A Low Maintenance Approach to Composting Cattle Mortalities on the Farm

by

Dolores M. Genaille

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

MASTER OF SCIENCE

Department of Biosystems Engineering

University of Manitoba

Winnipeg

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION

A Low Maintenance Approach to Composting Cattle Mortalities on the Farm

BY

Dolores M. Genaille

A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

OF

MASTER OF SCIENCE

ABSTRACT

Composting livestock mortalities is an environmentally sound and biosecure means of waste management. A two-year study on cattle mortality composting was conducted in 2004 and 2005. A low cost and maintenance approach to composting was utilized for easy adaptation by producers. A total of 21 static compost piles were constructed on seven farms in southern Manitoba. Straw, sawdust, straw/sawdust, woodchips, and sunflower hulls were used as carbon amendment. The static pile contained one or two carcasses per pile and was constructed with or without a liner. Pile temperature and moisture content were monitored at four layers over seven months. Soil nutrients from beneath a pile were measured to assess the effectiveness of a plastic liner in preventing leaching. Percentage of pile volume reduction was also measured. Results showed that moisture contents tended to progressively increase downward through pile layers while temperatures remained warmer in the layers near the carcass. Depending on the type of amendment, average pile temperature ranged from 19.5 to 38.4°C and moisture content ranged from 30.4 to 72.7%. Sawdust as amendment resulted in the most suitable pile temperatures and moisture for composting. Pile volume of the straw/sawdust reduced by 38.4%, straw by 31.3%, sawdust by 26.1%, woodchips by 22.3%, and sunflower hulls by 4.4%. The presence of a second carcass in a compost pile did not require additional amendment, slightly increased average pile temperature, and did not affect pile moisture content when compared to single carcass piles. The use of a plastic liner resulted in reduced nitrate-N and potassium levels in the soil beneath straw compost piles.

Keywords: Composting, Carcass, Cattle, Temperature, Moisture, Liner, Static, Soil, Carbon, Amendment

ACKNOWLEDGEMENTS

I would like to acknowledge the Waste Reduction and Pollution Prevention (WRAPP) Fund for providing the resources for this project. I would like to thank my advisor Dr. Ying Chen for her support and guidance. I would like to recognize Gerry Woods for his help in constructing and monitoring the sites. Also Van Doan and John Maltman from Manitoba Agriculture, Food and Rural Initiatives (MAFRI), Turtle Mountain Conservation District representatives, Les Routledge, Rick Verspeek, and Matt McDonald for their aid in conducting this research. Thank you to the producers Keith and Jo-Lene Gardiner, Alvin Jones, Robert Krentz, Allen Scott, and Cyril Stephenson who volunteered their land, time, and equipment.

A special thank you to my family and friends for their encouragement and support.

TABLE OF CONTENTS

APPENDIX A

APPENDIX B

LIST OF TABLES

LIST OF FIGURES

1. 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 provides an environmentally sound and biosecure means of waste management. Poultry and swine producers more commonly use this method of carcass disposal since the deadstock is smaller, decomposes faster, and deaths occur more frequently. Increasing interest in composting larger deadstock has prompted research to be done in order to adapt mortality composting techniques to the cattle industry. Differences arise due to the fact that only approximately 2% of cattle die per year and that the larger carcasses take longer to decompose.

Composting is the breakdown of organic material by microbes. To establish and maintain a microbial population in a compost pile, there must be moisture, oxygen, carbon to provide energy, and nitrogen for cell growth. Mortality composting requires these same elements. 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 establish optimum conditions for mortality composting, Keener et al. (2000b) recommend the use of an amendment with a particle size that provides a porosity of 30 to 50% and a carbon to nitrogen ratio (C:N) of 25:1 to 40:1. Moisture contents are dependent on the feedstock used and a feasible composting range is

40-60% (Glanville and Trample 1997). To determine if proper conditions are being met, internal pile temperatures are usually monitored since temperature is a key indicator of the composting process (Fonstad et al. 2003). The highest rate of decomposition occurs at temperatures in the range of 43-66°C while pathogen kill may be achieved if temperatures rise above 55°C for three consecutive days (Keener and Elwell 2003). Thus, mortality composting can be described as "above ground burial in a biofilter with pathogen kill by high temperatures" (Keener and Elwell 2003). Since moisture content affects microbial activity and airflow, it directly influences pile temperature and it is also useful to monitor.

A low maintenance approach to composting mortalities uses a static pile and reduces labour and cost by not turning the piles. As well this method eliminates carcass processing, the manual addition of moisture, and the use of an enclosure. Mukhtar et al. (2003) employed this approach, which they felt was necessary for it to be adopted by agricultural producers as a disposal method at the farm level.

2. REVIEW OF LITERATURE

Animal mortalities are a normal occurrence experienced by all livestock operations. The proper disposal of the carcass is an issue for many producers whose waste management options are diminishing. The four methods of mortality management currently recognized by the *Livestock Manure and Mortalities Management Regulation (MR 42/98)* includes rendering, incineration, burial, and composting. Due to concerns surrounding the spread of Bovine Spongiform Encephalopathy (BSE) and rising fuel costs, rendering is no longer available to many producers. Incineration is the most biosecure method of disposal but available facilities, cost, and air pollution concerns make this option less feasible (Sander et al. 2002). Burial is a popular method of mortality management since the carcass is not transferred off the farm. Limitations for this means of carcass disposal include the requirement of excavation equipment, it cannot be carried out during winter months, and the producer must consider the potential contamination of groundwater so that for areas with a high water table this is not an option. Composting is a disposal method that can also be done on-farm that eliminates the cost of transporting deadstock and the need for additional equipment that is not already available at most farms. Although composting raises some environmental concerns, these issues may be remedied with fairly simple, economical solutions.

2.1. General principles of composting

Composting is the biological decomposition of organic materials in a predominantly aerobic environment that occurs spontaneously in nature (Keener et al. 2000b). The composting process can be broken down into three phases. In the initial phase mesophilic microorganisms, which prefer temperatures between 10 and 45°C are predominant. As heat is generated in the pile the active phase begins. During this phase thermophilic microorganisms that prefer temperatures in the 45-50°C range thrive and peak degradation takes place. The third phase is the cooling phase at which point temperatures reach ambient and compost stabilizes (Hellmann et al. 1997).

During composting, bacteria, fungi, and other microorganisms consume organic matter and oxygen. Heat, water, and carbon dioxide are released as by-products. Factors that create an optimum environment for microbial populations to be present and proliferate are oxygen, moisture, a properly balanced carbon to nitrogen ratio (C:N), and temperature (Dougherty 1999; de Bertoldi et al. 1983). As well the microbes prefer a close to neutral pH ranging from 6.7 to 9.0 (Keener et al. 2000a).

The moisture content of a composting material must sustain microbial growth without impeding airflow. A reasonable moisture level for composting is between 40 and 65% although the optimum range is from 65-85% (Rynk 1992; Ahn et al. 2005).

De Bertoldi et al. (1983) state that the optimum oxygen content required for composting should not fall below 18% of the total gas composition. Rynk (1992) provides a reasonable composting oxygen range of greater than 5%.

Carbon (C) provides energy for microorganisms while nitrogen (N) is essential for cell growth and reproduction. Golueke (1992) recommends that a ratio of 30 parts of carbon to one part nitrogen (C:N ratio) is optimum for composting most types of waste. At a higher C:N ratio the composting process will slow until excess carbon is consumed and the C:N ratio becomes balanced again. For a lower C:N ratio excess nitrogen will be lost through ammonia volatilization.

Composting is an exothermic process and the heat produced can be used as an indicator of composting performance. Optimum composting conditions occur when the temperature ranges between 45 and 60°C while a reasonable range is considered to be between 43 to 66°C (Rynk 1992; de Bertoldi et al. 1983).

2.2. Organic material composting

The composting of organic material has become a popular means of reducing waste. Composting can be done on a large scale for example to reduce municipal and agricultural wastes or it can be done on a small scale in the backyard of any household.

The basic principles of composting apply regardless of the size of the composting mass and type of raw material being composted. In order to satisfy these principles the material or amendment must have a structure that allows air and water flow through the pile while providing a small enough surface area to promote good microbial growth. As well materials should create a balanced C:N ratio. Suggested amendments that provide a good carbon source are straw, sawdust, dry leaves, yard trimmings, and woodchips (Rynk 1992; Huang et al. 2004; Carr et al. 2002). Sources of nitrogen include manure, vegetables, and green grass clippings. The amount of each carbon and nitrogen source added to the compost to attain a C:N ratio of 30:1 may be estimated for small compost piles such as backyard composter while composting recipes have been developed to calculate the amount required when dealing with larger quantities of material such as manure composting (Rynk 1992).

In order to maintain a moisture content of 40-60%, water may be added to the compost pile to supplement the available moisture of the amendments. Again the amount needed may be estimated or calculated using a composting recipe.

For extremely acidic or basic compost that is outside the pH range of 5.5 to 9.0, materials such as gypsum may be added to reduce pH or wood ash to increase pH (Dougherty 1999).

Since composting requires several materials to be combined, mixing is required to create a homogeneous compost that ensures nutrients and moisture are available to microbes throughout the pile (Rynk 1992). Continual mixing or turning of the compost pile is necessary to ensure airflow into all regions of the pile, dissipate heat to maintain optimum temperatures, and further reduce particle size to increase surface area (Firey 2004; Rynk 1992).

As the organic material composts it loses mass and volume as carbon is lost as carbon dioxide and the particle size is reduced through microbial degradation (Breitenbeck 2004; Nelson et al. 2003; Brodie et al. 2000). Finished compost will have a dark humus look and an earthy odour (Keener et al. 2000a; Mohee and Mudhoo 2005).

2.3. Mortality composting

2.3.1. Pile structure

While the general principles of composting organic matter apply to mortality composting, pile structure and management practices differ. Unlike other organic materials, which are mixed to ensure an even consistency throughout the composting pile, mortality composting is an inconsistent mixture. The intact carcass is placed between layers of amendment in a "sandwich" formation that Keener et al. (2000b) best describe as aboveground burial in a biofilter. The bottom layer of amendment or base provides aeration under the carcass and absorbs liquids. The area of the base must extend past the carcass when it is placed in the center. The carcass is then covered with amendment that forms the top layer of the compost pile. The function of this layer is to allow air and water to flow into the pile, retain heat, and prevent odours. The amount of amendment used is dependent on the size of the animal carcass being composted and properties of the amendment.

In mortality compost piles the carcass provides the nitrogen and moisture while the amendment supplies the carbon and creates an aerobic zone or biofilter around the carcass. Since the animal inside the pile is not homogeneously mixed with the amendment, anaerobic decomposition occurs in and around the carcass. Odours and gases produced during the anaerobic breakdown of the carcass diffuse into the amendment and are ingested by microorganisms to produce water and carbon dioxide.

2.3.2. Oxygen

Keener et al. (2000b) suggest that oxygen levels should be greater than one percent, which is lower than general composting needs since mortality compost piles are not turned until the carcass has degraded. The availability of oxygen can also be viewed in terms of the porosity or the percentage of air-filled pore space in the amendment. Optimum porosity should be between 30 and 50% (Keener et al. 2000b).

2.3.3. Moisture

The optimum moisture range for composting mortalities does not change from the basic composting range of 40 to 60% as the microorganisms needs do not change (Keener et al. 2000b; Glanville and Trampel 1997). As the carcass is degraded liquid is released which contributes to the pile moisture content.

2.3.4. Nutrient availability

The carbon provided by the amendment must be balanced with the nitrogen provided by the carcass. Due to variations in amendment and carcass properties and the need to ensure complete coverage of the animal, the C:N ratio maybe as low as 10:1 or as high as 50:1 (Glanville and Trampel 1997). This differs from the suggested optimum composting C:N ratio of 30:1. Fulhage (2000) states that the proper coverage of carcasses may create extremely high C:N ratios that do not appear to limit composting other than to increase the time it takes to complete the process. Since producers may not be interested in the time it takes for the process to come to completion, C:N ratios outside the optimum composting range may be acceptable. Bonhotal et al. (2002) simplify mortality composting by overlooking the C:N ratio and suggesting that a 0.6 m thick base, perimeter, and cover of amendment should be used to surround the carcass regardless of what type of amendment is used.

A properly balanced C:N ratio should maintain a close to neutral pH of 6.5 to 7.2 (Carr et al. 1998).

2.3.5. Temperature

Optimum temperatures for mortality composting are the same as general composting and range between 43 and 66°C (Keener et al. 2000b). The ability of the entire compost pile to attain this temperature is more difficult for mortality composting due to the layering of carcass and amendment (Lawson and Keeling 1999). When temperatures remain above 55°C for three consecutive days most pathogenic viruses and bacteria are destroyed with the exception of spores (Sander et al. 2002). Dougherty (1999) points out that pathogen destruction is not solely due to high temperatures but is a due to a combination of temperature and the natural competition and predation of organisms.

2.3.6. Pile turning

General composting practices suggest frequent turning of the pile to generate a homogeneous mixture and to provide good aeration. For mortality composting it is recommended that the piles not be turned until the carcass has fully decomposed in order prevent exposure of the animal tissue that would cause odours and attract nuisances (Keener et al. 2000b). Research done by Mukhtar et al. (2003) found that the time required for large horse and cattle carcasses to decompose enough to be turned is between 3 and 6 months.

2.4. Poultry composting

The poultry industry was the first to use composting as a method to dispose of mortalities. Since the 1980's it has become an environmentally acceptable means of waste management (McCaskey et al. 1996). A method of placing birds in a single layer between alternating layers of amendment was adopted to accommodate frequent mortalities, ensure that there was enough body mass available for the composting process, and to avoid creating wet spots that would result in poor composting (Glanville and Trampel 1997). Poultry composting research conducted by Lawson and Keeling (1999) and Gonzalez and Sanchez (2005) found that laying hen carcasses are successfully degraded after only eight weeks. Finished poultry compost resembles dry, granular litter with few bones and feathers remaining (Fulhage 1995).

2.5. Swine composting

The success experienced in poultry composting lead to the application of this disposal method in the swine industry (Stanford et al. 2000; Fulhage 1995). Contrary to the opinion that swine are too large and their hides too tough for composting research has found that if composting is done right, the size of carcass does not matter (Sherman-Huntoon 2000). Research trials determined that composting is a safe method of swine carcass disposal that generates no odour and creates conditions conducive for pathogen kill (Garcia-Siera 2001). Morrow et al. (1995) constructed multiple layered compost piles during their swine composting research in order to create enough mass to generate the temperatures required for the composting process. Laibach and Bonhotal (2004) who researched deer composting constructed a pile with two layers of carcasses separated by a single layer of compost that was placed between a 0.6 m thick woodchip base and cover. Multiple layers were required to generate temperatures since deer, like swine, are considered to be medium sized carcasses.

2.6. Large carcass composting

Composting is now being researched as a viable means of disposal for large livestock such as cattle and horses. Challenges that arise for composting these animals include dealing with a large body mass that creates unbalanced pile nutrients, a lower frequency of mortalities so that producers are less likely to invest in a permanent composting structure, and the increased time required for decomposition. Glanville et al. (2003) composted cattle carcasses in windrows and found that all soft tissue and organs of a 450 kg carcass were decomposed after 110 day of composting. Mukhtar et al. (2003) found that it takes approximately nine months to compost fully-grown intact cattle or horse carcasses.

Due to lack of research it has not yet been determined whether prions that cause BSE are destroyed in the composting process so cattle showing signs of a neurological disease should not be composted (Bonhotal et al. 2002; Casolari 1998).

2.7. Approaches to composting

The approach taken towards mortality composting differs depending on the needs of the producer and intended use of the final compost. Some operations take a very costly and labour intensive approach to mortality composting in order to produce a marketable end product in a timely manner. Splaying cattle carcasses (slicing length wise and then flattening) can reduce the composting time from one year to 180 days while mechanically grinding the carcass can reduce the time to 120 days (Rynk 2003). A more frequent turning regime for a poultry (Gonzalez and Sanchez 2005) or sheep (Stanford et al. 2000) compost piles could improve the composting process and produce a saleable product. Morse (2001) suggests adding water to mortality compost piles to ensure piles do not dry out over the course of the composting process to improve performance.

For on-farm composting, a low maintenance approach can be used. This method of composting eliminates cleaving or grinding of the carcass, reduces or eliminates the turning of the compost piles, and adds no water relying only on natural precipitation. However, Fulhage (2000) and Bonhotal et al. (2002) do suggest puncturing the abdominal cavity or rumen prior to composting cattle to avoid possible bursting of the carcass. Mukhtar et al. (2003) reported that horse and cattle carcasses were successfully composted using a low maintenance approach that eliminated processing of the carcass, the manual addition of water, and only turned the pile twice during the composting trial.

2.8. Choice of amendment

Kalbasi et al. (2005) acknowledged that when applying composting techniques to carcass disposal, consideration must be given to the quantity and type of amendment used. The availability of the amendment is an important consideration and on-farm materials are more economical (Morse 2001). Physical characteristics such as particle size is also an important consideration so that sufficient surface area is provided for microbial growth, airflow is allowed through the pile, and moisture is absorbed.

Commonly used amendments include sawdust, straw, and woodchips. Sawdust is recommended as an amendment since it has a small particle size, good absorbency qualities for both odour and moisture, retains heat, and allows for good bone breakdown for larger animals (Michel et al. 2004; Morse 2001; Glanville and Trampel 1997). Straw or hay is considered to work well as an amendment for mortality composting (Ahn et al. 2005). Murphy and Harner (2004) investigated the performance of straw, sawdust, compost, and the combination of these materials as amendments for composting cattle carcasses and found that the straw and sawdust on their own produced acceptable mortality composting results. However, Fulhage (2000) felt that compared to straw, sawdust is a more ideal amendment. The advantage of using straw as an amendment here in Manitoba is that it is readily available on most farms and would be an economic choice. Laibach and Bonhotal (2004) were successful at composting road-killed deer using woodchips. Various other materials that are suitable to use as composting amendments include silage, leaves, and cornstalks. Manure can be added as a supplementary amendment to increase moisture and speed up the composting process since microbial populations are already established. Disadvantages to adding manure include increased nitrogen levels, odours, and presence of flies (Morse 2001).

2.9. Composting structures

The type of composting structure used is dependent on the size, number, and the frequency of mortalities as well as the individual needs of the producer.

2.9.1. Static pile

Static compost piles simply involve stacking materials to create a pile with a size that are usually less than 1.8 m high and 3.7 m wide in order to allow passive air movement (Rynk 1992). This type of composting structure is freestanding with no enclosure and as they are usually built outdoors their performance maybe affected by precipitation, wind, and outdoor temperatures. Static piles are well suited for mortality composting, as they are simple, cost effective, and can be done on-farm. Static piles were used by Gonzalez and Sanchez (2005) to compost poultry and by Fondstad et al. (2003) and Garcia-Siera (2001) to compost swine. Static piles have not been used for large carcass composting animals but this could be due to the fact that research in this area is fairly new. If a static pile is used for mortality composting Keener and Elwell (2003) suggest an impervious liner be placed below the pile to prevent soil contamination and a fence may be required to keep away scavenging animals.

2.9.2. Windrow

A windrow is constructed in a similar manner to the static pile but its shape is longer. The recommended height of a windrow is 1.5 to 2.1 m and width is 3 to 6 m (Rynk 1992). Windrows are usually turned more frequently than static piles and therefore require more labour and equipment though compost at a faster rate. This type of composting structure has been adopted as a means of composting livestock mortalities. It can be used to compost a large number of small carcasses such as spent laying hens (Nelson et al. 2003) or multiple large cattle carcasses (Glanville et al. 2003). The length of the windrow is dependent on the number of deads and has the benefit of being able to add on new carcasses. Laibach and Bonhotal (2004) successfully composted deer carcasses using a windrow structure that was extended each week as new carcasses were added.

2.9.3. Bin structure

Bin structures are frequently used for mortality composting. Usually the bins are permanent structures that are built on an impervious liner such as a concrete pad and may or may not have a roof depending on the regime for adding moisture. As well several bins are generally constructed for different stages of composting so that space is always available and the process can be done continually. The benefit of a bin structure is a more controlled environment for composting, increased heat retention, and reduced risk of pile leaching (Morse 2001). This method of composting is used for small to medium sized mortalities (Kalbasi et al. 2005; Lawson and Keeling 1999). The disadvantage of the bin system is the cost of construction and the size requirement of the structure if used for larger carcasses. However, straw bales on a sub-gravel base have been successfully used to construct a more economical, non-permanent bin-like structure for composing large carcasses (Muhktar et al. 2003; Murphy and Harner 2004).

2.9.4. In-vessel

Various in-vessel structures may be used for composting but the most common one is a rotating drum that improves aeration and mixing of compost. Although the in-vessel composting is effective at controlling odour and vectors, managing leachate, and decreasing composting time it is also costly (Plana et al. 2001; Mohee and Mudhoo 2004). Currently this type of equipment is used mainly by large farming operations and not by individual producers (Rynk 2003).

2.10. Environmental concerns

Peigne and Girardin (2004) state that the main environmental impacts of composting are air pollution and leaching, which contaminate groundwater and soil. Evans (1999) found that odours were emitted from fish and deer compost piles as a result of insufficient amendment covering of the carcasses. It is important to completely surround the carcass with amendment to act as a biofilter and prevent air pollution and odours from escaping the composting pile (Keener and Elwell 2003).

The impact of composting on water sources can be minimized by locating the site at least 100 m from any surface watercourse, sinkhole, spring, or well (LMMMR 1998). Building the compost pile on an impervious liner such as a cement pad or compacted clay can prevent soil and groundwater contamination. Prevailing winds and public viewing should also be considered when selecting a composting site (Morse 2001).

2.11. Composting equipment

Composting mortalities requires agriculture equipment that is usually available on the farm such as a tractor and bucket to move and lift amendment and carcasses as well as turn the compost pile. To handle smaller carcasses and manage small bin structures a skid loader may be preferred for maneuverability. For operations that generate large amounts of compost for marketing purposes, additional equipment such as grinders, screeners, and windrow turners may be required (Kalbsi et al. 2005).

Monitoring can be done to ensure conditions are suitable for the composting process. Temperature, oxygen, and moisture are parameters that are generally measured. Oxygen sensors can be used to monitor pile oxygen. Commercially available sensors can now take both oxygen and temperature readings (Kalbasi et al. 2005; Fondstad et al. 2003). Brodie et al. (2000) felt that monitoring temperature was preferred since it noticed changing trends in the pile even though oxygen monitoring can be used to predict a problem. For manual readings a probe type thermometer with a 0.9 m (3 ft) stem can be used to take internal pile temperatures (Morse 2001; Brodie et al. 2000). To continually monitored piles Glanville et al. (2003) and Avnimelech et al. (2004) both placed several thermocouples throughout the compost pile and attached them to a data logger. Due to the heterogeneous nature of compost Ekinci et al. (2004) suggests that the optimum placement of a thermocouple to assess pile temperatures is in the middle layers of the pile.

Due to the complex arrangement of pores within the compost it is difficult to find commercial equipment that can accurately determine compost moisture. The most accurate method of measuring the moisture content in compost is the gravimetric oven drying technique. However, the ability of commercially available moisture sensing devices to measure moisture at many locations without disturbing the pile and provide faster results are definite advantages of these instruments (Rynk 2000).

2.12. Mortality composting research

Mortality composting research began with poultry carcasses since they are small and deads occur more frequently. Gonzalez and Sanchez (2005) studied poultry composting using static piles that contained multiple layers of chicken carcasses, hen manure, and straw. Temperatures were monitored daily at four locations throughout the pile, two in the upper half and two in the lower half. Water was added to the pile as necessary. Temperature results showed a fast rise to around 60°C and remained in that range for approximately 50 days before gradually declining down to ambient temperatures. This study was successful at composting the carcasses and reached temperatures that would result in pathogen kill. The authors tested for temperature variations in the compost pile due to its layers but did not report any results, only the average pile temperature.

Lawson and Keeling (1999) also placed poultry carcasses between layers of litter though they used a bin system rather than a static pile. Wire mesh was used as a means to prevent access to the compost by vermin while still allowing effective aeration. Temperatures were measured at the center of the compost as well as the in a bottom corner. Results showed that the chicken carcasses decomposed at the end of eight weeks.

Temperatures were hotter inside the pile and reached 70°C while the bottom corner temperature reached 55°C.

A swine-composting project carried out in Saskatchewan by Fondstad et al. (2003) concluded that swine carcasses could be successfully composted after 250 days. An amendment of manure and straw was used and the compost pile was turned three times over the duration of the trial. Temperatures and oxygen levels were taken with a combination instrument while moisture content was measured using the gravimetric method. Pile volumes were measured with a tape measure. Results of the study found that temperatures fluctuated between 40 and 60°C, which was slightly lower than those reached during poultry composting. Pile turning resulted in an increase in pile temperature. Measurements taken showed oxygen readings were above 10%, moisture contents were in the 40-60% range, and the pile volume reduced by 50%.

