# Moisture and temperature distribution in cattle mortality composting on the farm

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Genaille, M., Y. Chen and V. Doan. 2009. **Moisture and temperature distribution in cattle mortality composing on the farm**. Canadian Biosystems Engineering/Le génie des biosystèmes au Canada. 51: 6.23–6.33. Composting livestock mortalities is an environmentally sound and biosecure means of waste management. A 2-year study on cattle mortality composting was conducted on four farms in Manitoba in 2004 and 2005. A total of 20 static compost piles with 24 carcasses were constructed with either straw, sawdust, woodchip, or sunflower seed hull as carbon amendment, and with or without a bottom plastic liner. Temperature and moisture content (MC) were monitored at four different layers in each pile during 7 months. Nutrients in the soil beneath the pile were analyzed to assess the effect of a liner on leaching. Results showed that the pile temperature ranged from 10 to 60°C and MC ranged from 10 to 80%. Differences in MC and temperature were observed among the layers in a pile. Several factors affected the trends, such as weather condition, amendment type, and location inside the pile. Among the amendments used, sawdust resulted in the most suitable pile temperatures and MC during the composting process. The presence of a second carcass did not require additional amendment and increased temperature. For the straw amendment, the plastic liner resulted in reduced nutrient levels in the soil, which was observed only in 2 out of 15 cases. For the sawdust amendment, the plastic liner did not make any differences in the soil nutrient. **Keywords:** Composting, carcass, cattle, temperature, moisture, liner, static, soil, carbon, amendment.

Le compostage des animaux d'élévage est une méthode écologiquement rationnelle et biosécuritaire de gestion de ces déchets agricoles. Une étude de deux ans sur le compostage de mortalité de bovins a été menée sur quatre exploitations au Manitoba en 2004 et en 2005. Un total de 20 piles de compost statique avec 24 carcasses ont été construites avec soit de la paille de céréale, de la sciure de bois, ou des enveloppes de graines de tournesol comme source de carbone, et puis avec ou sans bâche de plastique sous la pile. La température et l'humidité (MC) ont été suivies sur quatre couches différentes dans chaque pile pendant sept mois. Les teneurs en éléments nutritifs dans le sol sous la pile ont été analysés afin d'évaluer l'effet de la bâche de plastique sur le lessivage de contaminants. Résultats ont montré que la température dans les piles varie de 10 à 60°C alors que la MC varie de 10 à 80%. Les valeurs de température et MC diffèrent selon la position dans les piles. Plusieurs facteurs affectent les tendances, telles que les conditions météorologiques, la source de carbone et l'emplacement à l'intérieur de la pile. Parmi les sources de carbone utilisées, la sciure de bois favorise les conditions les meilleures en termes de température et MC de la pile au cours du processus de compostage. La présence d'une seconde carcasse ne requiert pas plus de carbone et augmente la température dans la pile. Lorsque de la paille de céréales était utilisée, une bâche en plastique a réduit la teneur en éléments nutritifs dans le sol sous la pile, phénomène observé uniquement dans deux des quinze cas. Avec de la sciure de bois, la bâche de plastique n'a apporté aucune différence dans les teneurs en éléments nutritifs du sol. **Mots clés:** Compostage, carcasse, bétail, température, humidité, doublure, statique, sol, carbone, amendement.

## INTRODUCTION

Animal mortalities are a normal occurrence experienced by all livestock operations. Methods of static pile, windrow, bin, and in-vessel have been adopted as a means of composting poultry, swine, and sheep mortality (McCaskey et al. 1996; Sherman-Huntoon 2000; Stanford et al. 2000). Static compost piles simply involve stacking feedstock to create a pile, which allows passive air movement (Rynk 1992). This type of composting structure can be freestanding without turning the pile during the composting process. Windrows are used to compost a large number of carcasses, such as laying hens (Nelson et al. 2003). Permanent bin structures were used for small to medium sized mortalities for the benefit of more controlled environment (Morse 2001). Various in-vessel structures, such as rotating drums, were used for a fast composting rate (Plana et al. 2001; Mohee and Mudhoo 2005). Windrows, bins, and in-vessel structures are usually turned several times during the composting process, which may require special equipment. The static pile method has the advantage of lower initial and maintenance cost.

This study aimed to develop a composting approach for small cattle operations, which must be economical and require minimal time and effort. Furthermore, the duration taken by the composting process is not crucial for those operations. The static pile method meets these requirements. This simple approach has been widely used for mortality composting such as for poultry (Gonzalez and Sanchez 2005), swine (Fondstad et al. 2003), and, lately, cattle in south-western Ontario (Fleming and MacAlpine 2006). In a static compost pile, intact carcasses are placed between layers of amendment in a ''sandwich'' formation (Keener et al. 2000). Animal carcasses provide nitrogen, and the amendment provides carbon and aerobic conditions. Commonly used amendments for on-farm composting include straw and sawdust (Laibach and Bonhotal 2004; Ahn et al. 2005) with straw being the most common, as it is readily available. Various other materials, such as corn silage and solid manure have also been used for on-farm mortality composting when they were available at the farms (Fleming and MacAlpine 2006).

