NPB FINAL RESEARCH GRANT REPORT

Shelby County Iowa Carcass Management Research Project
NPB PO-001514
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Industry Summary: Approximately twelve-hundred 260-lb. hogs ingested an adulterant and could not be processed in the human food chain or through rendering. Consequently, animals had to be destroyed and carcasses managed on the farm where they were being reared. The unfortunate situation provided the pork industry opportunity to conduct demonstrative research focused upon large-scale carcass management.

This project focused on the management of carcasses using grinding and mixing. The objectives of this project were to evaluate management, compost activity, and aesthetics associated with increasing amounts of tissue in the windrow core, to determine throughput or flow rate of carcasses through the system, and to compare manual temperature collection with dial-analog thermometers to electronic, remote, sensor technology.

This project took place on a 3-acre plot on a swine contract-finishing farm in Shelby County, Iowa. Compost windrows (approximately 12 feet wide x 6 feet tall) were built to compare four different composting treatments, windrow core animal tissue densities of 10, 15, 20, and 25 lb. of ground swine carcasses per cubic foot of mulch (carbon amendment). The core windrow animal tissue densities were achieved by feeding the grinder a different number of carcasses with each 2 yd^3 bucketful of mulch. The construction of compost windrows was accomplished using equipment provided and operated by Thorp Land Clearing, LLC, Billy Thorp Owner, Jefferson, IA. A 950-hp horizontal belt grinder simultaneously ground carcasses and mixed ground tissues with mulch. A loader with 2 yd^3 bucket placed mulch onto grinder infeed conveyor. Carcasses were loaded onto grinder infeed conveyor using a 295-hp excavator equipped with a root rake and hydraulic thumb. A loader with 10 yd^3 bucket received the tissue-mulch mixture as discharged from the grinder and placed it into compost windrows. The core compost material (mixture of ground tissue and mulch) was placed upon a 1-foot-deep windrow base of mulch that had been laid down using the 10 yd^3 bucket-payloader and the excavator. Windrows were capped or covered with 6 to 8 inches of mulch using both loaders.

Windrows were monitored daily for temperature, leachate, flies, vermin, odor, and change in shape by the farm owners and the investigative team. The horizontal grinder was operated continuously for about 1 hour to assess throughput. Electronic, remote sensors were placed in compost windrows in accordance with the current USDA (United States Department of Agriculture) composting protocol. Temperatures were measured at the same flagged locations using dial analog thermometers and electronic, remote sensors to evaluate and compare temperature monitoring methods.

Experienced operators were critical in grinding and mixing to compost swine carcasses. Carcass management took two days. There were no interruptions in carcass management due to the inabilities of the grinder. Similarly, the excavator and bucket loaders were capable of feeding carcasses and mulch continuously. Windrows appeared different depending on animal tissue density. With greater densities there was more aggregation of animal tissue as the material was being ground and dispersed by the 10-yd^3 bucket-loader into the windrow. Animal tissue density did not alter composting activity. Temperatures post-construction increased and were maintained similarly for all densities. Two weeks following windrow construction, the windrows were turned, aerated, and mixed using the self-propelled windrow turner. There were no visual or structural differences in any of the windrows. All were dry, yielding a little odor, and few flies.

Maximum throughput in the system used in this project was dependent upon the distance of the small loader from the mulch being put into the grinder and the distance of the large loader from the windrow where the core mixture was being placed. The maximum throughput of the carcass management system used in this demonstration was estimated to be 10 carcasses every 35 seconds or 1028 carcasses per hour. This was observed when using a 25 lb./ft^3 tissue density. On a weight basis, this throughput would be 267,429 lb. or 134 tons per hour.

The two temperature methods gave largely different values, a range of 4.4 to 15.1 degrees Fahrenheit different. Electronic, remote, sensor technology did not provide the accuracy needed to document compost activity and pathogen elimination.

The findings of this project enhance the preparedness of farms to respond to a highly consequential disease outbreak on their farm. How to use a system of grinding and mixing carcasses is better understood, so that access to appropriate equipment can be planned for. The success of composting greater tissue densities will lessen the resources/costs necessary to manage carcasses. The use of dial-analog thermometers will continue until greater accuracy is obtained in remote sensor technologies.

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Key Findings:

- An animal tissue density of 25 lb./ft^3 could be used to manage carcasses using a horizontal belt grinder in the composting system.
- Acceptable compost activity, windrow durability, and minimal negative aesthetics were observed using an animal tissue density of 25 lb./ft^3.
- Greater animal tissue density requires less land and carbon amendment for the successful management of carcasses using composting.
- The construction of compost windrows with carcasses resulting from a depopulation of a 2,400 head barn of near-market weight hogs, could be done in less than a day.
- Improved accuracy is needed for electronic, remote, sensor technology to be used to monitor compost temperatures.

Keywords: Carcass management, mass carcass management, grinding, throughput, animal tissue density, compost, temperature, remote sensors.

