Beef Facilities Conference

November 21, 2013
Best Western Ramkota Hotel and Conference Center
Sioux Falls, South Dakota

IOWA STATE UNIVERSITY
Extension and Outreach

South Dakota State University

UNIVERSITY OF NEBRASKA
EXTENSION

United States Department of Agriculture

National Institute of Food and Agriculture

United States Department of Agriculture

Agricultural Research Service
# Table of Contents

Speaker contact information .................................................................................................................................. 4

Results of the air emission research study ........................................................................................................... 5
   Erin Cortus, assistant professor and Environmental Quality Engineer, Agricultural and Biosystems Engineering, South Dakota State University; Mindy Spiehs, Research Animal Scientist, USDA ARS U.S. Meat Animal Research Center

Air quality regulations and how the research study relates to air quality reporting ........................................... 10
   Rick Stowell, associate professor and Extension engineer, Biological Systems Engineering and Animal Science, University of Nebraska—Lincoln

Capturing, managing, and using nutrients from the barn .................................................................................. 18
   Kris Kohl, Extension Ag Engineer, Iowa State University; Angela Rieck-Hinz, Extension Program Specialist, Iowa State University

Building management in four different barns: Producer panel profiles
   John Tweedt, Larchwood, Iowa .......................................................................................................................... 22
   Joel and Lindsay Schuitemann, Sioux Center, Iowa ......................................................................................... 23
   Harris and Dianna Haywood Farms, Eldora, Iowa ............................................................................................ 24
   Andrew Stroschein, Clear Lake, South Dakota .................................................................................................. 25

Cattle performance with four different barns: University panel
   A performance and cost of production comparison for three types of feedlot facilities ............................ 27
   R. H. Pritchard, Distinguished Professor, Animal Science, South Dakota State University

Cattle performance in hoop barns ......................................................................................................................... 30
   Dan Loy, professor, Animal Science, Iowa State University; Shawn Shouse, Extension Ag Engineer, Iowa State University

Evaluation of rubber mats over concrete slats in cattle confinement facilities .................................................. 33
   Russ Euken, Extension Livestock Field Specialist, Iowa State University
Speaker contact information

**Erin Cortus**
Assistant professor and Environmental Quality Engineer
Agricultural and Biosystems Engineering
South Dakota State University
Box 2120
Brookings, SD 57007
605-688-5144
erin.cortus@sdstate.edu

**Beth Doran**
Extension field beef specialist
Iowa State University Extension and Outreach
400 Central Ave NW, Suite 700
Orange City, IA 51041-1359
712-737-4230
doranb@iastate.edu

**Russ Euken**
Extension field livestock specialist
Iowa State University Extension and Outreach
327 W 8th St
Garner, IA 50438-1600
641-923-2856
reuken@iastate.edu

**Harris & Dianna Haywood Farms**
27295 Y Ave.
Eldora, IA 50627
641-858-3077
hardihay@yahoo.com

**Kris Kohl**
Extension ag engineer
Iowa State University Extension and Outreach
824 Flindt Dr
Storm Lake, IA 50588-3208
712-732-5056
kkohl1@iastate.edu

**Dan Loy**
Professor and Director, Iowa Beef Center
Animal Science
Iowa State University
313 Kildee Hall
Ames, IA 50011-3150
515-294-1058
dloy@iastate.edu

**Robbi Pritchard**
Distinguished Professor
Animal Science
South Dakota State University
Box 2170
Brookings, SD 57007
605-688-5165
robbi.pritchard@sdstate.edu

**Angela Rieck-Hinz**
Extension program specialist
Iowa State University Extension and Outreach
2104 Agronomy Hall
Ames, IA 50011-1010
515-294-9590
amrieck@iastate.edu

**Joel and Lindsay Schuitemann**
3828 Hickory Ave
Sioux Center, IA 51250
712-441-4030

**Shawn Shouse**
Extension ag engineer
Iowa State University Extension and Outreach
53020 Hitchcock Ave
Lewis, IA 51544-4058
712-769-2600
sshouse@iastate.edu

**Mindy Spiehs**
Research Animal Scientist
USDA ARS Meat Animal Research Center
Clay Center, NE 68933-0166
402-762-4271
mindy.spiehs@ars.usda.gov

**Rick Stowell**
Associate professor and Extension engineer
Biological Systems Engineering and Animal Science
University of Nebraska-Lincoln
215 L.W. Chase Hall
Lincoln, NE 68583-0726
402-472-3912
rstowell2@unl.edu

**John Twedt**
1652 Beech Ave.
Larchwood, IA 51241
johntwedt@gmail.com
Results of the air emission research study
Erin Cortus, assistant professor and Environmental Quality Engineer, Agricultural and Biosystems Engineering, South Dakota State University; Mindy Spiehs, Research Animal Scientist, USDA ARS U.S. Meat Animal Research Center

Background

Beef mono-slope facilities are increasing in popularity among cattle producers in the quad-state region of Iowa, Minnesota, South Dakota, and Nebraska. In these facilities, cattle are raised in complete confinement, sometimes on concrete floors, with bedding added once or twice weekly. Producers may maintain a pack of manure and bedding through one or more groups of cattle (Pack system), or they may remove the manure and bedding on a weekly basis (Scrape system). Most producers use locally available by-products of cereal grain production such as corn stover, soybean stover, and wheat straw for bedding, and have a stocking density of 38 – 50 square feet per head (Doran et al., 2010). Management style, bedding materials, stocking density, cattle diet, and type of cattle contribute to air quality inside and outside the barn.

Beginning in the 1980s, regulations were passed to protect the air and water from environmental contaminants created and disposed of by heavy industry. Air quality regulations including the Emergency Planning and Community Right-to-Know Act (EPCRA) were passed. EPCRA requires owners and operators to notify the proper authorities when certain amounts of hazardous substances are released into the environment. In recent years, the courts have clarified that livestock and poultry operations of certain size and emission potential are required to follow the EPCRA reporting guidelines. However, there are no generally agreed upon air emission estimates from most livestock and poultry facilities and there is no published research regarding gas emissions from beef mono-slope facilities. Currently, most reporting guidelines for beef feedlots use a single emissions factor for ammonia and hydrogen sulfide emissions based on data from open-lot feedlots in four states (some southern) that were collected during the summertime. This existing emissions data likely does not reflect emissions from deep-bedded facilities very well due to system and climatic differences.

There are also concerns about particulate matter (PM) or dust associated with beef facilities, especially very small particles that are micrometres of meters (µm) in size. Particulate matter less than 10 µm (PMₐₐ) and particulate matter less than 2.5 µm (PM₂.₅) are of particular concern; PMₐₐ can enter the human esophagus, whereas PM₂.₅ can enter the human lung. Published PM values for cattle facilities are limited and those available were collected exclusively from open feedlots.

Therefore, a team from South Dakota State University, Iowa State University, USDA ARS, and the University of Nebraska – Lincoln initiated an integrated research and outreach project to monitor air quality in and estimate emissions from beef mono-slope facilities. Monitoring started in August 2010 and continued until October 2012.

Objectives

The objectives of the integrated project were to:

1. Gather baseline data for the levels of gas emissions and particulate matter (PM) from beef mono-slope facilities.
2. Evaluate the effect of two different manure handling systems (Pack and Scrape) on air quality.
3. Provide information about building and management practices that may reduce gas emissions.

The objective of this paper is to describe the ammonia, hydrogen sulfide and particulate matter in and around four mono-slope barns in the Northern Great Plains, and the implications for barn management and design.

Materials and methods

Gases and particulate matter concentrations of four mono-slope beef finishing facilities were measured over a two-year period. Two barns were located in northeast South Dakota and two in northwest Iowa. All barns were 100 feet wide. Two barns used a Scrape system in which all bedding and manure were removed weekly and replaced with
fresh bedding. Two barns used a Pack system in which only the bunk aprons and edges surrounding the pack were scraped weekly. In the Pack system, bedding was added to the pack weekly, and the pack remained in place within the pen until the cattle were marketed.

Air temperature, relative humidity and speed were monitored in multiple locations in the north and south wall openings and on a nearby weather tower. Ammonia, hydrogen sulfide, methane, carbon dioxide and nitrous oxide were measured in each barn during month-long monitoring periods during fall, winter, spring and summer over a two-year time span. Results of ammonia, hydrogen sulfide and methane monitoring are presented in this paper.

