Salmonella in dairy calves: Why do outbreaks occur in well managed herds?

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Abstract

Modern calf-raising facilities are not designed for effective cleaning and disinfection. Common issues are lack of a sanitary design, absence of wash bays, improper floor drainage, plus open side curtains and peaks, which negates the use of thermal fogging, which is the only effective method available to decontaminate buildings. Doorway entry and exit points use outdated technology (foot baths) to control infectious agents, and there is a general unawareness by calf raisers and veterinarians of the dangers posed by a relatively small number of Salmonella serotypes such as *Salmonella* Heidelberg. The dangerous serotypes of *Salmonella* spp can quickly circumvent current best practices for raising dairy calves and lead to high morbidity and mortality disease outbreaks.

Key words: cleaning and disinfection, chlorine dioxide, superspreader, salmonella

Introduction

Salmonella needs food, water and the proper temperature to survive, which aptly describes the environment of a modern calf-raising facility. We don't have catastrophic disease outbreaks of Salmonella because of facility design and a failure to use current best practices to raise healthy calves, but because the dangerous serotypes of Salmonella are relatively uncommon except for *Salmonella* Dublin. Livestock managers and owners who discount the importance of Salmonella because every livestock facility has it and they don't have issues with Salmonella don't realize they are just fortunate to not have a dangerous serotype present on their premises. A catastrophic disease outbreak is just one highly virulent strain of Salmonella away from being introduced into the livestock operation. Veterinarians need to know which serotype they are dealing with because if the producer is having problems with a relatively benign serotype, such as *Salmonella* Cerro, then something is fundamentally wrong with the management in the livestock operation and corrective action requires finding out what has gone wrong. However, if a dangerous serotype such as *Salmonella* Panama is found, then aggressive steps must be taken to mitigate the disease outbreak because current best practices will not control the disease outbreak. When the Wisconsin Veterinary Diagnostic Laboratory (WVDL) isolates a dangerous, known calf killer serotype of Salmonella from bovine samples, it immediately alerts the submitting veterinarian for this reason.

The safety and efficacy of commercial or autogenous Salmonella vaccines for use in preweaned calves is unsettled, and there is no consensus amongst animal health experts as to their value in reducing both morbidity and mortality. Therefore Salmonella vaccines are just a tool, but they should not be the mainstay of effective Salmonella control programs.

I often pose these questions to livestock managers and veterinarians after a severe outbreak of salmonellosis caused by a dangerous serotype of Salmonella: What are you going to do now that the facility is heavily contaminated with a highly virulent strain of Salmonella and your facility is not designed for quick and efficient cleaning followed by thermal fogging? If you just place new calves in the facility without verification that proper cleaning and disinfection has been performed, then you can expect with reasonable certainty that another catastrophic disease outbreak will occur. Letting the facility sit empty for 1 or 2 months is not an option either, because Salmonella can survive for several months in the environment.[5] Also, how are you going to properly clean and disinfect dirt or gravel flooring? Since you can't properly clean and disinfect dirt or gravel, why did you put it in the facility in the first place? These scenarios point out the problems of constructing calf-raising facilities without a sanitary design and providing a mechanism to do thermal fogging.

For successful implementation of Salmonella control strategies, it is important to understand that Salmonella, like other environmental gram-negative bacteria, persists in the environment because of its ability to form biofilms in both wet and dry environments.[5] In addition, potable drinking water that is high in iron (≥ 0.30 ppm) will facilitate the survival and persistence of the organism, particularly in the intestinal tract of susceptible animals.[1] This is why Salmonella control is very difficult in facilities that have high iron levels (≥ 1.00 ppm) in the potable drinking water. Since Salmonella are ubiquitous on dairies, particularly large herds, it is important to remember that Salmonella control is largely a numbers game whereby control measures should be directed at lowering the numbers of bacteria in the environment particularly for the most susceptible group of animals, which are preweaned calves and transition cows. Since Salmonella is transmitted to susceptible animals by predominately the fecal-oral route, control measures should be directed at reducing bacterial numbers where the animal places its head and uses its tongue, which includes the animal's body (self-grooming), feed bunks, calf-feeding equipment, feed bunks, and water troughs.

