

NPB FINAL RESEARCH GRANT REPORT FORMAT

Effectiveness of Shallow Burial with Carbon with Low-Quality Carbon Material, NPB Proposal A#22-080

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Industry Summary: As stated in the contract, we require an industry summary of the project, suitable for immediate public release by the Board. The purpose of the industry summary is to provide producers with a quick reference to research results supported by Checkoff dollars. The content should include the following: an explanation of the objectives, a descriptive narrative of how the research was conducted, and a discussion of the research findings sufficient to give a thorough understanding of the results and explain what these findings mean to the industry. This summary is to be written for non-technical audiences. Please include your contact information.

This project was conducted to increase our knowledge of the implications of using low-quality carbon feedstocks as the carbon layer within a Shallow Burial with Carbon (SBC) system. This system is also known as the Trench Composting and Above Ground Burial. SBC requires a 1-foot layer of carbon material in the bottom of the trench. This carbon material serves three purposes: 1) absorbs and temporarily traps leachate released from the decomposing carcasses, 2) provides elemental carbon to the microorganisms that the system fosters to decompose carcasses, and 3) temporarily traps oxygen in the system. To date, most applications of the SBC system have utilized wood products such as shavings, wood chips, and mulch. These products are generally effective at all 3 functions. While these carbon materials are successful feedstock for SBC, wood products are not widely available in parts of the country.

Regions with few woody carbon sources often have ready access to crop residues such as corn stover, rice hulls, straw, or hay. These carbon feedstocks generally have a significantly lower carbon-to-nitrogen ratio than woody carbon sources. For example, wood shavings typically have a C:N ratio of around 550:1 while the C:N ratio of straw is 100:1 or less. Materials with a higher C:N ratio may have more elemental carbon available for the metabolic activities of the microorganisms. Crop residues tend to have a waxy cuticle layer that decreases their capacity to absorb leachate compared to woody materials. Finally, crop residues tend to compress under the weight of the carcasses and the SBC system's soil cover. This compression decreases the amount of

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oxygen trapped in the pore spaces between particles. The degree to which these differences in the physical and chemical properties of woody products compared to crop residues impact their effectiveness as a carbon source in an SBC system has been unknown.

Key Findings:

- The data indicates that all four carbon sources in this study (hardwood mulch, wheat straw, corn fodder, and fescue hay) provided an acceptable level of decomposition of whole swine carcasses after twelve months. This trial used finishing hogs. If larger breeding stock had been used the results may have been different.
- The fescue hay performed less effectively in both the ground trial and the whole carcass trial compared to the hardwood mulch, corn fodder and wheat straw treatments.
- The treatments with ground carcasses resulted in higher levels of ammonium nitrogen in the soil beneath the carcasses.
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- Please provide 3 to 5 bulleted points that highlight the most important findings of your study
- These can most simply be distilled from the “Discussion” section
- They should be written to convey information to pork producers
- Be brief

Keywords:

Shallow Burial with Carbon (SBC), Low-quality Carbon Materials, Carcass Decomposition, Foreign Animal Disease (FAD) Response, Nutrient Transport and Fate

Scientific Abstract: This should be a scientific description limited to one page in length to describe your project and its results.

Introduction:

Effective management of animal mortalities, particularly during foreign animal disease (FAD) outbreaks, is essential for maintaining biosecurity and preventing environmental contamination. For swine producers, the need for rapid, scalable, and cost-effective carcass disposal methods has become increasingly important in light of the risks posed by diseases like African Swine Fever (ASF) and Porcine Epidemic Diarrhea (PED) virus. These diseases can lead to mass animal mortalities, overwhelming traditional disposal methods such as incineration and rendering. Composting is a viable alternative for many catastrophic situations and may be a preferred option. However there will be situations when the resources required to successfully complete composting makes it impractical or not feasible. In such cases, shallow burial with carbon (SBC) offers a practical alternative that can be implemented on-farm, reducing the time and resources needed for carcass management while also minimizing the environmental footprint (Flory et al., 2017).

SBC not only provides swine producers with a tool for addressing carcass disposal during emergency situations but also offers long-term benefits by reducing the potential for nutrient runoff and groundwater contamination. By creating a carbon-rich layer under carcasses, SBC may enhance decomposition and mitigates the spread of pathogens, which is particularly valuable during disease outbreaks where biosecurity is a priority. As swine producers increasingly face regulatory pressure to implement environmentally sustainable practices, the integration of SBC into their mortality management plans could help meet these demands while ensuring compliance with environmental and health regulations (Miller et al., 2020).

Traditional carcass disposal methods, while effective, are not always feasible during large-scale outbreaks due to their logistical challenges and higher costs (Brown, 2007; Flory et al., 2019). SBC has been shown to offer a promising solution, particularly when high-quality carbon sources, such as wood chips or straw, are used (Miller et al., 2016). However, many swine producers may only have access to low-quality carbon materials like mulch or corn stover, whose effectiveness in facilitating decomposition is not well understood. This research addresses that gap by evaluating whether low-quality carbon feedstocks can be used effectively in SBC systems, providing critical information for swine producers looking for practical solutions during disease emergencies.