Scientific Abstract: This project focused on the mass carcass management of about 1200 destroyed market-weight swine using grinding and mixing. Objectives were to evaluate management, compost activity, and aesthetics associated with increasing amounts of tissue in the windrow core, to determine throughput, and to compare manual temperature collection with dial-analog thermometers to electronic, remote, sensor technology. *Methods.* Compost windrows, 12 feet wide x 6 feet tall, were built to compare four different windrow core animal tissue densities: 10, 15, 20, and 25 lb. of ground swine carcasses per cubic foot of carbon amendment. The core windrow animal tissue densities were achieved by feeding a 950-hp horizontal belt grinder carcasses and mulch, simultaneously. A loader with 2 yd^3 bucket placed mulch onto grinder infeed conveyor. Carcasses were loaded onto grinder infeed conveyor using a 295-hp excavator equipped with a root rake and hydraulic thumb. A loader with 10 yd^3 bucket received the tissue-mulch mixture as discharged from the grinder and placed it into compost windrows. The core compost mixture of ground tissue and mulch was placed upon a 1-foot-deep windrow base of mulch that had been laid down using the 10 yd^3 bucket-payloader and the excavator. Windrows were capped or covered with 6 to 8 inches of mulch using both loaders. Windrows were monitored daily for temperature, leachate, flies, vermin, odor, and change in shape. The composting system was operated continuously for one hour to assess throughput. Temperatures were measured using electronic, remote sensors and dial analog thermometers at the same windrow locations to evaluate and compare temperature monitoring methods. *Results.* Windrows appeared different depending on animal tissue density. With greater densities there was more aggregation of animal tissue as the material was being ground and spread into the windrow. Animal tissue density did not alter composting activity. There were no visual or structural differences in any of the windrows. All were dry, yielding a little odor, and few flies. The maximum throughput of the carcass management system used in this demonstration was estimated to be 10 carcasses every 35 seconds or 1028 carcasses per hour (267,429 lb. or 134 tons per hour). The two temperature methods gave different values. The average absolute value of the differences between temperatures taken using the remote probe or the dial analog thermometers, at the same location and depth, ranged from 4.4 to 15.1 degrees Fahrenheit different. *Conclusions.* Findings of this project enhance the preparedness of farms to respond to a highly consequential disease outbreak on their farm using a grinding and mixing system. Composting greater tissue densities will lessen the resources/costs necessary to manage carcasses. Dial-analog thermometers will continue to provide the accuracy needed to document compost activity and pathogen elimination.

Introduction: Approximately 1200 hogs, weighing an average of about 260 pounds, were exposed to an adulterant. Because of this exposure, hogs could not be processed in the human food chain or in the animal byproduct feedstuff chain through rendering. Consequently, animals had to be destroyed and carcasses managed on the farm where they were being reared. This was an unfortunate situation but provided the pork industry opportunity to conduct demonstrative research focused upon large-scale depopulation and carcass management.

This project focused on the carcass management of destroyed swine that were near a harvestable maturity.

The benefits of reducing whole carcasses into smaller portions or particles (grinding, shredding) have been reported previously and continue to be studied by the pork industry in preparation for a highly consequential disease event. With particle reduction, the decomposition of animal tissue occurs sooner. Instead of taking months, soft tissue may be fully composted and unrecognizable in 4 to 6 weeks (about 1 and a half months). Carcass reduction is mechanically accomplished, including the mixing with carbonaceous amendments which absorb carcass fluids quickly and evenly. Greater microbial activity and consequential temperatures, which contribute to pathogen inactivation in animal tissue and other organics are achieved more quickly and uniformly throughout compost material with carcass reduction.

Based on their experiences, given the circumstances on this farm, and recognizing the goals of an associated or companion depopulation co-project, these questions were proposed by our research team. Question 1. What is the most favorable windrow core animal tissue density for mass mortality composting intended to inactivate an identified pathogen and for the decomposition of animal tissue in preparation for cropland application? With carcass reduction (grinding/mixing) there is an opportunity to increase the amount of animal tissue per amount of carbon amendment in the windrow core, more than recommended in routine on-farm mortality composting. ‘Animal tissue density’ has historically been expressed as pounds of animal tissue per cubic foot of amendment. Greater core tissue density would give the emergency response plan developers an opportunity to reduce the amount of land, the amount of carbon required to manage carcasses using composting, and money needed to respond to the HCD (Highly Consequential Disease) emergency. However traditionally, compost advisors have feared greater animal tissue densities as it may result in compost material which leaches, smells, attracts flies and vermin, and quickly loses it shape (sagging or mushrooming downward and outward). Question 2. What is the throughput of horizontal grinding when used for carcass reduction and mixing? Throughput has been approximated previously by extrapolation of short 10 to 15-minute run times which were not consecutive. The availability of many hogs in this circumstance would allow for the assessment of throughput by operating the horizontal grinder for longer uninterrupted periods of time. Question 3. Could compost windrow temperatures be monitored using precise and remote technology? In the last decade, compost dial-analog thermometers have been used in labor-intense routines to collect hand-written temperature data into logs which document the decontaminating activity within the compost. overview of the researchable question and its importance to producers.

Objectives:
Objective 1: Evaluate management, compost activity, and aesthetics associated with increasing tissue densities in the windrow core by using grinding and mixing to manage swine carcasses.

Objective 2: Determine the throughput or flow rate when market size hogs are put through a horizontal grinder and mixed with mulch for windrow composting.

Objective 3: Compare temperature sensor technology to manual temperature collection with dial-analog thermometers and assess if electronic, remote, sensor technology can replace existing temperature recording methods.

