Evaluation and demonstration of composting as an option for dead animal management in Saskatchewan

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Fonstad, T.A., Meier, D.E., Ingram, L.J. and Leonard, J. 2003. **Evaluation and demonstration of composting as an option for dead animal management in Saskatchewan.** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **45**: 6.19 - 6.25. Pork producers in Saskatchewan are continuously looking for new developments that are both economic and environmentally sustainable. Composting is considered a potential option for dead animal management that may meet both requirements. The purpose of this investigation was to determine whether or not composting is viable for dead animal disposal for hog producers in Saskatchewan. The mortalities were composted in a test compost pile consisting of a straw/manure mix that was provided by animal shelters of the operation. Deads were added to this mix at time increments of 10-14 days. An additional compost pile composed of straw/manure mix was constructed for comparison purposes. Temperature, oxygen, volume reduction, and moisture conditions were monitored to track microbial activity and to evaluate the overall progress and efficiency of the mortalities composting. Observations of the compost pile during pile turning revealed that the carcasses were broken down successfully. This was verified when the compost pile was screened resulting in a minimal amount of uncomposted materials.

Les producteurs de porc de la Saskatchewan sont continuellement à la recherche de nouvelles techniques qui soient à la fois économiques et respectueuses de l'environnement. Le compostage est considéré comme une option potentielle pour la gestion des mortalités animales qui rencontre ces deux objectifs. Le but de cette étude était donc de déterminer si le compostage contituait effectivement une technique souhaitable pour l'élimination des mortalités sur les fermes porcines de la Saskatchewan. Des carcasses de porcs ont été compostées à l'intérieur d'un tas composé d'un mélange de paille et de fumier provenant des étables de la ferme. Les carcasses étaient ajoutées au mélange de composte à tous les 10 à 14 jours. Un tas de compost composé uniquement du mélange paille/fumier a également été construit à des fins de comparaison. La température, la concentration en oxygène, la réduction de volume et la teneur en eau ont été mesurés pour évaluer l'activité microbienne et l'évolution et l'efficacité du compostage des carcasses. Des observations réalisées durant le retournement du tas de compost ont montré que les carcasses se décomposaient de manière satisfaisante. Ceci a été vérifié lorsque le tas de compost a été tamisé et que peu de matériel non décomposé a été trouvé.

INTRODUCTION

The expansion of the hog industry in Saskatchewan has created the need for new advancements to develop an economically and environmentally sustainable industry. Dead animal management is one of the areas that needs advancement. Faced with increasing costs, concerns about environmental pollution, and disease transmission, livestock producers and environmental officials are seeking more sustainable options for on-farm disposal of dead stock (Glanville and Trampel 1997).

Dead animal management in Saskatchewan

Traditional methods used for dead animal disposal in Saskatchewan include rendering, incineration, and burying. Rendering is a method in which dead stock is picked up at the production site and transported to a rendering facility where carcasses are recycled into useful byproducts. Due to the limited number of rendering facilities in western Canada and the cost potential for transportation, the volume of carcasses produced determines if rendering is the most economic disposal option. Biosecurity is also a concern as the transport trucks travel between many locations in a trip, thus increasing the risk of herd contamination.

Burying is a common method of disposal that has long been accepted in Saskatchewan. Regulations state that animal remains may be buried, however the bottom of the pit must be at least 1 m above any water bearing formation and the carcasses must be covered with a minimum 0.6 m of soil. The burial pit must be located in a medium to fine textured soil, away from areas subject to flooding and at least 90 m away from a watercourse, a body of water, or a water well (SAF 2000). Burial as a method of disposal in Saskatchewan can prove to be difficult for producers during winter months when the ground is frozen. Larger hog operations may have refrigeration facilities on site to store deads in order to accumulate a large enough number that would be economical for burial or transport. Refrigeration is usually associated with eventual disposal to a rendering plant, but may also be used for storage during winter months when burial is not possible.

Incineration of mortalities is a method that also may be used in Saskatchewan. It is carefully monitored to ensure that proper procedures are followed and requires a producer to have a license from Saskatchewan Environment and Resource Management permiting the producer to install and operate an incinerator. Economics must be considered when choosing this type of disposal method since incineration requires a great deal of energy to fully complete the process.