Particulate matter (PM) was measured over two five-day periods in April and June 2011 at one of the Pack barns. Each five-day period included three days of routine operation and two days associated with a bedding event. Air containing total suspended particulates (TSP) was captured, from which two sizes of PM were measured, particulate matter smaller than 10 µm (PM$_{10}$) and particulate matter smaller than 2.5 µm (PM$_{2.5}$). The Pack barn PM data was used to determine differences in PM concentration between routine operation and a bedding event. In the Scrape barns, 24-h collections of PM$_{10}$ and PM$_{2.5}$ occurred at least twice during each monitoring period between August 2010 and December 2011. The Scrape barn PM data was used to determine the relationship of PM concentration with pen stocking density.

**Results**

**Baseline gas concentrations**

Concentrations specify the amount of a substance (i.e. gas or PM) in a given amount of fluid (i.e. air in a barn). The measured concentrations result from gases already present in the ambient air plus gases produced by the animal, manure and/or bedding. Elevated gas concentrations in a barn can affect both animal and worker health and productivity, and are also related to the gas emissions into the surrounding environment.

Table 1 shows average gas concentrations measured in the study barns. For comparison, seasonal average hydrogen sulfide concentrations in the center of Nebraska feedlots ranged from 2 to 37 ppb (Koelsch et al., 2004). Ammonia concentrations over Texas feedlots were approximately 1500 ppb, and up to 3000 ppb for stable air conditions (Todd et al., 2005).

<table>
<thead>
<tr>
<th></th>
<th>Scrape A</th>
<th>Scrape B</th>
<th>Pack A</th>
<th>Pack B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen sulfide</td>
<td>27</td>
<td>23</td>
<td>103</td>
<td>80</td>
</tr>
<tr>
<td>Ammonia</td>
<td>2100</td>
<td>2500</td>
<td>2100</td>
<td>3800</td>
</tr>
<tr>
<td>Methane</td>
<td>9200</td>
<td>8100</td>
<td>6200</td>
<td>8000</td>
</tr>
</tbody>
</table>

Gas concentrations peaked in the morning between 7 and 9 a.m. and in the evening between 8 and 9 p.m. These times coincide with increased animal movement, urination, feces elimination, and disruption of the manure or pack surface. These times also coincide with low wind speeds that tend to follow dusk and dawn. The evening peak was slightly higher than the morning peak, likely due to increasing air temperature and animal activity throughout the day.

As airflow through the barn decreased, gas concentrations in the barn increased – due to less opportunity for air mixing, dilution, and exchange – and vice versa. For periods of southerly winds, concentrations measured in the north wall opening, which served as the air outlet, were higher than in the south wall opening. For northerly winds, the south wall opening was the outlet and had higher gas concentrations. Both situations confirmed expectations that incoming outdoor air picks up gas and dust as it moves across and out of a barn.

Common assumptions are that windward openings act as inlets and that concentrations measured at that openings represent baseline outdoor air concentrations. These assumptions were challenged with these barns, however, as gas concentrations at the south sides of the barns were, on average, higher than at the north sides for comparable wind...
speeds when compared as either inlets or outlets. This implies that some mixing and back-drafting occurred in the south wall opening for both northerly and southerly winds. Back-drafting is known to occur in naturally ventilated buildings, especially those having mono-slope roofs, adding another level of complexity to air monitoring and emissions estimations.

There was a significant increase in hydrogen sulfide concentration with increasing temperature in both the Pack and Scrape barns. However, the increase was greater and more variable for the Pack barns compared to the Scrape barns. Similarly, ammonia concentration tended to increase with increasing temperature in the Pack barns.

**Baseline particulate matter**

Average 24-hour PM$_{10}$ and PM$_{2.5}$ concentrations for both Scrape barns and one Pack barn are shown in Table 2. Particulate matter was collected from the Scrape barns using Mini-vol samplers and PM concentrations were measured at least twice during each monitoring period between Aug 2010 and Dec 2011. This data included hours of routine operation and bedding events. Particulate matter was collected from one Pack barn using Lo-Vol samplers for three days each in April and June 2011 and only included hours of routine operations. Concentrations of PM$_{10}$ and PM$_{2.5}$ were similar in the two Scrape barns. During hours of routine operation, PM$_{10}$ and PM$_{2.5}$ concentrations were slightly lower for the Pack barn compared to the Scrape barns. However, during bedding events, the concentrations of PM$_{10}$ and PM$_{2.5}$ were substantially higher in the Pack barn compared to the Scrape barns. Concentration of PM$_{10}$ and PM$_{2.5}$ for both Pack and Scrape barns were lower or within the range of values reported for open feedlots.

Table 2. Overall mean concentration and size distribution of particulate matter in the Pack and Scrape barns compared to reference data for open feedlots

<table>
<thead>
<tr>
<th></th>
<th>Pack Barn A</th>
<th>Scrape Barns</th>
<th>Open feedlot†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Routine Operation</td>
<td>Bedding Event</td>
<td>Barn A</td>
</tr>
<tr>
<td>TSP (µg/m$^3$)‡</td>
<td>59</td>
<td>702</td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$ (µg/m$^3$)‡</td>
<td>5</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>PM$_{10}$ (µg/m$^3$)‡</td>
<td>18</td>
<td>141</td>
<td>25</td>
</tr>
<tr>
<td>PM$_{2.5}$/TSP (%)</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PM$_{10}$/TSP (%)</td>
<td>16</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>PM$<em>{2.5}$/PM$</em>{10}$ (%)</td>
<td>21</td>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

† Algeo et al., 1972, Sweten et al., 1988, Sweeten et al., 1998, Purdy et al., 2007, and Guo et al., 2011
‡ Significant difference (P < 0.05) between Pack Barn A Routine Operation and Pack Barn A Bedding Event

**Particulate matter and bedding events**

Concentrations of total suspended particulates (TSP), PM$_{2.5}$, and PM$_{10}$ were significantly higher during the three-hour bedding event than in normal operation (Table 2) in the Pack barn. The ratios of PM$_{2.5}$, PM$_{10}$, and TSP did not differ between routine operation and bedding events, though, indicating that dust composition was constant. Dust concentrations in the Pack barns during routine operation were substantially lower than reported for open feedlots, while concentrations measured during bedding events were, on average, slightly higher than for open feedlots. Bedding events in mono-slope barns are short – lasting only a few hours a week - and PM concentrations quickly return to baseline levels.

**Ventilation/curtain Management**

Most beef producers having mono-slope barns regulate ventilation by adjusting the amount of opening between the eave and top of the curtain in the north sidewall. The curtain is usually wide open in the summer; whereas, in the winter, the opening is usually reduced. As the ambient wind speed increased, the airflow through the barns typically increased in a linear pattern. For example, with an 11 mph south wind, there were approximately 10-70 air changes
per hour for closed curtain conditions (only 1-2 ft open) in the four barns, and 160 air changes per hour with open curtains (average 7 ft of opening).

Decreased air movement through the barn increased the concentration of gases in the barn compared to higher airflow conditions (other factors, such as temperature, being equal). However, since the emission rate depends on both the concentration and the airflow rate, the reduced rate of airflow through the barn resulted in decreased emission rates of ammonia, hydrogen sulfide and methane (Table 3).

**Manure handling system**

Ammonia and hydrogen sulfide emission rates (Table 3) for the Pack system were more variable than for the Scrape system. This increased variability may be attributed to the effects of the age and condition of the pack. Increased pack depth is associated with a higher internal pack temperature which may increase gas production. In the case of hydrogen sulfide, increasing pack depth and temperature can lead to anaerobic conditions, which promote hydrogen sulfide production.

**Table 3.** Range of daily average emission rates for ammonia and hydrogen sulfide with varying curtain openings and manure removal systems

<table>
<thead>
<tr>
<th>Curtain Opening</th>
<th>Manure Removal System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scrape</td>
</tr>
<tr>
<td>Open</td>
<td></td>
</tr>
<tr>
<td>Ammonia (g/head/d)</td>
<td>10-60</td>
</tr>
<tr>
<td>Hydrogen sulfide (mg/head/d)</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Closed</td>
<td></td>
</tr>
<tr>
<td>Ammonia (g/head/d)</td>
<td>&lt;15</td>
</tr>
<tr>
<td>Hydrogen sulfide (mg/head/d)</td>
<td>&lt;0.1</td>
</tr>
</tbody>
</table>

Gas production and emission are also related to diet, animal characteristics and animal activity. These factors were not exclusively monitored in this study and may account for some of the variability in the emission rates in this study.

