Environmental Conditions in a Bedded Hoop Barn with Market Beef Cattle

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Summary and Implications

The objective was to document the environment of a bedded hoop barn used for feeding market beef cattle. A comparison between a bedded hoop barn and an open-front feedlot building was conducted in southwest Iowa. The hoop barn was oriented north-south on a ridge with no windbreak. In summer, temperature was relatively consistent between the structures and ambient conditions, although the north end of the hoop barn had a slightly elevated dew point temperature. A summer temperature-humidity index showed that the hoop barn had fewer hours in “alert” category than either open front or ambient conditions. In winter, a cold stress index showed that the open-front barn provided the most shelter for the cattle with 92% of the hours classified as “no impact,” compared with the hoop barn at 77% of the hours as “no impact” and ambient at 51% of the hours as “no impact.” Both ends of the hoop barn were open, except for piled big round bales for a windbreak during winter. Bedded hoop barns offer a viable alternative for feeding beef cattle.

Introduction

Hoop barns offer a versatile low cost, alternative housing structure for livestock, including beef cattle. Beef cattle feedlots are under increased public scrutiny due to concerns with groundwater and surface pollution. Runoff control basins are currently designed for 25-year, 24-hour rainfall events, but legislation has allowed for the investigation of alternative technologies that meet or exceed performance standards of traditional systems. Producers are interested in non-basin technologies such as vegetated treatment systems and confined production systems to reduce environmental impacts and construction costs. One confined production system is deep-bedded hoop barn production, but the environment in these barns is not well understood. Feeding beef cattle in a hoop barn would eliminate or greatly reduce feedlot runoff.

The objective of this study was to document the environmental conditions in hoop barns when feeding market beef cattle in Iowa.

Materials and Methods

The demonstration was conducted at the Iowa State University Armstrong Research and Demonstration Farm near Lewis, IA. The 50 ft × 120 ft beef cattle hoop barn was constructed in November 2004. The hoop barn was oriented north-south on a ridge with no windbreaks. The south and north ends were open and the ridge had a continuous 6 in. gap or ridge vent. The concrete feed bunk and feeding driveway were located along the outside of the east wall of the hoop barn in order to avoid using costly building space for a drive alley. The bunk was covered by a permanent overhang or awning with a rain gutter to reduce rain and snow in the feed bunk. The frost-free cattle waterers were located just inside the feed bunk line. A concrete apron was formed the length of the hoop and parallel with the bunk to aid in cleaning the feeding area. The remaining area of the hoop barn was covered with packed limestone screenings over geotextile fabric. The limestone screenings were slightly coarser than ag lime.

The hoop barn was divided into three equal pens that were each designed to hold 40 head of market beef cattle. The west wall of the hoop barn was covered with tongue and groove lumber and the gates were covered with plywood to block the direct sun from heating the pens during the summer. The cattle remained in the hoop barn at all times except to be weighed and when manure was scraped from the concrete apron. Adjacent to the hoop barn was a conventional semi-confinement, open-front beef cattle feedlot, built in 1996, with an open-front shed containing a feed bunk and covered drive alley. The remainder of the shed was a concrete area that opened into dirt lots with small fence line mounds. There were four pens designed for 40 head of cattle each, plus a sick pen and cattle handling area. This facility was used to compare cattle performance in the hoop barn. The feedlot building was 11.0 × 61.0-m with a 1.8-m overhang and open to the south. Each pen was 12.2 × 48.2 m with 7.6 m under roof plus 40.5 m of open lot and provides 14.7 m^2 of total space per head. Approximately 20% of the lot is concrete and the remainder is earthen surface with a mound.

During August 2005 through April 2006, environmental data were collected. In order to evaluate the thermal environment within the facilities, temperature, humidity, and windspeed were measured. Each housing system used dataloggers to record dry bulb temperature (Tdb) and dew point temperature (Tdp) in two different pens to observe variations throughout the building. A logging anemometer was used at one location in each housing system to measure air speed. The farm had an automated weather station to collect outside or ambient weather data.

Evaluation and comparison of building environmental performance can be a challenge because of the massive amount of data that can be accumulated. The underlying concern is the impact that the facility has on animal comfort and performance. Approaching analysis from the impact that it has on performance is a logical approach.