Morrow et al. (1995) also conducted a swine composting study using wheat straw, peanut hulls, and turkey litter as amendment. They monitored pile temperatures and pathogen kill. They concluded that pile temperatures ranging between 54 and 64°C destroyed salmonella. Both carbon amendments were successful at composting the carcasses but the peanut hulls performed better since they decomposed more quickly.

Less research data is available for composting large livestock since this is a fairly new concept. Muhktar et al. (2003) found that a low maintenance approach to composting cattle and horse carcasses was successful at decomposing the carcasses after nine months. Their method used a bin structure made of straw bales placed in a U shape on a compacted gravel sub-base and wood shavings with horse manure was used as an amendment. Temperatures were taken above and below the carcasses with a stem thermometer and a data logger. Wooden pallets were placed under the carcass in an attempt to increase airflow in the bottom of the pile but results showed that after six months of composting there was no difference between piles built with pallets and without. Compost temperatures reported were above 55°C and the lower layers were hotter. Results from both this study and the work done by Lawson and Keeling (1999) showed that temperature distribution varied within a mortality compost pile. Murphy et al. (2004) also used a straw bin system to compost cattle but they investigated the performance of straw, sawdust, compost, and mixtures of the three as composting amendments. Moisture content readings of 64% on the outside of the pile and 21% near the carcass were reported but it was not stated with what instrument these readings was taken. As well temperatures were reported that reached 55°C but no equipment or schedule was given. Results showed that straw and sawdust amendments on their own were suitable for carcass composting.

2.13. Finished compost

Analysis of the finished compost should be done to check for nutrient values if the material is to be used as a fertilizer for land application (Morrow and Ferket 1993). Since no guidelines are available for compost application, manure application rates can be used for compost when it is applied as a fertilizer. As well disease concerns exist so the compost should not be used on crops intended for human consumption.

Fulhage (2000) found that finished compost from mortality compost piles still maintains a high level of carbon due to the unbalanced C:N ratios and that it can be recycled as an amendment for new composting processes. This reduces the cost of new amendment and provides a microbial inoculant (Morse 2001).

The final compost should also be tested for the presence of pathogens. Composting standards in Canada (Composting Council of Canada 1998) state that the quantity of fecal coliforms in compost must be < 1000 Most Probable Number (MPN/g total solid) and there can be no salmonella present (< 3 MPN/4g total solid). Morrow et al. (1995) found during their swine composting study that a properly managed compost pile that reaches temperatures 60°C will destroy 11 of 14 salmonella cultures.

Bones may be present at the end of the composting cycle since the decomposition of large bones can take over a year. Morrow et al. (1995) felt that the remainder of large bones from their swine composting trial were not a sign of a failure since the volume of the carcass was reduced and bones could easily be disposed of by burial or stored and sent for rendering. Since rendering and burial of the bones would add time and energy to the composting process the suggestion made by Bonhotal et al. (2002) to add them to the base of new compost piles to improve aeration and further degrade the bones is a more feasible solution.

2.14. Summary

To date little research has been done for the composting of large livestock. Cattle composting research that has been done was in the United States and has not been studied under Manitoba conditions. In order for this method of disposal to be adopted by producers it must be economical and require little time and effort. Therefore a low maintenance approach should be taken.

Composting livestock mortalities using various available amendments and a non-permanent liner have not been investigated under the same farm conditions. Realistically, either a single dead or multiple deads may occur on-farm at the same time. It would be valuable to study the effects of both single and multiple carcasses per pile on composting performance. Since mortality compost piles differ internally due to layering compared to other organic materials that are mixed, the effects of the layers on pile temperature and moisture should be investigated.

3. OBJECTIVES

The goal of this project was to investigate the static pile method to compost cattle mortalities. The primary objective was to study effects of carbon amendment on compost pile moisture contents and temperatures and the moisture and temperature distribution throughout the pile layers. Secondary objectives were to examine the effect that the number of carcasses per pile had on the moisture contents and temperatures, and to assess the effectiveness of a liner beneath the compost pile to prevent leaching.

4. MATERIALS AND METHODS

4.1. Criteria for composting

The major criterion for composting was low cost and low maintenance. Static compost piles were constructed for the composting trials at all sites. The following low maintenance approach was used for this project.

- Carcasses were not ground or cleaved;
- No moisture was manually added to the compost piles;

- Compost piles were not turned once they were established;
- Piles were not enclosed by walls or a roof and were accessible from all sides.

A letter was sent to Manitoba Conservation requesting permission to build the compost piles without an enclosure to determine if scavenging animals would be a problem and to reduce cost. The location of the compost piles at the field trial sites complied with *The Livestock Manure and Mortalities Management Regulation 42/98*. Piles were located at least 100 m from any surface watercourse, sinkhole, spring, or well. The piles were also located within the operation's boundaries.

4.2. Composting site description

In 2004, field trial sites for composting cattle mortalities were established on four farms in Southern Manitoba near the communities of Austin, Pansy, Killarney, and Boissevain. In 2005, sites at the same farms in Austin and Pansy were used plus a new site at a farm near Pilot Mound. All sites are shown on the map of Manitoba (Fig. 1). Trials began in the spring (April – May) of each year and were finished in late fall (October - November).

The Austin site, position 1 in Fig. 1, had approximately 120 head of cattle. The surficial soil type at the farm is classified as sandy with rapid drainage. Average annual precipitation received in this area is 476 mm.

The Pansy site, position 2 in Fig. 1, was located at a 4500 head cattle operation. The surficial soil type at this farm is sandy with rapid drainage. Average annual precipitation for this area is 539 mm.

The Killarney and Boissevain sites, position 3 in Fig. 1, were located in the Turtle Mountain Conservation District. The Killarney site was on a small farm while the Boissevain site was located at a feedlot operation with 4000 head of cattle. The surficial soil type at both of these locations is classified as loamy with well drainage. Yearly precipitation received in this area is about 531 mm.

Pilot Mound, position 4 in Fig.1, is a mixed operation with cattle, hogs, and crops. The surficial soil classification on this farm is loamy with well drainage. The average annual precipitation for this area is 504 mm.

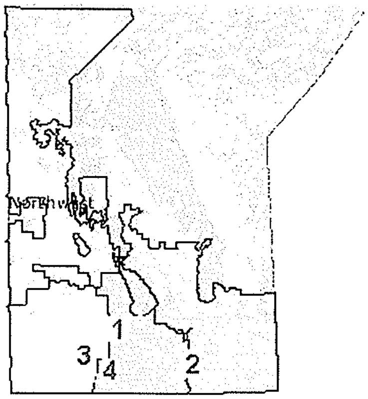


Figure 1. Map of southern Manitoba showing the field trial sites for the cattle mortality composting study conducted in 2004 and 2005. 1– Austin; 2 – Pansy; 3 – Killarney/Boissevain; 4 – Pilot Mound.

4.3. Experimental design

4.3.1. Study of carbon amendment

4.3.1.1. Treatments Various carbon amendments were tested to determine which material provided the best conditions for cattle mortality composting. The amendments used in the 2004 trials were straw, sawdust, woodchips, and sunflower seed hulls. For the 2005 trials, compost piles were constructed using straw, sawdust, a straw/sawdust mix, and compost material recycled from the 2004 trials. A total of 12 compost piles were included in the study of carbon amendment. Table 1 lists the amendments used at each site. Piles of every amendment were not tested at each site since the necessary number of deads was not always available.

Table 1. Amendment treatments for piles containing one carcass at different sites.

Site	Year	Amendment
Austin	2004	Straw, Sawdust
	2005	Straw/Sawdust Mix
Boissevain	2004	Sunflower seed hulls
Killarney	2004	Straw, Woodchip
Pansy	2004	Straw, Sawdust
	2005	Straw, Sawdust
Pilot Mound	2005	Straw, Sawdust

4.3.1.2. Description of carbon amendment

Straw Straw was used as a carbon amendment in both years, as it was readily available on the farms. The large particle size of straw allows airflow through the pile while the main drawback is that it does not retain heat as well as amendments with smaller particle sizes. Round straw bales weighing approximately 454 kg were used at all sites, though the type of straw (wheat or barley) and the age of the bales differed at each location.

Sawdust Sawdust was used as a carbon amendment due to its ability to absorb moisture, retain heat, provide good surface area for microbial growth, and allow airflow through the pile. The disadvantage of using sawdust as an amendment is that it is not readily available on the farm. Two different types of sawdust were used for construction of the compost piles. At the Pansy and Pilot Mound sites the sawdust used was fine and light with a particle size that ranged from approximately 0.05 to 0.5 cm and contained some thin wood shavings that measured between 1 and 2 cm. The sawdust at the Austin site had a similar particle size but contained heavier pieces of particleboard that were approximately 1 to 2.5 cm in size.

Woodchip The woodchips used were a mixture of tree branches that had been through a wood chipper and yard waste. The size of the woodchips varied in from 2.5 to 8 cm. The disadvantage of this material is that woodchips are not as degradable as other amendments due to the large particle size combined with a high lignin and cellulose content. Woodchips were used at the site in 2004 because it was a recycled waste product and was available to the farm.

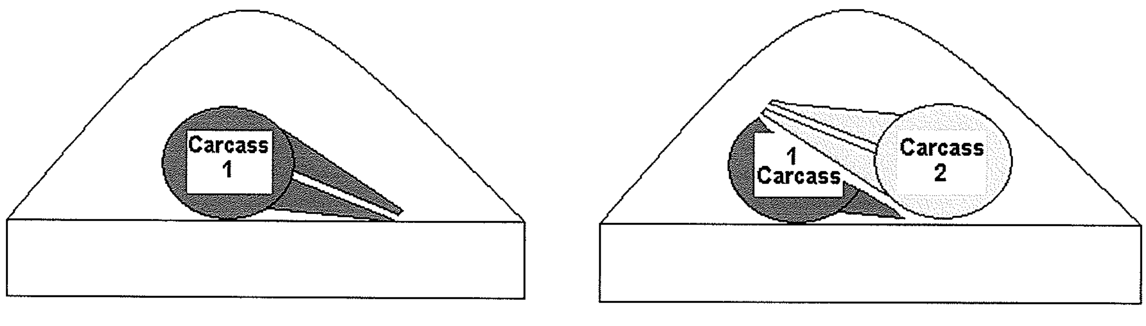
Sunflower Hull The sunflower hull material was a combination of the outer shells and seeds. This material was dense and had a small particle size of about 1.5 cm, which could prevent air and moisture flow through the pile. The sunflower hulls were a by-product from a nearby sunflower seed processing plant and were chosen as an amendment due to its availability and the opportunity to recycle a waste product.

Straw/Sawdust Mix A combination of straw from a round bale and sawdust was mixed to approximately a 60:40 ratio by volume. The combination of the larger particle size of the straw and the small particle size of the sawdust provided good surface area for microbial growth while being able to retain heat and allow airflow through the pile.

Again the disadvantage of this amendment is the lack of availability of sawdust on the farm.

4.3.2. Study of number of carcasses per pile

4.3.2.1. Treatments All compost piles constructed for the 2004 trials contained only one cattle carcass per pile. In the 2005 trials the compost piles were constructed with either one or two carcasses per pile. The position of the carcass in the compost piles containing one carcass per pile is demonstrated in Fig. 2a. The placement of two carcasses per pile attempted to improve the C:N ratio by increasing the nitrogen content of the pile. Overlapping of the bodies as shown in Fig. 2b created a larger body mass while taking up minimal space. Comparisons between one carcass and two carcasses per pile were made in 2005 at the Pansy site. Table 2 describes the treatments of the number of carcasses per pile and amendment.



(a) (b)

Figure 2. Cross sectional view of cattle mortality composting pile showing the positioning of (a) one carcass/pile and (b) two carcasses/pile, 2005.

Table 2. Treatments of number of carcasses per pile at Pansy site in 2005.

Treatment	Description
Straw-1C	Straw with one carcass per pile
Straw-2C	Straw with two carcass per pile
Sawdust-1C	Sawdust with one carcass per pile
Sawdust-2C	Sawdust with two carcass per pile
Windrow	Compost Mix with 18 carcasses

4.3.3. Study of liner

4.3.3.1. Treatments A liner placed under a compost pile was used to prevent any potential leaching to the soil below the pile. At sites where there were a sufficient number of deads to build two piles of the same amendment, one pile was built on a liner and the other was not. A heavy polyethylene plastic sheet with a thickness of 0.015 cm was used as a liner. The plastic was cost effective and temporary, which suited the purposes of this study and the needs of the producers. The liner treatments are summarised in Table 3.

Table 3. Liner treatments for piles containing one carcass at different sites.

Site	Year	Treatment	Description
Killarney	2004	Straw with liner	Straw-L
		Straw without liner	Straw-NL
Pansy	2004	Straw with liner	Straw-L
		Straw without liner	Straw-NL
		Sawdust with liner	Sawdust-L
		Sawdust without liner	Sawdust-NL
	2005	Straw with liner	Straw-L
		Straw without liner	Straw-NL
		Sawdust with liner	Sawdust-L
		Sawdust without liner	Sawdust-NL

4.4. Compost pile design

Two major requirements were met when piles were established. One was an adequate thickness of amendment cover surrounding the carcass or carcasses, and the other was a balanced C:N ratio in the pile. The adequate amount of amendment ensures that the carcass is properly covered, moisture is absorbed, heat is retained, odours are prevented, and scavengers are deterred. Adequate coverage of the carcass ultimately determined the size of the compost pile. The thickness of the base, perimeter, and top cover of amendment required ranged from 0.3-0.6 m (1-2 ft) depending on the feedstock. A pile C:N ratio of 30:1 was used as a criteria since this ratio is recommended to create an environment where microorganisms can flourish while generating minimal odour (Keener et al. 2000b).

4.5. Properties of feedstock

Samples of each carbon amendment were collected from 10-15 locations and combined into a composite sample and put into a plastic bag. The composite samples were sent to Norwest Lab to determine their total carbon and total nitrogen content using the AOAC-Protein (Crude) in Animal Feed, 990.03 method (Table 4). The initial C:N ratio of the feedstock was calculated using these two values. The initial moisture content of the amendment at the time of pile construction was determined using the gravimetric oven-drying method outlined in the ASAE Standard (2003) for Moisture Measurement of Forages.

Table 4. Initial moisture content, total carbon, and total nitrogen (%wet basis) of the carbon amendments.

Site	Year	Amendment	Initial Moisture Content (%)	Total Carbon (%)	Total Nitrogen (%)
Austin	2004	Straw	28.3	12.6	0.3
		Sawdust	40.0	26.3	0.1
		Straw/Sawdust	36	44.9	0.1
Boissevain	2004	Sunflower Hull	6.1	31.2	0.1
Killarney	2004	Straw	9.6	10.1	0.1
		Woodchips	31.3	33.9	0.4
Pansy	2004	Straw	10.8	12.3	0.1
		Sawdust	47.2	26.2	0.1
Pansy	2005	Straw	14.8	41.8	0.5
		Sawdust	31.2	46.8	0.1
		Compost Material	28.6	42.4	0.6
Pilot Mound	2005	Straw	40.8	42.7	0.9
		Sawdust	40.0	46.6	0.1

4.6. Pile construction

4.6.1. Static pile construction

Producers provided and operated the tractor with a bucket or forks that was needed to transport the amendment and carcasses when constructing the compost piles. Additional equipment used to construct the piles included shovels, pitchforks, and a measuring tape. All compost piles containing either one or two carcasses per pile were constructed using the following basic steps:

1. Measuring the dimension of the carcass (or carcasses)

   In order to build the proper sized base, the size of the carcass was needed prior to beginning construction.

2. Laying the liner

   For piles with a liner, a heavy polyethylene plastic sheet measuring 3 m wide and 3.5 m long (10 x 12 ft) was placed on the ground (Fig. 3a). For piles without a liner the amendment would be laid directly on the unprotected ground surface.

3. Estimating the amount of amendment

   The amount of amendment was estimated according to the weight and the composition of the carcass or carcasses with the objective to achieve the desired C:N ratio in the pile while ensuring adequate coverage of the carcass.

4. Building the base

   A base layer of amendment was constructed to ensure that liquids released during carcass decomposition were absorbed and to provide aeration underneath the carcass (Fig. 3b). Depending on the amendment used, the base depth ranged from 0.3-0.6 m.

5. Placing the carcass

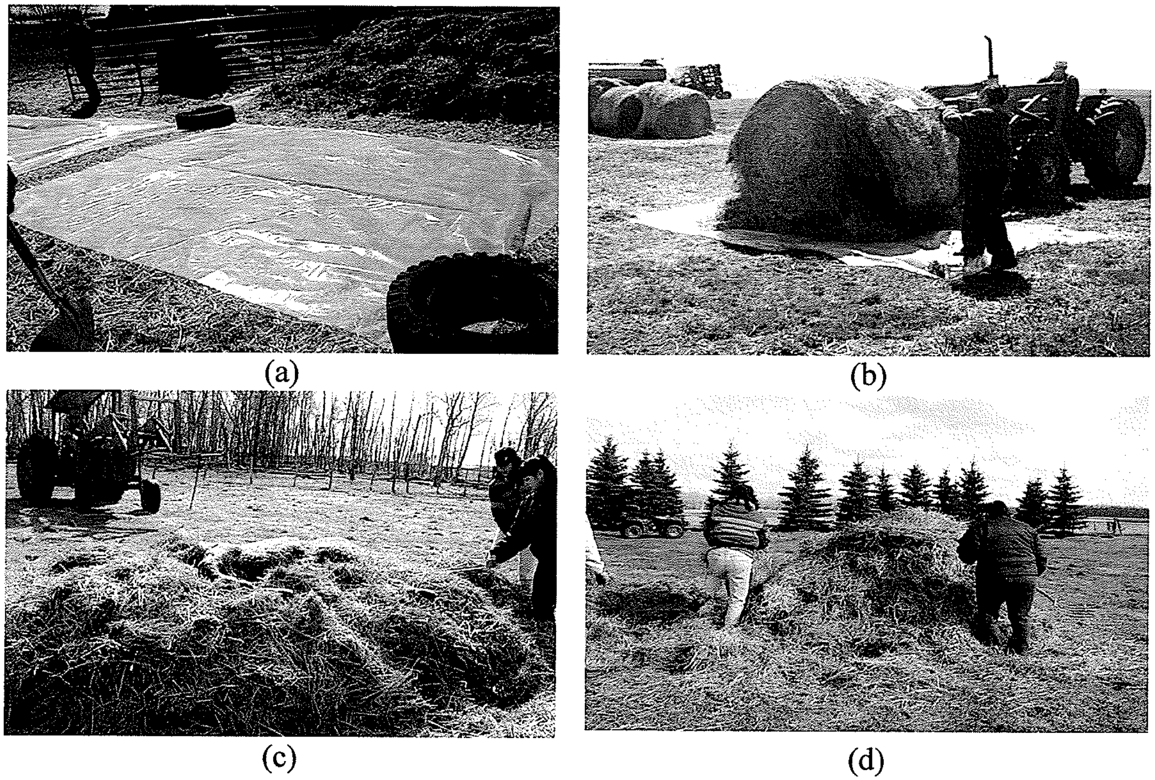
   The carcass was placed in the centre of the base (Fig. 3c). Again depending on the type of amendment used to construct the compost pile, the perimeter surrounding the carcass on all sides ranged from 0.3-0.6 m.

6. Covering the carcass

   The carcass was then covered with amendment to control odour and retain heat (Fig. 3d). Cover thickness depended on amendment and ranged from 0.3-0.6 m.

7. Finalizing pile dimensions

   The final dimension of the compost pile was equal to the size of the carcass plus the desired thickness of the amendment used for the base, perimeter, and cover.



(a) (b) (c) (d)

Figure 3. Photos showing the pile construction procedure. (a) Placing liner. (b) Breaking up a round straw bale for building the base. (c) Measuring perimeter after laying carcass. (d) Finished compost pile with adequate straw surrounding the carcass.

For the compost pile that used a mixed straw/sawdust amendment, straw and sawdust were manually mixed together with pitchforks and shovels (Fig. 4). The overall volume ratio of straw to sawdust was about 60:40. The pile was built using the aforementioned steps.

Figure 4. A bucket of sawdust waiting to be added to the straw while constructing the straw/sawdust pile.

4.6.2. Static windrow construction

A passive windrow was built at the Pansy site to dispose of a large number of deads (18) in 2005. Compost material from the straw and sawdust piles built at the Pansy site in the previous year (2004) were combined and used as the carbon amendment. The benefits of using compost as an amendment is that it is already inoculated with microorganisms, it reduces the cost of amendment, and recycles a waste product. Morse (2001) suggests that only 50% compost be used in the amendment for a new compost piles though this percentage can be higher depending on the level of degradation of the compost. Since the straw and sawdust compost from the 2004 trials was only slightly degraded, 100% of this material was used to construct the entire windrow.

The procedure used to construct the static windrow was similar to that used for the static piles. It began by laying down a plastic liner and overlaying on it a base made of 0.3 m (1 ft) of fresh straw and 0.3 m of compost mix (Fig. 5a). The first carcass was placed on the base at one end of windrow ensuring that it was 0.3 m from the edges. It was placed on its side and covered with approximately 0.15 m (6 inches) of amendment. The next carcass was laid up against the first as demonstrated in Fig. 5b. Consequent carcasses were placed in the same manner down the length of the windrow. A layer of 0.15 m of amendment separated each carcass (Fig. 5c). More compost amendment was added to create a 0.3 m cover on top of the carcasses to complete the windrow construction (Fig. 5d).

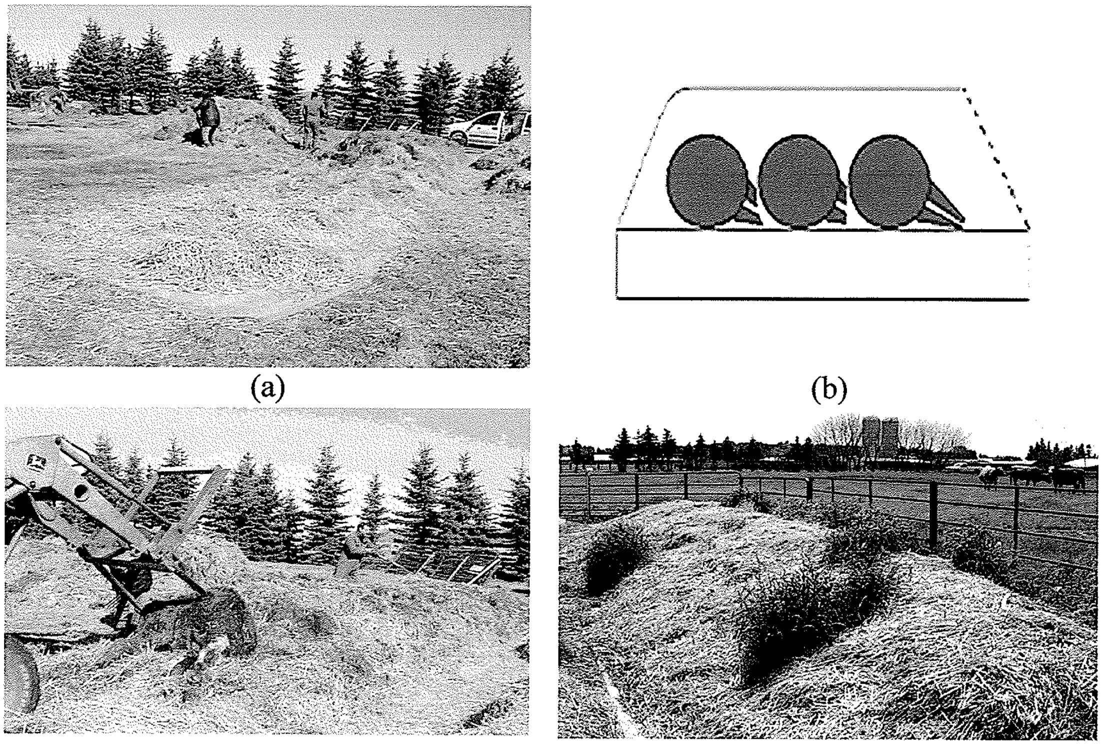


Figure 5. Photos showing the procedure of windrow construction in Pansy 2005. (a) Laying down plastic liner and building a base. (b) Position of cattle carcasses. (c) Cattle carcass being placed in windrow with a tractor. (d) A view of the finished windrow later in trial.

4.6.3. Determining of initial pile dimensions

The compost recipe outlined in the NRAES-114 *Field Guide to On-Farm Composting* (Dougherty 1999) was used to determine the mass of amendment required to cover the carcass that would result in a pile C:N ratio of 30:1. The moisture, carbon, and nitrogen values of the feedstock required to calculate the pile C:N ratio are listed in Table 4. Amendment densities for straw, sawdust, woodchips, and sunflower hulls used in the recipe calculations were 135, 243, 264, and 170 kg/m^3 respectively and were derived from literature (Rynk 1922; Schmidt 2000). A cattle carcass has a carbon value of 37.5%, a nitrogen value of 7.5%, a C:N ratio of 5, and a moisture content of 75% (Keener et al. 2000b). The weight of the cattle carcasses was provided by producer estimates (Table 5).

Table 5. Cattle carcass dimensions for compost piles at the various sites.