The main factors affecting the composting process are oxygen, moisture content, carbon to nitrogen ratio (C:N), and temperature. Keener et al. (2000) recommend a porosity of 30 to 50% and a C:N of 25 to 40. A feasible moisture range is 40–60% (Glanville and Trampel 1997; Keener et al. 2000). Keener and Elwell (2003) reported that the highest rate of decomposition occurred at temperatures in the range of 43–66°C. Temperature and moisture are usually monitored in compost piles to examine if conditions are suitable for the composting process. Fleming and MacAlpine (2006) placed two thermocouple probes into the pile at a depth of 1 m to monitor the internal compost temperatures, and reported that temperature readings in the static compost piles may be affected by the placement of the temperature probes in the pile. In a trial of composting cattle and horse carcasses in a bin structure made of straw bales (Mukhtar et al. 2003), the temperatures above the carcasses exceeded 55°C and those below were even higher. Murphy et al. (2004) reported a moisture content of 64% on the outside of the pile and 21% near the carcass. Those uneven distributions of pile temperature and moisture are due to the sandwich structure of the static piles (Lawson and Keeling 1999). Therefore, both temperature and moisture should be monitored at different layers of the pile.

To date, little research has pertained to the composting of cattle mortality using the static pile method. The limited research data were mostly collected in the United States and the Province of Ontario, Canada, and no data were collected under Manitoba conditions. Fewer research data were available for the layered structure of static piles in cattle mortality composting. The objectives of this research were to study: (1) the moisture and temperature distributions throughout different layers of static piles, and (2) the effects of different carbon amendments on the pile moisture and temperature. Investigations were also carried out on the necessity of a liner beneath a static pile in preventing it from leaching, and the effects of the number of carcasses per static pile on the pile moisture content and temperature.

## MATERIALS and METHODS

### Composting site description

Composting trials were conducted at four farms in Manitoba near the communities of Austin (Central region), Pansy (Eastern-interlake region), Killarney (Southwest region), and Pilot Mound (Central region) in 2004 and 2005. Trials began in the spring (April–May) of each year and ended in late fall (October–November).

### Experimental design

Experiments were designed with the purpose of studying ifferent amendments, the necessity of using a liner, and the effect of the number of carcasses per pile (Table 1). Straw was used as a carbon amendment, as it is readily available on farms. Sawdust was used due to its better performance reported in the literature and its availability in Manitoba. Woodchips and sunflower seed hulls were tested because of their local availability. At sites where there was a sufficient number of mortalities to build two piles of the same amendment, one pile was built on a liner of polyethylene plastic sheet 15 mm thick (L) and the other was built on the ground as control (NL). In 2005, and with more carcasses available at the Pansy site, compost piles were constructed with either one carcass/pile (1C) or two carcasses/pile (2C). Due to the limited number of mortalities at the farms, not all treatments could be carried out at each farm. A total of 20 static compost piles with 24 carcasses were built at the four farms during 2004 and 2005. The intention was to compare effects of different amendments within a site, not between sites.

### Characteristics of the feedstock

The size of the carcasses at the Pansy site was approximately $1.8 \times 1.2 \times 0.6$ m (length $\times$ width $\times$ height), each weighing approximately 270 kg. The sizes at the other sites were larger, each measuring approximately $2.4 \times 1.5 \times 0.75$ m, and weighing approximately 525 kg. The properties of the amendments, which are crucial to composting, are listed in Table 2. They were determined from the laboratory analysis. Initial moisture content (MC), the total carbon (TC) and total nitrogen (TN) were highly variable among the amendments.

### Construction of the compost piles

To prevent odours and deter scavengers, all pile carcasses were covered with a layer of amendment 0.3–0.6 m thick. According to the properties of the amendment, together with the assumptions that a cattle carcass had a TC of 37.5%, a TN of 7.5%, and a MC of 75% (Keener et al. 2000), the estimated overall pile C:N ratios were generally higher, ranging from 30 to 60 for the straw piles, from 130 to 300 for the sawdust piles, 39 for the woodchip pile, and 21 for the sunflower seed hull pile. Since the animal carcass is not homogeneously mixed with the amendment in a static pile, composting occurs only around the carcass, implying that only the carbon around the carcass would be used in the composting process. Therefore, the overall C:N ratio of the entire pile in a static pile is not as critical as in a homogeneously mixed compost pile. Fulhage (2000) reported that the proper coverage of carcasses may create extremely high C:N ratios that do not appear to limit composting other than to increase its process time.

All the compost piles were constructed using the following basic steps: (1) laying the liner if applicable (Fig. 1a); (2) building the base layer of amendment on the liner or on the bare ground (Fig. 1b); (3) placing the carcass or carcasses in the centre of the base (Fig. 1c), and; covering the carcass or carcasses with amendment (Fig. 1d). Figure 2a, b shows how carcasses were laid in piles. Overlapping of the legs in the 2C treatment created a larger body mass without taking extra space, to low the overall C:N by increasing the TN of the pile without significantly increasing the amount of amendment.

