RESEARCHREPORT
ANIMAL WELFARE

Title: Use of modified rendering trailers to achieve rapid depopulation of modern sow units - **NPB #20-100**

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Industry Summary:
The US swine herds are susceptible to the introduction of catastrophic diseases that may require mass depopulation to contain. While the industry is well versed on individual animal euthanasia, mass depopulation of mature swine present unique challenges due to their size and densities in which these animals are raised. No single method of depopulation fits all scenarios or species, and multiple methods likely will be required to complete tasks in a timely, biosecure manner. Most current methods for swine depopulation and disposal are not good candidates for mass depopulation in sow units because they are either time consuming (delivered at the individual level), create an unacceptable risk of disease dissemination for other swine populations (e.g. pathogen dissemination during movement of carcass material to disposal sites), or are practically infeasible to facility designs. In this project, we combined the depopulation and disposal steps by using rendering trailers as depopulation chambers.

We evaluated the following depopulation agents: carbon dioxide gas (CO2), nitrogen gas (N2), compressed air foam (CAF), CAF made with nitrogen gas (CAF-N2), and aspirated foam (AF). We used a gated approach where we assessed our ability achieve success at each step before moving to the next step. First was the ability fill the container in a rapid manner. Second, each treatment was used in a small scale trial on anesthetized sows. Third, each treatment was used in a small scale trial on conscious sows. Fourth, one agent (aspirated foam) was used for a large-scale field trial. While all methods were successful, aspirated foam had the shortest mean time to the cessation of movement, which was why it was selected for the large-scale field trial. Our results show that aspirated foam was comparable to the leading method of CO2, but had fewer potential pitfalls than CO2 (availability and sourcing CO2, vaporizing, delivery time, etc.). In our large-scale trial using aspirated foam, the average time to cessation of movement was 128 seconds for groups of 45 sows, which means that large sow farms could be depopulated rapidly with this method.

Water-based foam (WBF) depopulation is a preferred method in poultry, leading to rapid death and relatively ease of application and USDA has WBF generating units in the National Veterinary Stockpile, which makes it an attractive agent. Historically, foam has not been feasible in swine due to their housing; however, use of a trailer provides new opportunities. Our study shows that WBF for depopulation of sows in modified rendering trailers is a viable option for mature swine (and likely younger pigs too).

When a FAD is introduced to the US swine herd, the way to lessen the economic impact to producers is by preventing further spread in the national swine herd. The ultimate objective of project was to establish an effective method to facilitate both the depopulation of sow units and the disposal of carcasses in the face of an FAD outbreak. We demonstrated that use of inhalant–based depopulation methods on sows in modified rendering trailers can be a cost-effective and efficient method for stamping-out FAD-affected sow farms. Using an inhalant-based depopulation method in rendering trailers will allow for containment of a FAD as quickly as possible to help maintain continuity of business for non-infected animals and non-contaminated animal products.

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Key Findings:

- All methods worked in small-scale trials, but the scalability of some methods are limited.
- Aspirated foam had the shortest average time to cessation of movement (186 seconds), which was similar to the time recorded for carbon dioxide.
- Field trails with aspirated foam were successful and cost effective.
- Aspirated foam depopulation had fewer potential pitfalls than carbon dioxide.
- Aspirated foam depopulation in modified trailers is a viable option for mature swine

Keywords: Disease Outbreaks, Depopulation, Foam, Gasses, Rapid, Mature Swine, Disposal,

Scientific Abstract:

Increased global movement of people and animals increases likelihood of foreign animal diseases (FAD), like African Swine Fever (ASF), being introduced into the US swine population. Due to the risk of pathogen amplification in infected animals, swine on affected premises would need to be depopulated as soon as possible. The size of most US commercial swine operations makes rapid depopulation difficult, with large sow units being especially problematic due to number of large animals (>200 kg). Most current methods for swine depopulation and disposal are not good candidates for mass depopulation in sow units because they are either time consuming (delivered at the individual level), create an unacceptable risk of disease dissemination for other swine populations (e.g. pathogen dissemination during movement of carcass material to disposal sites), or are practically infeasible to facility designs. Rendering trailers are an ideal option for transportation of carcasses to disposal sites because their water-tight design means decreased release of the infectious agent in transit. Here, we combined the depopulation and disposal steps by using rendering trailers as depopulation chambers. With modification, rendering trailers can permit loading of live sows, which would allow sows to exit their housing facilities under their own power prior to depopulation. Depopulating sows after they have been loaded onto modified rendering trailers allows us to consider inhalation-based depopulation methods because we would overcome some of the inherent hurdles caused by housing facility designs (i.e. slatted floors and deep manure pits create large volume air spaces). The addition of modified rendering trailers to USDA's National Veterinary Stockpile would mean rapid and efficient depopulation and disposal of sows could be performed in the US swine herd.

