and had an offensive blood/slaughterhouse odour. It seemed that because the blood was still warm, the odours drifted further from the covered storage than ever occurred for liquid swine manure. Odours could be detected 50 to 100 metres downwind.

The blood contained few solids and could be easily pumped. Therefore, no additional swine manure was added for dilution - only the 6000 L initially in the storage. Because we had been led to believe there was a potential for the blood to separate/solidify over time, we chose to use the minimum amount of swine manure as a precaution. The swine manure represented 23.5% of the initial blood/manure mix.

On Day 6, each channel was opened up in several places using a pitch fork. Moisture levels and odours were assessed to determine if the compost should be turned. During application and turning on Day 7, there were some mechanical problems with the turner. This unscheduled maintenance delayed the application to Channels 1 and 2 (by one day), which put back the schedule for the third application. On Day 10, a new load of fresh blood was added to the storage, as the initial load was used up. There was no liquid manure mixed with this load.

On Day 13, cold weather was starting to become an issue. The aeration fan for Channel 3 froze and burned out when it tried to start. It took several weeks to get the appropriate part and make the repairs. Also, some of the liquid nozzles were frozen. The blood in the cold weather started to coagulate, resulting in some temporary plugging. A summary of all liquid additions and the turning frequency is recorded in Table 1. No other liquid was added after Day 13.

Table 1 - Dates and volumes of liquid application and turning of compost in channels

Day	Date	Channel	Liquid applied (L)	Number of passes/ turnings	Cumulative application (L)
1	Dec. 9	1	7800	3	7800
1	Dec.9	2	6218	3	6218
1	Dec.9	3	3170	2	3170
7	Dec. 15	3	1219	2	4389
8	Dec. 16	1	2438	2	10,238
8	Dec. 16	2	4633	2	10,851
13	Dec. 21	1	4267	2	14,505
13	Dec. 21	2	4755	2	15,606
13	Dec. 21	3	0	2	4389

On Day 30 (January 7, 2005), volumes were measured and samples collected from each channel. Samples were next collected on Day 57 (Feb. 3). On Day 61, compost was removed from each of the channels, weighed, and returned to the channels - at a depth of 1.8 m. Samples were next collected on Day 85 (Mar. 3). On Day 113 (Mar. 31), the aeration fans were turned off for Channels 1 and 2. This represented the target 16 weeks after start of project. Samples were collected and volumes measured for each channel.

On Day 122, the compost was removed from each channel, weighed and stacked for final curing. By this point the compost process was expected to be complete. However, temperatures in parts of the channels still exceeded 40^{o}C, suggesting that composting was still proceeding. By Day 138 (Apr. 25), the compost made with wood chips and that made with solid beef manure had cooled off to ambient temperatures, but the compost made with tree leaves remained warm. By this point, all materials looked like “normal” finished compost - it was at a stage where it could potentially be marketed or used.

Mass and Volume

In order to design a compost system, it is important to know the mass balance that can be expected for the various inputs. The additions of blood are given in Table 1. As has been previously mentioned, the first tankful of liquid contained a mixture of blood and liquid swine manure (19,500 L blood + 5978 L swine manure). In total, 28,522 L of blood was applied to the three channels plus the 5978 L of swine manure -

or 34,500 L of liquid.

The initial volume and mass of the three solid substrates is found in Table 2. For the wood fibre and tree leaves, the material was not weighed before it was placed in the channels. Masses are based on measured bulk densities and volumes. Later in the process, all material was removed from the channels and weighed.

Table 2 - Initial volume and mass of the three substrate materials

Channel	Carbon Source	Volume (m^3)	Mass (kg)	Bulk Density (kg/m^3)
1	shredded tree limbs	36.7	12,155[a]	726.6
2	tree leaves	48.0	2970[a]	387
3	solid beef manure	26.4	17,500[b]	829.1

a - mass estimated using bulk density
b - mass measured

As composting progresses, the mass reduces, mainly due to losses of moisture (through evaporation) and carbon (as carbon dioxide). There are usually similar reductions in volume. These changes are shown in Table 3. Notice that the final mass and volume are approximately one half of the initial values.

