Climate Change Impacts on Dairy Cattle

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All animals have a range of ambient environmental temperatures termed the thermo neutral zone. This is the range of temperatures that are conducive to health and performance. The upper critical temperature is the point at which heat stress effects begin to affect the animal. There are a number of environmental factors that contribute to heat stress. These include high temperature, high humidity and radiant energy (sunlight). Heat stress can be simply defined as the point where the cow cannot dissipate an adequate quantity of heat to maintain body thermal balance.

The environmental conditions that induce heat stress can be calculated using the temperature humidity index (THI). There are a number of equations that have been used to calculate THI. These equations usually include temperature and humidity to calculate THI. One equation is:

$$THI = (\text{Dry bulb temperature } ^{o}C) + (0.36^{*} \text{ dew point temperature } ^{o}C) + 41.2$$

Heat stress begins to occur in dairy cattle when the THI is > 72. Table 1 contains some of the signs that cows exhibit as the THI increases. Note that these range from mild changes in metabolism and milk production to potential cow deaths.

Table 1. Effect of Heat Stress on Dairy Cattle [a]

THI[b]	Stress Level	Comments
< 72	None	
72 – 79	Mild	Dairy cows will adjust by seeking shade, increasing respiration rate and dilation of the blood vessels. The effect on milk production will be minimal.
80 – 89	Moderate	Both saliva production and respiration rate will increase. Feed intake may be depressed and water consumption will increase. There will be an increase in body temperature. Milk production and reproduction will be decreased.
90 – 98	Severe	Cows will become very uncomfortable due to high body temperature, rapid respiration (panting) and excessive saliva production. Milk production and reproduction will be markedly decreased.
> 98	Danger	Potential cow deaths can occur

[a] Adapted from information provided by Monsanto
[b] Temperature humidity index

A number of changes occur in the animal as a result of heat stress. These include:

1. Elevated body temperature – Body temperatures > 102.5 ^{o}F (normal is 101.5 ^{o}F).
2. Increased respiration rates > 70-80/minute.
3. Increased maintenance energy requirement – Dairy cows will activate mechanisms in an attempt to dissipate the excess heat and maintain body temperature. The increased respiration rate is one example. The maintenance energy requirement may increase by 20-30% in animals under heat stress. This decreases the intake energy available for productive functions such as milk production. Blood flow to the skin will increase in an attempt to dissipate heat. At the same time, blood flow to the core of the body will decrease.
4. Feed nutrient utilization – An increased loss of sodium and potassium is usually associated with heat stress. This is due to losses associated with the increased respiration rate. This can shift the acid-base balance and result in a metabolic alkalosis. There can also be a decrease in the efficiency of nutrient utilization.
5. Dry matter intake – Dry matter intake decreases in dairy cows subjected to heat stress. This depression in dry matter intake can be either short term or long term depending on the length and duration of heat stress. Decreases of 10 to 20% are common in commercial dairy herds.
6. Milk production- There is normally a decrease in milk production for cows under heat stress. This decrease can be either transitory or longer term depending on the length and severity of heat stress. These decreases in milk production can range from 10 to >25%. In the summer of 2005, many New York dairy herds reported decreases in milk production of 5 to 15 pounds per cow per day. If heat stress lowers milk production in early lactation dairy cows, potential milk production for the lactation will be decreased. Dairy cows in later lactation may recover slowly from the effects of heat stress.
7. Reproduction – Heat stress has also been reported to decrease reproductive performance in dairy cows. There are a number of changes in reproductive performance that have been reported. The effects on reproduction can be prolonged and impact the animal for months after the heat stress exposure. These include:

    - The length and intensity of the estrus period decreases.
    - Decreased conception (fertility) rate.
    - Decreased growth, size and development of ovarian follicles.
    - Increased risk of early embryonic deaths.
    - Decreased fetal growth and calf size.

What Determines the Severity of Heat Stress?

The severity of heat stress experience by an animal depends on a number of factors. The key ones include:

- The actual temperature and humidity.
- The length of the heat stress period.
- The degree of night cooling that occurs.
- Ventilation and air flow.

- The size of the cow.
- The level of milk production and dry matter intake prior to the heat stress (higher producing animals will experience greater effects of heat stress).
- Housing – type, ventilation, overcrowding, etc.
- Water availability.
- Breed (?).
- Coat color (lighter color coats absorb less sunlight)
- Hair coat depth.

