# Dairy Calf Housing and Environment:
## *The Science Behind Housing and On-Farm Assessments*

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# Dairy Calf Housing and Environment: The Science Behind Housing and On-Farm Assessments

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# Introduction

This publication provides the background and science behind current recommendations for dairy calf housing and environmental management. It also includes an assessment tool for evaluating a calf's environment from birth through weaning. The ultimate goal of sharing this information is to improve the health, welfare, and performance of young dairy calves.

Additionally, we will summarize the research that has been done on the affects of the environment on morbidity and mortality rates in neonatal calves, placing special emphasis on the subject of calf hutches. We will also summarize the research done on the welfare aspects of social isolation of calves (Weary and von Keyserlingk 2008), along with the requirements for group housing, and, finally, how to assess or evaluate the dairy calf's environment, particularly in the intensively managed U.S.-style calf-raising facilities in the West.

The process of successfully raising dairy calves as replacement heifers or dairy beef has improved greatly over the past 6 decades as research has improved our understanding of calf physiology, disease, nutrition, immunology, and therapeutics. The U.S. dairy industry has reduced mortality rates in pre-weaned calves from more than 11% (USDA 1994) to 7.8% (USDA 2010) over the last 15 years. The organization of professional dairy calf raisers has set new goals for producers, such as achieving pre-weaning mortality rates of less than 5% (DCHA 2010).

Although colostrum management and nutrition play vital roles in calf health, the environment also plays an important role. For example, the environment can adversely affect the calf-raising system by encouraging pathogen growth or by stressing the calf itself. The environment also plays a role in the behavioral welfare of the calf. As a result of stress and disease, heifer survivability in the herd and its first lactation performance can be reduced. The environment also influences a calf's exposure to disease agents and affects its ability to fight infection.

We say that a calf's environment should be clean, dry, comfortable, and adequately ventilated in order to raise healthy calves. But how do we go about assessing these factors? The environment is one part of the epidemiologic or disease triad (Figure 1), along with the causal agents of disease and certain host factors that play a role in the development of disease. Dairy and veterinary professionals have determined that there are five basic requirements for successful calf housing: it must be dry, draft-free, and properly ventilated; it must provide easy access to feed and water and to calf handling and treatment; and it should be easy to clean and sanitize (Davis and Drackley 1998). Moreover, for decades, the recommendation has been to isolate neonatal calves to prevent contact and spread of disease.

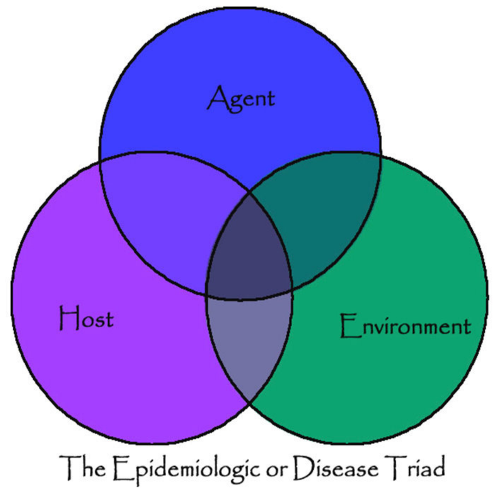



*Figure 1. The epidemiologic or disease triad.*

Factors that can affect calf health and performance include the calf's genetic make-up, colostrum quality, calf viability after delivery, and feed type. Other factors include the caretaking personnel, the money spent for calf care, the "bugs" or pathogens in the environment, and the environment and facilities themselves (Figure 2). All these factors enhance or detract from the health, welfare, and performance of young dairy calves.

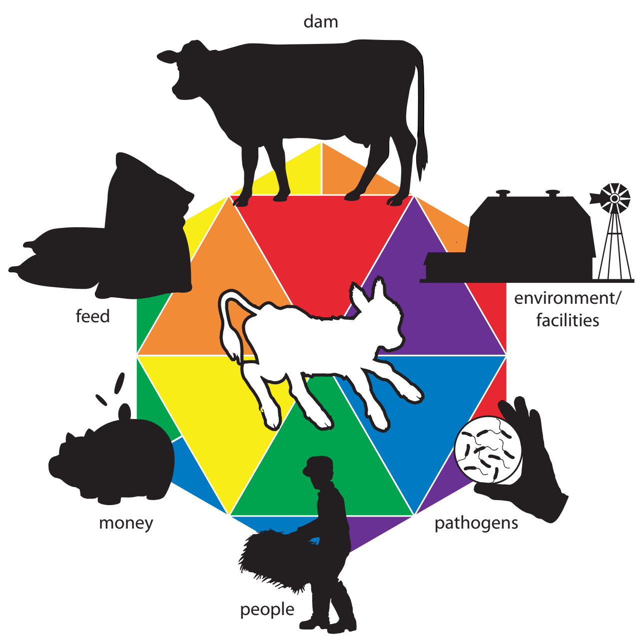



*Figure 2. Factors affecting calf health and performance.*

# Chapter 1. Hutches and Other Pre-Weaned Calf Housing

This chapter examines the evolution of pre-weaned dairy calf housing over the last 50 years. There are many ways to house pre-weaned dairy calves, and housing design plays an important role in optimizing calf health (USDA 2010). Individual hutches, group pens, greenhouses, tie stalls, dry lots, and pastures are common types of housing found in the United States (USDA 2010). Through research, we have learned that isolating young calves is vital to minimizing their exposure to pathogens and decreasing their rate of disease and death (Quigley et al. 2001).

## The History of Calf Housing

To understand how individual calf pens and calf hutches evolved, we must first look at the reasons calf isolation was thought to be the best method for raising dairy calves. In 1938, Olson recognized that dairymen thought it was a smart management practice to remove the calf from its mother immediately. This thinking was primarily due to the difficulty in training the calf to drink from a pail once it had learned how to nurse (Olson 1938). In the 1950s investigators found that if calves were allowed to nurse in open pens, there were increased occurrences of scours (Moore and Gildow 1953). There was a belief that feeding calves excessive amounts of milk was a frequent cause of scours on dairy farms. The rule of thumb was that a calf should not receive more than 10 pounds of whole milk per 100 pounds of live weight per day, divided into two equal feedings. If a calf got an excessive amount of milk in its rumen, such as when drinking from a bucket, this often resulted in spoilage or bacterial decomposition that eventually aggravated the calf's digestive tract, resulting in calf scours (Moore and Gildow 1953).

The need to control calf feedings led to the push for individual calf housing. If calves and dams were housed separately, producers were able to control many factors that affected the young calf and its health (Porter et al. 1961). Individual pens allowed for control over many environmental factors, such as cleanliness, ventilation, dampness, drafts, light, and pen congestion. Using individual pens or hutches also kept calves from suckling one another, which helped prevent the spread of mastitis (Moore and Gildow 1953).

Fifty years ago, dairy herds were smaller than they are today (USDA 2010). At that time, it was common to find calves and heifers housed in the same barns and buildings as the milking herd (Otterby and Linn 1981). Calves on these farms were often divided into groups of 4, 5, or 6 and housed in one pen. Calves would either be tied by neck ropes to the perimeter of the pen or housed in individual tie stalls 3 ft x 4½ ft in size, until 6 weeks of age (Porter et al. 1961). The advantages of these stalls included the availability of hay racks and feed boxes, which encouraged calves to start eating solids sooner in life. These stalls allowed more calves to be housed in less space and reduced the need for supplementary heat during the winter months.

## Changes in Calf Pens and Hutches Due to Herd Size

As the size of dairy herds increased, the way calves were housed and raised changed (Figure 3). Dairy farmers began using separate facilities or attempted to adapt existing facilities (Otterby and Linn 1981). However, as herd size increased, so did the incidence of respiratory disease and diarrhea in calves. Inadequate housing systems for calves led to research on and development of facilities consistent with good health, optimal growth, labor efficiency, and low construction and remodeling costs. As an example of the initial research, in 1954, Davis et al. compared individual, outdoor, portable pens to conventional barn housing. Although calves housed in outdoor pens were exposed to lower temperatures, for example, 9° F, they showed significant weight gain and fewer *Coccidian* and other parasite infections. They also had less diarrhea compared to barn calves. Calves that were housed in the barn had some form of respiratory disease compared to only one calf in

*Figure 3. Calf in a tie stall found in old-style confinement housing.*

the outdoor pens. On the basis of this information, researchers concluded that individual housing was better for calf health (Davis et al. 1954).

In the 1960s elevated stalls became a more common type of calf housing on dairy farms. These stalls had a stanchion or chain to hold the calf's head. The stalls had slatted floors that allowed urine and feces to fall away from the calf. These stalls were smaller than other conventional indoor types of housing, which commonly measured around 4 ft x 6 ft (Schmidt and Van Vlek 1974). These stalls were used primarily when calves were being fed milk-only diets. A major advantage of these elevated stalls was that they could be cleaned thoroughly after calves were removed and could be moved outdoors when not in use. Calves were also being housed outdoors in small hutches that were enclosed on three sides and had a burlap curtain over the doorway. Some dairymen were also using free stalls for calves and even though they were considered free stalls, calves on milk diets were still restrained for a short time after each feeding to prevent them from suckling one another (Schmidt and Van Vlek 1974).

In the 1970s numerous publications attempted to set standards for satisfactory housing for dairy animals that was based on research and field experience (Otterby and Linn 1981). Cleanliness, isolation of small calves from the milking herd, low humidity, protection from drafts, dry beds, and provisions for ventilation and shade were considered vital for growing calves and heifers. These publications also recommended that calves on a liquid diet be housed in individual pens or stalls, as well as calves at weaning. Additionally, they recommend that calves be sorted and placed in group pens with a limited number of animals of the same age and size. Papers presented at the 1973 Dairy Housing Conference described calf housing in many different forms. The size and style of calf pens varied from elaborate and expensive structures to improvised and inexpensive pens made from straw bales (Appleman and Owen 1975). With this housing, three factors determined per-calf floor area: whether bedding was used, the frequency that bedding was changed, and what humanitarian considerations were employed. Individual, elevated stalls commonly measured around 2 ft x 4 ft and were constructed on wood-slatted or steel-screened stall floors. One report noted that 150-pound calves preferred a 2.2 foot-wide stall over a stall that was 1.8 ft wide, and both these stall widths were preferred over the 1.5 foot-wide stalls. Recommendations from the 1973 conference suggested that solid pen walls were best at preventing excessive drafts and at preventing calves from suckling one another.

By the 1980s even though in certain areas of the United States dairy farmers were still housing calves with the milking herd, separate housing was becoming more popular, especially as herds increased in size (Otterby and Linn 1981). Dairy farmers used two types of barn structures for housing calves: a cold, uninsulated building with open eaves and open ridge-type natural ventilation and a warm, insulated, mechanically ventilated barn. For calves on liquid diets, individual stalls or pens were common. Elevated stalls made of steel or wood were used to keep calves clean and dry and were constructed with slatted flooring that eliminated the need for bedding. Individual housing was also popular because it minimized the spread of infectious organisms; however, these buildings, if improperly ventilated, could cause respiratory problems (Bates and Anderson 1979).

Calves raised for veal have received much attention because their housing greatly affects their welfare. For example, in the 1960s, Ruth Harrison published a book on animal welfare. She reported that while veal was in high demand, the manner in which it was raised often turned out to be inhumane. Veal calves were frequently put in very small pens where it was difficult for them to lie down (Harrison 1966). They were often housed in dark barns where pens were covered with lids that increased the darkness. The theory was that immobility increased the rate of growth, and darkness favored the production of white flesh. While a majority of the farms she visited were far from acceptable, there were a few progressive farms that used higher calf-care standards.

For instance, these farms provided ample space for calves (20 $ft^2$), which allowed them to get up, move around, lie down, and stretch their legs fully.

By the 1990s veal calves were raised in a variety of housing systems (Le Neindre 1993). One typical housing system used individual crates for calves. These crates ranged in size from 1.8 ft x 4.9 ft to 2.6 ft x 5.9 ft Another system tethered calves in tie stalls. The width of a tethering stall ranged from 1.6 ft to 2.3 ft, and it had small partitions between calves to prevent cross-suckling behaviors. Another type of housing was group housing on slatted floors, although this system was not often used (Le Neindre 1993). Some dairy farmers and calf raisers used veal systems or an adaptation of it to raise heifer calves.

## Current Calf-Housing Systems Used on Dairies or Calf Ranches

Calf housing today plays a vital role in calf health, welfare, and performance, and in a producer's ability to maximize the number of heifers entering the milking herd. Current housing criteria require that calves be housed in a dry area without direct contact with other calves, along with bedding that is dry and deep enough to keep calves warm during cold weather. Individual pens or hutches are also recommended for pre-weaned calves.

According to the USDA NAHMS Dairy 2007 report, most calves in the United States are raised in individual pens or hutches (Table 1). Hutches are four-sided pens usually constructed of fiberglass, polyethylene, or wood. They typically rest on well-drained soil and are often attached to a small outside run, which allows calves to choose between an outdoor or indoor environment. Calves are either tethered to the hutch or roam the fenced area attached to the front of the hutch. Individual, elevated pens are still used today. They typically have expanded wire or slatted wood floors and are placed over a flush system that washes waste away from the calves.

## Pre-Weaned Calf Housing Designs

There are many companies that offer calf hutches of different sizes and shapes as well as different ventilation systems (Figure 4).

*Table 1. Type of housing used for pre-weaned heifers by percent (USDA 2010).*

| Housing Type | Pre-Weaned Heifers (%) |
|---|---|
| Tie stall/stanchion | 12.1 |
| Free stall | 5.6 |
| Individual pen/hutch | 74.9 |
| Dry lot/multiple animal, outside area | 5.2 |
| Multiple animal, inside area | 23.6 |
| Pasture | 6.3 |
| Other | 1.5 |

Many producers construct their own hutches, usually from wood (Figure 5). This allows them to add individual features they might not get if they purchased a pre-manufactured hutch.

Shelters of various kinds have been designed and are used by dairy farmers (Figure 6).

Producers who want to raise calves in a barn have a variety of options for creating individual pens (Figures 7 and 8).

*Figure 4. Plastic hutch options: (A) poly dome, (B) hutch with metal run, (C) individual hutch, (D) hutch with a tether, and (E) hutch with wire run.*

*Figure 5. Wooden hutch options: (A) elevated triplet hutches, (B) individual wood hutches, (C) triplet hutches, and (D) individual hutches with metal roofs.*

*Figure 6. Covered individual hutches.*

*Figure 8. Multiple individual pens in a barn.*

*Figure 7. Single individual pen in a barn.*

Raising dairy calves on pasture is becoming more common as producers look for alternative ways to reduce energy costs associated with raising feed crops (Figure 9). This practice is used more commonly with weaned heifers than with pre-weaned heifers. However, with automated “mob” feeders for delivering milk or milk replacer, this option may become more viable.

Since 1988 greenhouse barns have been used to house livestock in the United States.  Prior to this, greenhouses had been used only in Europe (Figure 10).

To learn more about housing designs, ventilation practices, layouts, and cost comparisons, visit the Midwest Plan Service website: http://mwps.org/stores/mwps/files/Free/aed_40.pdf.

*Figure 9. Heifers being raised on pasture.*

*Figure 10. Greenhouse calf barn. Photo courtesy M.M. Schutz, Purdue University.*

# Chapter 2. The Maternity Pen (A Calf's First Environment)

In this chapter, we will discuss the first 24 hours of the calf's life and its relation to the calf's environment, health, and welfare. A review of maternity pens (the calf's first environment), dam and calf separation, and transportation of young calves is also included.

Research shows that the first 24 hours of a calf's life are the most critical. Newborn calves have an immature immune system, leaving them vulnerable to viruses and bacteria (University of California Cooperative Extension 2000). The USDA reports that young calves have the highest rates of morbidity and mortality than any other age group on the dairy (USDA 2010). So it makes sense that calving should take place in an environment that gives them the best start.

## Delivery to the Maternity Pen

Most dairy producers, about 70%, have a separate calving area, defined as "an area separate from housing for lactating cows designated specifically for calving" (USDA 2010). Some benefits of using a separate calving area are that it allows workers to maintain close watch over an expectant mother, provides additional help with calving, if needed, and improves the chances of preventing injuries to animals and workers (Croney et al. 2009). It is essential to provide the cow with a disinfected, well bedded, and well ventilated area, and enough room to deliver her calf (University of California Cooperative Extension 2000). The recommended size for maternity pens ranges from 100 $ft^2$ to 150 $ft^2$ per animal (Graves et al. 2006; USDA 2010). Flooring can be rubber, sand, dirt, concrete, or clay (Kammel and Graves 2007; Mee 2008). Clay, sand, or dirt flooring is preferred because it provides better footing for the cow and clean up is relatively easy (Kammel and Graves 2007). On top of the flooring, about 6 in. of bedding material should be placed to make a comfortable resting area for delivery. Straw is recommended (Mee 2008) and, according to a survey done of Michigan producers, 88% of them use this material (Frank and Kaneene 1993).