**Table 1. Description of treatments at all sites.**

| Year | Site | Amendment | Liner* | Number of carcasses** | Pile number | Purpose |
|---|---|---|---|---|---|---|
| 2004 | Austin | Straw | L | 1C | 1 | Piles 1 and 2 compared amendment effects |
| | | Sawdust | L | 1C | 2 | |
| 2004 | Killarney | Straw | L | 1C | 3 | Piles 3 and 4 compared liner effects; |
| | | Straw | NL | 1C | 4 | Piles 3, 5, and 6 compared amendment effects |
| | | Woodchips | L | 1C | 5 | |
| | | Sunflower seed hull | L | 1C | 6 | |
| 2004 | Pansy | Straw | L | 1C | 7 | Piles 7 to 10 compared both amendment and liner effects |
| | | Straw | NL | 1C | 8 | |
| | | Sawdust | L | 1C | 9 | |
| | | Sawdust | NL | 1C | 10 | |
| 2005 | Pansy | Straw | L | 1C | 11 | Piles 11 to 14 compared both amendment and liner effects; |
| | | Straw | NL | 1C | 12 | Piles 11 to 18 compared effects of the number of carcasses per pile |
| | | Sawdust | L | 1C | 13 | |
| | | Sawdust | NL | 1C | 14 | |
| | | Straw | L | 2C | 15 | |
| | | Straw | NL | 2C | 16 | |
| | | Sawdust | L | 2C | 17 | |
| | | Sawdust | NL | 2C | 18 | |
| 2005 | Pilot Mound | Straw | L | 1C | 19 | Piles 19 and 20 compared amendment effects |
| | | Sawdust | L | 1C | 20 | |

*L and NL stand for with and without a plastic liner underneath the pile, respectively;
**1C and 2C stand for composting one carcass and two carcasses per pile, respectively.

The final dimensions of the piles are listed in Table 2. The compost piles were not turned before the end of composting trial. A temporary fence made of used steel panels was built to prevent livestock from disturbing the pile at the Pansy site. At the other sites, a wire mesh (100 mm) was pegged over the piles to prevent scavengers. These solutions minimized costs.

**Measurements**

Data were collected in four different layers of a pile. The locations monitored for temperature were designated as T1, T2, T3, and T4, and those monitored for MC were designated as M1, M2, M3, and M4 (Fig. 2c). The locations T1 and M1 were in the middle of the covering

**Table 2. Initial moisture content (MC), total carbon (C), and total nitrogen (N) of the carbon amendments (feedstock).**

| Year | Site | Amendment | MC (%) | C (%) | N (%) | Pile length × width × height (m) |
|---|---|---|---|---|---|---|
| 2004 | Austin | Straw | 28.3 | 12.6 | 0.3 | 3.6 × 2.7 × 1.5 |
| | | Sawdust | 40.0 | 26.3 | 0.1 | 3.6 × 3.3 × 1.5 |
| 2004 | Killarney | Straw | 9.6 | 10.1 | 0.1 | 3.6 × 2.7 × 1.4 |
| | | Woodchips | 31.3 | 33.9 | 0.4 | 3.6 × 2.7 × 1.4 |
| | | Sunflower seed hull | 6.1 | 31.2 | 0.1 | 3.2 × 2.7 × 1.2 |
| 2004 | Pansy | Straw | 10.8 | 12.3 | 0.1 | 3.5 × 2.5 × 1.5 |
| | | Sawdust | 47.2 | 26.2 | 0.1 | 3.5 × 3.6 × 1.2 |
| 2005 | Pansy | Straw | 14.8 | 41.8 | 0.5 | 3.4 × 2.2 × 1.2 |
| | | Sawdust | 31.2 | 46.8 | 0.1 | 3.0 × 2.7 × 1.2 |
| 2005 | Pilot Mound | Straw | 40.8 | 42.7 | 0.9 | 3.7 × 2.4 × 1.2 |
| | | Sawdust | 40.0 | 46.6 | 0.1 | 3.7 × 2.4 × 1.2 |


**Fig. 1. Photos showing the composting pile construction procedure: (a) placing liner, (b) breaking up a round straw bale, (c) laying the straw base and measuring the perimeter after laying carcass, (d) finishing the pile with adequate straw surrounding the carcass.**

layer; the locations T2 and M2 were directly above the carcass; the locations T3 and M3 were directly below the carcass; the locations T4 and M4 were at heights midway through the base layer.

For all the piles at the Pansy sites, temperature was continuously measured using thermocouple wires (copper/constantine) at all four layers. Moisture was continuously measured using a CS615 Water Content Reflectometer (Campbell Scientific, Edmonton, AB) in 2004 and using $ECH_2O$ Soil Moisture Probes (Decagon Devices Inc., Pullman, WA) in 2005. Moisture was monitored at one layer (M2) only, due to the limited number of channels on the datalogger. For the sunflower seed hull pile at the Killarney site, temperature was continuously measured using 107B Soil Temperature Probes (Campbell Scientific) at all four layers, and moisture was continuously measured using the $ECH_2O$ Soil Moisture Probes at two layers (M2 and M3) only. For all these continuously monitoring piles, MC and temperature readings were recorded every 4 hours using the data acquisition system comprising a CR10X datalogger (Campbell Scientific). A solar panel facing south at a 65° angle maintained a charged battery for the datalogger. The data were downloaded to a laptop computer every 2 wk. For the other piles, moisture and temperature were manually monitored at all the layers on a bi-weekly schedule using a SW16136 Digital Hay Tester (John Deere, Moline, IL).