Table 3 - Changes in Mass and Volume between start and end of study

	Channel 1	Channel 2	Channel 3
Mass - Total inputs (kg)	26,660	18,576	21,889
Mass at 8 weeks	16,160	12,560	11,680
Mass at 16 weeks	13,140	11,440	9720
Final Mass as % of Inputs	49.3	61.6	44.4
Volume at start (m^3)	36.7	48.0	65.1
Volume at 16 weeks (m^3)	18.7	16.0	12.0
Final Volume as % of Inputs	50.9	33.3	45.3

For design purposes, two quantities are useful in determining the size of a compost facility where a liquid material is the main source of nitrogen. The first is the ratio of liquid to substrate. To create compost using wood fibre, 14,505 kg of blood (containing some liquid swine manure) was added to 12,155 kg of wood material. This gives a ratio of 1.2:1 (i.e. kg liquid to kg substrate). Corresponding values for tree leaves and for solid beef manure were 5.25 and 0.25, respectively. The higher the value the better, as there is generally a cost involved with bringing the carbon substrate to a site. Based on these values, the beef manure is the least desirable of the materials tested - greatest quantities would be needed.

It is also important to know the size of compost facility needed for a given recipe. The tests carried out were based on the assumption that no liquid could be applied after the first two weeks. By that point, the compost would have all the moisture it could hold, composting would be actively underway and it would be possible to remove material from the channels and pile it elsewhere in readiness for the “curing” stage. Based on a 14 day cycle for the channels, the amount of liquid applied in Channel 1 (wood fibre) was equivalent to 31.9 L/day per square metre of channel floor area. The application rate on the leaves was equivalent to 34.3 L/day per sq m, and on the beef manure was 9.7 L/day. Once again, the higher the number, the better. The beef manure appeared to be the poorest choice of the three materials.

Note that the compost was left in the channels for longer than the normal 14 days. That allowed for a much better environment to monitor compost progress and a means to record temperatures more easily. Compost was not removed until Day 121.

Temperatures

Each channel was equipped with six thermocouples that constantly recorded temperatures. For various reasons, not all thermocouples were installed in the compost at all times. However, at least two probes functioned continuously for each channel, and for most of the time, at least four probes functioned.

Once the blood was added to the substrate materials, the heating began. In general, temperatures rose quickly to the desired thermophilic range (i.e. approximately 55 to 70^{o}C). As expected, the temperatures varied somewhat within the channels, but no major temperature variations were noted. The process of composting appeared to be moving forward in a typical manner.

Figure 1 shows the temperature profile for the three channels. It shows an average value for each channel plus the outside air temperature. Rather than display hourly data for the duration of the study, only the midnight temperatures were used to calculate the channel average temperatures shown in Figure 1. The outside air temperature rarely rose above freezing for most of the study. During this time, the average channel temperatures were often above 50^{o}C. The dips in compost temperature in the first two weeks correspond to days when the compost was turned (and liquid applied). Similarly, the drop in temperature at Day 61 represents removal from the channels, weighing, and placement back into the channels for further composting.