Site	Year	Treatment	Carcass Dimensions	
			Weight (kg)	Length x Width x Height (m)
Austin	2004	Straw	453	2.4 x 1.5 x 0.6
		Sawdust	544	2.6 x 1.5 x 0.7
		Straw/Sawdust	500	2.1 x 1.7 x 0.6
Boissevain	2004	Sunflower hull	317	2.1 x 0.9 x 0.6
Killarney	2004	Straw	544	2.4 x 1.5 x 0.7
		Woodchip	544	2.4 x 1.5 x 0.7
Pansy*	2004	Straw	270	1.7 x 1.2 x 0.5
		Sawdust	270	1.7 x 1.2 x 0.5
Pansy*	2005	Straw -1C	270	1.8 x 1.2 x 0.6
		Straw -2C	270	1.8 x 1.2 x 0.6
		Sawdust -1C	270	1.8 x 1.2 x 0.6
		Sawdust -2C	270	1.8 x 1.2 x 0.6
		Windrow	270	1.8 x 1.2 x 0.6
Pilot Mound	2005	Straw	544	2.4 x 1.5 x 0.8
		Sawdust	500	2.4 x 1.5 x 0.8

*Average weight and size of cattle carcasses used at this site.

Calculations showed that the straw pile at the Austin site, the straw/sawdust pile, and the windrow were able to have an optimum C:N ratio while providing adequate cover for the carcass (Table 6). All other piles with the exception of the sunflower hull pile had high C:N ratios, which would increase the total composting time. The lower C:N ratio would result in ammonia volatilization. Since the function of adequate coverage was more critical than decreasing the composting time for on-farm composting, all straw compost piles were constructed with a 0.6 m thick amendment base, perimeter, and cover. The sunflower hull pile and the straw/sawdust also used an amendment thickness of 0.6 m for coverage. Since sawdust is more dense and has a very high C:N, a 0.3 m thick amendment base, perimeter, and cover was used. The woodchip pile also used an amendment thickness of 0.3 m. The compost material for the windrow was a 0.3 m thick for the cover and perimeter, and a 0.6 m base (0.3 m compost and 0.3m straw). Maximum pile dimensions for the completed compost piles are summarized in Table 6.

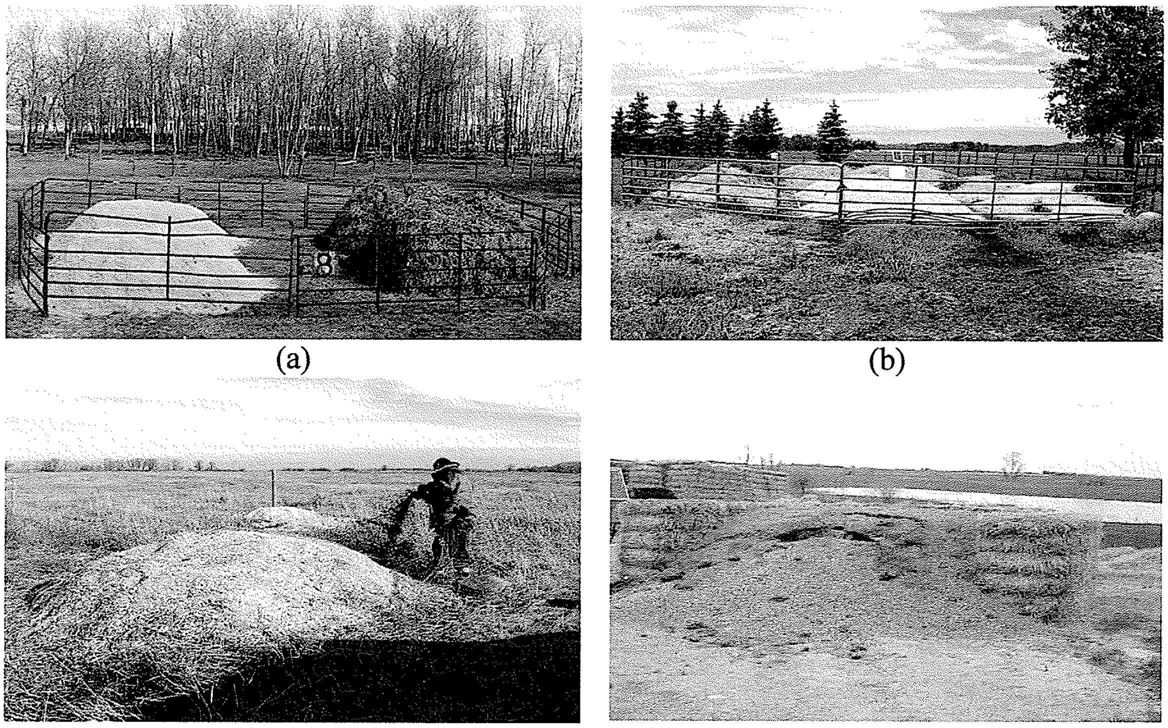
Table 6. Initial compost pile C:N ratios and maximum pile dimensions.

Site	Treatment	Initial Pile C:N ratio*	Maximum Pile Dimension
			Length x Width x Height (m)
Austin	Straw	33.5	3.6 x 2.7 x 1.5
	Sawdust	199.4	3.6 x 3.3 x 1.5
	Straw/Sawdust	25.1	3.6 x 3.0 x 1.4
Boissevain	Sunflower hull	20.9	3.2 x 2.7 x 1.2
Killarney	Straw	87.3	3.6 x 2.7 x 1.4
	Woodchip	39.0	3.6 x 2.7 x 1.4
Pansy 2004	Straw	43.5	3.5 x 2.5 x 1.5
	Sawdust	132.1	3.5 x 3.6 x 1.2
Pansy 2005	Straw -1C	50.3	3.4 x 2.2 x 1.2
	Straw -2C	62.1	3.4 x 2.5 x 1.4
	Sawdust -1C	219.7	3.0 x 2.7 x 1.2
	Sawdust -2C	238.4	3.4 x 3.2 x 1.2
	Windrow	35.1	14 x 2.4 x 1.4
Pilot Mound	Straw	49.8	3.7 x 2.4 x 1.2
	Sawdust	299.7	3.7 x 2.4 x 1.2

*Calculation of initial pile C:N ratio based on literature values.

4.6.4. Enclosures

Although no enclosure was originally planned for the compost piles, in 2004 it became obvious early in the trial that piles would need to be protected from scavengers and livestock that had access to the site. A panel fence was used to prevent livestock from disturbing the piles at the Pansy site (Fig. 6a and 6b). At the Austin, Killarney, and Pilot Mound sites a 2-inch wire mesh was pegged over the piles (Fig. 6c). The sunflower hull pile at the Boissevain site was surrounded on three sides by square bales (Fig. 6d).



(a) (b)

(c) (d)

Figure 6. Photos showing pile enclosures. (a) Panel fence surrounding compost piles at the Pansy site, 2004. (b) Panel fence for piles and windrow at the Pansy site, 2005. (c) Removal of the two-inch wire mesh from pile in the fall at the Austin site, 2005. (d) Sunflower pile enclosed on three sides with square bales.

4.6.5. Compost pile turning

When internal pile temperatures reached ambient air temperature, the compost piles were turned since no heat generation indicated that the composting process had ceased. Table 7 shows the dates that the cattle mortality compost piles were constructed at each site, the dates that the piles were turned, and the number of days piles composted.

Table 7. Dates of construction, turning, and the number of composting days for compost piles.

Site	Amendment	Year	Construction Date	Turned Date	Composting Days
Austin	Straw	2004	April 8	October 22	198
	Sawdust	2004	April 27	October 22	179
	Straw/sawdust	2005	April 29	November 2	187
Boissevain	Sunflower hull	2004	May 10	N/A*	169
Killarney	Straw, Sawdust	2004	May 10	November 2	176
Pansy	Straw, Sawdust	2004	April 19	November 5	202
	Straw, Sawdust	2005	April 22	October 27	189
Pilot Mound	Straw, Sawdust	2005	May 3	October 1	149

*Sunflower hull pile at Boissevain was not turned due to cattle from the feedlot getting into the area a week earlier and completely destroying the pile.

An internal examination of the pile was done by manually digging into the pile as seen in Fig. 7a to determine the state of decomposition of the carcass. Following the investigation the piles were turned with a front-end loader or tractor bucket supplied by the producer so that soil samples could be taken from beneath the pile (Fig. 7b).

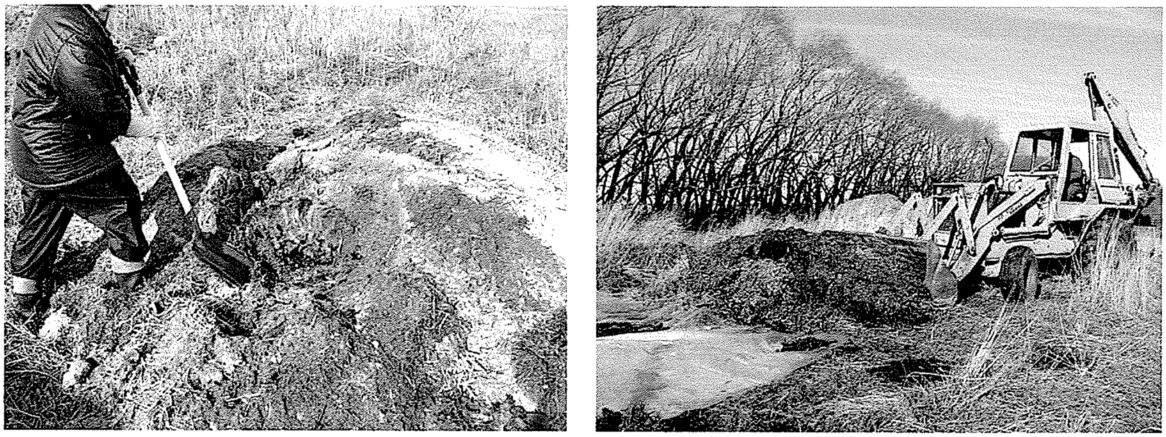

(a) (b)

Figure 7. (a) Digging into the straw/sawdust pile to determine decomposition state of cattle carcass. (b) Woodchip compost pile being turned by a front-end loader.

4.7. Analysis and measurements

4.7.1. Moisture content

Continual and manual monitoring of the compost piles was done to collect moisture content data for the duration of the study. Moisture content readings for the compost piles were taken at heights midway through the base layer at position M4, directly below the carcass at position M3, directly above the carcass at position M2, and in the middle of the covering layer at position M1 (Fig. 8).

The Pansy and Boissevain pile moisture contents were continually monitored over the course of the composting trial. For the Pansy sites, the moisture content for piles containing one carcass were monitored at layer M2 (Fig. 8) using a CS615 Water Content Reflectometer (Campbell Scientific, Edmonton, Alberta). For piles containing two carcasses per pile, the moisture content was monitored at the M2 layer using ECH_2O Soil Moisture Probes (Decagon Devices Inc., Pullman, WA). Moisture content readings for the compost pile at the Boissevain site was also monitored using the ECH_2O Soil Moisture Probes at layers M2 and M3 (Fig. 8).

Data was recorded using a data acquisition system comprised of a CR10X datalogger and PC208 Datalogger Support Software (Campbell Scientific). A solar panel facing south at a 65° angle maintained a charged battery for the system. Continual readings were taken every four hours and the data was downloaded to a laptop computer every two weeks.

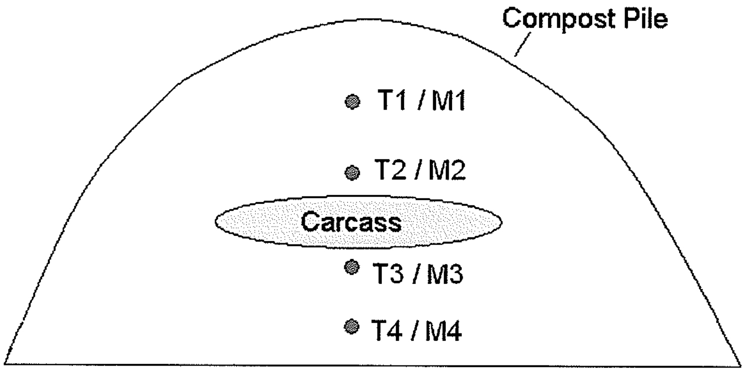
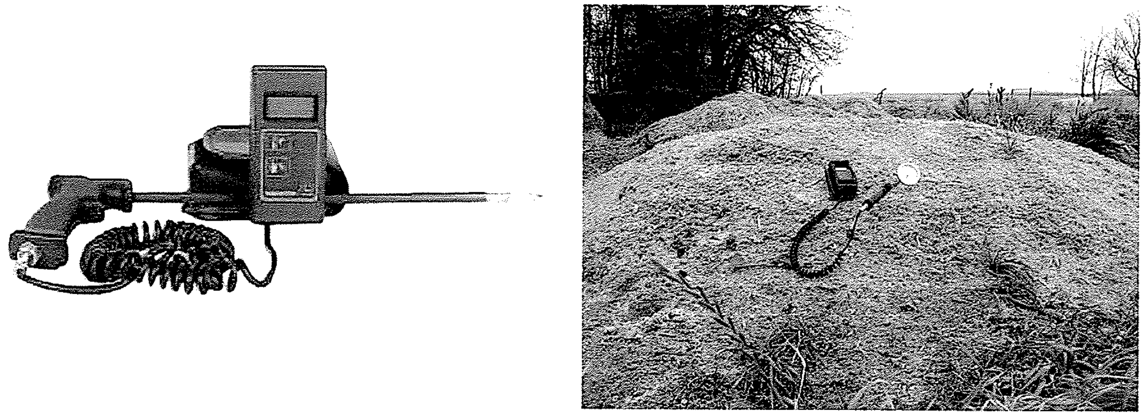


Figure 8. Cross-section of compost pile showing the top (T1/M1), above carcass (T2/M2), below carcass (T3/M3), and bottom (T4/M4) layers where temperature and moisture content readings were taken.

For the 2004 and 2005 Austin, Killarney, and Pilot Mound sites, manual moisture content readings were taken at positions M1 to M4 (Fig. 8). These readings were taken with a SW16136 Digital Hay Tester (John Deere, Moline, Illinois) (Fig. 9a). These moisture content readings were taken simultaneously with temperature readings since the hay tester had the capabilities to test both parameters. Readings were recorded on a bi-weekly schedule. Figure 9b shows moisture content and temperature readings being collected from a sawdust compost pile.



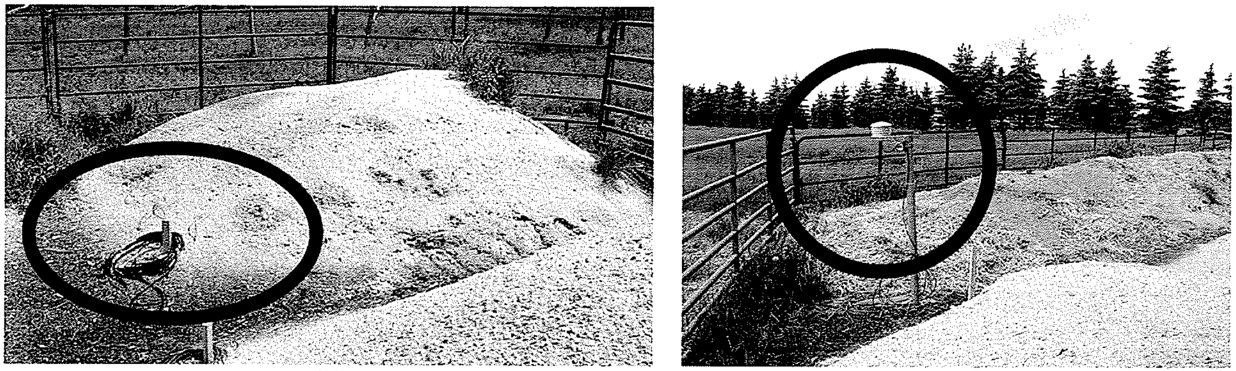
(a) (b)

Figure 9. (a) Digital hay tester used for taking manual moisture readings. (b) Taking pile moisture content and temperature readings.

4.7.2. Temperature

Temperature readings for the compost piles were taken from the centre of the pile at heights midway through the base layer at position T4, directly below the carcass at position T3, directly above the carcass at position T2, and in the middle of the covering layer at position T1 (Fig. 8).

The Pansy and Boissevain compost pile temperatures were continually monitored during the course of the composting trial. Temperatures at the Pansy site were measured using thermocouple wires (copper/constantine) (Fig. 10a). At the Boissevain site, four 107B Soil/Water Temperature Probes (Campbell Scientific) were used to collect temperature data. A 6-Plate Gill Shield (Campbell Scientific) housed a thermocouple that took ambient air temperatures near the piles (Fig. 10b). Temperature readings were recorded every four hours with the same data acquisition system used for taking moisture content measurements.



(a) (b)

Figure 10. Temperature measurement at the 2005 Pansy site. (a) Thermocouple and water reflectometer wires in a sawdust compost pile. (b) A 6-Plate Gill Shield houses a thermocouple to take ambient air temperatures.

Manual temperature monitoring was done on a bi-weekly schedule at all other sites and for the windrow at the Pansy site. The SW16136 Digital Hay Tester (John

Deere) and a dial stem thermometer (Fig. 9a) were used for this purpose. The dial thermometer was used as a means to check the performance of the hay tester. In the windrow, temperature measurements were only taken at position T2 at 6 locations along the length due to the difficulty of inserting the temperature equipment in between the carcasses (Fig. 11).

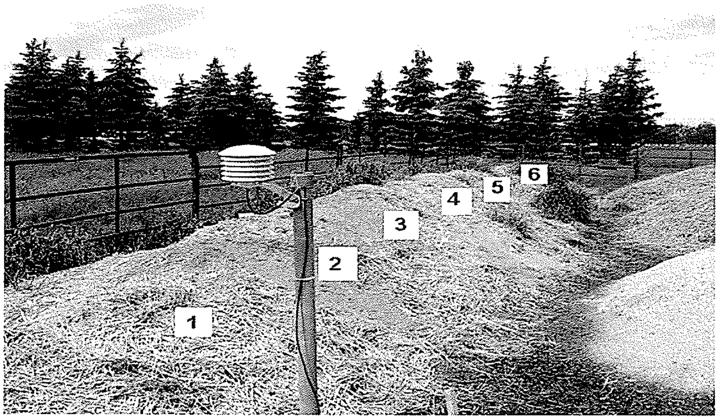


Figure 11. Six locations along the length of the windrow indicating where temperature and moisture content readings were taken, 2005.

4.7.3. Pile volume reduction

Initial and final compost pile dimensions were measured. A tape measure was used to take dimensions of the compost piles as shown in Fig. 12. The pile volume was estimated using the following equation:

$$\text{Volume} = 1/3 * H * \left(S_1 + S_2 + \sqrt{S_1 * S_2}\right)$$

where: H = Height,
S_1 = Base area (L_1 x W_1) (Fig. 12)
S_2 = Top area (L_2 x W_2) (Fig. 12)

A reduction in volume is desirable since it means there is a decreased amount of waste produced. The percent reduction in volume was calculated as:

$$\frac{Vi - Vf}{Vi}$$

where: Vi = initial pile volume taken when pile was constructed
Vf = final pile volume taken at time of pile turning

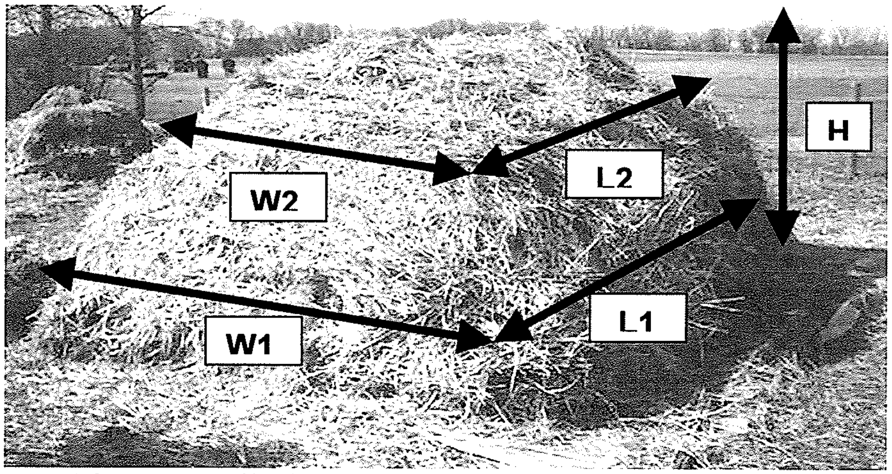


Figure 12. Pile dimensions used to calculate pile volume.

4.7.4. Properties of compost

Final compost samples were collected from the compost pile the same day that the pile was turned. Samples were taken from approximately 10 locations throughout each pile using a sterile glove and container. Composite samples were formed and sent to Norwest Labs to be tested for salmonella and fecal coliforms to determine pathogen kill. The method of analysis used for salmonella was the isolation of Salmonella Species – MSRV, Sept. 1998, MFLP-75. The Fecal Coliform Procedure, 9221 E was the methodology used to determine fecal coliforms.

Compost samples were also tested for total carbon (C), total nitrogen (N), and ammonium (NH_4) that were determined by the AOAC Protein (Crude) in Animal Feed, 990.03 method. Phosphorous (P), sulphur (S), calcium (Ca), potassium (K), magnesium (Mg), and sodium (Na) were analysed using the ICP – AOAC Metals and Other Elements in Plants 985.01 method. The method used to determine pH was the 1:10 DI water extraction, McKeague 1978.

The percent reduction in C:N ratio was calculated as:

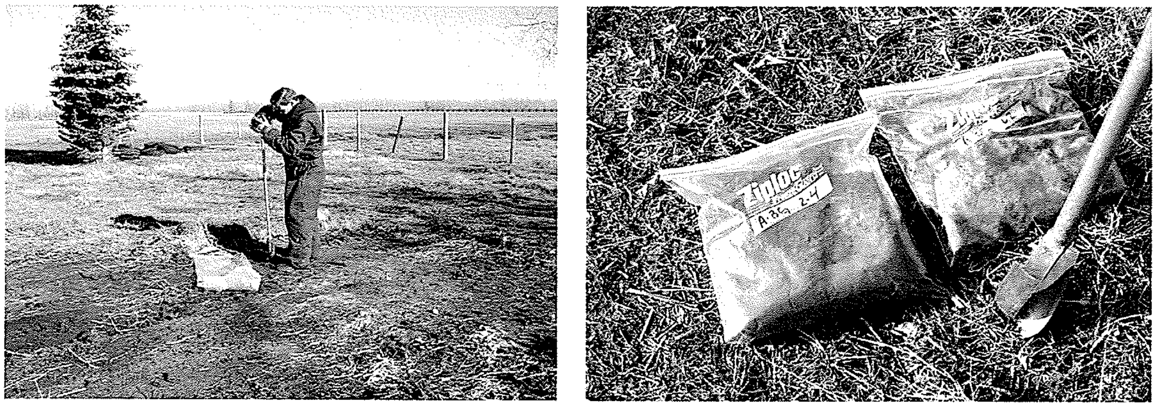
$$\frac{C:Ni - C:Nf}{C:Ni}$$

where: *C:Ni* = initial pile C:N ratio taken when pile was constructed
C:Nf = final pile C:N ratio taken when pile was turned

4.7.5. Soil sampling

At the time the piles were turned in each year, soil samples were taken directly beneath the compost pile. A comparison of samples taken beneath the piles between the liner and no-liner treatments was used to determine if nutrient levels were higher under the piles with no liners.

All samples were collected with a soil core sampler (Fig. 13a) at 3 locations to a depth of 1.2 m (4 ft). Composite samples (Fig. 13b) were formed for depths of 0-0.6m (0-2 ft) and 0.6–1.2 m (2-4 ft). Nutrient analysis was done at Norwest Lab to test for nitrate-N, phosphorus, and potassium using the Modified Kelowna Soil Test, Vol. 26, 1995 methodology. Soil pH was determined using the 1:2 Soil:Water Ratio, 4.12 method.



(a) (b)

Figure 13. (a) Soil samples taken with a soil core sampler. (b) Composite soil samples collected in plastic bags.

4.7.6. Cost analysis

The cost of the straw bales 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. Only materials purchased for establishing piles were recorded for cost analysis.

5. DATA ANALYSIS

Statistical analysis was performed using SAS 9.1 for the comparison of moisture content and temperature distribution and between treatments. For balanced data sets Fisher's Protected Least Significant Difference (LSD) test was used. For unbalanced data sets the mean and standard error were used for indicating significantly different results. All statistical analysis was performed at a $P = 0.1$ significance level.

At each site data was pooled for piles constructed with the same amendment. To investigate treatment effect, data was also pooled over pile layers and days. For continually monitored sites, hourly data readings taken in a 24-hour period were pooled to obtain average daily readings.

Data for the Killarney and Boissevain sites were analyzed together since these sites were located close to one another and experienced the same weather conditions.