At the end of the trial each year, final compost samples were taken from approximately 10 locations throughout each pile using a sterile glove and container. A composite sample was formed for each pile and sent to Norwest Labs for analysis of salmonella, fecal coliforms, and nutrient contents, including TC, TN, ammonium ($NH_4$), phosphorus (P), sulphur (S), calcium (Ca), potassium (K), magnesium (Mg), and sodium (Na). Soil samples were collected beneath the compost piles to compare the nutrient levels between the L and NL treatments. Samples were taken with a soil core sampler at three locations to a depth of 1.2 m. Soil samples were sent to the laboratory for soil nutrient analysis, including nitrate nitrogen ($NO_3$-N), phosphorus (P), and potassium (K).

## Data analysis

Statistical analysis was performed using SAS 9.1 software (SAS Institute, Inc. 2001). For the continually monitored piles, hourly data readings were pooled to obtain average daily readings. Data were not compared between sites due to the differences in weather condition and time of establishing the piles. For balanced data sets, Fisher's Protected Least Significant Difference (LSD) test was used to compare means. For unbalanced data sets, the means and standard errors were used for indicating significantly different means. All statistical analyses were performed at a $P = 0.1$ significance level.

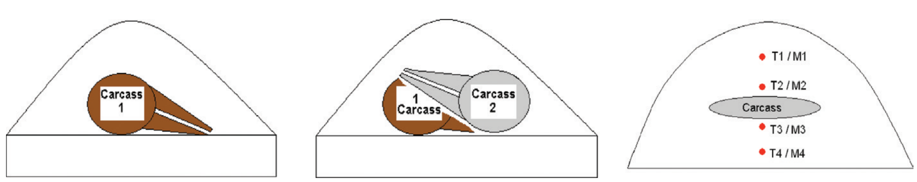


**Fig. 2. Diagram of cross sectional view of composting pile: (a) one carcass per pile (1C), (b) two carcasses per pile (2C), locations for temperature (T) and moisture (M) monitoring.**

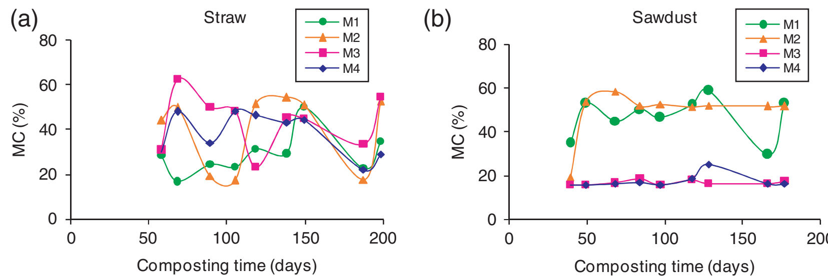


**Fig. 3. Average gravimetric moisture content (MC) taken at the top layer (M1), above carcass (M2), below carcass (M3), and bottom layer (M4) at the Austin site in 2004; (a) straw pile; (b) sawdust pile.**

## RESULTS and DISCUSSION

A large number of data were collected in this study and for more information, readers are referred to Genaille (2006).

### Moisture content

Moisture content from 10 to 80% was observed across the sites. All the piles reached the feasible composting range of 40–60% MC, maintained for the majority of the composting trial. In general, MC of the straw piles fluctuated over the course of the trial, and higher MC was generally seen in the two bottom layers, as shown by the data from Austin site (Fig. 3a). This trend is consistent with the flow of moisture down into the pile due to the large pore spaces in the straw. The top of the pile may have increased entry and evaporation of moisture, which resulted in the lower MC in the top layers for some periods of time. The moisture distribution in the woodchip pile (data not shown) was similar to that in the straw piles, as both amendments were coarser materials, and therefore, had similar aeration conditions. However, no specific trends in MC were found between layers for the woodchip pile. Unlike the straw piles, MC in the sawdust piles fluctuated less over time, and distinct moisture levels within the sawdust piles were observed (Fig. 3b). The upper M1 and M2 layers experienced similar MC maintained constantly in the feasible composting range of 40–60%; the M3 and M4 layers of the pile experienced similar MC ranging from 15 to 25%. At the Pilot Mound site, distinct moisture levels within the sawdust pile were also observed; however, the bottom layer had higher MC than the top layer (data not shown).

When comparing the MC averaged over time within a layer, the straw piles at the Austin and Pilot Mound sites were significantly dry at the top layer and wetter at the bottom layer (Table 3). There were no differences in MC between layers in the straw pile at the Killarney site and in the woodchip pile at the Killarney site. For the sawdust piles, the MC significantly decreased through the depth of the pile profile at the Austin site, and significantly decreases at the pilot Mound site due possibly to the different properties of the feedstock and the weather condition. The small pore size and the absorbent properties of the sawdust may have prevented precipitation from penetrating the lower layers of the pile in Austin, and prevented the moisture in the bottom layers from evaporating in Pilot Mound.

