Opportunities with Low Profile Cross Ventilated Freestall Facilities

J. F. Smith, J. P. Harner, B. J. Bradford, and M. W. Overton [1]

Summary

Low profile cross ventilated freestall buildings are one option for dairy cattle housing. These facilities allow producers to control the cows' environment during all seasons of the year. As a result, an environment similar to the thermoneutral zone of a dairy cow is maintained during both summer and winter, resulting in more stable core body temperatures. Low profile cross ventilated facilities allow buildings to be placed closer to the parlor, thus reducing the time cows are away from feed and water. Other advantages include a smaller overall site footprint than naturally ventilated facilities and less critical orientation because naturally ventilated facilities should be orientated east to west to keep cows in the shade. Other benefits of controlling the cows' environment include increased milk production and income over feed cost, improved feed efficiency and reproductive performance, reduced lameness and fly control costs, and the ability to control lighting.

Characteristics of Low Profile Cross Ventilated Facilities

The "low profile" results from the roof slope being changed from a 3/12 or 4/12 pitch common in naturally ventilated buildings to a 0.5/12 pitch. Figure 1 shows the difference in ridge height between 4-row naturally ventilated buildings and an 8-row low profile cross ventilated (**LPCV**) building. Contractors are able to use conventional warehouse structures with the LPCV building and reduce the cost of the exterior shell of the building, but the interior components and space per cow for resting, socializing, and feeding in an LPCV building are similar to a 4-row building. Differences in land space requirements between the 4-row naturally ventilated freestall buildings and an 8-row LPCV building are also shown in Figure 1.

Figure 2 shows an end view of an 8-row LPCV building. An evaporative cooling system is located along one side of the building, and fans are placed on the opposite side. More space is available for fan placement, and the cooling system is parallel to the ridge rather than perpendicular because the equipment doors are located in the end walls.

Figure 3 shows a layout of an 8-row LPCV building with tail to tail freestalls. From a top view, this design simply places two, 4-row freestall buildings side by side and eliminates the space between the buildings that is necessary for natural ventilation. One potential advantage of the LPCV, or tunnel ventilated, buildings is that cows are exposed to near-constant wind speeds. The air velocity, or wind speed, inside the building is normally less than 8 miles/hour during peak airflow. Ventilation rate is reduced during cold weather, with wind speed decreasing to less than 2 miles/hour.

[1] College of Veterinary Medicine, University of Georgia, Athens, GA.

Providing a Consistent Environment

Constructing a cross ventilated facility ensures the ability to provide a consistent environment year-round, resulting in improved cow performance. These buildings provide a better environment than other freestall housing buildings during all seasons of the year because of the use of an evaporative cooling system.

Ability to lower air temperature by evaporative cooling depends upon ambient temperature and relative humidity. As relative humidity increases, cooling potential decreases (Figure 4). Cooling potential is the maximum temperature drop possible, assuming the evaporative cooling system is 100% efficient. As relative humidity increases, the ability to lower air temperature decreases, regardless of temperature. The cooling potential is greater as air temperature increases and relative humidity decreases. Figure 4 also shows that evaporative cooling systems perform better as the humidity decreases below 50%.

Effect of LPVC Facilities on Core Body Temperature

One of the major benefits of LPCV facilities is the ability to stabilize a cow's core body temperature. A heat stress audit was conducted at a North Dakota dairy to evaluate the effect of a changing environment on the core body temperature of cows. Vaginal temperatures were collected from 8 cows located in the LPCV facility and 8 cows located in a naturally ventilated freestall facility with soakers and fans. Data were recorded every 5 minutes for 72 hours by using data loggers (HOBO U12, Onset Computer Corporation, Bourne, MA) attached to an intravaginal insert. Environmental temperature and humidity data were collected on individual dairies by using logging devices that collected information at 15-minute intervals. Environmental conditions and vaginal temperatures during the evaluation period are presented in Figures 5 and 6. Vaginal temperatures were acceptable in both facilities, but temperatures of cows housed in the LPCV facility were more consistent. Feedline soakers in naturally ventilated buildings effectively cool cows, but cows must walk the feedline to be soaked. On the other hand, cows in an LPCV facility already experience temperatures that are considerably lower than the ambient temperature. Reducing fluctuations in core body temperature has a dramatic effect on production, reproduction, and health of a dairy cow.