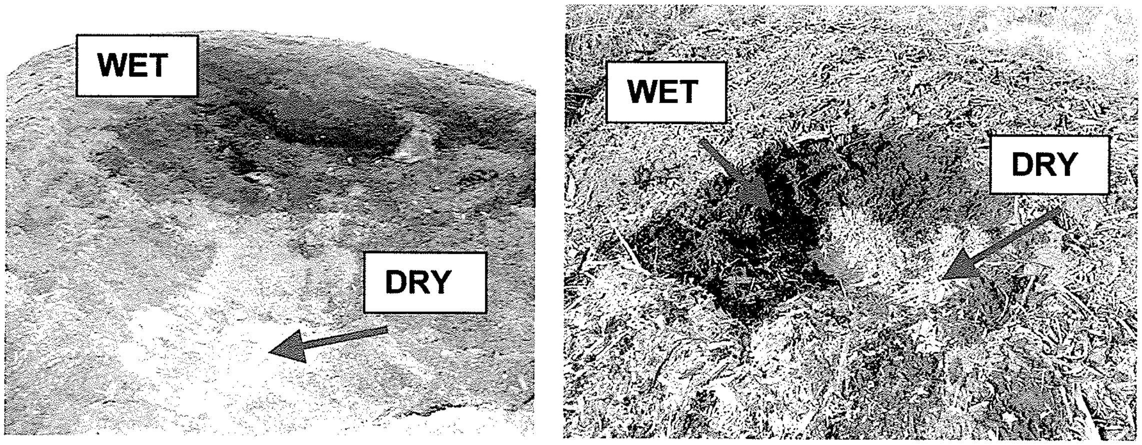
A strong correlation ($R^2 = 0.8$ to 0.92) was seen between readings taken with the dial stem thermometer and the hay tester. Therefore data collected with the hay tester is represented below for manually monitored sites.

Missing data at the beginning of the 2004 trials was due to equipment issues and excessive rainfall that prevented access to the composting sites. At the Pansy site, which was continually monitored, temperature data is missing for short periods due to the corrosion and subsequent replacement of thermocouples.

6. RESULTS AND DISCUSSION

6.1. Study of layers

Since mortality compost piles were built in layers (amendment-carcass-amendment) and piles were not turned, an inspection of the compost piles found areas of different moisture inside the pile. The lighter coloured amendment indicated drier areas while the dark areas contained more moisture as shown in Fig. 14a and 14b. Data collected during this study revealed that both moisture content and temperature were not uniformly distributed throughout the compost piles.



(a) (b)

Figure 14. Photos showing the wet and dry areas of compost piles. (a) Sawdust. (b) Woodchip.

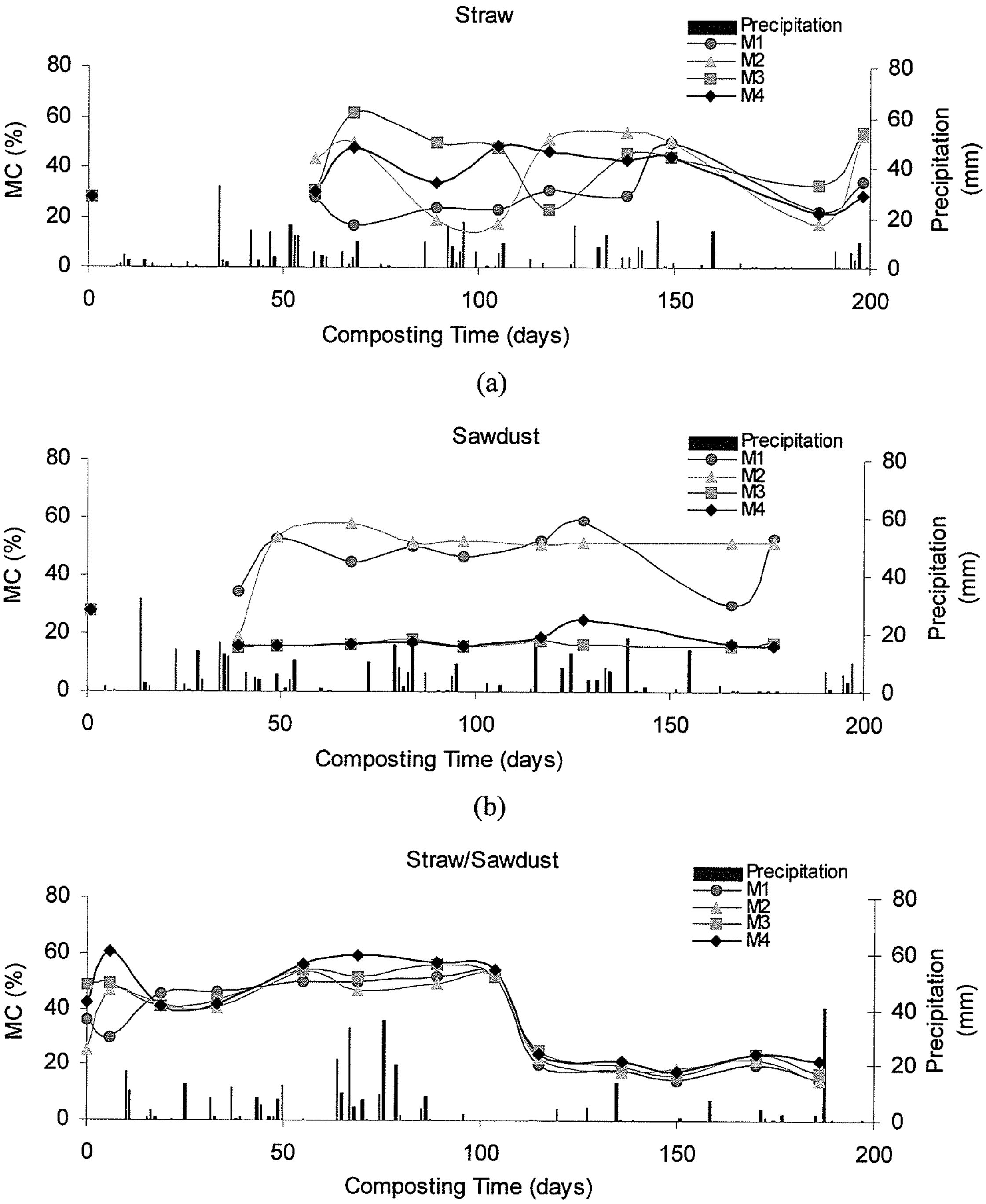
6.1.1. Moisture distribution in pile

Moisture contents for the manually monitored sites at Austin, Killarney, and Pilot Mound were taken at four different layers in the compost piles. The layers are shown in Fig. 8 and are referred to as M1 (top), M2 (above carcass), M3 (below carcass), and M4 (bottom). The daily amount of precipitation received at each site is included as background information. Precipitation data was recorded by Environment Canada weather stations for the area of each site. Moisture distribution was not analysed for continually monitored piles since data was not collected at all layers at the Pansy and Boissevain sites due to limited space on the data logger.

Austin Sites Moisture distribution was not uniform throughout the straw compost pile and each layer experienced different moisture contents (Fig. 15a). The moisture content in the four layers fluctuated over the course of the trial. Higher moisture contents were generally seen in the M3 and M4 layers that ranged from 35 to 60%. This trend is consistent with the flow of moisture down into the pile due to the large pore spaces in the straw. The increased entry and evaporation of moisture is apparent in the M2 layer above the carcass and in the top M1 layer, which maintained the lowest moisture content between 20 and 30%. With the exception of M1, the moisture contents in the pile layers were within the feasible composting range of 40-60%.

The sawdust pile showed two distinct moisture levels within the pile (Fig. 15b). Following a large amount of precipitation, the upper M1 and M2 layers experienced similar moisture contents that rose steeply and remained in a feasible composting range of 40-60%. The M3 and M4 layers of the pile experienced similar moisture contents that ranged from 15 to 25%. The small pore size and the absorbent properties of the sawdust may have prevented moisture from reaching the lower layers of the pile. Sawdust also forms a crust on top of the pile that sheds rainfall so that the inner pile would receive less moisture.

The moisture distribution throughout the straw/sawdust pile was uniform. Moisture contents in the four layers were similar and exhibited the same moisture trend for the duration of the trial. After an initial rise, all layer moisture contents remained in a feasible composting range of 40-60% for approximately the first 100 days. Following this period a sharp decrease in moisture content was seen that coincided with a decreased amount of precipitation. The fact that all layers maintained similar moisture contents demonstrated that the combination of straw and sawdust as an amendment is able to distribute moisture consistently throughout the pile. The larger particle size of the straw allowed moisture to flow through the pile. The smaller particle size and absorbency of the sawdust helped retain and distribute the moisture more evenly within the pile.



(c)

Figure 15. Gravimetric moisture content (MC) readings taken at the top layer (M1), above carcass (M2), below carcass (M3), and bottom layer (M4) for (a) straw, (b) sawdust, and (c) straw/sawdust mixed amendments at the Austin sites, 2004 and 2005.

Killarney Site The moisture distribution trend was similar for both the straw (Fig. 16a) and woodchip (Fig. 16b) compost piles. Moisture contents in the four pile layers fluctuated for the duration of the trial ranging between 15 and 55%, which corresponded to frequent bouts of precipitation. Therefore at times moisture contents were within the feasible limit of 40 to 60%. The moisture contents in the layers of these piles were more similar to each other than those in the Austin piles. Differences in moisture contents between piles of the same amendment at different sites could be due to variations in precipitation, carcass sizes, and amendment properties.

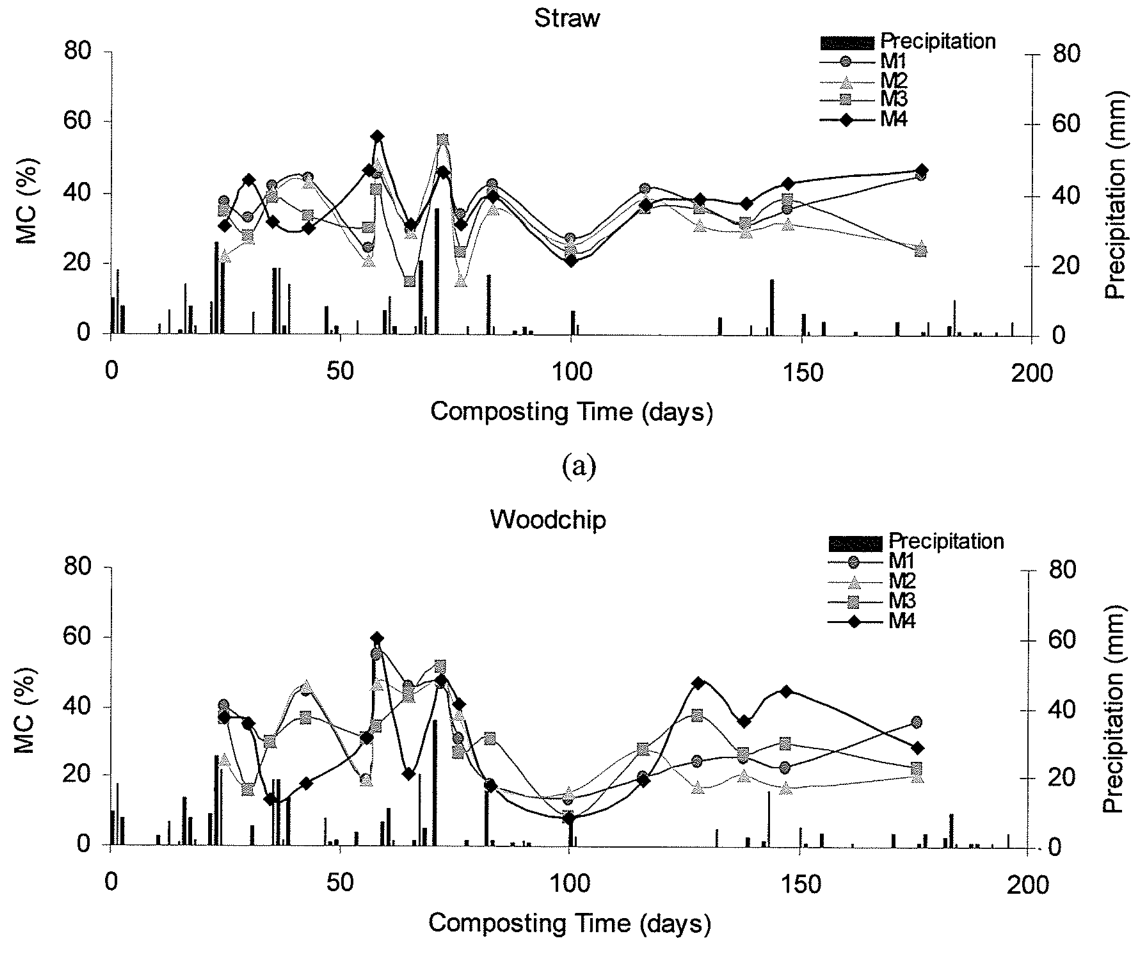
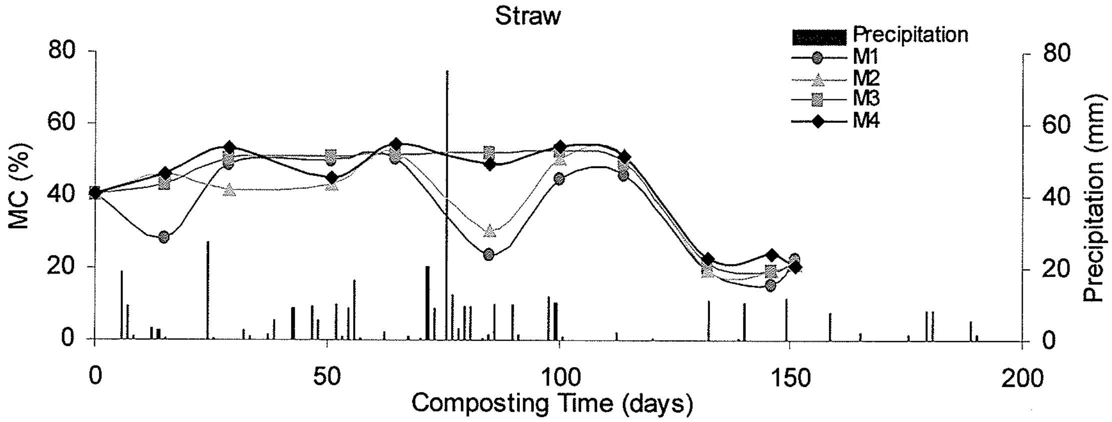
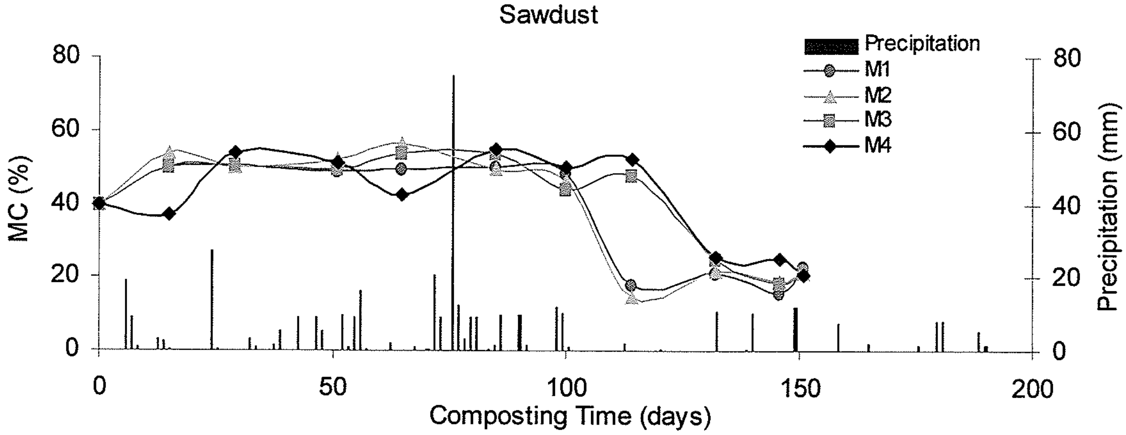


Figure 16. Gravimetric moisture content (MC) readings taken from top layer (M1), above carcass (M2), below carcass (M3), and bottom layer (M4) for (a) straw and (b) woodchip piles at the Killarney site, 2004.

Pilot Mound Site The moisture distribution in the straw pile at the Pilot Mound site was more stable than the straw piles at either the Austin or Killarney site. Moisture contents in a feasible range of 40 to 50% were seen in both the lower M4 and M3 layers (Fig.17a). After the large amount of precipitation received during day 70 to 100 the pile height decreased significantly. It is speculated that the increased moisture could cause the straw to become more pliable and compact. Following this period, layer moisture contents appeared similar due to the decreased distance between sampling.



(a)



(b)

Figure 17. Gravimetric moisture content (MC) readings taken from the top layer (M1), above carcass (M2), below carcass (M3), and bottom layer (M4) for the (a) straw and (b) piles at the Pilot Mound site, 2005.

The moisture distribution was fairly uniform throughout the layers of the sawdust pile (Fig. 17b). As with the straw pile, moisture contents in all the layers were similar and remained stable within the feasible composting range of 40 to 60% for the first 130 days. At this time the M1 and M2 layers showed lower moisture contents that could indicate the pile was drying from the top down. Decreased moistures contents after this period coincided with decreased precipitation. This pile differed from the sawdust pile at the Austin site, as there was no obvious distinction between the moisture contents of the upper and lower layers. This could be attributed to an increased amount of precipitation at the Pilot Mound location that would increase the amount of moisture available to the entire pile.

6.1.2. Differences in moisture content between layers

Statistical analysis of the moisture content data for the Austin site showed there was no significant difference between the moisture contents of the layers in the straw pile. The top M1 and M2 layers in the sawdust pile had higher mean moisture contents than the lower part of the pile. The straw/sawdust pile had significantly higher moisture contents in the lower M3 and M4 layers.

For the Killarney site there was no significance between layer moisture contents for either the straw or woodchip pile.

Analysis of the Pilot Mound data revealed that the lower M4 and M3 layers had significantly higher mean moisture contents than the upper M1 and M2 layers.

Table 8. Mean moisture content (% wet basis) values for layers for different amendment treatments at the Austin (2004), Killarney (2004), and Pilot Mound (2005) sites. Data was pooled over composting days within the year.

		Layer				
Site	Treatment	**M1**	**M2**	**M3**	**M4**	**Pr>F**
Austin						
	Straw	28.8b*	38.9a	43.4a	38.2a	0.08
	Sawdust	46.9a	48.9a	16.9b	17.7b	0.0001
	Straw/Sawdust	34.3b	34.0b	37.7a	39.9a	0.0001
Killarney						
	Straw	35.7a	32.3a	29.9a	35.5a	0.39
	Woodchip	32.0a	28.1a	30.9a	31.5a	0.62
Pilot Mound						
	Straw	35.5b	37.9b	41.6a	42.3a	0.0001
	Sawdust	37.4c	38.6b	41.6b	42.4a	0.02

*Means in the same row and followed by the same letter do not differ significantly (P=0.1) according to Fisher's Protected Least Significant Difference (LSD) test.

6.1.3. Temperature distribution in pile

Temperature readings were taken at four layers T1 (top layer), T2 (above carcass), T3 (below carcass), and T4 (bottom) (Fig. 8) in a compost pile.

Austin Site The temperature distribution in the straw compost pile was consistent over the duration of the trial (Fig. 18a). The T3 and T4 layers in the lower region of the pile maintained higher temperatures than the T1 and T2 layers. Temperatures in the T3 and T4 layers reached temperatures in the feasible composting range of 43 to 66 °C.

The sawdust (Fig. 18b) and the straw/sawdust (Fig. 18c) piles had similar patterns of temperature distribution where the upper T1 and T2 layers consistently experienced higher temperatures. Temperatures between the upper layers were 5 to 20°C higher than bottom layers. The T1 layer in the sawdust and the T1 and T2 layer in the straw/sawdust pile experienced temperatures in the feasible composting range.

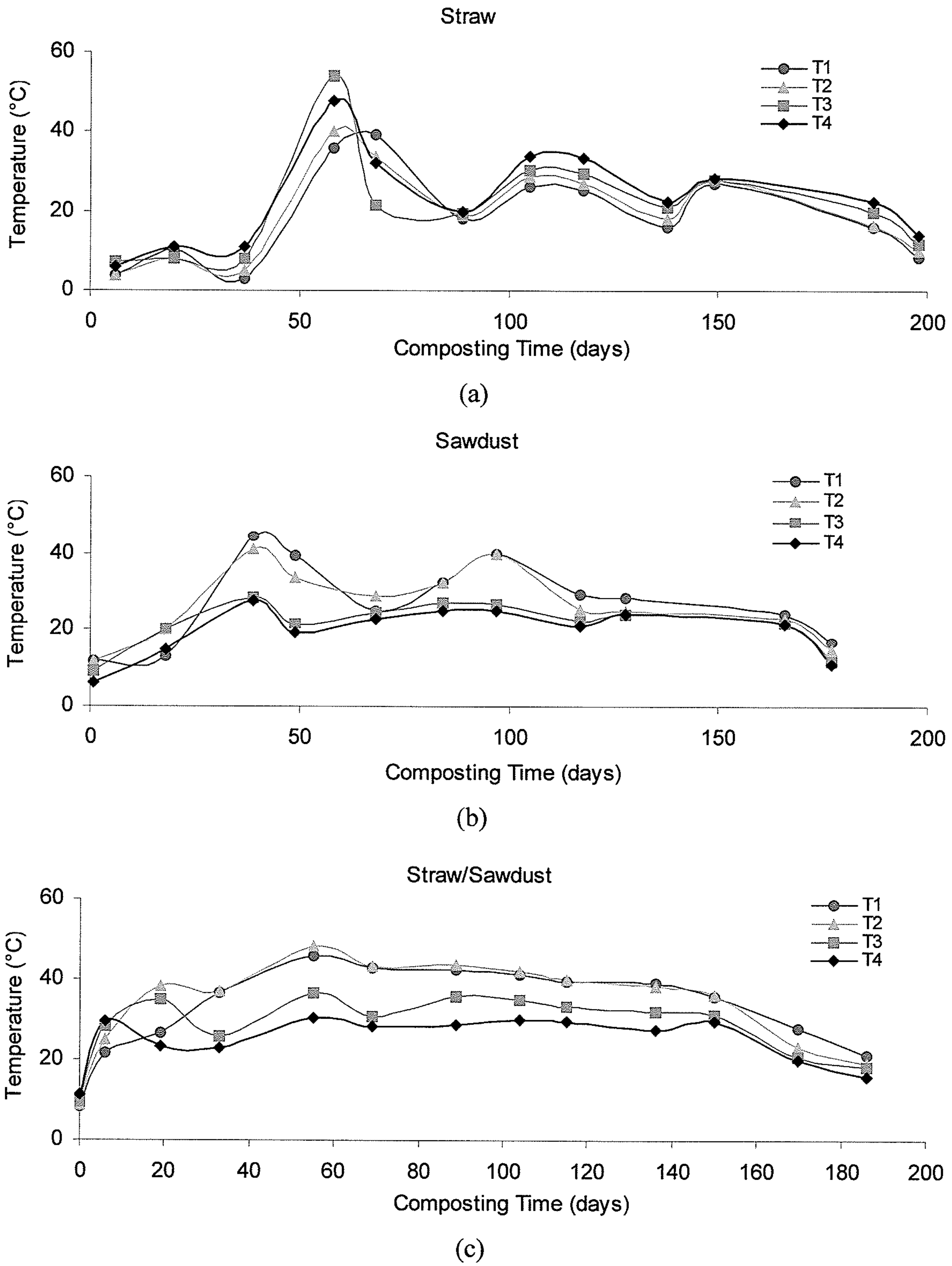
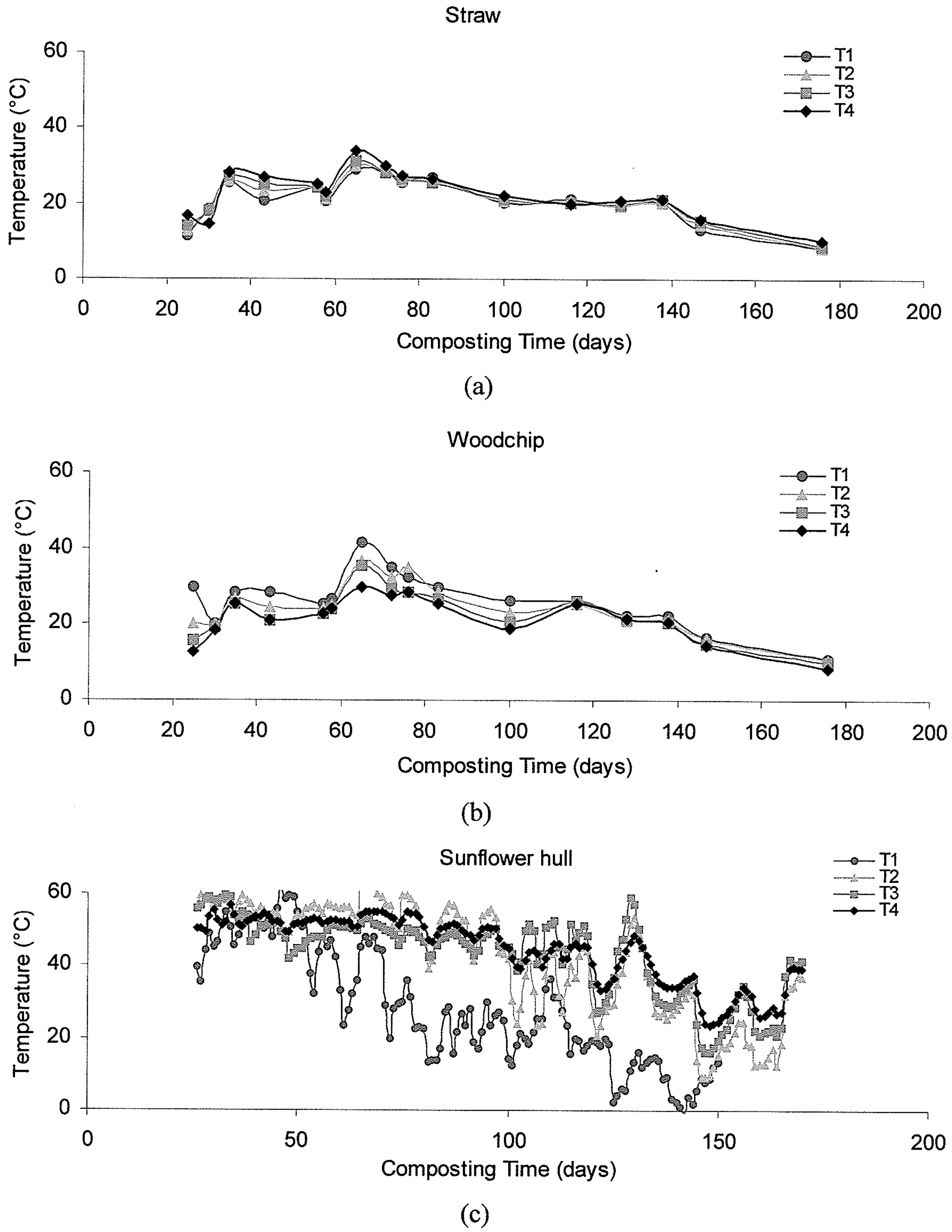


Figure 18. Average daily pile temperatures taken at top (T1), above carcass (T2), below carcass (T3), and bottom (T4) in the (a) straw, (b) sawdust, and (c) straw/sawdust compost piles at the Austin sites, 2004 and 2005.

