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Effect of carbon amendment on the temperature during composting of cattle mortalities

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Abstract

The objective of this research was to evaluate the effect of various carbon amendments on internal pile temperatures during composting of cattle mortalities. A low maintenance approach was used to establish and maintain compost piles constructed of straw, sawdust, woodchips, and sunflower hulls. Pile moisture content and temperatures were monitored for the duration of the heating cycle of the compost pile. The sawdust and straw piles were able to reach optimum moisture contents above 50%, while the woodchip and sunflower hull piles did not. The sawdust and sunflower hull compost piles took on average 30 days to reach optimum temperatures above 43ºC. Straw and woodchips took about 50 days to reach their maximum temperatures. The sawdust and sunflower hulls maintained higher and more stable temperatures than the straw and woodchip piles. Approximately seven months after construction the compost pile temperatures returned to ambient air temperature and at this time the piles were turned. Examination of the piles showed that of the cattle carcasses only bones and patches of hide remained. Fecal coliforms and salmonella counts in all the compost piles were below the limits stated by the Composting Council of Canada except for the woodchip pile that had a high fecal coliform count. Based on temperature and moisture content sawdust performed the best as a mortality composting amendment.
Keywords. Compost, Amendment, Cattle, Temperature, Moisture

INTRODUCTION

The *Livestock Manure and Mortalities Management Regulation (MR 42/98)* requires that livestock mortalities in Manitoba be disposed of in a timely manner by either rendering, incineration, burial, or composting. Due to issues of biosecurity and cost, rendering and incineration are not viable options for many producers. Burial is not possible during winter months and is only allowed in areas with low water tables. Composting animal mortalities is a practical solution that is more commonly used by poultry and swine producers since the animals are smaller, they decompose faster, and deaths are more frequent. Increasing interest in composting larger livestock has prompted research to be done in order to adapt mortality composting techniques to the cattle industry. Differences arise due to larger carcasses that take longer to decompose and only approximately 2% of cattle die per year per farm.

Composting is the breakdown of organic material by microbes. To establish and maintain a microbial population in the compost pile there must be moisture, oxygen, carbon to provide energy, and nitrogen used for cell growth. Mortality composting requires these same elements and can be described as "above ground burial in a biofilter with pathogen kill by high temperatures" (Keener and Elwell 2003). The animal carcass, which provides moisture and nitrogen, is placed in contact with an amendment that provides carbon and allows for airflow. The amendment also acts as the biofilter material that absorbs odour and retains heat generated by the microbes. To achieve optimal conditions for mortality composting Keener et al. (2000) recommend a carbon to nitrogen ratio (C: N) of 25:1 to 40:1, a water content of 50%, and an amendment with a particle size that provides a porosity of 35 to 45%. In order to determine if optimum conditions are being met internal pile temperatures are measured since temperature is a key indicator of the state of the composting process (Fonstad et al., 2003). The highest rate of decomposition occurs at temperatures in the range of 43 to 66ºC while pathogen kill may be achieved if temperatures rise above 55ºC for three consecutive days (Keener and Elwell 2003). Since moisture content affects microbial activity and airflow it directly influences pile temperature and is also useful to monitor.

This study adopted a low maintenance approach to mortality composting which eliminated carcass processing, manual addition of moisture, frequent turning of the piles, and use of an enclosure. Saqib et al. (2003) employed this approach since it requires a minimum amount of labour, which is necessary for it to be adopted as a disposal method at the farm level.

The objective of this research was to adopt a low maintenance approach for composting cattle mortalities. The specific objectives were to investigate the effect of carbon amendments on compost pile temperatures, moisture contents, and to examine the risk associated with pathogens. Pile leaching potential will also be studied.

MATERIALS AND METHODS

Composting sites

In the spring of 2004, compost piles were constructed at four farms in southern Manitoba located near the communities of Austin, Pansy, Killarney, and Boissevain. In compliance with *The Livestock Manure and Mortalities Management Regulation 42/98* compost piles were located at least 100 m from any water source.