Environmental Effect on Nutrient Requirements and Efficiency

Dairy cows housed in an environment beyond their thermoneutral zone alter their behavior and physiology in order to adapt. These adaptations are necessary to maintain a stable core body temperature but affect nutrient utilization and profitability on dairy farms.

The upper critical temperature, or upper limit, of the thermoneutral zone for lactating dairy cattle is estimated to be approximately 70°F to 80°F. When temperatures exceed that range, cows begin to combat heat stress by reducing feed intake, sweating, and panting. These mechanisms increase cows' energy costs, resulting in up to 35% more feed necessary for maintenance. When dry matter intake decreases during heat stress, milk production also decreases. A dairy cow in a 100°F environment decreases productivity by 50% or more relative to thermoneutral conditions.

Compared with research on the effect of heat stress, little attention has been given to cold stress in lactating dairy cattle. The high metabolic rate of dairy cows makes them more susceptible to heat stress in U.S. climates, so the lower critical temperature of lactating dairy cattle is not well established. Estimates range from as high as 50°F to as low as −100°F. Regardless, evidence exists that performance of lactating cows decreases at temperatures below 20°F. One clear effect of cold stress is an increase in feed intake. Although increased feed intake often results in greater milk production, cold-induced feed intake is caused by increased rate of digesta passage through the gastrointestinal tract. An increased passage rate limits the digestion time and results in less digestion as the temperature drops. In cold temperatures, cows also maintain body temperature by using nutrients for shivering or metabolic uncoupling, both of which increase maintenance energy costs. These mechanisms decrease milk production by more than 20% in extreme cold stress. However, even when cold stress does not negatively affect productivity, decreased feed efficiency can hurt dairy profitability.

To assess the effects of environmental stress on feed efficiency and profitability, a model was constructed to incorporate temperature effects on dry matter intake, diet digestibility, maintenance requirements, and milk production. Expected responses of a cow producing 80 lb of milk per day in a thermoneutral environment with total mixed ration costs of $0.12/lb of dry matter and milk value of $18/hundred weight (cwt) of milk are shown in Figure 7. The model was altered to assess responses to cold stress if milk production is not decreased. In this situation, the decrease in diet digestibility results in an 8% decrease in income over feed cost as temperatures drop to −10°F ($6.94/cow vs. $7.52/cow per day).

Given these research results, cost benefits can be estimated for environmental control of LPCV facilities. Benefits of avoiding extreme temperatures can be evaluated by comparing returns at ambient temperatures with temperatures expected inside LPCV barns. For example, the model predicts that income over feed cost can be improved by nearly $2/cow per day if the ambient temperature is 95°F and barn temperatures are maintained at 85°F. Likewise, if ambient temperature is 5°F and the temperature inside the barn is 15°F, income over feed cost is expected to increase by $1.15/cow per day.

Besides effects on feed costs and productivity, heat stress also has negative effects on reproduction, immunity, and metabolic health. These factors represent huge potential costs to a dairy operation. Although responses to cold stress are not typically dramatic, increased manure production is a resulting factor. In this model, increased feed intake and decreased digestibility during cold stress also increased manure output by as much as 34%. Manure is a significant cost factor on many farms, requiring increased manure storage capacity and more acres for manure application.

Environmental Effect on Reproduction

Even though cold stress has little effect on reproduction, heat stress can reduce libido, fertility, and embryonic survival in dairy cattle. Environmental conditions above a dairy cow's thermoneutral zone decrease the cow's ability to dissipate heat, resulting in increased core body temperature. Elevated body temperatures negatively affect reproduction in both cows and bulls.

