FEASIBILITY OF BEDDED HOOP BARNS FOR MARKET BEEF CATTLE IN IOWA: CATTLE PERFORMANCE, BEDDING USE, AND ENVIRONMENT

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ABSTRACT. *The objective was to document a bedded hoop barn for feeding market beef cattle. A comparison between a bedded hoop barn (15.2 × 36.6 m) and an open-front feedlot building (11.0 × 61.0 m) 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% and ambient at 51%. Both ends of the hoop barn were open, except for piled big round bales for a windbreak during winter. Growth, feed-to-gain, and dry matter intake for the cattle were similar between housing systems. Quality and yield grades were similar. Mud scores may be less for cattle from the bedded hoop barn compared with the open-front feedlot where mud was possible. Labor usage was similar for the hoop barn and the open-front feedlot. Labor occurred throughout the feeding period for the hoop barn because manure cleaning occurred weekly. Bedded hoop barns offer a viable alternative for feeding beef cattle and may reduce feedlot runoff.*

Keywords. *Beef cattle housing, Bedding, Feedlots, Deep bedded housing.*

Hoop barns offer a versatile low cost alternative housing structure for livestock (Honeyman, 2005). The structures of tubular steel arches are covered with a U-V resistant polyvinyl fabric tarp. The arches are typically attached to posts. Hoop barns were developed in Canada during the early 1990s (Connor, 1993) and have been used primarily for housing swine (Honeyman, et al., 2001). Housing swine in hoop barns has been extensively documented (Honeyman and Harmon, 2003; Lammers et al., 2007) and relies on a thick bedding pack to absorb the swine urine and feces (Honeyman, et al., 2001).

Hoop barns are successfully being used to house dairy cattle (Kammel, 2004), sheep, horses and ratites (Harmon et al., 2004b), finishing pigs (Brumm et al., 2004), gestating sows (Harmon et al., 2004a), and beef cows and bulls (Shouse et al., 2004). Beef cattle feeding in hoop barns where the cattle are confined in the hoop barn with a bedded manure pack has not been documented (Shouse et al., 2004).

Beef cattle feedlots are under increased public scrutiny due to concerns with groundwater and surface pollution (Woodbury et al., 2002). 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 (Moody et al., 2006). Producers are interested in non-basin technologies such as vegetated treatment systems and confined production systems to reduce environmental impacts and construction costs. One of the confined production systems of interest is deep-bedded production but the performance, management, and costs are 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 use of hoop barns for feeding market beef cattle in Iowa including cattle performance, labor, and environmental conditions.

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METHODS

The demonstration was conducted at the Iowa State University Armstrong Research and Demonstration Farm near Lewis, IA (41°19'N, 95°10'W). Annual rainfall for this area is approximately 71 cm annually. In November 2004, the 15.24-m × 36.58-m beef cattle hoop barn was constructed with 3.05-m sidewalls (fig. 1). The height of the roof arch was 7.92-m. 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 15.2-cm 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

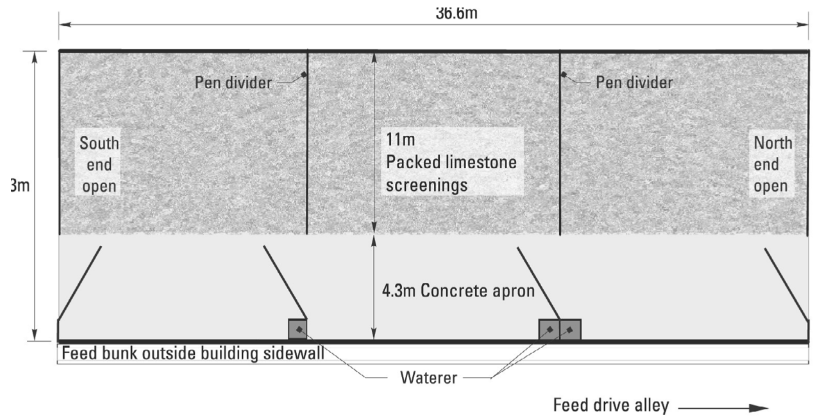

Figure 1. Layout of total confinement hoop barn with exterior feeding.

order to avoid using costly building space for a drive alley. The bunk was covered by a 0.76-m permanent overhang or awning (fig. 2) 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 4.3-m 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 (fig. 1). The limestone screenings were slightly coarser than ag lime.

