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Calf Housing and Environments Series

IV. Effects of Hutch or Pen Environment on Pre-Weaned Calf Health, Welfare, and Performance

The calf's environment should allow for thermal comfort, physical comfort, disease control, and behavioral satisfaction(Webster, 1983). There are many different hutch systems in which to raise calves successfully, and over the last 40 years quite a bit of research has been devoted to comparing different rearing systems and understanding their advantages and limitations. This factsheet will summarize research that bears on the issues of disease control, comfort and behavioral satisfaction, and provide some evidence for current calf housing recommendations.

Ventilation

When most people first consider the calf's environment, they think about ventilation. The quality of the air surrounding the pre-weaned calf can be spoiled with manure gases (such as hydrogen sulfide and methane),(Hillman et al., 1992) ammonia from the breakdown of nitrogenous wastes in urine and manure, dust from bedding and feed, as well as airborne bacteria, fungi, and endotoxins (from the breakdown of bacterial cell walls). In addition, respiration as well as excretion, contributes to environmental humidity. The function of ventilation is to remove heat, "fouled" air, and humidity, and replace it with fresh air. If ventilation is not adequate, respiratory disease is one of the possible consequences.

Respiratory disease pathogens include *Mycoplasma*, IBR, BVD, PI3, *Pasteurella*, and *Mannheimia*. Many of these pathogens live in the respiratory tract of calves without causing pneumonia. Factors that influence respiratory disease in calves include: 1) survival and spread of organisms in the air, 2) clearance of organisms within the respiratory tract, 3) clearance by the animal of these organisms (through local resistance), and 4) systemic resistance to infection (such as through vaccines) (Webster, 1983). Ventilation has an effect on the survival and spread of organisms in the air and although most airborne bacteria are not pathogenic, in large numbers they can overwhelm the clearance mechanisms inherent within the respiratory system.

Ventilation can be accomplished mechanically or naturally (through hot air rising or wind), and can remove heat from the calves' environment. The most important concept in ventilation is the number of air exchanges per hour. In one study, medical treatments increased by 60 percent as air exchanges decreased from 4 per hour to 1 per hour (Bates & Anderson, 1979). Ventilation systems should provide for a continuous level of air exchange to remove moisture, temperature control for air exchange to remove body heat, and air velocity to remove large amounts of heat during hot weather (Graves, 1995).

There is a large body of literature devoted to ventilation within barn structures used to house calves but little information on ventilation within calf hutches. Logically, though, solid fronted pens and pen covers reduce air speed around the calf (Roy, 1980). In a study of air exchanges within different hutches, Hoshiba et al. found that if more than one-third of the front area of a hutch was covered, air exchange rates decreased 2.5 to 7 times (Hoshiba et al., 1988).

Ammonia-- Concentrations of ammonia found in cattle housing are usually less than 100 ppm, however, the average person can sense ammonia levels at 5 ppm to 20 ppm (The Fertilizer Institute, 2010). The major impacts are eye and respiratory irritation but ammonia can play a role as a chronic stressor affecting the health of calves by directly affecting the mucocilliary transport mechanism in the respiratory tract – responsible for clearing dust and bacteria.

In a Danish study, calves were moved into 1 of 3 houses: 1) insulated and mechanically-ventilated housing heated with heated air, 2) insulated with controlled natural ventilation system of openings in the walls and roof, and 3) uninsulated and naturally-ventilated with perforated aluminum walls (Blom et al., 1984). The uninsulated, naturally-ventilated house had lower CO_2 and ammonia levels over time, and numerically lower incidence of respiratory disease. Thus, natural ventilation can serve to remove gases and result in lower disease incidence.

Airborne Bacteria and Dust -- Dust particles not only cause irritation to the respiratory tract but can also carry pathogens, other bacteria, and endotoxins. In the Danish study of the three different housing types the uninsulated, naturally ventilated barn had the least airborne bacteria and fungi (Blom et al., 1984). Airborne bacteria levels of crated veal calf units were monitored for 16 weeks in another study that found that bacterial numbers in the air were positively correlated with absolute humidity (Wathes et al., 1984). Hoshiba et al. found that airborne bacterial counts decreased from 1,100 BCFP/10L in the middle of the dairy barn, to 520 in calf pens within the dairy barn, to 44 within a plastic hutch, 15 within a plywood hutch, and 4 in a plywood hutch without a back wall (Hoshiba et al., 1988). The conclusion is that better ventilation (outside air) had fewer hazards.