Materials & Methods: This project took place on a 3-acre plot, corn field, adjacent to the farm building site on a swine contract-finishing farm in Shelby County, Iowa (see Photo 1). The size of the plot was determined based on desired windrow dimensions (approximately 12 feet wide x 6 feet tall), the number of destroyed swine (1200), an estimated average live weight (260 lb.), and a 10 lb./ft^3 animal tissue density. Windrow length varied depending on windrow core animal tissue density (treatment). Initially, two treatments (10 lb./$ft.^3$ and 15 lb./$ft.^3$) were planned for. But, shortly after beginning to build the windrow with a core containing the 15 lb./$ft.^3$, it was decided by the project investigators to add two additional treatments (windrow core animal tissue densities of 20 lb./$ft.^3$ and 25 lb./$ft.^3$) to this project. The decision was based on the stable shape maintained by the windrows containing cores with the tissue densities initially planned for.

To compare the four composting treatments of differing windrow core animal tissue densities (10, 15, 20, and 25 lb. of ground swine carcasses per cubic foot of mulch) we used three windrows:

- 10 lb./$ft.^3$ in the southernmost windrow
- 15 lb./$ft.^3$ in the middle windrow
- 20 lb./$ft.^3$ in the eastern 2/3rds of the northernmost windrow
- 25 lb./$ft.^3$ in the western 1/3rd of the northernmost windrow

Treatments (core windrow animal tissue densities) were achieved by feeding the grinder a different number of carcasses with each 2 yd^3 bucketful of mulch:

- 2.3 carcasses for 10 lb./$ft.^3$
  - Achieved by loading 2, 2, and 3 carcasses repeatedly
  - About 400 carcasses
- 3.3 carcasses for 15 lb./$ft.^3$
  - Achieved by loading 3, 3, and 4 carcasses repeatedly
  - About 400 carcasses total
- 4 carcasses for 20 lb./$ft.^3$
  - About 267 carcasses
- 5 carcasses for 25 lb./$ft.^3$
  - About 133 carcasses

Mathematically then, if all carcasses weighed exactly 260 lb. the animal tissue densities would have been 11.07, 15.89, 19.26, and 24.07 lb./ft^3. To be more exact, carcasses would have had to have been cut and portioned when feeding the grinder. Doing so would have had several drawbacks, including additional labor, safety risks to employees, and slowing throughput. The swine on this farm were not weighed prior to depopulation. Historical production records (weight per day of age) were used to estimate the approximate weight of the swine. The 4 treatment animal tissue densities were approximations and it was understood that some variation in uniformity of animal tissue density would exist within the compost windrow.

The construction of compost windrows was accomplished using equipment provided and operated by Thorp Land Clearing, LLC, Billy Thorp Owner, Jefferson, IA (Photo 2).

- Horizontal belt grinder to simultaneously grind carcasses and mix ground tissues with mulch
  - Vermeer® Model HG6800TX
  - 950 hp
  - Track-driven, self-propelled, radio remotely controlled
  - Equipped with Vermeer® SmartGrind system "which automatically controls grinding speed based on engine rpm levels"
  - Heavy duty infeed system
    - Table 60 inches wide, 19 feet long, and 6 feet above the ground
    - Welded slat chain conveyor
    - Infeed conveyor was operated at 70% of the manufacturers speed
  - Feed opening 38 inches high and 56.4 inches wide
  - Drum was operated at 60% of the 1200 rpm manufacturer's speed
  - Two screens, upper and lower, each with 7" square openings
  - Discharge conveyor 60 inches wide and 19 feet long
    - Discharge conveyor was operated at about 60% of the manufacturers speed of 877 ft/min
  - Custom drop curtain chute
- Excavator to load carcasses onto grinder infeed conveyor, lay windrow base, shape windrows, maintain carcass staging area
  - Hyundai® Model 330HX
  - 275 hp
  - Track-driven
  - Equipped with a root rake (Teran, Miami, FL) and hydraulic thumb attachment (Werk-Brau Co., Inc., Findlay, OH)
- Loader with 2 yd^3 bucket to load mulch onto grinder infeed conveyor
  - Ensign YX638
  - 160 hp
- Loader with 10 yd^3 bucket to receive the tissue-mulch mixture as discharged from the grinder, move it, and place it into compost windrows (Photo 3)
  - Volvo® Model L150E
  - 295 hp
  - 60,000 lb. payload

All core compost material (the ground tissue and mulch mixture) was placed upon a 1-foot-deep windrow base of mulch that had been laid down using the 10 yd^3 bucket-payloader and the excavator.
After the core of each windrow was put in place, the windrow was capped or covered with 6 to 8 inches of mulch using both loaders, but primarily the loader with the 10 yd^3 bucket (Photo 4).

To assess the second objective regarding the maximal throughput of the composting system, the horizontal grinder was to have been operated continuously for 1 hour if carcasses were available.
To assess the third objective regarding the use of electronic, remote sensors, 10 probes (BMP Logic, Trenton, FL) were placed at 18" and 36" depths in compost windrows in accordance with the current USDA (United States Department of Agriculture) composting protocol. Temperatures were measured at the same flagged locations using dial analog thermometers, in compost of all four animal tissue densities. This allowed the evaluation and comparison of the two different methodologies. The probes are also designed to measure moisture.

Windrows were monitored daily for temperature, leachate, flies, vermin, odor, and change in shape by the farm owners and Alex Thomas. Temperature data was compiled, and observational comments shared by email and text among investigators.