Beef Cattle Hoop Barn Design Decisions

Several key decisions were made in designing the hoop barn feedlot, including:

- Each beef animal was allowed 4.65 m^2 of space in the hoop barn.
- The hoop barn was oriented north-south to catch prevailing southerly summer winds.
- The feed bunk was covered by an overhang or awning to minimize rain and snow into the bunk. The awning was fitted with a gutter to control runoff.
- Drive alley was outdoors to keep the hoop barn smaller and reduce fixed costs.
- A continuous open ridge vent was included to allow heat to escape the facility.
- Only the scrape alley and area in front of the bunk was concrete. Remaining area was limestone screenings over geotextile fabric. The concrete use was limited to the highest traffic area to minimize building costs.
- The west wall and west gates were covered with lumber to keep afternoon sun out of the hoop barn.
- During the winter, big round bales were stacked on the north and south ends to provide a partial windbreak.
- The tarp color was white to reflect heat and allow some light through.

The hoop barn (fig. 1) was divided into three equal pens that were each designed to hold 40 head of market beef cattle (4.65-m^2/head). 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. 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 was adjacent to the hoop barn. The remainder of the shed was a concrete area that opened into dirt lots with small

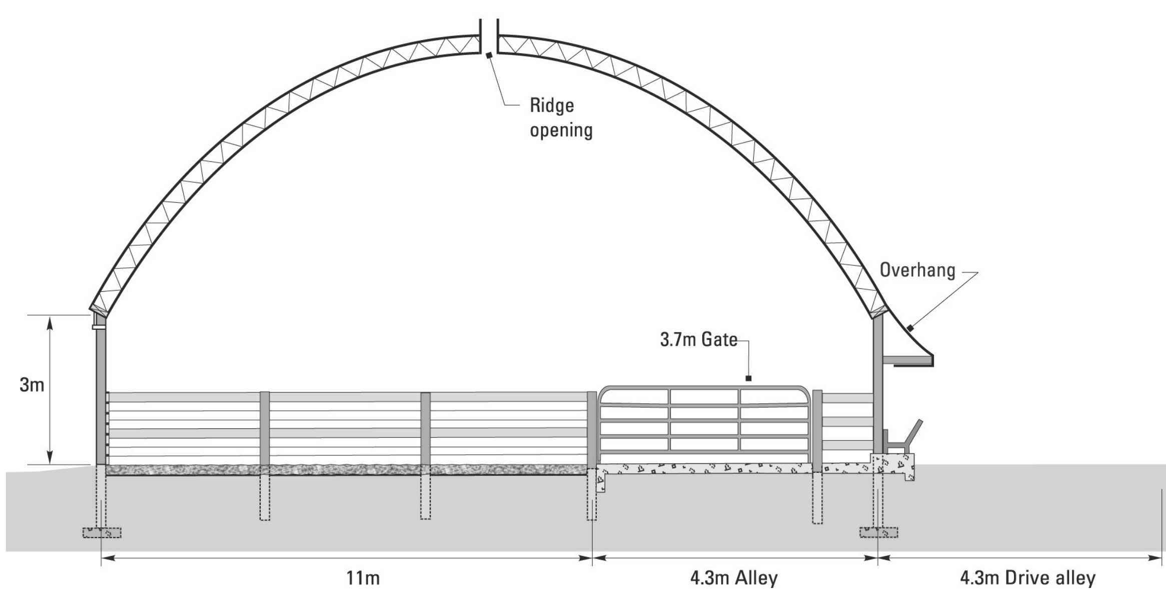

Figure 2. Cross-section of total confinement hoop barn with exterior feeding.

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.

The cattle feeding demonstration was conducted from December 2004 until April/May 2005. Subsequent feeding trials were conducted in these facilities under similar conditions (data not reported here) and during August 2005 through April 2006 environmental data was collected. The cattle in the demonstration were crossbred calves – a mixture of steers and heifers. There were 34 to 37 head of cattle per pen. The calves were single source from the ISU McNay Research Farm, Chariton, Iowa. Allotment was based on weight and sire groups. The diet was 74.2% dry whole-shelled corn, 15% ground hay, 3.3% pelletted protein supplement with monensin, and 7.5% added water. The monensin was fed at a rate of 300 mg/head/day. The cattle were fed once per day in the fence line bunks.

The cattle were condition scored at the beginning of the study. The condition score was a subjective score with 1 = very lean or no visible fat and 9 = very fat. At the first marketing, the cattle were scored for mud. The mud score was a subjective score with 1 = no visible mud and 5 = heavy mud on the animal. Cattle were marketed in two groups approximately 5 weeks apart based on a visual assessment of market readiness. Carcasses were tracked by housing treatment and carcass data was collected at the packing plant. Labor involved in bedding the pens and scraping manure only was recorded. Bedding use in each system was also recorded.