Experimental design

The protocol for this project adopted the low maintenance approach used by Saqib et al. (2003). A static pile was built that contained one unprocessed carcass, no moisture was manually added, no enclosure was required, and once established the piles were not turned until internal pile temperatures returned to ambient air temperature.

The treatments studied included different amendments (straw, sawdust, woodchips, and sunflower hulls) and liner requirement (liner and no liner). Since the *Livestock Manure and Mortalities Management Regulation (MR 42/98)* states that composting of mortalities cannot contribute to soil or water pollution a liner would be used to investigate potential leaching from the compost piles. Compost piles constructed of every treatment could not be done at each site due to the inability to produce the necessary number of deads. Table 1 lists the amendments used at each site.

Table 1. Carbon amendment used to construct pile, use of liner, initial C: N ratio of amendment, size of carcass and pile dimensions for compost piles, 2004.

Site	Pile Number	Treatment	C: N Ratio	Carcass Size		Pile Dimensions
				Weight (kg)	Dimensions (m)	(m)
Austin	1	Straw (liner)	124	453	2.4 x 1.5 x 0.6	3.6 x 2.7 x 1.8
		Sawdust (liner)	>450	544	2.6 x 1.5 x 0.7	3.2 x 2.1 x 1.5
Pansy	1	Straw (liner)	97	270	1.7 x 1.2 x 0.5	2.9 x 2.4 x 1.7
	2	Straw (no liner)	97	270	1.7 x 1.2 x 0.5	2.9 x 2.4 x 1.7
	3	Sawdust (liner)	>450	270	1.7 x1.2 x 0.5	2.6 x 1.8 x 1.2
	4	Sawdust (no liner)	>450	270	1.7 x 1.2 x 0.5	2.6 x 1.8 x 1.2
Killarney	1	Straw (liner)	106	544	2.4 x 1.5 x 0.7	3.6 x 2.7 x 1.9
	2	Straw (no liner)	106	544	2.4 x 1.5 x 0.7	3.6 x 2.7 x 1.9
	3	Woodchip (liner)	54	544	2.4 x 1.5 x 0.7	3.0 x 2.1 x 1.3
Boissevain	1	Sunflower Hulls (liner)	33	317	2.1 x 0.9 x 0.6	2.7 x 1.5 x 1.4

Pile Construction

All compost piles were constructed using the same basic steps demonstrated in Fig. 1:

1. For piles with a liner, a heavy polyethylene plastic sheet measuring 2.6 m wide and approximately 3.5 m long (9 x 12 ft) was placed on the ground (a). Piles without a liner the amendment would be laid directly on the unprotected ground surface.
2. An amendment base to collect liquids released during carcass decomposition and provide aeration underneath the carcass was constructed on the liner or on unprotected ground (Keener et al. 2000). The area of the base was large enough to ensure a sufficient perimeter around the animal when it was placed in the centre of the pile (b).
3. The carcass was then covered with more amendment to control odour and retain heat (c). Completed construction of straw and sawdust piles are shown in (d). Final dimensions of the pile were dependent on carcass size (Table 1).

Figure 1. (a) Placement of the heavy polyethylene plastic liner on the ground, 2004. (b) Measuring to ensure that carcass placed on pile base has a sufficient perimeter of straw around it, 2004. (c) Manually shoveling sawdust onto pile to ensure complete coverage of carcass, 2004. (d) Four constructed compost piles at the Pansy site, 2004.

Straw Compost Pile Using the compost recipe from the NRAES –114 *Field Guide to On-Farm Composting* (Dougherty 1999), the amount of straw required to provide a C: N ratio of 30:1 was found to be 1.5 kg of straw to 1 kg of carcass. Round straw bales weighing approximately 454 kg/bale were used at all sites. Moisture was not added to the pile in keeping with the low maintenance approach. Construction of the compost pile began by breaking up the bale to form a 0.6 m (2 ft) deep base. The area of the base was large enough to provide a 0.6 m border of straw on all sides of the carcass that was placed in the centre of the pile. The remainder of the first bale and half of a second were used to cover the carcass with 0.6 m of straw needed for odour and scavenger control.