Windrows were turned using a self-propelled windrow turner (Backus 21.33, Eggersmann Recycling Technology, Wardenburg, Germany) about 2 weeks after they were constructed, ending the project. At that time, the unfinished compost became the responsibility of the farm owners. Advice regarding continued composting was provided by the project investigators.

Results and Discussion: *Objective 1 - Management, Activity, and Aesthetics.* Equipment operation, each individually, and all units together as a carcass management system are critical. Carcass management took two days in which the grinding system worked flawlessly and was slowed by the speed of the depopulation demonstration. There were no interruptions in the operation because of inabilities of the grinder, such as lack of power or plugging, when grinding any of the experimental densities of animal tissue. Similarly, the excavator and bucket loader were fully capable of feeding carcasses and mulch continuously into the grinder at any of the animal tissue densities evaluated if carcasses were available.

During the construction of the windrows, we visually observed differences between animal tissue densities. With greater densities there was more aggregation of animal tissue as the material was being ground and dispersed by the 10-yd^3 bucket-loader into the windrow. There may be more concentrated pockets of animal tissue in compost windrow cores with greater animal tissue density.

In all windrows, there were small areas of exposed ground swine carcasses. Windrows had been covered or capped with mulch using both loaders and buckets. The covering or capping did not perfectly cover everything. So, the presence of flies and small amounts of odor were associated with all animal tissue densities (see comments in Table 1). The farm owners and investigators agreed that the prevalence of these concerns was not greater with greater animal tissue density, provided the capping of the windrow was near 100%. Furthermore, because of the proximity of the three windrows to one another made it difficult to assess that these concerns were more prevalent in any one of them or a given location within one of them (the 20 lb./$ft.^3$ and 25 lb./$ft.^3$ densities were in the same windrow).

Animal tissue density did not appear to influence composting activity, as temperatures post-construction increased similarly over the first couple of days post-construction (Figures 1, 2, 3, and 4). Visually it appears that temperatures within the 10 lb./ft^3 windrow were greater at the onset. That windrow was the first windrow constructed, and consequently was one day older on May 17, when temperature monitoring began. Compost activity was excellent, as indicated by the sustained temperatures over the two weeks following construction.

When the windrows were turned, aerated, and mixed using the self-propelled windrow turner two weeks after construction, there were no visual or structural differences in any of the windrows. All were dry, yielding little odor, and few flies (Table 1).

Objective 2 - Throughput. The speed of carcass management in this demonstration was limited by the speed of the depopulation. The second limitation was the movement of the ground tissue amendment mix post-grinder discharge, to the windrow using the 10-yd^3 bucket-payloader. Additional payloaders with the same bucket capacity could alleviate this slowdown. The third limitation was the loading of the carbon amendment by the loader with the 2-yd^3 bucket-loader. The excavator was never a limitation. The loading of pig carcasses by excavator as equipped in this demonstration could exceed the rate at which the grinder is capable could grind the carcasses. This was true even at the greatest animal tissue density.

To maximize throughput in the system used in this project, the use of 2 or more 10-yd^3 bucket-payloaders would be essential. Whether it be 2, 3 or more will be dependent upon the distance from grinder discharge to the location of the compost windrows.

Regarding the limitation of the 2-yd^3 bucket-loader, the range in time taken to make a one bucket addition to the grinder was 35 to 55 seconds. The range in speed was a result of how far away the mulch amendment was from the infeed conveyor of the grinder. It had been moved closer using the 10-yd^3 bucket-payloader during interims when no mortality was staged to be ground. The maximum throughput of the carcass management system used in this demonstration was estimated to be 10 carcasses every 35 seconds or 1028 carcasses per hour. This estimate is using a 25 lb./ft^3 tissue density, only requiring one bucket load of amendment per 10 carcasses. As stated above, an average carcass weighed 260 lb., so in terms of weight, the maximum throughput would be 267,429 lb. or 134 tons per hour. The weight per time estimate allows for the use of grinding in situations where animals are of different size and maturity.

An alternative to the use of payloaders and a grinder may be the use of tub grinder-mixer wagons or large spreaders that can form tall windrows upon discharge of the ground tissue-amendment mix to the windrow. The drawback with the use of mixer wagons may be a slower speed and with the use of spreaders the need to drive upon the windrow base and its compaction.

Objective 3 - Remote Sensor Technology. Three, 3, 2, and 2 probes were placed in windrows containing 10 lb./$ft.^3$, 15 lb./$ft.^3$, 20 lb./$ft.^3$ and 25 lb./$ft.^3$ of tissue to evaluate a remote approach of temperature recording. Temperatures multiple times each day, in the same location in the compost windrow; they were not relocated during their evaluation.

In Tables 2 through 5, comparisons of average daily remote probe temperature to the average daily dial analog temperature, in each tissue density and both depths into the compost are shown. The two temperature methods gave largely different values. The average absolute value of the differences between temperatures taken using the remote probe or the dial analog thermometers, at the same location and depth, were a range of 4.4 to 15.1 degrees Fahrenheit different.

The direction in which the thermometer methods differed was inconsistent. Remotely recorded temperatures were greater than the dial analog thermometer temperatures in most comparisons, with the exception being probe temperatures at 18” of depth in the 25 lb./$ft.^3$ of tissue compost, which were less than the dial analog temperatures. The same probes recorded temperature readings greater than dial analog temperatures at 36”.

