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Swine Carcass Characterization Exposed to a Small-scale Desiccation Environment

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Abstract

A catastrophic mortality event for swine would present numerous challenges with management and disposal of infected carcasses. This study explored a new strategy for biosecure in-barn processing of swine carcasses as an alternative to traditional management and disposal approaches. A small-scale, mobile laboratory with two discovery rooms (DRs), replicating a swine finishing facility, was constructed to execute tests of in-barn disposal methods. Carcasses were desiccated by subjection to heat at a room air temperature of 43°C (110°F) for 16 days. Three carcasses (average=82 kg, SE=1.27 kg) were elevated over individual leachate collection systems in DRA, thereby removing leachate from the room. Three carcasses in DRB were placed on concrete slats with cumulative leachate collection in the pit below. Carcasses were characterized by rectal and shoulder temperature monitoring and daily weighing of carcasses and leachate in DRA. Room environments were compared for thermal performance, and carcass temperatures were compared. Data suggested there was no significant impact of flooring material on internal carcass temperature. Gompertz and logistic models were fit to leachate production data and carcass mass reduction data. Further quantification and qualification of in-barn management strategies will result in better definition of biosecure disposal approaches in the event of a catastrophic mortality event.

Keywords

carcass, disposal, in-barn, leachate, pig

Disciplines

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Comments

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Swine Carcass Characterization Exposed to a Small-scale Desiccation Environment

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ABSTRACT. ***A catastrophic mortality event for swine would present numerous challenges with management and disposal of infected carcasses. This study explored a new strategy for biosecure in-barn processing of swine carcasses as an alternative to traditional management and disposal approaches. A small-scale, mobile laboratory with two discovery rooms (DRs), replicating a swine finishing facility, was constructed to execute tests of in-barn disposal methods. Carcasses were desiccated by subjection to heat at a room air temperature of 43°C (110°F) for 16 days. Three carcasses (average=82 kg, SE=1.27 kg) were elevated over individual leachate collection systems in DRA, thereby removing leachate from the room. Three carcasses in DRB were placed on concrete slats with cumulative leachate collection in the pit below. Carcasses were characterized by rectal and shoulder temperature monitoring and daily weighing of carcasses and leachate in DRA. Room environments were compared for thermal performance, and carcass temperatures were compared. Data suggested there was no significant impact of flooring material on internal carcass temperature. Gompertz and logistic models were fit to leachate production data and carcass mass reduction data. Further quantification and qualification of in-barn management strategies will result in better definition of biosecure disposal approaches in the event of a catastrophic mortality event.***

Keywords. carcass, disposal, in-barn, leachate, pig.

Introduction

Proper management of swine mortalities in response to a Foreign Animal Disease (FAD) outbreak is imperative to mitigate disease spread to other pig populations. If infected carcasses are improperly managed, the pathogen can remain in the environment and severely inhibit recovery efforts from FAD outbreaks. Existing mortality management options for swine include composting, shallow burial, landfill disposal, rendering, and incineration. However, all existing carcass management approaches challenge biosecurity and threaten pathogen spread via air, water, soil, vegetation, or fomites (USDA, 2020). Therefore, if pathogen inactivation can be achieved before carcass removal from the barn, a reduction in the exposure of mortalities or leachate to transmissive agents is possible.

Composting has been the preferred method for catastrophic mortality events because of the potential for the pile to reach elevated temperatures to inactivate pathogens, the wide availability of carbon sources near animal production facilities, and the creation of a usable end product (Glanville et al., 2005; Wilkinson, 2006; Kalbasi, Mukhtar, Hawkings, & Auvermann, 2005). However, composting systems managed improperly can quickly become a biosecurity hazard if a pile is turned before completion of the primary inactivation stage, windrows are sized improperly, or an inappropriate site is selected where soil and water contamination is a risk (Wilkinson, 2006; Kalbasi, Mukhtar, Hawkings, & Auvermann, 2005; USDA, 2012).

Modified Ag-Bag composting systems mitigate many of the biosecurity risks associated with traditional composting, but are not ideal for large carcasses such as swine, and specialized carcass-handling equipment is required for the system (Ag-Bag Forage Solutions, 2020; Kalbasi, Mukhtar, Hawkings, & Auvermann, 2005).