Sawdust Compost Pile Due to the high C: N ratio of sawdust (>450), the amount of amendment needed to achieve a desired C: N ratio of 30:1 would not be enough to sufficiently cover the carcass for odour and scavenger control. Therefore, the amount of sawdust required for each compost pile was determined by ensuring adequate coverage with the least amount of sawdust possible. The sawdust piles were constructed by forming a 0.5 m (1.5 ft) high base that would provide a 0.3 m (1 ft) perimeter around the carcass and cover the animal with 0.3 m of amendment.

Woodchip Compost Pile The C: N ratio for the woodchip amendment was 54. Although the compost recipe determined that a pile C: N ratio of 30:1 could be larger, a 0.3 m high base, with a 0.3 m border around the carcass and a 0.3 m covering of woodchips was used do to limited available woodchips on site. This amount of amendment would be sufficient to provide odour and scavenger control.

Sunflower Hull Compost Pile The sunflower hulls had a C: N ratio of 33. Since this ratio is low the compost recipe could not be used to determine the amount of amendment required for a pile C: N ratio of 30:1. The amount of amendment needed would make a compost pile that would be unreasonably large. Therefore the amount of amendment used to construct the sunflower pile was determined by sufficient coverage of the carcass to provide odour and scavenger control. A 0.5 m high base with a 0.3 m border around the carcass was constructed. The carcass was then covered with 0.3 m of sunflower hulls.

Pile enclosures

Although no enclosure was originally planned, a panel fence was needed to prevent livestock from disturbing the compost piles at the Pansy site. At the Austin and Killarney sites a wire mesh was pegged over the piles to prevent access to the carcass by scavenging animals.

Measurements

Measurements were done at all composting sites to evaluate the composting process, by monitoring pile moisture content and temperature. The final compost material was analysed for the presence of pathogens.

Moisture content The moisture content of the compost piles was monitored to determine if the low maintenance approach provided enough water to maintain the composting process. Pile moisture readings were taken at M1 and M2 (Fig. 2 (a)).

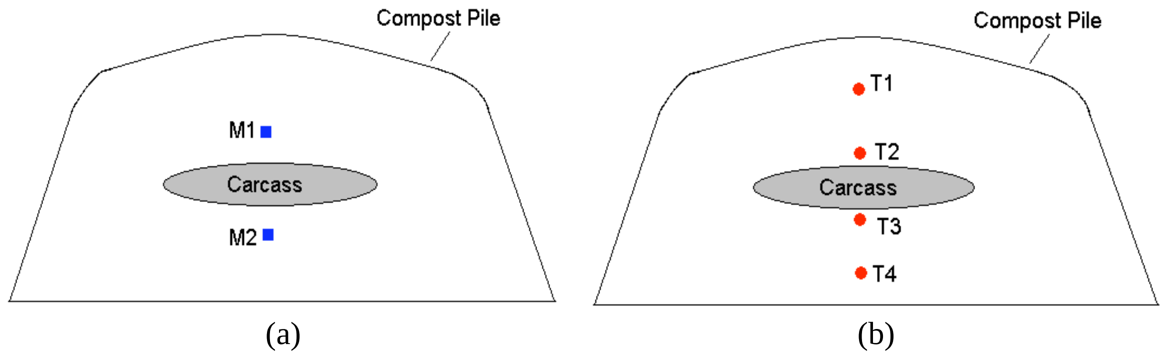

Figure 2. Cross-section of compost pile showing the positions where (a) moisture content readings and (b) temperatures were taken, 2004.

Continual and manual monitoring was done to collect moisture content data. The Pansy and Boissevain site were continually monitored with a data acquisition system (DAS). The system was comprised of a CR10X datalogger and PC208 Datalogger Support Software from Campbell Scientific. The moisture content in each pile was taken at position M1 using a CS615 Water Content Reflectometer from Campbell Scientific. At Boissevain, moisture readings were taken at both M1 and M2 positions with two ECH$_2$O Soil Moisture Probes manufactured by Decagon Devices Inc. Moisture content readings were taken every four hours and the data was downloaded to a laptop computer every two weeks.