Adequate ventilation is also necessary to provide healthy air quality, which can decrease newborn morbidity and mortality by eliminating ammonia and hydrogen sulfide gases, moisture, microbes, and heat (Moore 1993). In naturally ventilated areas, the recommendation is to use open, high-sided buildings with a peaked, ridge-vented roof, to allow warm air to exit quickly (Southern California Edison 2004). The building should be arranged to allow wind to blow through it. Using 10 circular, 4-foot fans per 100 cows provides additional air movement and cooling. To prevent heat stress and protect calves from the elements, providing shade, via a roof, is recommended. For mechanically ventilated areas, a minimum of 4 air exchanges per hour is recommended (Bates and Anderson 1979).

Adequate light is required to allow for close observation of delivery. If pens are located in a barn, 25 to 30 foot-candles (fc) of light are recommended (Graves et al. 2006). For general observations, 20 fc are adequate. However, if surgery, such as a C-section, is required, 100 fc are recommended (Southern California Edison 2004). Fluorescent or metal halides are the best types of lighting for this. Portable halogen lights can provide additional lighting, if needed, when assisting with difficult births or performing surgery.

There are several options for calving areas or pens in terms of location and design. The main goal for the calving area is to minimize both stress and disease. Calves born in maternity pens have lower mortality rates compared to other indoor calving locations (Waltner-Toews et al. 1986b). However, if the maternity area is used as a hospital pen more than once a month, there is a 0.5% increase in cows testing positive for *Salmonella* spp. (Fossler et al. 2005). Based on this information, it seems essential to have the maternity area dedicated specifically to calving. The most common practices are to use individual- or group-calving pens (Figure 11).

Multiple or group calving pens are designed to hold 6 to 10 pre-parturient cows, with each cow and calf

*Figure 11. Example of group calving pen.*

pair removed from the pen just after calving (Graves et al. 2006). In a national survey, the majority of producers used a group calving pen (USDA 2010). Another survey found that many larger farms employed this method because it was less labor intensive than individual pens (Chastain 2000), since fewer workers were needed to monitor expectant cows. An alternative facility is a large group maternity pen with adjoining individual pens (Chastain 2000). The next most frequently used type of maternity pen is the individual calving pen with cleaning after two or more deliveries (26.3%), followed by individual calving pens with cleanings between each delivery (25.5%) (USD 2010). The individual calving pen was originally used to halt transmission of disease at birth (Mee 2008).

Many researchers have concluded that the individual pen (Figure 12) is the preferred option (Kohlman 2007; University of California Cooperative Extension 1998; USDA 2010), but to date, there are no studies directly supporting this conclusion. However, Losinger and colleagues did find a lower risk of pre-weaned calves shedding *Salmonella* if they were born in individual areas (Losinger et al. 1995). Another study found that lack of individual calving pens was linked to higher probabilities of *Salmonella* shedding in cows. In this study, 2.9% of individual calving pens had cows that tested positive for *Salmonella* compared to 5.9% for calves without an individual pen (Fossler et al. 2005). The only study that investigated health differences in calves born in individual versus multiple calving pens showed no significant difference in occurrences of subsequent disease in pre-weaned calves (Pithua et al. 2009). One possible reason there were no differences between the two systems is that other management practices (e.g., sanitation, nutrition, colostrum management, and housing from birth to weaning) could have a greater influence on subsequent calf health. Consequently, it may not be necessary for herds with adequate management protocols to use individual maternity pens (Figure 13) to improve calf health. However, this study only followed calves up to 90 days of age and did not evaluate health benefits at later ages, for example, in preventing Johne's Disease.

## Timing and Separation of Calf from Cow

Cows should be moved to calving pens as close to calving as possible to maintain cleanliness. Of the dairies surveyed by the USDA, approximately 40% moved cows into the designated calving areas within one day or less of calving (USDA 2010). Kohlman suggested cleaning the dam's teats before she goes into the pen to prevent possible "manure meals" (Kohlman 2007). Once in the pen, manure removal could help prevent the spread of diseases such as Johne's (Kammel and Graves 2007). After individual calving, bedding should be replaced. Pithua et al. recommend the use of calving pens that undergo removal of feces, placental remains, and bedding materials, as well as disinfection of floors and placement of fresh bedding before the next cow enters (Pithua et al. 2009).

Many investigators have examined the risks and benefits of early separation of the newborn calf from its mother (Figure 14). For this discussion, early removal is defined as a calf's removal from the dam within 24 hours of birth. In a survey reported by the USDA's National Dairy Heifer Evaluation Project (NDHEP), 28% of producers separated the calf from the cow immediately, 39.6% within 12 hours of birth, and

*Figure 12. Individual maternity pen.*

*Figure 13. Dry lot corral maternity pen.*

10.4% within 12 to 24 hours of birth (Heinrichs et al. 1994). Reasons for early removal include: ensuring colostrum intake, reducing disease incidence, and reducing stress on both the cow and the calf.

*Figure 14. Newborn calf with its dam.*

It is well known that receiving colostrum and absorbing immunoglobulin are important for the development of a calf's immune system. Failure of the passive transfer (FPT) of immunity results from inadequate ingestion of colostrum (McGuirk and Collins 2004). In a study done by Brignole and Stott, 30% to 40% of calves remaining with their mothers did not ingest enough colostrum to provide any more immunity than the calves had at birth (Brignole and Stott 1980). By hand-feeding colostrum to calves following early separation, producers can ensure that calves are getting the healthiest start.

Studies also support early removal by demonstrating reduced incidence of disease. In one study, calves staying with their mothers for longer than 1 hour had a 39% higher probability of having diarrhea than those separated within 1 hour (Trotz-Williams et al. 2007). Calves left with cows for more than 2 hours had a higher risk of fecal-oral transmission of microbes (McGuirk and Collins 2004), possibly because they were exposed to large amounts of infectious agents in the maternity pen, likely from bedding and manure (Gulliksen et al. 2009c). There is a possibility that *Cryptosporidium parvum* oocysts shed by the cow during calving could increase the probability of calf infection (Faubert and Litvinsky 2000). When calves were allowed to nurse for 3 days, there was an increase in exposure to *Cryptosporidium parvum* and *Giardia* spp. (Quigley and Martin 1994). The probability of developing respiratory disease increased by 17 times if calves were kept with cows for the first week, and respiratory disease increased the calves' risk of death about six-fold (Gulliksen et al. 2009c). Many studies have shown that there is a greater chance of a calf dying if it remains with the dam for more than 24 hours, whether from inadequate colostrum intake or greater exposure to disease-causing agents (Gulliksen et al. 2009c; Waltner-Toews et al. 1986a; Wells et al. 1996).

Removing the calf from the dam early is also considered more compassionate. Contact time between the cow and calf increases the response to separation: the more time spent together, the more severe the response (Flower and Weary 2003). If the calf remains with the dam for an extended amount of time, the dam is distressed for a longer time after separation, and the calf may have problems adjusting to new environments (Le Neindre 1993). In a study looking at differences in behavior between calves separated at 6 hours, 1 day, and 4 days after birth, investigators found that those separated after 4 days vocalized more frequently following separation (Weary and Chua 2000). Vocalization is considered a sign of cattle discomfort (Grandin 1997). However, in a study looking at vocalization in newborn calves, calls of newly separated calves were found to be partly due to milk deprivation and not completely due to separation distress (Thomas et al. 2001). Vocalization by newly separated calves is also partially due to social, physical, and dietary changes. Not only do vocalizations increase following later separation, but calves can also become fussy and destructive. (Albright 1987). Calves removed from the cow at 4 and 7 days of age had faster heart rates for longer periods of time following separation compared to those separated earlier, indicating a higher stress level (Stehulova et al. 2008). Calves separated at 4 and 7 days also showed more agitated movements: standing, moving, pushing their heads out of the pen, as well as sniffing walls and bedding. It has also been observed that the longer calves stayed with the dam after calving, the more time they spent standing (Flower and Weary 2001; Lidfors 1996). Based on these studies, it appears that calves experience less stress if they are removed from the dam earlier rather than later.

Although the benefits of early separation have research support, Weary and Chua concluded that "dairy producers have little to gain from separation at less than 4 days of age, since the colostrum-rich milk cannot be sold within this period and early separation simply involves a longer period during which the calves have to be fed by farm staff instead of by the cow" (Weary and Chua 2000). Mothering is also critical for stimulating activity in the calf, feeding the newborn, and limiting cold stress (Le Neindre 1993). Also from a socialization stand-point, it might be beneficial to keep calves with their dams for longer than 1 day. Calves that stayed with their dams for 2 weeks following calving were more receptive to new calves (licking, butting, or rubbing heads) (Flower and Weary 2001). This resulted in an improvement in displayed social behaviors (Flower and Weary 2003). Calves that were separated later also weighed more and kept that advantage through 28 days of age. In another study, calves allowed to suckle and later housed in hutches weighed more at the end of 35 days (Quigley et al. 1995). Metz's study supported this observation and reported that cow-reared calves gained 1.2 lb per day more than separated calves (Metz 1987). However, two other studies disagreed with these findings and observed no weight difference (Stehulova et al. 2008; Weary and Chua 2000).

Herds with a low risk of disease, however, may benefit from having the calf stay with the cow because absorption of immunoglobulin might be increased (Mee 2008). Allowing the calf to suckle promotes higher serum immunoglobulin G and M and lowers the incidence and severity of scours (Quigley et al. 1995). Calves also tend to have higher rates of IgG absorption and a higher maximum absorption of immunoglobulin (Stott et al. 1979). Although the reasons for different absorption rates are unknown, there appears to be "some phenomenon in suckled calves that greatly stimulates colostral immunoglobulin absorption" (Stott et al. 1979). The evidence for letting the calf suckle differs among studies. Gulliksen and colleagues, for example, found that suckling caused an increased probability of death over the first week of life (Gulliksen et al. 2009). There appear to be both advantages and disadvantages to each approach. Most research leans toward early separation to meet the health and welfare needs of the newborn calf. While there are some socialization benefits from keeping the calf with its mother, the risk of morbidity and mortality is higher and puts the cow and calf under more stress at the time of separation.

## The Calf's Environment from Separation to End of the First Day

If a dairy separates the calf from the cow within the first 24 hours, the next concern is where to house the calf until transport to the calf-rearing or transition areas.

The primary reasons for housing the young calf are to protect it from weather and extreme temperatures, allow it easy access to food, protect it from injury, and monitor its health and welfare (Stull and Reynolds 2008). Newborn housing should be located in an isolated area of the cow barn or in a separate building (Clapp 1981). The space requirements differ depending on which facility the farm uses. For individually housed calves (Figure 15), the recommendation is 32 $ft^2$, while for group-housed calves, 28 $ft^2$ per calf is adequate (Stull and Reynolds 2008). The newborn resting area should provide a comfortable, clean, dry surface to protect the calf from cold temperatures, while providing it with cushioning that keeps its coat dry (Gooch 2000; Kohlman 2007). The surface should have deep bedding to keep the calf warm. These transition pens need routine cleaning, disinfection, and bedding replacement (Clapp 1981).

*Figure 15. Jersey calf housed in an individual pen.*

Effective air exchange is needed to provide acceptable air quality, and the air supply should be dedicated to the calf-housing area. The calf's shelter could be arranged to take advantage of prevailing winds in summer and to allow sunlight absorption in the winter, although care needs to be taken to avoid drafts that could chill the calf. If the nursery area has high humidity (>80%), the temperature should be maintained around 70°F. However, if the humidity is relatively low, a temperature of 50°F should be sufficient to provide a healthy, warm environment. For the very young calf, the thermal comfort level ranges from 59°F to 77°F (Clapp 1981). To maintain these temperatures in the winter, the calf's coat needs to be dry and using a heat lamp is recommended. It is important to keep the calf from experiencing cold stress because it increases vulnerability to disease (Butler et al. 2006). Mild hypothermia can start at a body temperature of 100°F. There are several options for preventing cold stress: a calf jacket, a hot box, or a warm water bath. For the hot box or warming box, the temperature should be maintained at between 106°F and 108°F using a thermostatic control (Butler et al. 2006), but some air movement and venting is needed. With the warm bath, gradually heating the water to 100°F and maintaining this temperature is required (Butler et al. 2006). Each method is effective, so the choice depends on the type of facilities available.

There are some housing options for a newborn calf's first 24 hours that depend on whether the calf will be staying on-farm or off-site. Most sources report that the preferred option is to house newborns individually in a hutch or pen until they are moved to the calf-rearing area (Clapp 1981; Gooch 2000; Kohlman 2007; USDA 2010). This option lowers the risk of disease transmission, allows for easier observation, and eliminates competition for food and water.

## Transporting Newborns to Calf-Rearing Facilities

A popular management practice is to move heifer calves off the dairy and into a separate rearing facility, whether it is part of the dairy complex or a contract heifer-raising facility (Botheras 2006; Eicher 2001; Stull and Reynolds 2008). Bull calves are moved at a very young age (Figure 16) to a grower facility to be made into veal or to a dairy beef production facility (Botheras 2006). Handling and movement are strong stressors for livestock, and calves are affected to an even greater extent than cows.

Calves are typically transported by covered pickup trucks, trailers of various types and lengths, specialized semitrailer trucks, or calf trucks (Figure 17). Neonatal calves prefer to lie down during transport, so they will need plenty of space (Botheras 2006; Eicher 2001; Stull and Reynolds 2008). For calves weighing 200 pounds, there should only be 2 animals per linear foot, giving each calf a minimum of 3.8 $ft^2$ of space. (Stull and Reynolds 2008). Calves need protection from wind chill and rain but also need to be provided with proper ventilation (Botheras 2006). In hot weather, especially with high humidity, stocking density should be lower and plenty of time allowed for animals to load and unload to prevent overexertion. Shade is required in summer, and in extreme temperatures, it may be necessary to wet the calves down (Stull and Reynolds 2008). It is vital for calves to maintain critical temperatures due to the length of time between feedings and their inability to cope with extreme temperatures (Eicher 2001). To aid in this maintenance during the winter, they should have protection from wind on both sides and the front of the truck. Clean, dry bedding, such as straw should be used to keep the calf warm. Not only does the bedding keep calves dry and warm, it also provides a comfortable lying area.

Before transporting calves, follow procedures that ensure a healthy calf at the end of transport. Make sure that the calves and their navels are dry, and that every calf has received a sufficient amount of high quality colostrum (Botheras 2006). This is important because the stress of transport adds to the chance of illness, which is compounded by immunosuppression due to lack of IgG absorption.

Loading and unloading calves is stressful as indicated by elevated blood cortisol levels (Eicher 2001) because the calves have not yet learned to be herded or to navigate ramps and inclines (Botheras 2006;

*Figure 16. Calves loaded into a livestock trailer.*

*Figure 17. Calves loaded in a transport trailer.*

Eicher 2001). Non-slip flooring in the loading area and transport vehicle is recommended (Stull and Reynolds 2008). Calves may have trouble walking without help, since some calves have not yet learned "following" behaviors (Botheras 2006). Forcing movement may lead to calves being mistreated. If calves refuse to move or cannot walk, calf carts, sleds, and slings can be used (Figure 18). If these fail, the calf may need to be carried.

During transport, when food and water are withheld, it is common for calves to lose weight. This can lead to dehydration and hypoglycemia (Botheras 2006). To counteract these conditions, electrolytes can be given orally during or after transit or administered subcutaneously after transport. This reduces dehydration and increases appetite upon arrival.

Calves transported at 4 days of age are particularly susceptible to stress and disease. While only a small number of calves die during transport, they often acquire secondary infections typically within 4 weeks of transport (Botheras 2006; Eicher 2001).

With transport, time traveled is more important than distance traveled (Eicher 2001). While there is no specific guideline for neonatal calves, a section of the federal law known as the "28-hour Rule" states that after 28 hours animals must be unloaded for rest, food, and water. However, this rule applies mostly to older animals. Within this 28-hour timeframe, a calf can become severely dehydrated. At the start of transport, including loading and unloading, and up to an hour afterwards, cortisol levels rise (Eicher 2001). These levels then drop from 2 to 6 hours after initiating transport. A skilled transport driver can start and stop smoothly and reduce speed on curves and turns to lower the risk of calf injury (Stull and Reynolds 2008). If transportation and management procedures are followed, transportation should go smoothly, and the destination facility will receive healthy calves ready to be raised as replacement heifers or grown for beef.