Correlation coefficients were determined to assess the relationship between remote probe average daily temperature and average daily dial analog temperature for each thermometer depth in compost of each tissue density. In compost containing 10 lb./$ft.^3$, a weak linear relationship ($r = 0.35$ and 0.38) for 18” and 36” depth, respectively. With other tissue densities, stronger linear relationships between the two temperature recording methods were seen ($0.69 \leq r \geq 0.94$).

Lack of agreement between reading compost temperature between the remote probe method and the dial analog method could be related to constant positioning of the probe and the daily relocating of the dial analog thermometer, near the flag, and at the different depths. Probes were not removed and reinserted. It could also be a result of the probe reading being a daily average of many readings, taken 24-hr per day, and the dial analog temperature being recorded once daily, mid-to-late mornings. These variables should be considered in future validation of remote monitoring of compost conditions.

Initial moisture readings did not make sense and were variable. We did not pursue a comparison to drying oven or other moisture assessment methodologies.

Photo 1. Carcass management site plan (Flory).

Photo 2. Excavator, grinder, loader (Flory).

Photo 3. Placing ground tissue-amendment upon windrow base (Flory).

Photo 4. Windrows nearing completion of construction (Flory).

Table 1. Investigator observations and comments shared in email and text messages.

Date	Event or topic	Related text message (Investigator)
19 May 23	Temperatures	Here are the temps for the Shelby site. I talked with Mary and Bob(?) this morning and everything seems on track so far. I checked a few of the temps, including the 112 at 18" for the 10# pile and what I got matched pretty much what they wrote. I think flag 6 on the 10# pile is perhaps getting some heat stolen from today's wind. I labeled the windrows with some extra flags onsite today as well. I also moved the BMP sensors and will work with Brett to get them relabeled online. Right now there are 2 in the 25 and 20 pound sections of the north windrow and 3 in each of the others. I spread them out. No observed leachate at this moment and flies are present but fairly minimum. Slight slumping observed in piles but nothing significantly so. (Thomas)
20 May 23		It is interesting how the core of 10# windrow heated up quickly and the other ratios are slower but heating up nicely. (Flory) I made up a temp tracking sheet for the site. I took my own temps this morning as well as did the farmer. They were on their way out when I got there this morning but will be sending me photo copies of their temp sheets moving forward. Observations from the site are minimal. I noticed a few spots, especially on the 20# and 25# pile where maggots can be observed, where flesh wasn't fully covered or covered sloughed. But nothing too crazy and flies are fairly minimal still. Only one or two spots that have noticeable odor. I did also notice some dog and bird tracks around the piles but no signs of digging. Piles are overall still maintaining shape. (Thomas)
22 May 23	Probes	BMP should hopefully be changing the probe names today. I asked Brett over the weekend and he responded but I suspect his tech crew were rightfully enjoying their time off. If anyone wants to translate the probes to where they are in the piles, the Serial # and corresponding placement is in the table below. The two not listed are 4 and 5 in the 25# pile. I didn't move them so didn't include them in the need to relabel. Serial # Name ID 52001 20# Flag 3 54894 20# Flag 6 51978 10# Flag 5 52449 10# Flag 3 24023 10# Flag 1 54580 15# Flag 5 55051 15# Flag 3 52722 15# Flag 1 (Thomas) Thanks! These names will make a lot more sense. (Flory)
23 May 23		One of the BMP probes is yet to get retitled but the rest all look good! (I wrote 4023 instead of 4025 it looks like). (Thomas)

24 May 23	Temperatures	Here are the temps from the last two days. Everything looked good before I left! I'll continue to send updated temps as farmers send them to me. (Thomas)
22 May 23 23 May 23	Activity	Here at the temps from Shelby today. Talked with farmers today and all is well at the site. They haven't noticed anything I haven't. I did dig into the piles today. I dug into 3 points for each of the piles and mostly found nothing in the first 3. I found only one pocket of dried flesh in the 10# pile, and the 15# and 20# all looked good inside. Hot, with plenty of actinomycetes, and really no flesh discernable, even where I found bone. For the 25# though, the inside was wet with pockets of flesh still left at all three sample points. The pile was plenty hot though and should be fine by the time piles get flipped. (Thomas) Interesting observations about the center of the 25 windrow section. We are one week out. In your judgement, would turning it today be beneficial? (Rozeboom) Great question Dale. I think turning would help, if only to incorporate a bit more carbon. I also think, with temps where they are, there is a good chance most flesh will be broken down by two weeks. If one turned them now, it'd be good to be prepared to recap where needed. (Thomas) Alex, agree with you on all points. I think the recapping could be avoided if we turned every 3 to 7 days. Frequent turning manages material that has low C:N. Turning leads to the need for added moisture, which would be harder to do at Shelby County. (Rozeboom) We do intend to turn at day 14. (Flory)
30 May 23	Temperatures	Here are the temps from the past few days for Shelby (Shelby Temps 5.30.23 attached). (Thomas)
30 May 23	Flies	Alex, thanks for keeping up and sharing the data. I noticed that the farmer said there were lots of flies (note with temperatures of 20 lb./ft3 windrow on 05/27/23). Did he give an indication of which pile they may have been coming from? Wondering if there is any relationship to pile tissue density. We will be turning on Friday this week which should help. (Hutchinson) Texting farmer quick, they said they were on all piles and haven't really left. They say the flies are still there but not bothersome. Worth observing when you get there I would think. Before I left, there were some flies present but nothing I would call substantial or problematic. (Thomas) Thanks for checking in with farmer. Turning the piles should help with any fly issues. I'll make sure to walk the piles before they get turned. (Hutchinson) I'm not surprised by flies. We had a little exposed tissue in all 4 windrows segments with densities. Theoretically, maybe more flies with the greater density of tissue. Has there been any rain on the piles in the past two weeks? (Rozeboom)