Manual moisture readings were taken at M1 and M2 for the piles at the Austin and Killarney sites using a SW16136 Digital Hay Tester from John Deere and a probe thermometer. Data was collected on a bi-weekly schedule.

Temperature Pile temperatures were taken midway through the base at position T4, below the carcass at T3, above the carcass at T2, and in the middle of the cover at T1 (Fig. 2 (b)). The Pansy and Boissevain sites were continually monitored using the DAS. Temperature readings at the Pansy site were measured using copper/constantine thermocouple wires. Temperatures were taken at Boissevain site with four 107B Soil/Water Temperature Probes from Campbell Scientific. Readings were recorded every four hours and downloaded to a laptop computer.

Manual temperature monitoring was done on a bi-weekly schedule at the Austin and Killarney sites using the digital hay tester and a probe thermometer.

Pathogen kill A sterile sample of the final compost was collected from each pile from 10 different locations throughout the pile. Composite samples were sent for analysis to Norwest Labs to test for salmonella and fecal coliforms.

Turning the Compost Pile

When internal pile temperature readings returned to outdoor ambient air temperature the compost piles were turned using a front-end loader. An internal examination of the pile was done by manually digging into the pile to see what state of decomposition the carcass was at.

Soil Conditions

Soil samples will be taken with a soil core sampler to a depth of 1.2 m (4 ft) from directly below the pile and from the surrounding site area to determine if leaching occurred.

RESULTS AND DISCUSSION

Moisture Content

Moisture content data analyzed in this section of the report was taken at position M1 (Fig. 2 (a)) as readings were taken at this point in all compost piles at all sites. Weather data was obtained from Environment Canada’s National Climate Data and Information Archive (2004).

Austin Weather data used for the Austin site was taken from the Carberry weather station for 2004. The amount of precipitation received during the composting time period was plotted against the moisture content measurements taken from the straw and sawdust piles (Fig. 3). The pile moisture contents were influenced by precipitation and fluctuated accordingly. Both amendments experienced moisture contents within the optimal composting range of 50-60%. However, the sawdust maintained moisture levels within the optimum range for more days then the straw.

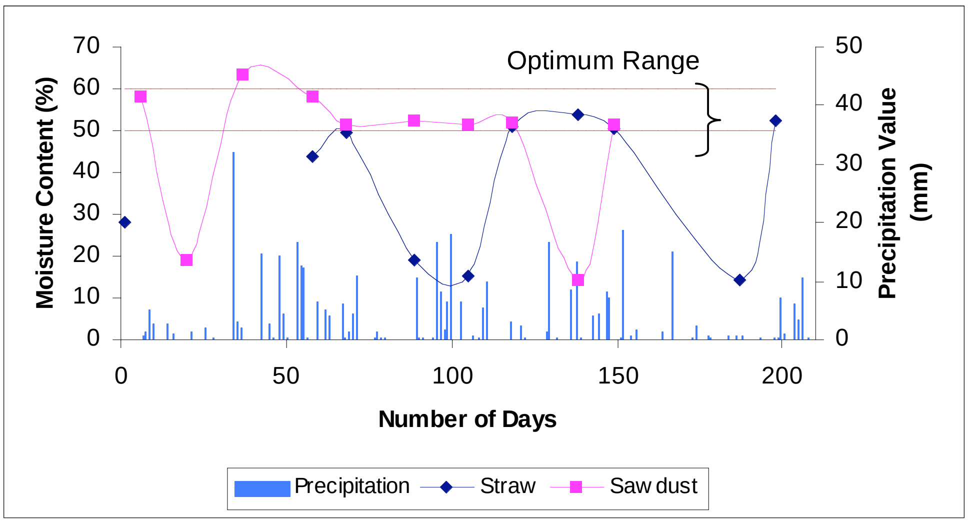

Figure 3. Moisture content readings taken at position M1 for straw and sawdust compost piles compared to annual precipitation for the Austin site, 2004.