**Conclusions**

Gas concentrations in beef mono-slope facilities are similar to slightly higher than open feedlots and vary with temperature. Particulate matter concentrations in Scrape mono-slope barns and in Pack mono-slope barns during routine operation are substantially lower than reported values for open feedlots. Particulate matter concentrations in Pack barns are slightly higher than open feedlots during a bedding event, however, bedding events in mono-slopes are short-lived, and PM concentrations quickly return to baseline levels. This research provided evidence that both curtain opening and type of manure handling system may affect gas emission rates. To improve air quality inside mono-slope facilities beef producers may consider ways to remove manure more frequently.
Acknowledgements

This project was funded by the USDA Agriculture and Food Research Initiative Competitive Grant no. 2010-85112-20510. The authors would like to thank the following people involved with this research project: our mono-slope barn beef producers and grant advisory committee; Steve Hoff, Iowa State University; Al Kruger, John Holman and Todd Boman, USDA, ARS, U.S. Meat Animal Research Center; Scott Cortus, Steve Pohl, Corey Lanoue, Ferouz Ayadi and Md Rajibul Mamum, South Dakota State University; Jill Heemstra, Leslie Johnson and Rick Stowell – University of Nebraska-Lincoln; and Greg Holt and James (Bud) Welch – USDA, ARS, Lubbock TX.

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S Department of Agriculture. USDA is an equal opportunity provider and employer.

References


Air quality regulations and how the research study relates to air quality reporting

Rick Stowell, associate professor and Extension Engineer, Biological Systems Engineering and Animal Science, University of Nebraska – Lincoln

Background

As livestock operations have expanded and animal production has become more concentrated, calls for greater environmental regulation have followed. Producers now may encounter air and water quality regulations on federal, state and local levels. Many who raise livestock in designated ‘animal feeding operations’ (AFO) have already faced requirements to construct approved runoff/waste control structures, implement manure nutrient management plans, and/or adopt other practices that address water quality concerns. Certain ‘concentrated animal feeding operations’ (CAFO) are required to obtain and follow a National Pollutant Discharge Elimination System (NPDES) permit as a result of the Clean Water Act.

Concerns about air quality generally have lagged those about water quality, but now air quality in animal agriculture is commonly raised as requiring environmental regulation. Consequently, efforts to develop, implement, and/or enforce air quality regulations that affect livestock operations have increased also. The result is that cattle producers may encounter air quality regulation ranging from local zoning ordinances to the federal Clean Air Act.

Lost in many discussions of regulations is the fact that many if not most livestock producers sincerely want to be good stewards of soil, air and water resources – whether they are required to do so or not. This likely applies to owners and managers of bedded (mono-slope) beef barns too. This paper describes air quality regulations that are most likely to apply to livestock operations and discusses relevant regulatory implications of the emissions study of bedded (mono-slope) beef barns.

Air quality regulations

Air quality regulations can be categorized as local, state or federal. It is important to know who is responsible for developing and enforcing a regulation. It is also helpful to know the nature and scope of what is being regulated.

Federal regulation

Federal air regulations can affect animal agriculture in a few key ways:

i) Maintenance of national ambient air quality standards (NAAQS);

ii) Reporting of hazardous substances under EPCRA; and

iii) Reporting of man-made greenhouse gas emissions.

iv) Exceeding personal exposure limits for employees.

NAAQS. The Clean Air Act establishes public health-based standards or NAAQS. These standards reference pollutant concentrations to which the public may be exposed, with the concentrations given as ‘parts per million’ (ppm) or per billion (ppb) or as fractions of a gram per cubic meter of air (e.g. µg/m³). NAAQS have been established for six ‘criteria pollutants’, of which, particulate matter (including dust) is generated by livestock production. The main public health concern with particulate matter (PM) involves fine particulates (PM$_{2.5}$) having very small size, which has been shown to get deep into human lungs and contribute to respiratory illness. EPA currently regulates both fine and ‘coarse inhalable particles’ (PM$_{10}$) via NAAQS, although there is movement toward regulating mainly or only PM$_{2.5}$. While agriculture in general and cattle operations in particular are known to generate dust, farm dust typically is fairly coarse material having mean particle size larger than PM$_{10}$. Very coarse airborne dust shows up in PM measurements as total suspended particulates (TSP). Ammonia has been shown to react with other air pollutants in the atmosphere to form PM$_{2.5}$, leading to concerns about future regulation of ammonia emissions under the Clean Air Act. Overall, considerable debate continues regarding agricultural contributions to a region not meeting national PM standards.
States are responsible for establishing procedures to attain and maintain the NAAQS via ‘state implementation plans’ (SIP). The U.S. Environmental Protection Agency (EPA) may enforce the NAAQS by requiring:

- Air permits for major sources of PM$_{2.5}$ and other hazardous air pollutants
- Implementation of control technology

The SIP procedures that must be taken and the requirements placed upon PM sources depend upon whether an area is designated by EPA to be in attainment or nonattainment of the NAAQS. Two counties in eastern Iowa currently don’t meet the NAAQS for PM$_{10}$ (Figure 1). Fortunately, designations for PM$_{10}$ (as of 2006) showed no counties in Iowa, Minnesota, Nebraska and South Dakota to be in nonattainment of the NAAQS (http://www.epa.gov/airquality/particlepollution/designations/2006standards/state.htm), which is favorable for long-term trends in regulation of particulate matter.

Figure 1. EPA-designated nonattainment areas for particulate matter.

EPA is also required to establish standards for hazardous air pollutants (HAP). The current list of more than 180 HAP does not include the major gases generated by livestock facilities (i.e. ammonia, carbon dioxide, hydrogen sulfide, methane). There is great concern that the list may be amended in the future, though, opening cattle operations to additional regulation.

Most livestock producers would strongly prefer to not be designated a major source of any regulated pollutant, which could lead to having to obtain an air permit and potentially install control technology. To avoid being designated a major source, emissions must remain below an established annual threshold. For particulate matter, the threshold in attainment areas is 100 tons of PM$_{10}$ per year (may be reduced to 70 tons per year in non-attainment areas). The default designation of a major source for an air pollutant – such as ammonia or hydrogen sulfide – is also 100 ton per year. The threshold decreases to 10 tons per year for a listed HAP or 25 tons per year for any combination of hazardous air pollutants.

EPCRA reporting. Two federal rules require reporting of releases of hazardous substances. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires that releases be reported directly to the (EPA) National Response Center. The Emergency Planning and Community Right to Know Act (EPCRA) requires reporting to designated emergency responders in the state in which the release occurs. CERCLA and EPCRA were both established to help plan responses to spills and other emergencies by creating awareness of pollutant sources and real or potential releases.
For many years, common perceptions within agriculture and even the U.S. EPA were that EPCRA and CERCLA reporting requirements did not apply to air emissions from operations associated with raising livestock and/or that agricultural operations were exempt from reporting. Lawsuits and resulting court rulings eventually pressed EPA to determine the application of these reporting rules. In 2008, a final EPA rule clarified that livestock and poultry producers were exempt from reporting air emissions from normal operations associated with raising animals to EPA under CERCLA. Emissions from small and medium AFO were also designated as exempt from reporting under EPCRA, but operations meeting the description of ‘large AFO’ were not. Lawsuits have since been filed by environmental groups and by a producer group (National Pork Producers Council) to remove the exemptions and to provide full exemption, respectively. EPA was directed to consider the merits of the lawsuits, but no further action has taken place to alter the 2008 final rule. So, livestock operations that have capacity to confine 1,000 or more head of beef cattle (or equivalent ‘animal units’) remain subject to reporting emissions of ammonia and hydrogen sulfide under EPCRA if a release of 100 pounds a day occurs or is anticipated to occur during normal operations.

A challenge for all parties has been coming up with reliable estimates of AFO air emissions. The National Air Emissions Monitoring Study (NAEMS) was conducted to aid EPA and livestock producers in assessing the expected emissions of regulated AFO air pollutants – other than greenhouse gases. The NAEMS did not include beef facilities, however. Separate studies have been conducted to monitor emissions from open feedlots. Based upon these limited studies, rough guidance has been made available to producers regarding ammonia and hydrogen sulfide emissions and EPCRA reporting. Contact a university extension engineer or your state cattleman’s association for additional details and guidance. Reporting under EPCRA needs to only occur once unless the amount of the maximum daily release changes significantly from what was reported.

Greenhouse gas reporting. In December of 2009, the U.S. EPA Administrator signed two findings stating that greenhouse gas (GHG) emissions threaten the public health and welfare. This action was an important step toward including greenhouse gases in the Clean Air Act. A year earlier, EPA issued the Mandatory Greenhouse Gas Reporting Rule that requires large GHG sources and suppliers to report annual emissions and other relevant data. Animal agriculture is primarily affected by the GHG Reporting Rule via a requirement to report GHG emissions resulting from management of manure – referred to in Subpart JJ of the rule. However, Congress has prohibited EPA from expending funds to implement this section of the reporting rule. Affected livestock producers are left in the precarious position of officially being required to report GHG emissions without being able to obtain additional guidance from EPA or certainty that EPA will actually require the reports.