Alternatively, carcass burial is a simple approach but presents many challenges: it can be cost-prohibitive due to land prices and equipment rental, suitable land is difficult to secure in many regions of the US, and the potential for long-term impacts on ground water exists (DeOtte Jr. & DeOtte III, 2010; Harper, DeRouchey, Glanville, Meeker, & Straw; Glanville, et al., 2005). Additionally, burial is not a biosecure option and in one case, poultry carcasses still infected with avian influenza were unearthed after 15 years (Malone, 2005). Rendering is only a viable carcass management option for non-diseased mortalities and is hindered by lack of capacity (DeOtte Jr. & DeOtte III, 2010; USDA, 2012). Landfill disposal of carcasses can incur costs of up to three times that of other options, and the ability of the landfill to contain and process leachate from carcasses is often challenged (Bendfeldt, Peer, & Flory, 2006). Finally, incineration commonly has inadequate capacity and odor problems can become a serious issue (Glanville, 2009).

Due to the biosecurity issues associated with existing management strategies for mass swine mortalities, efforts should be made to inactivate pathogens prior to removal from the facility. In-barn mortality management strategies have been tested and deployed for catastrophic poultry mortality events with success. As little as 50% of the labor is required for in-barn methods of disposal compared to traditional carcass disposal methods, limiting risk of disease transfer by workers (Tablante & Malone, 2006). Additionally, it is a relatively cost-effective option, high temperatures can easily be generated and maintained for pathogen inactivation, and exposure of pathogens to the environment is avoided (Tablante & Malone, 2006). For these reasons, in-barn mortality management strategies for swine should be explored and quantification of carcass responses are needed to determine feasibility of managing swine moralities in-barn.

A general-purpose laboratory for small-scale in-barn swine discoveries with ventilation and environmental instrumentation and control was previously constructed and validated. This laboratory was built to replicate a typical swine finishing facility with concrete slats, pit, and construction finishes. Both Discovery Rooms (DRs) were utilized to house three carcasses each for the duration of a 16-day trial in January 2021. A desiccation environment was created by heating each DR to 43°C (110°F) with minimal air changes. Carcasses and leachate were weighed daily, along with continuous recording of carcass temperatures. The objectives of this study were to 1) measure and quantify production of ammonia from in-barn carcasses; 2) weigh carcasses and leachate to determine a model appropriate for decomposition modeling; and 3) assess odor from in-barn carcass decomposition using an olfactometry panel.

Materials and Methods

The trial occurred in a general-purpose lab for small-scale in-barn swine discoveries during January of 2021. Two DRs (DR_A and DR_B) were utilized for different treatment of carcasses. Each room was set to 43°C (110°F) air temperature for the duration of the study and was maintained by a direct gas-fired circulating heater. Rooms were preheated to the set point temperature 24 hours prior to the start of the trial. A circulation fan was placed inside the room to increase convection across the surface of the slats.

Instrumentation

The instrumentation systems integrated into the small-scale mobile laboratory were used for room and ambient temperature, relative humidity (RH), and static pressure. The building automation controller (BAC) remotely monitored and controlled the heating and ventilation system. However, some additional instrumentation systems were added for this study.

Thermal

Slat temperatures were monitored during the trial using thermocouples embedded into the slats and data were logged on 30 second intervals using a 4-channel thermocouple data logger (Type K; accuracy: ±0.7°C; range: -260°C to 1,370°C; resolution: 0.04°C; UX120-014M, Onset, Bourne, MA, USA). Air temperatures inside the DRs were recorded using sensors already integrated in the laboratory. Outliers were removed using Chauvenet's criterion and data was averaged hourly and daily. Temperatures were compared using a statistical package to assess differences in room environment (SAS Institute, Inc., 2018). A t-test (α=0.05, df=30) assessed if daily mean DR temperatures were different from one another. Room conditions of slat and DR air temperatures comparison aided in evaluating carcass response.

Visual

Waterproof cameras (Hero5 Black, GoPro, San Mateo, CA, USA) were set up in each DR to record a time lapse of progress of decay. Still images were captured every hour and later combined into a continuous time lapse video for each room. Additionally, an outdoor surveillance camera (KC200 Kasa Cam Outdoor, TP-Link, San Jose, CA, USA) was installed for remote viewing and monitoring.