Composting is a natural process where microorganisms decompose organic material in a primarily aerobic environment

(Rynk 1992; Haug 1993). Microorganisms consume oxygen for energy as they feed on organic matter resulting in a metabolic release of heat, carbon dioxide (CO_2), and water vapor into the air. Carbon and water can contribute up to half the weight of the raw materials, therefore the loss of these two components causes significant volume and mass reduction (Rynk 1992). At present, composting in the food processing and agriculture industries has great potential to be an environmentally sound method to manage waste and produce a useful soil amendment as the end product. Composting as a method of dead animal disposal in Saskatchewan has been primarily used for poultry and smaller animals. Preliminary research and field studies suggest that mortalities from hog operations may also be successfully composted in Saskatchewan.

Composting swine mortalities

Composting has proven to be an environmentally sustainable method to dispose of swine carcasses and has been accepted in many areas of the world (Fulhage 1995). Due to their inconsistent nature, composting swine carcasses is unlike typical composting where materials are thoroughly mixed to ensure proper distribution. The pile in this case consists of a large bulk of material, the carcass, which has a low C:N ratio, low porosity, and high moisture content encompassed by the carbon amendment, a material which has a high C:N ratio, good porosity, and moderate moisture. Initial decomposition is anaerobic in and around the carcass, however as the decomposition process continues, gases and liquids are released; they diffuse away from the area and are trapped in the aerobic zone of the surrounding material. Microorganisms within this zone ingest and degrade the gases into CO_2 and water vapor (Keener et al. 2000). The compost pile is not turned until anaerobic decomposition of the carcasses has been substantially completed. For swine, this period is approximately three months after the last animal has been placed on the pile. The pile is then turned incorporating oxygen into the mix to encourage aerobic microbial activity and an additional three months generally is required to allow the compost to cure. A study conducted in South Carolina has shown that within a five month time period all that remained of a 295 kg, 10 year old boar was a dark humus like material and some large bones and teeth (Henry 1995).

Composting swine manure

Research using straw/manure has shown composting can be accomplished but may require a longer period of time when compared with using sawdust as a carbon source (Pittaway 1998; Morris et al. 1996). Swine manure independently has been classified as being nitrogen-rich with a high moisture content making it slightly more difficult to compost relative to other livestock manures. Odor is also a concern with this form of waste. Straw incorporated into the swine manure will improve its compostability by lowering the moisture content, increasing porosity, increasing the carbon content, and by providing some odor control (Rynk 1992).

Factors affecting composting

Temperature and oxygen content Temperature and oxygen content within the compost pile are key indicators of the progress of the composting process since the release of heat and the consumption of oxygen is directly related to aerobic microbial activity. All organisms have a temperature and oxygen range in which they can function optimally, thus initiating and sustaining biochemical reactions. Maintaining optimum temperature and oxygen levels during composting is essential to ensure a rapid and successful end result.

Composting process temperatures generally follow a pattern that begins with the active composting stage where a rapid increase in temperature to around 50 - 60ºC occurs as readily available compounds are decomposed. Thermophillic bacteria that thrive in this temperature range are found to be the most efficient at decomposing material in a composting environment (Henry 1995). The temperature remains at this level for several weeks. Oxygen supplies may become depleted during the active composting period thus slowing down activity resulting in a decrease in temperature. A minimum of at least 5% oxygen is required to maintain high activity. Aeration accomplished by pile turning or by methods of forced aeration can replenish oxygen to recommence activity as well as to remove water vapor and other gases that may be trapped within the pile (Rynk 1992; Haug 1993). If conditions are especially favorable for microbial degradation, activity is intense and the temperature may rise well above 60ºC. However, temperatures to the high or low extremes of the 50 – 60ºC range may limit the process kinetics (Haug 1993). Temperatures in the range of 75 - 85ºC are likely depressing activity since microorganisms die or become dormant at these high temperatures.