Effects of heat stress can be categorized by the effects of acute heat stress (short-term increases in body temperature above 103°F) or chronic heat stress (cumulative effects of prolonged exposure to heat throughout the summer). In acute heat stress, even short-term rises in body temperature can result in a 25 to 40% drop in conception rate. An increase of 0.9°F in body temperature causes a decline in conception rate of 13%. The effect of heat stress on reproduction is more dramatic as milk production increases, a result of greater internal heat load produced because of more feed intake.

Regardless whether the decline in pregnancy rates is voluntary, fewer cows becoming pregnant create holes in the calving patterns. Often, there is a rebound in the number of cows that become pregnant in the fall. Nine months later, a large number of pregnant cows puts additional pressures on the transition facilities when an above-average group of cows moves through the close-up and fresh cow pens. Overcrowding these facilities leads to increases in post-calving health issues, decreased milk production, and impaired future reproduction.

Table 1 examines the economic effect of heat stress by describing the reproductive performance for a hypothetical 3,200-cow Holstein dairy. As shown in Table 1, the herd has above-average reproductive performance during much of the year (insemination rate of 57%, conception rate of 30%, and pregnancy rate of 17%). During summer and throughout the month of September, both insemination rate and conception rate decline, resulting in pregnancy rates that are well below average. As a consequence of these periods of poor reproductive performance, the herd's annual pregnancy rate is 15%. On the basis of economic models that evaluate the value of changes in reproductive performance, this subpar performance during the five 21-day periods costs the dairy approximately $115,000.

Although this simple spreadsheet illustrates how heat stress adversely affects reproductive performance, it does not capture the total cost of the issues created by heat stress. Consideration of the increased number of abortions commonly seen during heat stress; the effect of transition facility overcrowding; and the negative effect on cow health, early lactation milk production, and future reproduction leads to estimated losses well beyond $135,000/year, or at least $42/cow per year, using a milk price of $0.18/lb and a feed cost of $0.12/lb.

Environmental Effect on Milk Production

Although the effect of cold stress on milk production is minimal, the effect of heat stress on milk production can be very dramatic. Numerous studies have been completed to evaluate the economic effect of heat stress on milk production, but because so many approaches are used to manage heat stress, standard evaluations are difficult. Heat stress not only affects milk production during summer but also reduces the potential for future milk production of cows during early lactation. For every pound of peak milk production lost, an additional 250 lb of production will be lost over the entire lactation.

A simple sensitivity analysis was conducted to observe the effect of heat stress on gross income. A net milk price of $18/cwt was used for this analysis. The milk production effect of 90 to 150 days of heat stress on gross income per cow is presented in Table 2. When daily milk production is reduced 2 to 12 lb/cow per day, the gross income loss related to heat stress ranges from $32.40/cow to $324.00/cow.

The effect of heat stress on future milk production is evaluated in Table 3. Gross income per cow per lactation is increased from $90/cow to $540/cow per lactation as peak milk production is increased from 2 to 12 lb/cow per day during periods of heat stress.

Lighting

Light is an important environmental characteristic in dairy facilities. Proper lighting can improve cow performance and provide a safer and more pleasant work environment. Meeting the lighting requirement of both dry and lactating cows in an LPCV facility can be challenging because lactating and dry dairy cattle have different lighting requirements. Dry cows need only 8 hours of light (8 L) and 16 hours of darkness per day, whereas lactating dairy cows exposed to 16 hours of light (16 L) per day increase milk production from 5 to 16% (8% being typical), increase feed intake about 6%, and maintain reproductive performance. It is important to note, though, that 16 L does not immediately increase milk production. A positive response can take 2 to 4 weeks to develop, assuming that nutrition and other management conditions are acceptable. Cows exposed to 8 L vs. 16 L during the dry period produce 7 lb more milk per day in the following lactation.

