MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY (MDEQ), ENVIRONMENTAL SCIENCE AND SERVICES DIVISION

Retired Engineer Technical Assistance Program (RETAP)
Technology Demonstration Program

FINAL REPORT

DEMONSTRATION PROJECT TITLE
Using composting to recycle meat processing by-products

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Executive Summary

From January 2 to October 14, 2004, meat processing by-products (including meat scraps, fat trim, bones, internal organs, gastro-intestinal tract contents, and wash-water solids originating from beef, pork, goat, cervidae, bison, and lamb harvest) were composted by Jones Farm Meats, LLC, Saranac, Michigan. This demonstration project was done with the technical assistance of Michigan State University and the financial support from MDEQ RETAP Technology Demonstration Program. The objective was to evaluate if a small meat processing business could use composting to effectively, safely and economically convert inedible by-products into a product that could be used beneficially by crop and plant growers as a soil amendment. A static pile system comprised of twenty-eight, 8 x 14' bins was constructed. The compositing bins were designed with floors having a 2% slope toward the back wall and with the back and end walls sealed at the floor-wall interface to retain leachate that may occur as the result of rainfall up to 4.25 inches (25-year, 24-hr storm). The facility was constructed to compost about 11,600 pounds of by-products produced each week, with a starting compost bulk density of about 15 lbs./ft^3. Prior to active composting, by-products were ground using a 20 hp Rietz Prebreaker/Grinder to reduce bone size and increase homogeneity. Grinding reduced the volume of animal tissue by-product by 250%. The chemical analysis of meat processing by-product was 79.2% dry matter, 71.4% fat, 5.0% crude protein, and 1.5% ash. Because of the high amount of lipid, composite pile shape was difficult to maintain. Piles slumped out of bins, especially in warmer months. This problem was corrected by managing clean dry sawdust as a base of each pile and as layers between animal tissue by-product layers. Composting reduced total volume of compost mixture by 42%, with finished compost chemically consisting of 51% dry matter, 1.2% total N, 0.5% NH_4, 0.9% P_2O_5, 0.3% K_2O, and 1.1% Ca. Hours of labor associated with inedible management at the butcher shop using composting instead of rendering, increased, but were offset by the conversion of refrigeration space and an increased slaughter capacity. Fixed and variable costs were estimated at about $12,400 annually, less than the present cost of rendering. Income from the sale of compost as a soil amendment or fertilizer ($5 to $6/yd^3) was sought, but not received during the demonstration period. The composting facility is expected to have a useful life of 30 years and long-term control of by-product management is expected to help sustain the meat processing business well into the future.

Introduction

Disposing of inedible by-products by small to moderate-scale meat processors (a.k.a. abattoirs, slaughterhouses, custom slaughter plants, or butcher shops) has become increasingly challenging in recent years. Traditionally, rendering firms have collected these by-products for free and manufactured them into valuable feedstuffs for livestock and pets. As a result of growing public concern about bovine spongiform encephalopathy, foot and mouth virus, and other serious diseases, feed manufacturers and animal owners have become more reluctant to use “animal by-product” feedstuffs. Consequently, rendering companies having given short “termination of service” notices and no longer collect animal tissues in many rural Michigan locations, or they have been charging a very large, constantly increasing fee to continue service. Rural meat processors are an integral part of sustainable niche food chains in rural areas. These firms need a viable and affordable means of by-product disposal if they are to continue serving local producers, consumers, communities, and economies.

In accordance with the current Michigan Bodies of Dead Animals Act (BODA; No. 239, Public Acts 1982, amended) and the Natural Resources and Environmental Protection Act (NREPA; 1994, PA 451, Part 115, Solid Waste Management), other than rendering, landfill and incineration are management alternatives for disposal of animal tissue. Both of these have significant environmental and economic disadvantages. Composting of meat by-products, as described in BODA and NREPA requires permission from both the Michigan Department of Agriculture and MDEQ. In the past meat processors have not sought this permission, however, with developments surrounding disease concerns, small-scale Michigan meat processors began to inquire about composting as an money saving, effective management alternative for meat processing by-products. Reports of composting being successfully used in a few other states, including New York (Jerose, 2001) enhanced the interest of Michigan meat processors. They believed that composting would provide long-term control of by-product management, less risk of terminated rendering service without notice, and sustainability of the meat processing business well into the future. Short-term, they believed that composting would reduce by-product management costs. Additionally, composting was expected to decrease exposure to pathogen risk, as a rendering truck would no longer stop at their processing plant after stops at other plants and farms. Lastly, the fact that composting recycles animal tissue nutrients was seen as beneficial, possibly providing a source of income from the sale of compost as a soil amendment or fertilizer.

Consequently, Michigan meat processors, led by Jones Farm Meats, LLC, sought the assistance of academics and policy makers in proving the efficacy, safety, and affordability of meat by-product composting, and for governmental approval to do so. Consequently, this demonstration project was developed and funds were sought and obtained from the MDEQ RETAP Technology Demonstration Program for its undertaking and completion.

Definitions

For MDEQ RETAP Technology Demonstration Program reporting purposes, "composting" is referred to as the "P2" pollution prevention technology and "rendering" was the "existing" or previous technology used prior to this demonstration project and implementing composting.

