Use of a Compressed Air Foam System in Response to Reportable Poultry Diseases

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Abstract. Firefighting foam has been previously demonstrated to be an effective means of depopulation for poultry reared in floor pens. However, foam made via an aspirated nozzle or high expansion generator is not thick enough to persist within layer cages. Foam has also been evaluated as a carrier for disinfectants in poultry houses, but much of the material is wasted. A compressed air foam system (CAFS) can create a foam that is thick enough to accumulate within layer cages and may also be used to apply disinfectants and cleaners to agricultural surfaces in an efficient manner. We found that the CAFS method of depopulation for cage reared layer hens is similar to the aspirated method of depopulation for poultry reared in floor pens. No significant differences were observed in gross pathology or serum corticosterone between the carbon dioxide control, the aspirated treatment or the CAFS treatment. Differences (P<0.05) were observed in cessation of movement between the carbon dioxide control and the foam treatments. However, the increased time observed may have been due to flow rates and concentrations required for each treatment. Foaming disinfectants and cleaners have been applied at the rate of 600 gallons per minute on tractor trailers, broiler transport coops, hatchery baskets, chick transport trucks, quail and layer farms via CAFS. Typically, a 1-4 log reduction of aerobic bacteria was observed on treated surfaces depending on the bacterial load and the amount of organic matter present. These data suggest that CAFS may be employed during a reportable disease response for depopulation and cleaning and disinfection.

Keywords. Poultry, foam depopulation, caged layers, cleaning and disinfection
Introduction

A reportable disease response is a logistically intensive process that has significant labor and material costs. The 2015 Avian Influenza outbreak has affected 48,091,293 birds (USDA, July 2015). Congress has allocated approximately $700 million for indemnity, depopulation, disposal and disinfection, but even more money has been lost by the growers and integrators in lost revenue (USDA, 2015). Gas asphyxiation of poultry with carbon dioxide and polyethylene tents or containers was previously used for depopulation. The process had many disadvantages such as exposure of workers to a low oxygen environment and potential zoonotic pathogens, contaminated plastic, freezing temperatures and difficulty achieving and sustaining appropriate concentrations of carbon dioxide gas throughout the house. The University of Delaware developed and patented a process than can produce firefighting foam to depopulate an entire broiler chicken house within 30 minutes (Benson et al., 2008). The North Carolina Department of Agriculture later developed a less expensive version of the system, but it was less efficient and more labor intensive. Researchers determined that the foam process similarly affected the physiology of the bird as compared to carbon dioxide euthanasia (Benson et al., 2007). These units are very effective and are commercially available or manufactured, in house, by the end user. “Foam may be used to depopulate floor reared birds if: 1) they are infected with a zoonotic disease, 2) they are infected by a pathogen that cannot be contained by conventional means and/or 3) they are within a structurally unsound building” (AVMA, 2013). However, foam has not been approved for use as a euthanasia strategy.

Foam produced for the depopulation of floor reared poultry is created by using an aspirated nozzle or a high expansion fan. While these methods manufacture a foam that works well for broilers and turkeys reared on floors, they are not viable solutions for caged layers. The Farnell laboratory was tasked with creating a thick foam that would fill a layer cage and effectively kill caged layer hens without filling an entire barn from floor to ceiling. Experts in the firefighting industry such as the Texas A&M University Engineering Extension Service (TEEX, College Station, TX), Rowe Industries (Hope, AR) and CAFSCO Fire Control (Joshua, TX) provided guidance on how to properly create the improved foam using a compressed air foam system (CAFS).

Firefighting foam is made from air, soap and water. In a CAFS unit, a water and soap solution (foam concentrate) are pumped into a water manifold and the compressed air is directed to a separate air manifold. These three agents are then mixed violently within a mixing chamber (Equalizer, Rowe Industries) to produce a dense foam. A compressed air foam is made very differently from other means of creating foam, as the product is made at the unit and not at the nozzle. The CAFS foam utilizes the energy of the compressed air to create foam, whereas other systems utilize water pressure. An additional benefit of CAFS is that the fire hoses are significantly lighter and easier to manage when filled with air versus water. A CAFS research unit was manufactured and tests were conducted at Texas A&M University and Mississippi State University (Figure 1A). The CAFS unit was capable of producing 600 gallons of foam per minute which has the consistency of wet shaving cream (Figures 1B and 1C). The foam exited
the fire hose with substantial velocity (Figure 1D). The speed was reduced by increasing the hose diameter for the depopulation trials.