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 see if there were 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 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 Hahn (1999) as adapted from Thom (1959):

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

In equation 1, THI is the temperature humidity index, Tdb is dry-bulb temperature (°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, obviously the THI would be an ineffective comparison. Brownson and Ames (1980) produced a chart for wind-chill index for cattle and a lower critical temperature based on seasonal coat thickness. Oklahoma Agweather (2007) developed a cattle stress model that produces maps of concern for heat and cold stress. A cold stress index (CSI) was produced using the traditional form of the wind chill temperature (WCT) when temperature was below 7.8°C and an interpolation between the actual air temperature and WCT for temperatures between 7.8°C and 15°C. The equations for WCT and CSI are:

For below 7.2˚C:

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

For between 7.8°C and 15°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 (°C), V is the wind speed in m/s and Tdb is the dry bulb temperature in (°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°C was considered "Severe." One between -17.8°C and -12.8°C was considered "Moderate" and one between -12.8°C and -7.2°C was considered "Mild." Each hour was classified in one of these categories and tabulated.

Cattle weights, feed usage, temperature, windspeed, cattle scores, and carcass data were summarized by housing system. The environmental data was collected later with other cattle fed under similar conditions in these facilities. The environmental data was during two trials. The first, referred to as the summer trial, was collected from 18 August 2005 to 16 November 2005. The second, referred to as the winter trial, was collected from 21 December 2005 to 4 April 2006. Design and structural observations after two years were noted. Relative feedlot system costs were compared.

Results

Environmental Monitoring

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°C to 5°C warmer in winter and 1°C to 2°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°C, 34°C, and 8.4°C, respectively. Values

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

	Dry Bulb Temperature (°C)			Dew Point Temperature (°C)	THI	
Location	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

for Tdp were relatively consistent, although the north end of the hoop barn had a slightly elevated dew point temperature (9.9°C on the south vs. 11.1°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°C and 60.2°C vs. 59.5°C and 59.6°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.

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. Eigenberg et al. (2005) examined the impact of these added environmental influences on cattle and found that cattle that were not shaded averaged 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.

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

	Weather Safety Index Classification (percent of hours)[a]			
Location	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

[a] Based on 2,160 h.

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,

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

	Dry Bulb Temperature (°C)			Dew Point Temperature (°C)	Wind Speed (m/s)	Cold Stress Index (°C)	
Location	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 (20 December 2005 to 4 April 2006).

	Cold Stress Index Impact Classification (percent of hours)[a]			
Location	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

[a] Based on 2,515 hours.

this is a reflection of the openness and site characteristics of the hoop barn in comparison with the open-front barn.

Cattle Performance and Carcass Characteristics

Results of cattle performance are shown in table 5. Average daily gain, feed-to-gain, and dry matter intake were similar between housing systems and within gender.

Carcass characteristics are summarized in table 6. Quality and yield grades were similar. Mud scores may be less for the cattle from the hoop barn compared with cattle from the open-front feedlot depending on feedlot conditions.

Labor, Bedding, and Cost Comparison

The hoop barn was bedded weekly and the alley was scraped weekly with a tractor and loader. Large round bales of corn stalks were set on end and the cattle were allowed to spread the bedding in the west two-thirds of the hoop barn. The open-front shed was also bedded as needed. The hoop barn required 1.71 kg of cornstalk bedding per head per day, which is more than three times the open-front feedlot (0.54 kg per head per day).

Table 5. Average performance by housing type and gender of cattle.

	Open-front		Hoop Barn	
Item	Steers	Heifers	Steers	Heifers
Initial head	74	69	72	34
Head marketed	72	69	70	34
Pens	2	2	2	1
Initial weight (kg)	295	277	296	277
Initial body condition score	4.85	4.98	4.88	5.00
On feed (days)	141	137	138	133
Final weight (kg)	533	482	529	483
Average daily gain (kg/d)	1.69	1.50	1.70	1.56
Feed-to-gain (kg feed/kg gain)	5.71	6.05	5.78	5.90
Dry matter intake (kg/d)	9.7	9.1	9.8	9.2
Age at marketing (days)	386	383	381	381
Weight per day of age (kg/d)	1.38	1.26	1.40	1.27

Table 6. Average carcass characteristics by housing type and gender of cattle.

	Open-front		Hoop Barn	
	Steers	Heifers	Steers	Heifers
Hot carcass weight (kg)	327	299	325	298
Fat cover (mm)	10.2	11.2	9.7	10.7
Ribeye area (cm^2)	80.7	80.7	81.9	81.3
Calculated yield grade	2.79	2.66	2.65	2.58
Yield grade 1 and 2 (%)	65	67	87	74
Marbling score	SM 43	SM 60	SM 55	SM 81
Low choice or better (%)	79	87	89	100
Final mud score[a]	1.92	1.90	1.70	1.53
Dressing percentage (%)	61.2	62.0	61.2	61.7

[a] Mud score: 1 = no mud; 5 = heavy mud.