Enhanced lighting for the milking herd is profitable. Cows move more easily through uniformly lit entrances and exits, and producers, herdsmen, veterinarians, and other animal care workers report easier and better cow observation and care. Workers also note that a well-lit area is a more pleasant work environment. Increased cow performance and well-being plus better working conditions make lighting an important environmental characteristic in a dairy facility.

Conclusions

Low profile cross ventilated facilities are capable of providing a consistent environment for dairy cows throughout the year. Changing the environment to reflect the thermoneutral zone of a dairy cow minimizes the effect of seasonal changes on milk production, reproduction, feed efficiency, and income over feed cost. The key is to reduce variation in the core body temperature of the cows by providing a stable environment.

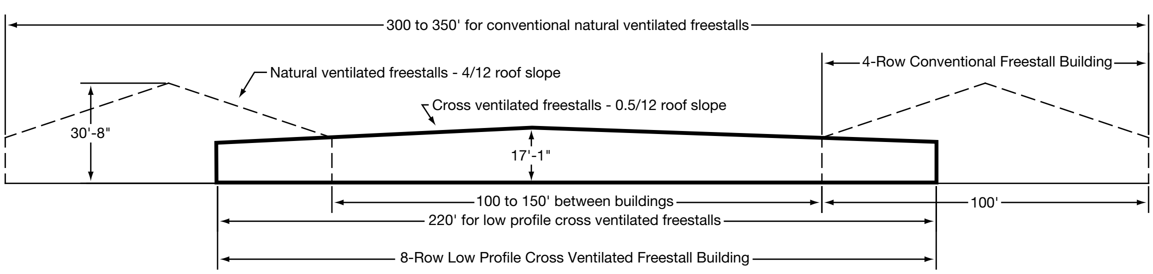

Figure 1. End views of 8-row naturally ventilated freestall buildings and an 8-row low profile cross ventilated freestall building.

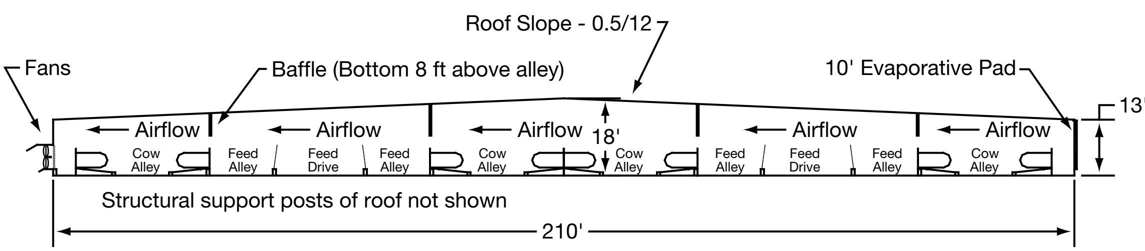

Figure 2. End view of an 8-row low profile cross ventilated freestall building.