According to the reporting rule, a livestock operation needs to meet or exceed two thresholds for a GHG report to be required. First, animal numbers must exceed an exemption threshold. For cattle operations, this threshold is 29,300 head of realized facility capacity. Additionally, reporting is only required if annual emissions of greenhouse gases (primarily methane) resulting from manure storage and handling are equivalent to 25,000 metric tons of carbon dioxide. EPA provides specific guidance in the rule for estimating reportable GHG emissions and assessing the need to report. Due to the complexity of the calculations, the inability to obtain assistance from EPA under the congressional budget restriction, and the importance of maintaining good documentation, producers who meet the animal number threshold are advised to work with a professional consultant.

**Worker exposure.** Under the Occupational Safety and Health Act, employers are responsible for providing a safe and healthful workplace. The Occupational Safety & Health Administration (OSHA) within the U.S. Department of Labor sets standards for worker exposure to toxic and hazardous substances. Limits for air contaminants are typically given as 8-hour, time-weighted average permissible exposure limits (PEL). The PEL for common AFO pollutants are listed in table 1 alongside of recommended exposure limits (REL) provided by the National Institute for Occupational Safety and Health (NIOSH).
Table 1. Permissible exposure limits and recommended exposure limits for common animal feeding operation pollutants.

<table>
<thead>
<tr>
<th>Air pollutant</th>
<th>OSHA PEL</th>
<th>NIOSH REL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia:</td>
<td>50 ppm</td>
<td>25 ppm</td>
</tr>
<tr>
<td>Carbon dioxide:</td>
<td>5,000 ppm</td>
<td>5,000 ppm</td>
</tr>
<tr>
<td>Hydrogen sulfide:</td>
<td>20 ppm – peak</td>
<td>10 ppm – 10-min exposure</td>
</tr>
<tr>
<td>Particulates:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total dust:</td>
<td>15 mg/m³</td>
<td>10 mg/m³</td>
</tr>
<tr>
<td>Respirable PM$_{2.5}$</td>
<td>5 mg/m³</td>
<td>5 mg/m³</td>
</tr>
</tbody>
</table>

OSHA standards are enforced by state departments of labor, health and safety. Some states may have additional or more stringent standards in place. It is important to distinguish between occupational exposure limits for workers – that apply to indoor air quality – and exposure standards for the public – that apply to outdoor air quality.

**State regulation**

State environmental regulations include SIP for implementing federal regulations and rules that address separate concerns. State implementation plans may be more stringent than required by the U.S. EPA. SIP cannot be less stringent or unenforced, though, or the EPA may impose federal implementation plans, which is generally viewed as being an undesirable scenario. States typically establish new environmental regulations to provide some minimum standard protections to all areas of the state, including areas that do not have local zoning or policy in place. State regulations often supersede local authority – as is generally the case with most water quality regulation – where livestock operations that satisfy state permit requirements usually cannot be required to meet more stringent requirements locally.

State air quality regulations generally are established specifically to protect the health of state residents from pollution that is generated by sources within the state. Like the U.S. EPA, states must have scientific evidence that exposure to one or more specific pollutants results in undesirable effects on human health or the environment before adopting regulations. States commonly refer to U.S. EPA for information on air pollutants. Information on health effects of AFO pollutants ranges from generally accepted to highly uncertain. For example, air quality standards for sulfur compounds are generally accepted as applying to hydrogen sulfide sources, whether the sources are agricultural or industrial facilities. On the other hand, attempts to tie health consequences of rural residents to the presence of livestock odors have produced conflicting conclusions, with some evidence of increased symptoms occurring, but no direct link proven between odor and specific diseases or long-term health status.

Most states require that AFO seeking a construction permit to develop a plan to control odor and/or air quality problems. Some states have specific regulations related to hydrogen sulfide and/or particulate matter concentrations that directly affect livestock operations. Several states also have rules that apply to off-site odor concentration (measured as ‘dilutions to threshold’). The following material highlights relevant regulation within the four-state region.

**Iowa.** In 2002, the Iowa Legislature directed the Iowa Department of Natural Resources (DNR) to perform a field study to determine airborne levels of ammonia, hydrogen sulfide, and odor near animal feeding operations. The department established a health-based standard for hydrogen sulfide to compare against monitoring data to determine if levels pose a risk to public health. If levels measured at separated locations such as homes, public areas, schools, or religious buildings pose health risks, the DNR may develop plans and programs to reduce emissions at animal feeding operations. Information on best management practices and other reports can be found at http://www.iowadnr.gov/Environment/AirQuality/AnimalFeedingOperations.aspx.

The Iowa DNR convened workgroups on best management practices, air emissions characterization, and dispersion modeling as part of a continuing effort to develop a working understanding of the technical issues involved in air quality concerns associated with AFO. Findings and recommendations of the workgroups are also available online.
**Minnesota.** The Minnesota Pollution Control Agency (MPCA) is responsible for maintaining state ambient air quality standards. Minnesota statutes (116.0713 Livestock Odor, 2013) state that:

(a) The Pollution Control Agency must:

1. monitor and identify potential livestock facility violations of the state ambient air quality standards for hydrogen sulfide, using a protocol for responding to citizen complaints regarding feedlot odor and its hydrogen sulfide component, including the appropriate use of portable monitoring equipment that enables monitoring staff to follow plumes;
2. when livestock production facilities are found to be in violation of ambient hydrogen sulfide standards, take appropriate actions necessary to ensure compliance, utilizing appropriate technical assistance and enforcement and penalty authorities provided to the agency by statute and rule.

(b) Livestock production facilities are exempt from state ambient air quality standards while manure is being removed and for seven days after manure is removed from barns or manure storage facilities.

(c) For a livestock production facility having greater than 300 animal units, the maximum cumulative exemption in a calendar year under paragraph (b) is 21 days for the removal process.

(d) The operator of a livestock production facility that claims exemption from state ambient air quality standards under paragraph (b) must provide notice of that claim to either the Pollution Control Agency or the county feedlot officer delegated under section 116.07.

(e) State ambient air quality standards are applicable at the property boundary of a farm or a parcel of agricultural land on which a livestock production facility is located, except that if the owner or operator of the farm or parcel obtains an air quality easement from the owner of land adjoining the farm or parcel, the air quality standards must be applicable at the property boundary of the adjoining land to which the easement pertains. The air quality easement must be for no more than five years, must be in writing, and must be available upon request by the agency or the county feedlot officer. Notwithstanding the provisions of this paragraph, state ambient air quality standards are applicable at locations to which the general public has access. The “general public” does not include employees or other categories of people who have been directly authorized by the property owner to enter or remain on the property for a limited period of time and for a specific purpose, or trespassers.

(f) The agency may not require air emission modeling for a type of livestock system that has not had a hydrogen sulfide emission violation.

**Nebraska.** Ambient air monitoring is conducted at sites throughout Nebraska for the following pollutants: particulate matter, carbon monoxide, sulfur dioxide, total reduced sulfur, pollutant deposition, and regional haze. These monitoring activities are carried out or administered through the Nebraska Department of Environmental Quality (NDEQ) in attainment of Nebraska Air Quality standards described in NDEQ Title 129 – Nebraska Air Quality Regulations (http://www.deq.state.ne.us/). The standards that relate to livestock operations are:

- Total reduced sulfur
  - 10.0 parts per million (10.0 ppm) maximum 1-minute average concentration, and
  - 0.10 parts per million (0.10 ppm) maximum 30-minute rolling average
- Except as provided in 007.01A and 007.01B these standards apply only where human exposure occurs.
  - 007.01A Ambient concentrations of total reduced sulfur (TRS) emissions occurring as a result of natural activities that have no associated economic benefits, such as seasonal stratification or turnover of lakes and lagoons, and the release of water uncontaminated by process or industrial activity from lakes, reservoirs, lagoons and water impoundment systems shall not constitute violation of the standards contained in section 007.
  - 007.01B The Department shall provide reasonable opportunity for any owner or operator of any source causing or contributing to a violation of the standards in 007 to develop and implement a program to eliminate such violations prior to taking enforcement action.
Particulate Matter

- PM$_{10}$ – Primary and secondary standards are 150 micrograms per cubic meter (24-hour average) with not more than one exceedance per year.

- PM$_{2.5}$ – Primary and secondary standards are 15.0 micrograms per cubic meter (annual arithmetic mean) and 35 micrograms per cubic meter (24-hour average)

- Notwithstanding any other provision of this Chapter, the Department shall not regulate emissions from normal farming practices, on-farm crop drying and handling, and animal feeding activities, provided that reasonable and practical measures to limit particulate matter from such sources are utilized.