As decomposition activity slows, the compost enters the curing stage and a drop in temperature to approximately 30 - 40ºC is noticed followed by a gradual decrease to ambient air temperature as the process stabilizes. Cured compost is a dark brown to black color with an earthy odor. Once the compost has cured for the required amount of time, it may be incorporated into the producers manure management plan or marketed as a soil amendment.

Nutrients Nutrients, mainly carbon (C), nitrogen (N), phosphorus (P), and potassium (K) are required by microorganisms during the composting process. As well, the value of the finished compost is a function of nutrient concentrations since N, P, and K are the chief nutrients used by plants. Nitrogen and C are especially important for aerobic microbial decomposition since C provides energy for microorganism growth while N is necessary for protein development and cellular reproduction. A ratio of carbon to nitrogen (C:N) has been adopted by the composting industry as a measure of a suitable nitrogen balance. For the purpose of composting, raw materials blended to achieve a C:N ratio between 25 and 30 (25:1 and 30:1) has been reported to be ideal, although ratios above 50 have been reported to be effective but require a longer composting period for complete carbon utilization (Haug 1993; Rynk 1992). A C:N ratio below 20 indicates that the available carbon has been utilized and converted to CO_2. The remaining unstable nitrogen may be lost as ammonia (NH_3) or nitrous oxide (N_2O) which may result in unpleasant odors. Odor can often be controlled in the composting process if the C:N ratio provides enough carbon to ensure that the majority of nitrogen will be stabilized (converted to microbial biomass).

Typical nutrient concentrations for swine manure in Saskatchewan are given in Table 1. Cereal grain straw is found to contain a C:N ratio ranging from 128-150 (Haug 1993). A mixture of these two raw materials should provide a suitable matrix for mortality composting.

Table 1. Average nutrient values for swine manure in Saskatchewan (SAF 1999).

Nutrient	Type of manure	
	Liquid swine (kg/1000 L)	Solid swine (kg/t)
Nitrogen (N)	3.0	8.4
Phosphorus (P)	0.9	4.6
Potassium (K)	1.0	10.8
Sulphur (S)	0.4	3.2

Moisture content

Moisture levels are important in a composting operation. Water acts as a medium to support the metabolic activity of the microorganisms. A moisture content of 40 – 70% (wet basis) by mass is recommended for optimum activity in most materials (Shuler 1980; Rynk 1992; Haug 1993). Below a level of 40% moisture content degradation slows and below 15% moisture content activity ceases entirely. At levels above 70%, water begins to inhibit the flow of oxygen by lowering the free air pore space within the pile affecting the balance of elements needed by microorganisms to thrive. Moisture values naturally present in swine carcasses should be sufficient for composting without an additional moisture source, particularly if manure is also part of the mixture, since the moisture content of swine tissue is generally greater than 70% (Pittaway 1998).

Composting swine mortalities in Saskatchewan

Composting swine mortalities has potential to be a method of dead animal management on hog operations in Saskatchewan. Manure is generally readily available and animal deaths are inevitable. Table 2 gives the volume of manure produced and number of deaths expected on a typical hog operation in Saskatchewan. With the incorporation of a bulking agent, such as straw, composting can be a solution for dead animal management that uses readily available materials, is economical, environmentally sustainable, and produces a useful end product.

The objective of this project was to determine the viability of composting as a method of dead animal disposal for hog producers in Saskatchewan. This management option was demonstrated and analyzed on a commercial hog operation over a two-year period. Results from this study will help to establish guidelines and protocols for producers to help implement this method of disposal in Saskatchewan.