1 Jun 23	Turning d 14	All three windrows are turned. No visual or structural differences in any of the windrows. Very little odor and no flies. Piles are very dry! (Hutchinson)  Any difference in moisture in the 25# windrow? (Flory) No (Hutchinson) Any noticeable pockets of tissue? (Rozeboom) Nothing. (Hutchinson) They look good! Not too dry to risk combustion, I hope? (Thomas) No, I don't think that will be an issue. (Hutchinson) Photo by Hutchinson

Table 2. Comparison of average daily temperature recorded using either an electronic, remote sensor (probe) or a dial analog thermometer in compost containing 10 lb./ft^3 of animal tissue, at 18” and 36” depth into the compost windrow.						
	18 “ Depth			36” Depth		
	Temperature Method			Temperature Method		
Day	Dial Analog	Remote	Difference[a]	Dial Analog	Remote	Difference[a]
5/19/2023	147.0	146.1	-0.9	147.8	140.7	-7.1
5/20/2023	154.0	151.9	-2.1	154.3	161.3	7.0
5/21/2023	138.5	163.5	25.0	149.7	163.5	13.8
5/22/2023	152.8	162.1	9.3	150.3	162.0	11.7
5/23/2023	148.0	159.8	11.8	147.8	161.0	13.1
5/24/2023	141.3	155.7	14.4	145.3	160.7	15.4
5/25/2023	144.3	155.1	10.8	147.5	160.9	13.4
5/26/2023	141.2	154.3	13.1	147.5	159.2	11.7
5/27/2023	132.8	151.9	19.1	144.2	155.8	11.7
5/28/2023	135.2	149.8	14.7	146.2	151.6	5.5
5/29/2023	134.2	148.8	14.6	146.0	150.6	4.6
5/30/2023	133.8	148.3	14.5	146.0	147.9	-0.4
Mean	141.9	153.9	12.0	147.7	156.3	8.5
Std	7.4	5.6	7.5	2.7	7.1	6.5
Max	154.0	163.5	25.0	154.3	163.5	15.4
Min	132.8	146.1	-2.1	144.2	140.7	-7.1
Avg Abs Diff[b]	-	-	12.5	-	-	9.6
r[c]	0.35		-	0.39		-

[a] Difference = dial analog minus remote.
[b] The average of absolute value of differences.
[c] Coorelation coefficient.

Table 3. Comparison of average daily temperature recorded using either an electronic, remote sensor (probe) or a dial analog thermometer in compost containing 15 lb./ft^3 of animal tissue, at 18" and 36" depth into the compost windrow.						
	18 " Depth			36" Depth		
	Temperature Method			Temperature Method		
Day	Dial Analog	Remote	Difference[a]	Dial Analog	Remote	Difference[a]
5/19/2023	152.2	159.8	7.7	125.3	135.6	-24.2
5/20/2023	154.7	160.0	5.3	147.7	150.3	-9.7
5/21/2023	151.3	153.3	2.0	143.5	154.1	0.8
5/22/2023	149.3	143.5	-5.8	147.5	154.8	11.2
5/23/2023	148.2	143.9	-4.3	147.5	154.1	10.2
5/24/2023	148.8	150.8	2.0	146.0	155.3	4.5
5/25/2023	140.3	148.5	8.1	146.5	155.6	7.2
5/26/2023	135.3	139.5	4.1	144.7	153.4	13.9
5/27/2023	135.0	135.9	0.9	141.8	150.2	14.3
5/28/2023	139.5	135.8	-3.7	141.2	149.7	13.9
5/29/2023	136.0	135.3	-0.7	139.0	151.9	16.7
5/30/2023	136.2	123.8	-12.3	134.0	151.2	27.3
Mean	143.9	144.2	0.28	142.1	151.3	9.3
Std	7.5	10.8	6.0	6.7	5.4	3.5
Max	154.7	160.0	8.1	147.7	155.6	17.2
Min	135.0	123.8	-12.33	125.3	135.6	2.7
Avg Abs Diff[b]	-	-	4.7	-	-	12.8
r[c]	0.85		-	0.85		-

[a] Difference = dial analog minus remote.
[b] The average of absolute value of differences.
[c] Coorelation coefficient.