Existing (Previous) Process

Meat processing inedible by-products were rendered. During slaughter and carcass fabrication employees collected and placed inedible animal by-products in 55 gallon barrels. Full barrels were stored under refrigeration until emptied into an open-topped trailer/semi-tractor that was owned and operated by a rendering company. The truck was mechanically equipped to lift and empty barrels into the truck trailer, which was done by the driver three times each week in summer and twice weekly during other times of the year. Barrels were cleaned in the meat processing facility by the staff of Jones Farm Meats, LLC shortly after each rendering truck visit. After making several stops to collect animal tissue by-products from other businesses and farms, the truck transported all contents to a rendering plant.

The rendering process for by-product removal required 18 to 30 barrels per week and 400 ft^2 of refrigeration space, but no other equipment. It cost $45 per stop or $90 per week for rendering service. After each render truck stop, barrels were washed requiring 1.5 hours of labor and an investment in degreasing soaps.

The advantages of rendering for by-product management were:

- By-products were removed from the business
- Nutrients in by-products were recycled as animal feedstuffs, unless of bovine origin. Bovine tissues are not used as feedstuffs any longer because of the potential spread of disease caused by prions.

The disadvantages of this process were

- Risk of disease pathogen spread frequent rendering truck stops after stopping at other farms and businesses
- Risk of abrupt termination of service and the cost of emergency measures such as landfill service, new large-scale dumpsters for delivery to land-fill and the cost of cleaning them dumpsters
- Increasing cost
- More barrels to store
- Need to separate tissues, visceral contents were not accepted
- Time and labor needed to clean the barrels

In 2002, Jones Farm Meats, LLC accumulated 601,310 pounds of by-products and paid a total of $13,670 for a rendering service. Cost increased in 2003 as the rendering company raised their "pick-up charges" several times, increasing the annual cost of by-product removal to Jones Farm Meats, LLC by another $3,214 over that paid in 2002. To provide perspective, in 1995 the same service was provided to Jones

Farm Meats at no cost and in the 1980's, the rendering company paid Jones Farm Meats about $45,000 per year for by-products.

Technology Description

Composting is the biological decomposition of organic material under controlled conditions to a state where storage, handling, and land application can be achieved in a safe, aesthetically acceptable, and environmentally-sound manner. Activity is dependent on optimum moisture, carbon-to-nitrogen ratio of material, and porosity or the presence of oxygen. This technology has been effectively and safely used by livestock producers to dispose of on-farm mortality (Rozeboom et al., 1998; Garcia-Siera et al., 2001). The same usefulness was anticipated for the meat processing industry.

A composting facility was built for use in this demonstration project and use thereafter. The composting facility has twenty-eight, 8 x 14 x 6' bins, arranged in four rows (two rows sharing common push wall or spine) with an apron around bins (see attached figure). The entire facility is enclosed with fencing thereby securing the composting facility from intrusion by wildlife and pets. The size of the facility was determined for about 11,600 pounds of by-products produced each week and a compost bulk density of 15 lbs. of animal tissue per ft^3. Each bin has a calculated volume of 672 ft^3 or nearly 25 yd^3. Using a three-sided bin structure lessens the effective composting volume by approximately 84 ft^3, assuming that the compost will pile at a 60° angle from the floor. Depending on exact pile depth (maybe slightly higher than the six foot walls), effective or operating volume may be about 12.5% less than total bin volume. Previous research has confirmed that optimal animal tissue decomposition occurs with 10 to 15 lbs./ft^3 foot (Rozeboom, 1998). With the calculation based on 15 lbs./ft^3, then only about 473 ft^3 (17.5 yd^3) effective volume per bin was needed. The additional 8% volume was expected to provide flexibility during seasons of greater animal by-product accumulation.

The composting facility was constructed with concrete floors and three-sided bins at a total cost of $52,202 or about $30/$ft^2$. Floors were constructed to be impermeable to water (less than 40 grams of water per square meter per hour; e.g., reinforced concrete, or equivalent) and capable of supporting the static and dynamic frost loads, and equipment used for handling compost. The spine wall of each row of bins was a reinforced vertical push wall three feet high for mechanical turning and compost handling.

Compositing bins were designed with floors having a 2% slope toward the back wall and with the back and end walls sealed at the floor-wall interface to retain leachate that may occur as the result of rainfall up to 4.25 inches (25-year, 24-hr storm). Data from another MSU study on leachate leaving static mortality compost piles (Sanders, 2004) constructed on a level surface indicated that no leachate is released for rainfall events up to 1.5 inches. With rainfall greater than 1.5 inches, about 15% of the total rainfall leaches. About 0.64 inches of water may leach with a rainfall of 4.25 inches. Taking into account the sloping floor and the available void space, the resulting depth of wet material was estimated to be approximately 2.5 inches. The elevation difference between the top of the slope at the driveway and the back wall was approximately 3.3 inches. Wet material was moved and mixed with drier material when aerated or when moved to curing.

In compliance with state laws, the composting facility was located:

- No closer to an active potable water well than the distance permitted by Michigan public regulations between a septic drain field and a potable water well (rule 122 of Act No. 368 of the Public Acts of 1978, R325.1622 of the 1979 Michigan Administrative Code).
- No closer than 200 feet from surface water.
- In an area which minimizes the odor impact on neighboring properties.