In addition to depopulation, infected poultry premises need to be rapidly and effectively cleaned and disinfected. Researchers have previously reported significant contamination and the associated difficulty of getting surfaces properly cleaned pre-harvest (Mead, 2005). Allen and colleagues report aerobic bacteria as high as 8 log\textsubscript{10} cfu per chicken crate floor (2008). Several strategies to reduce bacteria were employed, but they typically obtained only a 2 log\textsubscript{10} reduction in aerobic bacteria. They suggested that live production surfaces were difficult to clean and disinfect because of the significant load of organic matter present and the amount of niches for bacteria to hide.

An abandoned poultry barn was converted into a field laboratory for our foam depopulation trials. The building had suffered from many years of neglect and a significant rodent infestation. Interestingly, while depopulation trials were conducted the building became much cleaner and it was suggested by the farm manager that we look at using the compressed air foam system for cleaning and disinfection as well. The CAFS can produce a stream of foam, via a 1 ½” nozzle, that travels approximately 75 feet or more (Figure 1D). The soap and water in combination with the mechanical action of the foam application loosened and removed a significant amount of built up organic matter. We contacted allied industry representatives from IVESCO (Springdale, AR), Rochester Midland (Rochester, NY) and DuPont (Houston, TX) for technical support. Spielholz originally patented the process of using a foam generator to apply disinfectants in 1988, but no research publications were found evaluating the efficacy of the technique. Laboratory trials were carried out to determine compatible products for our unit. Field tests were then conducted to determine efficacy within the poultry industry.

The authors will summarize their research efforts from the past 7 years with this document. The objectives of these trials were: 1) to develop a rapid, practical and humane means of euthanizing caged layer chickens and 2) determine a quick and effective means to clean and disinfect poultry premises.
Figure 1.
A – Rowe Industries compressed air foam system,
B – Demonstration (CAFSCO) of the ability of a CAFS to rapidly cover and coat a surface,
C – Example illustrating the consistency of a 3.5% CAFS for caged layer euthanasia,
D – Demonstration of a CAFSCO compressed air foam system (CAFS)
Materials and Methods

Equipment – A commercially available CAFS unit was constructed and modified for the project (Figure 1A, Rowe Industries, Hope, AR). The unit was composed of: one 300 gallon water tank with a graduated bottom, an 8 gallon foam cell, a high flow foam proportioner (Foam Pro, Fire Research Corporation, Nesconset, NY), a 40 horsepower gasoline engine (Kohler Co., Kohler, WI), a 150 gallon per minute water pump (Hale Products Inc., Conshohocken, PA), and a 70 CFM rotary screw air compressor (Vanair Manufacturing, Michigan City, IN), installed within a bumper pull cattle trailer to protect the unit from the weather. The system had one 1 ½” water line, one 1 ½” CAFS line and one 1” CAFS line. The 1 ½” water line was utilized to provide water to an aspirated foam nozzle for comparison of foam (AG-1, Spumifer American, Ridgefield Park, NJ) and for wash-down.

Foam Selection Process – A variety of foams were tested for the project at concentrations ranging from 1-5% foam concentrates including: Silv-ex (Ansul, Marinette, WI), Phos-Chek, (ICL Performance Products LP), Fire Quench (Texas Correctional Industries, Huntsville, TX) and Perafoam (Rochester Midland). Sodium polyacrylate was tried as a potential thickening agent (VWR International, Radnor, PA). The Oklahoma University Surfactant Laboratory tested a series of products and combinations with the objective to find the optimal product and concentration.

Layer Depopulation Foams - The CAFS foam was made by using a 3.5% solution of foam concentrate (Phos-Chek, ICL Performance Products LP, Rancho Cucamonga, CA) applied through a 1 ½” CAFS line attached to a 2 ½” suction hose that was 20’ in length, to slow the foam velocity. The foam was created with the compressed air supply opened to 100% and the water supply barely open. The water valve opening was initially reduced until the foam would “spit and sputter”. The operator would then gradually open the water valve to achieve the foam consistency desired. The typical expansion ratio was calculated to be 70:1, meaning that 1 gallon of water and foam concentrate would produce 70 gallons of foam. An aspirated foam was created, to compare the CAFS foam to conventional foam, using an AG-1 Spumifer Nozzle (Spumifer America, Ridgefield Park, NJ).