*Figure 18. Calf being unloaded using a calf cart.*

# Chapter 3. Small Group Housing and Housing for Post-Weaned Calves

The primary disadvantage of individual housing is that calves cannot interact with one another. In response to this limitation, small group housing emerged. Group housing is based on the principle that dairy cattle are herd animals, so it allows calves a chance to exercise, socialize, and develop normal herd behavior (Stull and Reynolds 2008). Grouping 2 to 6 calves is ideal because it allows caretakers easy observation of each calf. As calves grow older, these small groups can be combined into larger groups. Group housing may also reduce the labor needed, since more labor is required for both individual calf feedings and pen and hutch cleaning.

Today, about one-half of the dairy operations in the United States house weaned heifers in multiple-animal groups (USDA 2010). A major component of successful calf rearing is moving calves from liquid to dry feed and from individual to group housing (Heinrichs et al. 1987). It is also an important transition step for calves to learn to socialize, eat from a bucket or trough, and transition into larger groups (Anderson and Bates 1983; Graves and Heinrichs 1984).

## Multiple Animal Pens (Superhutches)

The superhutch is essentially a large calf hutch that provides transitional housing for a small group of calves (Figure 19). Transition groups may also be housed in small group pens inside calf barns. The superhutch was created to provide housing for calves in small groups after 8 weeks of age. The main purpose of this housing was to prevent a calf's exposure to areas that have housed or are currently housing mature animals (Bates and Anderson 1982). The superhutch also allows calves to acclimate to group housing with a smaller number of calves, reducing stress when they are moved into larger groups. Another important benefit of the superhutch is that it provides calves with the experience of headlocks and eating from a trough or manger. A benefit for caretakers is that it allows them to handle calves as if they were in individual pens.

## Group Housing for Post-Weaned Calves

Most dairy farmers (approximately 80% in one study) group weaned calves at about 60 days of age (Heinrichs et al. 1994). To avoid additional stress after weaning, recommendations are to leave the calves

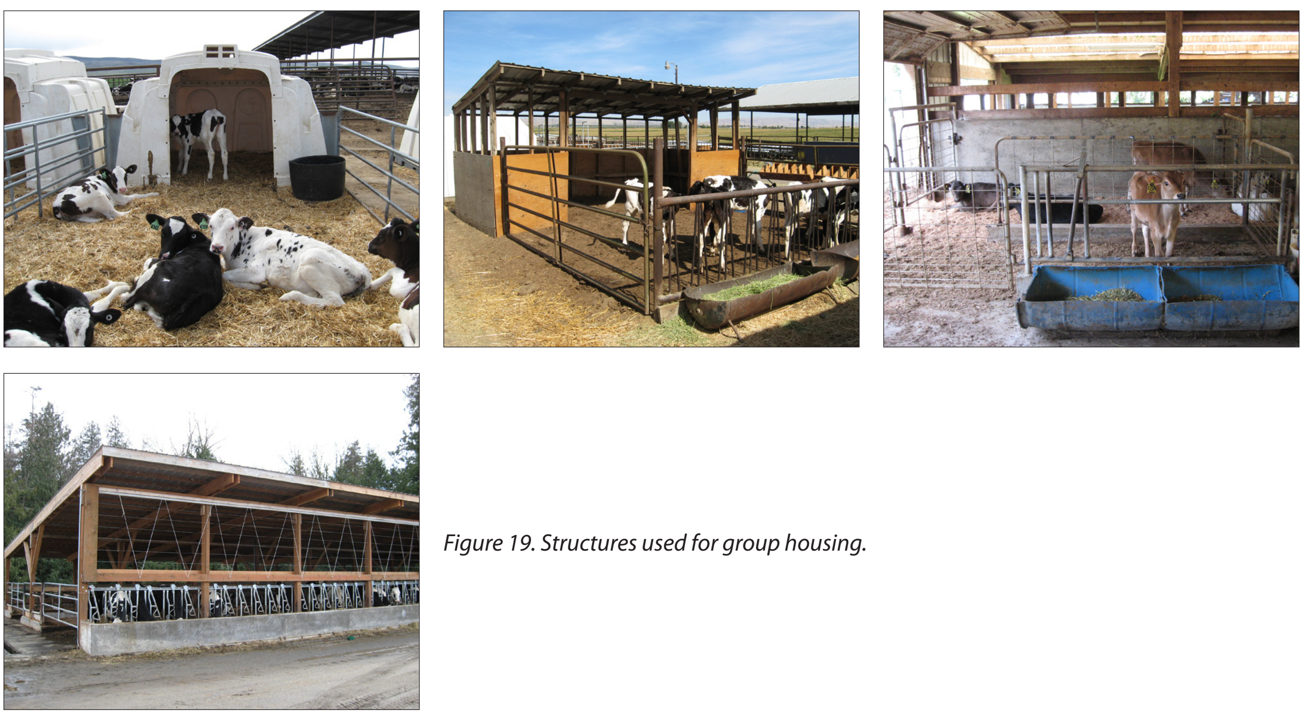


*Figure 19. Structures used for group housing.*

in their hutches for about 7 days (Davis and Drackley 1998) to make sure they are eating enough starter grain. Transition groups of 4 to 6 calves will ensure a smoother transition to larger group pens (Figure 20). If placed in large group pens too early, calves wander the perimeter looking for feed and water. In a smaller group, they can more readily find feed and water and socialize with other calves.

*Figure 20. Group housing calf pens in a naturally ventilated calf barn.*

Some producers use small group pens or superhutches even before weaning, often after 4 weeks of age. Although calves are still on milk or milk replacer, they have some opportunity to socialize with a smaller group of calves before being placed in larger group pens at weaning. In an experiment with 220 calves in group pens, investigators assessed lying down, eating, and moving times for calves in pens of different sizes. (Faerevik et al. 2007). The total duration of synchronous lying down (5 calves lying down simultaneously) was significantly shorter in the small (2.46 $ft^2$ per calf) resting areas than in the medium (4.10 $ft^2$ per calf) and large (5.74 $ft^2$ per calf) areas. There were no significant differences in synchronous lying down behaviors between the medium and large resting areas. Calves spent more time lying down in close proximity to other calves when they occupied the small- and medium-sized areas compared to the larger areas. Calves also rested more often in a recumbent position with their legs stretched fully when they occupied the medium and large areas than when they occupied the smaller areas. Investigators also noted that synchronization of resting behavior was more sensitive to changes in space allowance than in total resting time, and because cattle are social animals, anything that increases their ability to interact as a group will improve their welfare. One could also conclude from this study that in very hot climates, providing a larger space (Figure 21) for each calf would improve its comfort by allowing increased dissipation of body heat.

*Figure 21. Spacious group pen with straw bedding.*

In the West, many farms place weaned calves in corrals of various sizes. The housing elements that maximize their potential for growth include bunk space (1.5 ft per calf), shelter or shade areas (20 $ft^2$ per calf), and overall stocking density (200 $ft^2$ per calf) (University of California Cooperative Extension 1998). In addition, the effects of heat stress on younger calves could affect older calves as well (Figure 22). When using corral housing, it is important to consider the increased energy requirements that result from increased heat exposure, along with an increase in the need for water and shade and additional cooling or ventilation. Also, when calves are kept in corrals that are inadequately drained in winter or wet weather,

*Figure 22. Older heifers in a dry lot pen.*

they can be exposed to mud, which increases the nutrient requirements of cattle and can result in reduced feed efficiency (Fox et al. 1988).

## General Recommendations for Housing

There are many ways to successfully rear calves to weaning and beyond. After reviewing the literature on calf housing from birth to post-weaning, the following recommendations have been developed to optimize calf health and comfort. Although these recommendations may need to be revised as new information becomes available, the following information is a current summary of the literature:

- Birth can occur in group or individual maternity pens or pasture, depending on the hygiene conditions, the ability to observe for possible interventions, and the facilities and equipment available to assist in delivery.
- The calf should be removed from the cow immediately and fed at least 100 g of IgG.
- Transportation to the calf-rearing area should occur in clean, bedded, and well ventilated transport vehicles.
- For the first 4 weeks of life, calves should be in individual hutches or pens to prevent disease transmission during this vulnerable period.*
- During the second 4 weeks of life or until weaning, small group pens or superhutches can be used (with 3 to 8 calves each) in order to facilitate socialization and encourage solid feed consumption.
- Post-weaning, larger group pens, free stalls, or dry lot corrals with shades can be used for older calves if they have been allowed to transition through the smaller groups. Observing these calves for signs of respiratory disease is still necessary, and facilities must be available for treatment.

**Very recent research suggests that calves can be successfully raised in small groups with mob feeders within the first few days of life. However, this method has not yet experienced widespread adoption in the United States. Future research may show that these methods are less labor intensive and also better for calf health, welfare, and growth.*

# Chapter 4.
# Effects of Environment on Pre-Weaned Calf Health, Welfare, and Performance

The calf's environment should allow for physical comfort, disease control, and behavioral satisfaction (Webster 1983). There appear to be many different rearing systems in which to raise calves where these requirements can be met, and over the last 40 years much research has been devoted to comparing different rearing systems and understanding their advantages and limitations. This chapter will summarize this research and provide some recommendations for calf housing.

## Individual vs. Group Housing for Pre-Weaned Calves

The primary purpose of individual housing is to limit spread of disease among pre-weaned calves (Figure 23). There is some evidence that the prevalence of *Cryptosporidia, Coccidia*, and *Rotavirus* (agents of diarrhea) is lower when calves are housed in hutches rather than group pens.


*Figure 23. Calf in an individual hutch with a run.*

In addition, group housing of calves before weaning increases the odds of them shedding *E. coli* O157:H7 (Garber et al. 1995). However, in a cross-sectional study of herds in Virginia, the type of calf housing did not appear to influence mortality rates (James et al. 1984).

Epidemiologic data suggest that disease outbreaks, such as respiratory disease, are dependent on location and tend to cluster within calf housing (Miller et al. 1980), which indicates that close contact is indeed important in the spread of disease. In an Ohio study, calf mortality was lowest when calves were housed in hutches as compared to other types of housing (Lance et al. 1992).

In another study, rearing pre-weaned calves in small group pens with automated feeders resulted in similar rates of weight gain and morbidity as those seen with hutch housing (Kung et al. 1997). However, housing calves in individual hutches was a protective factor for pre-weaning calf pneumonia (Virtala et al. 1999).

Using USDA data from a 1996 survey, investigators found that herds where pre-weaned heifers were not placed in groups had a lower mortality rate (Losinger and Heinrichs 1997). In a study of 236 French dairy farms, Fourichon et al. found that calves housed in group pens after 1 week of age were more likely to get sick than were calves in individual housing, and this was particularly true if they were housed in groups with age differences of 3 or more weeks. Also, calves coming in contact with adult cattle had a greater tendency to get sick in comparison to calves who did not have this contact (Fourichon et al. 1997).

However, if managed carefully, and if infection pressure is not high, group housing for pre-weaned calves does not have to predispose calves to infection. In a Finnish study, the incidence of diarrhea was lower in calves housed in groups (Hanninen et al. 2003). Housing calves with adult cows in a cow barn, however, reduced average daily weight gain compared to calves housed separately from adult cows (Place et al. 1998).

A prospective study of calf morbidity in Sweden indicated that calves housed in large group pens had a greater risk of respiratory disease compared to calves in individual housing or small group pens (Lundborg et al. 2005). In a very large study of dairy calf mortality in Norway, Gulliksen and others also found that calves housed in group pens had a greater risk of mortality compared to calves housed in individual pens for the first month of life (Gulliksen et al. 2009c). However, calves housed in group pens appear to fare better in smaller groups of 6 to 9 animals compared to 12 to 18 per group (Svensson and Liberg 2006). In another study, the incidence of respiratory disease was lowest in calves housed individually, intermediate in those housed in small group pens (3 to 8 calves), and highest in calves housed in larger group pens (6 to 30 calves with automated feeders) (Svensson and Liberg 2006). Thus, if pre-weaned calves are going to be housed in group pens, the number of calves per group needs to be considered. Calves in pens with 12 to 18 calves had a higher incidence of respiratory illness and grew 0.022 cm/day less than calves housed in groups of 6 to 9 animals (Svensson and Liberg 2006).

Hutch housing (polypropylene Calf-Tel®) was compared to indoor metal pen housing (using a 3.94 ft x 3.94 ft pen with a metal mesh floor partially covered with rubber matting and plywood pen sides 3.61 ft high). This comparison was made to determine the effects of housing type and calf age on endogenous IgG immune responses to a specific antigen, plasma ascorbate concentrations, and plasma cortisol concentrations in colostrum-deprived calves (Cummins and Brunner 1991). Calves housed in polypropylene hutches had lower blood cortisol levels compared to calves housed in metal pens (16.2 mg/ml vs. 20.7 mg/ml), and they had higher plasma ascorbate levels. Although housing type had no significant effect on IgG concentrations during the study period, housing type did have a significant effect on specific antigen-antibody responses, with hutch calves showing a healthier response.

A study looking at the effect of initial housing on calves' average daily weight gain found that weight gain was lower for calves housed in cow barns or group pens than for calves housed in hutches or outside the cow barn (Place et al. 1998).

Tethering calves, such as was done in older style veal barns, has fallen out of favor but still may be employed in some locations. Although there may be no significant differences in daily weight gain between tethered calves and calves in individual pen housing, in some studies, pen design and pen width did affect hindquarter cleanliness, with calves in pens of increasing width accumulating more manure. There were also differences in left knee swelling scores with a general increase in knee and hock swelling as stall or pen width decreased.

This increase in swelling suggests that calves in smaller units had greater difficulty extending their front legs and in going from a lying to a standing position. Calves housed in 1.84 foot-wide pens had difficulty in moving from a lying down to a standing position and toward the end of the production cycle, they could not lie down with one or more legs extended. (Le Neindre 1993).

Although there appear to be disease control benefits to rearing calves in individual hutches, animals that are raised in confinement are often denied the opportunity to seek the most comfortable microenvironment for themselves (Brunsvold et al. 1985). However, if designed properly, hutches can allow for this microenvironment-seeking behavior. A behavioral study of calves housed individually evaluated the amount of time calves spent lying down in the back of the hutch, in the doorway, and in the outside area of outdoor hutches. In these varied locations, calves could capture solar radiation as needed in cold weather, shade as needed in hot weather, and were able to be most active during the times of moderate temperatures (Brunsvold et al. 1985).

The use of group housing may be beneficial when considering the calf's need for proper socialization and its need for play and movement (Gulliksen et al. 2009b). For example, group housing for 2 to 6 calves provides for more calf interactions and enriches their environment by adding stimuli (Stull and Reynolds 2008).

However, it is harder to maintain effective sanitation, manage nutrition, and control disease with larger group housing. Consequently, calves will typically encounter higher levels of pathogens at younger ages when housed in groups, resulting in higher rates of morbidity and mortality. (Gulliksen et al. 2009c). Another drawback to group housing is that calves can develop cross-suckling behaviors, which can be hazardous to them or their pen-mates (Stull and Reynolds 2008).

The effects of isolation on calf welfare and behavior have also been examined. Individually raised calves spent more time near or next to a human in a pasture setting than did group-raised calves (Le Neindre 1993), suggesting a greater bond to humans than to other calves. In a follow-up study in Texas, four different housing types were evaluated: tied in a stall with slatted floors and solid sides, in an elevated pen with slatted floor and solid walls, tied in plywood hutches with bedding, or located in a small, outdoor group pen (Friend et al. 1985).

Calves that were stalled or penned showed adrenal responses to ACTH and the thyroid hormone (T3) that were significantly higher than those seen in calves housed in hutches or group pens.

However, daily gain in body weight was the same among these groups, and there were few behavioral indicators of stress in any of them (Dellmeier et al. 1985).

In 1991, a Utah report looked at 7 pairs of monozygous twin heifer calves and the effect that isolation or group rearing had on them (Purcell and Arave

1991). There were no differences in average daily weight gain between isolated and group-reared calves, and no differences in some behaviors measured, for example, time spent recumbent or laterally, also known as limb dominance. However, the group-reared calves took longer to go through a maze and also spent more time eating, although total feed intake was no different between the two groups. After weaning, the calves were placed in one pen. The group-reared calves showed reluctance in approaching the human feeder, whereas the isolated calves ran to the feeder. Given this behavior, researchers concluded that isolation is not detrimental to calf well being and may even enhance the human-animal bond.

In one large, multi-site experiment, calves were raised without the ability to see other calves (isolation), or in individual hutches with the ability to see other calves (Figure 24) (Arave et al. 1992).

*Figure 24. Triplet wooden hutch with calves, located in Washington state.*

Rearing calves in isolation had some effect on socialization (in the short term) but did not affect health or subsequent milk production, in contrast to an older study where milk production was greater in cows reared in isolation when they were calves (Arave et al. 1985). The social skills of individually penned calves can equal that of group-reared calves if they are able to make visual contact with other animals (Le Neindre 1993).