Carcasses Management and Characterization

Six pigs (average: 82 kg, 180 lb; SE: 1.27 kg, 2.80 lb) which were culled because of umbilical hernias were obtained from a nearby cooperator. Carcasses were euthanized by electrocution and were free of punctures or ruptures. Each carcass was fully encased in plastic landscape netting to contain carcasses during decomposition (1.3 × 1.3 cm; 0.5 × 0.5 in. mesh size) and then wrapped in a chain secured with carabineers to aid in moving the carcasses for daily weighing. Carcasses in DR_A were placed in a leachate collection system while DR_B carcasses were placed directly on concrete slats for the duration of the study. The leachate collection system in DR_A consisted of plastic slatted flooring placed inside a plastic bin (1.12 × 0.50 × 0.17 m; 44 × 19.75 × 6.5 in.) and Ø1.6 cm (Ø0.63 in.) tubing routed through DR_A pit and drain valve to accumulate leachate in collection buckets outside the mobile laboratory (fig. 1b, 1c). Collection lines were periodically cleared using a plumbing drain snake to avoid build-up of solids. Leachate from DR_B was collected and stored in the pit for the duration of the study. Carcasses in each room and leachate from DR_A were weighed daily (fig. 1a) using a hanging scale (accuracy: ±0.91 kg, 2 lb; range: 0 to 250 kg, 0 to 550 lb; Tool Shop Model #8386, Menards, Eau Claire, WI, USA). At the completion of the trial, carcasses were weighed one final time before being removed from the DR and placed in a corn stover compost pile to complete decomposition.

(a) (b) (c)

Figure 1. (a) Daily carcass weighing in the rooms using a hanging scale. (b) Daily leachate weighing from leachate collection systems. (c) Leachate collection buckets routed from each carcass bin and through the pit and leachate release valve.

Temperature

Carcass rectal and shoulder temperatures were logged on 60 s intervals using a battery-powered two-channel datalogger (accuracy: ±0.2°C from 0°C to 70°C; range: -40°C to 100°C; resolution: 0.04°C; MX2303, Onset, Bourne, MA, USA). Dataloggers were contained and taped to each carcass for portability when carcasses were weighed. Temperature probes were inserted through a small incision (1 cm long) in the shoulder and secured using tape and epoxy. Temperature probes were secured in a similar way rectally, and the datalogger was affixed to the carcass. Carcass rectal and shoulder (n=6) temperatures were averaged in each room hourly and daily. Hourly temperatures for DR_A and DR_B were compared using a statistical package to assess differences in room environment (SAS Institute, Inc., 2018). A t-test (α=0.05, df=799) assessed if mean hourly DR temperatures were different from one another.

Carcass Decay Models

Several decay models were considered to model carcass mass reduction and leachate production to predict carcass mass change during exposure to an in-barn decomposition environment. A first order decay model was considered for carcass decay and is defined in equation 1:

$$y = A_0 e^{-k/t} \tag{1}$$

where
A_0 = starting mass (kg)
k = constant rate of decay (kg d^{-1})
t = time (d).

Choi et al. (2017) used a modified Gompertz equation to model leachate production from buried carcasses by collecting leachate in individual collection systems. Although the model was used only for leachate production, it could also be applied to carcass decomposition when written in terms of cumulative mass reduction. The modified Gompertz equation is show in equation 2:

$$M = P \times exp\left[-exp\left(\frac{R_m \times e}{P}(\lambda - t) + 1\right)\right] \tag{2}$$

where
M = cumulative leachate production (L $kg_{volatile\ solids}^{-1}$)
P = maximum production (L $kg_{volatile\ solids}^{-1}$)
R_m = maximum production rate (L $kg_{volatile\ solids}^{-1}$ d^{-1})
λ = lag phase (d)
t = time (d).