Filtering air entering a calf barn can reduce both incidence and severity of clinical and subclinical disease in calves (Pritchard et al., 1981). In hutches, typical airborne bacterial counts were 20,000 cfu/m^3 but exceeded 100,000 cfu/m^3 if bedding was disturbed (Nordlund, 2008). In addition, airborne dust particles less than 5 microns can reach the deeper lung tissue and are regarded as potentially hazardous. The prevalence of respiratory disease is higher with higher total bacteria counts. Bacterial counts tend to be lower in larger area calf pens, higher with higher pen temperatures, higher with straw bedding vs. other bedding materials, and higher with a greater number of solid panels making up the individual calf pens (Lago et al., 2006).

Endotoxin -- Lipopolysaccharide, or endotoxin, comes from the breakdown of Gram-negative bacteria cell walls. Human inhalation of endotoxins can result in respiratory tract irritation and flu-like symptoms with fever (Thorn et al., 2002). Intravenous endotoxin causes fever in calves (Borderas et al., 2008), but there is little known about inhaled endotoxin effects in cattle. It is suggested, that in feedlot cattle, airborne endotoxin contributes to acute interstitial pneumonia (Woolums et al., 2001). For workers, over an 8 hour period, a European recommended health-based exposure limit is 50 EU $^{m-3}$ and dairy facilities can sometimes exceed this level (Dungan & Leytem, 2009). A study of agricultural workers showed that exposure to dust and endotoxin was associated with respiratory tract inflammation (Burch et al., 2010). It would be logical to conclude that these environmental contaminants could contribute to disease in neonatal calves by inciting inflammation as they do in people.

Draft -- Draft in cold weather can add to chilling, particularly with damp bedding or a wet calf. In a Swedish study, draft was assessed for each calf pen using a smoke bottle. A draft was considered to be a wind velocity greater than 0.5 meters per second in the pen (Lundborg et al., 2005). Calves in drafty pens were almost four times more likely to exhibit moderate to severely increased respiratory sounds compared to calves in draft-free pens.

Ventilation in calf rearing facilities should remove heated air, moisture (humidity), toxic gases, dust, and endotoxins; airborne contaminants that can lead to respiratory disease. Recommended air exchange rates in a calf barn are 4 to 15 exchanges per hour, or about 10 cubic feet per minute per calf in the winter and about 30 cubic feet per minute in the summer.

Resting, Lying, Bedding, and Hygiene

Calves need enough space to attain total relaxation and rapid eye movement (REM) sleep. Their environment also needs to be sufficiently warm for temperature regulation and to attain REM sleep. Behavioral cues to comfort and welfare in the calf's environment include: the ability to lay with legs outstretched and oral activities (tongue rolling, scratching or licking of objects, grooming), and social interactions (Le Neindre, 1993). However, there appears to be disagreement among investigators as to which oral activities really indicate poor coping with their environment. It is clear from welfare guidelines that, at a minimum, calves should be able to stretch their legs while lying.

Surfaces upon which calves lie have two functions – as a comfortable resting area and as a clean or cleanable surface. Calves in hutches may be on slatted floors above a flush or clean-out area, on the ground or on gravel with bedding. Calves on slats may develop more leg and feet problems (Stull & Reynolds, 2008). Bedding provides an absorptive surface as well as insulation from the cold (Bourne, 1969). A low "nesting score" (less bedding), has been correlated with more respiratory disease in pre-weaned calves in cold barn housing (Lago et al., 2006).

Little work has been done to quantify the effect of hygiene of the calf facility with calf health and performance. Hygiene, specifically sanitation of housing between calves, should be common practice but there appears to be no standard method of disinfection. In a study we did looking at multi-drug resistant fecal *E coli* from neonatal calves on 33 different farms, calves in operations where the hutches were scraped between calves and those where they cleaned underneath the hutches had lower levels of multi-drug resistant *E coli* (Berge et al, unpublished data). This likely indicates that cleaning reduced exposure to these bacteria. In a study of calf diarrhea, cleaning housing between calves decreased their risk for *Coronavirus* infections by six times (Bartels et al., 2010).