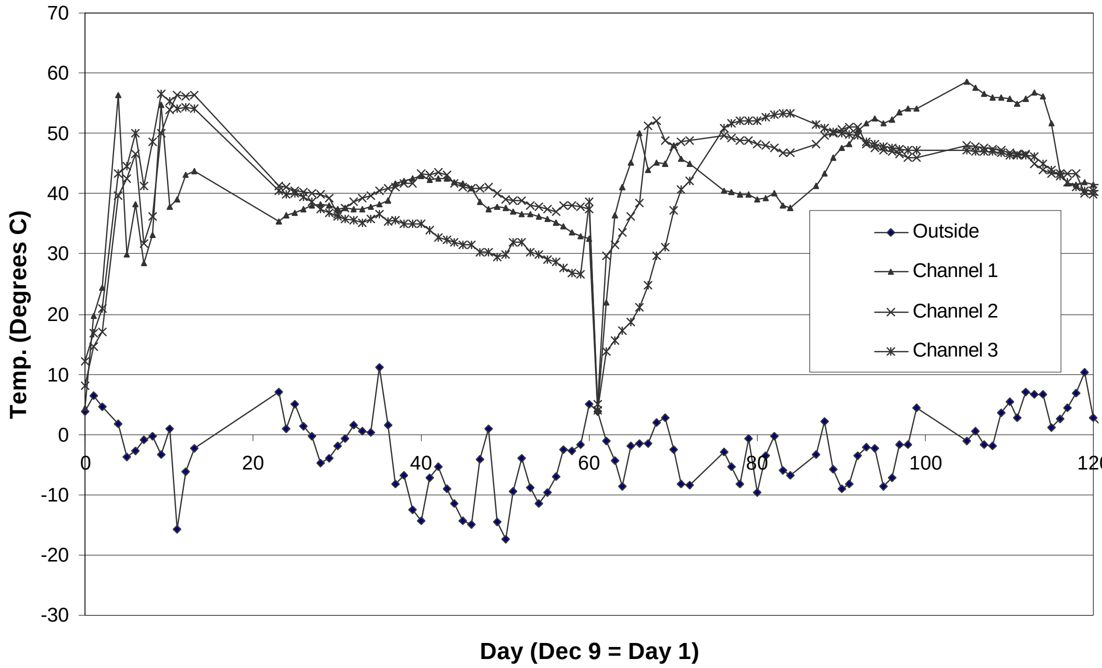

Figure 1 Temperatures within each channel and outside air temperatures, for 120 days in the channels (i.e. from Dec. 9, 2004 to Apr. 7, 2005)

Nutrients

When putting together a compost recipe, it is important to know the Carbon:Nitrogen (C:N) ratio of the various constituents. An ideal C:N for compost is in the range of 20-25:1. The C:N for liquid manure is typically close to 3, and we assumed that blood would be similar. The following three tables (i.e. Tables 4, 5 and 6) give many of the most useful nutrient analysis results for the three compost batches, including C:N ratios. Concentrations are reported on a Dry Matter basis. Table 7 gives a few summary concentrations on an “As-Is” basis, which may be more familiar to some.

The C:N ratios for all materials were lower than desired. When the C:N is too high, composting slows down or stops. However, when the C:N is too low, composting proceeds but there is more N available than needed. This excess N is often lost as ammonia. This certainly seemed to be happening during this test. Higher than normal levels of ammonia were noted in the compost building at various times in the process.

Table 4 - Average nutrient concentrations of raw materials and compost for Channel 1 (Wood Fibre) - dry weight basis

Material	NH_4-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									
Wood fibre	89.1	1.4	0.17	0.7	64.9	87.4	7.2	40.8	29.7
Blood 1 & swine man.	2581	15.1	0.14	0.5	12.0	94.2	6.8	49.9	3.3
Blood 2	7867	15.8	0.61	0.9	13.5	93.2	6.8	49.7	3.2
Compost									
Day 28	14,359	4.4	0.30	0.8	39.1	64.1	8.2	29.3	6.6
Day 54	11,544	3.9	0.36	0.7	42.1	58.2	8.2	28.9	7.4
Day 83	1248	3.8	0.54	1.3	35.4	78.2	7.9	24.4	8.1
Day 111	3234	1.6	0.32	0.9	39.3	66.0	8.3	23.7	14.6

Table 5 - Average nutrient concentrations of raw materials and compost for Channel 2 (Tree Leaves) - dry weight basis