Daily MC fluctuated in different trends for different piles (Fig. 4) and they corresponded to the daily amount of precipitation recorded by Environment Canada weather stations and received near the sites. At the Austin and Pilot Mound sites, the straw and sawdust amendments resulted in a similar range of MC for the majority of the composting trial (Fig. 4a,b). Occasionally, the straw amendment had some peaks or low points of MC explained by the fact that the looser structure of straw was more prone to the weather effect. For the 2004 Pansy site (Fig. 4c), the pile with straw amendment experienced a period of increased moisture before 100 days, due possibly

**Table 3. Means of moisture content at different pile layers.**

| | | Moisture content (% wet basis)* | | | |
|---|---|---|---|---|---|
| Amendment | Site | M1 | M2 | M3 | M4 |
| Straw | Austin | 28.8b** | 38.9a | 43.4a | 38.2a |
| | Pilot Mound | 35.5b | 37.9b | 41.6a | 42.3a |
| | Killarney | 35.7a | 32.3a | 29.9a | 35.5a |
| Woodchips | Killarney | 32.0a | 28.1a | 30.9a | 31.5a |
| Sawdust | Austin | 46.9a | 48.9a | 16.9b | 17.7b |
| | Pilot Mound | 37.4c | 38.6b | 41.6b | 42.4a |

*From the top layer (M1), above carcass (M2), below carcass (M3), and bottom layer (M4). Data were pooled over composting days within the year.
**Means in the same row and followed by the same letter do not differ significantly.

to the liquid released by the carcase during the early stage of composting. The pile with the sawdust amendment had much higher MC over the entire period of the composting trial. This was true for the 2005 Pansy site (Fig. 4d). At this site, increased MC was observed during the period of 20 and 90 days, which corresponded to the frequent bouts of precipitation. Similar moisture trends over time were observed for the straw and woodchip amendments at the Killarney site (Fig. 4e), fluctuating between 15 and 50%, which seemed to be related to the precipitation. In general, the straw amendment resulted in higher MC than with woodchips likely because woodchips did not allow as much water to penetrate into the pile. As compared with the straw and woodchip amendments, the sunflower seed hull gave less variation in MC over the duration of the trial. The stable MC could be due to the oily seeds in the sunflower seed hull, which shed some of the rainfall.

## Temperature

Temperature in a pile also varied over time with temperatures peaking before 15 to 65 days of the composting trial, depending on the site. Temperatures were also highly variable among the layers within a pile and among the amendments within a site. The temperature of 55°C required to kill pathogens was observed for the straw piles at the Austin site, the sunflower seed hull pile at the Killarney site, and the straw and sawdust piles at the 2004 Pansy site.

The temperature distribution throughout the straw pile was fairly uniform among layers as illustrated by the temperature profile at the Pilot Mound site (Fig. 5a). The temperature distribution in the woodchip pile at the Killarney site was similar to that in the straw pile (data not shown). Among all the piles, the sunflower seed hull pile at the Killarney site had the most variable temperature distribution (data not shown). Differences in temperature were seen between the upper and lower layers in the sawdust piles, for example, at the Pilot Mound site (Fig. 5b). An interesting observation was that the T2 or T3 layers near the carcass experienced the higher temperatures than the T1 and T4 layers (Genaille 2006). This occurred in the sawdust pile at the Austin site and the 2004 Pansy site, the sunflower seed hull pile at the Killarney site, and both the straw and sawdust piles at the 2005 Pansy sites. This phenomenon could be due to the increased microbial activity near the carcass, which generated more heat.

Over time and between the layers, average temperatures were significantly different in four out of five straw piles (Table 4). The mean temperature distribution in the woodchip pile followed the trend of T1 > T2 > T3 > T4, while in the sunflower seed hull it appeared to be opposite.

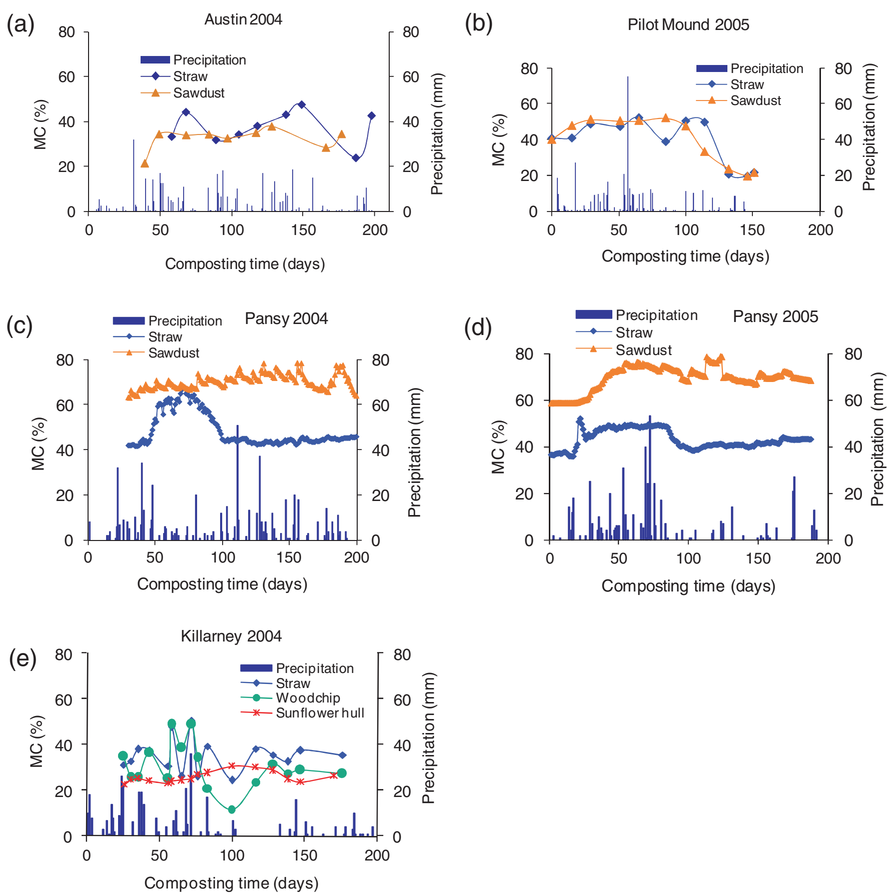


**Fig. 4. Daily gravimetric moisture content (MC) for different amendments: (a) Austin, (b) Pilot Mound, (c) Pansy 2004, (d) Pansy 2005, (e) Killarney.**