We evaluated the following depopulation agents: carbon dioxide gas (CO_2), nitrogen gas (N_2), compressed air foam (CAF), CAF made with nitrogen gas (CAF-N_2), and aspirated foam (AF). We used a gated approach where we assessed our ability achieve success at each step before moving to the next step. First was the ability fill the container in a rapid manner. Second, each treatment was used in a small scale trial on anesthetized sows. Third, each treatment was used in a small scale trial on conscious sows. Fourth, one agent (aspirated foam) was used for a large-scale field trial. While all methods were successful, aspirated foam had the shortest mean time to the cessation of movement (186 seconds [95% CI 145 – 228], which was why it was selected for the large-scale field trial. Our results show that aspirated foam was comparable to the gold standard CO_2, but had fewer potential pitfalls than CO2 (availability and sourcing CO2, vaporizing, delivery time, etc.). In the large-scale trial using aspirated foam, the average time to cessation of movement was 128 seconds (range 98-162; 95% CI 118 – 138) for groups of 45 sows.

Water-based foam (WBF) depopulation is a preferred method in poultry, leading to rapid death and relatively ease of application and USDA has WBF generating units in the National Veterinary Stockpile, which makes it an attractive agent. Historically, foam has not been feasible in

swine due to their housing; however, use of a trailer provides new opportunities. Our study shows that WBF for depopulation of sows in modified rendering trailers is a viable option for mature swine (and likely younger pigs too).

When a FAD is introduced to the US swine herd, the way to lessen the economic impact to producers is by preventing further spread in the national swine herd. The ultimate objective of project was to establish an effective method to facilitate both the depopulation of sow units and the disposal of carcasses in the face of an FAD outbreak. We demonstrated that use of inhalant–based depopulation methods on sows in modified rendering trailers can be a cost-effective and efficient method for stamping-out FAD-affected sow farms. Using an inhalant-based depopulation method in rendering trailers will allow for containment of a FAD as quickly as possible to help maintain continuity of business for non-infected animals and non-contaminated animal products.

Introduction:

Modern swine production coupled with increased global movement of people and animals increase the chance of introduction and spread of pathogens in US swine populations. Disease outbreaks cause negative impacts on animal health and welfare, public health and perception, the environment, the food supply, and the economy as a whole. To minimize such effects, control plans are needed. As an example, African Swine Fever (ASF) is a severe viral disease affecting domestic and feral pigs, for which currently there is no commercially available vaccine. Although the US swine herd is free of ASF, the facts that there is current ongoing transmission throughout China and parts of Europe (OIE, 2020) and that the virus can be transmitted by numerous modes of transmission makes the preparation of contingency plans a high priority for the US swine industry. These plans must include detailed steps for euthanasia and depopulation of large numbers of swine in a short timeframe.

Even though there are informative guidelines developed by the American Veterinary Medical Association (AVMA) on swine depopulation and euthanasia (AVMA 2019, AVMA 2020), applying recommended measures to large populations of swine under field conditions to assure rapid destruction of animals in a humane manner for both animals and involved human personnel is a recognized challenge. As recommended by the Association, developing and testing a plan before an incident occurs becomes imperative. The goal of best practice depopulation systems is to minimize or eliminate animal anxiety, pain, and distress before the loss of consciousness. Thus, when evaluating these systems, both the induction of unconsciousness and handling/ restraint processes should be considered (AVMA 2019). Current preferred depopulation methods include physical methods (nonpenetrating captive bolt, penetrating captive bolt, electrocution, manual blunt force trauma, and movement to slaughter) and inhaled methods (carbon dioxide and anesthetic overdose). Most of these methods, however, are not good candidates for mass depopulation in large farms because they are either time consuming (delivered at the individual level), and/or would represent a high risk of disease dissemination for other swine populations (e.g. movement to slaughter). Carbon dioxide and potentially other inhalation methods, on the other hand, are promising, considering they would allow for multiple animals to be terminated simultaneously, but limited testing of such methods have been conducted under field conditions in order to provide enough guidelines for execution under emergency situations (Meyer and Morrow, 2005; Kinsey et al., 2016; Rice et al., 2014). The National Animal Health Emergency Management System Guidelines on mass depopulation and euthanasia acknowledges that the currently approved recommended procedures may need to be adapted for field conditions.