**South Dakota.** The South Dakota Department of Environment & Natural Resources (DENR) addresses maintenance of ambient air quality in the state through the Air Pollution Control Program and federally established programs. Currently, the SD DENR does not have any air quality regulations that specifically apply to AFO.

**Local regulation**

Local regulations generally focus on pollutants that impact the local environment, that is, the health and well-being of area residents, with specific consideration given to defined communities and important natural features. Most local environmental regulation occurs through zoning policy and county health department ordinances. Counties and communities often use ‘setback distance’ requirements within their zoning policy as a way to regulate industries and minimize local environmental risk. In some situations, meeting minimum setback requirements and getting local approval (e.g. conditional use permit) may be big impediments for livestock operations that are looking to grow and expand.

Local air quality concerns with animal facilities and resulting manure application are commonly cited as reason to regulate these facilities. Air concerns typically include nuisance issues – like odor, dust, and flies – and immediate health factors – such as asthma triggers and wind-borne disease organisms. The common connections across these concerns are that they are all near-ground-level issues and debate usually centers on assessing the risk of one or more residents being exposed to pollutants from a neighboring livestock facility. These concerns are often hard to objectively define and typically are challenging to measure, monitor and control. So, local officials often choose to regulate air quality indirectly – wherein livestock operations are required to maintain some minimum prescribed separation from neighboring residences and communities, usually based upon size (e.g. in terms of animal numbers or ‘animal units’). In some cases, producers may agree to or be required to implement a locally approved control technology or practice. For example, in some settings animal housing systems that include bedding and manage mostly solid manure (i.e. some mono-slope barns) might be preferred and may be eligible for less restrictive setbacks or fewer operating restrictions.

Tremendous variation in local environmental requirements exists within and across Midwest states – ranging from areas having no local authority or policy in place to areas where existing restrictions make it virtually impossible to build any animal facility of average or larger size. The role of local politics in setting and implementing local policy may be a significant challenge for some livestock operations.

**Implications of the emissions study**

As described separately, a team from South Dakota State University, Iowa State University, USDA ARS, and the University of Nebraska – Lincoln initiated research to monitor air quality in and estimate emissions from beef mono-slope facilities.

**Occupational health**

Data on pollutant concentrations was collected primarily to calculate emissions from the facilities. The concentration data is also useful for describing indoor air quality and assessing the likelihood of compliance with occupational health standards were employees to actually spend long shifts inside of the barns.

**Ammonia.** Maximum hourly ammonia concentrations typically averaged 2-3 ppm in the Scrape barns. Ammonia concentration in the Pack barns varied more than in the Scrape barns – with measured maximum hourly averages exceeding 6 ppm – but the average concentrations over the course of the study were similar. Since the hourly
ammonia concentrations in both barn types were consistently well below NIOSH's recommended exposure limit of 25 ppm and the OSHA permissible exposure limit of 50 ppm, one can conclude that – given similar management is provided – occupational standards for ammonia should be met.

**Carbon dioxide.** Maximum hourly carbon dioxide concentrations generally were kept between 2,000 and 3,000 ppm in the study barns. As long as ventilation is managed as recommended for these facilities to maintain animal health, the PEL and REL of 5,000 ppm should be satisfied.

**Hydrogen sulfide.** Maximum hourly hydrogen sulfide concentrations ranged from nearly non-detectable levels to about 50 ppb (much less than 1 ppm) for the Scrape barns. Hydrogen sulfide in the Pack barns reached higher concentrations, close to 400 ppb (0.4 ppm), during warm weather. Since the hourly hydrogen sulfide concentrations in both barn types were consistently well below NIOSH's recommended exposure limit of 10 ppm and the OSHA permissible exposure limit of 20 ppm, one can conclude that – given similar management is provided and precautions are taken (e.g. ventilate) during removal of the pack material – occupational standards for hydrogen sulfide should be met.

**Particulates.** Measured TSP concentrations ranged as high as over 5,000 µg/m$^3$ (5 mg/m$^3$) during a bedding event in the one monitored Pack barn, while overall mean TSP, PM$_{10}$, and PM$_{2.5}$ concentrations were below 1,000 µg/m$^3$ (1 mg/m$^3$) in both types of monitored barns. Given that the REL and PEL for PM$_{2.5}$ are 5 mg/m$^3$ and PM$_{10}$ is a small fraction of TSP, it appears that dust levels may be a temporary nuisance and health concern for occupants during bedding events, but would not likely exceed OSHA limits or be a chronic health concern for those having normal lung function.

**Emissions**

Estimated ammonia and hydrogen sulfide emission rates from the study barns are shown in Table 1 in U.S. units. The emission rates are unitized on a per 1,000-head basis for two reasons: first, to make the values larger and easier to follow and, second, to denote the exemption threshold for EPCRA reporting.

<table>
<thead>
<tr>
<th>Curtain Opening</th>
<th>Manure Removal System</th>
<th>Scrape</th>
<th>Pack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia (lb per 1,000 head per day)</td>
<td>20-130</td>
<td>45-220</td>
<td></td>
</tr>
<tr>
<td>Hydrogen sulfide (lb per 1,000 head per day)</td>
<td>&lt;&lt; 1</td>
<td>&lt;&lt; 1</td>
<td></td>
</tr>
<tr>
<td>Closed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia (lb per 1,000 head per day)</td>
<td>&lt; 35</td>
<td>&lt; 65</td>
<td></td>
</tr>
<tr>
<td>Hydrogen sulfide (lb per 1,000 head per day)</td>
<td>&lt;&lt; 1</td>
<td>&lt;&lt; 1</td>
<td></td>
</tr>
</tbody>
</table>

Readers need to understand that estimation of emissions from these facilities involves making several assumptions and accepting a fair amount of uncertainty. Whether EPA and/or a court of law would accept the methodology used in this study is unknown at this time and different interpretations of the data could easily lead to different results. That being said, one can look at the data a couple of ways to draw a few inferences that may aid in making decisions.

**EPCRA.** Regarding EPCRA reporting, the data implies that emissions exceeding 100 pounds of ammonia would be expected to occur from a 1,000-head [or larger] mono-slope beef barn during one or more warm days a year – regardless of whether it was a Scrape or Pack barn. Actually, at the high end of the range of daily emission rates, 100 pounds would be emitted at an estimated 750 and 450 head for Scrape and Pack barns, respectively; but these capacities would be exempt from EPCRA reporting unless additional cattle or other livestock were raised on site. If use of the average daily rate during warm weather or the mean annual emission rate (both would be closer to 50 lb/1000 hd-day for the Scrape barn and 80 lb/1000 hd-day for the Pack barn) was accepted, then the threshold for needing to submit an EPCRA report would increase to as high as 2,000 head using the data from this study.
Based upon the emissions data provided, EPCRA reporting would not be required for either barn type based upon hydrogen sulfide emissions – an excess of 100,000 head would be required. This seems reasonable since hydrogen sulfide is produced in anaerobic environments typical of long-term, liquid manure storage. One caution is that elevated hydrogen sulfide levels could occur during removal of pack material, and this may deserve more scrutiny.

The author’s interpretation is that EPCRA applies to reasonably expected maximum daily emission rates – implying that mono-slope beef barns of large-AFO size should report ammonia emission per EPCRA rules. The author is not an expert in environmental law, though, and very little guidance has been provided to producers by EPA or other authorities to aid in this decision. Producers are advised to consult with a legal expert and/or trusted consultant to determine whether to submit an EPCRA report and what rates to report.

Clean Air Act. The Clean Air Act mainly affects major sources of designated criteria pollutants and hazardous air pollutants. PM is a criteria pollutant, while ammonia and hydrogen sulfide are not. On the other hand, the mono-slope barns had low emissions of PM and hydrogen sulfide, at least compared to ammonia. For illustration purposes only, then, it would take roughly 11,000 head of cattle in Scrape barns at a mean daily emission rate of 50 lb/1000 hd to emit 100 ton per year. Roughly 7,000 head in a Pack barn would generate this annual amount at a mean daily emission rate of 80 lb/hd. Conclusions that could be drawn from this are that very few producers need to be concerned about current EPA regulation of PM emissions from mono-slope barns. On the other hand, the cattle industry has a vested interest in limiting ammonia regulation by EPA and other authorities.