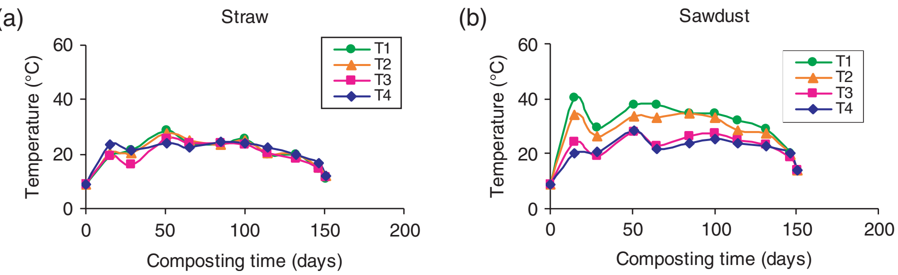


**Fig. 5. Daily temperatures taken from top (T1), above carcass (T2), below carcass (T3), and bottom (T4) layers at the Pilot Mound site; (a) straw pile; (b) sawdust pile.**

For the sawdust piles, the trend showed a lower temperature at the bottom of the piles than the other layers within the pile.

Daily temperatures in all piles remained above the ambient temperature recorded at Environment Canada weather stations for each area. (Fig. 6). This demonstrated that heat was generated in the pile, attributed to the composting process. Sawdust as an amendment caused the pile temperature to rise more quickly in the early spring when compared with straw (Fig. 6a), although the cattle carcass placed in the pile was frozen. While the weather was warming up, the temperature of the straw amendment increased quickly reaching about 45°C on day 58. Using the straw amendment, pile temperatures appeared to fluctuate corresponding to the fluctuations of the ambient temperature. At the Pilot Mound site, although the start temperature of the sawdust was lower than that of the straw, the temperature of the sawdust increased rapidly and remained higher than that of the straw during the course of the trial (Fig. 6b). The temperatures remained fairly stable for the duration of the composting trial for both the straw and sawdust amendments. Results from the 2004 and 2005 Pansy sites further demonstrated that the pile temperature at the start increased more quickly using sawdust as amendment than using straw (Fig. 6c,d). The higher temperature of the sawdust amendment persisted during the entire composting trial at the 2005 Pansy site. At the 2004 Pansy site, temperatures in the sawdust pile increased to 30°C on the 30th day, while the straw temperature was only 7°C. At the Killarney site, the temperature rose quickly and remained as high as 60°C when using sunflower seed hulls as an amendment (Fig. 6e). The straw pile experienced slightly lower temperatures than the woodchip pile; both piles appeared to be influenced by changes in ambient temperatures.

### Effects of carcass number

The addition of a second carcass did not appear to affect the MC (data not shown). The 2C treatment had higher temperatures than the 1C between 40 and 110 days when using straw as amendment (Fig. 7a). For the sawdust amendment, the pile heated faster and the differences in temperature between the 2C and 1C treatments were greater and detected earlier (Fig. 7b). The 2C pile experienced higher temperatures than the 1C pile from the beginning to 110 days. The differences in temperature

**Table 4. Means of temperatures (°C) at different layers.**

| Amendment and site | | Temperatures (°C)* | | | |
|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 |
| Straw | Austin | 23.2b** | 24.1b | 25.4b | 26.9a |
| | Pilot Mound | 21.1a | 21.1a | 19.8b | 21.0a |
| | Killarney | 20.8a | 21.2a | 21.9a | 22.7a |
| | Pansy 2004 | 28.9a | 25.1c | 27.5b | 27.7b |
| | Pansy 2005 | 18.7c | 20.9b | 24.4a | 15.3d |
| Woodchips | Killarney | 25.0a | 23.6b | 22.2c | 21.3d |
| Sunflower seed hull | Killarney | 29.2c | 40.1b | 42.5a | 41.9a |
| Sawdust | Austin | 29.6a | 28.3a | 22.6b | 21.6b |
| | Pansy 2004 | 28.4c | 46.1a | 30.8b | 25.3d |
| | Pansy 2005 | 19.5c | 23.7b | 31.4a | 12.8d |
| | Pilot Mound | 31.0a | 28.7b | 22.9c | 22.3c |

*From the top layer (T1), above carcass (T2), below carcass (T3), and bottom layer (T4). Data was pooled over composting days within the year.
**Means in the same row and followed by the same letter do not differ significantly.