This study also investigates the impact of grinding carcasses on the SBC process, exploring whether pre-processing can accelerate decomposition and further mitigate environmental risks. By focusing on nutrient dynamics and the role of carcass reduction, this research provides important insights that will help swine producers optimize SBC systems, enhancing their ability to respond to disease outbreaks and protect both human and animal health and the environment.

Objectives:

The primary objective of this research is to evaluate the effectiveness of Shallow Burial with Carbon (SBC) using low-quality carbon feedstocks as a cover layer for swine carcasses. The study aims to determine whether SBC remains a viable mortality management tool when lower-cost, readily available carbon materials such as mulch, corn stover, straw, and hay are used. These materials are often more accessible to producers compared to traditional, higher-quality carbon sources, such as wood chips, commonly employed in SBC systems. The research will focus on assessing the decomposition rate of carcasses and exploring the nutrient dynamics within the soil underneath the burial sites.

A key focus of the project is to investigate how both the carbon material type and the pre-processing of carcasses, specifically grinding, affect the efficiency of the SBC process. By evaluating nutrient transport and decomposition rates, the study seeks to ensure that SBC remains an environmentally sound and scalable solution for managing large-scale animal mortalities, particularly in the context of foreign animal disease (FAD) outbreaks.

The research addresses three essential questions. First, it seeks to establish whether SBC with low-quality carbon material is a viable mortality management tool. This is crucial for understanding if more readily available carbon sources can adequately support carcass decomposition while minimizing environmental risks. Second, the study explores how much additional time is required for swine carcasses to decompose when low-quality carbon materials are used, as slower decomposition rates could impact the practicality of the SBC method. Finally, the research investigates the impact of grinding carcasses on the decomposition process within the SBC system. Grinding is hypothesized to accelerate decomposition, which could provide significant benefits for producers by shortening the timeline for carcass breakdown and reducing the potential for environmental contamination.

By addressing these questions, the research aims to fill critical knowledge gaps in the application of SBC with low-quality materials, offering insights into optimizing this method for widespread use during animal disease outbreaks and other mass mortality events.

Materials & Methods:

This study was designed to evaluate the effectiveness of Shallow Burial with Carbon (SBC) using low-quality carbon materials for swine carcass disposal. The research aimed to assess both the rate of carcass decomposition and the environmental impacts associated with different carbon materials. The experiment included two carcass treatments—whole and ground carcasses—evaluated across four different carbon materials: mulch (baseline carbon), corn stover, straw, and hay.

Study Site and Setup

The study was conducted at the Horticulture Crops Research Station in North Carolina (Address: 2450 Faison Hwy, Clinton, NC 28328). This station is affiliated with NC Department of Agriculture and Consumer Services (NCDA&CS) and North Carolina State University (NCSU) is located in the coastal plains region of North Carolina. The site was selected for its minimal slope to reduce the risk of leachate migration. The project site contained a weather station belonging to the state climate office (ECONET Station ID: CLIN) with continuous monitoring of primary weather variables such as air temperature, precipitation, wind speed, in addition to soil temperature, soil moisture content, and evapotranspiration.

Individual trenches were excavated for each treatment, ensuring each treatment combination (carbon material and carcass condition) was isolated to prevent cross-contamination. The placement of treatments was randomized to minimize bias and allow for a more rigorous comparison of outcomes. A total of 72 pigs of similar size were used, divided between whole and ground carcass treatments. **Figure 1** below illustrates the site preparation.



Figure 1. Experimental site after excavating the individual plots and before carbon material placement, and (B) tabular format showing experimental design

Trenches were prepared with a 1-foot base layer of carbon material, on which the carcasses were placed. **Figure 2A** below illustrates the four different carbon types used in our study (1) hardwood mulch, (2) corn stover, (3) wheat straw, and (4) fescue hay. Subsequently, each trench was covered with the soil excavated during trench preparation. To monitor temperature throughout the burial process, a waterproof HOBOT Pendant® temperature data logger was placed in the plot center on top of each carcass (**Figure 2B**). Temperature data were collected at regular intervals to calculate accumulated degree days (ADD) for

threshold temperatures ranging from 0°C to 20°C, following the methods outlined by Michaud and Moreau (2011). Excavations were conducted at three intervals: 3-month, 6-month, and 12-month after burial.

Experimental Design and Treatments

The experimental design was fully randomized and replicated, with each carbon material—mulch, corn stover, straw, and hay—tested against both whole and ground carcasses. Each combination of carbon material and carcass treatment was replicated three times, with treatment locations randomly assigned across the study site. This randomization ensured that environmental variability across the site did not bias the outcomes. The primary response variables were the degree of carcass decomposition, soil nutrient profiles, and the nutrient concentrations within the carbon material after burial.