To achieve the desired carbon-to-nitrogen content during animal tissue composting a carbon source (bulking agent) is added. The bulking agent also decreases bulk density which promotes aeration (oxygen in, heat, moisture and gases out). Bedding (hardwood sawdust) from the calving pens of a neighboring dairy farm (John Hardy of Maple Row Dairy), which contained small amounts of manure was the bulking agent used in the first month of this demonstration project. It was chemically-analyzed to contain 0.17% Total N, 0.08% P_2O_5, and 3.98% Ca. From then on, clean dry hardwood sawdust was purchased and used as new bulking agent. Finished compost was mixed with new bulking agent in primary bins to speed the decomposition process by inoculating new material with necessary organisms. This material was substituted for clean dry bulking agent in the compost pile on an equal ratio (volume basis) and was typically used solely as the layers around ground animal tissue by-product.

On average, two bins were filled or loaded each week. The bottom layer or base was clean dry bulking agent, at least one foot thick. Subsequent layers alternated animal tissue and bulking agent. Bulking agent layers were two to six inches thick. Composting bin depth did not exceed five feet in height.

After filling a bin, compost was left undisturbed until aerated. The decision to aerate was based on compost temperature. The temperature of the active batch was expected to rise to 100 to 150 ºF over the course of one to four weeks, and then diminish to less than 100 ºF for one week or more. After this rise and fall in temperature, the pile (sometimes referred to as “primary”) was lifted with a loader, or turned with a loader into another bin to aerate the compost to rejuvenate the active composting process. Experienced composting people sometimes refer to the aerated or turned bins as “secondary” compost bins. Compost remained undisturbed during the monitoring of subsequent temperature cycles and accompanying aerations. Active composting was continued for at least three months, at which time it was moved to another location, piled, and left to cure. The finished or cured compost was to be applied to fields or sold. Application to fields was to be accomplished by following acceptable manure management practices as recommended for animal manure application to land in Michigan Right-to-Farm Program (2004) Generally Accepted Agricultural Management Practices (GAAMP’s). Application was to be based on the analysis of compost nutrient content. For this project, an agreement was made with a neighbor, to have all finished compost applied to fields locally. A tractor and manure spreader was to be used for land application as a soil amendment.

It has been reported that large commercial cattle feedlots have used commercial wood grinders to reduce the size of carcasses (mortality) prior to on-farm composting. In particular, the presence of large bones when spreading compost on fields, post-curing, is aesthetically unacceptable. At Jones Farm Meats, a Rietz Prebreaker (Model No. PB-10-H3228 and Serial No. P-740353; Rietz Manufacturing, Santa Rosa, CA 95402), with a 20-horsepower motor, was purchased (“Used” for $4,200) to reduce bone size pre-composting. It is operated without a die or plate. Large bones are reduced to “sheared fragments or slivers” of about 2 to 3 inches in length. Grinding reduced by-product volume by 250%.

Project Design/Plan

The goal of this project was to demonstrate that a small meat processing business could use composting to effectively, safely and economically convert inedible by-products into a product that could be used beneficially by crop and plant growers. Long-term control of by-product management was desired, in order to sustain the meat processing business well into the future. A reduction of costs associated with by-product management was also sought, as well as the potential development of income from the sale of compost as a soil amendment or fertilizer. Jones Farms Meats intended to operate the composting facility indefinitely, well beyond the termination of the RETAP project. The facility was designed to have a useful life of 30 years or more. A verbal agreement with Maple Row Dairy to apply compost onto cropland had no exact termination date as both parties anticipated a long-term arrangement. Continued monitoring of potential pollution and the financial benefits of the composting operation years after the termination of this project was anticipated. The long-term sustainability of by-product composting was viewed as critical for the long-term success of this family business. Adoption of this technology by other small meat processors in the next 5 to 10 years was desired and expected.

Composting procedures describe above were evaluated to assess its effectiveness in reducing and recycling animal tissue and to assess quality control. Measurements and observations deemed “critical” to the success of this demonstration were:

(1) Cost
   (a) Hours of labor devoted to post-harvest by-product management
   (b) Additional equipment

(c) Recouped refrigeration space
(d) Fuel
(2) Effect on food safety
(a) No increase in risk of food-borne pathogens at harvest plant
(3) Effect on environment
(a) No leachate movement to surface or ground waters
(b) Minimal smell
(c) No intact bones
(4) Sale of compost

Procedures used to evaluate the composting technology and to assure quality control are outlined below.

(1) Journal
- (a) Inquiries
  - (i) Other meat processing businesses
  - (ii) Regulatory agencies
  - (iii) Neighbors
  - (iv) Butcher shop clientele
- (b) General observations regarding the composting process
  - (i) Odors
  - (ii) Flies
  - (iii) Rodents
  - (iv) Leachate

(2) Records
- (a) Capital and operating costs
  - (i) Compost facility
  - (ii) Estimated hours of labor for managing by-products
    - (1) Tractor hours and fuel
    - (2) Loader
    - (3) Grinder
    - (4) Spreader (no field application to-date)
- (b) Start-up date for each new batch (pile contained in a bin)
  - (i) Estimated daily pounds of tissue
  - (ii) Estimated volume of bulking agent used
- (c) Internal temperature
- (d) Moisture content
- (e) pH of compost
- (f) NH_3, CH_4, H_2S ,O_2, and CO_2 gases
  - (i) On the surface of compost
  - (ii) Internal (within compost material)
- (g) Date batch is aerated
- (h) Depth of the saturated layer at the bottom of each bin
- (i) Estimated volume of finished compost.
  - (i) Nutrient analysis (N, P, K)
  - (ii) Field application
    - (1) Date
    - (2) Field location
    - (3) Application rate per acre
    - (4) Change in soil nutrient content
- (j) Any change in monthly microbiological surveys done by USDA in the meat-processing plant
- (k) Microbiological analysis of compost (12 batches annually or one per month)
  - *(i) E. coli*
    - (1) Generic
    - (2) O157:H7
  - (ii) *Listeria* sp.
  - (iii) *Campylobacter* sp.
  - (iv) *Salmonella* sp.