Stocking density for grouped calves is an important factor contributing to the risk of diarrhea (Bendali et al. 1999). If calves had less than 3.28 $ft^2$ of space, they had a 74% greater risk of developing diarrhea. In a transmission study of bovine Herpes virus-1, the cause of infectious bovine rhinotracheitis (IBR), the findings indicated that a distance of at least 14.44 ft between cattle populations would be needed to reduce transmission of the Herpes virus (Mars et al. 2000).

In summary, the potential advantages of individual calf housing are that:

- Individual calf behavior and health status can be viewed each day or at each feeding
- Specific feed types and amounts can be provided and consumption levels observed
- Spread of disease can be reduced
- Reasonable rates of weight gain can be achieved with no long-term effects on future milk production as an adult

The disadvantages of individual pen or hutch housing are that:

- It is more labor intensive
- Proper sizing and design are required
- There is reduced potential for calf socialization

## Indoor vs. Outdoor Housing for Pre-Weaned Calves

In one of the first studies to compare a traditional in-barn calf-rearing system with outdoor portable calf hutches, Davis et al. found that the in-barn system contained far greater numbers of *Coccidian* oocysts compared to the calf hutches (Davis et al. 1954). However, no difference in respiratory disease or scours cases were found in a study of 60 calves that were divided into indoor vs. outdoor (hutch) housing systems (Jorgenson et al. 1970). In a study of almost 2000 pre-weaned calves, mortality was highest in outdoor group pens compared to indoor individual or indoor group pens (Peters 1986), and calves that developed pneumonia did not survive as often in the outdoor group pens. Calves housed in groups outdoors in Finland had a higher incidence of diarrhea than did calves housed in groups indoors. The diarrhea outbreaks also lasted longer for outdoor groups, both effects likely due to cold outdoor temperatures (Hanninen et al. 2003). Standing cold-housed calves require higher metabolic rates to stay warm unless they are recumbent (Rawson et al. 1989); consequently, a comfortable resting area is important along with bedding for nesting.

In a recent study, outdoor polyvinyl hutch housing was compared to elevated indoor metal pens for individual calves in Kuwait (Razzaque et al. 2009). Calves in the outdoor hutches had higher average daily weight gains and lower mortality compared to calves in the indoor pens.

And although indoor calf housing can be managed for temperature and ventilation, it may still be a challenge for managers to apply the correct settings for mechanical systems or ensure the proper design for naturally ventilated barns. These challenges can result in potential problems with elevated ammonia concentrations, inadequate air movement, and a greater pathogen load. A substantial amount of research has focused on evaluation of indoor housing (calf barns), whether they are mechanically or naturally ventilated. Although most Western dairy calf raising units employ outdoor hutches, there are various styles of calf barns still in use and ventilation is important even for individual outdoor hutches, though this is not often discussed in the literature.

## Ventilation in Indoor Housing for Pre-Weaned Calves

The quality of the air surrounding the pre-weaned calf can be degraded by the presence of manure gases (such as hydrogen sulfide and methane) (Hillman et al. 1992) and ammonia from the breakdown of nitrogenous wastes in urine and manure. It can be further degraded by dust from bedding and feed as well as airborne bacteria, fungi, and endotoxin (from 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 consequences.

Respiratory disease pathogens include *Mycoplasma*, IBR, BVD, PI3, *Pasteurella*, and *Mannheimia*. Many of these pathogens can live in the upper respiratory tract of calves without causing pneumonia, but they can also be passed from calf to calf by direct contact or through aerosols or droplets. Factors that influence potential 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 (local resistance), and 4) systemic resistance to infection (Webster 1983). Ventilation of the calf facility also has a significant effect on the survival and spread of organisms in the air. And although most airborne bacteria are not pathogenic, in large enough numbers, they can overwhelm the clearance mechanisms inherent in a calf's respiratory system. These bacteria are carried in droplets or dust and the balance of these organisms in the calf's environment depends on their reproductive rate and their rate of disappearance.

Ventilation is the mechanism by which stale, "organism- and toxin-laden" air is replaced with fresh air. Ventilation can be accomplished mechanically or naturally (through thermal buoyancy or wind), and can also serve to remove heat from the calves' environment. The most important aspect of ventilation is air exchange as measured by the number of air exchanges per hour. In one study, medical treatments increased by 60% as the number of air exchanges decreased from 4 per hour to 1 per hour (Bates and Anderson 1979). Ventilation systems should provide for a continuous level of air exchange to remove moisture. They should also provide for temperature-controlled air exchange to remove body heat, and for air velocity to remove large amounts of heat during hot weather (Figure 25) (Graves 1995). (See Graves for guidelines on constructing naturally ventilated barns.)

*Figure 25. Anemometer measuring airflow through the ridge vent of a plastic hutch.*

There is a large body of research devoted to the subject of ventilation within barn structures that house calves but very little information on ventilation inside calf hutches. Solid fronted pens and pen covers reduce air speed around the calf (Roy 1980), and in a study of air exchanges inside different hutches, Hoshiba et al. found that if more than 1/3 of the front area of the hutch was solid or covered, air exchange rates decreased by 2.5 to 7 times the average air exchange rate (Hoshiba et al. 1988). The front covers of the plywood hutches being evaluated are shown in Figure 26. Clockwise from the upper left they are an open front, a 1/4 open front, a 1/2 open front, and a 2/3 open front.

Concentrations of ammonia found in cattle housing are usually less than 100 ppm; however, the average person can detect ammonia levels as low as 5 ppm

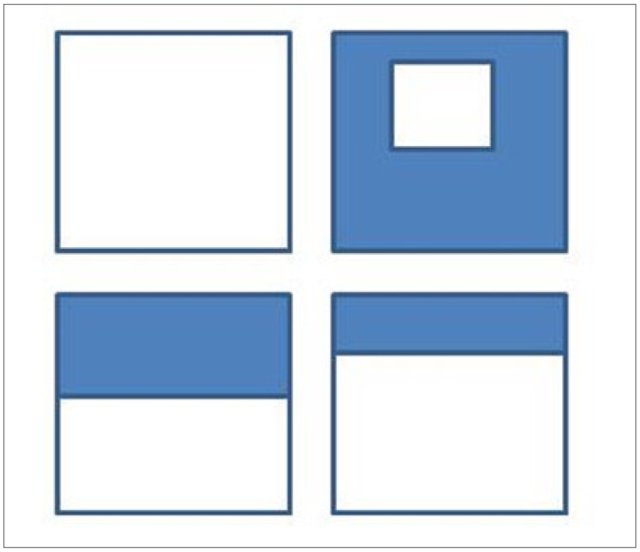


*Figure 26. Different calf hutch front covers.*

to 20 ppm (The Fertilizer Institute 2010) . Ammonia acts as an eye and respiratory irritant, but it can become a chronic stressor that affects the health of calves by impairing mucociliary transport in the respiratory tract, thereby reducing pulmonary function.

In one Danish study, calves were moved into 1 of 3 types of housing: 1) insulated and mechanically ventilated and heated (at 53.6°F) with maximum 70% RH, 2) insulated, with a controlled natural ventilation system of openings in the walls and roof, and 3) uninsulated and naturally ventilated with perforated aluminum walls 3.9 ft from the floor to the roof (Blom et al. 1984). The uninsulated, naturally ventilated housing had lower $CO_2$ and ammonia levels over time, numerically lower incidence of respiratory disease, and lower airborne bacteria and fungi levels in center house samples.

Dust particles not only cause irritation to the respiratory track, but they can also carry pathogens, other bacteria, and endotoxin. A few investigators have looked at airborne bacteria, dust, and remediation through air filtration in different types of calf housing. A study in Denmark compared 3 different types of calf housing (insulated with mechanical ventilation; insulated with natural temperature-controlled ventilation; and uninsulated with natural ventilation) for calves in group housing (Blom et al. 1984). On average, the uninsulated, naturally ventilated barn had the lowest level of airborne bacteria and fungi. For airborne bacteria, the values were 78,000 cfu/ml, 102,000 cfu/ml, and 68,000 cfu/ml of air sampled for the 3 barns, respectively. When the airborne bacterial content of crated veal calf units was monitored for 16 weeks, concentration of bacteria in the air was 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 the calf pens inside the dairy barn, to 44 inside a plastic hutch, 15 inside a plywood hutch, and 4 inside a plywood hutch without a back wall (Hoshiba et al. 1988). Thus, bacteria can be present in high numbers, but these numbers can vary depending on the type of calf housing or location of calves in relationship to older animals.

Air filtration for air entering a calf barn was associated with a reduction in both incidence and severity of clinical and subclinical disease in calves. Treatment for respiratory disease as well as the area of lung consolidation at slaughter were directly related to reductions in calves daily weight gain (Pritchard et al. 1981). In hutches, typical airborne bacterial counts were 20,000 cfu/$m^3$ but exceeded 100,000 cfu/$m^3$ if the bedding was disturbed (Nordlund 2008). In addition, airborne dust particles of less than 5 microns can reach the deeper lung tissue and are regarded as potentially hazardous.

Recently, researchers at the University of Wisconsin-Madison have taken a new look at airborne bacteria and ammonia in naturally ventilated calf barns (Lago et al. 2006). Their focus was at the level of the calf or the individual pen within the barns being evaluated, and on the factors that were associated with airborne bacterial counts in the calf pens, bacterial counts in the alleys, and the prevalence of calf respiratory disease in a cross-sectional study of 13 calf barns. The prevalence of calf respiratory disease increased with increasing total bacteria counts and decreased with the presence of solid dividers between the calf pens. The prevalence of respiratory disease also decreased with an increasing nesting score (nesting scores indicate how much a calf is covered by bedding material). Bacterial counts were lower in calf pens with a larger total area, higher with higher pen temperatures, higher with straw bedding vs. other bedding materials, and higher as the number of solid panels making up the pen increased.

Lipopolysaccharide, or endotoxin, comes from the breakdown of gram-negative bacterial 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 the effects of inhaled endotoxin on cattle. It is possible that in feedlot cattle, airborne endotoxin contributes to acute interstitial pneumonia (Woolums et al. 2001). For dairy workers, a health-based exposure limit is 50 EU m-3 over an 8 hour period, but dairy facilities can sometimes exceed this limit (Dungan and Leytem 2009). Studies of agricultural workers have shown that exposure to dust and endotoxin are associated with respiratory tract inflammation (Burch et al. 2010). Thus, it would be logical to conclude that these environmental contaminants could also contribute to disease in neonatal calves by causing similar inflammation.

A drafty condition is different from ventilation and in cold weather can add to chilling, particularly if there is damp bedding. In a Swedish study, a draft was assessed for each calf pen using a smoke bottle. A draft was defined as a wind velocity greater than 0.5 m/s (Lundborg et al. 2005). Calves in drafty pens were almost 4 times more likely to exhibit moderate to severe increases in respiratory sounds compared to calves in draft-free pens.

In conclusion, ventilation in calf-rearing facilities should remove heated air, moisture (humidity) and toxic gases, dust and endotoxins, and airborne contaminants that could lead to respiratory disease. Recommended air exchange rates in a calf barn are from 4 to 15 exchanges per hour, or about 10 CFM/calf in the winter and about 30 CFM in the summer.

## Resting, Lying, Bedding, and Hygiene

Calves need enough space and warmth to attain total relaxation and REM sleep (Figure 27). Behavioral indicators of comfort include the calf's ability to lay down with legs outstretched, oral activities (such as tongue rolling, scratching or licking objects, and grooming), and social interactions (Le Neindre 1993). However, there is some disagreement among investigators as to which oral behaviors actually indicate that a calf is coping poorly with its environment. Based on calf welfare guidelines, at a minimum, calves should be able to stretch their legs while recumbent. Based on research, widths of individual housing systems may need to be more than 1.84 ft wide, so that calves can extend their legs (Wilson et al. 1999).

In calf housing, floor surfaces need to serve as a comfortable resting area, and they need to be cleanable. Calf hutches may have slatted floors above a flush or clean-out area, or they may be on the ground or on gravel with bedding. However, calves on slats may develop more leg and foot problems (Stull and Reynolds 2008). Bedding provides an absorptive surface as well as a microenvironment to insulate calves from the cold (Bourne 1969), so it is particularly important in colder climates or seasons.

Little work has been done to quantify the effect that bedding and hygiene have on calf health and performance. Hygiene, specifically sanitation of housing between calves, should be common practice, but

*Figure 27. Dairy calf on fresh straw bedding.*

there appear to be no standard hygiene protocols. In a University of California study, researchers looked at multi-drug-resistant fecal *E. coli* from neonatal calves on 33 dairy farms in the state. They found that calves in operations where hutches were scraped between calves and operations where hutches were cleaned underneath between calves had lower levels of multi-drug-resistant *E. coli* (Berge et al unpublished data). These lower *E. coli* levels most likely indicate that the cleaning procedures were reducing calf exposure to environmental bacteria.

In a Netherlands study of calf diarrhea, cleaning calf housing consistently between calves protected against *Coronavirus* infections (an almost six-fold decrease in risk) (Bartels et al. 2010). Also, in addition to cleaning hutches between calves, allowing the ground underneath the hutch to "rest" between calves can be helpful. Flipping hutches up after cleaning or moving them to "new ground" allows sunlight to kill pathogens, since *Cryptosporidium* and other pathogens are susceptible to ultraviolet light as well as desiccation (Moore 1989).

Calves' growth rates and feed efficiency from day 1 to 42 were not affected by any of 5 different bedding materials (Panivivat et al. 2004). However, the number of days calves were treated with antibiotics due to scours was affected by bedding materials during the first 2 weeks of life. Calves on sand and granite fines had the highest rates of treatment. However, bedding materials had no effect on a calf's serum IgG concentrations or stress indices (such as cortisol and neutrophil/lymphocyte ratios).

Researchers in the School of Veterinary Medicine at the University of Wisconsin-Madison developed a scoring system for bedding levels in individual pens. It is called the "nesting score" and has been correlated with increased or decreased incidence of respiratory disease in pre-weaned calves in cold barn housing (Lago et al. 2006).

Although calf welfare guidelines are clear about calves being able to stretch their legs, there is some evidence to support wider pen width for individual calves. Two pens with different widths and surfaces were evaluated by comparing their effects on calf 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 weight post-weaning than the calves in 2.17 ft-wide pens with a grated floor (2.0 lb/day vs. 1.6 lb/day).

## Effects of Cold Temperatures on Pre-Weaned Calves

Much of the early literature on calf housing dealt with keeping calves warm in cold environments and stressing the fact that calves have a lower critical temperature (32°F). Recent research from Norway correlated winter births with a greater risk of developing diarrhea (Gulliksen et al. 2009a). Most research on winter management of calves focuses on meeting the increasing energy demands (by increasing dry matter intake) during cold weather.

However, there are some environmental management practices that might also be useful. Hutches and other housing structures should provide protection from cold stress due to wind, as well as provide a resting area for calves to keep warm. Bedding can help calves maintain body heat, as does erect coat hair, which provides the calf with an insulating layer (McFarland 1996). Keeping coat hair dry is important for the calf to retain heat. In addition to staying dry, blocking drafts, and increasing dry matter intake, heaters can also be useful, as well as other means of providing additional warmth, such as calf jackets or blankets. Additionally, heat loss through ventilation in a calf barn can be controlled, although the warmer the air temperature, the more moisture it can hold, and thus, the higher the humidity levels. The challenge for calf caretakers is to provide for adequate ventilation while preventing drafts in winter.

Another management approach is to orient the fronts of calf hutches or open sides of shelters to the southeast during the cold months in North America (McFarland 1996) or orient them facing south to maximize the low levels of winter sunlight.

## Effects of Heat Stress on Pre-Weaned Calves

There is a great deal of research on the effects of heat stress on lactating cows and some information on transition cows (Collier et al. 1982; Cook et al. 2007; Cook and Nordlund 2007; Urdaz et al. 2006). Cook et al. 2007; Cook & Nordlund 2007) (Urdaz et al. 2006). Less information is available on the effects of heat stress on young calves, but the literature that is available provides good evidence for the importance of heat stress mitigation for this age group. Heat stress has specific effects on the young calves themselves but also, in a follow-up study of calf-rearing practices, an association was made between heat stress and subsequent first lactation. The higher temperatures and humidity experienced by calves resulted in higher average heifer age at first calving (Heinrichs et al. 2005), a known economic cost to the dairy producer.

The thermal neutral zone for young calves is narrower than for cows (National Research Council 2001). The upper end of the thermal neutral zone for calves appears to be approximately 84°F and heat stress can occur at temperatures greater than 90°F (at 60% 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 this can result in impairments in the calf's physiology and behavior.

Heat stress (as measured by a combination of temperature and humidity) can affect a number of different calf-rearing outcomes. Rectal temperature appears to be one measure of heat stress in calves, but the increases in body temperature are small. Skin temperature at different sites has been used but is an even less sensitive measure (Spain and Spiers 1996). Respiratory rate may be the most sensitive and easily obtained measure of heat stress in calves (Findlay 1957).