MATERIALS and METHODS

Compost pile construction

The initial deads compost pile was constructed October 1999 at Marvel Acres Stock Farms, Hepburn, Saskatchewan. This particular facility is a 350-sow farrow to finish operation where finishing takes place in a series of 14 covered shelters which use straw as bedding for the animals. The pile was constructed in a field near the operation where enough room was available for pile turning and for the producer's machinery to easily access the piles. The estimated area that was to be used for composting was approximately 1000 m^2. Deads compost pile construction was modeled after the method described by Keener et al. (2000). The initial deads compost pile (labeled "Deads I") was built by constructing a manure/straw mix base approximately 0.6 m thick with an area of 4 x 6 m to accommodate the producer's available equipment. A group of deads was placed on the base, laid side by side, totaling approximately 150 kg and covered by a layer of straw/manure mix 0.6 m thick. This group consisted of five pigs with a mass of approximately 30 kg. A second group of deads, totaling 128 kg was laid beside the first group and again covered by a layer of manure/straw. The second group consisted of one 80-kg pig and four 12-kg pigs. Samples of the covering and base were collected for a baseline nutrient analysis. This method of pile construction continued on a continuous basis as mortalities became available until early February 2000 when a new pile was started. Groups of deads within the pile were typically 120 to 150 kg per group. Deads within the group ranged in size from 1 to 150 kg or new born to fully grown sow or boar. The initial deads composting pile incorporated a total of 2845 kg of swine mortalities. Additional deads piles were constructed as each pile reached a limit of approximately 2000 – 2500 kg of carcasses using the method consistent with that used for "Deads I". Only "Deads I" compost pile was used for evaluation during this research project.

A pile consisting of a straw/manure mix only was constructed at the same time as "Deads I" (October 1999) as a control and to investigate the volume reduction potential of composting swine manure in Saskatchewan conditions. This pile was monitored using the same methods as the deads piles. The manure/straw pile continued to compost until August 2000, when it was concluded that this pile was mature and ready to be land applied.

Compost pile turning

Pile aeration was accomplished using a front-end loader provided by the producer. The manure/straw compost pile was simply pushed or turned a distance equal to the width of the pile. The piles containing carcasses were aerated in a similar manner with

Table 2. Swine manure production and expected animal losses in Saskatchewan (SAF 2000).

Animal type	Daily manure production for storage		Average death loss (% per cycle)	Cycles per year
	Solid (kg/d per animal)	Liquid (L/d per animal)		
Boars and gestating sows (150 kg ave)	21.1	15.9	3	1
Nursing sows (150 kg ave)	29.0	21.8	3	1
Gilts (125 kg)	16.9	12.7	1	1
Feeder pigs (100 kg)	11.3	8.5	1	3
Weanling pigs (16 kg)	2.1	1.6	1.5	6

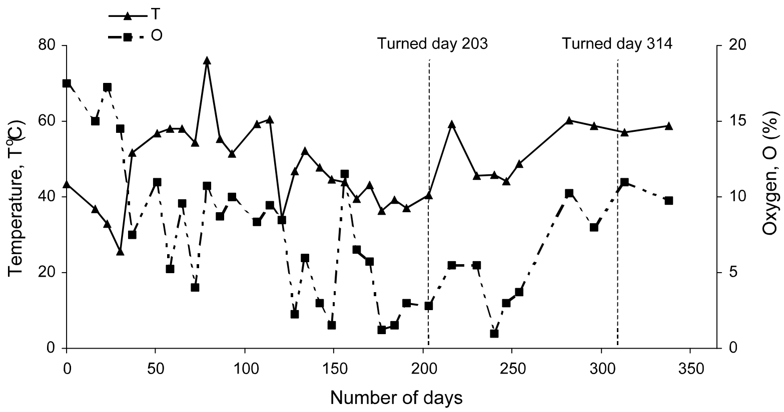

Fig. 1. "Deads I" compost pile temperature and oxygen measurement.

the exception of the first turning. This was accomplished by constructing a base of manure/straw 0.6 m thick and turning the pile onto this base using a front-end loader provided by the producer and recovering the pile with 0.6 m of the manure/straw mix from the shelters. This was done in an attempt to ensure that any uncomposted carcasses would be covered with material and allowed to reach composting temperatures as ambient temperatures were expected to be as low as -30°C.

Compost pile monitoring

Oxygen, temperature, volume, and moisture content were monitored throughout the study on all piles to track the composting progress. Temperature and oxygen readings were taken once a week using an Oxygen-Temperature Monitor (Model OT-21, Demista Instruments, Wheeling, IL). This device consists of a probe 1.5 m long that penetrates the compost pile to measure both temperature (ºC) and oxygen (%). Temperature and oxygen measurements were taken by inserting the probe its full length at various positions in the piles to track the overall progress of microbial activity thus indicating when the piles required aerating. Average values of at least six measurements per pile per monitoring event are seen in Figs. 1 and 2.