Material	NH_4-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									
Tree Leaves	27.0	1.0	0.11	0.8	71.0	86.6	5.0	43.6	41.8
Blood 1 & swine man.	2581	15.1	0.14	0.5	12.0	94.2	6.8	49.9	3.3
Blood 2	7867	15.8	0.61	0.9	13.5	93.2	6.8	49.7	3.2
Compost									
Day 28	14,024	5.2	0.22	0.9	27.8	79.8	8.5	42.5	8.1
Day 54	26,222	5.7	0.22	0.8	27.0	82.7	7.7	45.6	5.9
Day 83	138	7.0	0.32	1.0	34.2	76.5	8.6	41.6	6.0
Day 111	18,143	6.1	0.26	0.9	30.2	76.9	8.6	40.6	6.6

Table 6 - Average nutrient concentrations of raw materials and compost for Channel 3 (Solid Beef Manure) - dry weight basis

Material	NH_4-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									
Beef Manure	1083	1.9	0.46	2.5	25.1	86.3	8.2	42.5	22.0
Blood 1 & swine man.	2581	15.1	0.14	0.5	12.0	94.2	6.8	49.9	3.3
Blood 2	7867	15.8	0.61	0.9	13.5	93.2	6.8	49.7	3.2
Compost									
Day 28	8406	3.8	0.74	4.2	25.1	78.1	8.9	39.3	10.3
Day 54	16,148	5.0	0.70	4.1	24.4	80.8	8.6	40.5	8.2
Day 83	2181	2.2	0.68	3.7	23.1	76.1	8.0	38.5	17.7
Day 111	3607	3.0	0.53	4.3	22.6	73.4	8.1	35.3	11.8

Table 7 - 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					
Wood Fibre	60	0.89	0.106	0.44	64.9
Tree Leaves	19	0.74	0.080	0.59	71.0
Solid Cattle Manure	285	0.48	0.109	0.58	25.1
Blood 1 & swine man.	310	1.81	0.017	0.06	12.0
Blood 2	1047	2.13	0.078	0.12	13.5
Compost at 111 Days					
Wood Fibre	1270	0.64	0.125	0.34	39.3
Tree Leaves	5470	1.84	0.078	0.27	30.2
Solid Cattle Manure	816	0.68	0.121	0.96	22.6

The solid cattle manure was at the desired moisture level and C:N ratio before the trials started. The addition of blood did nothing to improve the composting process. It only created a compost that was more moist than desired and that lost more than normal amounts of ammonia-N. Moisture levels in the wood fibre and tree leaves were more desirable.

The high NH_4 concentrations at Day 111 suggest that the compost is not finished yet - normally most of the N would be present in an organic form when the compost is nearly mature.

When the project started, none of the nutrient analysis data were available, so management decisions were based on the proven track record using liquid swine manure. However, blood has a much higher solids content than typical liquid swine manure. Therefore, in order to apply the correct amount of moisture to facilitate composting, there is a danger of applying too much N. This lowers the C:N ratio below the desired range. It means that solid manure is a poor choice for a carbon substrate. The higher the C:N ratio of the substrate, the better. The leaves and the wood chips appear to be better choices for composting. Other agricultural materials to consider would be straw or corn stover.

Indicator Bacteria

Because of the potential for the compost to be land-applied, it was essential that at least a minimum amount of microbiological testing be carried out at this stage. Composting, with its high temperatures, has the ability to destroy most pathogens. Testing was done to verify that this was happening and to assess levels in the raw materials.

Two organisms were measured: *E. coli* and *Salmonella*. *E. coli* was used because it is a standard indicator organisms and is found in high numbers in livestock manure. *Salmonella* is a pathogenic organism that is of great concern to the livestock industry.

E. coli numbers were highest in the blood (and the blood/liquid manure mix). The three samples submitted contained levels of 2.3×10^5, 4.3×10^4 and 4.3×10^4 MPN per g (Most Probable Number per gram). These three samples were the only samples testing positive for *Salmonella* - the highest level being 43 MPN/g. No other *E. coli* levels exceeded 427 MPN/g and all samples of compost after Day 28 were negative for *Salmonella* and below the detection limit (of 3.0 MPN/g) for *E coli*.

