HOUSING FACTORS TO OPTIMIZE RESPIRATORY HEALTH OF CALVES IN NATURALLY VENTILATED CALF BARNS IN WINTER

Ken Nordlund, DVM
School of Veterinary Medicine
University of Wisconsin-Madison

INTRODUCTION

Although hutches are usually considered to be the preferred housing for pre-weaned dairy calves (Brand et al., 1996; McFarland, 1996), dairy owners continue to build calf barns because of the discomfort and inconvenience of cold weather, snow, and rain for calf care-givers. In recent years, naturally ventilated barns with individual pens to house calves from birth through weaning (McFarland, 1996; Holmes, 2000) have been constructed on many dairy farms. Based upon field investigations of herds referred to the University of Wisconsin's School of Veterinary Medicine, enzootic pneumonia of calves is common in these barns, particularly during the winter months. Enzootic pneumonia of calves is traditionally associated with poorly ventilated housing conditions (Radostits et al., 2000; Callan and Garry, 2002).

Figure 1. Interior view of a naturally ventilated calf barn with four rows of pens. There is a ridge opening above the translucent-panel roof to the south, adjustable curtain sidewalls, and individual calf pens surrounded by solid panels and a feeding opening in the front.

The design features of these barns meet the general recommendations for natural ventilation of livestock buildings in winter by providing eave or sidewall openings that allow prevailing winds to force fresh air into the building, and ridge openings that allow warmed air to rise by thermal buoyancy and exit the building (Albright, 1990). While the barns share the common features of a ridge opening and adjustable curtain sidewalls, they vary widely in terms of construction materials, pen size and enclosures, bedding, and management of the sidewall openings.

Inside the barns, many calf pens are enclosed by solid panels on 3 or 4 sides, some also with covers, to minimize drafty conditions in cold weather (Holmes, 2000), and these enclosures may restrict ventilation of the pens. In addition, calves produce relatively little heat compared to adult cows, which limits the potential to ventilate the pen by thermal buoyancy. These factors could result in poorly ventilated microenvironments within the pens that house the individual calves.

During the winter of 2004, we conducted a field trial in 13 different calf barns (Lago et al., 2006) to identify housing factors associated with improved respiratory health. The prevalence of respiratory disease was determined using a respiratory scoring system wherein points are assigned for temperature, cough, nasal and eye discharge, and ear droop. The physical environments were evaluated in terms of space, temperature, humidity, bedding, ventilation rate, and other characteristics. Air hygiene in the pens and alleys was assessed using airborne bacterial counts. Based upon the findings in that study, our field investigation service has recommended a number of modifications of the calf pens, bedding practices, and ventilation. In particular, the natural ventilation of the barn has been supplemented with positive-pressure fabric air distribution ducts to ventilate the calf pens microenvironments. This paper will summarize the key findings of the field trial and the related clinical recommendations that we associate with improvements in calf respiratory health.

THE PENS ARE MICROENVIRONMENTS WITHIN THE BARN

One of the key findings of the 2004 trial was that the calf pens are microenvironments within the barn. Using an impaction-type air sampling device (airIDEAL, bioMérieux, Inc., Hazelwood, MO), the concentrations of airborne bacteria were measured in pens and alleys of barns. The device is programmed to move specific quantities of air across an agar plate, causing the airborne organisms to impact the agar. After incubation, the live organisms produce visible colonies which are counted and reported out as colony-forming units per cubic meter of air. Concentrations of airborne bacteria were evaluated as risk factors for respiratory disease, and building characteristics were evaluated for their associations with airborne bacterial concentrations.

In Figure 2, the average airborne bacterial counts for pens and alleys are shown for the 13 barns in the study. While the airborne bacterial counts in the alleys were generally considered excellent, the pen counts were highly variable. The exception was Barn L where the ridge, eaves, and sidewalls had been closed completely and the barn ventilation rate was estimated at near zero changes per hour.