Killarney/Boissevain Sites The temperature distribution was uniform throughout the straw pile as all layers experienced similar temperatures for the duration of the trial (Fig. 19a). For approximately the first 120 days, the temperatures in the woodchip pile layers differed by about five degrees from each other (Fig. 19b). The top T1 layer experienced the highest temperatures while the bottom T4 layer had the lowest. After 120 days all layers experienced the same temperatures. No layers in the straw pile and only the top T1 layer of the woodchip pile achieved temperatures within the feasible composting range of 43 to 66°C.

The sunflower hull pile did not have a uniform temperature distribution. Temperature readings were lower in the T1 layer for this pile. The T2 and T3 layers near the carcass experienced the highest temperatures. This could be due to increased microbial activity generating heat inside the pile. Temperatures in all layers of the sunflower pile achieved temperatures in the feasible composting range of 43 to 66°C. The T1 and T2 layers experienced temperatures above 55°C for three consecutive days for pathogen kill. The denser sunflower hull amendments retained more heat generated during the composting process than the straw pile.



(a)

(b)

(c)

Figure 19. Average pile temperatures taken in the top (T1), above carcass (T2), below carcass (T3), and bottom (T4) layers for the (a) straw, (b) woodchip, and (c) sunflower hull compost piles at the Killarney and Boissevain sites, 2004.

Pansy Site In 2004 (Fig. 20a) and 2005 (Fig. 20b), straw piles had similar temperature distribution. The temperatures in the T3, T2, and T1 layers were higher than in the bottom T4 layer. During the latter part of the composting trial all four layer experienced similar temperatures.

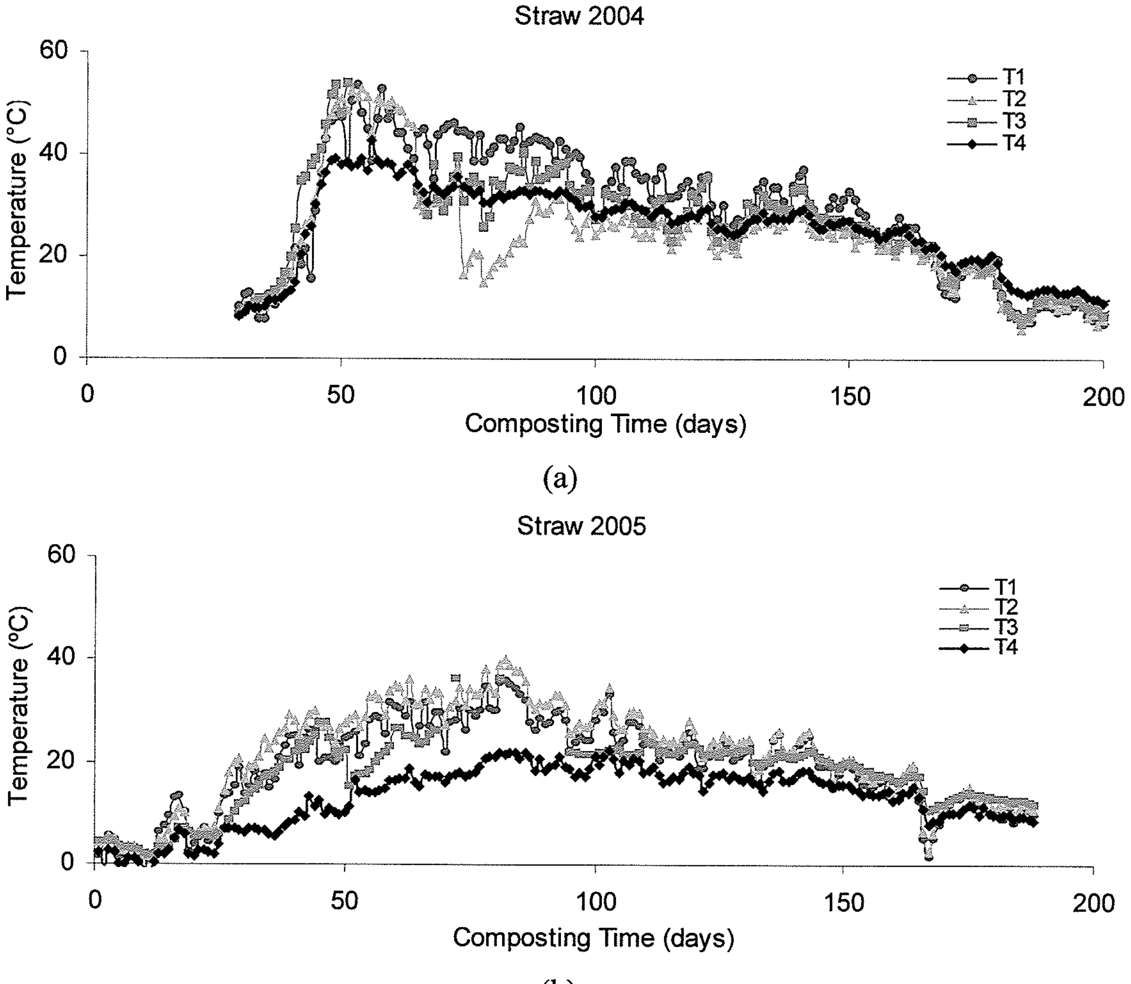
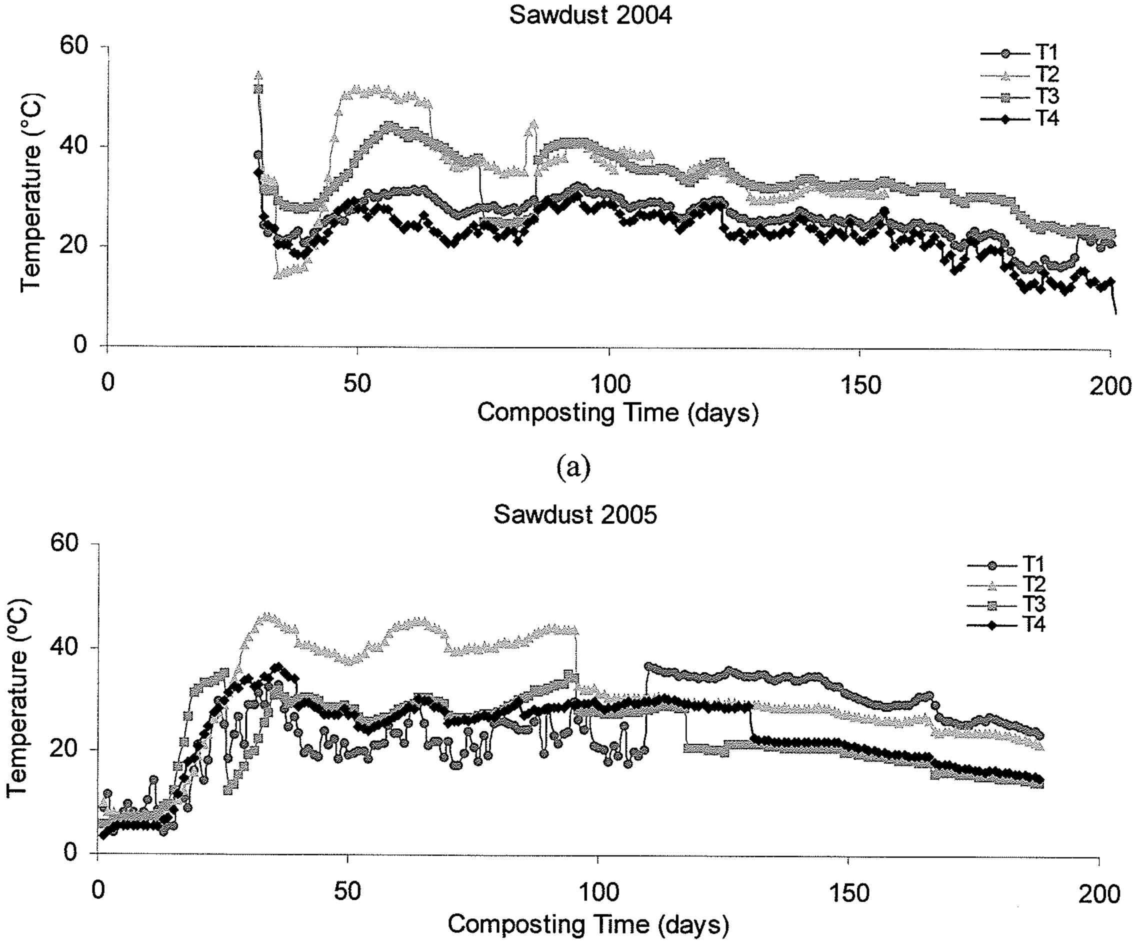


Figure 20. Average pile temperatures taken from top (T1), above carcass (T2), below carcass (T3), and bottom (T4) layers for the (a) 2004 straw and (b) 2005 straw compost piles at the Pansy site.

The 2004 sawdust pile had the highest temperatures in the T2 and T3 layers, which generally ranged from 35-45°C (Fig. 21a). Higher temperatures in these layers closest to the carcass are consistent with increased microbial activity generating heat inside the pile. The temperatures in the top T1 and bottom T4 layers of the pile were cooler ranging between 25 and 35°C.

Temperatures in the 2005 sawdust pile (Fig. 21b) were higher in the T2 layer near the carcass. The top T1 layer had lower temperatures for the first 120 days. In both trial years, temperatures in the T2 layer reached into the feasible composting range.

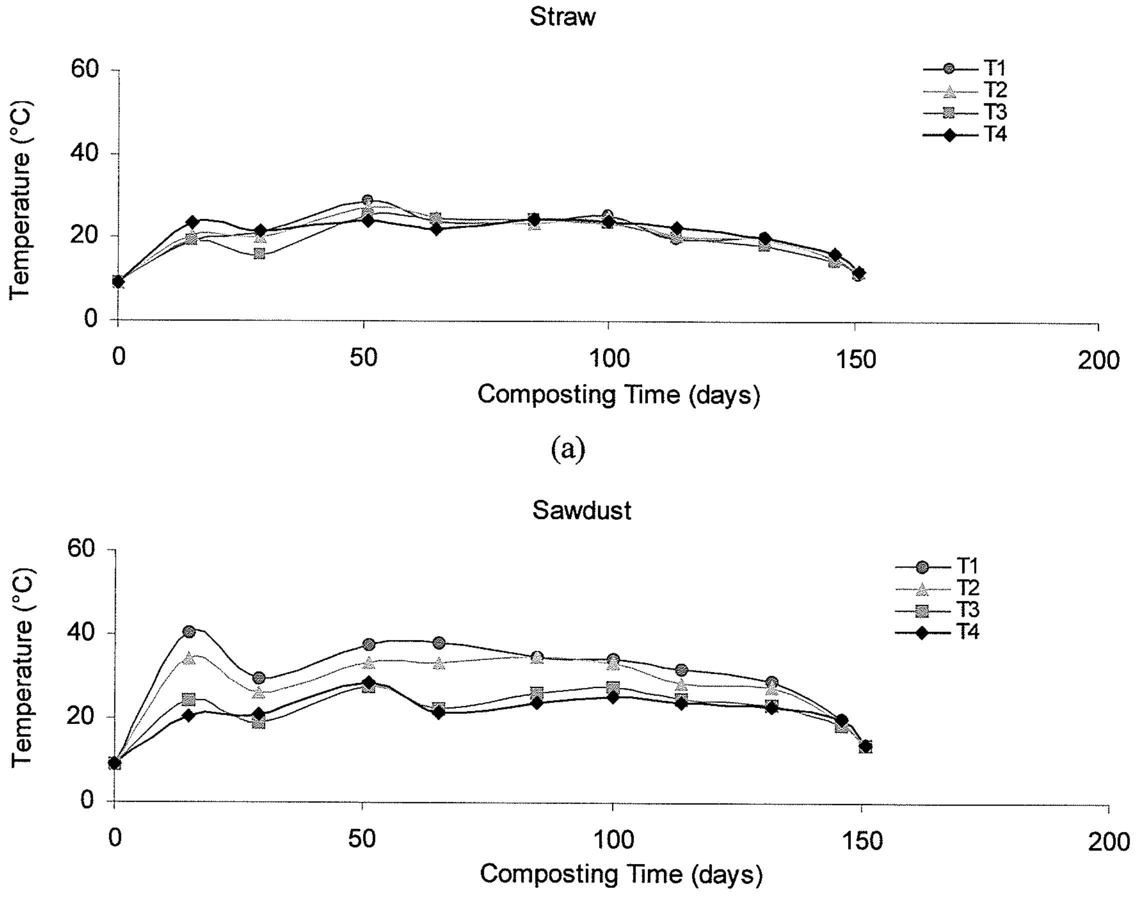


(a)

(b)

Figure 21. Average pile temperatures taken from top (T1), above carcass (T2), below carcass (T3), and bottom (T4) layers for the (a) 2004 sawdust and (b) 2005 sawdust compost piles at the Pansy site.

Pilot Mound The uniform temperature distribution throughout the straw compost pile could be attributed to a large decrease in pile height that shortened the distance separating the layers (Fig. 22a). In the sawdust pile, differences were seen between the upper and lower layer temperatures (Fig. 22b). The T1 and T2 temperatures usually ranged from 30-40°C and were consistently higher than the T3 and T4 layers that ranged from 20-30°C. Temperature distribution in this sawdust pile was similar to the Austin sawdust pile. Neither the straw or sawdust piles at this site reached temperatures in the feasible composting range.



(a)

(b)

Figure 22. Average daily temperatures taken from top (T1), above carcass (T2), below carcass (T3), and bottom (T4) layers for the (a) straw and (b) sawdust compost piles at the Pilot Mound site, 2005.

6.1.4. Differences in temperatures between layers

Table 9 shows that the mean temperature in the T4 layer of the Austin straw pile was significantly higher than the rest of the pile temperatures. Mean temperature readings taken at positions T1 and T2 in the Austin sawdust and straw/sawdust piles were significantly higher than the temperatures in the lower layers of these pile.

Statistically there was no significant difference between the layer temperatures in the straw compost pile at the Killarney site. The mean temperature followed the trend that T1 > T2 > T3 >T4. The bottom T3 and T4 layers in the sunflower hull pile were significantly higher than the upper layers of the pile.

During the 2004 Pansy trial, the straw compost pile experienced the highest mean temperature in the top T1 layer while the T2 layer had the lowest. In the sawdust pile, temperatures in T2 were significantly higher than the rest of the pile temperatures. In 2005, mean temperatures for all layers were significantly different from one another. The T3 layer below the carcass had the highest mean temperature, followed by T2. The bottom T4 layer experienced the lowest mean pile temperature.

For the straw pile at the Pilot Mound site the mean temperature in the T3 layer was significantly lower than the rest of the pile. Temperatures were significantly higher in the top T1 layer of the sawdust pile.

Overall statistical findings showed that there was no consistency in the temperature distribution for piles of the same amendment at different sites. Variations in precipitation, carcass size, and amendment properties could account for this.

Table 9. Temperature probe readings (°C) taken at different layers in compost piles, 2004 and 2005. Data was pooled over days.

		Layer					
Site	Treatment	**T1**	**T2**	**T3**	**T4**	**Standard Error**	**Pr>F**
Austin							
	Straw	23.2b*	24.1b	25.4b	26.9a		0.11
	Sawdust	29.6a	28.3a	22.6b	21.6b		0.0001
	Straw/Sawdust	34.3a	35.3a	29.6b	25.8c		0.0001
Killarney/Boissevain							
	Straw	20.8a	21.2a	21.9a	22.7a		0.66
	Woodchips	25.0a	23.6b	22.2c	21.3d		0.0001
	Sunflower hull	29.2c	40.1b	42.5a	41.9a	0.2	
Pansy 2004							
	Straw	28.9a	25.1c	27.5b	27.7b	0.3	
	Sawdust	28.4c	46.1a	30.8b	25.3d	0.4	
Pansy 2005							
	Straw	18.7c	20.9b	24.4a	15.3d	0.2	
	Sawdust	19.5c	23.7b	31.4a	12.8d	0.3	
Pilot Mound							
	Straw	21.1a	21.1a	19.8b	21.0a		0 .02
	Sawdust	31.0a	28.7b	22.9c	22.3c		0.0001

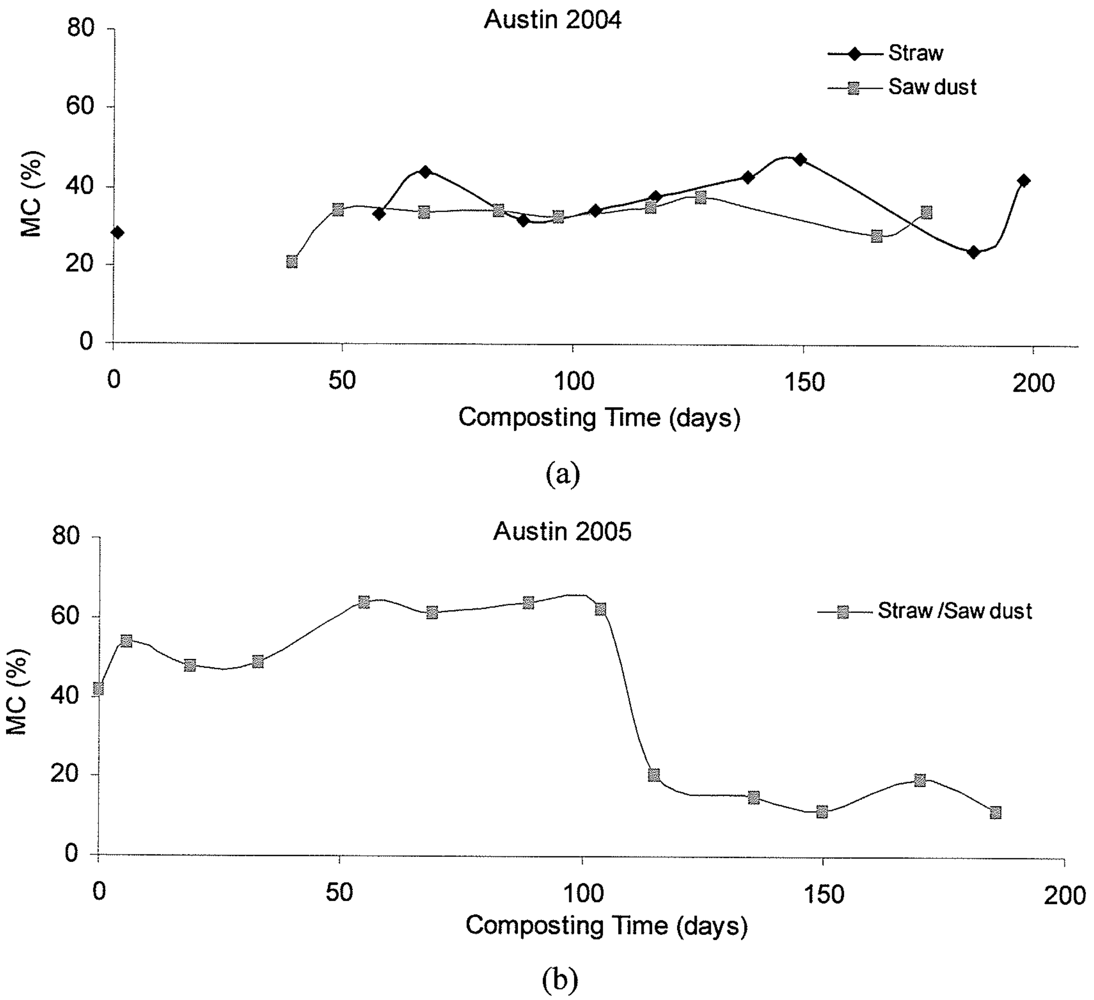
*Means in the same row and followed by the same letter do not differ significantly (P=0.1).

6.2. Study of amendment

6.2.1. General moisture content trends over time

Austin Site The moisture content of the sawdust pile reached a high of 35% on day 50 while the straw pile increased to 45% and peaked near day 65 (Fig. 23). Following this period, pile moisture contents remained fairly stable ranging from 30 to 40%. The moisture trend in each pile was comparable though the fluctuations for the sawdust pile were subtler than that for the straw pile. Since the straw has larger pore sizes and more moisture enters and evaporates from the pile, greater variations in moisture are expected.

The moisture content of the straw/sawdust pile remained in a feasible composting range of 40 to 60% for the first 110 days of the trial. After this period there was a sharp decline and the moisture content then remained around 20% for the duration of the trial.



(a)

(b)

Figure 23. Average gravimetric moisture content (MC) for the (a) straw and sawdust and (b) straw/sawdust compost piles at the Austin sites, 2004 and 2005.

Killarney/Boissevain Sites The straw and woodchip compost piles demonstrated similar moisture trends (Fig. 24). Pile moisture contents for both piles ranged between 15 and 50%. On average, the straw pile had the higher moisture content. This could be due to the more dense woodchips not allowing as much water to penetrate into the pile.

The sunflower hull pile maintained stable moisture contents for the duration of the trial ranging from 20 to 30% (Fig. 24). This lower moisture content could be due to seeds being mixed in with the hulls, which gave the material an "oily" feel. As well this amendment formed a crust on top of the pile that could shed some of the rainfall.

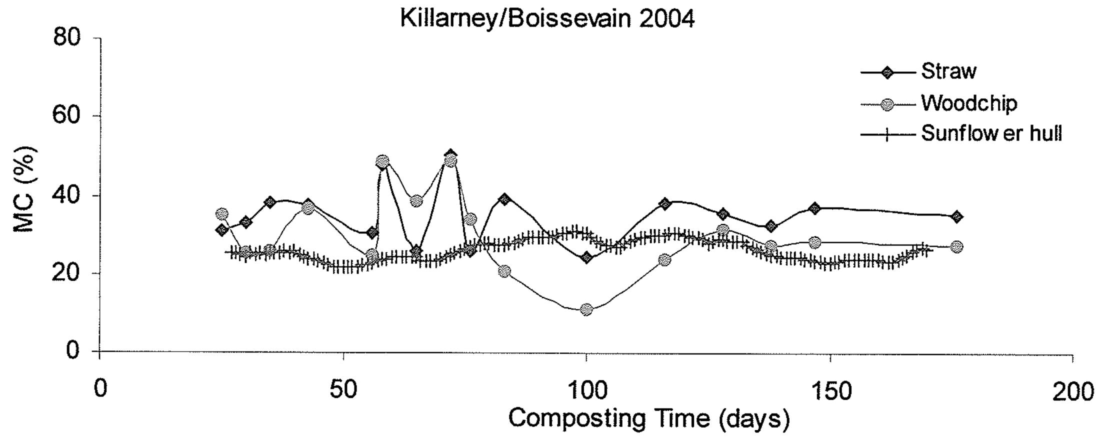


Figure 24. Average gravimetric moisture content (MC) of the straw, woodchip, and sunflower hull compost piles at the Killarney and Boissevain sites, 2004.