In Salmonella problem herds, valuable information can be obtained by collecting environmental samples from floors,

walls, feed bunks, calf-feeding equipment, and waterers. In addition, samples should be collected from holding pens, alleyways and from flush water. Specialized booties designed specifically for Salmonella environmental sampling are extremely useful because a large surface area can be easily sampled in a short period of time. Supplies for environmental testing, which includes the booties, can per purchased from the WVDL. The bovine environmental Salmonella kit can be found under the supply order form category. Veterinarians and producers should focus their cleaning and disinfection efforts where high numbers (hot spots) of Salmonella are found that are the same serotype that is causing clinical disease in the livestock operation. Remember, you can't identify hot spots if the environmental Salmonella isolates are not serotyped. Proper cleaning should be verified with an ATP meter prior to disinfection. Break points for cleanliness have been established and verified for The Hygiena ATP meter by Dr. Sockett. The ATP meter cleanliness verification guidelines are available from Dr. Sockett upon request. A word of caution, *Salmonella* Dublin is extremely difficult to culture from environmental samples so anywhere that Salmonella is found should be considered a potential "hot spot" for *Salmonella* Dublin. The following is the author's protocol for cleaning and disinfection of livestock facilities and calf pens. They have become the gold standard for the dairy industry in the United States and other countries as well. Similar facility cleaning and disinfection protocols without the knowledge or approval of Dr. Sockett are not recommended.

Cleaning and Disinfection: Calf Pens and Buildings

It is important that livestock barns and calf pens be properly cleaned before the disinfectant is applied. If the calf pens and livestock barns are not properly cleaned, the disinfection step is much less effective at killing disease-causing microorganisms. Whenever possible, high-pressure washing should not be used because of the risk of cross-contamination of the environment. Livestock owners and managers must understand that while high-pressure washers do remove gross soils such as dried fecal material, they do not consistently remove biofilms. Biofilm disruption and removal is an essential and vital component of proper cleaning, because the highest numbers (≥ 90%) of disease-causing organisms are found in the biofilm layer.

1. Remove all the bedding material
   After the bedding material has been removed, a barn broom can be used to sweep up the remaining feed, dust, and organic debris.
2. Measure the garden hose water pressure
   Attach a commercial water test gauge to the end of the garden hose and turn on the water. Measure the maximum water pressure in pounds per square inch (psi). If no gauge is available to measure water pressure, use a water pressure value of 40 psi.
3. Soak with water for 1 to 2 minutes: Warm water (≥ 90 to 100 °F; ≥ 32 to 38 °C is preferred but not obligatory)
   Thoroughly wet the calf pens or livestock barn with water using a garden hose. The water should be applied from high to low starting at the highest point and ending at the lowest point such as a floor drain.
4. Alkaline foam cleaning: Hot water (≥ 135 °F; ≥ 57 °C is preferred but not obligatory)
   Apply an alkaline (pH 11 to 12) foaming detergent[a] to the calf pens and livestock building using a hand-held airless foamer[b]. Start at the lowest point of the calf pen and/or livestock barn and finish at the highest point. Apply the alkaline foaming detergent evenly to all the surfaces.
5. **Soak** ≥ 10 to 15 minutes
   Do not allow the foaming, alkaline detergent to dry.
6. Rinse
   Rinse thoroughly with cold water using a garden hose going from the highest point to the lowest point of the calf pen or livestock trailer.
7. Acid foam cleaning
   Apply an acid (pH 3-4) foaming detergent[c] to the calf pen or livestock barn with cold water using a hand-held airless foamer.[b] Apply the acid foaming detergent evenly to all the surfaces.
8. **Soak** ≥ 10 to 15 minutes
   Do not allow the foaming, acid detergent to dry.
9. Rinse
   Rinse thoroughly with cold water using a garden hose going from the highest point to the lowest point of the calf pen or livestock trailer.
10. Dry
    Allow the calf pen or livestock barn to completely dry out before the disinfectant is applied.
11. Verify cleanliness using the ATP meter
    After drying, verify cleanliness using the Ultrasnap™ surface test swabs with measurements provided by the Hygiena SystemSure Plus™ATP meter. If the calf pens and/or livestock barn are not clean, then repeat the entire cleaning process.
12. Disinfection

Twelve to 24 hours prior to use, disinfect the calf pens or livestock barn with cold water that contains chlorine dioxide at 250 to 500 ppm going from the highest point to the lowest point of the calf pens and/or livestock barn. An airless sprayer[d] can be used to apply the chlorine dioxide. It is obligatory that the working concentration of chlorine dioxide be verified with plastic test strips[e] prior to use. There should be 5 to 10 minutes of contact time. When using chlorine dioxide at concentrations of ≥ 200 ppm, operators should wear protective eyewear and an R95-approved, particulate respirator mask that is carbon lined (grey color). The masks can be obtained in the paint section of a local hardware store.