Similar to the Gompertz model, a logistic decay model has an S-shaped curvature which is symmetrical about the point of inflection, whereas the Gompertz model is not. A logistic model can be defined by equation 3:

$$y = \frac{c}{1+ae^{-bt}} \quad (3)$$

where
y = cumulative production (kg)
$\frac{c}{1+a}$ = initial mass value (kg)
c = carrying capacity or limiting value (kg)
b = constant rate of growth (kg d^{-1})
t = time (d).

Results and Discussion

Thermal Environment

Outdoor, DR_A, and DR_B temperatures were averaged on hourly and daily intervals, and room temperatures were found to be significantly different from each other ($p<0.01$). Average temperature of DR_A = 45.7°C (σ = 3.3°C) and DR_B = 44.2°C (σ = 2.9°C). Slat temperature was colder than DR temperatures throughout the trial with an average temperature of 23.7°C (σ = 2.1°C). The decrease in room temperatures on day 9 was caused by an empty propane tank, resulting in no heating for approximately four hours (fig. 2).

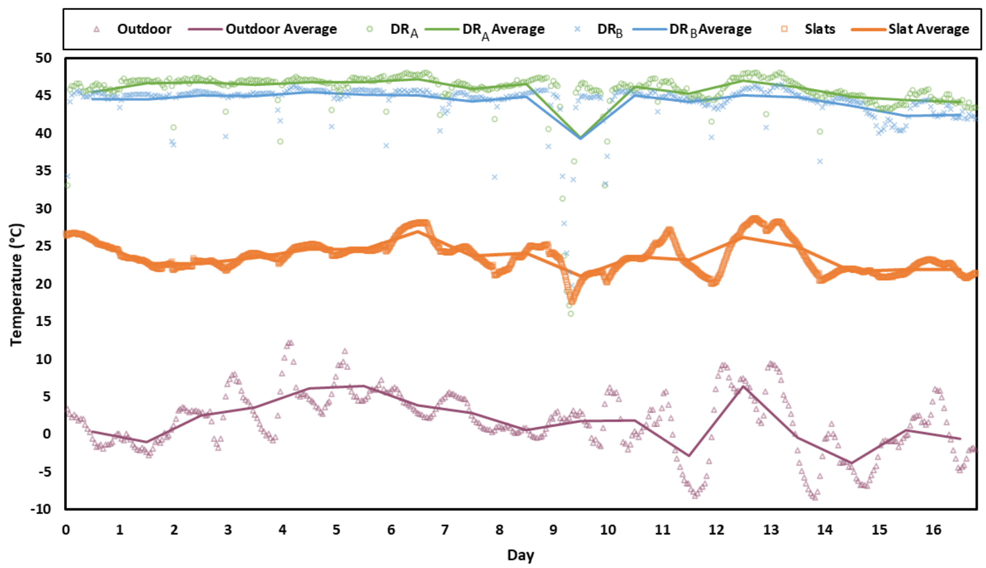

Figure 2. Outdoor, DR_A, DR_B, and slat temperatures shown by one hour increments and daily averages.

Carcass Management and Characterization

Measured parameters of carcass mass and odor were analyzed to characterize response of six carcasses exposed to air temperatures of 43°C. Carcass decay was modeled to characterize carcass response to a desiccation environment.

Temperature

In each DR, carcass rectal and shoulder temperatures were averaged hourly and daily (fig. 3). Carcasses housed on concrete slats in DR_B had significantly lower temperatures than carcasses housed on elevated plastic slatted flooring in DR_A ($p<0.01$), suggesting that the flooring material may have an impact on carcass thermal response. However, when the differences in carcass and air temperatures were compared, DR_A was found to have a greater difference between carcass and air temperature than DR_B. Although DR_B carcass temperatures were colder and suggest flooring material may have an impact on carcass temperature, the later test conflicts the initial observation and suggests flooring material has no impact. More research is needed to determine if managing carcasses on flooring materials with a lower thermal mass than concrete, or placing carcasses on solid surfaces to minimize convection with cooler air from the pit may aid in reaching elevated carcass temperatures.