Pansy Site For both the 2004 (Fig. 25a) and 2005 (Fig. 25b) composting trials the moisture content for the straw and sawdust piles followed similar patterns. The moisture content in the sawdust piles remained stable near 60% and was generally higher than the moisture content in the straw piles. The 2004 straw pile showed an increase in moisture to near 60% between day 50 and 100. A subtler increase in moisture was also observed in the 2005 pile that happened earlier between days 30 to 80.

Compared to the Austin sawdust pile, the moisture content of these sawdust piles were higher but showed the same trends. The straw piles at the Pansy site did not fluctuate like the straw piles at the Boissevain site or increase over time as the Austin piles did. Different amounts of precipitation received at each site and different carcass sizes could be responsible for the variation in behaviour of piles of the same amendment.

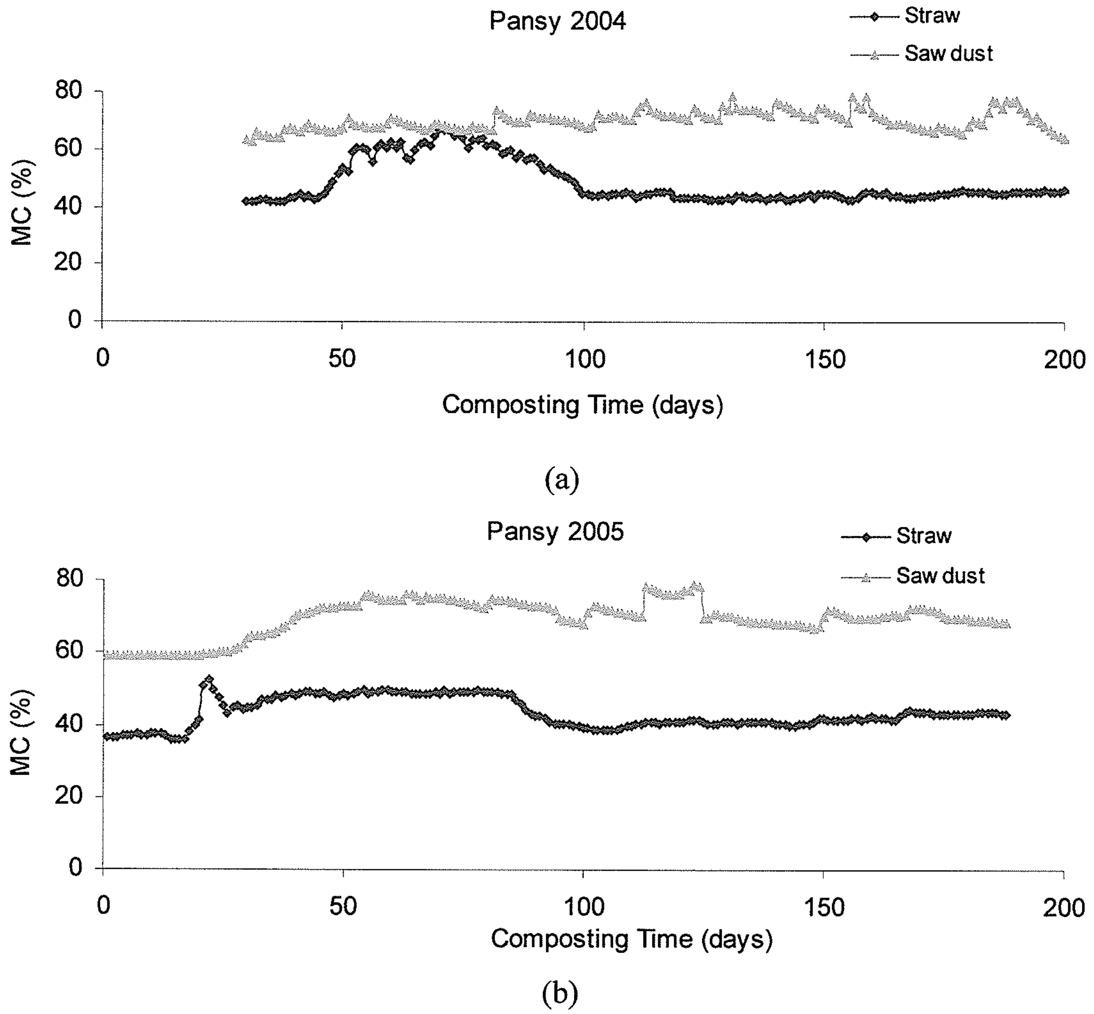


Figure 25. Average gravimetric moisture content (MC) for straw and sawdust compost piles at the (a) 2004 and (b) 2005 Pansy sites.

Pilot Mound Site The moisture contents for both the straw and sawdust piles remained near 50% for the first 100 days of the composting trial (Fig. 26). After this the moisture content for both piles decreased. Like the straw and sawdust piles at the Austin site, moisture content changes in the sawdust pile were subtler than in the straw pile.

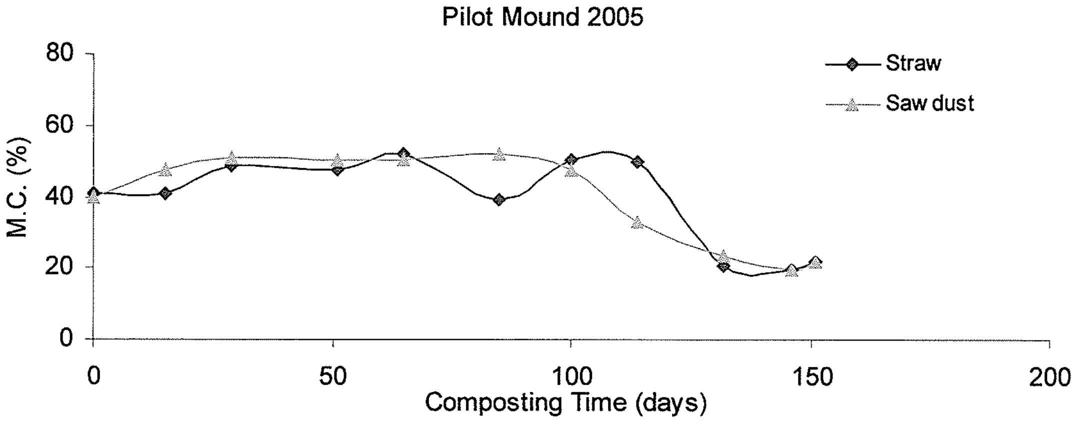


Figure 26. Average gravimetric moisture content (MC) for straw and sawdust compost piles Pilot Mound, 2005.

6.2.2. Amendment effect of moisture

Table 10 shows the results of the statistical analysis performed on moisture data collected from the compost piles constructed of the various amendments. At both the Austin 2004 site and the Pilot Mound site no significant difference was seen between the mean moisture content of either the straw or sawdust piles. Analysis of the Killarney/Boissevain data revealed that the mean pile moisture content for the straw pile was significantly higher than that of the woodchip and sunflower hull piles. For both the 2004 and 2005 Pansy trails the sawdust pile had a significantly higher mean moisture content than the straw pile.

The straw/sawdust pile was not included in the analysis since it was the only pile constructed at the Austin site in 2005.

Table 10. Mean moisture contents (% wet basis) for amendment treatments at composting trial sites, 2004 and 2005. Data was pooled over layers and composting days within the year.

Site	Treatment	**Mean**	**Standard Error**	**Pr>F**
Austin 2004				
	Straw	37.8a*		0.14
	Sawdust	32.6a		0.14
Killarney/Boissevain				
	Straw	35.5a	1.1	
	Woodchip	30.6b	1.6	
	Sunflower hull	30.4b	1.1	
Pansy 2004				
	Straw	48.2b	0.3	
	Sawdust	72.7a	0.3	
Pansy 2005				
	Straw	37.0b	0.9	
	Sawdust	45.3a	0.3	
Pilot Mound				
	Straw	40.9a		0.7
	Sawdust	40.2a		0.7

*Means in the same column and the same site followed by the same letter do not differ significantly (P=0.1).

6.2.3. General temperature trends over time

Ambient temperatures recorded at Environment Canada weather stations for each area are included as background information. A comparison of the compost pile temperature to the ambient temperature demonstrates that heat is generated in the pile, which could be attributed to the composting process.

Austin Sites The cattle carcass placed in the straw pile was frozen since it had died earlier in the spring when temperatures were still in the freezing range. This could account for the compost pile temperatures being below ambient temperature at the start of the trial since the straw would act to insulate the carcass and prevent thawing, which would delay the composting process. Approximately 35 days after construction the temperature of the straw pile increased quickly reaching 44°C on day 58 (Fig. 27a). Following this period, pile temperatures continued to decrease gradually until they neared ambient temperature. While the temperature in the straw compost pile remained above ambient temperatures for the majority of the composting trial, pile temperatures appear to fluctuate with the changes in ambient temperatures.

The overall temperature trend in the sawdust pile was stable, maintaining temperatures within a 25 to 35°C range (Fig. 27a). The sawdust pile temperatures remained above ambient temperature for the entire duration of the composting trial and did not appear to be influenced by changes in outdoor temperatures.

Figure 27b shows that the temperature in the straw/sawdust compost pile rose quickly within the first 10 days after construction and remained fairly stable for the duration of the composting trial. Pile temperatures remained well above ambient temperatures and did not appear to be influenced by outdoor temperatures. The heating trend for the straw/sawdust pile was similar to the sawdust pile although temperatures were not as high.

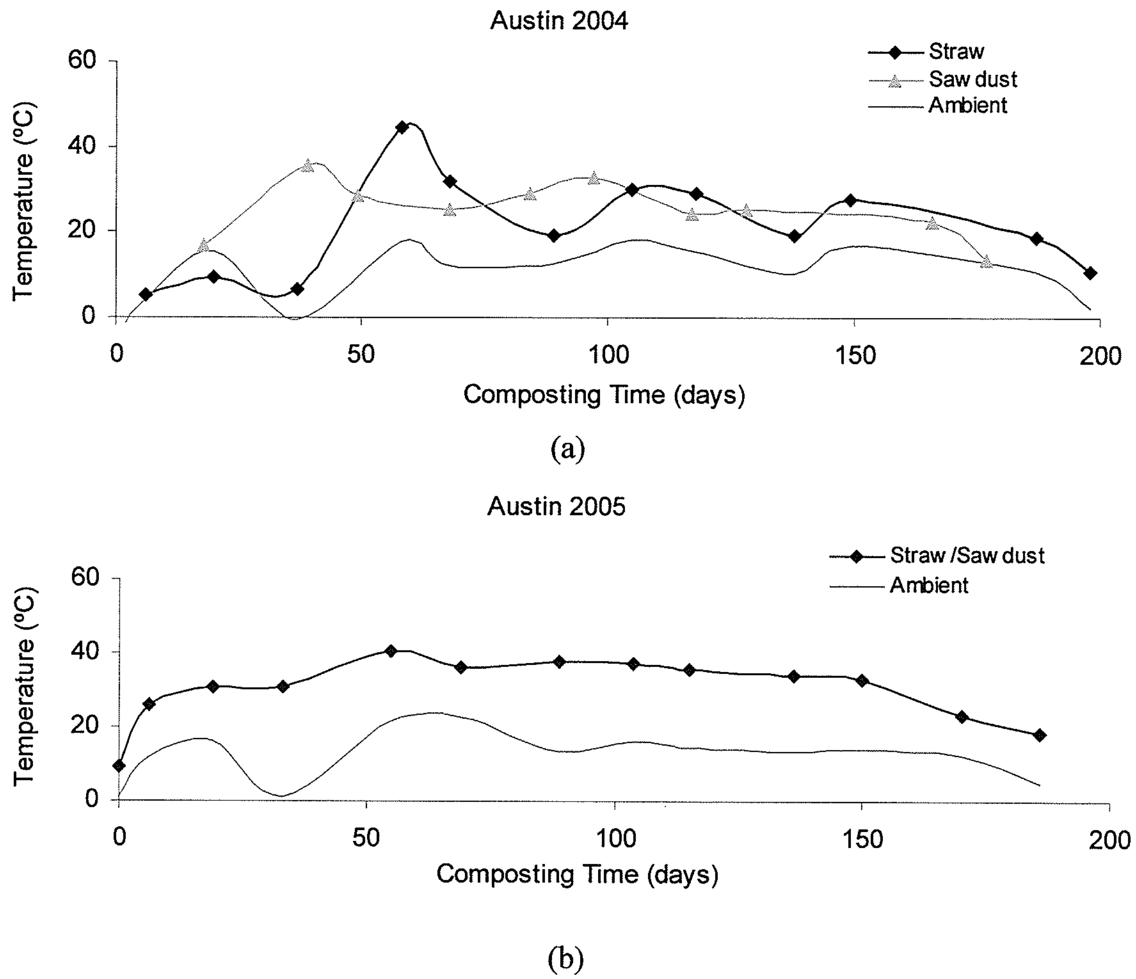
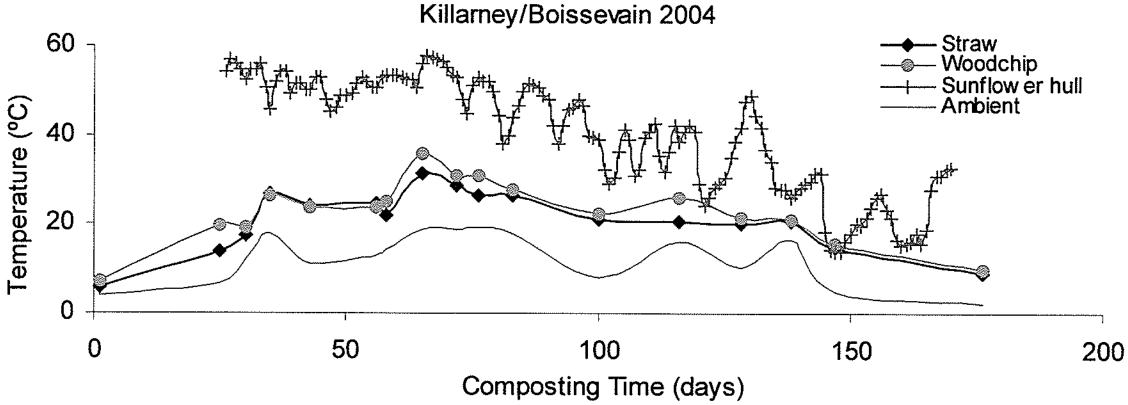


Figure 27. Average pile temperatures for straw, sawdust, and straw/sawdust compost piles at the (a) 2004 and (b) 2005 Austin sites.

Killarney/Boissevain Sites Approximately 65 days after the straw and woodchip pile were built they experienced peak temperatures of 31°C and 36°C respectively (Fig. 28a). For the remainder of the trial both pile temperatures showed a gradual decline. The straw pile experienced slightly lower temperatures than the woodchip pile. Although their temperatures remained above ambient for the duration of the trial, both the straw and woodchip piles appeared to be influenced by changes in outdoor temperatures. The straw pile at this location followed a similar heating pattern as the straw pile at the Austin site but did not reach as high temperatures.

The continually monitored sunflower hull pile at the Boissevain site experienced higher temperatures than the straw and woodchip piles (Fig. 28b). Increased temperatures in the first 100 days ranged between 40 and 60°C. Temperatures showed a gradual decline over the duration of the trial. Temperatures in the sunflower hull pile remained consistently higher than the ambient temperatures.

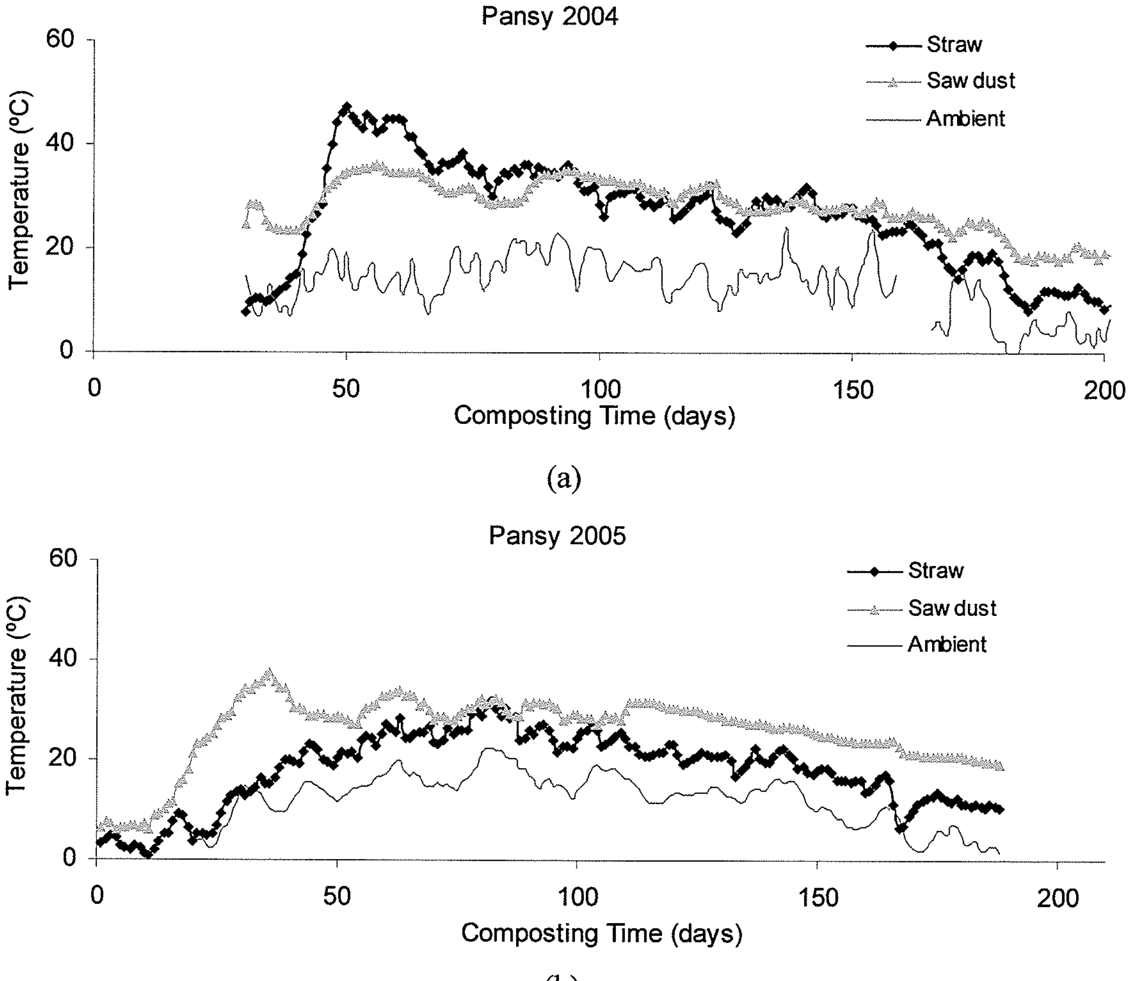


(a)

Figure 28. Average pile temperature readings taken for straw, woodchip, and sunflower hull compost piles at the Killarney and Boissevain sites, 2004.

Pansy Site The pile temperature in the 2004 straw piles (Fig. 29a) showed a steep increase in temperature reaching a peak temperature of 50°C on approximately day 55. Following this event, pile temperatures gradually dropped until they reached ambient temperatures around day 150. This pattern is similar to the straw piles at both the Austin and Killarney sites. Temperatures in the 2004 sawdust pile increased to 35°C on day 30 while the straw temperature was only 7°C (Fig. 29a). Straw pile temperatures were higher between 45 and 80 days and lower for the rest of the time

In 2005, neither the straw nor the sawdust pile attained the high temperatures experienced by piles of the same amendment in the 2004 trial (Fig. 29b). The sawdust pile temperature increased faster and maintained a higher temperature than the straw pile. The piles showed an increase in temperature in the first 100 days. Sawdust and straw pile temperatures remained above ambient for the duration of the trial.



(a)

(b)

Figure 29. Average pile temperature of straw and sawdust compost piles for the (a) 2004 and (b) 2005 Pansy site.

Pilot Mound Site Both the straw and the sawdust piles experienced low temperatures that remained fairly stable for the duration of the composting trial. Temperatures in the straw and sawdust piles remained around 20 and 30°C respectively (Fig. 30). The straw pile temperature was similar to the ambient temperature indicating that heat was not generated as a result of composting. The reason for this pile not heating was not known but was speculated to be caused in part by the excess precipitation received at the site, which caused the pile to compact.

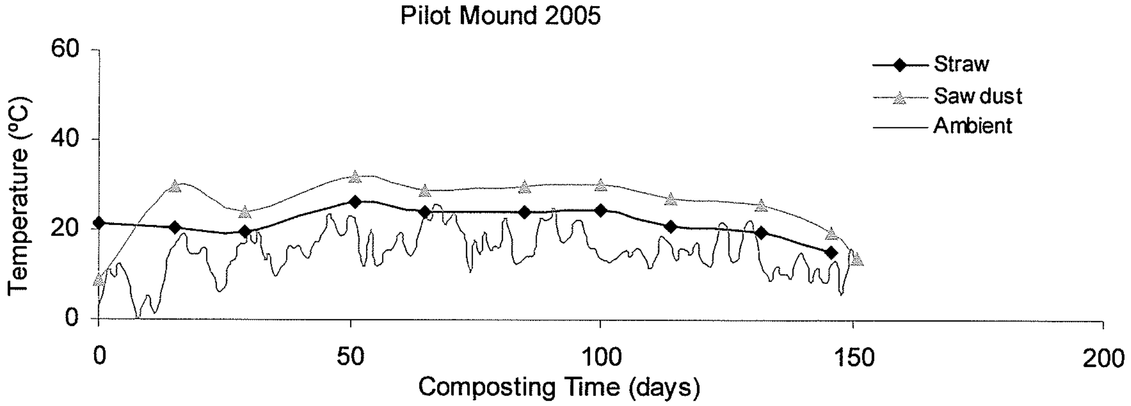


Figure 30. Average pile temperature of straw and sawdust compost piles at the Pilot Mound site, 2005.

6.2.4. Amendment effect on temperature

Table 11 demonstrates that the mean temperature for the sawdust pile was significantly higher than the mean temperature in the straw pile at all sites. Results of the temperature analysis for the Killarney/Boissevain sites showed that the mean temperature for the sunflower hull compost pile was significantly higher than both the woodchip and straw piles. The mean temperature of the woodchip pile was in turn significantly higher than the straw pile.

Again analysis was not done for the straw/sawdust pile constructed for the 2005 Austin trial.

Table 11. Mean pile temperatures (°C) of different amendments at the Austin, Killarney/Boissevain, Pansy, and Pilot Mound sites, 2004 and 2005. Data was pooled over layers and days.

Site	Treatment	**Mean**	**Standard Error**	**Pr>F**
Austin				
	Straw	23.3a*		0.39
	Sawdust	26.4a		0.39
Killarney/Boissevain				
	Straw	21.7c	0.7	
	Woodchip	23.8b	1.0	
	Sunflower	38.4a	1.1	
Pansy 2004				
	Straw	27.3b	0.3	
	Sawdust	38.0a	0.3	
Pansy 2005				
	Straw	19.5b	0.1	
	Sawdust	28.7a	0.1	
Pilot Mound				
	Straw	20.8b		0.0001
	Sawdust	26.2a		0.0001

*Means in the same column and same site followed by the same letter do not differ significantly (P=0.1).

6.2.5. Correlation of moisture content and temperature

Correlation analysis was performed between temperature and moisture content. Weak correlations were seen between the two variables at all sites (values of R^2 were up to 0.6).

6.2.6. Pile volume reduction

Compost piles constructed with the same amendment at the various sites showed similar volume reductions. Therefore, the average values of each amendment are presented. Loss of pile volume was attributed to carcass degradation and settling of the amendment. Table 12 lists the pile volume reduction for each amendment type. The straw/sawdust compost pile showed the greatest reduction in volume of 38.3%. The straw piles showed the next largest reduction of 31.3% while the sawdust and woodchip piles reduced by 26.1 and 22.3% respectively. Both of these amendments were dense and so did not settle as much as the piles that used straw. The sunflower hull pile only showed a 4.4 % volume reduction. The sunflower hulls were dense and the particles would not have much room to settle.

Table 12. The percent volume reduction of different amendment compost piles, 2004 and 2005.

Treatment	Initial Volume (m^3)	Final Volume (m^3)	Volume Reduction (%)
Straw	8.3	5.6	31.3
Sawdust	7.1	5.2	26.1
Straw/Sawdust	9.5	5.9	38.3
Sunflower hull	8.2	7.8	4.4
Woodchip	9.1	7.1	22.3

6.2.7. Carcass and amendment degradation

Regardless of the amendment used to construct the compost pile, only large bones and patches of hair were found when the piles were inspected at the end of the heating cycle. No soft tissue remained. Most bones were solid although some found in the sawdust piles appeared to be scorched and were more brittle (Fig. 31a and b). Bones from the straw (Fig. 31c), straw/sawdust (Fig. 31d), and woodchip piles were clean but not scorched.