Choice of Disinfectant

There are many disinfectants available that have efficacy against Salmonella under laboratory conditions. Unfortunately, many fail to mention whether the disinfectant can penetrate biofilms or are inactivated by organic material and if the disinfectant is adversely affected by temperature, hard water or by pH. Minimum contact time information is often not available as well. Chlorine dioxide has emerged as an excellent choice for control of salmonellosis because it can be used at low concentrations, has very short contact times for pathogen inactivation, and is the least-corrosive of all the oxidizing disinfectants. Corrosion of metal surfaces is a significant problem with oxidizing disinfectants, including some types of stainless steel. Typically, chlorine dioxide is used at a concentration of 25 to 50 ppm with 2 to 4 minutes of contact time for sanitizing calf-feeding equipment and at a concentration of 250 to 500 ppm for facility and/or calf pen disinfection with 5 to 10 minutes of contact time. In addition, chlorine dioxide activity is not affected by pH or organic material, it can penetrate biofilms, and it is EPA-approved to treat potable drinking water.[3] Whatever chlorine dioxide product is used it is obligatory that the concentration of chlorine dioxide is verified prior to use, because there can be tremendous variability in the chlorine dioxide concentration of commercial products in the marketplace. The chlorine dioxide product that is chosen should meet or exceed the following specifications.

1. The product is NSF/ANSI Standard 60 certified for chemical treatment of potable drinking water and for equipment sanitation. Certification means an independent organization has reviewed the product and it complies with governmental standards for safety, quality, purity, sustainability, and performance.
2. Food-grade chemicals are used. Non-food-grade chemicals often contain impurities which reduces chlorine dioxide sanitation and disinfection efficiency.
3. The product is activated with a strong acid and not a weak acid. Strong acids are 60% more efficient than weak acids in converting sodium chlorite to chlorine dioxide, and unlike weak acids they produce no toxic residues and do not have large amounts of unreacted sodium chlorite. Chlorite cannot be higher than 1.0 ppm in potable drinking water, and large amounts of unreacted sodium chlorite reduce the predictability and performance of chlorine dioxide.
4. The vendor has expertise in cleaning, sanitation, disinfection, and chemical treatment of potable drinking water.
5. The vendor has knowledge and expertise into the subtle intricacies of chlorine dioxide generation and how changing variables such as water temperature can have a marked effect on the time required for chlorine dioxide activation.
6. The vendor provides the capability to quickly and reliably verify the chlorine dioxide concentrations are correct for different applications, such as chemical treatment of potable drinking water, sanitation, disinfection, and thermal fogging.
7. Dr. Sockett can provide the name(s) of reputable chlorine dioxide vendors upon request.

Oral Antimicrobial Drugs for Treatment of Clinical Salmonellosis

Currently, the WVDL does not perform an antimicrobial susceptibility test for Salmonella isolates obtained from bovine fecal samples unless requested by the submitting veterinarian. Some of the reasons for this laboratory policy are listed below.

1. There are no veterinary approved Clinical and Laboratory Standards Institute (CLSI) break points for Salmonella. The only break points available are for human use.
2. Oral antibiotics cause gut microbiome dysbiosis (less diversity) leading to an increased probability of *Salmonella* colonization and increased risk of invasive *Salmonella* complications.[2]
3. Oral antibiotics increase the risk of antimicrobial resistance (AMR) for many different types of gut bacteria, including *E. coli* and *Salmonella*.[2]
4. Enteric *Salmonella* are often resistant to the most common classes of oral antibiotics that are approved for use in livestock.
5. Oral antibiotics increase the number of *Salmonella* superspreaders, and their use also increases the duration of *Salmonella* shedding.[4] It has been estimated that superspreaders account for roughly 80% of *Salmonella* transmission.[4] Superspreaders are especially problematic, since they cause an increase in environmental load of *Salmonella* which serves as a reservoir of new infections.
6. For dairy beef and veal operations oral antibiotics, particularly those that use the aminoglycoside class of antimicrobial drugs, increase the risk of drug residues being detected at the time of slaughter.
7. *Salmonella* are intrinsically resistant to the aminoglycoside class of antibiotics, which includes neomycin.
8. Some commercial, non-medicated probiotics have good activity against enteric *Salmonella*, do not cause drug residues, and have been shown to improve gut microbiome diversity. This means there are viable alternatives to oral antibiotics in livestock that are relatively inexpensive.

Endnotes

[a]Total Alkaline Presoak™, Triton Chemical, Lakeville, MN

[b]Compact Model 25 Airless Foamer, Lafferty® Equipment Manufacturing Inc., Little Rock, AR
[c]Surface Bright™, Triton Chemical, Lakeville, MN
[d]Compact Model 20 or Model 50 Airless Sprayer, Lafferty® Equipment Manufacturing Inc., Little Rock, AR
[e]Insta-Test®, high range chlorine dioxide, La Motte, Chestertown, MD

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