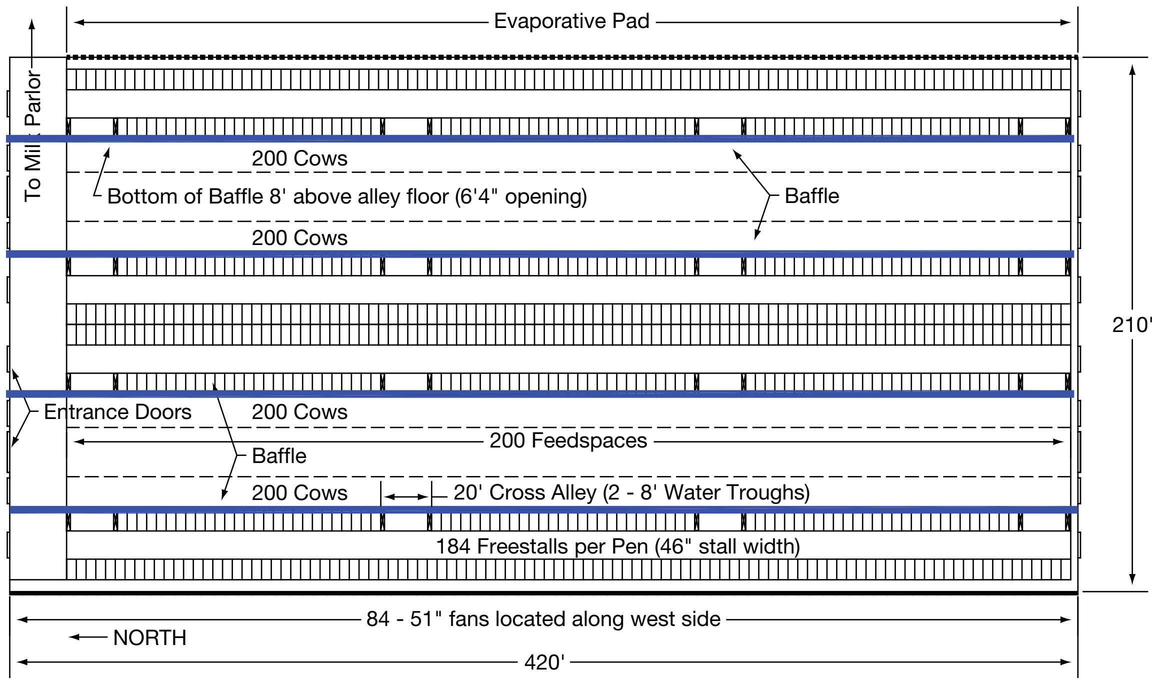

Figure 3. Top view of an 8-row low profile cross ventilated building (adjustable building length based on cow numbers).

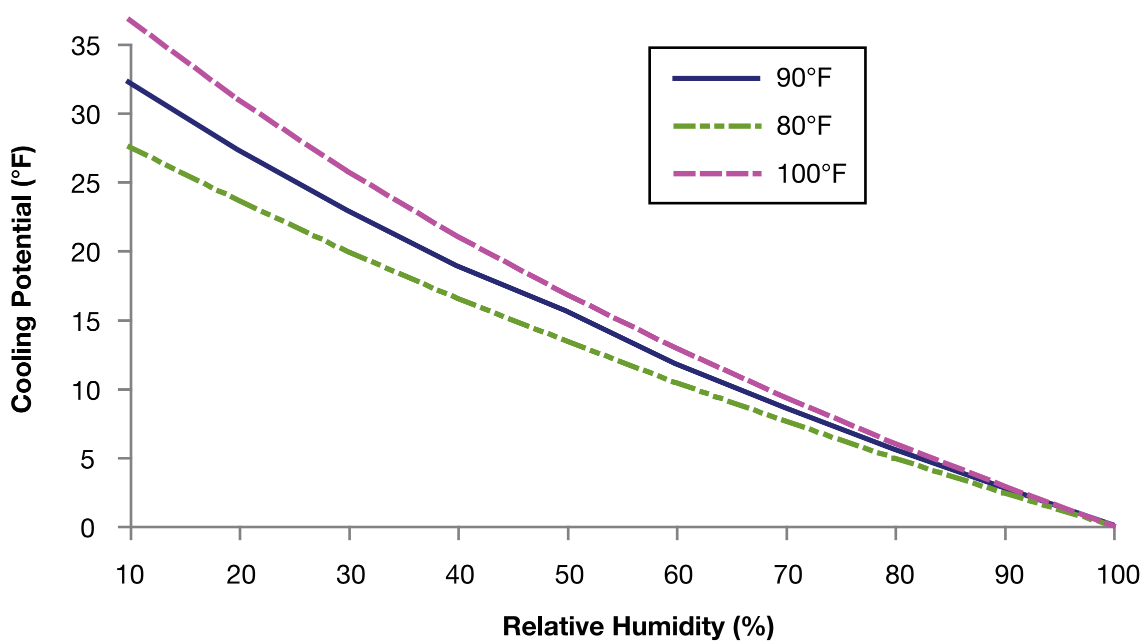

Figure 4. Effect of relative humidity and temperature on cooling potential when using an evaporative cooling system.