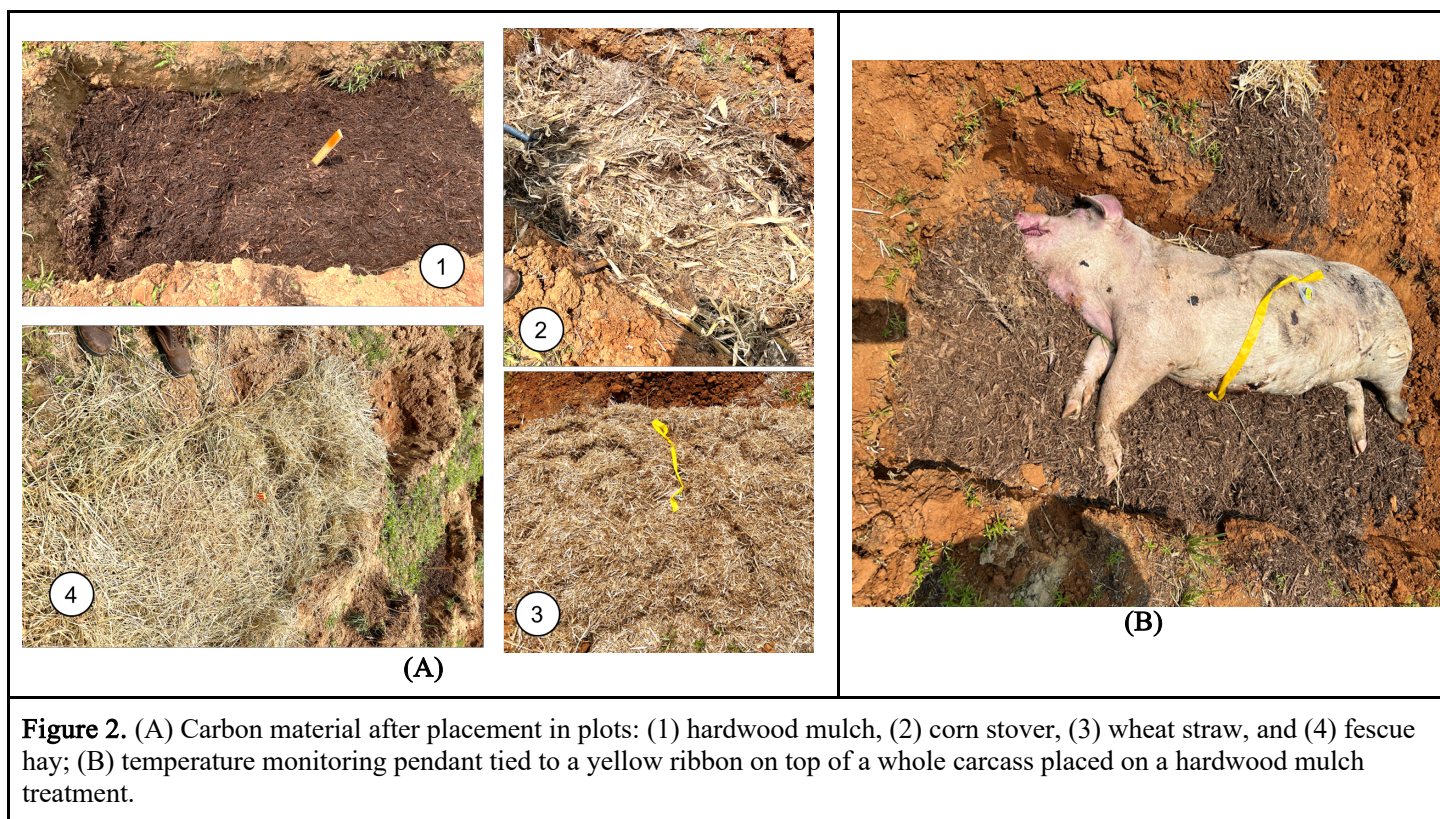


Figure 2. (A) Carbon material after placement in plots: (1) hardwood mulch, (2) corn stover, (3) wheat straw, and (4) fescue hay; (B) temperature monitoring pendant tied to a yellow ribbon on top of a whole carcass placed on a hardwood mulch treatment.

Carcass decomposition was assessed using a five-point scale developed by Brown (2007), as adapted by Lochner et al. (2022) (Table 1). Observers scoring the decomposition were all trained and experienced carcass management subject matter experts, ensuring consistent and reliable assessments of carcass breakdown across all treatments.

Table 1. Decomposition score values and criteria associated with each score.

Score	Criteria
1	Large amounts of flesh, hide and hair present. Internal fluid is still visible. Carcass still discernible.
2	Flesh, hide and hair present in smaller amounts. Carcass is no longer discernible. No internal fluid visible.
3	Slight amounts of hair and hide present. Numerous large and small bones are present.
4	No hide present. Minimal hair visible. Flesh completely degraded and only large bones were present.
5	No flesh, hide, or hair present. Few to no large brittle bones present.

Soil and Carbon Sampling

At the 12 month excavation interval, composite soil samples were collected from the carbon base layer at a depth of one foot directly underneath the carcasses. Additionally, soil columns extending six feet below the burial sites were extracted to assess nutrient leaching. These samples were analyzed for macro and micronutrient content, focusing on nitrogen (N) and phosphorus (P) species, including ammonium nitrogen (NH₄-N), nitrate nitrogen (NO₃-N), organic nitrogen, ortho-phosphorus, and total phosphorus concentrations. The carbon material at the base of each treatment was also analyzed to evaluate changes in nutrient concentration. This allowed for an assessment of the role of each carbon material in nutrient retention and its effectiveness in promoting carcass decomposition while preventing nutrient release into the soil.