For summer trials, a temperature-humidity index (THI) was calculated for each half hour using:

$$THI = 0.8\ Tdb + (Tdb - 14.4)\ RH/100 + 46.4 \qquad (1)$$

In equation (1), THI is the temperature humidity index, Tdb is dry-bulb temperature (^{o}C) and RH is relative humidity percentage. Threshold values for THI were identified in LCI (1970). A THI less than 74 is "normal." THI greater than 74 but less than or equal to 79 is considered "Alert." THI greater than 79, but less than or equal to 84 is considered "Danger" and above 84 is considered "Emergency." Each half hour was categorized into one of these categories in order to compare ends of an individual building, between buildings and to ambient conditions. The percentage of time spent in each category was then tabulated for comparison.

For winter, the THI would be an ineffective comparison. A cold stress index (CSI) was produced using the traditional form of the wind chill temperature (WCT) when temperature was below 7.8^{o}C and an interpolation between the actual air temperature and WCT for temperatures between 7.8^{o}C and 15^{o}C. The equations for WCT and CSI are:

For below 7.2^{o}C:

$$CSI = WCT = 33 - (10.45 + 10V^{0.5} - V)\ (33 - Tdb) / 22.04 \qquad (2)$$

For between 7.8 and 15^{o}C:

$$CSI = (Tdb - 7.2) / 7.8 * Tdb + (15 - Tdb) / 7.8 * WCT \qquad (3)$$

In equations (2) and (3) WCT is the wind chill temperature (^{o}C), V is the wind speed in m/s and Tdb is the dry bulb temperature in (^{o}C). The CSI was computed for both housing types and for the ambient conditions. Oklahoma Agweather (2007) categorized the impact of cold for different seasonal hair coats. For cattle with heavy winter coats, a CSI below -17.8^{o}C was considered "Severe." One between -17.8^{o}C and -12.8^{o}C was considered "Moderate" while one between -12.8^{o}C and -7.2^{o}C was considered "Mild." Temperatures above -7.2 ^{o}C were considered "normal" or a "no impact" situation. Each hour was classified in one of these categories and tabulated.

Environmental data were collected during two trials. The first, referred to as the summer trial, was collected from August 18, 2005 to November 16, 2005. The second, referred to as the winter trial, was collected from December 21, 2005 to April 4, 2006.

Results and Discussion

The environment in a livestock building is determined by numerous factors including: ambient temperature, air speed, temperature of surfaces, and relative humidity. Hoop barns are designed to slightly modify the environment. Iowa hoop barns with finishing swine were shown to be 3 to 5^{o}C warmer in winter and 1 to 2^{o}C cooler in summer than outside temperatures (Honeyman et al., 2001). With cattle, not only is the comparison between facilities important, but also the comparison to ambient conditions since most cattle are fed in open feedlots without shelter.

Heat stress is a concern in cattle feeding. In order to combine environmental factors into a common comparison, the THI was used and the number of hours within various thresholds of weather safety index was evaluated. The comparison of dry bulb temperature, dew point temperature, and THI are shown in Table 1. Dry bulb temperature was relatively consistent between the structures and ambient conditions in average, maximum, and standard deviation, approximately 16^{o}C, 34^{o}C, and 8.4^{o}C, respectively. Values for Tdp were relatively consistent, although the north end of the hoop barn had a slightly elevated dew point temperature (9.9^{o}C on the south vs. 11.1^{o}C on the north). This indicates less air exchange in the north end of the building. THI was slightly elevated for the open-front building compared with the hoop (60.1^{o}C and 60.2^{o}C vs. 59.5^{o}C and 59.6^{o}C) but differences were minor. All of the conditions were similar to the ambient conditions. This illustrates that the hoop structure and the open-front structure are both open enough to exchange air freely and maintain conditions at least as good as an outside feedlot. The shelters, however, offer the advantage of shade, which is known to impact heat stress greatly.

For this experiment, we classified each hour by the THI computed based on an hourly condition, and then these were compared for each building and location. Table 2 illustrates these comparisons. The hoop barn had fewer hours in the "alert" category (8.6% and 8.2%) than either the open-front facility (10.8% and 10.5%) or ambient conditions (9.7%). However, the north end of the hoop barn had more "danger" hours (3.0%) than any other area. This is likely related to the higher dew point temperatures measured in this area. Another factor to consider when making this comparison is that cattle in the hoop barn were restricted to the barn and cattle in the open-front facility had access to a lot and could freely choose between shelter and lot. This makes the creation of an acceptable environment in the hoop barn even more important.

THI does not account for wind speed or solar radiation. Cattle that are not shaded average 16 breaths per minute more than their shaded counterparts in the same conditions. This would indicate a much greater level of heat stress in the same environmental conditions. Wind speed also has an impact. Therefore, a shelter, which essentially functions as a shade, would be beneficial to cattle compared with a feedlot where no shade is provided, especially if the structure was open enough to allow wind through the pen. This study compares two shelter options, thus radiation and wind effects for summer were not included.