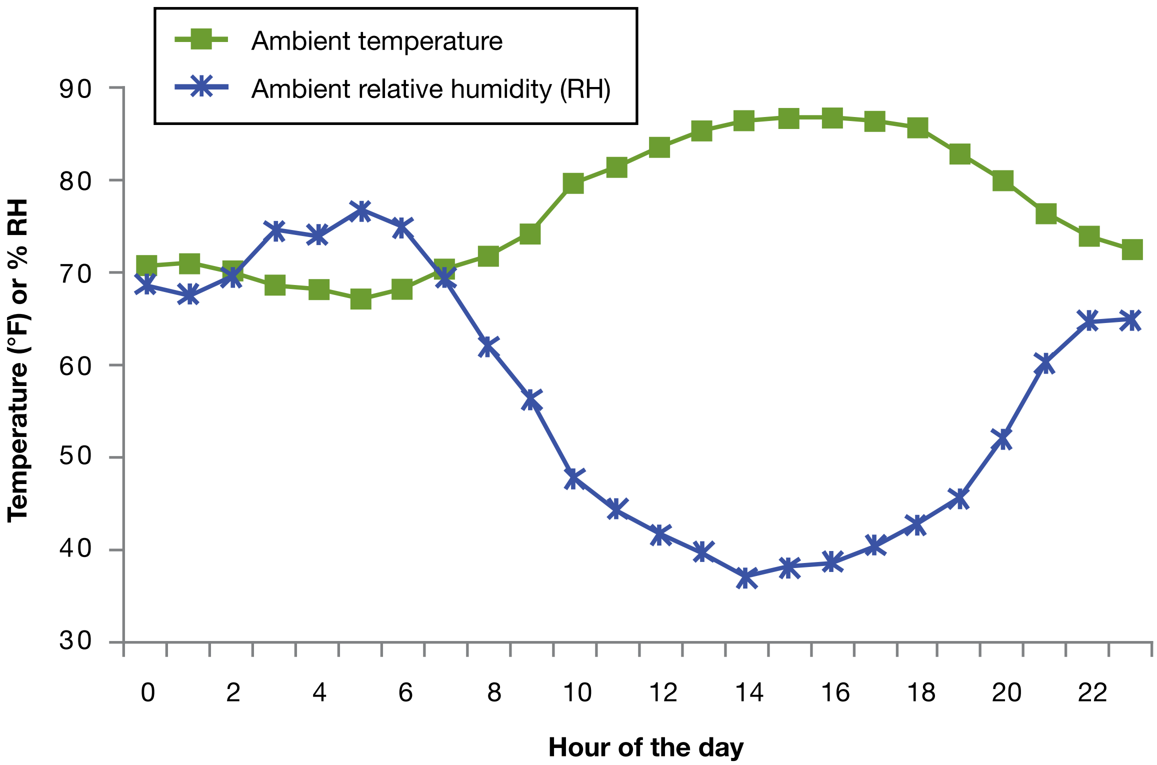

Figure 5. Ambient temperature and percentage relative humidity for Milnor, ND (July 6 to 9, 2006).