Statistical Analysis

Ranking data were analyzed using non-parametric statistical methods to assess the impact of different carbon materials on carcass decomposition. A one-way t-test was applied to evaluate the effects of carbon material type and carcass state (whole versus ground) on soil nutrient profiles and carbon material nutrient concentrations. Means comparison tests were conducted to determine significant differences ($p < 0.05$) between the different treatments.

Results:

Site weather conditions during study period

The study spanned 367 days from carcass placement and burial (Day 0: July 17, 2023) to excavation after 12-month (Day 367: July 18, 2024). Weather data for this period was retrieved from the NC Climate Office web interface (<https://products.climate.ncsu.edu/cardinal/request/>). Daily air temperature followed seasonal trends and averaged 17.5 Celsius (63.5 Fahrenheit) with highest and lowest daily averages reported to be 29.6 Celsius (85.3 Fahrenheit) and -2.8 Celsius (26.9 Fahrenheit) respectively. A cumulative precipitation of 47.6 inches [1209 mm] were recorded during this interval with top wettest months being 2nd (7.2 inch [184mm]), 6th (7.3 inch [186mm]), and 12th month of the trial (6.6 inch [167 mm]). **Figure 3** shows monthly rainfall in millimeter (mm) units from study initiation until termination (25.4 mm = 1 inch). The recorded rainfall falls within typical values reported in this part of the NC coastal plains; i.e., an average of 51.3 inches according to NOAA 2006-2020 climate normals.

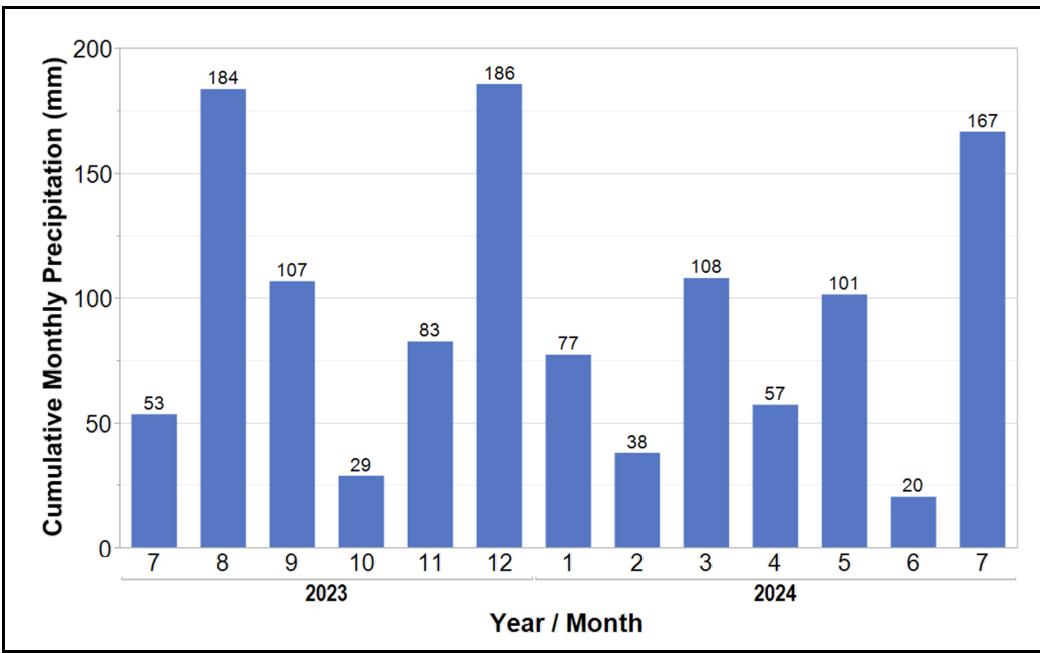


Figure 3. Monthly precipitation at experimental site in millimeters during the 12-month study period (Data source: ECONET Network, Station ID: CLIN).

Precipitation was analyzed in relation to evapotranspiration on a day-by-day basis. This was conducted by running a daily tally of precipitation less evapotranspiration for the entire study period; a positive value indicated a net water surplus (accumulation) while a negative value suggested deficit (or drying). The goal of this assessment is to estimate the water saturation experienced by the buried carcasses during the study period since saturated soils can retard the carcass decomposition. **Figure 4A** shows the cumulative difference between precipitation-evapotranspiration. The results suggest that throughout the 12-month, rainfall exceeded evapotranspiration with the exception of approximately 80 days distributed throughout the study period. These observations align with the volumetric water content (VWC) for the site soil, which was retrieved from the site weather station and shown in **Figure 4B**. Throughout the study period, the VWC fell between 25% and 35% which is close to the field capacity (FC) value for the site soil types. **Collectively, these observations indicate the site soils experienced near-saturation conditions during the study period.** Observers during each excavation activity reported noticeable soil wetness in the burial areas; but no pooled water.