Pile volume data were manually taken once a month using a standard measuring tape to obtain all approximate pile dimensions. Compost moisture contents were obtained by hand collecting a minimum of three samples once a month at various locations in each pile. Once collected the samples were stored in 1-L airtight plastic bags until oven dried immediately upon returning to the lab. Samples were weighed wet and then dried at temperature of 105ºC to obtain the overall average moisture content for each individual pile. Again, only average values are reported in this paper.

"Deads I" was screened in September 2000 to evaluate the amount of objectionable material that remained in the pile, i.e. any large bones or sharp fragments that may pose a threat to machinery if the compost was to be land applied. An 11.5 m^3 tandem truckload of "Deads I" was transported to a commercial screening operation. The truck was weighed before and after the compost was loaded to determine the mass of compost that was to be screened. Moisture content of the compost was determined and used to convert results to a dry mass basis. The screen used was a horizontal rotating tube with 19 mm openings. As screening took place, any recognizable remains were separated out for general observation and then dried and weighed. Results were used to calculate the percentage of uncomposted material on a dry matter basis.

All initial and final samples of the screened compost, as well as samples of the final manure/straw compost, were collected and taken to Enviro-Test Laboratories, Saskatoon, Saskatchewan for nutrient analysis. As there are no "official" manure analysis methods in North America, labs generally apply their soil or plant methods to manure. Samples for this project were analyzed for total nitrogen by sample combustion and detection of N by thermal conductivity (AOAC 990.03) (AOAC 1995). Phosphorus, potassium, and sulphur were analyzed by digestion of sample in nitric/perchloric acid. Analysis of extract was by ICP-OES (AOAC 968.08) (AOAC 1990). Moisture analysis was by ASTM D2216-92 (ASTM 1995). The sample is heated overnight at 105°C. Moisture content is then determined by mass loss and reported as mass of water divided by mass of dry solids.

RESULTS and DISCUSSION

Temperature and oxygen monitoring

Because of the cool temperatures in October when "Deads I" was constructed, the active composting stage took place over a period of six months, or three months after the last group of deads was added to the pile. According to the weekly oxygen and temperature readings, the rate of active composting began to increase slightly during warmer ambient temperatures. Temperature and oxygen readings from October 1999 through September 2000 for "Deads I" are shown in Fig. 1. The first month of readings demonstrates the initial "bloating" stage where decomposition is accomplished mainly by anaerobic microbes. As the organic material becomes more readily available to the aerobic microbes in the manure/straw medium, the temperature increases and the oxygen consumption begins. This pattern was observed as deads were added to the pile in approximately 10 – 14 day increments. Once "Deads I" pile was completed in mid February 2000 (day 142), the

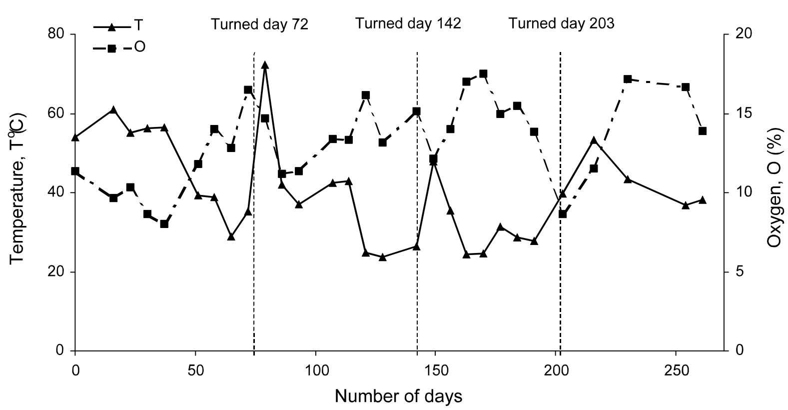

Fig. 2. Manure/straw compost pile temperature and oxygen measurements.