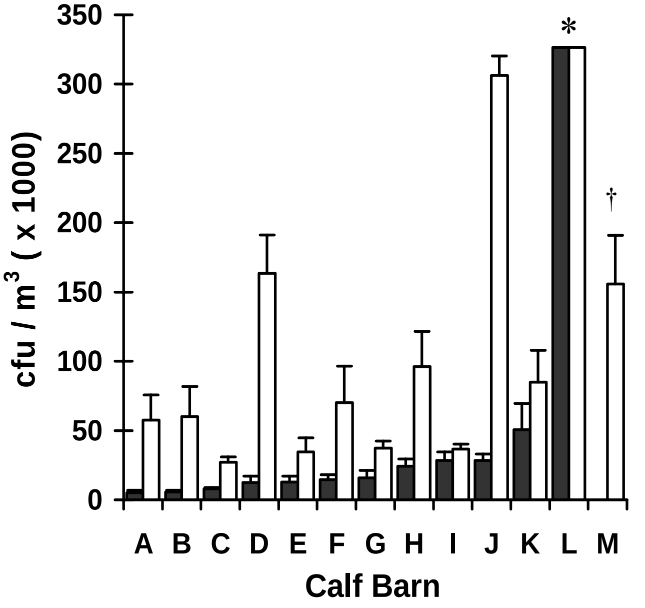

Figure 2. Average bacterial colony forming units per cubic meter of air on blood agar plates from alley (■) and pens (□) of 13 calf barns, ranked by increasing alley cfu/m^3.
* All samples from Barn L exceeded our ability to count them and were reported as the maximum countable value of 326,400 cfu/m^3.
† Alley samples were not collected in Barn M.

Barn ventilation rate was significantly associated with alley bacterial concentration, but was not significantly associated with bacterial concentrations within the pens. The barn ventilation rate (*Q total*) was calculated using estimates of thermal buoyancy-induced (*Q thermal*) and wind-induced (*Q wind*) ventilation rates summed through quadrature as described by Albright (1990). Temperature and humidity data loggers (Dickson, Addison, IL) were placed exterior to the barn under shade and in the building central alley and the data were used to estimate ventilation due to thermal buoyancy. The difference between the interior temperature minus the exterior temperature for a two-hour time period starting in late morning averaged 1.6˚C, but ranged from -4.2 to 11.8˚C. From these temperature differences, it is clear that thermal buoyancy is a minor force for ventilation in calf barns in the winter. Prevailing wind speed was measured using an Anemometer 840003 (Sper Scientific, Scottsdale, AZ), wind direction relative to the building was noted, and these factors were used to estimate ventilation due to wind.

In the study herds, the average calf barn was estimated to have an air exchange rate of 18 changes per hour (range 0-94), well above the recommended minimal 4 changes per hour during winter conditions (Bates and Anderson, 1979). The quality of air in the pens of many of the "over-ventilated" barns was poor. Based upon the values in Figure 2, a poorly ventilated barn probably assures unhygienic air within the pens. However, a well-ventilated barn does not insure hygienic air. The pens are microenvironments within the barns.

KEY HOUSING FACTORS ASSOCIATED WITH CALF RESPIRATORY HEALTH

Three factors emerged as significant in their association with reductions in the prevalence of calves with respiratory disease; a solid panel between each calf, sufficient depth of bedding for the calf to "nest", and reduced total airborne bacteria counts in pen air. The relationships between these factors are shown in Figure 3.

Solid panel between calves

The difference in prevalence of respiratory disease in pens with a wire mesh or a solid panel between each pen was substantial as shown in Figure 3. A solid panel between each calf is a traditional recommendation from veterinarians and perhaps helps to limit movement of pathogens from one calf to another. However, increasing the number of solid sides was associated with higher airborne bacterial counts, a factor adverse to respiratory health. This confounding effect will be discussed later in this paper, but the key point is that the pens should be separated by a solid panel, but the ends and top of the pens should be as open as possible.