Pansy Moisture content measurements for straw and sawdust compost piles, with and without liner, were compared to precipitation levels taken from the Steinbach weather station for 2004 (Fig. 4). The sawdust piles had higher moisture contents than the straw and were able to retain the moisture for longer periods. All piles were able to reach the 50-60% optimum range suggested for composting.

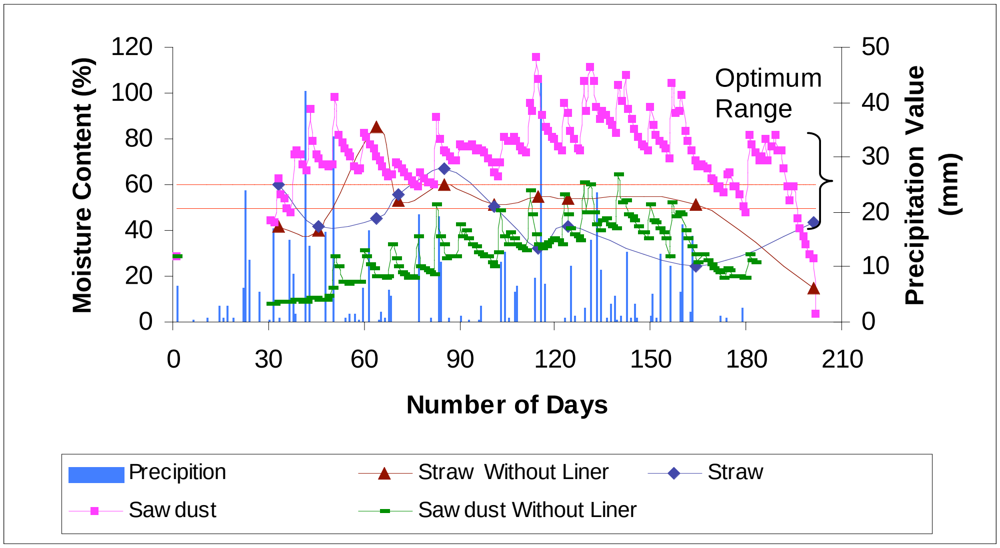

Figure 4. Moisture content readings measured at M1 position in straw, straw without liner, sawdust and sawdust without liner compost piles compared to annual precipitation for Pansy site, 2004.

Killarney Annual precipitation levels for the Killarney area for 2004 were graphed with the moisture contents of the compost piles at the Killarney site (Fig. 5). The moisture contents of the straw with liner, straw without liner, and woodchip compost piles appeared to fluctuate in accordance to the fall of precipitation. Both straw compost piles attained moisture contents within the optimal composting range.

Boissevain Due to the location of the Boissevain site, precipitation levels for the Killarney area were compared to the moisture contents of the piles (Fig. 5). The sunflower hull pile had lower than optimum moisture levels, which could be due to the oiliness of the sunflower seed mixed throughout the hulls.