Mortality rates are certainly one measure of the effects of heat stress. Two years of 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 rates among calves and cows. Calf death rates were highest at temperatures above 77°F and below 57°F. The changes in mortality rates were greater for calves than for cows, when controlled for temperature.

Weight gain is another indirect measure of heat stress in calves. Calves born in the summer and raised in outdoor hutches on whole milk gained significantly less weight compared to calves born in the fall in a temperate climate (Broucek et al. 2007). These lower body weights remained unchanged until at least 180 days of age. Calves reared in temperatures of 80°F gained 19 lbs less in a 3 month period than calves raised in the cooler 50°F temperatures (West 2003).

An individual hutch is designed to provide shelter from the elements, primarily precipitation and cold weather. However, some hutches (such as plastic hutches) may accumulate heat and contribute to heat stress in hot climates. A variety of hutch types and construction are available but most are either plastic/polyethylene (Figure 28) or wood (Figure 29). Lamb et al. noted during a year-long study that the temperature of polyethylene domes tended to average 5-10 degrees higher than wooden hutches (Lamb et al. 1987). A Pennsylvania study evaluated the temperatures inside and outside hutches as well as the rectal and skin temperatures of calves in wooden hutches (painted either white or black) and polyethylene domes (with or without supplemental 100% shade) (Lammers et al. 1996).

*Figure 28. Plastic hutches.*

*Figure 29. Empty triplet hutches.*

Hutch surface temperatures (inside and out) were significantly higher for the black wooden hutches (104°F and 100°F), followed by polyethylene hutches and the white wooden hutches. Relative humidity was also higher in the polyethylene hutches. In this study, calf rectal temperatures were not a very sensitive measure of heat load, but the skin temperature (using an infrared thermometer) of black pigmented areas 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 rates were also a sensitive measure and were significantly lower for calves in the wooden hutches (57 and 65 breaths per minute) compared to calves in the polyethylene hutches with shade (72 breaths per minute) and without shade (97 breaths per minute). Calves in the white wooden hutches and those with shade also consumed 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 their affect on heat stress in calves. The following housing types were used: conventional wooden hutches (3.9 x 7.9 x 3.9 ft high) with an outdoor pen (3.9 x 5.9 ft), enclosed molded polyethylene domes (7.2 ft in diameter x 4.9 ft high), and thermo-molded opaque polymer hutches (4.6 x 7.2 x 4.3 ft high) with ridge-top ventilation systems, and an outdoor pen (3.9 x 5.9 ft) (Macaulay et al. 1995). The polyethylene domes were the warmest (with maximum temperatures of 90.86°F), followed by the wooden hutches (with maximum temperatures of 84.70°F), and the polymer hutches (with maximum temperature of 79.30°F).

Some remediation of heat stress may be necessary if pre-weaned calves are housed outdoors. Shade is likely the most cost-effective way to mitigate heat stress but has been evaluated for calves in only a few studies. In a study of calves in Arizona, Stott et al. evaluated calf health in 3 different housing systems: 1) hutches made of a 1 in.$^2$ tube and corrugated steel (with a corrugated metal roof and near-solid sidewalls), 2) hutches with corrugated metal shade 30 ft wide and 10 ft high with the long dimension in an east-west orientation, and 3) hutches with the same metal shade and an evaporative cooling system (Stott et al. 1976).

During this investigation, the daily peak temperature humidity index (THI) ranged from 80 to 88°F. Serum IgG levels were lower in calves housed in hutches and although serum cortisol levels decreased as calves aged, they were significantly higher in calves in hutches. In this same study, hutches had the highest peak THI compared to the other two housing systems. The high heat and humidity experienced by calves in hutches was associated with immunoglobulin absorption, which is one indicator of stress. Mitigation with shade and/or evaporative cooling was found to be beneficial.

In a Missouri study, some calves were housed in commercial plastic hutches with or without a shade structure (a shade structure of 80% barrier to solar radiation that was located 6.9 feet from the ground) (Spain and Spiers 1996). Air temperatures were 2 degrees lower in the hutches, but hutch surface temperatures were 5 to 10 degrees lower in the shaded areas. Calf rectal temperatures showed smaller increases in shaded hutches as outside air temperature increased. Respiratory rates were, on average, 10 breaths per minute higher for calves in unshaded areas. An increase in respiratory rates occurred at air temperatures greater than 79°F.

In a study looking at supplemental shade (80% shade cloth suspended 7.4 feet over polyethylene calf hutches) (Figure 30) in the southeastern United States, added shade decreased the hutch temperatures by 7 degrees in the late afternoon (Coleman et al. 1996). Humidity did not increase inside the hutches and there were variable effects on calf rectal temperatures. The shaded calves did appear to have a better feed-to-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 unshaded animals (Eigenberg et al. 2005).

As the research shows, there are some simple ways to mitigate heat stress: maximize shade available to calves; orient calf hutches to face north during summer months in hot climates to maximize shade; improve ventilation of calf hutches sitting on the ground; and elevate the back of the hutch using a concrete block. It can also be useful to orient naturally ventilated calf barns with open ridge vents and sidewall openings so the ridge runs perpendicular to the prevailing winds (McFarland 1996).

*Figure 30. Shade cloth above poly domes.*

## Summary

As the research on dairy calf housing suggests, what is important is to select the right type of housing for a specific climate, place it in the correct location on the farm, and to manage ventilation, drafts, hot and cold temperatures, and the welfare aspects of young calf housing.

# Chapter 5. Mitigation of Pathogen Loads in the Calf's Environment

The calf's environment includes feed and water, materials and equipment for handling and distributing it, materials and equipment for cleaning, and physical housing that provides shelter. Attributes of the environment directly affect calf health (e.g., ventilation) and impact behavior (e.g., individual versus group housing). But the calf environment and how it is managed have a significant affect on the amount of exposure a calf has to disease pathogens.

## The Pathogens (Calf and Public Health)

The primary focus when managing pathogen loads in the calf environment is on animal health, but it is also important to recognize that many of these pathogens have health implications for farmers, farm employees, their families, and their communities. The names of the pathogens are familiar and many are associated with diarrheal disease in pre-weaned calves: *E. coli, Salmonella, Coronavirus, Rotavirus, Campylobacter, Cryptosporidium,* and *Coccidian*. Occasional cases of diarrhea can be caused by *Giardia* or *Clostridium perfringens*, and new research provides evidence for the role of *Clostridium difficile* toxins in calf enteritis (Hammit et al. 2008). Some of these calf pathogens (e.g., *Salmonella, Cryptosporidium, Campylobacter*) also have public health implications, and there are other bacteria that are strictly of public health concern, including the shigatoxin-producing *E. coli* such as O157:H7, which is not associated with disease in calves (Nielsen et al. 2002). Many of these pathogens can persist in the environment from weeks to years, leading to pathogen build up if not properly managed.

## A Model for Environmental Loading of Pathogens

There is little research available on how to remediate pathogen loads in the environment; although, there have been numerous studies on the prevalence and potential risk factors for calfhood diseases (Bartels et al. 2010; Gulliksen et al. 2009a; Lefay et al. 2000; Lundborg et al. 2005; Svensson et al. 2003; Trotz-Williams et al. 2007; Uga et al. 2000; Uhde et al. 2008; Veling et al. 2002; Younis et al. 2009). The qualitative model in Figure 31 summarizes the major factors that can increase or decrease the environmental pathogen load. No available data describe, quantitatively, how much each of these paths (denoted by the arrows) contributes to the overall pathogen load. Data of this kind would provide valuable insights for prioritizing interventions.

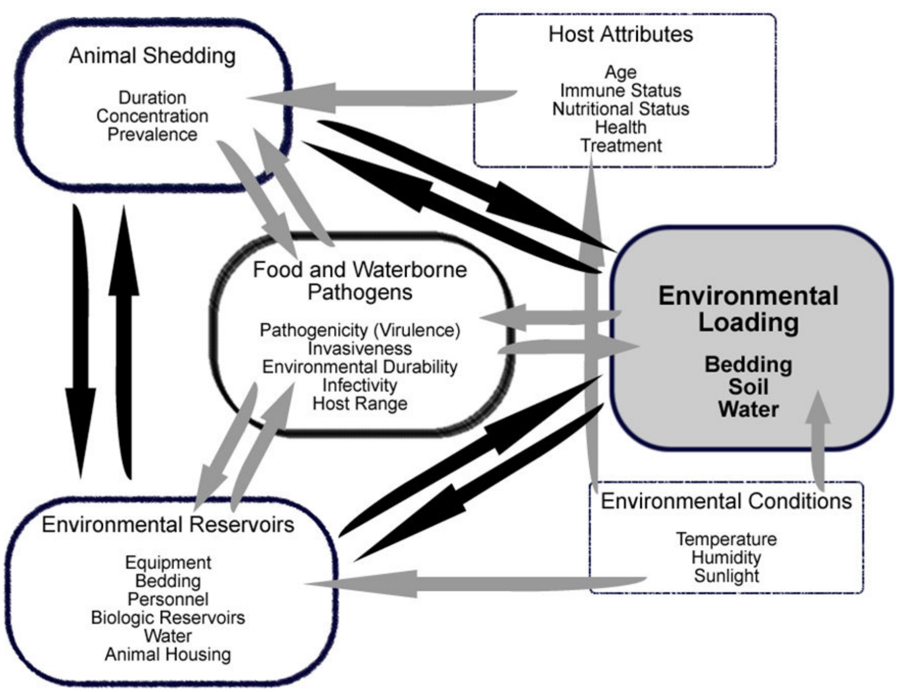



*Figure 31. Environmental loading model.*

## The Significance of Environmental Pathogen Loads to Dairy Calf Rearing

In the United States, dairy source calves are raised in a continuous flow system. Most of our dairy farms milk year round, and calves are continuously being introduced to the farm and the calf area. Because most dairy farms are designed for fixed and specific housing in order to accommodate management tasks, calf rearing invariably takes place in a particular location. While the physical design of this housing allows for a relatively consistent management approach to rearing calves, the challenge in a continuous flow environment is that pathogens introduced into the housing area can persist and become endemic. In addition, the constant introduction of new animals and the rapid changes in the environment mean calves are being raised in a disturbed microbial ecosystem. While the dynamics of this ecosystem are not well researched, it is known that the microbial populations of these ecosystems are not stable, which could lead to dramatic fluctuations in pathogen numbers.

## Introduction of Pathogens into the Calf Environment

There are two common philosophical attitudes toward calf rearing—one is that calves should be raised on the dairy of origin and the other is that they should be raised on custom calf-raising operations (calf ranches). Calves reared on the dairy of origin are moved from common calving areas to calf housing. Calves are transported to the housing area in a variety of ways, but actively moving the animals infers that pathogens are being introduced from one housing area containing cows to another housing area containing calves. Calf ranches buy or contract-rear bull and heifer calves most often as day-old calves. Calves arrive at ranches from multiple sources that can change from day-to-day. Thus, they could be exposed to a variety of pathogen types and strains (Wray et al. 1990a).

While movement of calves to housing areas may be a significant source of pathogen transfer to these areas, pathogens can also be introduced into the calf environment from external sources, such as farm equipment and personnel (Kirk et al. 2002a; Rice et al. 2003). Other external sources are aerosols and feed (milk, water, and contaminated grain) (Davis et al. 2003; Hancock et al. 1998; Lejeune et al. 2001a, 2001b).

In all of the calf-raising systems, there are numerous opportunities to introduce potential pathogens into the calf environment. The health of the calf then becomes a function of a pathogen's ability to survive and possibly amplify in the environment, along with its ability to infect an animal and cause disease.

## Animal Sources for Environmental Loading

It can be argued that although there are many sources and routes for pathogens to enter the calf-housing environment, it is highly likely that there is limited amplification of these organisms within the environment. It can also be argued that infected animals are the most likely source of amplification and environmental loading.

One of the principles of infectious disease is that manifestation of a disease state is a function of the interactions of the host, the pathogen, and the environment. Calf diarrhea has a specific pattern of clinical presentation and shedding of agents. Figure 32 shows that on two different farms, the diarrhea cases in calves peaked in the second week of life. Clearly, the immunological status of the calf and the biology of the pathogenic agent impact this infection and shedding pattern. However, it is highly likely that these peaks are a function of the calf's exposure to pathogens in the environment, and the increased prevalence indicates an amplification of the pathogen within the animal. The pathogen buildup that occurs in the environment due to amplification from infected animals continuously maintains an infectious dose that then impacts susceptible calves. *Cryptosporidium* infection is a good example of shedding and amplification. Susceptible calves are infected by relatively low doses of *Cryptosporidium*, but they shed very large numbers of oocysts into the environment that then function as a loading dose for other susceptible calves (Nydam et al. 2001).

That this infection includes host factors as well as environmental contamination can be supported by observing that calves can be quickly identified as they shed bacterial pathogens after birth (Hoyle et al. 2004), but they do not manifest clinical disease until much later. Thus, the shedding of pathogens by newborn calves is linked to the maternity pen environment, and these calves are shedding pathogens but not amplifying them.

Pathogens can also be shed by animals that are without clinical disease or following clinical disease, and these pathogens can persist in the environment. Many studies have found that in some locations, specific *Salmonella* bacteria can persist despite the absence of any apparent clinical disease for up to 2 years. (Gay and Hunsaker 1993; McLaren and Wray

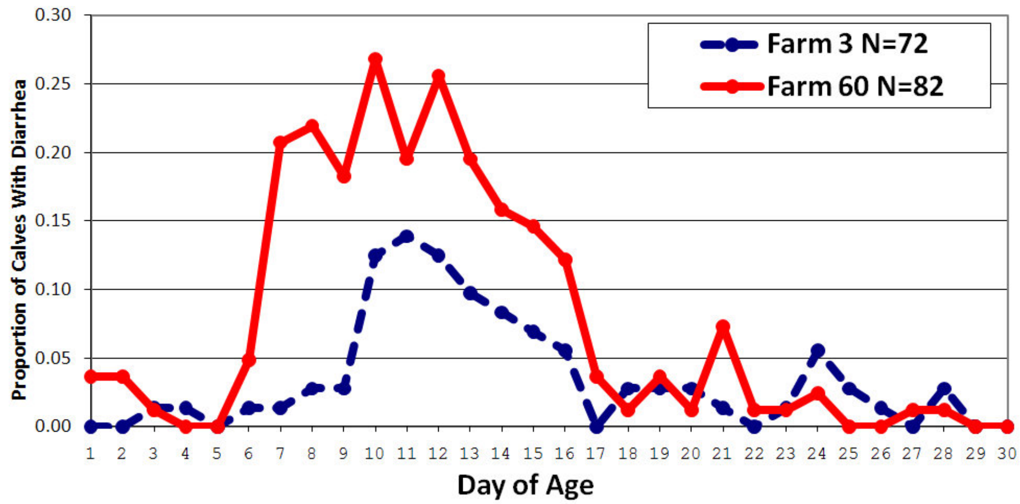



*Figure 32. Proportion of calves with diarrhea by age on two large western U.S. dairy farms (Moore 2009 unpublished data).*

1991). Following clinical disease, *Salmonella* bacteria may be shed for approximately 30 to 50 days (Alexander et al. 2009; Cummings et al. 2009). Table 2 summarizes data on bacterial shedding and persistence for selected pathogens.

*Table 2. Diarrhea-causing pathogens, shedding duration, and persistence in the calf environment.*

| Pathogen | Duration of Shedding | Persistence in the Environment |
|---|---|---|
| E. coli | 2 days | Up to 3 months |
| Rota/corona viruses | 6 days | Up to 1 year |
| Salmonella | 30 to 50 days | Up to 2 years |
| Cryptosporidium | 10 days | Up to 2 years |

The cycle of introduction, amplification (clinical or non-clinical), and environmental loading through fecal shedding is likely to be the most important part of the disease cycle found in calf-rearing facilities. As the number of pathogens in the environment increases, so does the probability of a calf being exposed to and infected by them. Understanding the environmental loading cycle and the potential interventions to reduce loading are fundamental to reducing calf disease rates on dairy farms and calf ranches.

## Remediating Pathogen Load: Stopping the Cycle

The three areas where pathogens impact environmental loading are: introduction, amplification, and loading. Minimizing or preventing the introduction of new pathogens into the environment is a key objective in stopping the cycle of infection. Minimizing the number of sources from which pathogens may originate and ensuring that the equipment used to move animals is kept clean are also essential prevention measures. For example, feeding utensils can serve as fomites upon which infectious agents can be carried from one calf to another. Cleaning these items after every use should be standard procedure, but currently may not be practiced on every farm. In a cross-sectional study of 119 dairy herds in Ontario, Canada, (after controlling for other risk factors), the use of soap or detergent when washing feeding utensils reduced the risk of *C. parvum* oocsyt shedding (Trotz-William et al. 2008). Another method for minimizing risk is to follow biosecurity procedures on the farm by keeping personnel and equipment solely dedicated to calf management rather than having them moving across the farm. A study by Kirk et al. showed that *Salmonella* could survive on the bottom of rubber boots for an extended period of time and could serve as a effective transport vehicle (fomite) for moving *Salmonella* around the farm (Kirk et al. 2002b).