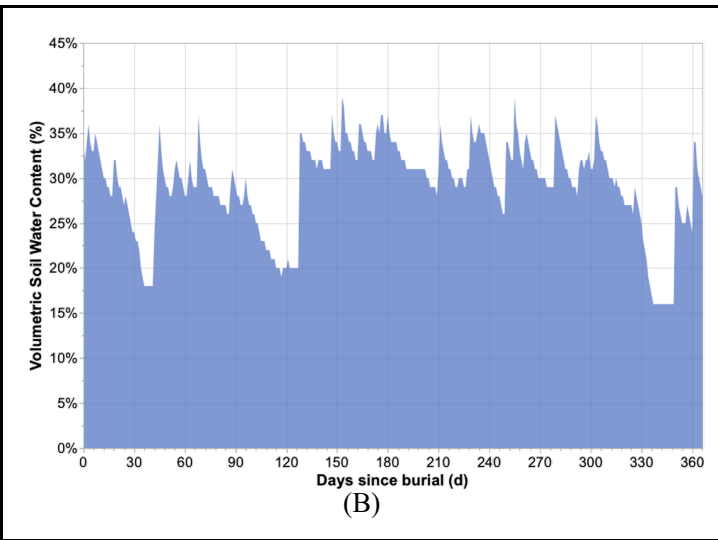
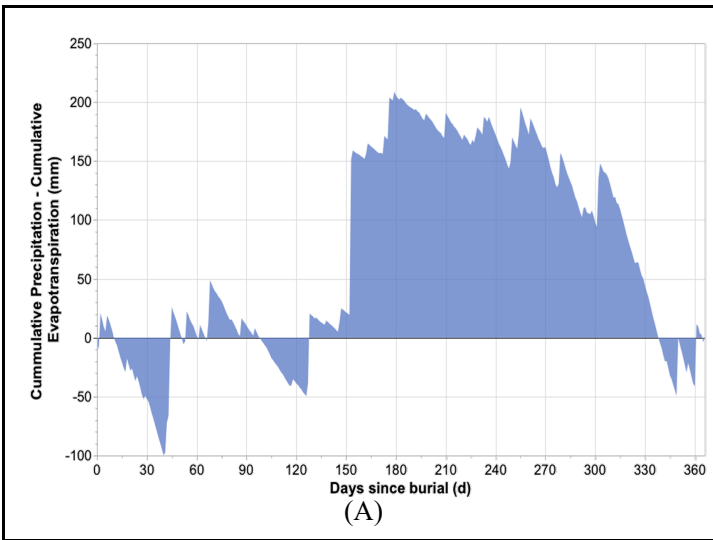
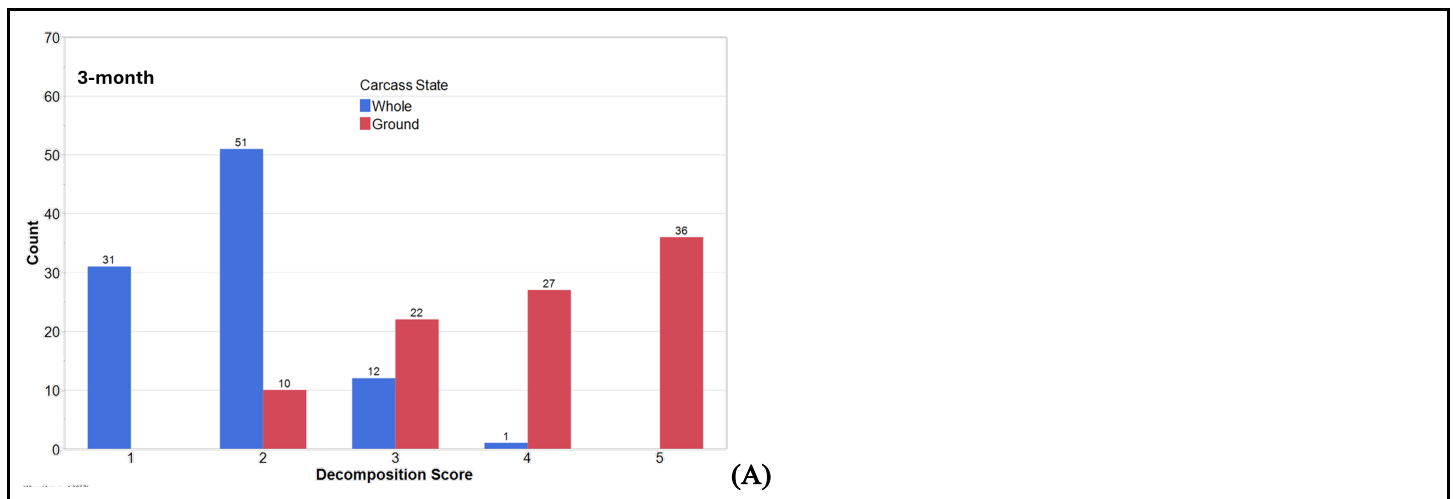


Figure 4. (A) Cumulative difference between precipitation and evapotranspiration throughout the study period, **(B)** volumetric soil water content recorded by the weather station located at the project site (ECONET Network, Station ID: CLIN).