Odour Assessment

Following is a log of odour observations during the test:

Day 1 Dec. 9 - Odours during application of liquid (blood and liquid manure) were only slightly offensive at the beginning. However, the odour of the fresh warm blood became more offensive (almost nauseating) as time went on (i.e. during application to the carbon materials). Workers in an indoor compost facility should wear an activated carbon respirator to eliminate odours. Odours were also detected outside the building at a distance of up to about 100 metres downwind from the composter.

Day 2 The doors of the building had been closed overnight and the odour levels were moderate inside the composter in the morning. The source of most of the indoor odour appeared to be the small amounts of spilled blood and blood in aeration ducts, gutters and the sump. Odours outside the building were slight or not detectable. By the afternoon, the odours were intensifying. Odours from the beef manure mix suggested there were anaerobic regions in the batch.

Day 4 There was a fair amount of water vapour present inside the building and odours were moderate in intensity but quite offensive (inside the building).

Day 6 There were high temperatures in all channels now. Odours had diminished inside the building and could not be detected outside.

Day 8 The piles were turned and additional liquid applied on Days 7 and 8. Odour levels during application appeared to be much lower than the initial levels, presumably because the blood had cooled down.

Day 9 Because the doors of the building were almost completely closed (thus minimizing air flow through the building), ammonia levels were quite high. Ammonia was measured in the building using a Gastec tester. Concentrations were in the range 50 to 60 ppm (which is unacceptably high). The building was opened up and the ammonia quickly dissipated. Other odours were slight.

Day 10 Odours were slight with a little ammonia still detected.

Day 21 It appeared that ammonia was coming off Channel 3, while Channels 1 and 2 had little or no odour. Odours were not detected outside of the building.

From this point on, odour levels were relatively low. There were some odours associated with Channel 3, mainly because the aeration fan was not working properly and it took several weeks to make the necessary repairs. Even these odours were fairly low however and were not detectable outside of the building.

In general, it appeared that the greatest potential for odour problems was when the blood was warm. These odours were quite offensive. In addition to the brief period of odour emission during application of liquid to the carbon substrate, there is potential for emission from any spilled or pooled blood. Every effort would have to be made to prevent spills and have no places where blood could collect in drains (gutters and aeration pipes). There appeared to be lower odour levels from blood that had been cooled down before application. Leaving it for too long before composting may not be wise, however. The liquid that remained in the storage tanks was used once this study was complete (i.e. spring, 2005). It had been stored for four to five months. Odours were quite offensive during application.

Summary and Conclusions

During the winter of 2004/2005, a composting study was carried out at the Ridgetown College campus of the University of Guelph to assess the feasibility of using composting as a technique for treating blood from a slaughterhouse. The blood was mixed with three different materials: a) wood fibre (created by chipping tree limbs), b) tree leaves and c) solid beef manure. These were chosen based on their perceived availability in the agricultural community.

Composting was carried out in three separate batches in a covered in-vessel compost facility, equipped with a mechanical turner and forced aeration. The compost process was monitored for more than 120 days.

Some of the main findings:

- a good quality compost was created using blood as part of the recipe in all three cases
- the poorest choice for substrate was solid beef manure, as it initially contained the proper nutrients and moisture for composting - before the addition of the blood
- one kg of tree leaves could compost 5.25 kg of blood
- one kg of wood fibre could compost 1.2 kg of blood
- temperatures were in the desired range for composting for long periods of time
- C:N ratios were somewhat low during these tests, creating a potential for losses of ammonia - these were confirmed
- *E. coli* and *Salmonella* appeared to be destroyed during the compost process
- warm blood has a greater odour potential than cold blood - but both can create odours if left on surfaces or in pools in the building - once composting was underway, the odours disappeared

It appears that under the proper conditions and with an informed selection of a composting substrate, blood could easily serve as an ingredient in a compost recipe. Because both the N level and the total solids are fairly high, it must be matched with a material having a high C:N.

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