Amplification of pathogens is not likely to occur to any great extent in the environment. Most amplification occurs within the animal, often as a part of the disease process. Since the manifestation of disease is a function of the interaction of pathogen, host, and environment, managing amplification means managing that interaction. Supporting host immunity can be accomplished through nutrition and, most importantly, through adequate transfer of passive immunity. These measures allow the host to respond to an infection challenge with minimal clinical manifestation, which will most likely minimize amplification. Minimizing the pathogen's ability to spread from one animal to another will reduce the probability of spreading infectious doses from infected to susceptible animals. Another method of prevention is to use individual hutches during the times a calf is most susceptible to infection.

The concept of "intervention" to decrease the environmental load of food- and water-borne pathogens originating from animal agriculture is relatively new. Smith et al. demonstrated a beef-calving system aimed at decreasing a calf's environmental exposure to neonatal diarrheal-associated pathogens (*Salmonella* and *Cryptosporidium*) (Smith et al. 2003). The goal of the system was to isolate neonates from older calves that were moving in and out of the high risk period for shedding pathogens (5 to 20 days of age). The system was effective in reducing the infectious dose in the pasture environment, which was associated with decreasing the rates of neonatal diarrhea.

In the dairy calf-rearing environment, use of concrete flooring was believed to be protective for calves shedding *C. parvum* oocysts (Trotz-William et al. 2008), and the use of slatted flooring was considered a risk factor for diarrhea (Gulliksen et al. 2009a). This thinking may have developed due to the inhospitable environment that solid concrete presents to pathogens or to the greater ease of cleaning and disinfecting concrete.

Another method for reducing pathogen loads in the environment is to monitor stocking density. Stocking density is typically associated with group pens, but the same concept can be applied to individual calf housing. Spacing out hutches may change the dynamics of pathogens in the environment by creating more open space for sun and wind to reduce pathogens. Although reducing density is a standard management tool, there are no data to support the effectiveness of this intervention.

Sanitation and hygiene are the most reliable practices for pathogen reduction. Yet, on farms, (except for the milking system because of milk handling for human consumption), there are no specific, evidence-based protocols for cleaning and disinfection. This is true for cleaning the calf nursery area as well. Nearly every extension publication and dairy magazine article that discusses calf diseases also discusses biosecurity, sanitation, and hygiene. Yet there are very few studies that present the outcome of these practices. However, one study did provide evidence that if calf bedding was removed weekly from individual pens, the risk of diarrhea was reduced four-fold (Gulliksen et al. 2009a).

In a study of *salmonellosis* in calves, transport vehicles and sales yards were evaluated (Wray et al. 1991). *Salmonella* was isolated from floors or walls of half of 14 sales yards. Before washing, *Salmonella* was found in 20% of 107 samples taken from transport vehicles and 6.5% in samples after washing (no details on cleaning procedures were given). In another study looking at *Salmonella* in calf-holding areas, the bacterium was found even after housing areas were cleaned, suggesting that cleaning was not always effective (Wray et al. 1990b). It makes sense that cleaning could help decrease environmental pathogen loads, but there is little or no data to describe the proper approach to effectively clean up the calf's environment–that is, reduce the pathogen load.

As discussed earlier, water and feed can be sources of infection and can also become sufficiently contaminated as to present infectious doses to calves. Water was a persistent source of *E. coli* O157 for calves housed in superhutches on one farm in Wisconsin (Shere et al. 1998). Other research has shown the same outcome for *Salmonella* (Kirk et al. 2002a). The *Cryptosporidium* outbreak in Milwaukee in the 1990s was spread by municipal water that was inadvertently contaminated by treated sewage (MacKenzie et al. 1994). Methods for keeping water troughs clean cannot be found in the literature, but some research suggests that a stable water trough flora (not cleaned) may reduce bacteria like *E. coli* O157:H7 (Field Disease Investigation Unit (FDIU), College of Veterinary Medicine at WSU unpublished data).

## Cleaning and Monitoring Protocols

One farm-specific, bottom-up method for reducing calfhood disease by decreasing the environmental pathogen load is to develop a Hazard Analysis Critical Control Point (HACCP) program for the calf-rearing area. This program helps in developing the protocols and monitoring procedures necessary for pathogen reduction in the calf environment (Cullor 1995; Noordhuizen and Metz 2005). HACCP programs have been successful on dairy farms, particularly in the reduction of clinical mastitis and milk quality problems. However, HACCP programs have not been used to any great degree for calf-rearing operations (Sischo et al. 1995).

When developing protocols for reducing animal exposure to pathogens, the timing of pathogen shedding and clinical cases, as well as the environmental risk factors for disease must be considered. Different agents of disease have similar points of control, particularly those that are transmitted through the fecal-oral route that results in diarrhea or septicemia in neonatal calves. These points of control can include anything that a calf touches and anything that touches a calf.

The following is a list of potential risk factors (lists may vary from farm to farm):

- Other calves
- Calf blankets
- Walls, floors, and roofs of hutches and pens
- Feeding equipment—mixing tanks, hoses, bottles, nipples, buckets
- Treatment equipment—esophageal feeders, balling guns, halters
- Caretakers—hands, boots, clothes

Attention to cleaning and disinfecting these items will reduce the dose of infectious agents and, therefore, reduce the risk of disease. Understanding the difference between the process of cleaning and the process of disinfection will aid in prevention. Establishing the farm-specific protocol and monitoring the behaviors that make up this protocol are the biggest challenge. Monitoring cleanliness of bottles and surfaces by swabbing and culturing is one method of monitoring behavioral outcomes. Calf hygiene scoring might be another way to provide objective information, but for both of these methods of monitoring, providing feedback to caretakers is the most effective way to improve compliance.

When formulating cleaning protocols, it is important to educate caretakers on the kinds of pathogens that need to be reduced, as well as how they are spread to the calves and what kinds of tools help them successfully reduce pathogen loads. Cleaning agents are used to remove dirt, scum, and manure. Some cleaning agents are soaps and may not include disinfecting agents. The primary function of these soaps is to release the potential infecting material from the fomite and reduce the amount of organic material that may interfere with the action of the disinfectant.

It is important to clean a surface *prior* to using a disinfectant (Moore 2004). For hutch or pen walls and floors, the process is: 1) scrape (remove large particles); 2) wash (with soap or detergent to lift dirt and microbes); 3) rinse; 4) disinfect; 5) rinse; and 6) dry. Drying or allowing sun exposure (UV light irradiation) on surfaces is also an important step.

If using a disinfectant, the contact time, concentration, temperature, pH, water hardness, and amount of organic material present determine its success (Barrington et al., 2002). Different disinfectants are used for different pathogens, see Disinfectant Resources – ISU CFSPH at: www.cfsph.iastate.edu/Infection_Control/disinfectant-resources-for-veterinarians.php. The disinfectant labels provide the necessary information for their use. Check to make sure the disinfectant is not inactivated by organic material (e.g., manure). For information on reading labels, see the Iowa State University Center for Food Security and Public Health document: www.cfsph.iastate.edu/Products/resources/DisinfectantLabelDocument.pdf.

Additional considerations for cleaning equipment include using water at temperatures of 120°F or higher and making sure equipment is dry before reuse. It is also important to know the pH of the material to be disinfected, the hardness of the water to be used, the surface material to be cleaned, and the necessary contact time for killing pathogens.

Cleaning steps for feeding equipment are: 1) rinse with lukewarm water; 2) wash with detergent; 3) rinse off the detergent and soil loosened by it; and 4) complete the disinfection process. Cleaning the panels inside pens and any equipment or items that might be shared between calves should follow a similar procedure.

If the farm is using outdoor hutches, they should be tipped up (Figure 33) after a calf is moved and all manure scraped from its surfaces and the pack underneath. Hutches should then be cleaned and disinfected and allowed to stand upright in the sun for several days (if very hot), otherwise, for up to a week before housing another calf. However, moving hutches to a new location is the most effective approach. Some dairy producers and calf ranch owners may want to reuse a hutch after a calf dies. However, these hutches should not be reused immediately without cleaning or disinfecting them because the calf may have been shedding large numbers of pathogens. Counting empty hutches is also a method for estimating mortality rates on large calf-raising operations.

*Figure 33. Tipped up hutch.*

A common recommendation for contagious disease control in calves is to work from the youngest to the oldest calves; however, there is no empirical evidence to support this practice. In looking back at Table 2, it shows that the highest shedding period is most likely to be between 2 to 3 weeks of age, when the prevalence of diarrhea is highest. Working with these calves and then the younger ones is likely the riskiest. Calf caretakers who come in contact with calf secretions, such as feces or saliva, should disinfect their hands and boots, and change their clothes, if possible, before coming in contact with another calf. It is also best to work as much as possible outside the hutch, and to have caretakers avoid going in and out of the hutches.

## Summary

Reducing the pathogen loads in the calf environment means 1) increasing host immunity in order to limit infection and shedding, 2) following cleaning and disinfection protocols, and 3) preventing new pathogen introduction by separating young calves from each other and from older animals. Caretakers must understand what the pathogen hazards are and why protocols for cleaning and disinfection are needed. They should also receive feedback via a monitoring system to ensure compliance. Reduction of the pathogen load in the calf environment will reduce the incidence of infection and disease in calves as well as reduce the potential for pathogens to reach the human population.

# Chapter 6. The Calf Environment and Caretaker Health

Although physical injuries, heat stress, and farm accidents are major factors affecting farm workers' health, individuals working with calves are subject to the same environment and come into contact with the same pathogens that calves do.

## Potential Health Hazards

The same air quality problems that affect young calves can affect the individuals who care for them. Ammonia can affect a worker's respiratory tract by damaging the cilia and mucosal barrier that protect against infection. Respiratory symptoms can include inflammation, shortness of breath, wheezing, coughing, and a decrease in pulmonary function (Mitloehner and Calvo 2008).

Poor air quality in some environments may be due to volatile organic compounds (VOCs). Health effects from exposure to VOCs include headache, nausea, and loss of coordination. VOCs can also cause eye, nose, and throat irritation. Heavy exposure to these compounds may cause damage to the liver, kidneys, and central nervous system.

Dust may also become a hazard for calf caretakers, particularly dust from feed and bedding. General respiratory effects of dust may be present, compromising the mucociliary clearance function of the upper respiratory tract. Dust may also contain specific allergens, animal dander, urine proteins, and fecal proteins (Mitloehner and Schenker 2007).

Airborne bacteria and endotoxins (from breakdown of bacterial cell walls) not only affect calf health, but can also affect the human respiratory system.

In the calf environment, several pathogens can be transmitted by calf manure. Some examples are:

***E. coli* O157:H7—**Although not recognized as a cause of disease in calves, this pathogen can be carried and shed by calves, contaminating the surrounding environment and the caretaker's hands, boots, and clothing. In adults, this pathogen can cause diarrhea and bloody diarrhea. In children, it can go so far as to cause systemic disease and hemolytic uremia syndrome (HUS), which could lead to kidney failure, particularly in very young children.

***Salmonella*—**This bacterium, found in many environments, may cause disease and can be shed by calves. In humans, the infection can cause diarrhea and could also cause septicemia and other serious illness, particularly infants.

***Cryptosporidium parvum*—**C. *parvum* is a single-celled protozoal organism (not a bacteria or virus) that commonly causes diarrhea and subsequent dehydration in calves. It can also cause diarrhea in humans not previously exposed to it and can cause chronic, life-threatening diarrhea in immunocompromised individuals (such as those with AIDS). People with healthy immune systems will develop immunity to subsequent infection. Farm workers or other individuals who have worked with cattle and have been previously exposed to this pathogen may not become ill, but they may, unknowingly, expose susceptible family members and others to this organism.

***Campylobacter*—**Although usually associated with poorly cooked chicken, this bacterium is also shed by cattle and can cause disease in humans, such as gastrointestinal illness.

***Giardia*—**This is also a protozoal organism and is associated primarily with contaminated surface water. There have been some outbreaks of diarrheal disease in calves infected by this organism. Although less common, it can be transmitted to humans by the same contaminated water or contaminated calf environment.

Not all common diseases of calves pose a risk to humans. The species-specific *corona* virus and *rotavirus* infections (which cause diarrhea in calves) are not transmitted to humans. Respiratory pathogens found in cattle, such as *Pasteurella, Mannheimia, Mycoplasma*, and viral diseases of cattle also do not pose a health risk to humans.

## Routes of Transmission for Disease-Causing Organisms

Diseases transmitted from animals to humans are known as zoonotic diseases or zoonoses. When working on dairies, caretakers can contract diseases via different routes of transmission. Some disease agents can survive for extended periods of time in soil, bedding, and other environmental locations. Understanding pathogen transmission routes can assist calf caretakers in disease prevention (Center for Food Safety and Public Health: Iowa State University 2008). Transmission routes include:

1. **Aerosol—**Transfers pathogenic agents through infected droplets from animal to ani-

mal and from animal to human. Most pathogens do not survive in the environment for extended periods of time. Pathogens dispersed by coughing or sneezing are examples of this route of transmission.

2. **Direct contact—**Transfers pathogenic agents or organism through direct contact with an infected animal or from contact with a contaminated environment.
3. **Fomite—**Transfers pathogens from infected animals to humans through hand-to-mouth or direct contact. Transfer can occur when handling buckets, lead ropes, pitchforks, calf hutches, clothing, boots, and so forth.
4. **Oral—**Transfers pathogenic agents through contaminated food, water, or objects in the environment, for example, objects that calves have licked or chewed.
5. **Vector-borne—**Transfers pathogens by arthropod or insect vectors, such as mosquitoes, fleas, ticks, and flies that have been in contact with an infected animal. This vector then transfers the pathogen to other animals or humans.

## Preventive Measures

The following preventive measures can reduce the risk of caretaker exposure to the pathogens associated with cattle and their environments.

1. Improving ventilation in the calf-rearing area benefits both calves and their caretakers by reducing ammonia, VOCs, airborne bacteria, and endotoxins.
2. Wearing dust masks when moving bedding and feed reduces the risks posed by dust particles, including allergic reactions.
3. Washing hands with soap and running water after contact with animals, feces, blood, body fluids, and exudates. Hand washing removes organic material and reduces the number of transient organisms on the skin. Hand washing is especially necessary before meals.
4. Wearing gloves when working around calves and in their environment reduces the risk of contamination by manure. Milker's gloves or work gloves can be used.
5. Leaving coveralls, boots, and other work-related clothing at work reduces the risk of transmitting pathogens to family members. When work clothes and boots are worn home, they should be removed before entering the house and kept separate from the clothing of other family members. Wash clothes using detergent and household bleach in water that reaches 130°F.
6. Providing a dedicated break area with a hand-washing facility can reduce the incidence of worker illness.
7. Providing uniforms, laundry service, and an employee dressing room can reduce the rate of pathogen transfer.
8. Cleaning and disinfecting non-disposable equipment and boots before and after entering calf areas can reduce pathogens. Also, disinfect with an EPA-approved disinfectant or diluted household bleach solution for boots, footbaths, tires, and the like. For a bleach solution mix ¼ cup of household bleach with 1 quart of water. For hard surfaces, mix ¼ teaspoon of household bleach with 1 quart of water.

## Summary

Having policies and preventive measures in place is the best way to prevent zoonotic disease transmission on dairy farms. Conditions that affect disease transmission vary based on a variety of factors, such as climate changes, host-species habitat changes, or mutations of disease organisms. Learning about zoonotic diseases is not enough. Caretakers need to be proactive by learning to identify potential hazards linked with the spread of infection to themselves, their families, and others that they might come in contact with.

For an English or Spanish presentation and notes on zoonoses on the dairy farm, go to: www.cfsph.iastate.edu/Infection_Control/zoonotic-disease-information-for-producers.php.

# Appendix A.
# Dairy Calf Environment and Housing Assessment

When problem-solving dairy calf health and performance problems (in addition to assessing or evaluating overall calving management, colostrum management, nutrition and feeding systems, and disease detection and treatment protocols), the calf-management advisor can help evaluate the calf environment. There are several areas to assess, based on a literature review:

- Housing systems and space requirements,
- Ventilation or air quality around the calf,
- Housing hygiene and sanitation, and
- Calf comfort and welfare (associated with housing).