GHG reporting. EPA’s Mandatory Greenhouse Gas Reporting Rule requires following a prescriptive, quasi-process-based approach to estimating GHG emissions rather than applying [per-head] emission factors. So, for the small fraction of cattle operations that are not exempt from reporting, GHG results from this study may not be directly usable for estimating methane and nitrous oxide emissions from mono-slope barns. The results could, however, be useful for the cattle industry in assessing the accuracy of equations that EPA uses for bedded systems.

Other implications. This study did not monitor odor or downwind concentrations, which make drawing inferences for state and local regulations challenging at best. Given that a significant share of regulatory actions are initiated as a result of complaints, limiting dust and gas emissions from mono-slope barns is generally recommended wherever reasonably practical.

**General references**


Capturing, managing, and using nutrients from the barn

Kris Kohl, Extension Field Ag Engineer, Iowa State University; Angela Rieck-Hinz, Extension Program Specialist, Iowa State University

Introduction

Environmental pressure to reduce manure runoff from traditional beef feedlots is one reason for the increase in the number of beef housing systems in the upper Midwest. These housing systems allow manure nutrients to be better captured, managed and utilized as a fertilizer source for crop production systems while reducing potential environmental impact from runoff.

Manure from beef cattle contains all major nutrients needed for crop production making it a rich form of fertilizer. Some of the challenges in using manure include nutrient variability, nutrient loss, and the physical challenges of capturing and managing those nutrients.

The key components of successfully managing the manure are:

1) capturing the manure,
2) managing the manure nutrients, and
3) appropriately using the nutrients in a land application system for crop production.

Capturing manure

The key to capturing manure, and subsequently manure nutrients, is having properly designed facilities and appropriate equipment to collect and store the manure.

Manure handling in buildings is substantially different than manure handling on open lots. Open lots usually have large areas of space available allowing the manure to dry and subsequently reduce in volume prior to collection and land-applying. In addition, nutrient loss from a feedlot is substantially higher due to nutrient runoff, leaching, and volatilization. Table 1, adapted from Animal Manure as a Plant Nutrient Resource (Purdue ID-101, 2001), shows the nutrient losses from manure as affected by handling and storage.

Table 1. Nutrient losses from animal manure as affected by method of handling and storage.\(^a\)

<table>
<thead>
<tr>
<th>Manure handling and storage method</th>
<th>% Nutrient Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrogen</td>
</tr>
<tr>
<td>Solid Systems</td>
<td></td>
</tr>
<tr>
<td>Daily Scrape and Haul</td>
<td>15-35</td>
</tr>
<tr>
<td>Manure Pack</td>
<td>20-40</td>
</tr>
<tr>
<td>Paved Lot</td>
<td>40-60</td>
</tr>
<tr>
<td>Liquid System</td>
<td></td>
</tr>
<tr>
<td>Anaerobic Deep Pit</td>
<td>15-30</td>
</tr>
</tbody>
</table>

\(^a\) Based on composition of manure applied to the land vs. composition of freshly excreted manure, adjusted for dilution effects of the various systems.

Deep-bedded mono-slope barns and hoop buildings

On average, a beef animal will produce 1 cubic ft of manure per day per 1000 lbs of animal weight (MWPS-6, 1987). For example, a 600-pound steer will excrete 0.6 cubic feet of manure. Large finishing cattle (1300 lbs) will
produce about 1.30 cubic foot of total manure. Table 2 shows average manure deposition, in inches per week, based on stocking density.

Table 2. Manure deposition (inches per week) by cattle size and stocking density.

<table>
<thead>
<tr>
<th>Animal Size</th>
<th>60 ft/hd</th>
<th>40 ft/hd</th>
<th>35 ft/hd</th>
<th>30 ft/hd</th>
<th>25 ft/hd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Cattle (600 lb)</td>
<td>2.03</td>
<td>3.01</td>
<td>3.43</td>
<td>4.06</td>
<td>4.83</td>
</tr>
<tr>
<td>Large Cattle (1300 lb)</td>
<td>3.43</td>
<td>5.11</td>
<td>5.81</td>
<td>6.79</td>
<td>8.19</td>
</tr>
</tbody>
</table>

Bedding is added in mono-slope and hoop buildings to provide animal comfort and to soak up the manure waste produced. Care must be taken when and where the bedding is added to minimize animal consumption and maximize animal comfort. The wet sloppy manure that is near the bunk is often cleaned 2 to 3 times a week and stockpiled for land application when the weather and land are available. Often times in deep-bedded barns, the remainder of the area in the barn may have the manure removed weekly, or the pack may be allowed to accumulate until the cattle are marketed. In buildings with limited space the manure accumulates fast requiring bedding and frequent removal to maintain cattle cleanliness and hair coat protection. On average, 1,000 to 1,200 pounds of bedding are used per animal space per year to soak up the manure from bedded barn systems. Weather conditions will require adjustments in bedding need, with summer requiring more bedding than winter due to high humidity and increased water consumption leading to wetter bedding.

The facility needs to be constructed to prevent the entry of surface water. The facility also needs to be constructed so that the placement of the manure spreader and curbs will facilitate the removal of loading manure in a pen full of cattle. Little space for cattle to stand during cleaning and the need for the operator to constantly see both the front and back of the equipment can lead to cattle injuries especially when they are nearly finished and are accustomed to the equipment. Facilities should be designed to allow for straight runs for manure handling equipment that require little to no turning and reduce the need to back equipment down long aisles (MWPS, 2012). Frequent facility cleaning that is needed in cattle buildings necessitates adequate push walls that can accommodate the size of a pay loader or skid steer used in the operation. The loader is the standard equipment used to clean the barns which is the same one used to handle feed requiring the necessary cleaning after each job to maintain biosecurity and prevent cross contamination.

Deep-pit barns

On average, a slotted-floor, deep-pit barn is 8-10 feet in depth. Manure in a deep-pit building will fill quickly adding about one-foot of depth per month at stocking density of 40 square feet per head. Manure removal from most deep-pit barns is accomplished by the addition of extra gates that allow moving cattle to pull up a gang slat. These systems provide approximately 180 days of manure storage and will require manure removal at least twice per year. Nutrient concentrations tend to be higher in deep-pit barns due to complete collection and lower losses. In cattle systems where manure has been primarily handled as a solid or semi-solid, cattle-feeders must now consider the costs associated with pumping manure and investing in liquid manure-handling equipment they may not have previously had access to in their farming operation.

It should be noted that many states have requirements for sizing and constructing buildings and manure storage as well as rules on manure removal, stockpiling locations and timing of land application. It is not uncommon that facilities are required to have a minimum of 180 days or six-months of manure storage.

Managing manure nutrients

Another key to capturing and conserving nutrients is recognizing when and how nutrient losses occur and how to minimize those losses. Nutrient loss in a cattle building comes primarily from gaseous losses of nitrogen. Theoretically all phosphorus and potassium should be recoverable if the barn has a concrete floor, but it is possible to have physical losses of nutrients via the small amounts of manure that are accidentally moved out of the building (tire-tracking and manure on animal hides). Research shows hoop barns with partial concrete floors do experience
minor loss of nutrients that leach into the soil (Shouse, et al., 2008). Once manure is removed from the barn, other losses may be more prevalent depending on how the manure is handled and stored.

**Scraping frequency**

More frequent scraping, aids in cattle cleanliness and comfort, and can reduce slippage which results in foot, leg and hip injuries. More frequent scraping may also allow more nitrogen capture in scrape systems versus pack systems, assuming the nutrients can be readily used. Data from the mono-slope research project suggest the rate of ammonia production in the pack barns may be lower or consistent with the scrape systems for younger packs, but higher than the scrape barns for older packs. This theory suggests higher loss of N from the pack system and translates to less nitrogen in the manure over the long term (Cortus, 2013).

Manure storage in-barn versus moving off-site has several pros and cons. The “pro” attributes include, convenient for manure removal schedule in any weather conditions; exclusion of precipitation that can dilute nutrients and cause environmental runoff; and, daily inspection of the manure storage when feeding and inspecting cattle. The “con” attributes include: manure storage takes valuable housing space and increases cost per head; requires manure to be handled twice; and manure stockpiles attract and often breed flies.

Most facility owners use a combination of storage with a week or two of manure storage in or near the building followed with offsite facilities for most of the storage.

Offsite storage helps move the manure to a location close to where it will be land applied during the accumulation period when time pressure is not as great. Many of the fields that will benefit the most from cattle manure application are located farther from the feeding facilities. Stockpiling during the summer provides more even labor management and working during the day light hours.

Manure storage can be in the building or off-site following the state regulations and community standards for protecting others’ property. Providing short term stacking storage in the building is convenient and can help reduce nutrients lost from leaching, but can be costly for the space needed. Stockpiles located outside are subject to nutrient loss from volatilization, denitrification and leaching of nutrients, although one research study shows that stockpiled manure retains more nutrients than composted manure (Luebbe, et al., 2008).