In addition to cleaning hutches between calves, allowing the area upon which the hutch resides to "rest" between calves is advised. Flipping hutches up after cleaning, or moving them to new "ground" will allow the sun exposure to pathogens. *Cryprosporidia*, and other pathogens, are susceptible to ultraviolet light from the sun as well as dessication (Moore, 1989).

What size of pens should be recommended for individual calves? Although welfare guidelines are clear about calves being able to stretch their legs, there is some evidence to support wider width pens for individual calves. Two different width pens with different surfaces were compared for calves' weight gain and feed conversion up to and just after weaning (Fisher et al., 1985). Calves in 4.46 ft pens on straw bedding gained more post-weaning compared to calves in 2.17 ft wide pens with a grated floor (2.0 lb/day vs 1.6 lb/day).

Cold Effects

Much of the early literature on calf housing dealt with keeping calves warm in cold environments and addressing issues of the lower critical temperature of calves (0°C or 32°F). Recent research from Norway correlated calves born in winter with a greater risk of developing diarrhea (Gulliksen et al., 2009). Most of the research and extension information for winter management of calves has been focused on meeting the increasing energy demands (by increasing dry matter intake) during cold weather, but there are some environmental management practices that might be useful.

Hutches and other housing structures should provide protection from cold stress due to wind, as well as a resting area for calves to keep warm. Bedding can help calves maintain body heat, as does an erect hair coat, which provides an insulating layer (McFarland, 1996). Keeping the hair dry is important for the calf to retain heat. In addition to staying dry, sufficient bedding, blocking drafts, heaters and increasing dry matter intake, other means to keep calves warmer, such as calf jackets or blankets are available.

Heat loss through ventilation in a calf barn can be controlled. However, the warmer the air temperature is, the more moisture it can hold, thereby increasing the humidity (Bourne, 1969). Calves are remarkably cold tolerant and can effectively withstand cold when recumbent (Rawson et al., 1989). Metabolic rates and, hence, energy needs, are higher in colder weather or climates once calves are below their thermal comfort zone. Orientation of calf housing for cold months in North America should have the fronts of hutches or open sides of shelters oriented southeast (McFarland, 1996) or south so as to maximize low winter sun exposure.

Heat Stress

There is quite a bit of research on heat stress effects on lactating cows and some information on transition cows (Collier et al., 1982; Cook & Nordlund, 2007; Cook et al., 2007; Urdaz et al., 2006). Less information is available for the young calf but the body of literature that is available provides good evidence of the importance of heat stress mitigation for this age group. There are specific heat stress effects on young calves themselves but also, in a follow-up study of calf-rearing practices' associations with subsequent first lactation, higher humidity and temperature created an environment that increased heifers' age at first calving (Heinrichs et al., 2005), a known economic cost to the dairy producer.

The thermal neutral zone is narrower for young calves compared to cows (National Research Council, 2001). The upper end of the thermoneutral zone for calves appears to be about 29°C (84°F) and heat stress can occur at temperatures greater than 32°C (90°F) at 60 percent humidity (Gebremedhin et al., 1981; Neuwirth et al., 1979). When the calf's total heat gain exceeds its ability to lose heat, heat stress develops and can result in impairments in the calf's physiology and behavior. Heat stress (as measured by a combination of temperature and humidity) can have effects on a number of different calf-rearing outcomes. Rectal temperature of the calf appears to be one measure of heat stress but the increases in body temperature are small with rising ambient temperatures. Skin temperature at different sites has been used to measure heat stress but is an even less sensitive measure in calves (Spain & Spiers, 1996). Respiratory rate may be the most sensitive, easily-obtained measure of heat stress in calves (Findlay, 1957).

Mortality rates are certainly one measure of the effects of heat stress. Two years worth of rendering company data were used to assess average daily temperature effects on cow and calf mortality (Stull et al., 2008). From 2003 to 2005, average daily temperatures at the extremes were associated with higher death loss among calves and cows. At temperatures above 25°C (77°F) and below 14°C (57°F) calf death losses were highest. The changes in calf mortality observed during this time period were larger than those observed in cow deaths for the same changes in temperature.

Body weight gain of calves is another indirect measure of the effects of heat stress. Calves born in the summer and raised in outdoor hutches on whole milk gained significantly less weight compared to calves born in fall in a temperate climate (Broucek et al., 2007). These lower body weights remained until at least 180 days of age. Calves reared in a hot temperature of 27°C (80°F) gained 19 lbs less in three months than calves raised at a cooler temperature of 10°C (50°F) (West, 2003).