It is crucial to evaluate housing needs for both the winter and summer months. Providing for sufficient airflow without drafts is essential in winter. However, maximizing removal of heat and humidity in summer requires a different set of farm management protocols.

## General Guidelines for Calf Housing

Standard Housing Guidelines set by the Dairy Calf and Heifer Association. See www.calfandheifer.org/?page=GoldStandardsII.

### Birth to 6 months of age:

- Calves 24 hours to 60 days of age: clean, dry, draft-free, good air quality, pen size large enough so calf can turn around.
- Calves 61 to 120 days of age: clean, dry, draft-free, good air quality, minimum resting space of 34 sq ft per animal, and adequate feeding space for all animals to eat at the same time.
- Calves 121 to 180 days of age: clean, dry, draft-free, good air quality, minimum resting space of 40 sq ft per animal, adequate feeding space for all animals to eat at the same time.
- Calves in free stall housing: one stall per animal.

The following is a list of tools an assessor might want to have available:

- ☐ Checklist and guidelines (below)
- ☐ Graph paper
- ☐ Clipboard
- ☐ Tape measure or laser measuring device
- ☐ Anemometer (new models will also measure temperature and humidity)
- ☐ Calculator
- ☐ $CO_2$ sampler and sticks
- ☐ Smoke sticks
- ☐ Temperature/humidity data loggers (2)
- ☐ Sterile culture swabs and blood agar plates
- ☐ Sterile whirlpaks for bedding samples
- ☐ Ruler to measure bedding depth or evaluate nesting score

Once equipped, the assessor needs to examine all areas of the environment in which the calf spends time, from the maternity pen to the weaned calf pens.

## Purchasing Information for Ventilation Tools and Equipment

### Measuring $CO_2$

***Fisher Scientific***—www.fishersci.com, 1-800-766-7000

*Air Sampling System (Sensidyne). $670*

*$CO_2$ detector tubes (Sensidyne). $97 for pack of 10*

### Anemometers

There are various brands of good anemometers available that can be purchased online at www.amazon.com, and www.kestrelmeters.com. Useful information to record would be wind speed, temperature, and humidity. Anemometers can also be found by doing a Google search for "handheld wind meters."

***Kestrel 3000*** *wind meter. $149*

***Extech 45158*** *Mini Waterproof Thermo Anemometer and Humidity Meter. $140*

### Smoke Tubes (airflow indicators)

Ventilation Smoke Tube Kit. Smoke tube kits are designed for easy visual determination of air current directional patterns. Useful in tracing air currents in barns, pens, individual calf hutches, etc.

***Fisher Scientific***—www.fishersci.com, 1-800-766-7000

*Kit with 6 plastic smoke tubes. $138 each*

*Kit with 2 glass smoke tubes. $60 each*

*Plastic smoke tubes. $149 for pack of 12*

*Glass smoke tubes. $111 for pack of 10*

***Cole-Parmer***—www.coleparmer.com, 1-888-358-4717

*Airflow Indicator Tube Kit. $96*

### Digital Measuring Devices

Helps to measure barns, pens, alley ways, etc. Recommend having one that measures 150-ft range with accuracy. Available at local hardware store.

*Bosch Digital Laser Rangefinder Kit (165-ft range). $130. www.amazon.com.*

## First Day of Life—Maternity Pen Evaluation

### Space

- ☐ Individual pen dimensions are either 12x12 ft or 10x14 ft
- ☐ Group pen dimensions are at least 120 $ft^2$ per cow
- ☐ Stocking density (cows/pen area)____________
- ☐ Maternity pen capacity (number of cows the pen will hold) ____________

  *From the dairy herd records, plot weekly or monthly calvings for the last two years.*
- ☐ What is the maternity capacity?_________________________
- ☐ Does this capacity match the times when there are the largest number of fresh cows?
- ☐ Does the maternity area have the capacity to handle this many cows?

## Bedding

- ☐ Dry matter (%) ___________________________
  (Fresh bedding is about 65% dry matter for most bedding types.)
  (See www.extension.org/pages/Dry_Matter_Determination)
- ☐ Bacterial count from bedding (in cfu/ml)
- ☐ Ready to accept occupancy, count should be < 5,000 colonies/ml
- ☐ During occupancy, count should remain < 2,000,000 colonies/ml (McGuirk 2003)

## Maternity Barn Ventilation

☐ Positive pressure ☐ Negative pressure ☐ Natural ventilation

*(Evaluate ventilation, if needed, using the calf barn ventilation assessment, below.)*

## Hygiene/Sanitation

To evaluate hygiene levels, score 12–14 cows in maternity pens in each of three zones—lower leg, udder and upper leg, and flank zones (score each zone separately) using the hygiene scoring guide (Figure A1).

Count the number of cows with scores of 3 and 4 and calculate the proportion of cows with these scores. (Scores of 3 and 4 indicate a level of poor hygiene that is unacceptable.) You may wish to establish the herd baseline and try to make improvements from this point. (University of Wisconsin investigators found that in free stall barns, the median proportion of cows with these scores was 19%.)

## Hygiene Scoring Guide

Lower Leg—Observe the distance manure extends proximally up the leg: 1 = little or no manure above the coronary band; 2 = minor splashing above the coronary band; 3 = distinct plaques of manure above the coronary band but with leg hair visible; 4 = solid plaque of manure extending high up the leg.

Udder—Observe the udder from the rear and the side if possible: 1 = no manure present; 2 = minor splashing of manure near the teats; 3 = distinct plaques of manure on the lower half of the udder; 4 = confluent plaques of manure encrusted on and around the teats.

Upper Leg and Flank—Observe the upper part of leg and flank: 1 = no manure; 2 = minor splashing of manure; 3 = distinct plaques of manure with hair showing through; 4 = confluent plaques of manure.

*(Adapted from Instructions for Using the Hygiene Scoring Card written by N.B. Cook, University of Wisconsin-Madison, with permission.)*

## Maternity Pen Cleaning Protocol

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

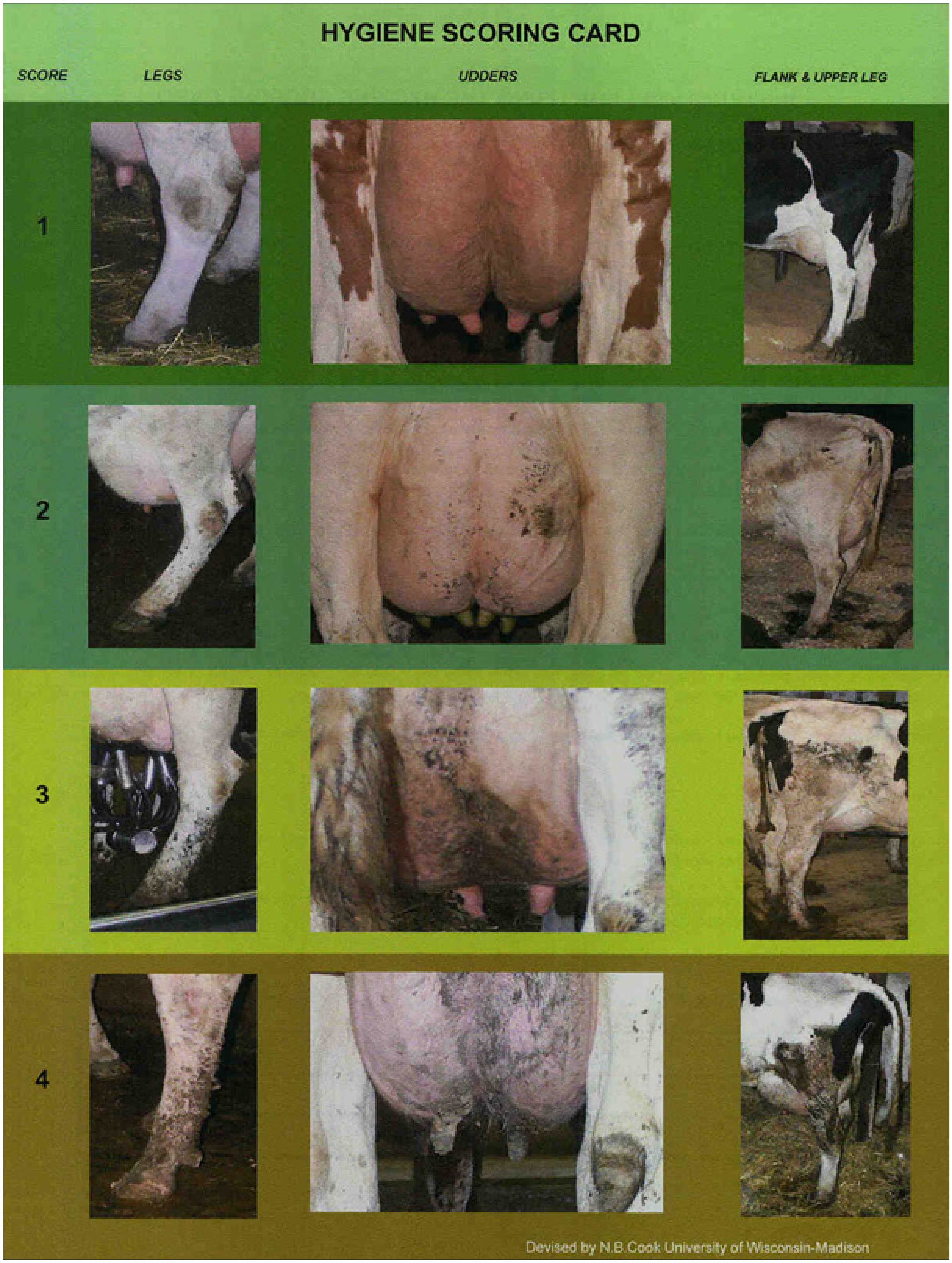



*Figure A1. Hygiene scoring card.*
*(Provided with permission of Dr. N.B. Cook, University of Wisconsin-Madison)*

## Calf Transport Evaluation (from maternity pen to calf-raising facility)

- ☐ Acceptable levels of calf dryness before transport
- ☐ Appropriate amounts of colostrum received before transport
- ☐ Appropriate method of transport
- ☐ Adequate livestock trailer space (one linear foot per calf)
- ☐ Adequate ventilation
- ☐ Acceptable levels of hygiene/sanitation
- ☐ Appropriate bedding quantity, quality, high dry matter% (~ 65%)

## Pre-Weaned Calf Environment—Newborn to 2 Months of Age

### Hutch Housing Evaluation

Use an aerial map of the facility or draw a plot of the calf-raising area.

Note the following:

- ☐ Compass directions and prevailing winds (in summer and winter)________________________________

  (The calf-rearing area should be upwind from cow housing without wind blocks to impede airflow) [University of California Cooperative Extension 1998].
- ☐ Wind blocking structures (distance and height) ________________________________
- ☐ Distance between hutches ________________________________
- ☐ Distance between hutch rows ________________________________
- ☐ Wind speed at the front of each hutch† ________________________________

  (Using an anemometer, measure air speed across the front of hutches in each row and at the end of each row.)
- ☐ Different wind speeds in different areas of the calf-rearing area† ________________________________
- ☐ Hutch design provides for upward air venting

  (Body heat will rise in winter and moisture will accumulate unless the roof is single-sloped upward toward an opening or unless a vent is located at the highest point of the hutch ceiling.)
- ☐ Space available for each calf (based on Holsteins) ________________________________

  (24 to 32 $ft^2$/calf allows animals to turn around comfortably, stand up, and lie down with legs fully stretched—without touching the enclosure.)
- ☐ Calves' ability to see other calves
- ☐ Hutches tightly secured to the ground without slats or cracks that would allow wind to blow on calves from underneath in cold weather
- ☐ Hutches facing south or southeast during cold months to maximize sunlight
- ☐ Hutches facing north during the warm months to maximize shade
- ☐ Substrate (ideally 4 in. or more of crushed rock) for adequate liquid drainage (of urine, etc.)

## Bedding Evaluation

Bedding provides necessary thermal insulation. In winter, straw is preferred over shavings. Additional bedding should be added weekly, and old bedding should be removed only after calves are weaned and moved out. (Bare concrete is not an option.)

- ☐ Nesting score—evaluate how much of the calf is covered by bedding when it is reclining (Lago et al. 2006). A score of 1 = lying on top of bedding; 2 = legs partially covered; 3 = legs completely covered by bedding
- ☐ Dry matter %—estimate percentage of dampness in bedding samples
- ☐ Hair loss—examine the calf's hindquarters for areas of hair loss (indicates urine scald or very damp bedding)
- ☐ Body cleanliness—score calf's coat based on observations made of forequarters, belly, hindquarters, and overall body appearance (Terosky et al. 1997). A score of 1 = very little manure through 5 = caked-on manure.

## Hutch Comfort Evaluation (for calves just leaving the hutch)

- ☐ Score ambulation

  1 = moves normally; 2 = slight staggering or stiffness of leg joints; 3 = modest staggering, stiffness of leg joints; 4 = moderate staggering or stiffness, needs slight assistance to walk; 5 = needs assistance to stay erect and move; 6 = falls frequently, must be partially carried; and 7 = non-ambulatory, must be carried.

- ☐ Score knee or hock swelling 1 = no swelling through 5 = severely swollen

## Calf Barn Assessment

Barn Characteristics

- Barn dimensions (Figure A2)
  - ◊ Total area ______________________
  - ◊ Total volume ______________________
  - ◊ Ridge ______________________
  - ◊ Side wall & curtain opening ______________________
  - ◊ Alleys ______________________
  - ◊ Calf pens ______________________

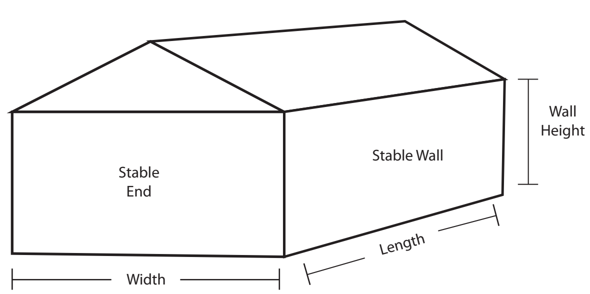



*Figure A2. Barn layout.*

- Barn construction materials
  - ◊ Barn building materials ____________________
  - ◊ Calf pen materials ____________________

- Barn and pen proportion *(total pen area ÷ total barn interior area = proportion of pen area)*

  Total pen area________÷ total barn interior area________

  = proportion of pen area__________

- Barn stocking density (*width x length ÷ number of calves = stocking density*)

  Barn width______× barn length_______÷ number of calves_______ = stocking density________
  - ◊ Number of calves in barn ____________________
  - ◊ Number of calves per row ____________________
  - ◊ Number of rows in barn ____________________

- Barn box factor pen score ____________________

**Score 1** (***1–3 solid planes:*** floor and 3 mesh sides; or floor with 2 solid sides and 2 mesh ends)

**Score 2** (***4 solid planes***: floor and 3 solid sides with mesh front and open top)

**Score 3** (***5 solid planes***: floor with 4 solid sides and open top; or floor with 3 solid sides, cover, and mesh front)

- Barn Bedding
  - ◊ Type ____________________
  - ◊ Quantity ____________________
  - ◊ Nesting score ____________________

    Most calves appear to be:

    1–Lying on top of bedding with legs exposed

    2–Nestled slightly into bedding, part of legs visible above bedding

    3–Nestled deeply, legs not visible

- Barn Conditions
  - ◊ Temperature and humidity measurements (HOBO data logger)

    (To record temperature and humidity, place one data logger inside the barn and one in a shady area outside the barn. Record data in 2-hour increments.)
    - – Start date & time ____________________
    - – End date & time ____________________

  - ◊ Wind measurements (in naturally ventilated barn)
    - – Prevailing wind speed ____________________
    - – Prevailing wind direction ____________________

– Barn ventilation rate ________________________

– Distance to nearest building ________________

◊ Crude airflow (in mechanically ventilated barn) (Measure fan capacity both dirty and clean)

– Exit fans

diameter ________________________________

velocity (ft/min)* ___________________________

– Inlet fans

diameter ________________________________

velocity (ft/min)* ___________________________

*using anemometer

◊ Air exchange in $ft^3$/ head/min for calves (area=3.14*$r^2$) (Table A1)

Volume/time *(airflow velocity x size of fan opening)*

airflow velocity_____x fan diameter_______= volume/time_________

Volume/time *(ft/min × ft² = ft³/min ÷ number of calves = ft³/calf/minute)*

ft/min_______× $ft^2$________= $ft^3$/min______ ÷ number of calves_________= $ft^3$/calf/minute_________

*Minimum air space for calf up to 200 lb = 3.9 in. per calf*

*Table A1. Recommended air exchange rates in ft³/head/min for calves.**

| Age range | Cold weather | Mild weather | Hot weather |
|---|---|---|---|
| 0–2 months | 15 $ft^3$/hd/min<br>(~10 $ft^3$/100 lb/min) | 50 $ft^3$/hd/min<br>(~33 $ft^3$/100 lb/min) | 100 $ft^3$/hd/min<br>(~66 $ft^3$/100 lb/min) |
| 2–12 months | 20 $ft^3$/hd/min<br>(~5 $ft^3$/100 lb/min) | 60 $ft^3$/hd/min<br>(~15 $ft^3$/100 lb/min) | 130 $ft^3$/hd/min<br>(~33 $ft^3$/100 lb/min) |

*(Adapted from Structures and Environment Handbook 1983, Midwest Plan Service, Iowa State University, Ames, IA 50011.)*

**Estimates of ft³/100 lb/min have been added based on average weights of 150 lb at 0–2 mos. and 400 lb at 2–12 mos.*

◊ Air flow patterns

– Dead spots (use smoke sticks to observe patterns of airflow)

– Drafts (air striking a calf at 88 ft/min or 1 mph)

◊ Airflow rates

– Measure $CO_2$ level (at calf's nose level) in several locations of the barn

Rate Standards: Hot weather below 350 ppm. Mild weather below 600 ppm. Cold weather below 1400 ppm.