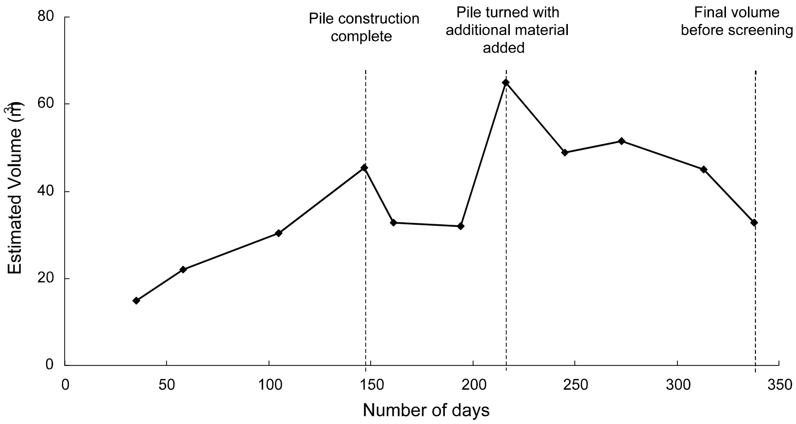

Fig. 3. "Deads I" pile volume measurements.

temperature and oxygen began to follow a continuous pattern, temperature values decreased as the oxygen supplies were gradually depleted. "Deads I" was determined to be ready for turning when the oxygen content approached the minimum of 5% and the temperature began to drop below 40ºC.

"Deads I" was turned for the first time April 26, 2000 (day 203). Observations taken during pile turning showed that the decomposition of the swine mortalities was quite successful at this time. There was no evidence of large bones or of any recognizable portions of the carcasses that were added to the pile although carcass locations were evident as areas of soft, homogeneous, light-colored material. The compost pile was a dark color emitting no offensive odors. Temperature and oxygen values rapidly recovered soon after pile turning. "Deads I" continued to be monitored until it was turned August 14, 2000 (day 313) when oxygen and temperature values began to decrease and until it was screened September 12, 2000, 338 days from initial pile construction.

Temperature and oxygen readings for the straw/ manure pile are shown in Fig. 2. The initial activity in this pile commenced much more quickly than "Deads I". This behavior is expected because of the more readily available organic matter in the straw/manure compared to swine carcasses. This pile was turned for the first time on December 15, 1999 (day 72) when temper-ature levels began to drop. Microbial activity was stimulated resulting in an increase in temperature. This pattern continued and the pile was turned three more times during the composting period. A final sample of the compost was taken June 24, 2000 (day 261) to compare the nutrients in the compost to the original material.

Pile temperature time above 55ºC is often used to evaluate the potential destruction of pathogens and/or weed seeds. For this study, "Deads I" obtained temperatures above 55ºC from Day 45 to 115 (November 20, 1999 to January 29, 2000) during pile construction when no compost turning occurred and ambient temperatures ranged between 0 and –30 ºC and from day 280 to 335 (July 12, 2000 to September 5, 2000) during compost turning when ambient temperatures ranged between 5 and 30ºC. The control manure/straw pile obtained temperatures above 55ºC from day 3 to 40 (October 9, 1999 to November 15, 1999) immediately following pile construction. The manure straw mixture used for this study was obtained from a stockpile of material that had recently been removed from the animal shelters and this material did have temperatures higher than ambient.

Volume reduction

Carcasses were added periodically to pile "Deads I" until February 14, 2000. Volume increased due to the addition of new deads to the pile before the deads, already within the pile, were broken down (Fig. 3). Once the pile was completed, the incorporated deads were decayed and a volume reduction was observed. The straw/manure pile volume measurements (Fig. 4) showed significant reduction during the composting period. Over the entire composting period, pile measurements showed that the straw manure pile volume reduced by an estimated 50-60% of the original. Bulk density measurements collected from each compost pile to further assess volume reduction were found to be inconclusive due to the inconsistent nature of the compost. Volume reduction was based on physical pile dimensions measured periodically.

