Effect of Shelter on Heat and Cold Stress on Feedlot Cattle in Iowa

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Russ Euken, ISU Extension Livestock Specialist

Summary and Implications

Roofed facilities provide feedlot cattle shelter from solar radiation, precipitation, and wind. In warm weather solar radiation can increase heat stress and in colder weather precipitation and wind can increase cold stress. Over a 9 year period providing a roof or shelter would have resulted in 5 percent less days of cold stress according to the wind chill index, 12 percent less days of cold stress as calculated by the cattle comfort index and 17 percent less days of cold stress estimated by the NRC calculations for increased energy requirement based on lower critical temperature. It was calculated there would be 4 percent less days of heat stress by providing a roof or shade to reduce solar radiation in feedlot cattle according to the Cattle Comfort Index. This reduction in cold or heat stress could potentially could increase cattle comfort and performance.

Introduction

A variety of feedlot facilities are in use across the Midwest. In recent years there has been increased use and construction of confinement buildings in Iowa and other Midwest states. One reason for the increased interest in confinement is potentially increased cattle performance due to offsetting adverse weather conditions.

As part of a project including material development and workshops on feedlot facilities, Iowa weather data from 2006-2014 was used to calculate potential number of days of heat stress and cold stress for feedlot cattle with or without shelter.

Materials and Methods

Historical daily weather data for six weather stations geographically located across Iowa was accessed from two locations for a 9 year period, 2006 through 2014. The weather data was obtained at the Iowa Mesonet website.
http://mesonet.agron.iastate.edu/agclimate/hist/dailyRequest.php
http://mesonet.agron.iastate.edu/request/coop/fe.phtml?network=IACLIMATE

Data included daily high and low temperature, average wind speed, total precipitation, average relative humidity, and average solar radiation. To get accurate precipitation data for each day, two data sets were combined.

That daily data was used in existing cold stress and heat stress equations to determine how many days during that time period would have resulted in cold stress or heat stress without any adjustment in weather factors.

To estimate effect of shelter on cold stress the reported wind speed was reduced by 66% in calculations. Three different cold stress indexes or calculations were used.

One was the wind chill index, Wind Chill Index = (35.74 + 0.6215 * Temperature - 35.75 * Wind speed^0.16 + 0.4275 * Temperature * Wind Speed^0.16). The second was the cattle comfort index (CCI) developed by Dr. Terry Mader formerly at University of Nebraska and now a private consultant. The CCI adjusts ambient temperature for relative humidity, wind speed and solar radiation for both cold stress and heat stress. The equation is Ta+
Relative Humidity adjustment $\{e^{(0.00182 \text{x} RH + 1.8 \text{x} 10^{-5} \text{ x Ta x RH}) \text{ x}}$ $(0.000054 \text{ x Ta}^2 + .00192 \text{ x Ta} - .0246) \text{ x } (RH - 30)\}$ +
Wind speed adjustment $[-6.56/e^{[\{1/2.26 \text{x} WS + .23\}.45 \text{x} \{2.9 + 1.14 \text{x} 10\text{-}6 \text{x x } WS2.5 - \log 0.3 (2.26 \text{x} WS + .33)\text{-}2]}$ $-0.00566 \text{x} WS^{2+} 3.33$ +
Solar radiation adjustment $(0.0076 \text{ x RAD} - 0.00002 \text{ X RAD X Ta} + 0.00005 \text{ x Ta}^2 \text{ x } \sqrt{} \text{ RAD} + 0.1 \text{ X Ta} - 2)$
Ta–ambient temperature, RH-relative humidity, WS-wind speed, RAD-solar radiation
Wind speed was the only adjustment made when using shelter for wind chill index or cattle comfort index for cold stress calculations. Effect of precipitation or mud on hair coat insulation properties is not considered in wind chill index or Cattle comfort index.

The additional calculation used to estimate cold stress was the National Research Council (NRC)-Nutrient Requirements of Beef Cattle maintenance energy adjustment for external insulation as affected by wind speed and insulation value of the hair coat. The animal type used in this calculation was an 825 lb. steer with body condition score of 5 on a 1-9 scale, average hide thickness, consuming a normal intake of a feedlot growing ration.

The NRC formula for external insulation or EI is EI = (7.36-.296 x wind speed - 2.55 x Hair length (cm)) x Mud code (1 or 0.5) x Hide code (1)). The mud code represents the effectiveness of the hair coat condition in providing insulation and can be a factor of 1, 0.8, 0.5 or 0.2. In this calculation the mud code was 1 for days with no precipitation outside and all days under roof. For cattle not under roof on days with precipitation the mud code was changed to 0.5. Actual effect of precipitation on the hair coat may differ than what was estimated. The external insulation calculation is added to the tissue insulation, in this exercise a constant, to arrive at an insulation value IN used in the lower critical temperature calculation or LCT. LCT= 39-(IN * HE x .85). HE is the heat production from feed intake and digestion, again a constant in this exercise. The calculated LCT – actual reported temperature C^0 /IN x

SA (Surface area of the steer (.09 x shrunk body weight$^{.67}$)) = Metabolizable energy or ME required due to cold stress. If additional ME was required on average for that day it was assumed there was cold stress.