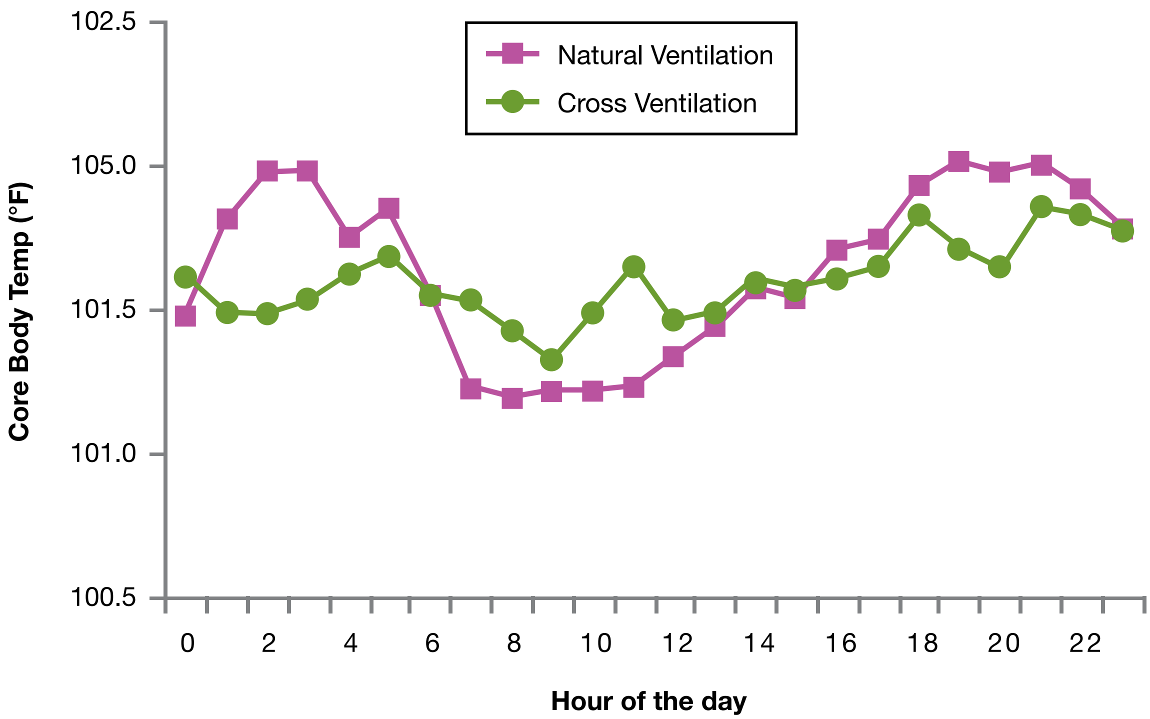

Figure 6. Core body temperature of cows housed in naturally ventilated (fans and soakers) and low profile cross ventilated freestalls (evaporative pads).