Stockpiles should be located where the risk of runoff is eliminated or minimized. Consult your local state’s regulatory requirements for stockpiled manure.

**Using nutrients**

In the Midwest, manure nutrients are predominantly land-applied for crop production systems. Overall, a very small volume of manure is used as an energy source, recycled bedding or in other non-fertilizer uses.

Getting the most from manure nutrients requires 1) knowing how much manure is produced, 2) sampling manure for nutrient content, 3) calibrating application equipment and 4) evaluating the feedback loop.

Manure production was discussed earlier in the paper and several sources of “book values” exist for manure production numbers. Due to differences between cattle-feeding operations including, but not limited to: feed inputs, manure collection systems, size of cattle, amount of bedding added and potential evaporation to reduce volume, manure production is best measured rather than calculated.

Manure nutrient concentration can be affected by size of animal, feed inputs, manure handling, management, moisture content and season. Manure sample analysis costs about $30 to $40 per sample and will provide essential information on the manure that is being applied to the field. Moisture and bedding can both play a roll in the variability of the product. A 10% to 15% variation at an individual facility is normal and a 20% variation from operation to operation is not unusual.

Table 3 summarizes information from ASAE D384.2 and show the difference in nutrients retained per space per year in pound between excreted manure and manure collected from different management systems.
Table 3. Summary of beef nutrients retained per space per year (lbs).

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excreted</td>
<td>122</td>
<td>75</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>Bedded Barn</td>
<td>90</td>
<td>60</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Deep Pit</td>
<td>96</td>
<td>60</td>
<td>84</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Per Ton</th>
<th>Per Ton</th>
<th>Per 1000 gal.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Lot</td>
<td>64</td>
<td>48</td>
<td>4 tons</td>
</tr>
<tr>
<td>Per Ton</td>
<td>16</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Bedded Barn</td>
<td>90</td>
<td>60</td>
<td>5 tons</td>
</tr>
<tr>
<td>Per Ton</td>
<td>18</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Deep Pit</td>
<td>96</td>
<td>60</td>
<td>2,400 gal</td>
</tr>
<tr>
<td>Per 1000 gal.</td>
<td>40</td>
<td>25</td>
<td>35</td>
</tr>
</tbody>
</table>

Manure spreader application consistency has improved with the increased use of vertical beater spreaders, however all manure application equipment must be calibrated to obtain confidence in applying the right rate for growing crops. Under-application of manure nutrients could limit yield potential; over-application of manure nutrients wastes nutrients and could lead to environmental concerns. Most producers utilizing manure from cattle will apply 25% to 40% of the needed crop nitrogen with commercial sources to provide early season consistency while the manure is decomposing into the crop available components.

Current fertilizer prices in October 2013 are $0.40/lb N, $0.48/lb for P$_2$O$_5$, and $0.41/lb K$_2$O. If we use the nutrient concentration for bedded manure in Table 3, our analysis is 18 lb/ton N, 12 lb/ton P$_2$O$_5$, and 14 lbs/ton K$_2$O. Adjusting our N availability for the first year at 35%, this leaves us with 6.3 lb/ton N.

\[
\text{Nitrogen} \times \text{price} = \text{value} \\
0.40 \times 6.3\, \text{lb/ton} = 2.52 \\
\text{Phosphorus} \times \text{price} = \text{value} \\
0.48 \times 12\, \text{lb/ton} = 5.76 \\
\text{Potassium} \times \text{price} = \text{value} \\
0.41 \times 14\, \text{lb/ton} = 5.74
\]

Total value = $14.02/ton

Using manure in a cropping system requires the use of feedback loop. Once you know how much manure you have produced, the nutrient concentration, the total of amount of nutrients available and you have calibrated your equipment to deliver the right rate based on soil tests and cropping requirements, you need to determine how the system worked and what changes you might need to make for the following year. All of this must be accomplished by evaluating cost, time, agronomic and environmental challenges as well as producers’ access to resources.

References


Producer panel profiles

John Twedt
1652 Beech Ave., Larchwood, IA 51241 | johntwedt@gmail.com

Description of facility
This is a slatted floor barn with a deep pit and gable roof. The building is 70 feet wide x 200 feet long and typically houses 480 head, with an animal density of 22.5 square feet per head. The building is oriented east-west and contains two pens of equal size. There is a north, indoor alley with a fenceline bunk on the south side of the alley. Automatic waterers are located centrally in each pen on the southern edge of the building. A working facility is adjacent to the northeast corner of the barn.

Building cost
The building cost was $750 per head space (without the mats). To improve animal comfort, mats were placed on top of the slats and secured with plastic wedges at an additional cost of ~$100 per head space. Thus, total cost was $850 per head space. The building was put up two years ago.

Special management with cattle
We primarily finish steers in this barn. Cattle are placed at approximately 900 pounds and marketed at 1400 pounds.

Special management for feeding
Our finishing diet is comprised of corn, corn silage, modified wet distillers grains, corn condensed distillers solubles and a hay/cornstalk mix. This 60 Mcal diet is delivered via tractor and wagon twice daily, as bunks are only located on the north side of the pens.

Special management for bedding
This facility contains a 12-foot deep pit under the slatted and matted floor. Cattle work the manure down through the slats. Hence, additional bedding is not used.

Special management for manure handling
Because there is a deep-bedded barn housing 350 head to the north of the slatted barn, we have a manure management plan. We use a custom manure applicator to pump the pit in the spring and in the fall. There are four pump-outs per pen, and we use two pumps (one to agitate and one to pump) per pit. The pumping process involves two days each in the spring and fall.

Special management for ventilation
We have a one-piece, manual curtain on the north wall. This curtain is completely shut in November and is completely opened in April. There may some adjustment to this schedule depending on weather. For example, we were later in opening the curtain this spring due to cold weather. However, we don't make daily adjustments. We do have 12 high velocity fans in the building (three on the south and north side of each pen) to provide ventilation in hot weather.

What has worked well
We were looking to expand, but were land-locked with our open feedlot facility. The slatted, deep-pit barn has been a good solution. The pit building has a low number of manure management hours. Cattle comfort is high, especially when the summer or winter weather is inclement. Our dry matter intakes have been more even, and we get pretty good gains and feed efficiencies compared to our open concrete lots.
What has surprised me
The first year we did not have mats in this facility, and we had some leg issues. Hence, we installed mats on top of the slats. The first year we also had some necrotic tails. We now routinely band tails before placement in the facility. Another new experience was the handling of liquid manure produced by beef animals. Because it is thicker than swine manure, we add water prior to pumping manure from the building.

What would I change
I'd recommend the mats initially in a slatted floor barn. If I were building this barn again, I’d put bunks on both sides of the pens. Currently, I feed twice daily because there isn’t enough bunk space to feed once a day.

---

Joel and Lindsay Schuitemann
3828 Hickory Ave., Sioux Center, IA 51250 | 712-441-4030

Description of facility
We have two wide mono-slope barns with solid cement floors. The floors have a 4-5% slope from the center of each pen and a 4-inch curb that rolls into each pen from the gate. The southern building is 110 feet wide x 900 feet long; the northern building is 110 feet wide x 1350 feet long. Our one-time capacity is 3300 head. Both buildings are oriented east-west. There are 16 pens with capacities of 200-240 or 125-145 head per pen. Our animal density is 50 square feet per head. There is a north, indoor alley with a fenceline bunk on the south side of the alley and a southern, outdoor alley with a fenceline bunk on the north side. Waterers are centered on the northern and southern bunk aprons both N/S and E/W. The working facility is located east of the southern barn. Alleys, connecting both barns, allow for animal movement to the processing facility.

Building cost
The original building cost was $570 per head space. The buildings were constructed in 2005 and 2007.

Special management with cattle
We finish both steers and heifers in these barns. Placement weights vary from 650-pound calves to 1100-pound yearlings. Cattle are marketed at 1300-1400 pounds.

Special management for feeding
Our finishing diet contains cracked corn (either dry or 18-25% high moisture corn), cornstalks, wet distillers grains with solubles and dry protein. We feed twice a day with a truck.

Special management for bedding
We scrape the bunk aprons once a week and bed one to two times weekly using a bale shredder. The bedding material is primarily cornstalks, but we sometimes use bean stubble. It takes about five to six hours to clean and bed the barns. We figure one large bale per head per turn. If it is really windy and a north wind, we will close the curtain temporarily while bedding to reduce dust inhaled by our crew.