The amendment on the outside of the piles appeared to be weathered but not degraded. Examination of the amendment on the inside of the pile found that it appeared darker and slightly degraded.

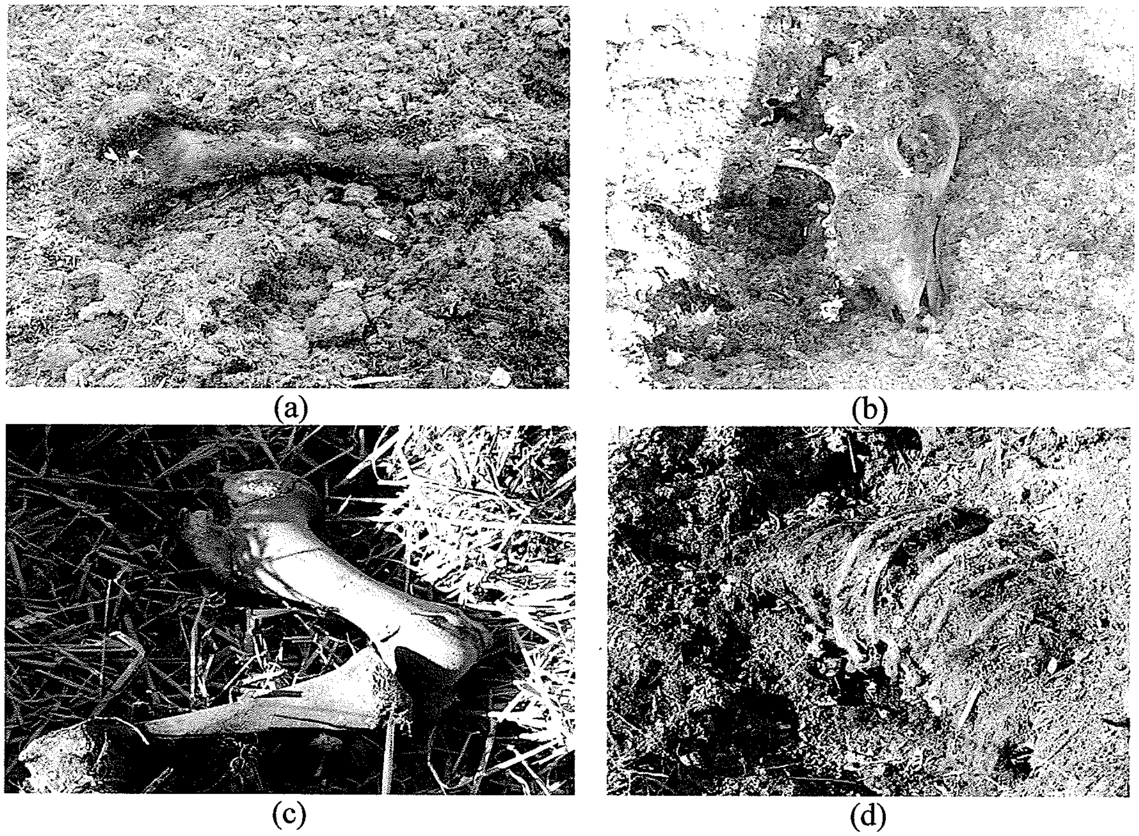

(a) (b) (c) (d)

Figure 31. Photos of bones from composted cattle carcasses. (a) Large leg bone. (b) Skull bone. (c) Leg Bone. (d) Rib bones.

6.2.8. Compost nutrient

Lab results for the total carbon and total nitrogen analysis are shown in Table 13. The pH for all piles ranged from 6.0 to 7.4 and was close to the optimum mortality composting range of 6.5 to 7.2 (Carr et al. 1998). Nutrient values for other parameters are listed in Appendix B.

Table 13 also shows the percent reduction in C:N ratio that was calculated using the initial pile C:N ratio (Table 6) and the final pile C:N ratio. The sawdust and straw/sawdust piles showed a decrease in carbon levels from the original feedstock values. All straw piles with the exception of the 2004 Pansy straw piles showed a decrease in carbon. Utilization of the carbon source by the microorganisms and the production of CO_2 during the composting process could account for loss of carbon. All straw, sawdust, and straw/sawdust piles increased in nitrogen concentrations due to the decomposition and release of nitrogen from the carcass. Only the woodchip pile had a nitrogen value that did not increase and this was reflected by the fact that the final C:N ratio for this pile only reduced by 5.7%. The C:N ratio decreased as a result of the changed amounts of carbon and nitrogen in the pile for all piles. 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%.

Table 13. Total carbon, total nitrogen, and reduction in C: N ratio for final compost, 2004 and 2005.

Site	Year	Amendment	Total Carbon (%)	Total Nitrogen (%)	Reduction in C: N ratio (%)
Austin	2004	Straw	9.8	0.5	45.8
	2004	Sawdust	18.8	0.9	89.8
	2005	Straw/Sawdust	17.9	1.3	46.4
Killarney	2004	Straw	9.3	0.3	58.5
	2004	Woodchip	16.9	0.5	5.7
Pansy	2004	Straw	15.8	0.6	34.0
	2004	Sawdust	16.1	0.2	44.6
Pilot Mound	2005	Straw	9.1	0.5	61.2
	2005	Sawdust	15.8	0.3	81.2

*Data for Boissevain site was not available.

6.2.9. Pathogen kill

Analysis of the final compost found that all pile samples were negative for salmonella (Table 14). Fecal coliform levels for all compost piles were less than 1000 (MPN)/g with the exception of the woodchip compost pile that had a slightly elevated count of 1100 (MPN)/g. Woodchips do not degrade easily and as a result internal temperatures may not have been high enough to kill pathogens. Results for the sunflower hull compost pile were not available, as cattle broke through the fence at the feedlot had destroyed the pile before sampling could be done.

Table 14. Salmonella and fecal coliform counts for final compost, 2004 and 2005.

Site	Year	Amendment	Salmonella (Positive/Negative)	Fecal Coliforms (MPN/g)
Austin	2004	Straw	Negative	<3
		Sawdust	Negative	<3
		Straw/Sawdust	Negative	4
Killarney	2004	Straw	Negative	9
		Woodchip	Negative	1100
Pansy	2004	Straw	Negative	9
		Sawdust	Negative	231
	2005	Straw	Negative	15
		Sawdust	Negative	<3
Pilot Mound	2005	Straw	Negative	43
		Sawdust	Negative	4

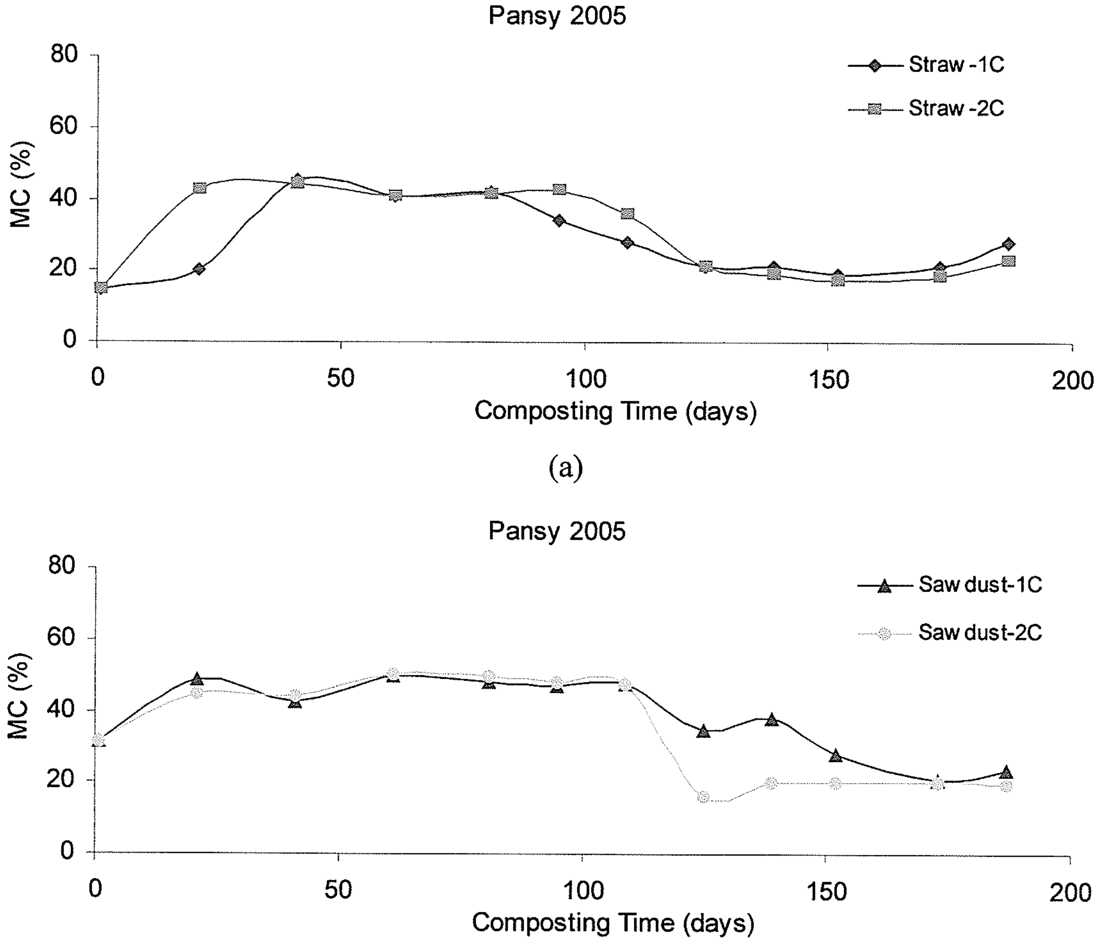
*Data for Boissevain site was not available.

6.3. Study of the number of carcasses

6.3.1. Comparison of moisture content

Figure 32 demonstrates that the Straw-2C pile showed a quicker increase in moisture content that could be due to additional liquid being released from the second carcass. The moisture content trend of the Straw-2C pile was similar to the Straw-1C pile after the initial increase in moisture content.

Sawdust-1C showed a similar moisture content trend as the Sawdust-2C pile. The addition of another carcass did not appear to affect the moisture content for sawdust piles.



(b)

Figure 32. Average gravimetric moisture (MC) for (a) straw with one carcass (Straw-1C) and with two carcasses (Straw-2C) and (b) sawdust with one carcass (Sawdust-1C) and with two carcasses (Sawdust-2C) compost piles at the Pansy site, 2005.

Table 15 shows that there was no significant difference between 1C and 2C moisture contents.

Table 15. Statistical analysis results for moisture content data (%wet basis) from compost piles containing one (1C) and two (2C) carcasses per pile at Pansy site, 2005.

Treatment	**Mean**	**Standard Error**
Straw- 1C	28.0a*	2.5
Straw- 2C	30.5a	2.5
Sawdust-1C	36.4a	3.0
Sawdust-2C	32.5a	3.0

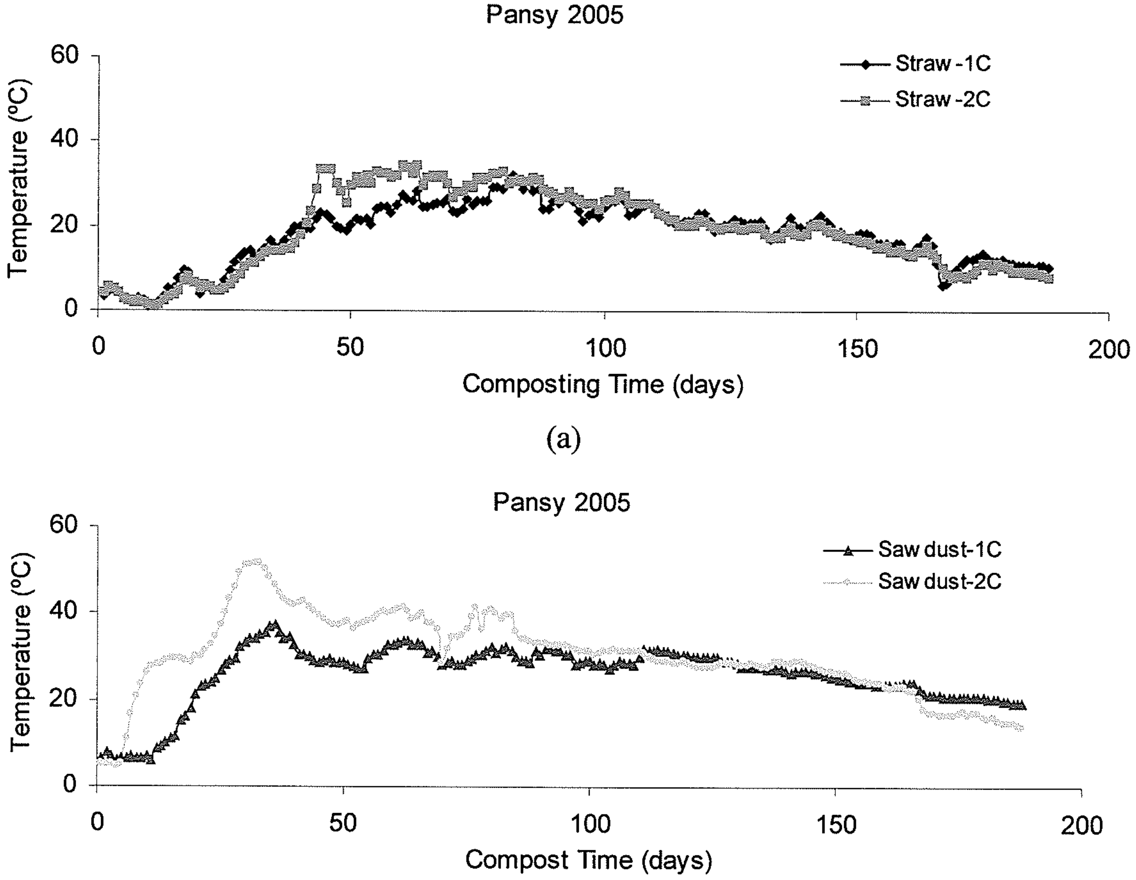
*Means in the same column and same amendment followed by the same letter do not differ significantly (P=0.1).

6.3.2. Comparison of temperature

A comparison of pile temperatures in one carcass (1C) and two carcass (2C) compost piles found that the piles followed similar trends. However, the Straw-2C pile achieved higher temperatures than the Straw-1C pile between 40 and 110 days (Fig. 33a).

The Sawdust-2C pile heated faster and experienced higher temperatures than Sawdust-1C from the beginning to 110 days (Fig. 33b). Composting of the increased body mass due to the two carcasses could generate more heat than a single carcass.

Statistical analysis of the temperature data revealed that the Straw-2C had a significantly higher mean than the Straw-1C pile (Table 15). The Sawdust-2C pile also had significantly higher mean temperature than the Sawdust-1C.



(a)

(b)

Figure 33. Temperature readings for the (a) straw with one carcass (Straw-1C) and two carcasses (Straw-2C) and (b) sawdust with one carcass (Sawdust-1C) and two carcasses (Sawdust-2C) compost piles at the Pansy site, 2005.

Table 16. Statistical analysis results for temperature (°C) data from compost piles containing one (1C) or two (2C) carcasses per pile, 2005.

Treatment	**Mean**	**Standard Error**
Straw- 1C	19.6b*	0.1
Straw- 2C	20.1a	0.2
Sawdust-1C	28.2b	0.2
Sawdust-2C	29.1a	0.2

*Means in the same column and followed by the same letter do not differ significantly (P=0.1).

6.3.3. Comparison of pile volume reduction

Volumes were pooled for piles of the same amendment containing the same number of carcasses. The Straw-2C compost pile showed a greater reduction in volume than the Straw-1C pile while no difference was seen between volumes of the Sawdust-2C pile and Sawdust-1C pile (Table 17).

Table 17. The percent volume reduction for compost pile of different amendment and number of carcasses in pile, 2005.

Treatment	Initial Volume (m^3)	Final Volume (m^3)	Volume Reduction (%)
Straw-1C	8.3	5.6	31.3
Straw-2C	8.7	5.4	37.5
Sawdust-1C	7.1	5.2	26.1
Sawdust-2C	7.3	5.4	26.6

6.3.4. Comparison of compost nutrient

The percent reduction in C:N ratio was calculated using the initial pile C:N ratio (Table 6) and the final pile C:N ratio. The total carbon and nitrogen in the compost from both the 2C and 1C were comparable (Table 18). As a result, the reduction in C:N ratio from the original 2C pile was higher than that from the 1C pile.

Table 18. Total carbon, total nitrogen and C: N ratios for final compost from straw and sawdust compost piles at the Pansy, 2005.

Treatment	Total Carbon (%)	Total Nitrogen (%)	Reduction in C:N ratio (%)
Straw-1C	15.30	0.79	59.1
Straw-2C	15.20	0.98	71.9
Sawdust-1C	16.60	0.27	75.1
Sawdust-2C	18.75	0.42	81.3

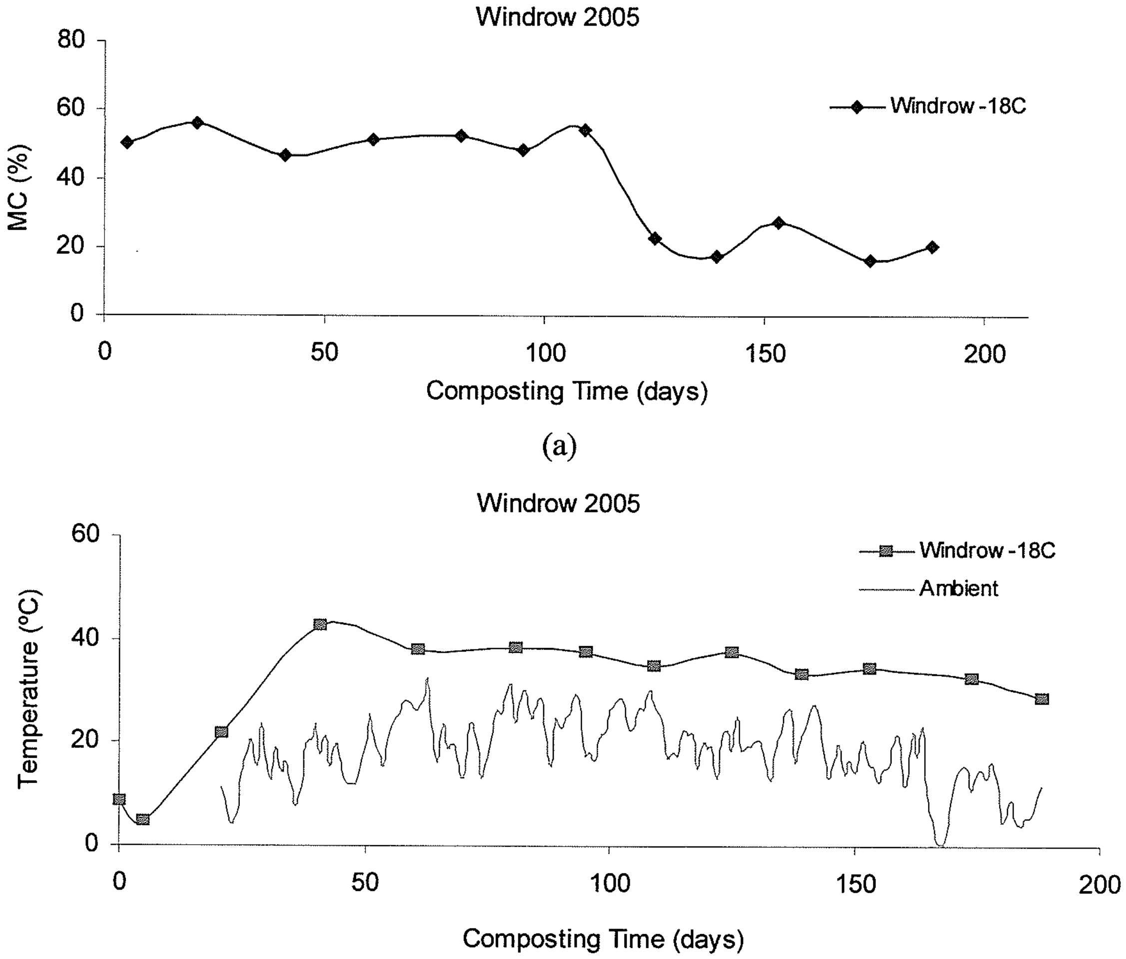
6.3.5. Windrow

Moisture and temperature data was pooled over the readings taken at six positions along the length of the windrow. The moisture content of the windrow remained in a feasible composting range between 50 and 60% for the first 120 days of the trial (Fig. 34a).

The temperature trend for the windrow was similar to that of a smaller compost piles (Fig. 34b). Initially pile temperatures increased rapidly to a peak temperature of 40°C around day 40. Temperatures declined gradually after this. The windrow maintained average temperatures above ambient and did not appear to be influenced by outdoor temperatures. The windrow did not attain temperatures in the feasible composting range of 43-66°C.

The initial volume of the windrow was 30 m^3 and the final volume was 19 m^3, which meant a 36% reduction. The height of the windrow decreased the most of the dimensions measured.

Windrow compost had a pH of 6.8, total carbon of 13.6, a total nitrogen of 0.74, and a 47.5% C:N ratio reduction from initial values. Additional compost nutrient parameters are listed in Appendix B.



(a)

(b)

Figure 34. (a) Moisture content (MC) and (b) temperature readings for the windrow at the Pansy site, 2005. Data taken at six positions along the windrow length was pooled.

6.4. Study of liner effectiveness

Soil data was pooled over sampling depths of 0-0.6 m and 0.6-1.2m. The nitrate-N, phosphorous, and potassium values for soil beneath the Straw-L and Straw-NL piles at the Killarney site did not differ significantly (Table 19). Soil samples taken below the Straw-NL pile had significantly higher potassium levels than the Straw-L pile at the 2004 Pansy site. No significant difference was seen between the nutrient levels of soil collected from beneath the Sawdust-L and Sawdust-NL piles. The 2005 Pansy trials showed that soil nitrate-N values beneath the Straw-NL pile was significantly higher than the Straw-L pile. Again no significant difference was seen between soil nutrients collected from beneath the Sawdust-L and Sawdust-NL piles. The effect of a liner may not be apparent for sawdust piles, due to its absorbent nature.

Results indicate that the use of a liner could be beneficial for straw piles since moisture flows through this amendment. However, since a limited number of compost piles with and without liners were built and tested during this trial, further studies would need to be done to verify these findings. Additional soil results are listed in Appendix B.

Table 19. Statistical analysis of soil samples comparing nitrate-N, phosphorous, and potassium values for different treatments with liner (L) and without liner (NL) for the Killarney 2004, Pansy 2004 and Pansy 2005 sites.

Site	Treatment	**Nitrate-N (ppm)**	**Phosphorous (ppm)**	**Potassium (ppm)**
Killarney 2004				
	Straw-L	44.0a*	16.5a	187.0a
	Straw-NL	84.0a	15.0a	199.0a
	Pr>F	0.36	0.25	0.41
Pansy 2004				
	Straw-L	13.0a	45.5a	499.0b
	Straw-NL	24.0a	65.0a	755.0a
	Pr>F	0.38	0.22	0.03
	Sawdust-L	5.0a	43.5a	423.0a
	Sawdust-NL	36.5a	53.5a	500.0a
	Pr>F	0.38	0.22	0.32
Pansy 2005				
	Straw-L	9.3b	39.8a	365.0a
	Straw-NL	43.3a	48.5a	395.0a
	Pr>F	.0001	0.28	0.30
	Sawdust-L	1.3a	18.5a	327.5a
	Sawdust-NL	2.3a	25.8a	370.0a
	Pr>F	0.82	0.37	0.30

*Means in the same column and same site and year followed by the same upper or lower case same letter for the same year do not differ significantly (P=0.1) according to Fisher's Protected Least Significant Difference (LSD) test.

6.5. Cost analysis

Woodchips were provided by the town of Killarney free of charge since it was a recycled waste. Sunflower hulls were a by-product from a sunflower processing plant in the Boissevain area and were available at no charge. Since the 2004 trial, they have become a marketable product and now cost \$30.00/tonne. Therefore the cost of a sunflower hull pile would now be about \$6.00. The only amendment to incur a cost was sawdust, which cost \$200.00 (transportation fees). The 25 m^3 of sawdust was enough to build approximately 4 piles at about \$50.00/pile. A 30 m roll of plastic cost \$45.00 and was long enough to line eight piles for about \$6.00 each. The cost of the mesh wire cover, including the cost of 12 pegs/pile, was approximately \$65.00/pile.

The total cost of amendment, liner, and wire cover for a sawdust pile would be \$121.00, a sunflower pile \$77.00, and woodchip and straw piles \$71.00 each. Subsequent compost piles would cost less, since at least half of the compost material and the enclosure could be recycled. The cost of these piles reduces to \$31.00 for sawdust, \$7.50 for the sunflower hull, and \$6.00 for the straw and woodchip. Fencing available on the farm could reduce cost. At the Pansy site the producer was able to provide the straw and panel fencing at no cost. So the straw piles at this site had no direct cost.