Under field conditions, if it becomes necessary to depopulate a sow facility, it would be ideal to have animals move under their own power prior to termination. This is important from a practical perspective, since removing individual sow carcasses from facility housing would be labor-intensive. Manual removal of carcasses would also increase the potential for spreading infectious agents due to higher amounts of foot traffic involved with removal efforts. Delays in timely decontamination of affected properties would also occur due to the prolonged presence of contaminated carcasses. In general, livestock carcasses being disposed of during a foreign animal disease outbreak response require landfill disposal, and regardless of depopulation method would have to be transported in sealed containers to prevent the release of the infectious agent in transit. Trailers currently used for transport of non-diseased carcasses to rendering facilities are watertight and meet these criteria. Since rapid depopulation of sows and rapid removal of carcasses from facilities is important, validating the depopulation of mature swine following loading onto rendering trailers modified to permit group asphyxiant depopulation would be an improvement over current depopulation methods.

The ultimate objective of this project was to establish an effective and safe method to facilitate both the depopulation of sow units and the disposal of carcasses in the face of a foreign animal disease outbreak. The goal was to identify a solution that can be implemented to minimize the loss of livestock and economic impact to producers by preventing further spread of such a disease in the national swine herd. The central hypothesis of this project was that group asphyxiant dpopulation using modified rendering trailers could serve as a safe and effective method for the depopulation of sow facilities.

Objectives:
Two objectives were investigated to validate use of inhalant agents in rendering trailers as an appropriate sow depopulation strategy herd during a foreign animal disease outbreak:

Objective 1: Complete a small-scale experimental study to assess use of inhalant depopulation agents to induce rapid loss of consciousness and death of sows in a roll-off dumpster. Objective was assessed in three parts (A, B, C) to answer the following scientific questions:

A. Are we able to achieve suitable conditions in a small roll-off dumpster for depopulation of sows using individual depopulation agents: carbon dioxide (CO2), nitrogen gas (N2), water-based foam (WBF), and water-based foam with nitrogen (N2WBF)?
B. Can we effectively use individual depopulation agents to induce rapid loss of consciousness and death in anesthetized sows held in a small roll-off dumpster?
C. Can we effectively use individual depopulation agents to induce rapid loss of consciousness and death in non-anesthetized sows held in a small roll-off dumpster?

Objective 2: Complete a large-scale experimental study to assess use of inhalant depopulation agent to induce rapid loss of consciousness and death of sows in a modified rendering trailer. Key differences from Objective 1 included: increased volume of depopulation container, increased sow group sizes, and use of a single depopulation agent. Objective 2 was assessed in two parts (A and B) to answer the following scientific questions:

A) Are we able to achieve suitable conditions in a rendering trailer for depopulation of sows using the top-performing agent from Objective 1?
B) Can we effectively use the top-performing agent from Objective 1 to induce rapid loss of consciousness and death in large groups of sows held in a rendering trailer?

Materials & Methods:
Ethics and institutional oversight
The Institutional Animal Care and Use Committee at Ohio State approved use of animals (protocol no. 2020A00000036). A penetrating captive bolt device was at the ready in the event a supplemental method of euthanasia was necessary.

Animal subjects
A total of 194 cull sows (450-600#) were purchased for pilot and field trial experiments conducted by OSU personnel Delivery of animals was coordinated to permit immediate use in experiments.

Pilot study
A roll-off dumpster for the small-scale trials. Based on flow rate capacity of the gas-generating equipment, a custom wooden insert was constructed within the 9.8 m3 dumpster to reduce the functional volume to 4.0 m3 (2.21m x 1.48m x 1.22m). A lid for the dumpster was constructed a wood frame lined with clear poly sheeting was constructed and placed on to enclose the space during the trials. Gaps where the swinging dumpster door met the walls and floor were eliminated using rubber weather seal.

Sows were assigned to one of the following treatments: carbon dioxide gas (CO2), nitrogen gas (N2), compressed air foam (CAF), CAF made with nitrogen gas (CAF-N2), and aspirated foam (AF). Each treatment was used to depopulate a total of 12 sows (6 anesthetized, 6 conscious). Groups of 3 sows were loaded into the dumpster. Pigs in anesthetized treatment groups received a single intramuscular injection of [Telazol 4mg/kg / ketamine 25mg/kg / xylazine 2.5mg/kg] following loading into container.

Individual pigs in both anesthetized and conscious groups were fitted with single use electrocardiography (ECG) devices (CardeaSolo, Cardiac Insight, Bellevue, WA, USA). The skin along the left lateral thorax just caudal to the elbow (approximately the 5/6th intercostal space) was clipped and shaved to remove hair, wiped with alcohol-soaked gauze, and lightly exfoliated with an abrasive pad before placing and activating devices. Pigs in conscious groups had accelerometers (HOBO Pendant G, Onset Computer Corporation, Bourne, MA, USA) secured to a distal forelimb with elastic wrap.