An individual hutch is designed to provide shelter from the elements, primarily precipitation and cold. However, some designs, such as some plastic hutches, may accumulate heat and contribute to heat stress. Lamb et al. noted that the temperature of polyethylene domes tended to average 5-10°C higher than wooden hutches during a yearlong study (Lamb et al., 1987). A Pennsylvania study evaluated temperatures inside and outside hutches as well as rectal and skin temperatures of calves in wooden hutches (painted white or black) and polyethylene domes (with or without supplemental shade) (Lammers et al., 1996). Hutch surface temperature (inside and out) was significantly higher for black wooden hutches (104°F and 100°F), followed by polyethylene hutches and then white wooden hutches. Relative humidity was also higher in the polyethylene hutches. In this study, calf rectal temperature was not a very sensitive measure of heat load but the skin temperature (using an infrared thermometer) of a black spot on the calf did appear to be a sensitive measure. Skin temperatures were highest on calves in polyethylene hutches without shade (103.3°F), followed by polyethylene hutches with shade (101.5°F), black wooden hutches (99.1°F), and white hutches (98.8°F). Respiratory rate was also a sensitive measure and was significantly lower in wooden hutches (57 and 65 breaths per minute) compared to a polyethylene hutch with shade (72 breaths per minute) and without shade (97 breaths per minute). Calves in white wooden hutches and those with shade also ate more starter grain. Opening the vents of the polyethylene hutches did not appear to affect the inside air temperature or relative humidity.

Another study evaluated several different housing types and the effect on heat stress in calves (conventional wooden hutches with an outdoor pen ,enclosed molded polyethylene domes, and thermo-molded opaque polymer hutches with ridge-top ventilation systems, and an outdoor pen (Macaulay et al., 1995). The polyethylene domes were warmest (maximum temperature of 32.7°C) followed by wooden hutches (maximum temperature of 29.28°C) and then polymer hutches (maximum temperature of 26.28°C).

Some remediation of heat stress may be necessary. Shade is likely the most cost-effective way to mitigate hutch-calf heat stress but has been evaluated in only a few studies. In Arizona, investigators evaluated calf health in three different housing systems: hutches made of a square tube and corrugated steel, corrugated metal shade and the same metal shade with an evaporative cooling system (Stott et al., 1976). The daily peak temperature humidity index (THI) ranged from 80-88 during this experiment. Serum cortisol levels decreased as calves aged but were significantly higher in calves in hutches. Hutches had the highest peak THI compared to the other two housing systems. The high heat and humidity of calves in the hutches was associated with immunoglobulin absorption and one indicator of stress. Mitigation, through the shade and/or evaporative cooling was beneficial.

In Missouri, calves were housed in commercial plastic hutches with or without a shade structure of 80 percent barrier to solar radiation located 2.1 m (6.9 ft) above the ground (Spain & Spiers, 1996). Air temperatures were 2°C lower in the hutches but hutch surface temperature was 5-10°C lower in shaded areas. Rectal temperatures of the calves increased less in shaded hutches as outside air temperature increased. Respiratory rate was, on average, 10 breaths per minute higher in unshaded calves. The increase in respiratory rate occurred at air temperatures greater than 26°C (79°F).

In a study of supplemental shade (80% shade cloth suspended 7.4 ft) over polyethylene calf hutches in Southeastern US, the added shade decreased the temperature by 7°C in the late afternoon (Coleman et al., 1996). Humidity did not increase within the hutches. The shaded calves had a better feed:gain ratio (0.53 vs 0.70). In a study of feedlot calves, respiratory rates for shaded animals were, on average, 16 breaths per minute lower than those of un-shaded animals (Eigenberg et al., 2005).

An easy way to help mitigate heat stress is to maximize shade available to calves. Orientation of hutches during summer months in hot climates should be to the north, so as to maximize shade for the calf. To improve summer ventilation of calf hutches that are set on the ground, the back of the hutch can be elevated using a concrete block. Calf barns utilizing natural ventilation, with an open ridge-vent and sidewall openings, are best oriented so that the ridge runs perpendicular to the prevailing winds (McFarland, 1996).

Summary

From all the research evidence on raising calves in different kinds of facilities, it still boils down to choosing the best method for the specific climate, having the correct location on the farm and having control over ventilation, draft, cold, heat, and welfare aspects of young calf housing.

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