7. CONCLUSION

The following conclusions on the performance of composting cattle mortalities using a low maintenance method were drawn from this study:

1. Composting using static piles is a low cost and maintenance approach, which is feasible for on-farm cattle carcass disposal.

2. Pile temperature and moisture content were not uniformly distributed throughout the depth profile of the pile die to the layering of carcass and amendment. The temperatures in the piles amended with the wood products, the sawdust, the straw/sawdust, and the woodchips were all warmer in the upper layers of the pile. The sunflower hull temperatures were higher in the lower layers and the straw piles had no layer that was consistently higher. Most piles were generally wetter in the lower layers regardless of amendment.
3. Average sawdust pile temperatures ranged from 26.2 to 38.0°, while average moisture contents ranged from 34.2 to 78.6%. When compared to sawdust, straw resulted in similar pile moisture contents, but experienced lower pile temperatures, sunflower hulls generated higher pile temperatures but lower pile moisture contents, and woodchips had lower pile moisture contents and temperatures.
4. Pile volumes showed a reduction of approximately 5 - 40% with straw having the greatest loss followed by sawdust, and woodchips. The sunflower hull pile showed the least amount of reduction.
5. Based on the temperature and moisture content data as well as pile size reduction, sawdust is considered to be the best amendment for composting cattle mortalities. Although straw amendment did not result in pile temperatures as high as sawdust amendment, carcasses were successfully decomposed after approximately seven months. Since straw is available on most farms in Manitoba it is considered to be the most economical and practical option for on-farm composting.
6. Placing two carcasses per pile is recommended as it improves the composting process by slightly increasing temperatures without creating excess moisture. Overlapping

the carcasses allowed the initial pile size to remain similar to that of a single carcass pile. The final pile size showed greater reductions in volume after both carcasses had degraded.

7. The final pile C:N ratios decreased in all compost piles and the windrow as carbon was consumed and nitrogen was released from the carcass.
8. The proposed method for constructing windrows proved to be feasible for the disposal of multiple carcasses. The ability to add carcasses as they occur would be advantageous.
9. Although not every pile reached temperatures above 55°C, all 21 piles tested negative for salmonella. Fecal coliforms counts were all below guideline limits with the exception of the woodchip pile that had slightly elevated counts.
10. A plastic liner was found to be an effective solution for preventing increased soil nutrient levels beneath the compost piles. In the absence of a permanent liner this simple, low cost alternative could be used. However, due to the limited number of piles constructed with and without liners during this trial, further study should be done to verify the effectiveness and necessity of a liner.

8. RECOMMENDATIONS

Recommendations that can be made from the findings of this study include:

1. The use of an enclosure is necessary to deter scavengers and livestock from disturbing the compost piles. Wire mesh or fencing that is already available on the farm should be used to reduce composting costs.

2. The final compost and the remaining bones should be recycled as amendment for new compost piles.
3. The composting process would likely not start during the cold winter months should a mortality occur.
4. A geomembrane may be selected as a non-permanent liner.
5. Liquid from beneath the compost piles could be collected and analysed to provide a better understanding of nutrient loss from the compost pile.
6. Thermocouples should not be used for monitoring purposes since a reaction involved in the composting process corrodes the wires.

9. REFERENCES CITED

American Society of Agricultural Engineers Standards. 2003. Moisture Measurement – Forages. ASAE S358.2. St. Joseph, Michigan: ASAE.

Ahn, H.K., T.L. Richard, T.D. Glanville, J.D. Harmon and D.L. Reynolds. 2005. Estimation of optimum moisture levels for biodegradation of compost bulking materials. ASAE Paper No. 054089. St. Joseph, MI: ASAE.

Avnimelech, Y., R. Eilat, Y. Porat and P.A. Kottas. 2004. Factors affecting the rate of windrow composting in field studies. *Compost Science & Utilization* 12(2): 114-118.

Bonhotal, J., L. Telega and J. Petzen. 2002. Natural rendering: composting livestock mortality and butcher waste. Ithaca, New York: Cornell Waste Management Institute.

Breitenbeck, G.A. and D. Schellinger. 2004. Calculating the reduction in material mass and volume during composting. *Compost Science & Utilization* 12(4): 365-371.

Brodie, H.L., L.E. Carr and P. Condon. 2000. A comparison of static pile and turned windrow methods for poultry litter compost production. *Compost Science & Utilization* 8(3): 178-189.

Carr, L.E., H.L. Brodie, J.H. Martin Jr., G.W. Malone, D.H. Palmer and N. Zimmermann. 1998. Composting catastrophic event poultry moralities. Fact Sheet 723. Maryland Cooperative Extension. University of Maryland.

Carr, L.E., G.K. Felton, C.E. Prigge and J.C. Bouwkamp. 2002. Testing composting strategies to control N and P. *Biocycle* 43(6): 48-50.

Casolari, A. 1998. Heat resistance of prions and food processing. *Food Microbiology* 15: 59-63.

Composting Council of Canada. 1998. Setting the standard: a summary of compost standards in Canada. Toronto, ON.

de Bertoldi, M., G. Vallini and A. Pera. 1982. The biology of composting: a review. *Waste Management & Research* 1: 157-176.

Dougherty, M., ed. 1999. *Field Guide to On-Farm Composting*. NRAES-114. Ithaca, New York: Natural Resource, Agriculture, and Engineering Service.

Ekinci, K., H.M. Keener and D. Akbolat. 2004. Effect of thermocouple location of the optimum composting rate. *Biosystems Engineering* 89(3): 345-353.

Evans, T. 1999. Tackling fish scraps and animal mortalities. *BioCycle* 40(5): 79-80.

Firey, C. 2004. Small farm composting. *Small Farm Today* 21(1): 39-41.

Fonstad, T.A., D.E. Meier, L.J. Ingram and J. Leonard. 2003. Evaluation and demonstration of composting as an option for dead animal management in Saskatchewan. *Canadian Biosystems Engineering* 45: 6.19-6.25.

Fulhage, C. 1995. Carcass composting. *Small Farm Today* 12(3): 40.

Fulhage, C. 2000. Composting dead animals. In *Innovative Technologies for Planning Animal Feeding Operations Comprehensive Nutrient Management Planning Program and Proceedings*, 167-174. Denver, CO. December 4-6.

Garcia-Siera, J. 2001. Studies on survival of pseudorabies virus, Actinobacillus pleuropneumoniae, and Salmonella serovar Choleraesuis in composted swine carcasses. *Journal of Swine Health and Production* 9(5): 225-231.

Glanville, T.D. and D.W. Trampel. 1997. Composting alternative for animal carcass disposal. *Journal of the American Veterinary Medical Association* 210(8): 1116-1120.

Glanville, T.D., T.L. Richard, J.D. Harmon, D.L. Reynolds, S.S. Sadaka and A. Akinc. 2003. Environmental impact & biosecurity of composting for emergency disposal of livestock mortalities. ASAE Paper No. 032262. St. Joseph, MI: ASAE.

Gonzalez, J.L. and M. Sanchez. 2005. Treatment of poultry mortalities on poultry farms. *Compost Science & Utilization* 13(2): 136-140.

Golueke, C.G. 1992. Bacteriology of composting. *BioCycle* 33(1): 55-57.

Huang, G.F., J.W.C. Wong, Q.T. Wu and B.B. Nagar. 2004. Effect of C/N on composting of pig manure with sawdust. *Waste Management* 24: 805-813.

Hellmann, B., L. Zelles, A. Palojarvi and Q. Bai. 1997. Emission of climate-relevant trace gases and succession of microbial communities during open-windrow composting. *Applied Environmental Microbiology* 63(3): 1011-1018.

Kalbasi, A., S. Mukhtar, S.E. Hawkins and B.W.Auvermann. 2005. Carcass composting for management of farm mortalities: a review. *Compost Science & Utilization* 13: 180-193.

Keener, H.M., W.A. Dick and H.A. Hoitink. 2000a. Composting and beneficial utilization of composted by-products. In *Land Applications of Agricultural, Industrial, and Municipal By-Products*, ed. W.A. Dick, 316-341. Madison, WI: Soil Science Society of America, Inc.

Keener, H.M., D.L. Elwell and M.J. Monnin. 2000b. Procedures and equations for sizing of structures and windrows for composting animal mortalities. *Applied Engineering in Agriculture* 16(6): 681-692.

Keener, H.M. and D.L. Elwell. 2003. Composting livestock mortalities, road kill and meat processor by-products in Ohio. NIAA Conference Paper, April 9, 2003, Cincinnati, OH: NIAA.

Laibach, T. and J. Bonhotal. 2004. Composting road-killed deer in New York. *Biocycle* 45(5): 25-26.

Lawson, M.J. and A.A. Keeling. 1999. Production and physical characteristics of composted poultry carcasses. *British Poultry Science* 40: 706-708.

McCaskey, T.A., J.A. Little, R,M. Krotz, S.P. Lino and T. Hannah. 1996. On-farm composting feasible for disposal of swine carcasses. *Highlights of Agricultural Research* 43(1): 18-20.

Michel, F.C., J. Rigot, T. Wilkinson and J. Pecchia. 2004. Effects of straw, sawdust and sand bedding on dairy manure composting. ASAE Paper No. 044030. St. Joseph, MI: ASAE.

Mohee, R. and A. Mudhoo. 2005. Analysis of the physical properties of an in-vessel composting matrix. *Powder Technology* 155: 82-89.

Morrow, W. M. and P.R. Ferket. 1993. The disposal of dead pigs: a review. *Swine Health and Production* 3(3): 7-13.

Morrow, W.E., P. O'Quinn, J. Barker, G. Erickson, K. Post and M. McCaw. 1995. Composting as a suitable technique for managing swine mortalities. *Swine Health and Production* 3(6): 236-243.

Morse, D.E., 2001. *Composting Animal Mortalities*, St. Paul, Minnesota: Agricultural Development Division, Minnesota Department of Agriculture.

Mukhtar, S., B.W. Auvermann, K. Heflin and C.N. Boriack. 2003. A low maintenance approach to large carcass composting. ASAE Paper No. 032203. St. Joseph, MI: ASAE.

Murphy, P.M. and J.P. Harner. 2004. Composting cattle mortalities. ASAE Paper No. 044027. St. Joseph, MI: ASAE.

Nelson, V., B. Sexton, and W. Winchell. 2003. Windrow composting of spent hens. RL0803. Lethbridge, Alberta: Agtech Centre.

Plana, R., S. Mato, F. Aguilera, A. Artola, C. Perez and A. Sanchez. 2001. Comparison between in-vessel and turned pile composting systems. *Biocycle* 42(10): 63-66.

Peigne, J. and P. Girardin. 2004. Environmental impacts of farm-scale composting practices. *Water, Air, and Soil Pollution* 153: 45-68.

Province of Manitoba. 1998. Livestock manure and mortalities management regulation. The Environment Act.

Rynk, R. ed. 1992. *On-Farm Composting Handbook.* NRAES-54, Ithaca, New York: Natural Resource, Agriculture, and Engineering Service.

Rynk, R. 2000. Monitoring moisture in composting systems. *BioCycle* 41(10): 53-57.

Rynk, R. 2003. Large animal mortality composting goes mainstream. *BioCycle* 44(6): 44 -50.

Sander, J.E., M.C.Warbington, and L.M. Myers. 2002. Selected methods of animal carcass disposal. *Journal of the American Veterinary Medical Association* 220(7): 1003-1005.

Schmidt, D. 2000. Odour, hydrogen sulfide, and ammonia emissions from the composting of caged layer manure. St. Paul, MN: Broiler and Egg Association of Minnesota.

Sherman-Huntoon, R. 2000. Composting animal mortalities in North Carolina. *BioCycle* 41(12): 57-59.

Standford,K., F.J. Larney, A.F. Olson, L.J. Yanke and R.H. McKenzie. 2000. Composting as a means of disposal of sheep mortalities. *Compost Science & Utilization* 8(2): 135-146.

APPENDIX A

Composting may be local solution to increasing number of dead cattle

BY MARCY NICHOLSON

A closed United States border means farmers have more dead cattle on their hands, but an innovative group wants regional stakeholders to find a local solution.

"More cattle are being kept back now," said Mark Witherspoon, Turtle Mountain Sustainable Ventures secretary and Killarney mayor.

"We need to get all the rural municipalities talking about this because it's a regular problem."

Sustainable Ventures wants municipalities to discuss raising funds to research the possibility of establishing a dead stock compost facility in the southwest region.

One landfill near Souris is licensed to receive dead stock.

Already, Killarney has allocated $15,000 over three years, to assist in the initiative.

On-farm dead stock burials are labour-intensive and most landfills are not licensed to receive them. Changes to national policy have decreased the need for rendering, meaning such companies have gone from picking up dead stock for free to charging fees.

"Dumping it in the bush is a $500 fine and that's not the way we want to go," said John Popp, southwest regional beef specialist for Manitoba Agriculture.

Witherspoon is also concerned cattle producers could dump carcasses in areas which are less than ideal, such as road allowances.

The U.S. border has been closed to live Canadian ruminants since one Alberta cow tested positive for mad cow disease May 2003. Manitoba's cow-calf producers have consequently been hanging onto their cull cows for longer than usual, increasing the number of those which are too sick to travel for slaughter from 0.125 per cent of their herds to up to one per cent.

This could tally up to 6,000 head which need to be disposed of annually since the border closed, based on the province's estimated cattle population of 600,000. This does not include other ruminants affected by the closed border, such as bison, sheep, goat and elk.

Municipality representatives will meet in Boissevain's Civic Centre Nov. 8, when technical consultants from B.C. and Alberta will provide regulatory and program status updates.

"There's a need to see the (Canadian Food Inspection) Agency involved with this," said Les Routledge, Prairie Practitioners Group president.

Prairie Practitioners is a rural development consulting firm.

"We'd like to see scientific research published," said Routledge.

Research specific to discarding dead stock in the post-bovine spongiform encephalopathy era has not yet been published.

It is premature to estimate how much money will need to be collected to complete this research, said Routledge.

Livestock producers who opt to dispose of dead stock on their property can compost, incinerate or bury the carcass approximately two metres deep. While burials are considered a fairly big undertaking, Popp considers composting easier than most people think.

The dead animal must be placed on and under one foot of straw, and turned over time. Farmers considering this can contact their agricultural representatives.

mnichols@brandonsun.com

The fine art of rotting a cow

CAFÉ WESTMAN

Darci Clark

Spring has sprung and, while a young person's fancy likely turns to love, I'm pretty sure a good many folks out there, young and old, are also wondering how to compost a cow.

I know this because, for the last couple of years, my Manitoba Association of Regional Recycler's (MARR) display has shared trade show space with that of the Compost Action Project (CAP) at the Association of Manitoba Municipalities (AMM) spring and fall conventions.

It may sound like acronym soup, but due to BSE's domino effect; CAP guru **Christine Schroeder** has fielded so many inquiries about safe composting of carcasses that she worked with Livestock Environment Engineer **Van-Ly Doan** of MAFRI (Manitoba Agriculture Food and Rural Initiatives) to develop a step-by-step guide complete with full colour photos.

It's not rocket science, which is a good thing as the Café's clientele rarely seek such high-flying fare, but the time seems ripe to try her tips on our weekly menu to show that death does have options.

It should be beyond obvious that one starts with that ultimate oxymoron: dead livestock. It doesn't matter what kind as long as it is dead.

Step 1 involves preparing a two-foot base of absorbent organic material such as straw, wood chips or sawdust that will soak up the soup. Make sure to leave a matching two-foot clearance around the base, the reason for which is revealed in step 5.

Step 2 is when the carcass is laid squarely (and to echo Foghorn Leghorn, I do say squarely, boy!) on back or side upon this bed of eternal rest.

Step 3 is when it gets a bit ugly, as ruminants (commonly a cow, sheep or goat) larger than 300 pounds should have their rumen punctured to prevent intestinal explosion. If one is not dealing with a ruminant, thank one's lucky chickens and skip to step 4.

Step 4 is covering up one's carcass with at least another two feet of absorbent organic material. Bury well, as haste now will be cause to repent at leisure. The goal is to prevent odour and get the pile to heat up to 40-65 degrees C within a couple of weeks.

Note: When dealing with more than one carcass, it's time for livestock lasagne!

Step 5 is inaugural turning time, usually two to three months later, but only if the pile temperature has consecutively dropped for at least 10 days. Ignore the lumps and repeat the heat-turn cycle weekly until the inside temp definitely no longer rises to the occasion.

Step 6 is when one gets to pan this black gold, remembering to set aside screenings to kick-start another batch.

And there you have it, folks: the bare bones.

I do stress bare though, as Christine has much more toll-free expertise available at 1-866-394-8880 or at www.resourceconservation.mb.ca/cap.

And while we're talking homemade dirt, councillors and landfill operators interested in how organics diversion fits into an effective waste management strategy are invited to check out CAP's Municipal Composting 101 workshops at the following Westman locations: Melita on May 24 and Minnedosa on May 25, 2006. For registration details, give Christine a toll-free call or e-mail her at christine@resource-conservation.mb.ca

•••

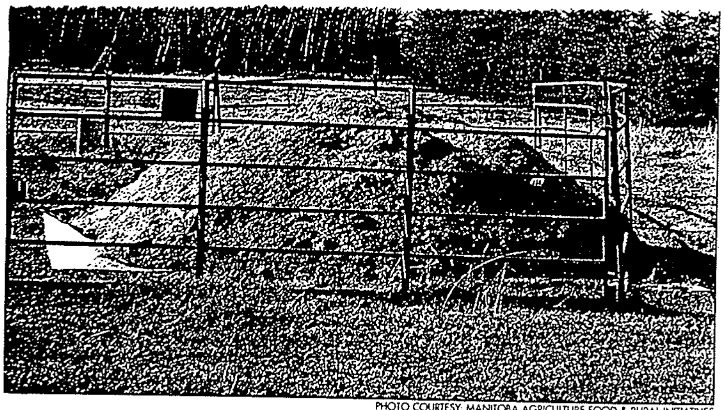


PHOTO COURTESY: MANITOBA AGRICULTURE FOOD & RURAL INITIATIVES

Carcass compost

What is the well-covered cow wearing these days?

APPENDIX B

Final compost nutrient results

Nutrient analysis results for the final compost material from cattle composting piles trials in 2004 and 2005.

Site	Amendment	pH	NH_4 (%)	Nitrate-N (%)	Total Sulphur (%)	Ca (%)	Phos (%)	K (%)	Mg (%)	Na (%)
Austin	Straw	7.4	310	270	0.1	0.18	0.08	0.47	0.06	0.02
	Sawdust	6.6	2600	273	0.05	0.05	0.03	0.09	0.01	0.07
	Straw/Sawdust mix	6.0	1940	1060	0.07	0.10	0.07	0.19	0.02	0.08
Boissevain	Sunflower Hull	7.3	1150	20.9	0.11	0.89	0.17	0.97	0.44	0.04
Killarney	Straw	7.2	104	334	0.04	0.11	0.05	0.44	0.04	0.03
	Straw	6.6	10	88	0.01	0.06	0.02	0.14	0.03	<0.01
	Woodchip	7.4	221	91	0.03	0.57	0.05	0.16	0.12	<0.01
Pansy	Straw	7.1	311	806	0.04	0.09	0.02	0.60	0.07	0.20
	Straw	7.2	1110	224	0.12	0.11	0.12	0.78	0.167	0.47
	Sawdust	6.6	1330	393	0.03	0.03	0.02	0.05	<0.01	0.03
	Sawdust	6.8	754	147	0.01	0.03	0.00	<0.01	<0.01	<0.01
	Straw	6.7	159	180	0.09	0.12	0.06	0.13	0.04	0.06
	Straw	6.4	150	491	0.13	0.14	0.11	0.17	0.06	0.04
	Sawdust	6.4	553	385	0.03	0.07	0.01	0.03	0.01	0.02
	Sawdust	6.4	253	316	0.03	0.05	0.02	0.04	0.01	0.04
	Straw-2C	6.9	190	158	0.17	0.16	0.11	0.14	0.07	0.03
	Straw-2C	6.8	2260	528	0.16	0.21	0.11	0.22	0.07	0.03
	Sawdust-2C	6.7	1230	602	0.04	0.12	0.03	0.03	0.03	0.01
	Sawdust-2C	6.3	1350	628	0.03	0.18	0.09	0.05	0.02	0.04
	Windrow-18C	6.8	2430	1110	0.1	0.11	0.05	0.12	0.04	0.05
Pilot Mound	Straw	6.4	259	422	0.04	0.13	0.04	0.05	0.04	0.11
	Sawdust	7.0	770	242	0.03	0.17	0.01	0.04	0.05	0.02

Soil nutrients

2004

Soil nutrient levels taken prior to construction (pre) and after turning (post) of mortality compost piles constructed with straw and sawdust and with or without a liner, 2004. All piles contained one carcass/pile. Composite soil samples were tested from 0-0.6 and 0.6-1.2 m depths.

Site	Pile	Depth	Nitrate-N (ppm)		Phosphorus (ppm)		Potassium (ppm)		pH	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post
Austin	Straw	0 - 0.6	<2	8	15	10	124	147	7.5	7.4
		0.6 -1.2	<2	<2	6	<5	83	93	7.8	7.5
	Sawdust	0 - 0.6	<2	14	15	10	124	139	7.5	7.9
		0.6 -1.2	<2	3	6	6	83	72	7.8	8.1
Pansy	Straw -NL	0 - 0.6	<2	37	55	93	299	640	8.0	8.2
		0.6 -1.2	<2	11	19	37	423	870	8.6	8.7
	Straw -L	0 - 0.6	<2	21	55	74	299	398	8.0	8.0
		0.6 -1.2	<2	5	19	17	423	600	8.6	8.5
	Sawdust -NL	0 - 0.6	<2	67	55	88	299	341	8.0	7.8
		0.6 -1.2	<2	6	19	19	423	660	8.6	8.4
	Sawdust -L	0 - 0.6	<2	8	55	62	299	388	8.0	7.9
		0.6 -1.2	<2	2	19	25	423	458	8.6	8.2
Killarney	Straw -NL	0 - 0.6	4	140	16	24	145	313	7.4	6.3
		0.6 -1.2	3	28	<5	6	79	86	8.1	7.8
	Straw -L	0 - 0.6	4	51	16	23	145	261	7.4	6.7
		0.6 -1.2	3	37	4	10	79	113	8.1	7.7
	Woodchip	0 - 0.6	4	42	16	19	145	151	7.4	6.8
		0.6 -1.2	3	10	4	4	79	94	8.1	7.8
Boissevain	Sunflower Hull	0 - 0.6	8	<2	<5	<5	159	191	8.2	8.1
		0.6 -1.2	4	2	<5	<5	140	74	7.9	8.7

2005

Soil nutrient values from samples taken from directly below the mortality compost piles (pile) and from the surrounding pile area (background), 2005. The number of carcasses per pile is listed below. Composite soil samples were tested from 0-0.6 and 0.6-1.2 m depths.

Site	Sample	Depth (m)	Nitrate-N (ppm)		Phosphorus (ppm)		Potassium (ppm)		pH	
			Back ground	Pile	Back ground	Pile	Back ground	Pile	Back ground	Pile
Austin	Straw/ Sawdust	0.0-0.6	1	34	19	22	230	180	7.7	6.4
		0.6-1.2	1	11	11	9	130	130	7.7	7.0
Pilot Mound	Straw	0.0-0.6	3	2	44	43	230	150	7.9	8.2
		0.6-1.2	1	1	6	<5	90	80	8.3	8.6
	Sawdust	0.0-0.6	3	10	44	14	230	280	7.9	8.3
		0.6-1.2	1	3	6	<5	90	80	8.3	9
Pansy	Straw-1C	0.0-0.6	7	15	14	55	14	330	8	6.8
		0.6-1.2	2	4	<5	25	<5	390	8.1	8.1
	Straw-1C	0.0-0.6	7	50	14	65	14	220	8	6.2
		0.6-1.2	2	54	<5	28	<5	450	8.1	7.7
	Straw-2C	0.0-0.6	7	13	14	66	14	520	8	7.8
		0.6-1.2	2	5	<5	13	<5	220	8.1	8.4
	Straw-2C	0.0-0.6	7	31	14	79	14	400	8	7.1
		0.6-1.2	2	38	<5	22	<5	510	8.1	8.3
	Sawdust-1C	0.0-0.6	7	3	14	52	14	370	8	8
		0.6-1.2	2	2	<5	17	<5	140	8.1	8.4
	Sawdust-1C	0.0-0.6	7	1	14	36	14	500	8	8.5
		0.6-1.2	2	1	<5	10	<5	200	8.1	8.6
	Sawdust-2C	0.0-0.6	7	3	14	26	14	270	8	8.3
		0.6-1.2	2	1	<5	8	<5	70	8.1	8.4
	Sawdust-2C	0.0-0.6	7	2	14	23	14	500	8	8.4
		0.6-1.2	2	<1	<5	<5	<5	110	8.1	8.6
	Windrow	0.0-0.6	7	4	14	90	14	570	8	16
		0.6-1.2	2	1	<5	20	<5	400	8.1	4