Sufficient bedding for the calf to "nest"

Calves are vulnerable to cold stress in winter. The thermoneutral zone of a newborn calf is between 10 and 26 ºC and between 0 and 23 ºC for a 1-month old calf (Wathes et al, 1983). The field trial was conducted on Wisconsin dairies during the months of January through March. The average temperature in the barns for a 2-hour period near noon was 3.9˚C and ranged from -6.7 to 12.2˚C. Overnight temperatures would be lower. Clearly, the young calves were exposed to temperatures below their thermoneutral zone during many days and nights through the period in which the trial was conducted.

Bedding provides a potentially effective mechanism for calves to reduce heat loss. If the bedding is sufficiently deep, the calf can "nest" and trap a boundary layer of warm air around itself, which reduces the lower critical temperature of the calf (Webster, 1984). While several aspects of bedding were evaluated including type and dry matter, the factor that emerged as having a significant association with the prevalence of calves with respiratory disease was "nesting" score. Nesting score 1 was assigned when the calf appeared to lie on top of the bedding with legs exposed. Score 2 was assigned where calves would nestle slightly into the bedding, but part of the legs were visible above the bedding. Score 3 was used when the calf appeared to nestle deeply into the bedding material and legs were not visible as shown in Figure 4. Because all of the calves were not observed while lying down, a nesting score was assigned to each barn based upon the most frequently observed score.

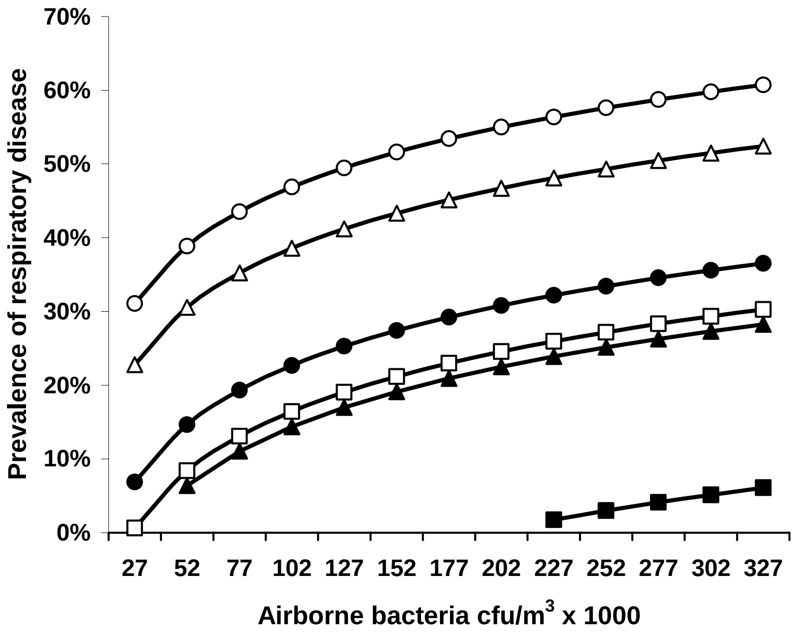

Figure 3: Model of the association between airborne bacterial concentration and prevalence of calf respiratory disease with different combinations of nesting scores and the presence or absence of a solid barrier between each pen. Nesting score 3 and presence of a solid barrier (■); nesting score 3 and absence of a solid barrier (□); nesting score 2 and presence of a solid barrier (▲); nesting score 2 and absence of a solid barrier (△), nesting score 1 and presence of a solid barrier (●); and nesting score 1 and absence of a solid barrier (○).

Low total airborne bacterial counts within the pens

Lower total airborne bacterial counts were associated with reduced prevalence of respiratory disease in the barns. The total airborne bacteria recovered on the plates are a mixed population, usually dominated by various Staphylococci, Streptococci, Bacillus, and E. coli, not considered to be respiratory pathogens. We also measured airborne coliform concentrations as counted on eosin-methylene blue differential media, but found no significant association with prevalence of respiratory disease.