Barn volume calculations (Figure A3)

Calculating approximate volume of a pitched roof:

**Calculate Volume A** *(width × length × height = $ft^3$):*

width ________ × length _______ × height________ =________$ft^3$

**Calculate Volume B** *(width x length x height = $ft^3/2$ = $ft^3$):*

width ______× length ______ × height______ =_______$ft^3/2$ =_______ $ft^3$

**Calculate Total Barn Volume C** *(Volume A + Volume B):*

Volume A_______$ft^3$ + Volume B________$ft^3$ = Volume C__________$ft^3$

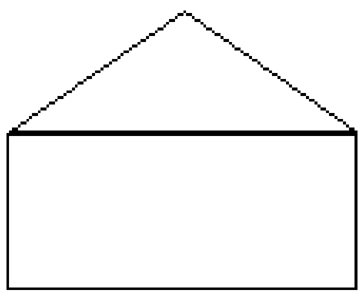


*Figure A3. Schematic of volumes used to calculate total barn volume.*

## Estimating Pre-Weaned Calf Housing Needs

Although most dairy herds in the United States breed year-round, the effects of heat stress on conception rates in some areas can cause a “flush” or “surge” of calvings at certain times of the year. To estimate the amount of pre-weaned calf housing that may be needed in the near future, the number of calvings must be counted over time. (When estimating, it is preferable to examine a two-year period of calving data, although one year’s worth may be all that is available.)

For example, the PCDART® Dairy Records Management Systems software report “147 Herd Summary” provides the number of calvings by month (Table A2). If calves are weaned on a weekly basis and are weaned at 8 weeks, at some point there will be approximately two months worth of pre-weaned calves (halved, if bull calves are not kept). In this example, the number of calvings were counted on nonstandard test dates—they were not counted every month. A best estimate then is that about 40 calves might be the greatest number of calves born in a month (January). If the herd raises all the bull calves and weans them at 8 weeks, the farm would need at least 80 pre-weaned calf housing units.

*Table A2. 147 TDU – Yearly herd summary.*

**147 TDU- Yearly Herd Summary (DHI Rolling Herd Averages)**

DRMS

| | YEARLY TOTALS | LAST TEST* | PREVIOUS TESTS * * * | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 031310 | 011610 | 120109 | 101709 | 091209 | 080109 | 062709 | 052309 | 041109 |
| REPRODUCTION: | Totals | | | | | | | | | |
| Voluntary Waiting Period | | 70 | 70 | 70 | 70 | 60 | 60 | 60 | 60 | 60 |
| No. 1st services ........ | 211 | 30 | 39 | 24 | 14 | 25 | 12 | 12 | 25 | 30 |
| % successful .......... | 45 | | | 58 | 57 | 56 | 42 | 33 | 28 | 40 |
| Service sire pta$...... | +466 | +440 | +448 | +432 | +423 | +473 | +502 | +413 | +503 | +513 |
| No. 2nd services ........ | 123 | 19 | 11 | 8 | 9 | 9 | 10 | 16 | 21 | 20 |
| % successful .......... | 42 | | | 38 | 22 | 44 | 60 | 25 | 38 | 60 |
| Service sire pta$...... | +468 | +396 | +260 | +559 | +533 | +451 | +544 | +533 | +428 | +522 |
| No. 3rd+ services ....... | 146 | 8 | 12 | 14 | 13 | 21 | 26 | 21 | 19 | 12 |
| % successful .......... | 37 | | | 64 | 62 | 33 | 23 | 33 | 21 | 50 |
| Service sire pta$...... | +459 | +194 | +285 | +561 | +346 | +447 | +463 | +524 | +495 | +537 |
| No. services (all) ...... | 480 | 57 | 62 | 46 | 36 | 55 | 48 | 49 | 65 | 62 |
| % successful .......... | 42 | | | 57 | 50 | 45 | 35 | 31 | 29 | 48 |
| Service sire pta$...... | +465 | +399 | +399 | +476 | +440 | +459 | +493 | +500 | +477 | +521 |
| % heats observed ........ | 55 | 58 | 60 | 60 | 48 | 54 | 46 | 52 | 54 | 61 |
| No. pregnant this test .. | | 29 | 36 | 23 | 20 | 22 | 13 | 19 | 34 | 17 |
| No. pregnant total ...... | | 133 | 131 | 127 | 123 | 122 | 119 | 125 | 125 | 107 |
| No. calvings ............ | 255 | 44 | 39 | 31 | 28 | 21 | 27 | 28 | 21 | 16 |
| No. actual abortions..... | 2 | | | 1 | 1 | | | | | |
| No. apparent abortions... | 14 | 2 | 1 | | 3 | 1 | | 1 | 4 | 2 |

Using the Dairy Herd Improvement Association (DHIA) summary report, you can determine the number of calvings between test days, and using the DHI-Plus® Herd Management report (Table A3), you can determine the number of calvings by month (making sure to include the archive files so every cow is represented).

*Table A3. DHI-Plus calendar record.*

| DIM | Data | Apr 10 | Mar 10 | Feb 10 | Jan 10 | Dec 09 | Nov 09 | Oct 09 | Sep 09 | Aug 09 | Jul 09 | Jun 09 | May 09 | Apr 09 | Mar 09 | Feb 09 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lact. All | | | | | | | | | | | | | | | | | |
| Transition | # Calved | 3 | 330 | 277 | 234 | 199 | 201 | 190 | 147 | 215 | 174 | 214 | 212 | 121 | 103 | 81 | 2701 |
| Lact. 1 | | | | | | | | | | | | | | | | | |
| Transition | # Calved | | 198 | 186 | 101 | 74 | 91 | 63 | 51 | 70 | 59 | 114 | 123 | 55 | 44 | 42 | 1271 |
| Lact. 2 | | | | | | | | | | | | | | | | | |
| Transition | # Calved | 1 | 59 | 43 | 60 | 66 | 48 | 55 | 50 | 84 | 61 | 43 | 37 | 38 | 28 | 19 | 692 |
| Lact. 3+ | | | | | | | | | | | | | | | | | |
| Transition | # Calved | 2 | 73 | 48 | 73 | 59 | 62 | 72 | 46 | 61 | 54 | 57 | 52 | 28 | 31 | 20 | 738 |

As seen in the DairyComp305® summary report (Table A4), there appears to have been a recent surge in calvings in February and March of 2010. So if bull calves are kept until weaning and are weaned at 8 weeks, over 600 pre-weaned calf housing units would be needed.

*Table A4. DHI-Plus calendar record.*

| DIM | Data | Apr 10 | Mar 10 | Feb 10 | Jan 10 | Dec 09 | Nov 09 | Oct 09 | Sep 09 | Aug 09 | Jul 09 | Jun 09 | May 09 | Apr 09 | Mar 09 | Feb 09 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lact. All | | | | | | | | | | | | | | | | | |
| Transition | # Calved | 3 | 330 | 277 | 234 | 199 | 201 | 190 | 147 | 215 | 174 | 214 | 212 | 121 | 103 | 81 | 2701 |
| Lact. 1 | | | | | | | | | | | | | | | | | |
| Transition | # Calved | | 198 | 186 | 101 | 74 | 91 | 63 | 51 | 70 | 59 | 114 | 123 | 55 | 44 | 42 | 1271 |
| Lact. 2 | | | | | | | | | | | | | | | | | |
| Transition | # Calved | 1 | 59 | 43 | 60 | 66 | 48 | 55 | 50 | 84 | 61 | 43 | 37 | 38 | 28 | 19 | 692 |
| Lact. 3+ | | | | | | | | | | | | | | | | | |
| Transition | # Calved | 2 | 73 | 48 | 73 | 59 | 62 | 72 | 46 | 61 | 54 | 57 | 52 | 28 | 31 | 20 | 738 |

Using the DairyComp305 events menu (Table A5), you can find the number of fresh cows by month. (Include all the archived information so even if cows have been removed from the herd, their calvings are counted.)

*Table A5. DairyComp305 events summary report.*

| Event | Total | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FRESH | 1913 | 129 | 116 | 141 | 141 | 172 | 155 | 207 | 175 | 173 | 162 | 198 | 144 |
| SOLD | 811 | 81 | 59 | 69 | 62 | 34 | 59 | 50 | 71 | 70 | 140 | 62 | 54 |
| DIED | 129 | 12 | 14 | 11 | 4 | 13 | 8 | 17 | 16 | 6 | 14 | 8 | 6 |
| TOTALS | 2853 | 222 | 189 | 221 | 207 | 219 | 222 | 274 | 262 | 249 | 316 | 268 | 204 |

Looking again at the data in Table A5, there were over 200 calvings in one month in a herd of 3000 cows. If the bull calves were not kept and there was about a 50:50 ratio of bulls to heifers and they were weaned at 8 weeks, over 200 pre-weaned calf-housing units would be required.

From the baseline information on fresh events or calvings, you can estimate what the surge capacity requirements will be for calf housing (and maternity pen needs) by reviewing weekly calvings. Reviewing calving reports that also include the number of heifer and bull calves will give you a more refined look at the data. Consider having 10–20% more housing if the herd is growing internally.

## Weaned Calf Environment—2 to 4 Months of Age

- ☐ Super hutches have 34 $ft^2$/calf of space (DCHA 2010)
- ☐ Transition groups of 5–12 calves have 34 $ft^2$/calf of space
- ☐ Dry lot corrals have 200 $ft^2$ /calf, 1.5 ft of bunk space, and 20 $ft^2$ of shade per calf
- ☐ Bedding sample DM % is estimated (as a substitute for dampness)
- ☐ Total calf raising space/facilities are adequate for surge capacity

- ☐ Calves are kept in stable groups and not mixed
- ☐ Calf groups are sorted by age, size, and behavior (based on dominance)
- ☐ Calves in a group have no more than a 2-month age difference
- ☐ Facilities, equipment, fittings, and pasture used by the animals are free of debris
- ☐ Respiratory rates are normal during periods of summer heat stress

  (For neonates, 50 breaths per minute is normal. Respiratory rate is often used clinically to detect animals with pneumonia. However, under heat stress, panting occurs, and calf caretakers need to differentiate heat-stressed calves from those with pneumonia.)††

Table A6 lists average respiratory rates for calves at different environmental temperatures based on two studies (Eigenberg et al. 2005; Findlay 1957).

*††An unvalidated rule of thumb is that if calves are breathing faster than 90 breaths per minute, heat stress remediation is necessary.*

*Table A6. Temperature and average respiratory rate.*

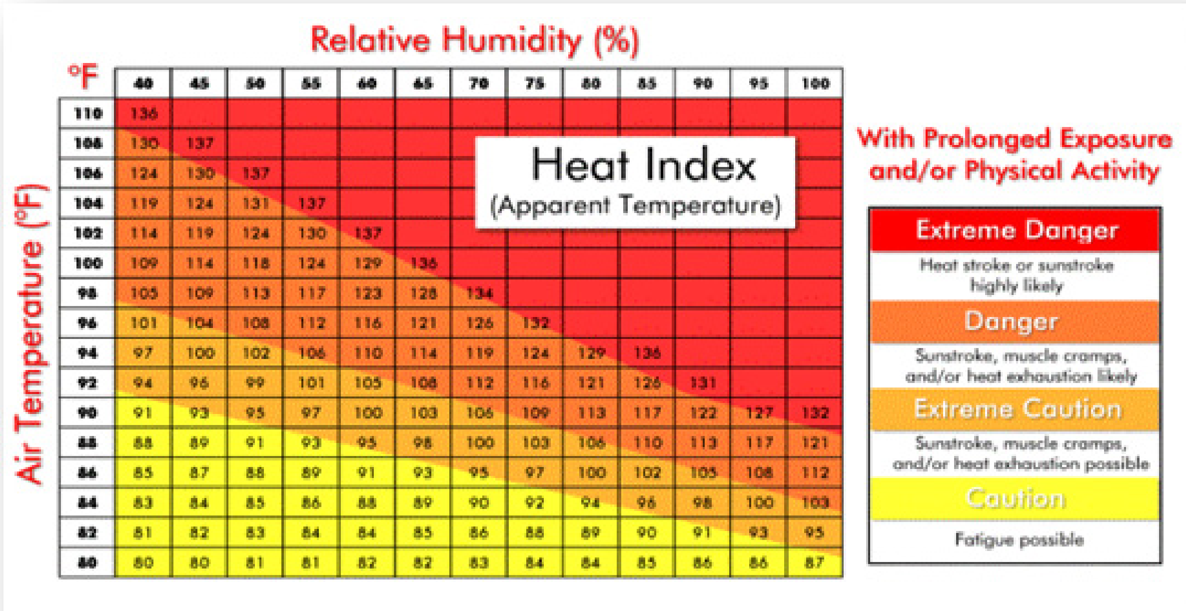
| Dry Bulb Temperature °F (°C) | Breaths per Minute |
|---|---|
| 41 (5) | 60 |
| 50 (10) | 70 |
| 59 (15) | 80 |
| 68 (20) | 70–90 |
| 77 (25) | 100 |
| 86 (30) | 110–120 |
| 104 (40) | 130–140 |

- ☐ Skin Temperatures are within normal range.

  (Infrared thermography can be used to measure skin temperature in cattle. If the skin temperature is less than 95°F, calves can effectively use all four routes of heat exchange—conduction, convection, radiation, and evaporation (Collier et al. 2006). Infrared skin temperature is highly correlated with respiratory rate in dairy cows.)

- ☐ Heat Stress is within normal limits.

  A Heat Index chart (Figure A4) can be used to assess potential heat stress within the calf environment. A Heat Index chart can also be found at www.erh.noaa.gov/rah/heat/heatindexchart.gif.




| °F | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 110 | 136 | | | | | | | | | | | | |
| 108 | 130 | 137 | | | | | | | | | | | |
| 106 | 124 | 130 | 137 | | | | | | | | | | |
| 104 | 119 | 124 | 131 | 137 | | | | | | | | | |
| 102 | 114 | 119 | 124 | 130 | 137 | | | | | | | | |
| 100 | 109 | 114 | 118 | 124 | 129 | 136 | | | | | | | |
| 98 | 105 | 109 | 113 | 117 | 123 | 128 | 134 | | | | | | |
| 96 | 101 | 104 | 108 | 112 | 116 | 121 | 126 | 132 | | | | | |
| 94 | 97 | 100 | 102 | 106 | 110 | 114 | 119 | 124 | 129 | 136 | | | |
| 92 | 94 | 96 | 99 | 101 | 105 | 108 | 112 | 116 | 121 | 126 | 131 | | |
| 90 | 91 | 93 | 95 | 97 | 100 | 103 | 106 | 109 | 113 | 117 | 122 | 127 | 132 |
| 88 | 88 | 89 | 91 | 93 | 95 | 98 | 100 | 103 | 106 | 110 | 113 | 117 | 121 |
| 86 | 85 | 87 | 88 | 89 | 91 | 93 | 95 | 97 | 100 | 102 | 105 | 108 | 112 |
| 84 | 83 | 84 | 85 | 86 | 88 | 89 | 90 | 92 | 94 | 96 | 98 | 100 | 103 |
| 82 | 81 | 82 | 83 | 84 | 84 | 85 | 86 | 88 | 89 | 90 | 91 | 93 | 95 |
| 80 | 80 | 80 | 81 | 81 | 82 | 82 | 83 | 84 | 84 | 85 | 86 | 86 | 87 |

*Figure A4. Heat index chart.*

Although this assessment tool can be used to help investigate calf-raising problems, it can also be used to help establish baseline measures for use when determining if progress is being made. The dairy advisor could develop a monitoring program for dairy calf environments using many of the measurements and tools provided in this assessment.

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