Moisture content was determined by drying in a laboratory drying oven according to AOAC (1995). Temperature and pH were measured using a Hanna Waterproof pHep® pH and temperature tester (Hanna Instruments Professional Equipment Inc., 30 Oscer Ave. Suite 500, Hauppauge, NY 11788 USA). Ammonia, hydrogen sulfide, carbon dioxide, and oxygen were measure using a Sensidyne Model AP-20s hand operated pump (Sensidyne, Inc., 163338 Bay Vista Drive, Clearwater, FL 33760) and Sensidyne gas detector tubes (ammonia - Tube 105SD with sensitivity 0.2 to 20 ppm and Tube 105SC with sensitivity 5 to 260 ppm; carbon dioxide - Tube 126H with sensitivity 1 to 20%; hydrogen sulfide - Tube 120SD with sensitivity 10 to 60 ppm; and oxygen - Tube 159SC with sensitivity 1.5 to 24%. Methane was measured using a Gas-Sentry™ Model CGI-201 Natural Gas Detector, with a sensitivity of 0 to 100% and calibrated with methane. This instrument was obtained from Bascom-Turner Instruments, Inc. (111 Downey St., Norwood, MA 02062).

Technology Installation

Labor required for the installation of the P2 technology is listed in Table 1. Installation began in late October of 2003, and was completed by January 1, 2004, with the exceptions of trees, grass, and asphalt apron. The completion of concrete work during cold weather increased the amount of labor.

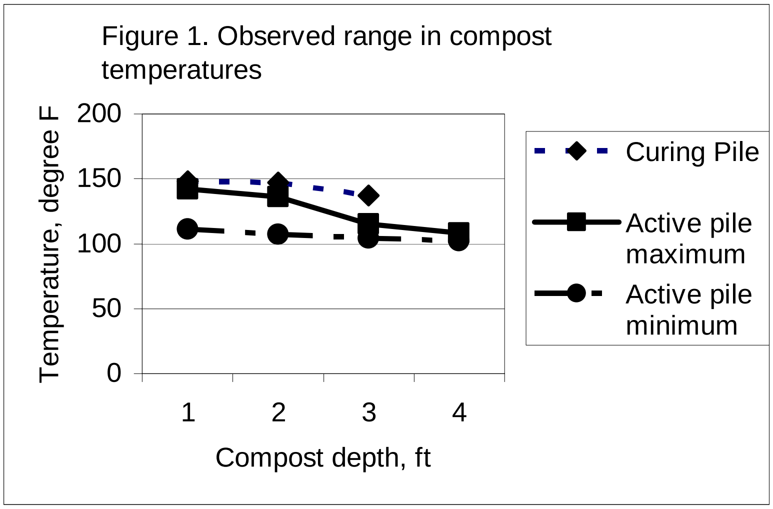
Table. 1 Labor required for the construction of the composting facility.

Description	Man hours
Excavating and site preparation	38
Driveways	8.5
Concrete work (4 men @ 40 hr each)	160
Electrical connection for grinder	18.5
Asphalt apron around bins (4 men @ 6hr each)	24
Fencing	16
Total	265

Technology Evaluation

Composting was proven useful in recycling animal tissue by-products generated from a small butcher shop. The facility was of an appropriate size to actively compost all by-products produced. It was effective in reducing material in an environmentally-acceptable non-nuisance setting. Meat sales or the “business” were not decreased because of any concerns of customers about this practice. The owners of the small meat harvest business were able to manage the composting technology with satisfactory control of the composting process.

Measurements of temperature within piles of compost indicated that a desirable composting activity was achieved (Figure 1). Temperature ranges were consistent with those reported by other researchers (Garcia-Siera et al., 2001) and in field studies (Rozeboom et al., 1998; Natural Resources, Agriculture, and Engineering Service, 1999). Temperatures recorded deep within the pile were less than those observed in the outer one to two feet, thought to reflect lack of air at those depths. The temperatures observed in the curing pile, suggest that the compost was still actively decomposing, not as low as those generally observed in curing compost.



About 11,600 pounds of by-product were generated each week and the grinding of by-products using the Rietz equipment reduced tissues by over 250% (e.g. meat process collected during processing and contained in four barrels were ground and subsequently contained in only one and a half barrels). The chemical analysis of meat processing by-product was 79.2% dry matter, 71.4% fat, 5.0% crude protein, and 1.5% ash.