Heat stress calculations included the Temperature Humidity Index, (0.8*Temperature) + ((Temperature-14.4)*(RH/100)) + 46.4 and the Cattle comfort index (same formula as cold stress CCI). In the CCI heat stress equations the solar radiation was reduced by 80% to calculate effect of a roof or shade and it was assumed that the roof or shade would not affect wind speed.

Calculations and frequencies of cold stress and heat stress for each regional weather station were determined separately. There were differences by location but differences were small so only the averages of all locations are being reported with the exception of the Wind Chill Index and Temperature Humidity Index with northern and southern Iowa averages reported.

Results and Discussion

Cold or heat stress in feedlot cattle have many factors that are sometimes interrelated making actual determination of occurrence of cold stress or heat stress difficult. Impact will vary by type and size of animal and how they interact with the environment. Length of exposure and variation in environmental conditions would also seem to be a factor in how the stress would affect an animal but was not considered in this exercise. In this exercise an acclimated growing feedlot animal consuming a normal amount of a common ration was assumed. In addition, for cold stress it was assumed cattle had a heavy winter hair coat and average hide thickness. Daily determinations of a cold stress or heat stress were determined based on daily weather data averages although the stress conditions might have occurred for only a portion of the day.

One measure of cold stress was the wind chill index which estimates an effective temperature by factoring in the wind speed. For a feedlot animal with a dry heavy winter hair coat it was assumed that a wind chill index of 20 degrees or less Fahrenheit would result in cold stress. In table 1 below, the percent of days are shown for both north and south Iowa at different levels of wind chill index for both reported and reduced wind speed.

The Cattle Comfort Index has five categories for cold stress as defined by Mader. Percent of days in each category, assuming a dry hair coat and reported wind speed or a reducing wind speed to 33% of reported, are shown in the following table 2.

The NRC cold stress calculations were divided into 10 degree temperature ranges. Effects on percent of days below LCT (lower critical temperature) and increased energy requirements with and without wind speed reduction and with a dry hair coat or wet hair coat are show in table 3.

The three calculations all indicate different percentages of cold stress days for cattle in the time period investigated. The Cattle Comfort Index has the highest percentage of days, followed by the Wind Chill index and finally the NRC calculation increased energy requirement based on lower critical temperature. Reducing wind speed results in 5% less cold stress days using the wind chill index and 12% less cold stress days using the Cattle Comfort Index and 7.5% less cold stress days using the NRC lower critical temperature formula. By estimating hair coat insulation effect in the NRC energy requirement calculation, there are 10.35% less cold stress days as a result of keeping the hair coat dry and not reducing hair coat insulation. A large amount of the reduction in cold stress days occurs in the range of 0-40 degrees for all cold stress formulas, but especially in the NRC lower critical temperature formula. 5.5 % of the 7.5% less cold stress days due to wind reduction and 10% of the 10.35% less cold stress days due to a dry hair coat were in the 0-40 degree temperature range.

The categories of heat stress for the temperature humidity index and percent of days that in each category are shown in table 4. Using this index there were larger differences by geographic location with higher index levels in the southern part of the state. Since shelter or roofed facilities have been shown not to change air temperature or humidity greatly no adjustments or comparisons were made for a roofed facility.

The Cattle Comfort Index has five levels of heat stress as defined by Mader. With shelter or roof the solar radiation was reduced to 20 % of reported. The percent of days with heat stress in overall and in each heat stress category without or with shade are shown in Table 5. According the Cattle Comfort Index there were 14 % of days that would have some level of heat stress without shade and providing relief from solar radiation with shade would have 4%.less heat stress days The highest % of days were in the mild to moderate levels at approximately 12%. With shade there was 2.5 percent less days in those two categories. The extreme or extreme danger category were death loss is typically observed was reached .33% of the days and reduced to only .02% of days when shade was factored in. If the shelter or shade would reduce wind speed the number of heat stress days would likely not decrease as much as indicated.

The Cattle Comfort Index has about 8.5% more days of heat stress than the temperature humidity index. This is presumably due to the solar radiation and wind speed effects being included in the index.