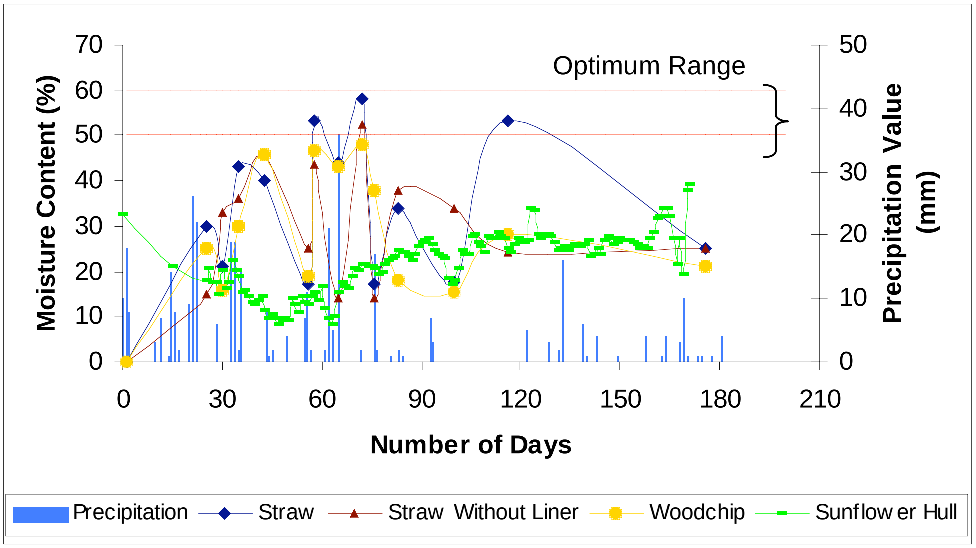

Figure 5. Moisture content data measured at M1 position in straw, woodchip and sunflower hull compost piles compared to annual precipitation for Killarney and Boissevain sites, 2004.

Temperature

The internal temperatures of each compost pile were monitored until they reached ambient air temperature. Temperature readings recorded at noon taken at position T2 (Fig. 3) were plotted against the number of days the carcass was composted. The temperatures at T2 were used for the comparison, as they were most representative of the temperature generated by the composting process. Noon was chosen, as this was the approximate time of day that temperatures for the manually monitored piles were taken.

Austin The maximum temperatures recorded for the straw and sawdust piles were 42 and 43 °C respectively (Fig. 6). The optimum temperature range at which the highest rate of decomposition occurs is 43-66°C (Keener and Elwell 2003), which was achieved by the sawdust pile. The sawdust pile heated to maximum temperature faster (40 days) than the straw pile (60 days) and maintained higher temperatures than the straw pile.

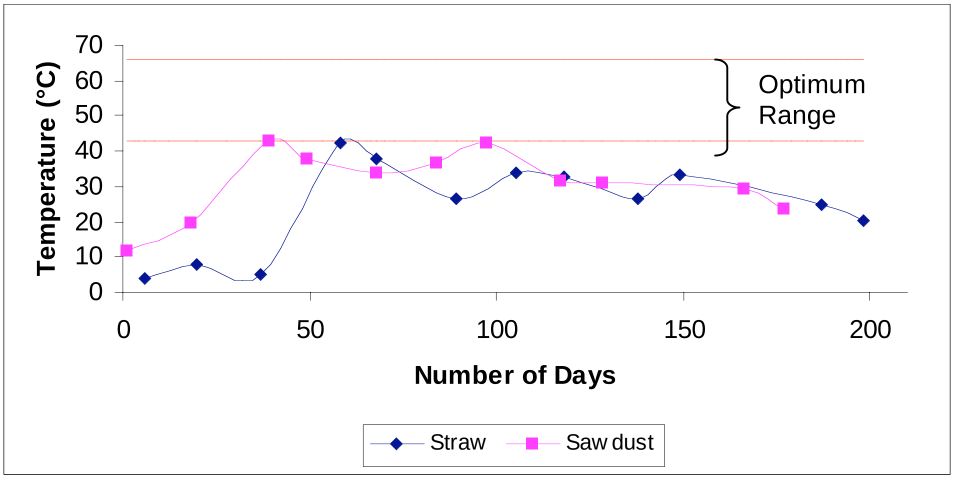

Figure 6. Temperature measurements taken at pile position T2 for the straw and sawdust compost piles at the Austin site, 2004.

Pansy All compost piles achieved temperatures between 43-66°C which is in the optimum range for composting (Fig. 7). The sawdust pile with liner was the first to reach a maximum temperature of 54°C on day 19. The straw pile without a liner reached a maximum temperature of 60°C on day 49. The sawdust without liner and the straw with liner pile both attained maximum temperatures of 51°C on day 50 and 53 respectively. The straw pile without liner was able to maintain temperatures above 55°C for three consecutive days required for pathogen kill (Keener and Elwell 2003).