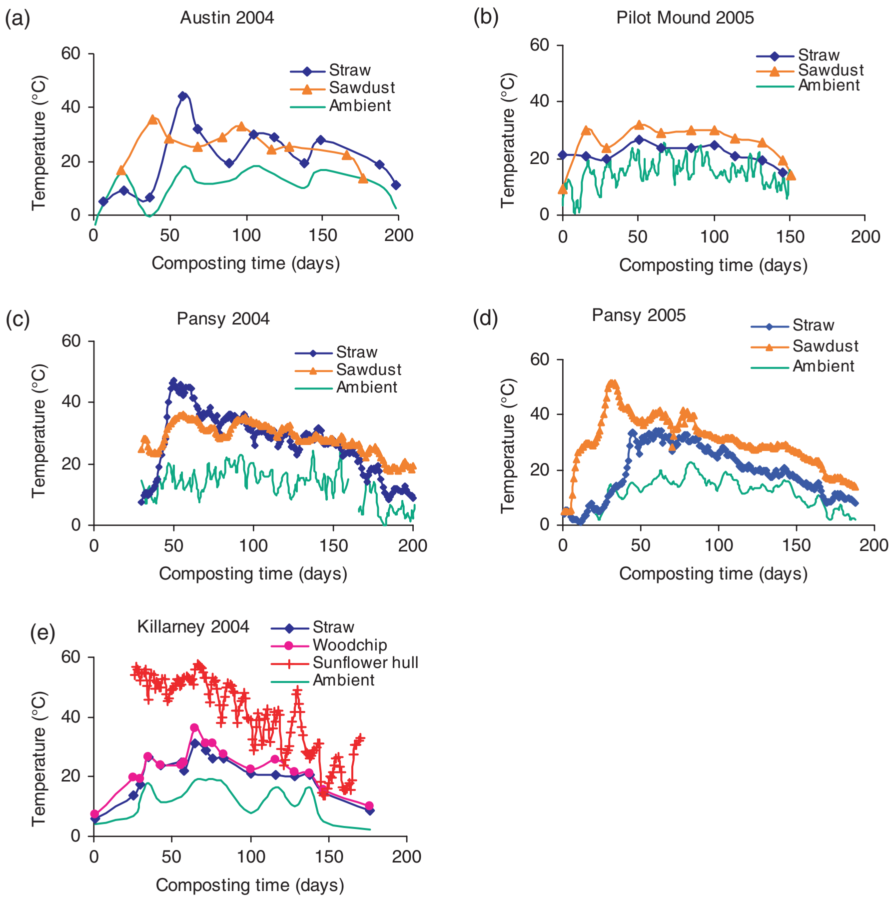


**Fig. 6. Daily pile temperatures for different amendments: (a) Austin, (b) Pansy 2004, (c) Pansy 2005, (d) Pilot Mound, (e) Killarney.**

between the 2C and 1C treatments were statistically significant for both amendments. This resulted from the two carcasses increasing the body mass and generating more heat than a single carcass.

## Characteristics of final compost

At the end of the composting trial, no soft tissue remained and only large bones and patches of hair were found. The amendment on the outside of the piles appeared to be weathered but not degraded. In general, compost TC decreased while TN increased compared with the original values of the feedstock (Table 5), which decreased the C:N ratios. Utilization of TC by the microorganisms and the production of $CO_2$ during the composting process could account for the loss of carbon. The increase in nitrogen concentrations was due to the decomposition and release of nitrogen from the carcass. The sawdust piles at the Austin and Pilot Mound sites showed the greatest reduction in C:N ratio that ranged from 81.2 to 89.8%. The levels of the compost for the other nutrients levels measured can be found in Genaille (2006).

All 20 piles tested negative for salmonella (Table 5). Fecal coliform levels for all compost piles were much less than 1000 (MPN)/g, the guideline limit, with the exception of the woodchip compost that had a slightly elevated count. The woodchips were a recycle waste which may have been contaminated before being used as the amendment. Results for the sunflower seed hulls compost were not available, as cattle broke through the fence and destroyed the pile before sampling could be done.

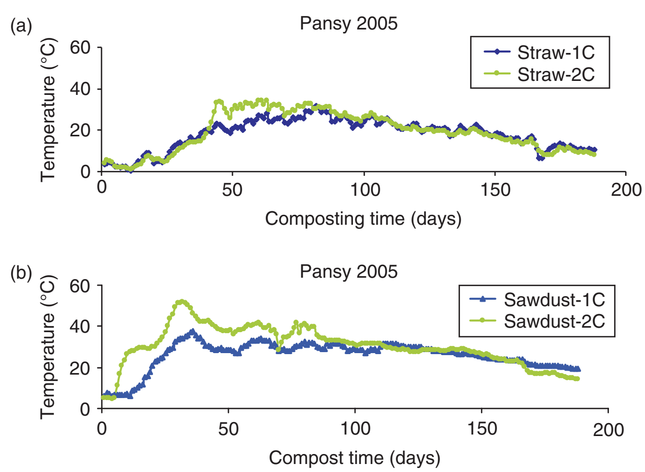


**Fig. 7. Daily temperatures for the treatments with one carcass per pile (1C) and two carcasses per pile (2C) at the Pansy site in 2005: (a) straw, (b) sawdust.**