Gas production and application

High-pressure vapor gas liquid (VGL) containers delivered either liquid CO2 or liquid N2 to a 480 volt vaporizer (Thermax Inc., North Dartmouth, MA, USA) set at 65 °C. Gases flowed from the vaporizer at maximal output through in-line mass flow controllers (Alicat, Tucson, AZ, USA) and into a 947 L (250 gal) bulk tank. Vaporizer and mass flow controller power were supplied by a 25 kVA diesel engine generator (Multiquip Inc., Carson, CA, USA). Oxygen and CO2 levels within the dumpster were monitored with a CO2 meter. The bulk tank was filled to 120 psi with 100% CO2 gas or N2 gas before initiating gas delivery to the dumpster via 15 m length of fire hose. CO2 or N2 gas were delivered to the dumpster until oxygen levels dropped below 5%, after which gas delivery continued for 7 minutes. Once the initial bolus of stored gas the bulk tank was depleted (approximately 4 minutes), continued vaporization throughout the delivery period provided gas to the dumpster at a rate equal to vaporizer output (35-45 cfm).

Foam production and application

During pilot experiments AF, CAF, and CAF-N2 foam were produced using a compressed air foam system (CAFS; Rowe CAFS LLC, Hope, AR, USA). The CAFS system consisted of: 1982 L/m (70 cfm) rotary screw air compressor (Vanair Inc., Michigan City, IN, USA), 29.42 kW (40 HP) gasoline engine (Kohler, Kohler, WI, USA), 567 L/m (150 gal/m) centrifugal water pump (Hale Products, Inc., Ocala, FL, USA), and foam proportioning unit (0.1–10%) (FoamPro, Kingston, NY, USA). The CAF unit consisted of a water manifold, supplied by a 1136 L (300 gal) water tank, and separate air manifold, supplied by the air compressor (air) or vaporizer (gaseous N2), that fed into a mixing chamber. The foam proportioning unit was used to inject PHOS-CHEK WD881 Class A foam concentrate (Perimeter Solutions, Rancho Cucamonga, CA, USA) into the water manifold. The foam-water solution (1-2%) was agitated with gas in the mixing chamber of the CAFS unit to produce CAF (air) or CAF-N2 (nitrogen gas). Resulting CAF or CAF-N2 foams were transported from the unit through 15-30 m length firefighting hose (3.8 cm diameter) connected to a distal 6 m length suction hose (6.4cm diameter). In the case of CAF infused with N2, 100% N2 gas was mixed with the foam water solution in a mixing chamber to make CAF N2 foam. Foam-water solution was transported through 3.8cm diameter fire hose to a Spumifer nozzle, bypassing agitation in the CAFS mixing chamber, for AF production. Desired consistency and thickness of foams were achieved by adjusting the flow of aqueous foam solution. For AF, CAF, and CAF-N2 treatments, the container was filled with foam until it reached a depth of 4 feet (48 inches). Following filling, the container was not disturbed for 15 minutes, after which death was confirmed based on lack of: heartbeat, spontaneous breathing, corneal reflex, and response to noxious stimulus. Postmortem examination of large airways was performed for CAF, CAF N2, and AF treatment groups.

Field trial experiments: Modified rendering trailer – Aspirated foam

A 45 cubic-meter (dimensions 2.4m x 12.2m x 1.5m) rendering trailer was custom modified to allow loading of sows through the rear swing door of the trailer. Three trailer loads of 44-45 cull sows were loaded directly into the rendering trailer using a gangway apparatus to bridge the gap between trailers. Prior to the loading process, ten sows in each trailer load were briefly restrained for local anesthesia and placement of subcutaneous data loggers (Star-Oddi, Gardabaer, Iceland) caudal to the left or right triceps.

Immediately upon completion of loading process, foaming process was initiated. Three individual foaming systems were used in tandem. One system consisted of the equipment previously described for pilot study experiments where AF was produced using the CAFS system and Spumifer nozzle. Two additional systems were each comprised of a 2 inch gasoline powered trash pump (Wacker Neuson, Menomonee Falls, Wisconsin, USA), 2 inch suction hose connected to pump inlet and placed in water reservoir containing 1% foam-water solution, 3.8 cm diameter rubber firefighting hose and high-expansion foam nozzle (Ansell or Spumifer) connected to pump outlet via brass 2 inch female NPSH x 1-1/2 inch male NH firehose adapter (Grainger). Three individuals were placed on the roof of the rendering trailer and each was responsible for operation of high-expansion nozzle during the process. A fourth individual was responsible for initiating the three foam systems and confirming operating status during foam application process. Foam was applied until it reached the top of the trailer and overflowed.