Foam Depopulation Experimental Design – The newly developed CAFS foam was compared to a negative control (no treatment other than handling), carbon dioxide asphyxiation treatment (placement into a 100% pre-charged chamber) and aspirated foam treatment (such as used to depopulate floor reared birds). Single combed white Leghorn chickens were used for the depopulation trials. Pullets (n=6) coming into production were used for one trial and spent hens (n=6 and 7) used for the other trial. Each trial was replicated two times. Physiological stress was evaluated by analyzing corticosterone in blood serum (Enzo Life Sciences, Inc., Farmingdale, NY), and cessation of movement was determined by utilizing accelerometers (Onset Computer Corporation, Bourne, MA) attached to the bird’s shank.
**Foam Disinfectant Selection** – While foaming disinfectants are commonly used in food processing plants, at a relatively low volume, we needed to determine which products were compatible with our CAFS and with our selected foaming agents. Coupons (Figure 2, samples of materials) of ABS plastic, galvanized metal and rubber were used to determine disinfectant efficacy, when mixed with a foaming agent, against Salmonella Typhimurium. Successful candidates were then tested in our CAFS for foam quality.

**Environmental Swabs** – Surface swabs were collected using sterile gauze pads soaked in buffered peptone water and stored in a sterile Whirl-Pak bag (Nasco, Ft. Atkinson, WI). A sterile 2” X 2” template made of stainless steel (Rowe Industries) was utilized to define the area sampled. The media was squeezed out of the swab with a clean latex glove and the collector wiped the area from left to right and from top to bottom one time. The templates were flame sterilized with 100% ethanol prior to each sample collection. Other samples were collected due to a naturally defined area provided by wire floor spacing, individual drinker cups, etc. The sample were stored on wet ice and transported to the laboratory for processing. All samples were blended at normal speed for 30 seconds with a stomacher paddle blender (Seward Laboratory Systems, Davie, FL). Samples were serially diluted in phosphate buffered saline and spread plated on tryptic soy agar (Becton-Dickinson and Company, Franklin Lakes, New Jersey) plates (Figure 3). Plates were incubated at 37°C for 24 hours prior to bacterial enumeration on the next day. To determine reduction of aerobic bacteria, samples were collected pre and post treatment for all trials. All pre and post treatment samples were paired according to location.

**ATP Swabs** – Commercially available surface tests were used to detect the presence of adenosine triphosphate, which is a source of energy found within all living cells. A portable luminometer and ATP surface tests were utilized for some trials (SystemSURE II Luminometer and Ultrasnap ATP Swabs, Hygenia, Camarillo, CA).

**Quail Farm Disinfection Field Trials** - Prior to the completion of the laboratory disinfectant selection tests, we were approached by a quail producer who was having significant problems with bird health. The company allowed us to try commercially
available products over the course of two site visits. Environmental swabs were collected from walls, metal rails on top of footings and posts within a floor pen barn. On the second site visit, environmental swabs were collected from cages and manure belts within a colony breeder cage system. ATP swabs were used concurrently for each site visit.

*Broiler Transport Coop Disinfection Trials* – Broiler transport coops were soiled with fresh feces and treated with water alone, foam alone, foam and peracetic acid, chlorinated/alkaline foam cleaner and/or a high pressure water rinse. Initial trials utilized a fecal slurry, from a layer barn, and a paint roller to uniformly contaminate broiler transport coops to reduce sample variability. Later trials utilized freshly soiled coops at a poultry integrator holding shed.

*Hatchery Disinfection Trials* – Freshly soiled hatchery baskets were treated with foam and peracetic acid or a chlorinated alkaline foaming cleaner. A chick delivery truck received the same treatments to determine effectiveness on transport vehicles.

*Layer Farm Disinfection Trials* – Pullet and layer cages were treated with foam and peracetic acid or a chlorinated alkaline foaming cleaner. Cage floors and drinker cups were sampled.

**Results**

*Foam Selection* – Numerous foam concentrates were tested with the CAFS system. The Fire Quench product produced a poor quality foam that was highly variable from pail to pail. Other products produced a viable foam for firefighting, but didn’t have adequate cage residency time. Phos-Chek was found to be the optimal product at a concentration of 3.5%. Additives such as sodium polyacrylate were added to the foam, but these foams dewatered quickly. The sodium polyacrylate product created a slippery hazard on concrete which was difficult to remove with water. The Oklahoma Surfactant Laboratory did not find anything better than the Phos-Chek at a 3.5% concentration.