A description of the volume and weight of ground by-product animal tissue, clean sawdust, and finished compost used in the filling of a compost bin is provided in Table 2. Each new bin (total usable bin volume of about 17 yd^3) on average contained 7 to 8 yd^3 of clean sawdust (base and biofilter caps), 4 to 5 yd^3 of ground animal tissue by-product, and 5 to 6 yd^3 of finished compost. Ranges are presented here, as the use of a 0.75 yd^3 bucket on a loader tractor expectedly leads to some variation in quantities spread in the layers of a pile. A base layer of clean sawdust (1 x 8 x 14' or 4.15 yd^3) was placed first in each bin. On top of this, layers of finished compost and ground animal tissue by-product (2 to 3" thick over a 7 x 13' area; 0.75 yd^3) were placed. When static for one or more days, a sawdust biofilter cap (4 to 5" thick over an 8 x 14' area or about two loader buckets) was placed over the top of a pile. Pile height after formation was about five feet. The bulk densities of clean sawdust, ground animal tissue by-product, and finished compost were 485, 1,535, and1,010 lbs./yd^3, respectively. Depending on season, about seven bins were filled each month.

The final volume of compost produced per bin after active composting and after four to six months of curing was about 10 to 11 yd^3, or a reduction of compost mixture volume of about 42%. Finished compost has a bulk density of about 1,010 lbs./yd^3. The reduction of volume observed with composting at Jones Farm Meats was greater than the 25% reduction reported by Kube (2002) during whole bovine carcass composting. Just over half of this finished compost (about 5 to 6 yd^3 from each finished bin would subsequently be used as bulking agent in newly formed piles. Weight reduction was slight more (about 45 to 50%) than volume reduction.

Throughout the entire demonstration period all of the compost removed from bins after three to four months of active decomposition has been place into a larger pile of "curing" compost where it has remained. There was no land application as a soil amendment. But the goal of composting at Jones Farm Meats is still to recycle nutrients. All compost was cured with possible sale of uncured and cured products explored continuously.

Compost from the active composting bins could have been applied to cropland as a fertilizer with a known nutrient value without further curing (Table 2.). Even though complete curing had not taken place, it could have been used as soil amendment and incorporated into the top soil of crop land, without potential phytotoxic effects on crops. If the compost would have been sold to a compost broker or directly to greenhouse growers as a plant medium, complete curing would have been recommended, to assure that phytotoxic properties of uncured compost would be avoided. Complete curing would have been done at Jones Farm Meats or at another location pre- or post- sale.

Use as a soil amendment or rooting medium reduces the pollution potential of Jones Farm Meats as compared to use of landfill, burial and incineration methods of by-product disposal. Furthermore, it lessens the expenditure crop growers need to make for inorganic fertilizers, as compost would be equivalent to $11.60 per ton of commercial fertilizer. This estimate is based on the compost analysis shown in Table 2, and commercial fertilizer prices per pound of $0.30, $0.28, $0.19 for plant available N, P_20_5, and K_20, respectively. Plant available N is equal to NH_4 plus 30% of the organic N (0.5 + (0.72 x 0.3) = 0.72% or 14.4 lb. plant available N per ton of compost). Organic N is calculated as total N minus NH_4 (1.22 - 0.5 = 0.72). By Michigan Right-to-Farm Program (2004) GAAMP's, two years worth of P_2O_5 could be applied every two years for soils testing less than 75 ppm. Thus, compost could be applied at 6.2 tons per acre every two years for 150 bushels of corn produced per acre. At this rate, 89.3 lbs. of plant available N would be applied and this would be less than the 171 lbs. that this corn crop would need. Supplemental inorganic N would still be required.

Table 2. Description of finished compost (n=1)						
Density, lbs./yd^3	Moisture, %	Total N, %	NH_4, %	P_2O_5, %	K_2O, %	Ca, %
1,010	49	1.22	0.50	0.90	0.29	1.12

Short-term, the land area required for application of compost material as a soil amendment crop nutrient source would be greater than that needed for burial under Michigan law. Under the Bodies of Dead Animals (BODA) Act, a common grave may include a maximum of 2.5 tons per acre. Jones Farm Meats would need about ten acres per month for burial, but the law unclear on "reuse" of burial acres for future burial. New acres may be required for each common grave, so over time, more acreage may be required for burial. Other stipulations in the BODA Act which would add further complexities to butcher shop operation year-round include: covering with minimum of one foot of soil within 24 hours, having at least two feet of soil as final cover.

Fresh animal by-products can not be land applied so a comparison of the land-base required to spread fresh verses that required when spreading composted by-product is mute. If current Michigan Right-to-Farm Program (2004) GAAMP's are followed in applying compost to cropland at agronomic rates, then approximately 300 acres of crop land producing corn are needed each year for use of all the compost nutrients produced by Jones Farm Meats. That total is based on 11,600 pounds of by-product per week, an accumulation of 3000 pounds of finished compost per 1000 pounds of animal by-product, a 150 bushel per acre corn yield, and a 0.37 pound P_2O_5 per bushel of corn removal.

Admittedly, by-products could be rendered into a soil amendment as well. The cost of doing so is not known, but is suspected to have to be near that charged for rendered feedstuffs on a weight basis. To compete with composting on a cost basis, then the cost of rendered soil amendment must be the same or less than that cost of compost amendment (dollar per amount of nutrients). If the cost of composting is the same as the cost of rendering and they both provide the same output of nutrients, then rendering would remain a viable alternative for by-product management by butcher shops with achievement of a goal of recycling nutrients. If however, rendering is more expensive than composting, not providing enough value to justify the transportation and processing associated with rendering.