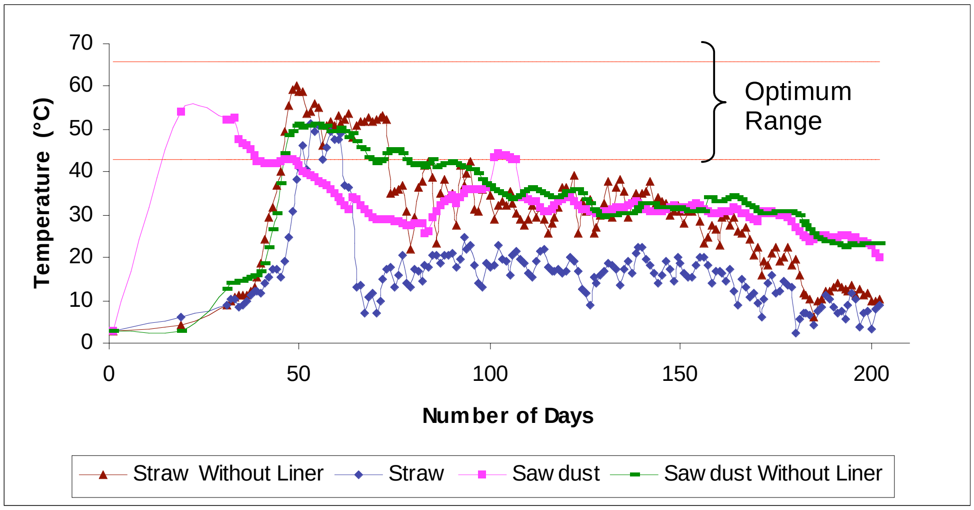

Figure 7. Temperature measurements taken at position T2 for straw, straw without liner, sawdust and sawdust without liner compost piles constructed at the Pansy site, 2004.

Killarney Measurements of the compost pile temperatures from the Killarney site is shown in (Fig. 8). The straw, straw without liner, and woodchip piles followed very similar temperature patterns over the duration of composting. All piles reached their peak temperature at about 60 days.

Boissevain The sunflower hull compost pile achieved optimum temperatures in 26 days and reached temperatures above 55°C required for pathogen kill (Fig. 8).

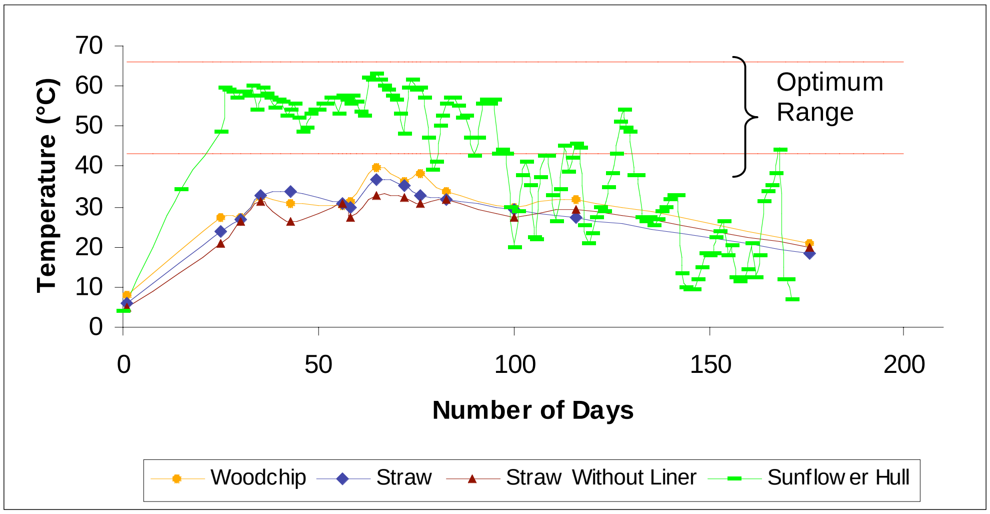

Figure 8. Temperature measurements taken at position T2 for straw, straw without liner, woodchip and sunflower hull compost piles constructed at Killarney 1 and Boissevain sites, 2004.

Pathogen Kill

Standards outlined by the Composting Council of Canada (1998) state that the quantity of fecal coliforms present in compost must be <1000 Most Probable Number (MPN)/g of total solids calculated on a dry weight basis and there can be no salmonella present (<3 MPN/4 g total solids). Analysis of the final compost demonstrates that all samples were negative for salmonella (Table 2). Fecal coliform levels in all straw and sawdust compost piles are below the set standards. Only the woodchip compost pile showed an unacceptable quantity of fecal coliforms,

>1100 MPN/g. Results for the sunflower hull compost pile were not available, as cattle that had broken through a fence destroyed the pile.