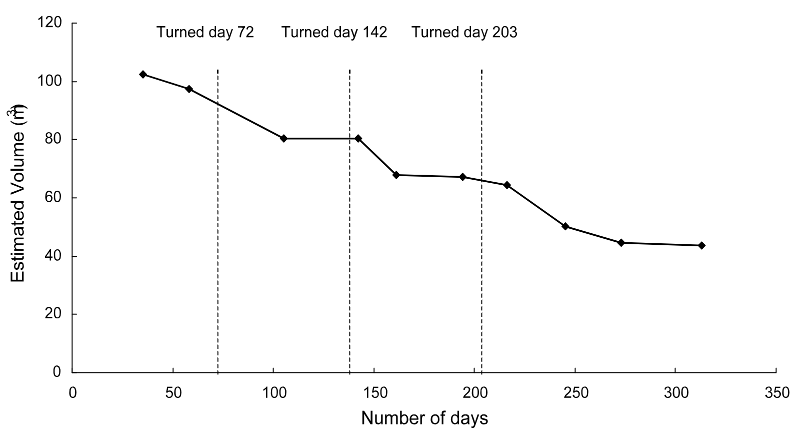

Fig. 4. Straw/manure compost pile volume measurements.

Nutrient values

Macronutrient value analyses of the original manure/straw, the finished manure/straw compost, and the screened "Deads I" compost are shown in Fig. 5. The nutrient contents were found to be higher in the finished compost and were further increased with the addition of mortalities into the manure/straw mix. Figure 5 shows nutrient concentration increases in the control of 62, 50, and 46% for nitrogen, phosphorus, and potassium, respectively, and the result of incorporation of mortalities into the compost enhanced the nutrient content with increases over the original manure/straw mix of 108, 130, and 51% for nitrogen, phosphorus and potassium, respectively. Sulfur increase was less evident in

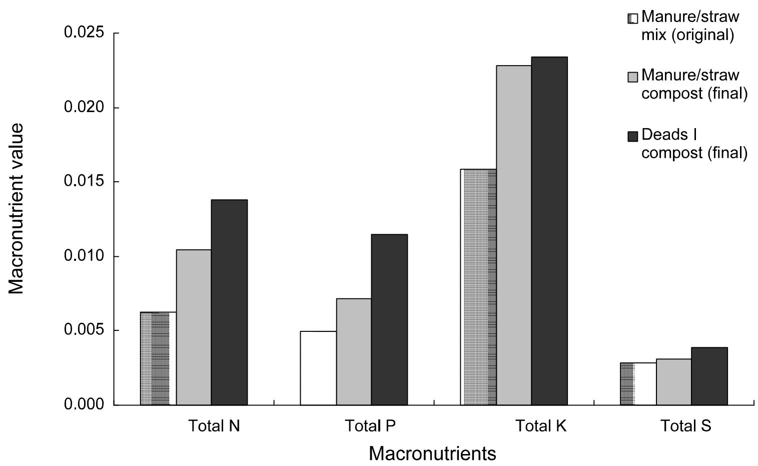

Fig. 5. Macronutrient values found in original manure/straw mix, finished manure/straw mix, and Deads I finished compost piles.

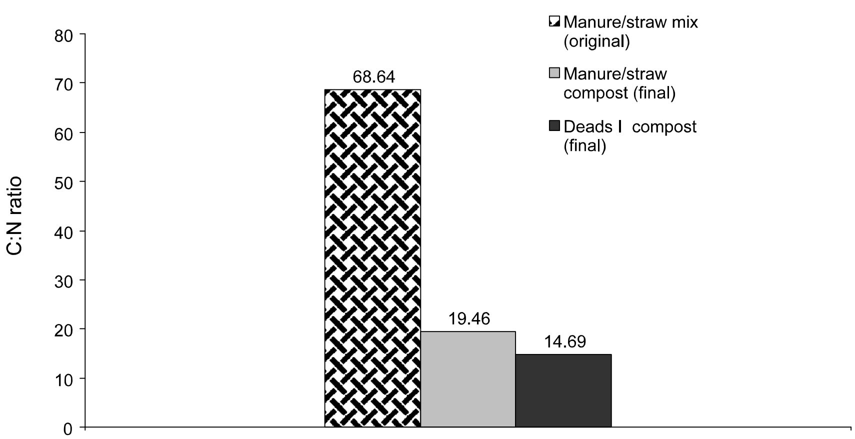

Fig. 6. C:N ratios for manure/straw original, manure straw finished, and "Deads I" finished compost.