Table 5. **Total carbon, total nitrogen, salmonella, and fecal coliform counts in the final compost.**

| Site | Year | Amendment | Total Carbon (%) | Total Nitrogen (%) | Salmonella | Fecal Coliforms (MPN/g) |
|---|---|---|---|---|---|---|
| Austin | 2004 | Straw | 9.8 | 0.5 | Negative | <3 |
| | | Sawdust | 18.8 | 0.9 | Negative | <3 |
| Killarney | 2004 | Straw | 9.3 | 0.3 | Negative | 9 |
| | | Woodchip | 16.9 | 0.5 | Negative | 1100 |
| Pansy | 2004 | Straw | 15.8 | 0.6 | Negative | 9 |
| | | Sawdust | 16.1 | 0.2 | Negative | 231 |
| | 2005 | Straw | 15.3 | 0.8 | Negative | 15 |
| | | Sawdust | 16.6 | 0.3 | Negative | <3 |
| Pilot Mound | 2005 | Straw | 9.1 | 0.5 | Negative | 43 |
| | | Sawdust | 15.8 | 0.3 | Negative | 4 |

### Liner necessity

Comparisons of soil nutrients levels beneath the piles with and without a liner indicated that the use of a liner had no or little benefit. In general, no significant differences in soil nitrate-N, phosphorus, and potassium beneath the piles were observed between the L and NL treatments, except for the 2004 and 2005 Pansy sites (Table 6), where higher soil K and $NO_3$-N were observed for the NL treatment than for the L treatment. The liner effect was not observed for any sawdust piles possibly due to the absorbent nature of sawdust.

### Cost analysis

The cost of the straw, woodchips, sunflower seed hulls, and the equipment use on the farm as well as the producer's time were not included in the cost analysis, since these were available on site or free of charge. The sawdust transportation cost was $50.00/pile. The plastic liner cost was $6.00/pile. The cost of the mesh wire cover and 12 pegs was approximately $65.00/pile. Given these values, the most costly composting piles were the sawdust piles. The total cost was $121.00/pile, including the cost of transportation, liner, and wire cover. Since at least half of the compost material and the enclosure could be recycled, the subsequent compost piles would be reduced to $31.00/pile.

## CONCLUSIONS

The objectives of this study were to examine moisture and temperature distributions throughout different layers of static composing piles, the effects of different carbon amendments and carcass number on the pile moisture and temperature; and the effects of liner on the soil nutrient concentrations beneath the piles. The temperature and moisture content (MC) in a static compost pile were not uniformly distributed throughout the depth profile of the pile due to the layering of carcass and amendment. The straw piles were wetter in the lower layers; the sawdust piles had mixed results; the woodchips pile did not show the differences in MC among layers. The temperatures in the sawdust and the woodchips piles were warmer in the upper layers of the pile; the temperatures in the sunflower

Table 6. **Comparisons of soil nitrate nitrogen ($NO_3$-N), phosphorus, (P) and potassium (K) values for treatments with liner (L) and without liner (NL).**

| Site-Year-Amendment | Treatment | $NO_3$-N (ppm) | P (ppm) | K (ppm) |
|---|---|---|---|---|
| Killarney–2004-Straw | L | 44.0a* | 16.5a | 187.0a |
| | NL | 84.0a | 15.0a | 199.0a |
| Pansy–2004-Straw | L | 13.0a | 45.5a | 499.0b |
| | NL | 24.0a | 65.0a | 755.0a |
| Pansy–2004-Sawdust | L | 5.0a | 43.5a | 423.0a |
| | NL | 36.5a | 53.5a | 500.0a |
| Pansy–2005-Straw | L | 9.3b | 39.8a | 365.0a |
| | NL | 43.3a | 48.5a | 395.0a |
| Pansy–2005-Sawdust | L | 1.3a | 18.5a | 327.5a |
| | NL | 2.3a | 25.8a | 370.0a |

*Means in the same column and same site-year-amendment followed by the same letter do not differ significantly.

seed hull pile were higher in the lower layers, and mixed results were obtained for the straw piles.

Among straw, sawdust, woodchip, and sunflower seed hull as amendments, sawdust resulted in the most suitable pile temperatures and moisture during the composting process. In two out of four sites, sawdust retained more moisture when compared with straw. Woodchips and sunflower seed hulls had lower MC than straw, observed in one site. When compared with straw, sawdust had a quicker rise in temperature at the beginning of the composting process; sawdust also experienced higher temperatures for the majority of the trial. In a site where straw, woodchips, and sunflower seed hulls were compared, the sunflower seed hull amendment had the highest pile temperatures.

Placing two carcasses per static pile had no significant effects on the pile MC. However, it slightly increased the temperature in straw piles and significantly increased the temperature in sawdust piles, potentially improving the composting process. The other advantage of the two carcasses per pile over one per pile was that overlapping two carcasses in a pile allowed the initial pile size to remain similar to that of a single carcass pile. This will reduce the amount of the final compost. It may be necessary to use liner under a straw pile, while it may not be necessary to use liner under a sawdust pile, based on the results of nutrients leaching.

Static pile method is a low cost and maintenance approach for on-farm cattle carcass disposal for small cattle operations. Placement of two carcasses per pile in the way suggested is recommended as it may potentially improve the composting process without increasing the pile size. The use of an enclosure (wire mesh or fencing) is necessary to deter scavengers and livestock from disturbing the compost piles which actually occurred in this trial. Since a limited number of compost piles with and without liners were built and tested during this trial, further studies would need to verify the liner effect. Due to the highly variable nature of temperature, moisture, and nutrient contents in porous mediums, such as carbon amendments and soil, further research may be required to verify the findings of this study.

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