Table 2. Salmonella and fecal coliform levels for the final compost material from cattle mortality compost piles, 2004.

Site	Pile Number	Pile	Salmonella (Positive/Negative)	Fecal Coliforms (MPN/g)
Austin	1	Straw (liner)	Negative	<3
	2	Sawdust (liner)	Negative	<3
Pansy	1	Straw (no liner)	Negative	9.2
	2	Straw (liner)	Negative	23
	3	Sawdust (no liner)	Negative	<3
	4	Sawdust (liner)	Negative	<3
Killarney	1	Straw (no liner)	Negative	<3
	2	Straw (liner)	Negative	15
	3	Woodchip (liner)	Negative	**1100**
Boissevain	1	Sunflower Hull (liner)	N/A	N/A

Compost Pile Turning

Compost piles were turned when internal pile temperatures reached outdoor ambient air temperature. At this time no heat generation indicated that the composting process had stopped.

Austin The compost piles at the Austin site were turned approximately seven months (198 days) after pile construction. No odour was detected except for a faint ammonium smell released from the sawdust pile. Internal examinations of both the straw and sawdust piles showed that only bones and patches of hide remained of the cattle carcasses. The bones found were solid, strong, and not brittle. Nine days after turning the piles temperatures measurements were taken. While the straw pile showed no increase in temperature the sawdust pile reading was 51°C, which indicated renewed composting within the pile.

Pansy The compost piles at the Pansy site were turned approximately seven months (202 days) after construction. Before turning the piles with a front-end loader they were examined internally and the temperature and moisture probes were removed. No odour was detected when turning the sawdust piles though was quite noticeable when turning the straw piles. In all piles only bones and patches of hide remained. The bones in the straw piles were solid and strong. The bones in the sawdust piles appeared charred and some were brittle enough to break. Temperature probes were put back into the piles to determine if turning the pile would reactivate composting. However, it was difficult to insert the thermocouple wires into the piles and no temperature readings registered with the datalogger.

Killarney The compost piles at this site were turned about six months (176 days) after the piles were constructed. The piles were examined internally prior to turning with the front-end loader. No odour was detected upon turning the piles. Again all that remained of the carcasses were strong, solid bones and some hide. Manual temperature measurements taken 18 days after turning the piles showed no heat generation.

Boissevain The sunflower hull pile at this site was not turned and no final compost samples were taken since the pile was destroyed when cattle got into the pile area. The pile was demolished about one week before it was to be turned.

CONCLUSION

Approximately seven months after straw, sawdust, woodchip, and sunflower hulls were used to construct cattle mortality compost piles, an inspection showed that only bones and some hide remained of the carcasses. This indicated that a low maintenance approach to composting was successful. The only problem encountered with this approach was pile disturbance from scavengers and livestock, which made an enclosure necessary.

Precipitation and amendment porosity provided sufficient moisture for sawdust and straw compost piles to reach optimum moisture contents above 50%. The woodchip and sunflower hull piles did not achieve optimum levels.

The sawdust and sunflower hull compost piles showed a quicker rise in temperature taking on average about 30 days to reach optimum temperatures above 43ºC. The straw and woodchip piles took about 50 days to reach their maximum temperatures. The sawdust and sunflower hulls were also able to maintain higher and more stable temperatures than the straw and woodchip piles. Fecal coliform and salmonella counts for all piles except the woodchip pile were within the composting standards for Canada. Overall based on temperatures and moisture contents achieved and maintained and pathogen counts, sawdust performed the best as a mortality composting amendment.

Results from static compost piles containing one carcass per pile were reported in this research paper. Further studies are being conducted with piles containing two carcasses as well as windrow piles in an attempt to improve C: N ratios and enhance the composting process. Additional testing of a straw/sawdust mixture and compost material as carbon amendments are being tested. Soil sampling to investigate the potential of pile leaching is also being done.

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