Pathogens or possible health risks associated with the composting by-products were monitored using monthly microbiological surveys done by USDA in the meat-processing plant and by microbiological analysis of compost. Monthly monitoring of pathogens inside the meat processing plant established that the quantity of *E. coli* (Generic and O157:H7), *Listeria* sp., *Campylobacter* sp., and *Salmonella* sp. in samples did not differ when the months of composting by-products are compared with the preceding months of rendering by-products. No pathogens were found during the use of either method of by-product management. One sample of finished compost was tested for the presence of the same pathogens with only insignificant amounts of *E. coli* found (Table 3). These findings may be invalid because of the overwhelming competition from numerous other beneficial organisms in compost in laboratory cultures.

Most laboratories including the one that conducted the analysis for this demonstration question the reliability of organism isolation and quantification, particularly if *Listeria* sp., *Campylobacter* sp.

Table 3. Results of microbial analysis of compost[a]	
Microorganism	Colonies / weight
Salmonella sp.	Negative / 50 grams
Escherichia coli (Generic)	< 10 / gram
Escherichia coli 0157:H7	Negative / 50 grams
Listeria sp.	Negative / 50 grams
Campylobacter	Negative / 50 grams

[a]Sample reference W04137:18. Alliance Analytical Laboratories, Inc, Coopersville, Michigan. October, 20, 2004.

The activity of composting was monitored using chemical measures of temperature, moisture and pH, and measuring the gas concentration in the compost piles which were static one to two weeks prior to sampling. Generally, moisture content and pH were within the desired range for active decomposition (NRAES, 1999); with a slight tendency for compost material to be too dry at times. Oxygen concentration below 5% limits aerobic activity. The average oxygen content of compost was 2% suggesting that the amendments and tissue by-products lacked porosity and (or) that oxygen was being measured after piles had sat undisturbed for a long period of time and were in need of aeration. Anaerobic activity was likely occurring as indicated by the methane concentrations measured and is an expected activity when composting animal tissues (NRAES, 1999). Odors were released when digging into piles, with ammonia being consistently present and hydrogen sulfide detected less than 15% of the time (6 of 44 samplings).

Table 4. Conditions in active compost piles			
Measurement	n	Average	Range
Moisture, %	28	42	25 - 54
pH	41	7.4	6.4 – 8.8
Ammonia, ppm	44	53	41 – 900
Hydrogen sulfide, ppm	6[a]	17.3	4 – 30
Methane, %	43	0.26	0 – 3.8
Oxygen,%	27	2	0 - 11
Carbon dioxide, %	42	2	0 – 14

[a]In addition, 38 other measurements were taken in which all concentrations were non-detectable.

During the course of the demonstration project, the importance of managing the composting process in order to control the odors released and moving from compost batches was recognized by the employees managing compost, the owners of Jones Farm Meats, and the project consultants. First, they all agreed that putting too much tissue in a bin should be avoided, as doing so lowered the C:N ratio, and caused disproportionately more anaerobic activity. Second, they learned that dry, clean sawdust was needed as a base of each new pile, at a depth of at least one foot for its absorbance and porosity characteristics. Partially-cured compost was used as an amendment around new ground by-product, but not as the base nor as the top layer or biofilter cap of a pile. Project personnel thirdly identified that it was beneficial to have a “biofilter cap” of dry, clean (sometimes called “fresh”) amendment as the outside or top layer of every pile to be left undisturbed for a day or longer. Surface ammonia was measured comparing active compost piles with and without a biofilter cap. Uncovered piles averaged 10.5 ppm NH_4, with one of seven measures being non-detectable (possibly an inactive pile, but not known with certainty). Conversely, 6 of 7 piles with biofilter caps had non-detectable concentrations of surface NH_4. A biofilter cap was also applied to the curing compost pile to minimize odors. Relative to odor management, control of movement of odors (dispersion) away from the butcher plant and neighbors is anticipated with greater growth of the pine trees that were planted on the berm which surrounds the compost facility.

Slaughter volume at Jones Farm Meats was constant over the course of this demonstration project and similar to that capacity experienced previously when rendering was used as the tissue by-product management technology. This is true even though there was an increase in slaughter capacity with the conversion of refrigeration space formerly used for inedible storage (prior to pick-up by the rendering firm) into storage of edible product. A change in meat processing capacity at the butcher plant was not anticipated with the adoption of the composting technology. By-product generation stayed at 11,600 pounds per week after the change from rendering to composting (Table 5).

Composting allowed Jones Farm Meats to maintain meat processing costs. If composting had not been instituted and the use of rendering continued, meat processing volume may have stayed the same provided customers would be willing to pay more. Rendering costs have continued to climb and that cost has been passed back to the meat processing customer. The processing cost increase has been the result of price increases in rendering of $15 per stop ($30 per week). Composting has allowed Jones Farm Meats to avoid increasing custom butchering costs.

Table 5. Data summary sheet comparing technologies on an average monthly operating basis.