An Example:

The Cornell Net Carbohydrate and Protein System (CNCPS) model was used to evaluate the effect of heat stress on dry matter intake and milk production in dairy cattle. Rations were evaluated for a dairy cow weighing 1,400 pounds and producing 80 pounds of milk. An initial ration was balanced for this cow in an environment with an ambient temperature of 60 ^{o}F. Subsequent runs were made varying either temperature, humidity or the night temperature. The use of night temperature provides a way to estimate the impact of night cooling. Key results from this exercise are:

- The maintenance energy requirement was increased by 22% at 90 ^{o}F compared with the base run at 60 ^{o}F.
- Predicted dry matter intake decreased by 18% between runs 1 and 4.
- Predicted ME milk decreased by 32% between runs 1 and 4.
- Predicted MP milk decreased by 20% between runs 1 and 4.

An adjustment was made in run 5 by adding 1 pound of a rumen bypass fat source to the ration to provide additional energy. The result was a predicted increase of 8 lbs/day (14%). Even though this was of some benefit, it was still not adequate to counteract the effects of temperature and humidity. This example indicates the importance of finding ways to use heat abatement practices to assist cows experiencing heat stress. It is important to remember that these are simulations of the effects of heat stress. Actual farm responses will vary from these predictions.

Table 2. Predicted Dry Matter Intake and Milk Production [a]

Run	Temp., ^{o}F	Humidity	Night Temp., ^{o}F	Maintenance ME, Mcal [b]	DMI, lbs.	ME Milk, lbs. [c]	MP Milk, lbs. [d]
1	60	50	50	16.38	48.8	85.3	81.8
2	90	50	60	18.27	47.2	77.8	78.9
3	90	70	60	19.95	46.6	73.1	77.8
4	90	70	75	19.95	39.8	57.7	65.5
5	90	70	75	19.95	40.8	65.7	65.3

[a] Runs with the CNCPS model for a 1,400 lb. dairy cow
[b] Energy required to meet the daily maintenance requirement
[c] Predicted milk production from metabolizable energy
[d] Predicted milk production from metabolizable protein

What's The Economic Impact of Heat Stress?
There is no simple way to assess this on a whole farm basis. At current milk prices, a decrease in milk production of 10 pounds would decrease income by $1.50 per cow per day. The changes in reproduction are longer term and more difficult to estimate. A group at The Ohio State University published a paper to take a look at the question (St.Pierre et.al. 2003). This paper considered all classes of livestock in the US. In addition, they made estimates for each state. Some of the primary points from this paper are:

- Estimated yearly cost in the US from heat stress was about $2.4 billion with minimal heat stress abatement practices in place.
- This was reduced to about $1.7 billion if heat stress abatement practices were implemented.
- Nationally, implementing heat stress abatement practices for all dairy cattle decreased the predicted heat stress losses from $1.5 billion to $0.9 billion.
- The largest portion of these losses was dairy cattle at 52% of the total loss. The losses for beef cattle, swine and poultry were 21, 17 and 10% of the total.
- The total yearly loss to heat stress in New York was $25 million per year. Dairy accounted for >95% of this loss. It was assumed that optimal heart abatement practices were in place for dairy cows in making this estimate.
- The average dairy cow is exposed to heat stress about 14% of the total annual hours. This value was 49% for cows in Florida and 8% for cows in New York.
- The predicted average decrease in dry matter intake was 152 lbs/cow in New York. The predicted milk loss per cow was 306 lbs.
- There would be an economic benefit to implementing some type of heat abatement practices for dairy cattle.

How Do Cows Dissipate Heat?
The animal has a number of mechanisms available to assist in trying to dissipate heat and maintain a normal body temperature. These mechanisms include:

1. Conduction – Heat moves from a warmer to a cooler surface. A cow needs direct contact with a surface for this to occur.
2. Convection – The layer of air next to the skin is replaced with cooler air.
3. Radiation – Heat can radiate from a warmer environment to a cooler environment.
4. Evaporation – Sweat or moisture is evaporated from the skin or respiratory tract.