*Foam Euthanasia* – Corticosterone levels in all treatments were statistically similar to the untreated negative control, with the exception of using CAFS within a chamber in one of the four trials. This may have been due to the additional stress of moving the birds from a cage to a separate chamber. Time to cessation of movement was an average of 90, 192 and 194 seconds with the CO2 chamber, CAFS and nozzle aspirated foam treatments, respectively. The foam treatments took significantly more time for cessation of movement, but the CAFS foam was comparable to the AVMA approved depopulation foam produced by the aspirated nozzle. The authors believe that one reason for the difference was that the CO2 chamber was pre-charged with gas prior to bird placement. In a field response, it would take much longer to fill a cage with the correct concentration of CO2. Cessation of movement was determined once the treatment began. During the foam application birds were monitored for movement as
the cage was filling and before it completely covered the head of the bird. Therefore, we may have inadvertently skewed the results in favor of the CO2 treatment. Application of the foam from the top of the cage worked well and completely filled the cage. However, application of the foam from the side of the cage resulted in air pockets forming in the back corners allowing for birds to survive the treatment. Additionally, the CAFS treatment required a support structure for the foam such as a manure belt. Otherwise, the foam would fall through the wire floor.

Foam Disinfection Selection – A combination of peracetic acid (3%) and Phos-Chek at 1% were found to produce a viable foam via CAFS that was efficacious against aerobic bacteria. A foaming alkaline cleaner called Chlor-a-Foam (3%, DuPont, Houston, TX) was also found to reduce bacteria and break up organic matter. Interestingly, quaternary ammonia and quaternary ammonia blended with glutaraldehyde did not produce a viable foam with or without a foam concentrate with our CAFS. Products such as potassium peroxymonosulfate (Virkon S, Neogen, Lexington, KY) were not used due to the corrosive nature of the product.

Quail Farm Disinfection Field Trials – A commercial chlorinated/alkaline foaming cleaner was used in one area and firefighting foam by itself was used in another within floor pen and cage rearing facilities. While numerical reductions in aerobic bacteria were observed with each treatment, only the application of the foaming cleaner applied to the floor pen barn resulted in any significant differences (reduction of 1.56 log10 cfu). Both products seemed to loosen up organic matter, but neither were labeled as a disinfectant. Therefore, the lack of differences observed should've been expected. However, significant reductions of microbial ATP were observed with all of the treatments at each location. This compound is present in all living things, so it may be possible that we isolated ATP from microorganisms that were not culture-able by our aerobic plating method.

Broiler Transport Coop Disinfection Trials – Pre-cleaned transport coops were used for the laboratory trials. These coops were uniformly contaminated with fresh layer of hen feces applied with a clean paint roller. Significant reductions up to 5 log10 cfu of aerobic bacteria per sample were observed with all of the treatments as compared to the water rinse control. The addition of a power rinse prior to or after product application did not improve product efficacy (Hinojosa et al., 2015). “Naturally” contaminated coops were treated at a commercial poultry integrator’s holding shed. The treatment of coops with the chlorinated alkaline foaming cleaner and the peracetic acid reduced aerobic bacteria up to two log10 cfu per sample. The addition of the high pressure water rinse further increased product efficacy. Greater reductions were probably not observed during field trials due to increased amounts of organic matter present on broiler transport coops.

Hatchery Disinfection Trials – Peracetic acid and a chlorinated alkaline foaming cleaner were applied to forty chick baskets, which were previously soiled by newly hatched chicks at a commercial broiler hatchery. Two heavily soiled broiler chick delivery trucks were also treated. Significant differences of up to a three log10 cfu reduction of aerobic bacteria were observed per paired surface area with all treatments.
Layer Farm Disinfection Trials – A commercial pullet and layer hen barn were treated with peracetic acid and the chlorinated alkaline foaming cleaner (Farm Brand Alpha Foam, Douglas, GA). Typically, a two log reduction of aerobic bacteria were observed on floor and drinker surfaces treated with the disinfectant. However, no improvements have yet been observed with the foaming cleaner treatment. The lack of efficacy may be due to the new environment and product differences. Further repetitions need to be conducted to confirm these results.

Conclusions

- A compressed air foam system may be used to effectively depopulate hens in cages with manure belts.

- Major deficiencies exist when using a CAFS for layer depopulation. Air pockets may form in cage corners allowing for survivors. Although the foam is dense enough to remain with a layer cage, a structure to support the foam such as a manure belt is required.

- The addition of carbon dioxide to the foam may improve its efficacy as a depopulation technique. However, increasing levels of carbon dioxide may have a negative effect on foam quality.

- A CAFS may be used to clean and disinfect poultry facilities and surfaces such as plastic, wire, and sheet metal which are commonly used within quail barns, broiler transport coops, hatcheries and pullet/layer barns.

- While utilizing CAFS to disinfect poultry associated surfaces results in a 1-5 log_{10} cfu reduction in bacteria, improvements are still needed to further reduce the bacterial and viral load on these surfaces.

References


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