Parameter	Existing (Previous) Technology	P2 (Composting) Technology
Data collection period	1/1/02 to12/31/03	1/1/04 to 10/22/04
Meat processing by-products, yd^3 (tons)	72.5 (23.2)	29 (23.2)
Bulking agent, yd^3 (sawdust and finished compost)	-	87
Finished compost volume (yd^3)[a]	-	67
Average volume reduction (%)	-	42
Fuel usage - tractor (gallons)	-	80
Fuel cost ($), @ $1.29/gallon	-	$103
Electricity usage - grinder (kwh)	-	5
Electricity cost ($), @ $22.50/kwh	-	$112
Labor/operator requirements (hrs)	5 (barrel cleaning)	25
Labor/operator cost ($), @ $25/hr	$125	$625
Maintenance requirements (hrs)	-	2
Maintenance cost ($)	-	$50
Regulatory requirements (hrs)	-	-
Regulatory costs ($)	-	-
Disposal cost by-products, $	$1407	-
Operator training cost ($)	-	-
Initial facility capital cost ($)	-	$52,202
Dollar equivalents of compost nutrients as inorganic commercial fertilizer ($/$yd^3$)	-	$5.86
Acres required for land application	-	25
Potential income from compost sold ($)[a]	-	$820

[a]Finished compost for sale or land application. Each month about 45 yd^3 of finished compost is reused as amendment in starting new compost piles (about 5 to 6 yd^3 in each new pile, seven new piles per month) and about 20 yd^3 is cured for sale or land application.

With composting, energy consumption (fuel and electrical) increased as a result of tractor and grinder use (Table 5). Less soaps and water were used to clean barrels since the change from rendering to composting. However, more materials have been needed for composting, specifically sawdust. Dry dairy bedding (hardwood sawdust) was hauled to the composting facility at the beginning of the project, at no cost for the material. It contained very small amounts of manure. The use of this material was discontinued shortly after the start of the project with clean hardwood sawdust used as the composting amendment thereafter (used solely at the pile base and as a biofilter cap, but mixed with finished compost around ground tissue by-products when placed into the compost pile). Other materials needed for this project included soil for berm construction and Spruce trees used for air dispersion or windbreak.

Employees at Jones Farm Meats appreciated the composting technology and the advantages it offered their business. Total hours of employee labor for by-product management increased with the change in technologies. About 20 hours more time was taken to grind by-products, move material to the compost facility, wash barrels, and aerate compost than was needed for rendering (to prepare and store by-products for rendering, load the rendering truck and wash barrels). Notably, composting reduced beef slaughter time as all contents of the bovine viscera no longer have to be manually removed and separated. That job required one person and 20 minutes per hour. On days cattle were harvested, this would add up to 1.5 hours per day. Approximately half the number of barrels was needed with composting as compared to rendering, which meant less cleaning.

A summary of the economics associated with the composting technology is shown in Table 5, with the $52,202 investment including the $3900 asphalt apron and the $4,200 used grinder. There were no unanticipated expenses or savings that significantly altered the cost as projected in the application budget. The overall decrease in operating costs with the new composting technology was expected. A manure spreader was not purchased. With a 30-year life of the facility and straight-line depreciation figured, the facility and operating cost totaled about $12,400 annually, without any interest cost included.

Project Challenges and Management Adjustments

Overall the composting technology was proven very useful in the management of meat processing animal tissue by-products. Most difficulties encountered during the project were addressed successfully, with alternative or new management practices adopted.

Starting the compost process in the winter was slower because of the low amount of material in the facility. Temperatures in bins on the west end of the facility were lower initially, but as the facility filled, heat transferred from adjacent bins and improved composting activity in the end bins. Desirable temperatures have been recorded in all bins since then, providing an indication that the composting process is actively working. No compost process failure was encountered during this demonstration. Future failure is not expected, knowing now that composting activity continues in winter months provided that new tissue is not frozen, compost material is consistently aerated depending on temperature, and previously composted material is mixed with clean dry bulking agent when filling bins. However, if composting activity is unexpectedly slowed during severely cold weather, it coincides with a season of less meat processing, resulting in additional bin space for temporary storage until compost activity is resumed.

In the winter months the ground around compost bins failed to freeze because of the heat generated by compost activity. Consequently the front tires of the tractor/loader would sink into the gravel and soil, creating ruts. An asphalt apron (25 feet wide between bin rows, and eight feet wide around the outside of the facility) was laid in the spring of 2004, after the apron area had dried sufficiently, at a cost of $3900 to alleviate this problem and to facilitate the movement of machinery around the bins year-round. It has also made it easier to clean around bins.

In retrospect, a height of five feet would have been sufficient for side walls. Six feet of height was excessive, as pile heights of greater than five feet could not be achieved when composting animal tissue by-products. Because of the high amount of lipid, composite pile structure or form was difficult to maintain, as piles melted, sagged, and flowed out of bins slightly, especially in warmer months. This problem was corrected by placing a minimum of one foot clean dry sawdust at the base of each pile, including more layers of less thickness, and increasing the volumetric ratio of by-product to bulking agent from 2:1 to 3:1.The height of the push wall or spine at 3 ft was adequate. Also in retrospect, the inward slope of bin floors may have been greater, possibly 3%, to accommodate more rainfall before leaching occurs.