Improving cattle comfort is of interest to feedlot operators since it is assumed as cattle comfort increases, performance and cattle well-being is improved. The effects of cold stress and heat stress on cattle performance are difficult to estimate and measure. With the exception of the NRC maintenance energy calculation the formulas used have no direct relationship to performance. Mild cold stress will typically stimulate intake but extreme cold stress could depress intake. As cold stress increases maintenance energy requirements increase which would decrease energy for gain. Heat stress would typically decrease feed intake and cattle performance. Extreme levels heat stress can cause catastrophic death loss and economic loss to feedlot operators. In addition to shade or roofed structures there are other measures that can be implemented to reduce catastrophic death loss.

Additional factors that may be related to cattle comfort and are not accounted for in this project is daily variation in weather and impact of longer periods of adverse weather.

Also related to facilities is the impacts of mud that is not included in the formulas used and is difficult to estimate from weather data. Mud would likely have additional impact on hair coat insulation and in severe situations could impact maintenance energy requirements and cattle intake. In addition to facilities, lot maintenance and bedding cattle in open lots can reduce the potential impact of mud. These average longer term percentages would likely not be accurate for one pen or group of cattle that might be on feed during a period with more adverse weather that could lead to heat or cold stress.

Iowa feedlot operators can use this information to estimate longer term weather effects on cold stress or heat stress impact of cattle on feed and how roofed facilities or shelter would potentially change the percent of days that cold stress or heat stress would affect feedlot cattle.

Acknowledgments

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Table 1. Percent of days from 2006-2014 in different levels of cold stress with and without wind reduction according to the Wind Chill Index.

Wind chill index	% days with no windbreak		% days with wind reduction		% less days with reduced wind- % point change	
	N Iowa	S Iowa	N Iowa	S Iowa	N Iowa	S Iowa
<20	23.10%	16.91%	17.55%	11.74%	5.56%	5.18%
10-20	8.08%	11.30%	7.42%	7.70%	0.67%	3.59%
0 to 10	6.30%	4.84%	4.41%	3.57%	1.89%	1.27%
-10 to 0	3.25%	2.57%	2.88%	1.16%	0.37%	1.42%
-20 to -10	2.80%	0.84%	0.75%	0.15%	2.05%	0.70%
-30 to -20	0.68%	0.11%	0.03%	0.00%	0.65%	0.11%
<-30	0.02%	0.00%	0.00%	0.00%	0.02%	0.00%

Table 2. Percent of days from 2006-2014 in different levels of cold stress with and without wind reduction according to the Cattle Comfort Index CCI.

Cattle Comfort	Winter CCI acclimated cattle	% of days assuming dry hair coat	% of days with reduced wind	% less days with cold stress with reduced wind - % point change
Some level of cold stress	<0	37	25	12
Mild	0 to -10	18	16.5	2.5
Moderate	-10 to -20	14	7.5	6.5
Severe	-20 to -30	5	1.7	3.3
Extreme	-30 to -40	.25	.04	.2
Extreme danger	< -40	0	0	0

Table 3. Percent of days from 2006-2014 with calculated additional energy requirements according to NRC lower critical temperature without shelter and with shelter to reduce wind and precipitation effect on hair coat insulation.

Ambient temperature Fahrenheit	% of days avg. temp in this range	% of days <LCT	% of days < LCT with reduced wind	% of days <LCT reduced wind and dry coat	% less days wind reduction- % point change	% less days for dry hair coat- % point change
< 60	62.4	18	10.5	.15	7.5	10.35
50-60	13.6	.08	0	0	.08	0
40-50	13.8	1.69	0	0	1.69	0
30-40	14.3	5.21	2.86	0	2.35	2.86
20-30	11.4	4.34	3.78	0	.56	3.78
10-20	7.3	3.01	2.19	0	.82	2.19
0-10	3.7	2.4	1.22	.07	1.18	1.15
-10-0	1.2	.9	.29	.08	.61	.21
<-10	0.1	.08	.06	.06	.02	0

Table 4. Percent of days from 2006-2014 in different levels of heat stress according to the Temperature Humidity Index

Cattle Comfort category	Temperature Humidity Index - THI	% of days in northern Iowa	% of days in southern Iowa
Some level of heat stress	>74	5.5	9.7%
Alert	74-79	4.75	7.5
Danger	79-84	.75	2.2
Emergency	>84	.05	.1

Table 5. Percent of days from 2006-2014 in different levels of heat stress with and without shade according to the Cattle Comfort Index.

Cattle Comfort Category	Summer CCI index	% of time no shade	% of time with shade	% of less heat stress days with shade - % point change
Some heat stress	>25	14%	10%	4%
Mild	25-30	7.6 %	7%	.6%
Moderate	30-35	4.35%	2.47%	1.9%
Severe	35-40	1.71%	.41%	1.3%
Extreme	40-45	.31%	.02%	.29%
Extreme danger	>45	.02%	0%	.02%