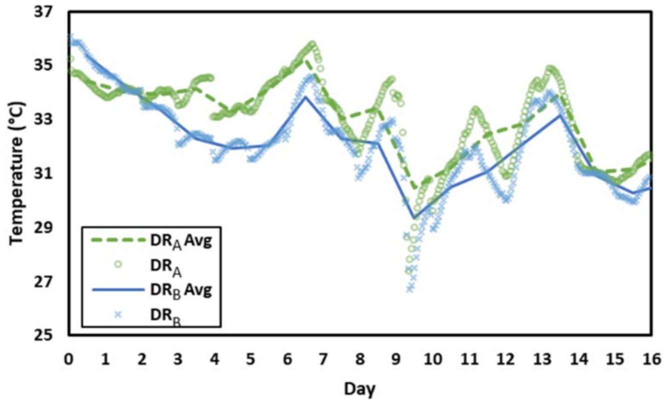

Figure 3. Carcass thermal response on one-hour intervals and daily average carcass temperatures.

Carcass Decay Models

Carcass condition was recorded by visual inspection from the researchers daily. They observed carcass swelling until days 2 to 3 for the smaller carcasses (<80 kg;177 lb) before rupture followed by deflation. Carcasses most often ruptured in the posterior ventral region as abdominal pressure exceeded the strength of the skin, with intestines being the first exposed organs. Because the larger carcasses did not rupture, it was hypothesized that as carcass mass increases, skin thickness also increases and is able to withstand the pressure exerted by swelling of abdominal organs post-mortem. Time lapse images displayed noticeable swelling of carcasses during the first days, followed by rupture, then deflation. Still images of the time lapse are recorded in figure 4 to depict decay and state of the carcasses at various points in the study.

Figure 4. (a) DR_A and (b) DR_B carcass decay selected still photos from time-lapse recording.

Daily weights of carcasses indicated a gradual decrease in weight the first 2 days of the study. From days 3 to 9, a more drastic decrease in weight occurred daily, with peak day-to-day loss occurring between days 4 and 5 (fig. 5). The same trends can be observed in daily leachate production. At the end of the study, some leachate remained in each of the collection bins. The remaining leachate was weighed, and the average (kg d^{-1}) was added to the leachate weights from each day.

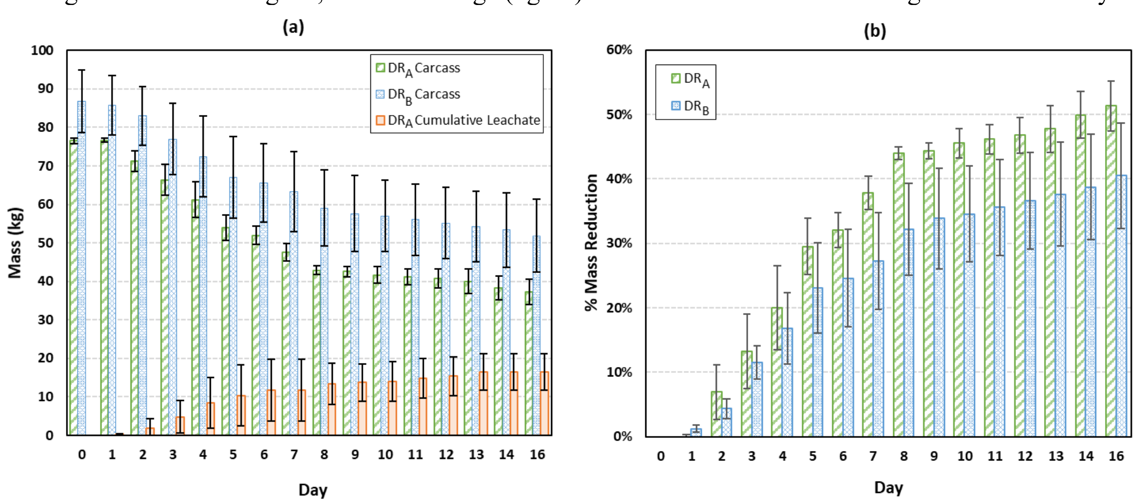

Figure 5. (a) Daily carcass weights and leachate weights by room with standard deviation uncertainty, and (b) daily average carcass percent mass reduction with standard deviation uncertainty. Remaining leachate in collection bins was averaged and added to daily leachate totals. Carcass and leachate were not weighed on day 15 of the trial.