Odor control will be a constant management consideration. Some odor production is expected as the composting process includes both aerobic and anaerobic microbial activities. The goal is to have the greatest proportion of activity be aerobic. Odorous compounds not measured in this demonstration are typically products of anaerobic fermentation such as alcohols, esters, aldehydes, phenols, and volatile organic acids. Aerobic decomposition can cause odors, notably NH_4, when a C:N ratio of 20:1 or less results when starting a new pile. This may have unintentionally been the situation when high concentrations of NH_4 were measured in this demonstration project, but measurements of C:N in compost was not taken simultaneously with NH_4 readings. To avoid anaerobic activity, care is taken not to allow the saturation layer at the bottom of bins to remain static too long after rainfall accumulation. Timely aeration, especially after rainfall, keeps oxygen concentrations above 3%. Pile height is kept at four to five feet to avoid compaction and further anaerobic activity. A porosity of 40% or greater is sought by keeping layers of ground animal tissue by-products thinner (4 to 6 inches) and eliminating clumps in pile. Lastly, pile moisture is kept in the desired range of 40 to 60% and C:N ratio is managed in the 30:1 to 40:1 range.

Compost containing ground animal tissue tended to form clumps or balls, even with aerating and after movement to curing piles. This was more problematic if fresh ground by-product was piled 8 to 12 inches in depth when initially added to a batch of compost, and was avoided by spreading thinner, alternating layers of ground by-product and amendment.

Some challenges were not addressed before the project completion date of October 22, 2004, but have been since then as Jones Farms Meats has continued to compost animal tissue by-products. All compost was cured in a common pile from January 2004 until April 2005. Samples of cured compost were taken and sent for laboratory tests (results pending) to determine if completely cured to the point of no further microbial activity and respiration. On April 20, 2005, 140 yd^3 of cured compost were spread on neighboring crop land at agronomic rates. No sale of material was made in this transaction, leaving the establishment of a compost market yet to be done. The sale of compost will make this technology more financially attractive as an alternative to rendering. If compost would be sold for $820 per month, the annual cost of composting would be reduced to $2,560.

A new tractor has been purchased recently (but not delivered as of this writing) because Jones Farm Meats thought it necessary to protect personnel managing composting technology, to decrease traffic on the asphalt apron decreasing wear of the asphalt apron, and to lessen time devoted to compost management with larger bucket on loader. An industrial-type telescopic tractor loader (Caterpillar TH 220B, Model 3054E) was purchased ($62,500) to move sawdust, by-product, and compost. The loader bucket capacity will increase from 0.75 to 2.0 yd^3 to lessen the amount of time required to manage by-product and compost. The larger bucket speeds the slaughter process as the accumulation of bovine viscera is localized into one large volume instead of several smaller volumes. With a larger bucket fewer trips are needed from the inedible grinder to bins, from amendment pile to bins, and from bins to curing windrows, reducing the time needed to manage the composting process. The extendable bucket arm reduces the number of movements (back and forth) needed when aerating active compost piles, reducing the wear on the asphalt apron surrounding compost bins. The cab on the tractor will provide for operator safety (decreased exposure to windblown sawdust and compost gases dissipating during aeration). If amortized over 15 years, the purchase of this tractor increases annual composting cost to about $16,600, still comparable to current rendering cost for a business this size.

Also to be done in the future will be the placement of berms around the facility to contain any runoff and grass filter strips to use the nutrients in runoff. These may be completed in the summer of 2005. Runoff from the driveway will be routed to a settling basin and a vegetative infiltration area. If excess leachate is produced, it will overflow into the driveway, and will be treated in the vegetative infiltration area. This has not been completed at the time of this writing. Selecting a site for the curing of compost that is appropriate for further aeration but having no water quality risk also remains yet to be done. During the demonstration project period and since then, no attempt has been made to compost blood because of its high moisture content. About 400 gallons of blood is accumulated each week at Jones Farm Meats, LLC. Plans to do so are being contemplated, with regard to space limitations and the need for much greater amounts of clean dry sawdust.

When the project was completed October 22, 2004 with the Open House, less microbiological, gas, compost chemical analysis, sampling had been completed than committed to in the project protocol (12 batches annually or one per month). The reliability of the collected data is not believed to be compromised. More sampling for microbes in the compost should have been done, but more labor and funds would have been needed to conduct all of the testing that was described in the project proposal. The monitoring of potential pathogenic organisms in compost is planned to be completed on a semi-annual basis in the future.

Conclusions

Composting of butcher plant animal tissue by-products was very effective in achieving the goals of safely recycling nutrients and limiting costs associated with the meat processing business. Composting methods determined to be essential to the success of this process include: 1) optimizing pile conditions (moisture, C:N, porosity, etc.) to enhance aerobic activity, 2) reducing bone size by grinding, 3) using a biofilter cap to limit odor movement from piles, 4) using more layers and bulking agent to avoid slumping problems inherent with ground high-fat animal tissue by-products, 5) having floors slope inward to accumulate rainwater and avoid leachate flowing out of piles, and 6) aerating when temperatures suggest decreasing activity. Investments associated with the composting technology included the $52,202 structure (30-year life), the $3900 asphalt apron, and the $4,200 used grinder, and when combined with operating costs totaling $890 per month, composting is costing Jones Farm Meats about $12,400 annually. This is about $4,500 less than it would cost to have a rendering service to the butcher plant. Compost has not been sold yet, but when accomplished is expected to decrease actual costs associated with by-product management by 50% or more and the eventual cost of custom meat processing to consumers.

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