The total airborne bacterial counts should not be viewed as the cause of respiratory disease, but rather as a marker of poorly ventilated spaces. Wathes et al. (1984) point out that most airborne bacteria are non-pathogenic, but that even dead airborne bacteria can be a burden to respiratory tract defenses. The actual disease stimulus could include any of many components of bacterial or fungal cellular components including endotoxin, enzymes, glucans, and others. Because calves spend 100% of their time in the pens, the exposure to the air within the microenvironment is continuous and chronic. Air that is highly contaminated with noninfectious microorganisms in work environments of people is recognized as a risk factor for respiratory disease and, although specific exposure limits have not been established, air with bacterial concentrations an order of magnitude greater than found outdoors or in "uncontaminated" areas (usually less than 10^4 cfu/m^3) is considered to be "contaminated" (Eduard and Heederik, 1998).

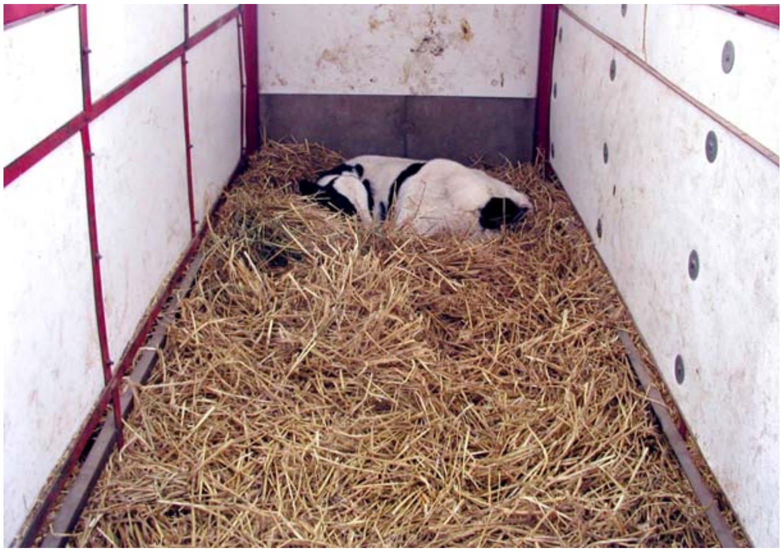

Figure 4. An example of "nesting" score 3 because the legs of this calf are completely submerged in loose bedding and not visible.

Upon hearing the points discussed above, many people will inquire about ammonia levels in the pen. Ammonia was measured and averaged 2.2 ppm across all barns, ranging from 0-4 ppm, all considered to be low levels and not associated with any respiratory problems.

TECHNIQUES TO REDUCE AIRBORNE BACTERIAL COUNTS IN PENS

Four factors were found to be significantly associated with lower total airborne bacterial counts in pen air; fewer solid sides surrounding the pen, larger area in the pens, decreasing pen temperature, and wood shavings and other non-straw bedding materials. Two of these factors to reduce airborne bacterial counts, reduced number of solid sides and non-straw bedding, are confounding with the factors to reduce respiratory disease, specifically a solid panel between each pen and deep nesting in straw bedding. In practical terms, the health benefits of a solid panel between calves and good thermal control from nesting in deep straw outweigh the effects of increasing airborne bacterial counts. The applicable points are to increase the area of the pen, place a solid panel between each calf but leave the ends and top as open as possible, and use supplemental ventilation systems to dilute the concentration of organisms within the pens.

Increase the area within the pen

Stocking density is considered to be the primary determinant of airborne bacterial concentrations (Wathes et al., 1984). Mean area of individual pens in all barns was 3 m^2 (32.3 ft^2) with a range from 2.3 to 4.1 m^2. Our data suggests that increasing area from 2.3 to 4.1 m^2 reduces the total airborne bacterial count to approximately half.