Cold stress was evaluated in much the same way as THI. Table 3 compares the environmental conditions in the buildings and the ambient conditions. Again the Tdb conditions are similar with the buildings only slightly warmer than outdoors. Air speed in the hoop barn was 2.72 m/s, only 1.35 m/s in the open-front barn, and 4.78 m/s outside. This is intuitive because the open-front barn was closed on three sides during winter and the hoop barn was more open. The hoop barn was on a slightly higher, more open site making it more accessible to wind. The CSI was colder for the hoop barn (-1.9°C) than the open-front barn (1.4°C) because of the higher air speed within the hoop barn. The minimum CSI was much lower in the hoop barn (-38.6°C) than for the open-front barn (-20.2°C). If cattle had been kept outside they would have experienced an average CSI of -5.7°C during this trial.

Each hour was classified as “no impact,” “mild” impact, “moderate” impact, or “severe” impact as described earlier. Table 4 gives the CSI for both housing types and for ambient conditions. Unlike the THI comparison for hot weather, there were large differences during winter weather. The open-front barn provided the most shelter for the cattle with 92.1% of the hours classified as “no impact,” compared with the hoop barn at 76.8% and ambient at 51.5%. This means that the performance of cattle kept outside would have been impacted about half the time. This trend held for impacts classified as “mild,” “moderate,” and “severe” with the open-front barn having the shortest time impacted and the hoop barn having about half the hours impacted as an outside feedlot. Again, this is a reflection of the openness and site characteristics of the hoop barn in comparison with the open-front barn.

Bedded hoop barns offer a viable alternative for feeding beef cattle in confinement. Additional research is required to quantify the performance and management of hoop barns for beef cattle feeding. By keeping the cattle under the hoop roof at all times the potential for feedlot runoff is greatly reduced or eliminated. Environmental conditions in the hoop barn are similar to ambient conditions in the summer with the added advantage of shade to reduce solar radiant load on cattle. During winter, the hoop barn environment was much improved over outdoor conditions but did not perform as well as the open-front barn. A balance between protecting the cattle from wind and keeping humidity low is the key to winter environmental management.

Table 1. Environmental data for a summer trial (August 18 to November 16, 2005).

Location	Dry bulb temperature (°C)			Dew point temperature (°C)	THI	
	Average	Maximum	SD	Average	Average	Maximum
Hoop south	16.1	34.0	8.4	9.9	59.9	82.0
Hoop north	16.0	34.0	8.4	11.1	59.6	82.4
Open-front east	16.2	34.4	8.4	10.6	60.1	82.6
Open-front west	16.2	34.2	8.4	10.0	60.2	82.6
Ambient	15.6	34.2	8.7	10.6	59.9	81.6

Table 2. Weather safety index (THI) of the environmental conditions for a summer trial (August 18 to November 16, 2005).

Location	Weather safety index classification (percent of hours)[1]			
	Normal	Alert	Danger	Emergency
Hoop south	89.8	8.6	1.6	0
Hoop north	88.7	8.2	3.0	0
Open-front east	86.4	10.8	2.8	0
Open-front west	86.8	10.5	2.7	0
Ambient	88.8	9.7	1.5	0

[1]Based on 2,160 hours.

Table 3. Environmental data for the winter trial (December 20, 2005 to April 4, 2006).

Location	Dry bulb temperature (^oC)			Dew point temperature (^oC)	Wind speed (m/s)	Cold stress index (^oC)	
	Average	Minimum	SD	Average	Average	Average	Minimum
Hoop south	1.4	-20.2	6.1	-2.7	-------	-------	-------
Hoop north	1.2	-21.0	6.1	-2.8	2.72	-1.9	-38.6
Open-front east	1.8	-20.2	5.9	-1.2	1.35	1.4	-20.2
Open-front west	1.7	-21.0	6.0	-2.2	------	------	------
Ambient	0.9	-23.1	6.4	-2.4	4.78	-5.71	-38.8

Table 4. Cold stress index (CSI) of the environmental conditions for the winter trial (December 20, 2005 to April 4, 2006).

Location	Cold stress index impact classification (percent of hours)[2]			
	No impact	Mild	Moderate	Severe
Hoop north	76.8	15.3	4.8	3.1
Open-front east	92.1	5.8	1.8	0.3
Ambient	51.5	29.8	11.8	6.9

[2]Based on 2,515 hours.