Decomposition rate during decomposition period

Experimental plots were excavated after three months, six months, and 12 months from burial. At each excavation time-point, a team of eight to nine observers were enlisted to provide decomposition scores for each plot according to the decomposition criteria listed earlier (Table 1). Before scoring, observers were instructed on how to interpret the scoring scale and to avoid sharing their scores or discussing their observations with fellow observers. A project team member was present by each plot with a pitchfork to ensure observers can see the plot content clearly. **Figure 5 (A, B, and C)** shows the total count of votes for each score assigned to either whole and ground carcass plots (number on top of each bar is the total votes for this score). Consistently, ground carcass plots were scored to be further along in the decomposition process than whole carcass. At each excavation, the most common score for whole carcass plots was 2, as compared to a score of 5 for ground carcass plots. This can be attributed to the combined effect of the expedited breakdown of carcasses after maceration, as well as the visual effect of intact versus fragmented carcasses that is mixed with carbon. Over the burial period, whole carcass decomposition was shown to gradually transition from a relatively low to higher decomposition score. Since these scores are ordinal but not continuous variables, we opted to avoid averaging them to eliminate confusion in interpretation.



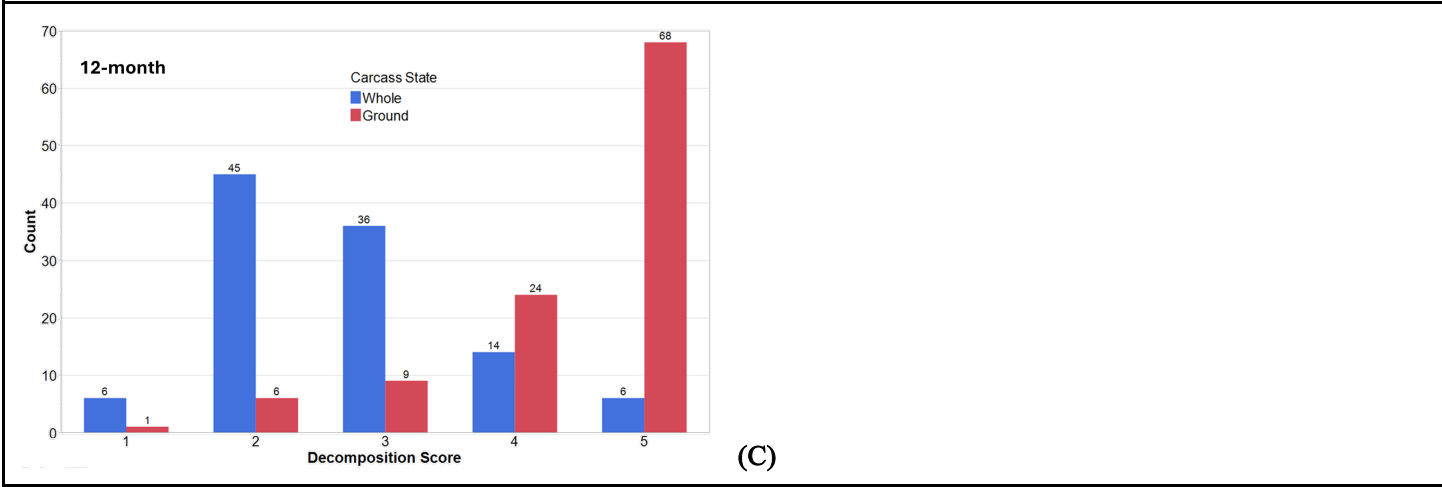
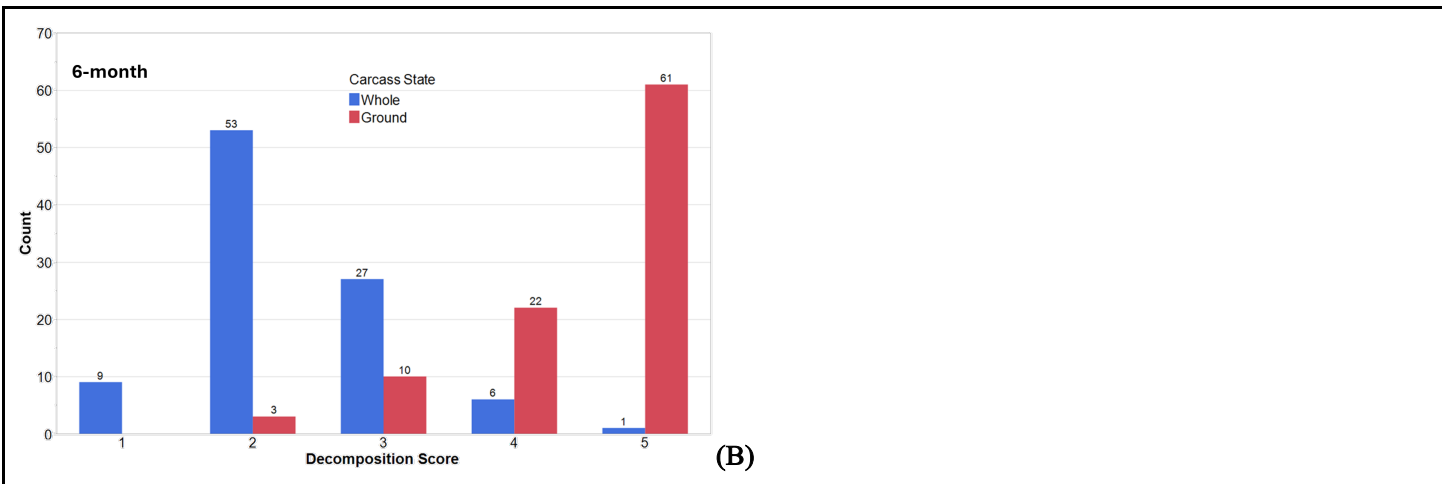


Figure 5. Decomposition score counts aggregated by carcass condition (whole vs. ground) after (A) three months, (B) six months, and (C) 12 months. See Table #1 for decomposition score ratings.