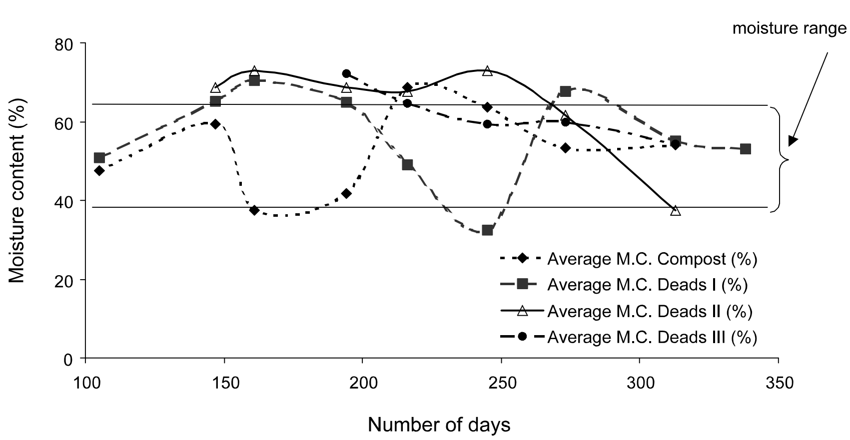

Fig. 7. Moisture content values for all compost piles.

the control compost pile but addition of the mortalities increased sulfur levels by 43% over the original manure/straw mix.

The C:N ratios, shown in Fig. 6, show the degradation of carbon as a result of the composting process. The original C:N ratio of the manure and straw from the shelters started at a value of 68 which is slightly higher than ideal, but is still an acceptable value for compost process initiation. The finished compost displayed a value of 19 to 20 that shows that the composting process had stabilized. The final C:N ratio of the "Deads I" pile was between 14 and 15 due to the nitrogen addition of the carcasses. This level of nitrogen may have hindered further composting past the date the pile was taken for screening.

Moisture content

Moisture contents in all piles were within the ideal range of 40 - 65% moisture by weight without any adjustment being required by the researchers or the producer. Sufficient moisture values can be attributed to the initial moisture content of the carcasses (> 70%), the manure/straw covering (50-70%) and some precipitation. Figure 7 shows moisture contents from three deads piles and the manure/straw pile.

Deads I screening

Approximately 11.5 m^3 of the "Deads I" compost pile containing 3900 kg dry matter was screened to evaluate the amount of material that had not been composted. Materials that were ejected from the screen were bone fragments that were not greater than 150 mm long, having a brittle to spongy texture. The total dry mass of objectionable materials was 1.5 kg resulting in a total of 0.04% material that was recognizable remains. The remains did not have any severely threatening characteristics that would likely cause damage to equipment. Results from screening of "Deads I" indicate that the composting process was successful in the decomposition of carcasses.

CONCLUSIONS

Composting mortalities as a method of dead animal management on a commercial hog operation in Saskatchewan has been shown to be successful. Results show that carcasses can be effectively disposed of with minimal effort from the producer. Information from this study will help to establish guidelines and protocols for producers in Saskatchewan to follow for establishment of a composting program on their operation.

Composting both reduced the volume of the original material by 50 to 60% and concentrated the nutrients with increases of 62, 50, and 46%

for nitrogen, phosphorus, and potassium, respectively. Incorporation of mortalities into the compost enhanced the nutrient content with increases over the control of 108, 130, and 51% for nitrogen, phosphorus, and potassium, respectively. Sulfur increase was less evident in the control compost pile but addition of the mortalities increased sulfur levels by 43% over the original manure/straw mix.

For the mortalities compost, the mass of objectionable materials was a total of 0.04% material (dry basis) that was recognizable remains. The remains did not have any severely threatening characteristics that would likely cause damage to equipment.

The producer of this operation is quite satisfied with the results and plans to continue composting mortalities. He stated that this method did not take any additional time compared to his former disposal method and that the operation is considering investing in equipment to accommodate the process such as a manure spreader and possibly a windrow turner to expand compost production.

ACKNOWLEDGMENTS

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