Data analysis and interpretation

Accelerometry and positional data retrieved from Star-Oddi or HOBO pendant G devices were used to assign time of cessation of movement (COM) based on visual recognition of device stasis. COM was used as an indication of unconscious state in individual pigs. Electrocardiogram (ECG) tracings recovered from superficial cutaneous devices was reviewed to determine time of death as indicated by asystole or presence of a fatal arrhythmia (3rd degree AV block, atrial standstill, ventricular fibrillation). Persistent electrical activity (PEA) was defined as presence of any rhythm at the time of physical confirmation of death (i.e. clinical asystole).

Descriptive and analytic statistics were performed in Stata v.14 (StataCorp, College Station, Texas, USA). Data normality was determined by Shapiro-Wilk test. Normal data were assessed using student's t test or ANOVA with Bonferroni multiple comparison test. Intergroup comparison of non-normal data was performed with Kruskal-Wallis rank test. Intergroup comparison of binary outcomes was performed with Pearson's chi-squared test. An a priori significance level of p=0.05 was used for hypothesis-based analyses.

Results:

Objective 1

Mean time to reach 5% oxygen inside the chamber during CO_2 gas was 88.3 seconds (95% CI 79.5 – 97.0). Mean time to reach 5% oxygen inside the chamber during N_2 gas was 101.5 seconds (95% CI 28.4 – 174.6). However, time to 5% oxygen during the first N_2-anesth trial was more than twice the duration of subsequent trials; mean time to 5% oxygen among subsequent N_2 gas trials was 70.7 seconds (95% CI 62.0 – 79.3). Time to 5% oxygen in CO_2 trials was significantly higher than in N2 trials (excluding first trial) (p = 0.0104, two-sample t test).

The mean time to fill was 155 seconds (95% CI 117 – 192) for CAF trials, 183 seconds (95% CI 153 – 213) for CAF-N_2, and 53 seconds (95% CI 39.5 – 66.0) for AF. Fill time was significantly different between various foam-based methods (p = 0.0001, one-way ANOVA). Bonferroni multiple comparisons test showed both CAF and CAF-N_2 fill times were significantly longer than AF fill time (CAF vs AF, p = 0.001; CAF-N2 vs AF, p < 0.001), while CAF-N_2 and CAF fill times were not significantly different (p=0.479).

Death was confirmed in 12/12 sows treated with CO_2 (6 anesthetized, 6 conscious) and 12/12 sows treated with N_2 (6 anesthetized, 6 conscious) following maintenance of oxygen levels below 6% for 7 minutes. Death was confirmed in 12/12 sows treat with CAF (6 anesthetized, 6 conscious), 12/12 sows treated with CAF-N_2 (6 anesthetized, 6 conscious), and 12/12 sows treated with AF (6 anesthetized, 6 conscious) at 15 minutes following completion of filling process.

The mean time to COM during CO_2 gas trials was 202 seconds (95% CI 151 – 253), while mean time to COM during N_2 gas trials was 268 seconds (95% CI 234 – 301). [Note: COM was not measured during trials with anesthetized sows, so the first N2 trial that saw an extended time to reach 5% oxygen is not represented here]. Time to COM was significantly lower in sows treated with CO_2 gas compared to those depopulated with N2 gas (p = 0.0077, two-sample t test).

The mean time to COM in conscious sows was 382 seconds (95% CI 337 - 427) for CAF, 215 seconds (95% CI 186 - 244) for CAF-N_2, and 186 seconds (95% CI 145 - 228) for AF. Bonferroni multiple comparisons test showed time to COM was significantly higher in CAF groups than CAF-N_2 ($p<0.001$) and AF ($p<0.001$) groups. Time to COM was not significantly different between CAF-N2 and AF groups ($p=0.963$).

	AF	CAF	CAF-N2	CO2
CAF	0.000			
CAF-N2	1.000	0.000		
CO2	1.000	0.000	1.000	
N2	0.022	0.001	0.581	0.143

Table 1. Reported p-values using Bonferroni's multiple comparisons test to detect significant differences in time to cessation of movement (COM) between foam- and gas-based methods (aspirated foam, AF; compressed air foam, CAF; nitrogen infused CAF, CAF-N2; carbon dioxide gas, CO2; nitrogen gas, N2). P-values considered significant at the level of 0.05.