Modified Gompertz and logistic models were used to fit data for leachate production (fig. 6) and carcass mass reduction (fig. 7) using statistical curve fitting tools (MATLAB, 2018). A first order decay model was fit for carcass mass but did not fit the data as well as the logistic and Gompertz models (table 1). Although both Gompertz and logistic models fit the data well, additional research is needed to assess applicability of a model to a range of carcass sizes under varying environmental conditions such as temperature and air exchange rate.

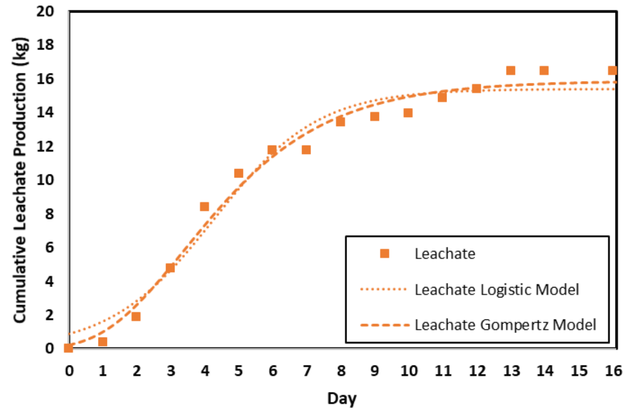

Figure 6. Gompertz and logistic models for cumulative leachate production.

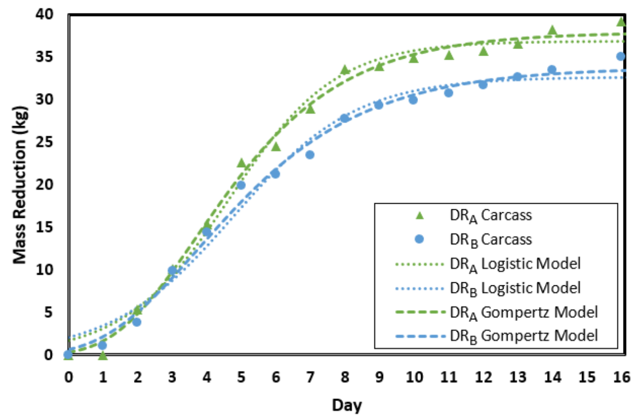

Figure 7. Gompertz and Logistic models for carcass mass reduction by day.

Table 1. First order decay, logistic model, and Gompertz model summaries with coefficient values, 95% confidence intervals, R^2 and root mean square error (RMSE).

Model	Source	Coefficients (95% CI)			R^2	RMSE (kg)
		t				
First Order Decay	DR_A	17.8 (16.2, 19.4)			0.94	3.49
	DR_B	25.34 (23.3, 27.4)			0.94	2.94
		a	b	c		
Logistic Model	DR_A	20.7 (9.0, 32.5)	0.7 (0.5, 0.8)	36.9 (35.3, 38.4)	0.99	1.60
	DR_B	14.9 (6.2, 23.5)	0.6 (0.4, 0.7)	32.7 (30.9, 34.4)	0.98	1.69
	Leachate	16.2 (2.8, 29.6)	0.7 (0.5, 0.8)	15.4 (14.4, 16.4)	0.97	1.05
		P	R	λ		
Gompertz Model	DR_A	37.9 (36.7, 39.2)	5.9 (5.2, 6.5)	1.3 (1.0, 1.7)	0.99	1.07
	DR_B	33.8 (32.4, 35.2)	4.6 (4.0, 5.2)	1.0 (0.6, 1.5)	0.99	1.07
	Leachate	15.9 (15.0, 16.7)	2.5 (2.0, 3.0)	1.0 (0.4, 1.7)	0.99	0.76

Conclusions

Six swine carcasses were exposed to a desiccation environment for 16 days in a small-scale swine production laboratory. Carcass and room temperatures were continuously monitored, and carcasses and leachate were weighed daily. Gompertz and logistic models were found to fit data well for carcass mass reduction and leachate production, with a Gompertz model having a slightly better fit. The parameters assessed aid in preliminary characterization of carcasses during in-barn carcass management for swine. Additional data collection may lead to creation of an accurate model for swine carcass decomposition under controlled conditions based on initial carcass mass and varying environmental factors.

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