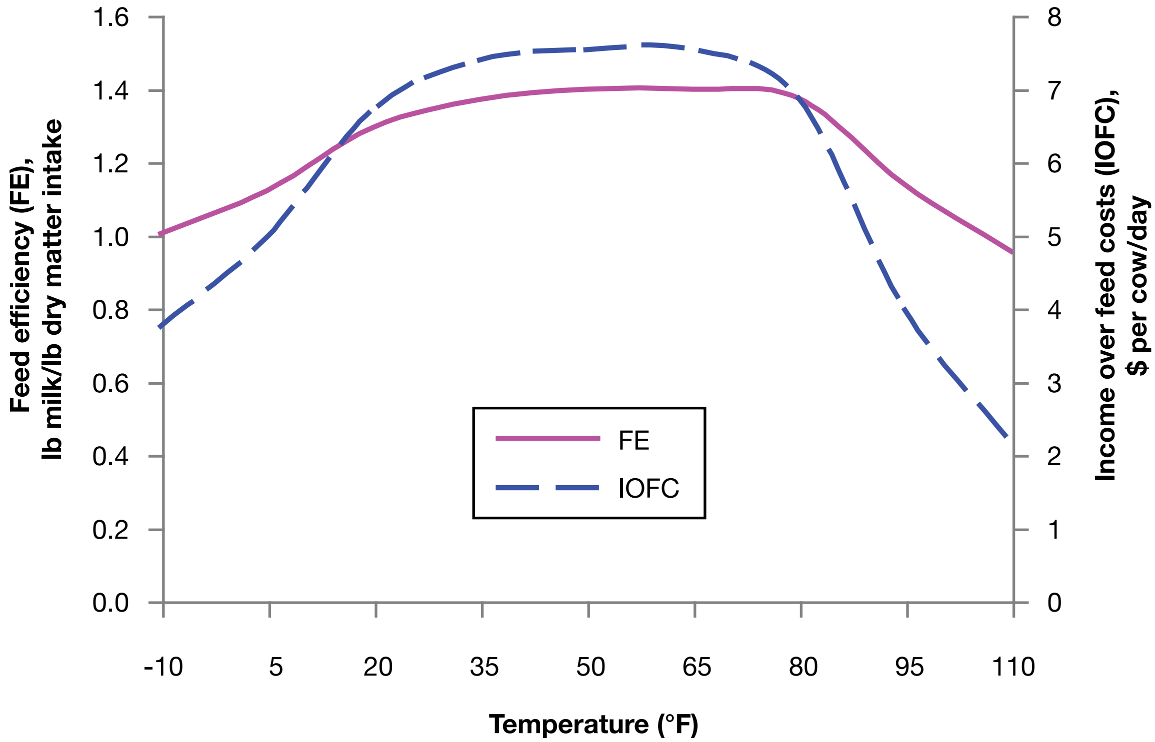

Figure 7. Responses to environmental stress (thermoneutral production of 80 lb/day, total mixed ration cost of $0.12/lb of dry matter, and milk value of $18/cwt).

Table 1. Historical reproductive performance for a hypothetical 3,200-cow Holstein dairy

Date	Eligible (n)	Insemination rate (%)	Bred (n)	Conception rate (%)	Pregnant (n)	Pregnancy rate (%)
1-Jan	932	57	531	30	159	17
22-Jan	905	57	516	30	155	17
12-Feb	884	57	504	30	151	17
5-Mar	868	57	495	30	149	17
26-Mar	855	57	487	30	146	17
16-Apr	845	57	481	30	144	17
7-May	833	57	475	30	142	17
28-May	831	57	473	30	142	17
18-Jun	825	46	376	21	79	10
9-Jul	883	46	402	21	85	10
30-Jul	930	46	424	21	89	10
20-Aug	983	46	448	21	94	10
10-Sep	1041	49	514	24	123	12
1-Oct	1078	54	582	30	175	16
22-Oct	1049	57	598	30	179	17
12-Nov	1014	57	578	30	173	17
3-Dec	965	57	550	30	165	17
24-Dec	945	57	539	30	162	17
Total or avg.	16,664	54	8,974	28	2,513	15

Table 2. Potential loss of gross income for different periods of heat stress

Reduction of milk production (lb/cow per day)	90 days of lost production (lb)	120 days of lost production (lb)	150 days of lost production (lb)	Lost income 90 days ($0.18/lb)	Lost income 120 days ($0.18/lb)	Lost income 150 days ($0.18/lb)
2	180	240	300	32.40	43.20	54.00
4	360	480	600	64.80	86.40	108.00
6	540	720	900	97.20	129.60	162.00
8	720	960	1,200	129.60	172.80	216.00
10	900	1,200	1,500	162.00	216.00	270.00
12	1,080	1,440	1,800	194.40	259.20	324.00

Table 3. Effect of increasing peak milk during heat stress on future milk production and gross income

Increase in peak milk production (lb/cow per day)	Additional milk production (lb/lactation)	Additional gross income per lactation ($0.18/lb)
2	500	90.00
4	1,000	180.00
6	1,500	270.00
8	2,000	360.00
10	2,500	450.00
12	3,000	540.00