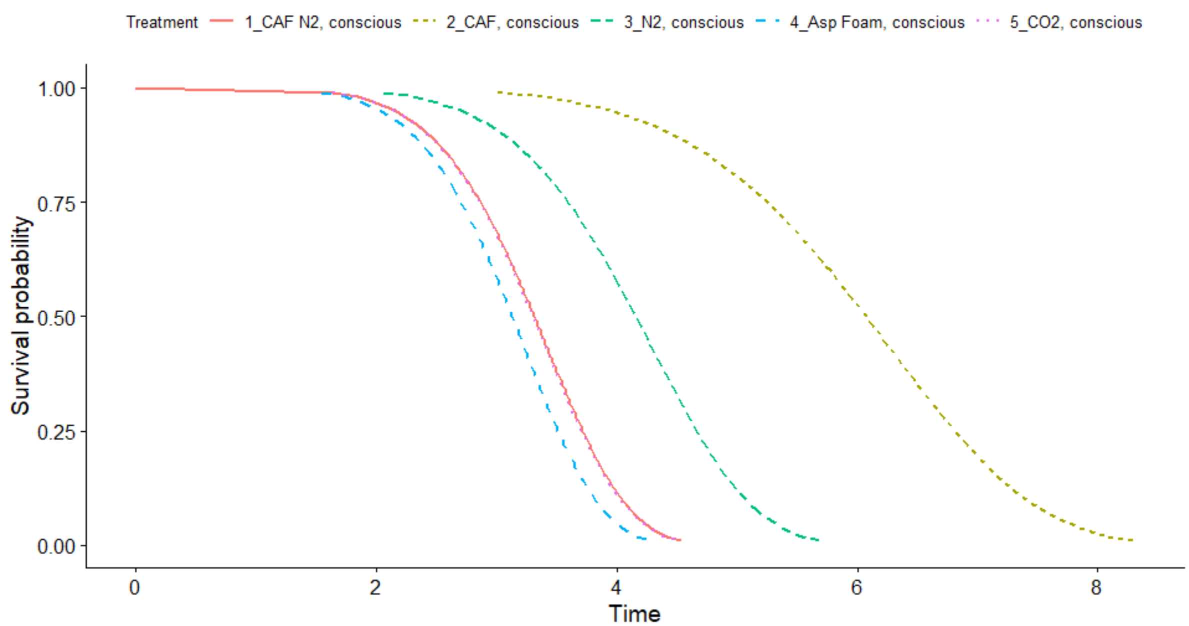


Figure 1. Survival curve analysis of within-group time to cessation of movement (COM) for foam- and gas-based methods (aspirated foam, AspFoam; compressed air foam, CAF; nitrogen infused CAF, CAF-N2; carbon dioxide gas, CO2; nitrogen gas, N2). N=6 sows per treatment.