Reduce the number of solid panels surrounding the pen

The number of solid panels around the stall should be limited to two sides. Our ideal pen would have two solid sides and a short solid panel limited to about 20 inches high at the rear of the pen. Further enclosure of the pens increases airborne bacterial counts dramatically. If there are multiple rows of stalls within a barn, each row should be separated with an alley of several feet width. If they must be adjoined, a third solid side should separate the calves and additional methods should be employed to reduce bacterial concentrations.

The practice of covering the pen with a “hover” or enclosing the pen with a solid front with a small feeding access hole should be discontinued. It has become clear from this field study that it is strongly preferable to control for thermal stress by providing ample bedding rather than through enclosure.

Supplemental mechanical ventilation

Because total airborne bacterial counts are associated with the prevalence of respiratory disease in young calves, a number of techniques have been tried in our clinical services in problem barns. The most successful intervention has been the installation of supplemental positive-pressure ventilation systems as shown in Figure 5. Fresh, outside air is forced into a positive pressure duct system and directed downward into the pen microenvironment. Compared to metal ductwork, we have usually recommended fabric or polyethylene vent tubing because of cost savings.

The goal is to introduce small volumes of fresh air into the microenvironment without creating a draft. Drafts are described as air speeds of greater than 50 ft per minute (Wathes et al., 1983).

In general terms, the supplemental installations have been designed with the following general specifications. Fresh air is delivered to each pen at an approximate volume of 15 cfm per calf. This volume of air is consistent with traditional ventilation recommendations for mechanical systems (MWPS-32, 1990). The fans are mounted in exterior walls and the tubes are fixed directly to the fans, preventing any recirculation of interior air. The air distribution tubes are attached to suspended cables stretched between support walls.

The custom-punched holes are sized so that air is expected to exit the holes at a speed of approximately 800-900 fpm. The tube suppliers usually offer a range of hole diameters ranging from 1 to 3 inches. If air exits two holes of different diameters at precisely the same speed, the air emerging from the larger diameter hole will have the greater “throw” distance. Assuming that the recommended exit velocity has been observed, we recommend 2.0” holes if the calves are within 11 ft of the tube, 2.5" holes if within 12-15 ft from the tube, and 3" diameter holes if the calves are more than 16 ft from the tube.

The holes are punched as various clock locations. The higher above the pens, the more vertical the hole location. If the bottom of the tube is located 8 to 12 ft above the floor, holes are usually punched at 4 and 8:00 o'clock positions. If higher than 12 ft, the locations of the holes are usually 5 and 7 o'clock.

The positive-pressure tubes can provide supplemental ventilation to microenvironments in both natural and negative-pressure systems. One complication has been identified using the tubes within wind-tunnel calf barns. Clinical investigations have shown high airborne bacterial counts within solid sided pens in wind-tunnel barns where air traveling across the tops of the pens exceeds 250 ft per minute. Efforts to direct small volumes of air from a distribution duct have failed in these situations, presumable because the air coming from the positive-pressure duct gets caught in the wind-tunnel air stream and never reaches the microenvironment within the pen. In these situations, the exhaust capacity of the negative-pressure wind tunnel system must be reduced substantially for the supplemental system to work.

Figure 5. Interior of a naturally ventilated calf barn with 4-rows of individual calf stalls. Two positive-pressure air distribution duct systems have been installs to deliver small volumes of fresh, outside air to each pen within the barn.

CONCLUSION

Individual calf pens should be viewed as microenvironments within the calf barn and ventilating the barn does not insure ventilation of the pen. In cold weather when the young calf is frequently exposed to temperatures below it's thermoneutral zone, three key housing factors associated with respiratory health are a solid panel separating each calf, deep straw bedding that allows the calf to "nest", and low airborne bacterial concentrations in the air in the pen. Practical approaches to reducing the concentrations of total airborne bacteria in the pens include making the pens larger, reducing the number of sides and eliminating covers from the pen, and through the use of supplemental positive-pressure ventilation systems to direct small volumes of fresh air into the pens. Clinical experiences show that these approaches are typically successful in achieving significant reductions of endemic calf pneumonia frequently found in modern naturally ventilated calf barns.

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