The same results were combined into a holistic figure (**Figure 6**) to capture studied variables impacting the decomposition score.

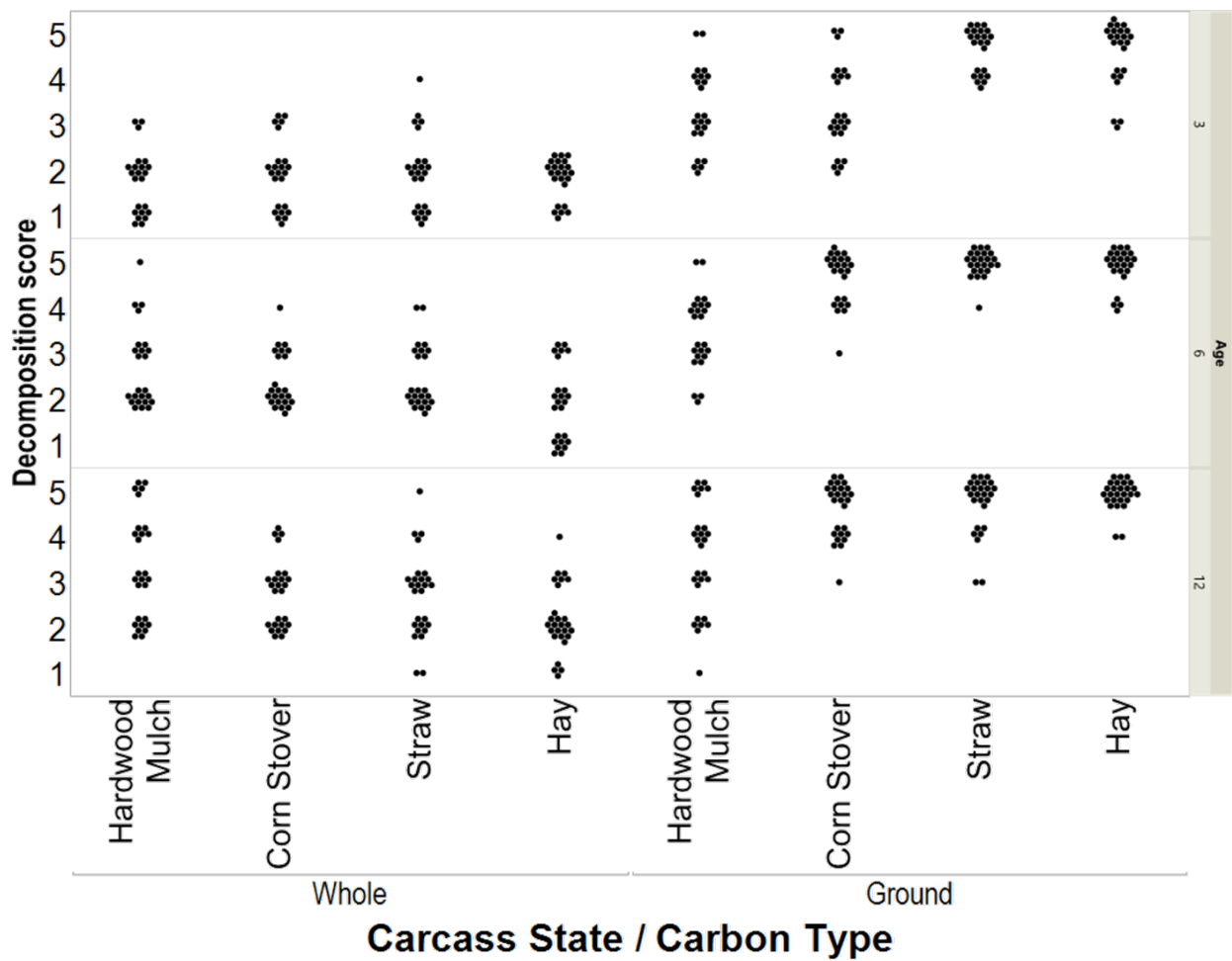


Figure 6. Decomposition scores assigned to each plot (1 to 5 scale score) aggregated by carcass condition, carbon type, and burial age.