The cow can primarily control or regulate only the evaporative cooling mechanism. She has little ability to control the sensible losses (conduction, convection and radiation).

What Can Be Done to Counteract Heat Stress?
There are a number of options that exist to assist in minimizing the effect of heat stress on dairy cattle. The two primary options are making some ration adjustments and altering the environment that the cow lives in.

Ration adjustments:

The goal is to adjust rations to increase energy and protein intake while maintaining rumen and cow health. The temptation is to increase the quantity of grain fed and decrease the

quantity of forage in the ration. This shift will frequently induce rumen acidosis and impair cow health. The following ration adjustments should be considered in cooperation with the nutrition professional providing the ration formulation for the specific herd:

1. Select and feed higher quality forages if possible.
2. Lower ration fiber (ADF, NDF) levels slightly while maintaining effective fiber levels. This may require the use of some non-fiber byproduct feeds such as soy hulls, beet pulp or citrus pulp.
3. Consider adding some additional fat to the ration. Total ration fat levels should not exceed 5 – 5.5% of total ration dry matter.
4. Select feed ingredients that have a high digestibility in the animal. This lowers the heat produced by nutrient utilization within the animal.
5. Balance ration protein levels to minimize high levels of soluble and rumen degradable protein. The animal must expend energy to excrete excess protein from the body.
6. Consider adding buffers (sodium bicarbonate, magnesium oxide, and sodium sesquicarbonate) to help in maintaining a normal rumen environment.
7. Consider increasing ration potassium levels to counteract the higher potassium losses in heat-stressed cows. Ration magnesium levels may also need to be increased.
8. There may be some benefit to adding yeast or yeast cultures to the ration.

Feeding management:

The feeding management practices used also offer opportunities for alteration in trying to minimize the effects of heat stress. Some of the key considerations in this area are:

1. Fresh, palatable, high quality feed should be in the feed bunk at all times to provide maximum opportunity for feed consumption. If the feed in the bunk is warm, musty or spoiled, it needs to be removed and discarded.
2. Is the feed pushed up frequently? Can the cows reach the feed?
3. Are rations mixed and delivered uniformly on a daily basis?
4. Can all cows eat at the feed bunk at the same time?
5. Is there evidence that cows are sorting the ration and leaving the coarse particles? If so, some added water or molasses may help the feed stick together better.
6. It may be useful to shift feeding times to match cow behavior. Cows tend to change meal patterns and eat more feed during the cooler times during the day.

Water:

1. Do the watering devices contain clean and fresh water?
2. Is there enough water space available? There should be at least 2-3 inches of water space per cow.
3. Is there more than 1 watering device for each group of cows? This may encourage water consumption and decrease competition.
4. Is fresh water available to cows after milking?
5. Is there adequate pressure to keep the watering devices filled?

6. Water intake may increase by 20 to > 50% during heat stress conditions. Is an adequate quantity of water available?

Housing and facility adjustments:

1. Are cows overcrowded? If so, what can be done to minimize overcrowding?
2. How long are cows in the holding area? Can thus be reduced? Frequently, the holding area is a very crowded and poorly cooled area on many farms.
3. Is shade available to all cows? This reduces the effect of radiation.
4. What is the air flow over the cow housing area? A goal is 4-5 mph. Are there ways to open the facility up to obtain more ventilation? In many cases, the addition of fans will be required to assist in increasing air flow.
5. Is it possible to provide some misters or sprinklers? The goal is to increase evaporative cooling by wetting the skin. The goal is to wet the cow not soak the cow.

What about Other Species?

The THI threshold values for other species are:

- Beef cattle	72 – 75
- Swine	72 – 74
- Poultry	70 – 78

These species would also have decreases in both productivity and reproduction under heat stress conditions. Heat stress abatement practices such as shade, cooling and ventilation would assist in reducing the impact of heat stress.

Summary

Heat stress can impact animal production and profitability in dairy cattle by lowering feed intake, milk production and reproduction. There are a number of management and housing alterations that can be made to decrease the impact of heat stress. The challenge with these is to balance the investment cost versus the projected production and economic responses. In the Northeast, we typically have fewer heat stress days than the southern US. However, some of these management and housing alterations can be made at a relatively low cost and should be seriously considered by our producers. Many of the new facilities being built include housing components to minimize the effect of heat stress.

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