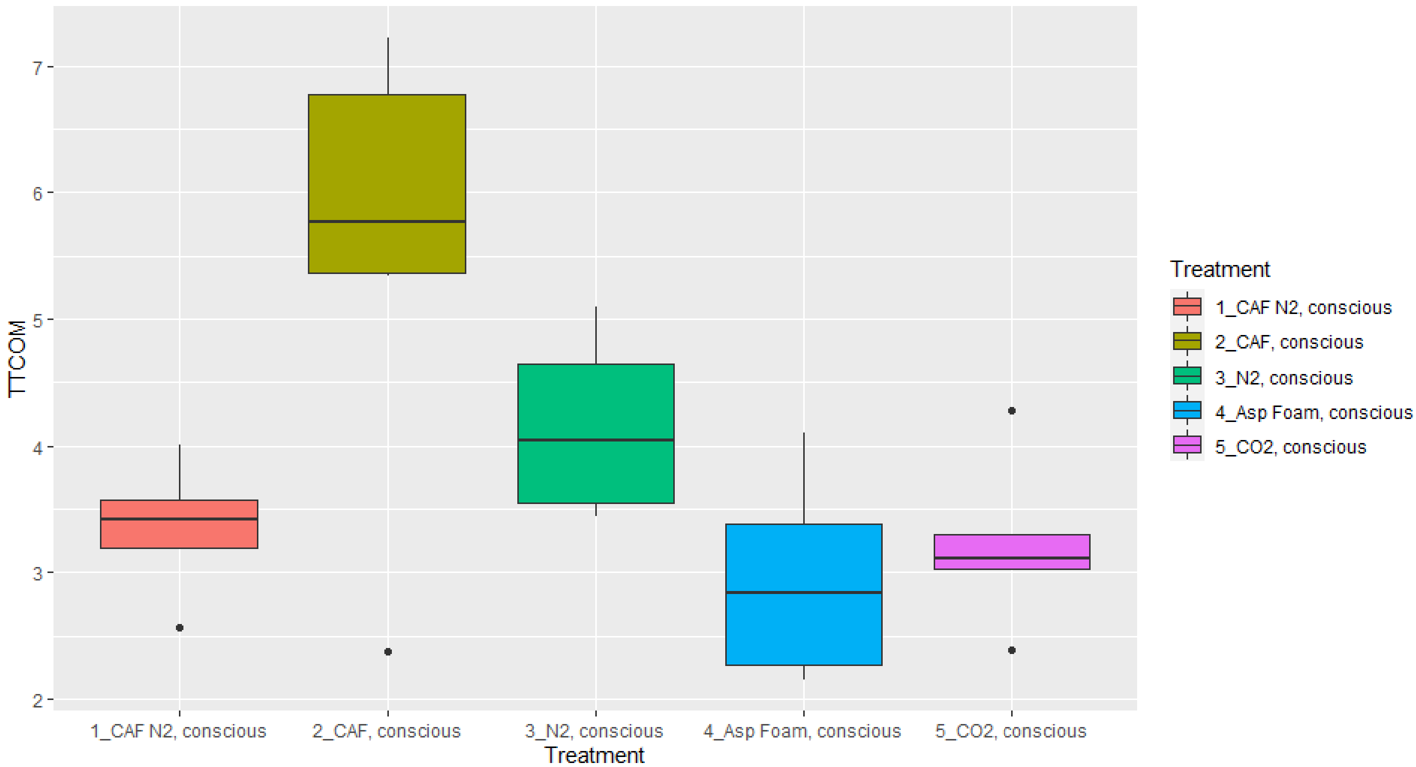


Figure 2. Box plots for time to cessation of movement (TTCOM) for foam- and gas-based methods (aspirated foam, AspFoam; compressed air foam, CAF; nitrogen infused CAF, CAF-N2; carbon dioxide gas, CO2; nitrogen gas, N2). N=6 sows per treatment.

Postmortem examination of the lower respiratory tract detected the presence of foam at or beyond the level of the tracheal bifurcation in 28 of 36 sows depopulated with foam-based methods: 11 of 12 CAF sows, 7 of 12 CAF-N2 sows, and 10 of 12 AF sows. There was no significant difference in proportion of animals with foam present at or beyond the tracheal bifurcation among the different foam-based methods ($p=0.124$, Pearson chi-squared).

ECG tracings were recovered from 41 of the 60 external CardeaSolo devices placed on individual sows and independently examined (Table 2). Data recovery was negatively impacted in conscious sow groups due to several factors, including increased technical difficulty achieving adequate lead contact with skin during placement. Devices were also more likely to be dislodged during animal-animal contact in conscious groups. Fatal arrhythmias including 3rd degree atrioventricular block, atrial standstill, and ventricular fibrillation were noted in 15 of 28 anesthetized sows and 9 of 13 conscious sows (Table 3). Presence of persistent electrical activity (PEA) was noted in 15 anesthetized sows and 5 conscious sows; this was independent of presence of fatal arrhythmia and the fact that death had been confirmed clinically at the time PEA was occurring.

	Treatment	**No. ECGs readable / No. animals**
Anesthetized	Aspirated foam	6 / 6
	CAF foam	6 / 6
	N2 CAF foam	6 / 6
	N2 gas	5 / 6
	CO2 gas	5 / 6
Conscious	Aspirated foam	3 / 6
	CAF foam	1 / 6
	N2 CAF foam	5 / 6
	N2 gas	4 / 6

	CO_2 gas	0 / 6

Table 2. Recoverable data from single-use external ECG (CardeaSolo) devices placed on individual sows in small-group experiments

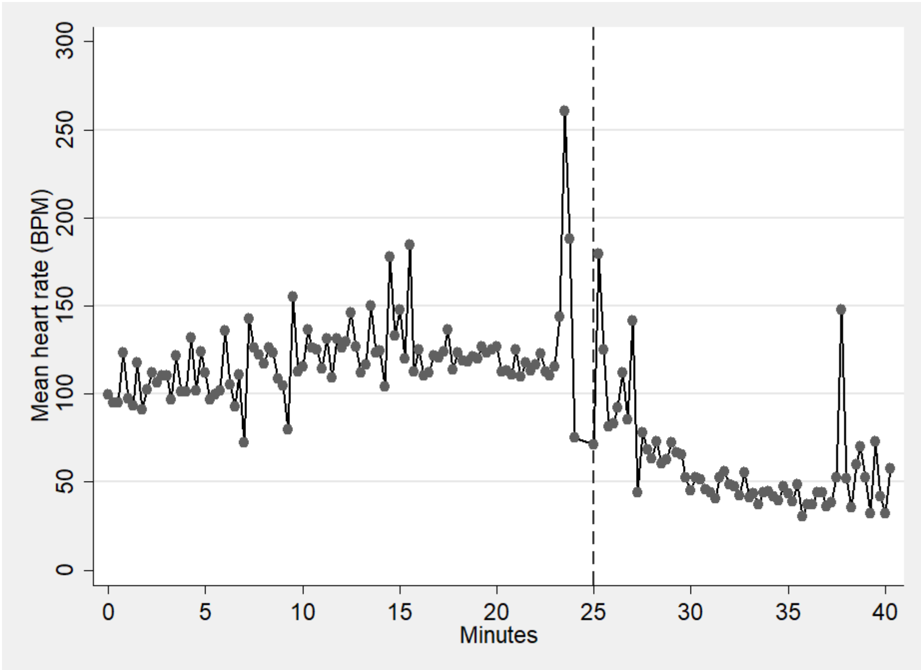
	PEA	3rd Degree AV Block	Atrial Standstill	Ventricular Fibrillation
AF-Anesthetized	1	2	3	
AF-Conscious	1		2	
CAF-Anesthetized	3	3	1	1
CAF-Conscious		1		
CAF-N2-Anesthetized	3	2	1	
CAF-N2-Conscious	2	1	2	
CO2-Anesthetized	3	1		
CO2-Conscious				
N2-Anesthetized	5	1		
N2-Conscious	2	1	1	1
Anesthetized	15	9	5	1
Conscious	5	3	5	1