Statistical analysis package JMP® Pro 17.0.0 (JMP Statistical Discovery LLC., Cary, NC) was used to conduct the analysis. Ordinal logistic regression was used to analyze the impacts of study variables (carcass condition, carbon type, burial period) and their interactions on the decomposition score received by each plot. **Table 2** shows the summary of effect for each explanatory variable ranked by logWorth (in descending order) and *p*-value (in ascending order). Individual variables and their interactions were all found significantly impacting the decomposition score with the exception of the *Age X carbon type* interaction. Collectively, the model explains 32.5% of the variance in decomposition scores assigned to burial plots. The relatively low R^2 value can be attributed to the potential subjectivity of score interpretation and assignment by individual rankers and the lack of incremental units to capture subtle differences between plots. Nonetheless, these results suggest the scoring approach may provide a holistic and robust approach for comparative assessment of carcass decomposition extent; a challenging property to assess using quantitative means. The parameter estimates derived from ordinal logistic regression fit cannot be interpreted as immediate multipliers to estimate the score. Yet, they can be transformed, through exponentiation, to estimate the odds ratio associated with each explanatory variable. The sign of each multiplier then indicates whether the odds are greater or less than 100% (i.e., more or less likely) to increase the decomposition score.

Table 2. Effect summary showing explanatory variables ranked by p -value in ascending order (R^2 for the regression = 0.3253, number of observations = 597)

Source	Logworth	p -value
<i>CarcassState</i>	111.162	0
<i>CarbonType*CarcassState</i>	22.358	0
<i>Age</i>	12.301	0
<i>CarbonType</i>	7.379	0
<i>Age*CarcassState</i>	1.55	0.02821
<i>Age*CarbonType</i>	0.764	0.1722

Table 3 illustrates the odds ratio for each studied explanatory variable. The results indicate that a ground carcass is 9.1 times more likely to receive a higher decomposition score than the whole carcass with all other variables held constant. Similarly, older buried carcasses are 1.2 times more likely to be ranked as further decomposed with all other variables held constant. Looking at the carbon type alone, it appears that plots with wheat straw as base material were 1.96 times more likely to be ranked more decomposed with all other variables held constant. The interaction between carcass condition and carbon type was highly significant. Looking at the interaction between whole carcasses and the carbon material shows that hardwood and corn stover plots are respectively 3.6 and 1.3 times more likely to be ranked more decomposed. Conversely, fescue hay plots lining whole carcass burial are 66% less likely to be ranked as further decomposed.

Table 3. Odds ratio for each of the explanatory variables and their interactions (odds ratio is exponentiated parameter estimates) and the probability of each odds ratio.

Term	Odds Ratio (OR)	Prob. > χ^2
CarcassCondition [<i>Ground</i>]	9.06	0.00
Age	1.18	<.0001
CarbonType[<i>Hardwood Mulch</i>]	0.48	<.0001
CarbonType[<i>Corn Stover</i>]	0.86	0.27
CarbonType[<i>Wheat Straw</i>]	1.96	<.0001
CarbonType[<i>Fescue Hay</i>]	1.24	<.0001
CarbonType[<i>Hardwood Mulch</i>]*CarcassCondition[<i>Whole</i>]	3.59	<.0001
CarbonType[<i>Corn Stover</i>]*CarcassCondition[<i>Whole</i>]	1.32	0.0485
CarbonType[<i>Wheat Straw</i>]*CarcassCondition[<i>Whole</i>]	0.63	0.0025
CarbonType[<i>Fescue Hay</i>]*CarcassCondition[<i>Whole</i>]	0.34	0

Report your research results by objective.

1. Is SBC with low-quality carbon material a viable mortality management tool? Based on the results of this research, SBC with hardwood mulch, fescue hay, straw, or corn stalks is a viable mortality management option. One trial does not mean acceptable results will be attained under all conditions but successful results were attained in this trial.

2. How much additional time does it take swine carcasses to decompose with low-quality carbon is used? In this trial, all four carbon sources tested achieved acceptable decomposition by the end of year one. The data shows that the fescue hay treatment and straw treatment achieved significantly slower decomposition of whole carcasses. We estimate it would have taken an additional six months (beyond the 12 month time period) to achieve the same level of decomposition for both the hay and straw compared to the corn fodder and hardwood mulch treatments used in this trial.

3. What is the impact of grinding carcasses on the SBC process? Grinding greatly increased the rate of carcass decomposition compared to whole carcass. All four carbon sources with ground swine achieved higher decomposition at the six month evaluation than the whole carcasses treatments. The hardwood mulch treatment with ground pork had a lower decomposition score than the other three carbon treatments with ground pork. The entire mass of the hardwood mulch and ground pork was lower in the trench than the other treatments due to the density of the mix. We speculate this impacted decomposition. Grinding carcasses resulted in higher ammonium nitrogen in the soil beneath the trench compared to the whole carcass treatments. We speculate that grinding the carcass into smaller pieces enabled the nitrogen to be released from the mortality more quickly than the whole carcasses.

Discussion: Explain your research results and include a summary of the results that is of immediate or future benefit to pork producers.

References:

Brown, L. C. (2007). The effects of various co-composting materials on the decomposition of equine carcasses (Master's thesis, West Texas A&M University). Retrieved from <https://wtamu.edu/research/equine-carcass-composting>.

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<http://www.fao.org/documents/card/en/c/cb2464en>

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Any publications, presentations or abstracts of the project results, need to recognize proper funding credit by using this statement: “Funding, wholly or in part, was provided by the National Pork Checkoff” (Or in the case of state Pork Producers Association funding “on behalf of the [state] Pork Producers Association”). Thank you for your attention to these instructions. Please contact the National Pork Board via E-mail: grants@pork.org if you have any questions.