Labor usage was similar for the two systems (8.1 vs. 9.0 min per head for the hoop barn and open-front systems, respectively). Labor usage was spread more evenly throughout the feeding period for the hoop barn because partial manure cleaning occurred weekly. The open-front feedlot cleaning occurred after the cattle were marketed when the lots were cleaned. Cleaning the open-front feedlot was more dependent on weather and lot conditions than the cleaning of the hoop barn.

Longer-term comparisons of cattle performance are needed. The facilities are currently involved in a long-term (three year) study to evaluate market beef cattle performance and behavior in a bedded hoop barn compared with a semi-confinement feedlot.

Beef cattle feedlots can be built for a wide range of costs. An earthen lot with windbreak is the lowest cost, and total confinement with slatted floor is the most expensive, almost three times as much (Lawrence et al., 2006). There is also a wide variation in costs within a feedlot type depending on the construction details and choices. The authors believe that the bedded hoop barn confinement would cost slightly more per head of capacity than an open-front shelter with earthen lot. For a confined hoop barn feedlot, the major cost considerations are: the area of floor covered with concrete, whether the feeding alley is inside the hoop barn, and the amount of floor space allotted per beef animal. Based on prices in western Iowa at the time of construction, a confined hoop barn feedlot for beef cattle could be built for approximately $370/head of capacity and a semi-confinement with earthen lot would be about 10% less. These costs do not include land or feed and cattle handling facilities. The facilities would be similar to the feedlots described in the Methods section.

Structure and Design Observations

After 2 years of operation, several observations about the structure and design are noted. The geotextile and limestone screenings floor surface has performed well in the hoop barn. The limestone stays firm enough to support animal and tractor traffic. During cleaning, the loader bucket slides across the limestone surface without gouging. Spots have softened and needed repair only at the gates in the west wall of the hoop barn where rainwater from the roof accumulates. This flooring combination will work only in areas where the bedding pack is kept dry or moist, in wetter conditions of raw manure or very wet bedding pack the limestone would soften and fail. The performance of the limestone for preventing moisture or nutrient migration into the soil has not yet been evaluated. In the author's opinion, the migration of water and nutrients through the limestone is expected to be exceedingly small, but possibly not zero. Limestone floors require more attention and care than concrete. For long-term reliability and ease of cleaning, concrete floors are the best option.

The ridge vent is unnecessary on a hoop barn of this size with good wind exposure. It would be more important on longer buildings (perhaps over 61 m) or buildings with poor summer wind exposure. Minor problems with the ridge vent ties coming loose as the hoop arches migrate slightly end-to-end have occurred.

For the hoop barn, the bedding bale windbreaks have provided adequate winter wind protection as an alternative to end walls. It would be easy to close the building too tightly with end walls, creating harmful humidity problems. End walls for hoop barns used to feed beef cattle are not recommended.

The roof awning on the hoop barn has minimized rain and snow in the sidewall bunk. An awning of sufficient size to deflect rain and snow outside the bunk is necessary. Fabric awnings are more expensive than other alternatives and are difficult to outfit with rain gutters. Round eave support pipes do not provide a drip edge to direct water off the curved tarp surface and into the gutter. Tarp awnings are not recommended. Awnings should be built from lumber and ribbed roofing steel. The awning does not need to be the full width of the feed bunk. Catching rainwater from the roof and deflecting snow that slides off the roof enough to miss the bunk is all that is necessary. As an alternative to gutter and awnings, a hoop barn wide enough to place the feed alley under the roof should be evaluated for cost comparison.

Due to the excellent south summer wind exposure at this site, the total hoop barn length of 36.58-m, and the requirement of 40-head pens for research, the north-south orientation of this hoop barn made sense. North-south orientation gives the best summer sun protection and winter sun exposure. However, on sites where total building length exceeds 76-m, or summer wind is not primarily south, or winter wind protection is more critical than summer wind exposure, an east-west orientation should be considered as an alternative. Incidentally, the hoop structure has successfully endured winds greater than 80 km/h. The goal of the structure is to protect the cattle from the harmful effects of rain, severe winter wind, and summer heat. Any building shape or orientation that meets these objectives should be considered.

Conclusions

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.

As concerns and regulations regarding feedlot runoff increase, confined bedded cattle feeding becomes more advantageous and may offset the slightly higher cost of the facility compared with open earthen lots. In hoop barns, cattle performance is similar and costs are competitive with a semi-confinement feedlot with earthen lots. The hoop barns may be more suitable in areas of higher rainfall. Additional research is also needed regarding appropriate space allotment for each beef animal, bedding management, and hoop barn layout and design. The hoop barn system requires more bedding and slightly more labor, but is environment-friendly because of the enhanced control of the manure and reduced potential for runoff. Additional work is needed to verify the reduced runoff and quantify any leaching.

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