Table 4. Comparison of average daily temperature recorded using either an electronic, remote sensor (probe) or a dial analog thermometer in compost containing 20 lb./ft^3 of animal tissue, at 18" and 36" depth into the compost windrow.						
	18 " Depth			36" Depth		
	Temperature Method			Temperature Method		
Day	Dial Analog	Remote	Difference[a]	Dial Analog	Remote	Difference[a]
5/19/2023	141.6	157.4	15.8	124.7	131.2	6.4
5/20/2023	152.6	162.6	10.0	145.4	152.1	6.7
5/21/2023	153.1	160.1	7.0	143.0	157.7	14.7
5/22/2023	152.7	155.7	3.0	154.1	159.9	5.7
5/23/2023	149.3	147.9	-1.4	150.4	159.0	8.5
5/24/2023	145.4	150.5	5.0	149.6	158.3	8.8
5/25/2023	145.9	146.8	0.9	149.6	158.4	8.8
5/26/2023	138.1	138.5	0.4	141.4	154.6	13.2
5/27/2023	133.1	134.8	1.7	140.1	150.6	10.4
5/28/2023	133.0	133.0	0.0	139.4	146.8	7.3
5/29/2023	134.9	137.5	2.6	141.6	146.0	4.4
5/30/2023	133.4	128.1	-5.3	136.9	144.5	7.7
Mean	142.8	146.1	3.3	143.0	151.6	8.6
Std	8.1	11.5	5.6	7.8	8.4	3.0
Max	153.1	162.6	15.8	154.1	159.9	14.7
Min	133.0	128.1	-5.3	124.7	131.2	4.4
Avg Abs Diff[b]	-	-	4.4	-	-	8.6
r[c]	0.90			0.94		-

[a] Difference = dial analog minus remote.
[b] The average of absolute value of differences.
[c] Coorelation coefficient.

Table 5. Comparison of average daily temperature recorded using either an electronic, remote sensor (probe) or a dial analog thermometer in compost containing 25 lb./ft^3 of animal tissue, at 18" and 36" depth into the compost windrow.						
	18 " Depth			36" Depth		
	Temperature Method			Temperature Method		
Day	Dial Analog	Remote	Difference[a]	Dial Analog	Remote	Difference[a]
5/19/2023	140.5	156.9	16.4	116.2	132.8	16.6
5/20/2023	154.7	149.8	-4.9	139.0	147.8	8.8
5/21/2023	155.2	143.7	-11.4	138.7	152.6	13.9
5/22/2023	153.3	132.4	-21.0	140.5	152.1	11.6
5/23/2023	146.2	132.6	-13.6	140.0	152.8	12.8
5/24/2023	148.3	133.7	-14.6	139.3	152.0	12.6
5/25/2023	146.0	136.4	-9.6	143.2	152.0	8.8
5/26/2023	140.5	131.4	-9.1	137.3	149.9	12.6
5/27/2023	137.2	121.7	-15.5	137.8	145.9	8.1
5/28/2023	135.8	112.0	-23.8	133.3	142.0	8.6
5/29/2023	134.3	111.8	-22.5	139.3	141.7	2.4
5/30/2023	133.2	114.1	-19.1	134.2	142.2	8.0
Mean	143.8	131.4	-12.4	136.6	147.0	10.4
Std	8.0	14.5	10.8	6.9	6.2	3.7
Max	155.2	156.9	16.4	143.2	152.8	16.6
Min	133.2	111.8	-23.8	116.2	132.8	2.4
Avg Abs Diff[b]	-	-	15.1	-	-	10.4
r[c]	0.69		-	0.85		-

[a] Difference = dial analog minus remote.
[b] The average of absolute value of differences.
[c] Coorelation coefficient.

Figure 1. Daily average temperature (°F; 6 locations per depth) in windrow constructed to contain 10 lb. per cubic foot of core amendment.

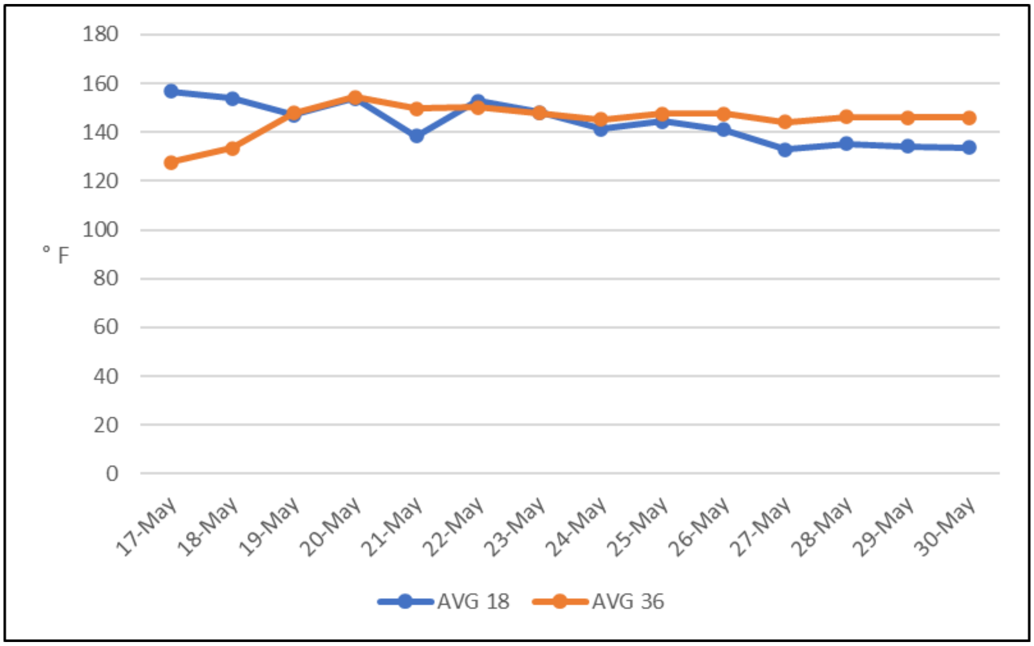

Figure 2. Daily average temperature (°F; 6 locations per depth) in windrow constructed to contain 15 lb. per cubic foot of core amendment.