Table 3. Frequency of persistent electrical activity (PEA) and fatal arrhythmias (3rd degree AV block, atrial standstill, ventricular fibrillation) identified in electrocardiograph tracings recovered from individual sows.

Objective 2: Depopulation in modified rendering trailer with Aspirated Foam (AF)

Loading process - The first experimental group of sows (group 1) was divided into two subsets of 25 and 20 sows, with each being loaded and depopulated separately. Time to load was 19 minutes and 8 minutes for these subgroups, providing an aggregate loading time of 27 minutes. Modification of loading strategy to locate more individuals inside the depopulation trailer during the pushing process improved loading time in subsequent experimental groups. Time to load was 17 minutes for group 2 sows (n=44) and 17 minutes for group 3 sows (n=45). Mean time to load was 20.3 minutes (95% CI 6.0 – 34.7) per group of 44-45 sows, corresponding with a loading time per individual sow of approximately 27 seconds.

Filling time - Mean time to fill during the four applications of AF in the depopulation trailer was 103.8 seconds (range 92-115; 95% CI 88-120). (*Note: time to COM is based only on HOBO monitor data in the following results, and time to COM is inclusive of foam filling time*). Mean time to COM across the four applications was 128 seconds (range 98-162; 95% CI 118 – 138). Mean time to COM within the four applications was: 136 seconds in group 1A (95% CI 111-161), 143 seconds in group 1B (95% CI 133 – 152), 109 seconds in group 2 (95% CI 99.2 – 119), and 124 seconds in group 3 (95% CI 111 – 137). An estimated 1136 L (300 gal) of 1% foam-water solution was required to completely fill the 68,000 L (68 m3) volume rendering trailer at each application, indicating an approximate expansion ratio of 45:1.



<u>Figure 3.</u> Mean heart rate in beats per minute (BPM) among sows fitted with Star-Oddi centi-HRT devices in groups 1A, 1B, 2, and 3. Note: only HR values with the highest quality rating (QI=0) are represented in these data. X-axis shows relative time across the multiple groups; data shown cover 25 minutes prior to and 15 minutes following fill start time (denoted by vertical dashed line). Heart rate data in the subcutaneous devices are collected using ECG-based proprietary technology and algorithms (Star-Oddi). Accordingly, HR data indicate only electrical activity and not cardiac function; persistent electrical activity (PEA) may be detected following confirmation of clinical asystole by physical methods (e.g. auscultation, pulse detection).

Discussion:

Inhalation-based depopulation methods are promising because they allow for multiple animals to be terminated simultaneously.

Depopulating animals after they have been loaded onto modified rendering trailers allowed us to consider inhalation-based depopulation methods because we would overcome some of the inherent hurdles caused by swine housing facility designs (i.e. open-air pens, slatted floors and deep manure pits create large volume air spaces, etc.).

Water-based foam (WBF) depopulation is a preferred method in poultry, leading to rapid death and relatively ease of application, and USDA has WBF generating units in the National Veterinary Stockpile, which makes it an attractive agent. Historically, foam has not been feasible in swine due to their housing; however, use of a trailer provides new opportunities. Our study shows that WBF for depopulation of sows in modified rendering trailers is a viable option for mature swine (and likely younger pigs too).

Our results show that WBF resulted in a death that was comparable to CO2, but had fewer potential pitfalls than CO2 (availability and sourcing CO2, vaporizing, delivery time, etc.).