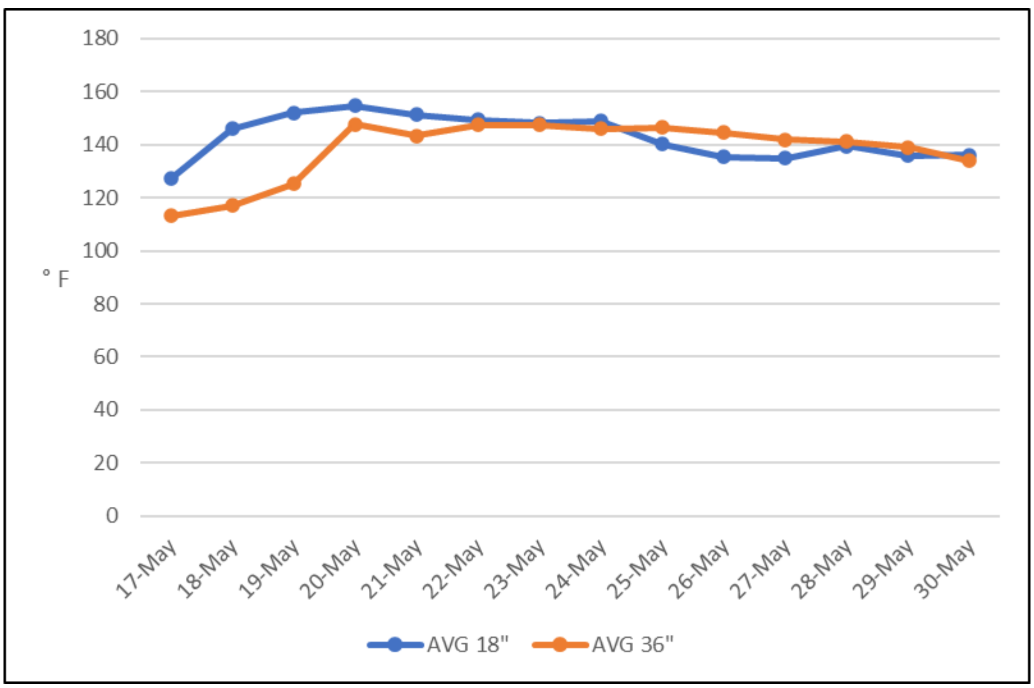

Figure 3. Daily average temperature (°F; 7 locations per depth) in eastern two-thirds of the northern windrow, constructed to contain 20 lb. per cubic foot of core amendment.

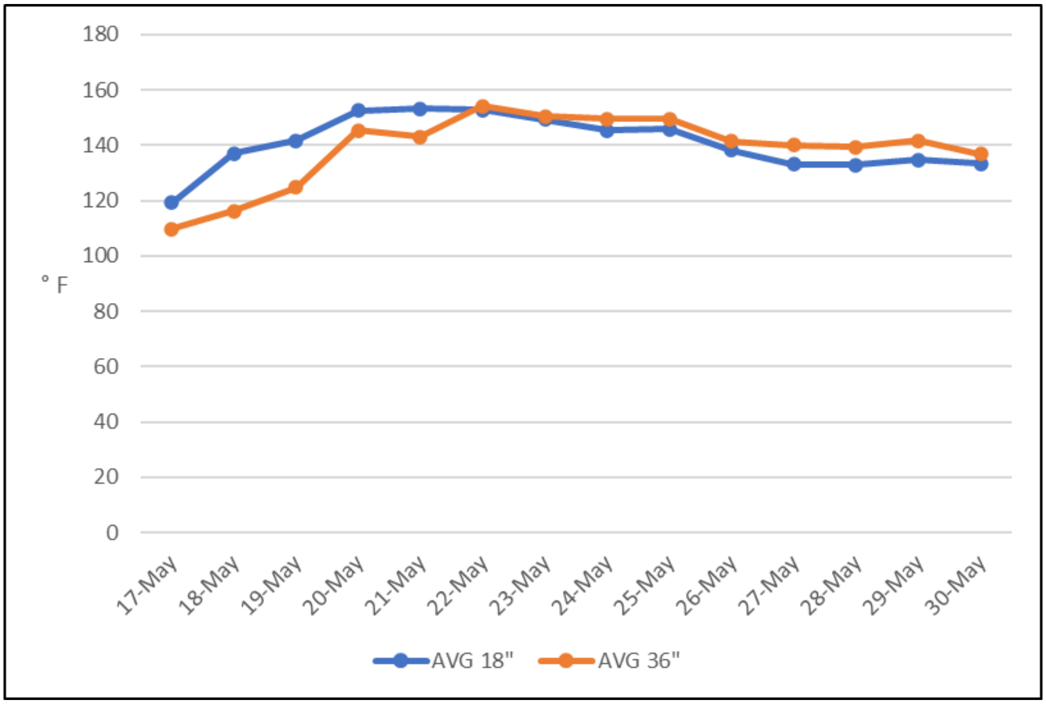

Figure 4. Daily average temperature (°F; 6 locations per depth) in western third of the northern windrow, constructed to contain 25 lb. per cubic foot of core amendment.