Special management for manure handling
This is a permitted facility originally with a Comprehensive Nutrient Management Plan, but now operates with an Iowa Manure Management Plan. Usually the pack is removed once yearly, but not always. We like to clean the pack at the beginning of the year and allow it to rebuild before placing calves in the spring. In our weekly cleaning, we will scrape and remove the manure with a side dump trailer. This manure is stockpiled outside and land applied twice yearly.
Special management for ventilation
We have a two-piece, hydraulically operated curtain on the north wall. The curtain is wide open 95% of the time unless there is extreme wind, snow or rain. It is never shut completely. We have noticed that the barn is wettest when there is hot, humid weather.

What has worked well
The building is much cooler in the summer compared to an outside lot, and we do not have to sprinkle cattle. Consequently, we also don’t have mud holes. At certain times of the year, our feed conversions are greatly improved. And, with a confinement facility, we have less problems meeting environmental regulations.

What has surprised us
We have found that we need to scrape once weekly, and we now use a little more bedding than originally. We also have noticed that in the summer, the bedding packs and cattle are hotter than we had originally thought.

What would we change
On the south barn, we’d change the gates. Currently, there are double gates that hinge on east and west poles. We’d replace these with one gate hinging on the west side only so animals exit the pen without having to go around a gate. On the north barn, we’d make two changes. We’d place the pen gates in the southwest corner of each pen. Also, we would slope the outside feed alley away from the bunks so that water would flow away from the building.

Harris & Dianna Haywood Farms
27295 Y Ave., Eldora, IA 50627 | 641-858-3077 | hardihay@yahoo.com

Description of facility
We have nine narrow mono-slope buildings with solid cement floors. The older buildings were built in 2001; more recently constructed buildings were put up in 2008. Each building is 40 feet wide x 280 feet long. Total one-time capacity for all buildings is 3500 head. Animal density averages close to 28 square feet per head, but ranges from 28-50 square feet per head. The buildings are oriented east-west and contain three to four pens per building. Larger pens accommodate 150 head maximum; smaller pens would hold 75 head. There is an outside feeding alley located on the south side of the buildings, and we allow 14 inches of bunk space per head. Frost-free waterers, which are non-electric, are centered on a gated fence that divides the pens. A working facility is adjacent to the barns.

Building cost
The building cost was $475 per head space for buildings constructed in 2008.

Special management with cattle
We finish steers and heifers for a high-quality, restaurant trade. Incoming calves and yearlings average approximately 600 pounds and are fed to approximately 1300 pounds or “finished.”

Special management for feeding
We feed a total mixed ration consisting of whole shelled corn, modified wet distillers grains, ground hay, wet corn gluten feed, earlage and husklage. Feeding is done once daily with a truck.

Special management for bedding
Cornstalk bedding is shredded and blown into each pen once a week. We average approximately two bales per pen per week. Bedding involves two to three hours per week.

Special management for manure handling
All manure and bedding is removed from the pens every 5-6 weeks. In the summer, we may be able to extend the time between removal and re-bedding. Manure is stockpiled on stacking pads that have a concrete base and is
hauled in the fall, winter and spring. We have a comprehensive nutrient management plan for our manure and an NPDES permit for the buildings.

**Special management for ventilation**
There is a two-piece curtain on the north wall that can be raised and lowered mechanically with a drill. The top curtain rolls down; the bottom curtain rolls up. In the fall/winter/spring, the bottom curtain is ¾ closed and the top curtain is open unless there is snow. In the summer, both curtains are wide open. We also have a ventilated awning to the south of the building that extends over the fenceline bunks. We find that the buildings are wettest in the winter.

**What has worked well**
There is absolutely no wood or wear and tear on the buildings - so they should last and have a long life-span. There are normal repairs, such as replacing gates and fixing waterers. It is easy to handle cattle in less time. Handling manure is also easier. We can clean and bed a 450-head barn in one hour, and building upkeep is easier than an open lot. Another big advantage is the year-round animal comfort. We have found a “corn crib effect” with the ventilation in these buildings, and we close our outside lots in the summer. The buildings were designed so that in the winter, there is good sun penetration clear to the back wall with the southern sun exposure.

**What has surprised us**
We have noticed improved feed efficiency in our mono-slope buildings compared with our outside lots. Animals are not as affected by snow, cold and wet conditions. It is much easier to handle both the cattle and manure.

**What would we change**
We have made some changes. We used to have one-piece drop curtains that we replaced with the two-piece curtains. This has improved air flow and reduced rodent damage. The walls separating pens in the older buildings were concrete, and the back wall was four feet tall. We increased the back-wall height in the older buildings to five feet by installing guard rail around the top of the four-foot walls. Our newer buildings have gated fencing separating pens, and the back walls are five feet high and all concrete, which was a cost-effective opportunity at the time. We’d like to have paved the outside allies, but cement is considerably more expensive than rock.

---

**Andrew Stroschein**
18751 473rd Ave., Clear Lake, SD 57226 | 605-520-4399 | andy.sam.stroschein@gmail.com

**Description of facility**
I have two hoop barns that have a 14’ concrete bunk apron and concrete around the waterers. Both buildings have crushed concrete in the back of the pens. The south building, which is 43 feet wide x 320 feet long, contains four pens housing 80 head each. It has three waterers – one in each of the two west pens and a shared waterer in the two east pens. The north building is 43’ x 400’ and has six pens – two pens at 40 head each and four pens at 80 head each. There are three shared waterers – one for the two 40-head pens and two for the four 80-head pens. One-time capacity is 720 head at 43 square feet per head. Each pen has a fence that extends along the back of the bunk apron, with gates on each end. Buildings are oriented east-west with an outside alley on the south side of the buildings. The working facility is adjacent and to the west of the barns.

**Building cost**
The buildings, which were constructed in 2012, cost $660 per head space.
Special management with cattle
I feed both steers and heifers. Incoming calves average 700 pounds. Yearling cattle would weigh 1000-1050 pounds. Occasionally, I place 1200-pound yearlings, which I feed for a month. Usual market weights average 1350-1400 pounds.

Special management for feeding
The starting diet consists of dry rolled corn, modified wet distillers grains, ground grass hay, corn silage, 35% high moisture earlage, and a liquid supplement. In the finishing diet, the hay is replaced with ground cornstalks or oat straw. We deliver feed with a tractor and wagon twice daily in hot weather and once-a-day when the weather is cooler.

Special management for bedding
We typically drive by and blow shredded corn stalks into the pen twice a week. In the larger pens, we average 2.5 bales/pen/week; the smaller pens average 1.25 bales/pen/week. Sometimes we bed with oat straw or wheat straw, averaging 2.0 and 1.75 bales/pen/week, respectively.

Special management for manure handling
The bunk apron is scraped twice weekly and normally involves 1.5 hours per scraping. There is outside, concrete manure storage on the ends of the buildings, which can provide two months of temporary storage. When field conditions permit, manure is directly land applied. The buildings are totally cleaned in the spring and fall. Our manure management is conducted according to a manure management plan issued by the South Dakota Department of Agriculture.

Special management for ventilation
There are one-piece, manual curtains on the north wall of each building. Curtains are completely open when the temperature is 40º, partially open between 32º and 40º and completely closed when temperatures are less than 32º. The curtains are in 3-4 pieces and manually lowered with a hand-winch. Ten-inch spacing between the curtain and the back wall allows ventilation when the curtain is completely closed in the winter.

What has worked well
The crushed concrete has provided good drainage within the pens. Wooden bunks have been cost effective, and the tongue-and-groove makes replacement easy. When we scrape, we lock the cattle in the back of the pen, and they are never outside in the elements. The gated fence to the back of the bunk apron facilitates cattle sorting. These buildings are cooler in the summer and drier in cold weather than outside lots.

What has surprised me
The buildings have taken more bedding and management than an outside lot. They also have involved more labor, but the hours are more routine and scheduled.

What would I change
We put a cage around the shared waterers and replaced the sucker rod with square tubing for the cage because it was easier to weld and more solid. We added a third bar in the neck rail above the fenceline bunk to keep cattle out of the bunk. We plan to shorten the chains on the building doors to prevent cattle from tugging on them. And, if building again, we’d extend the awning 1-2 feet further out over the bunk.
A performance and cost of production comparison for three types of feedlot facilities

R. H. Pritchard, Distinguished Professor, Animal Science, South Dakota State University

Introduction

The Opportunities Farm south of Lennox, SD provides a unique facility for evaluating feedlot facility designs on a commercial scale. The 3 pen designs on this site include:

1. Open: W 80 ft by 275 ft deep, earthen pens with large mounds and a concrete feeding apron.
2. Open w Shelter: W 80 ft by 215 ft deep, earthen pens with mounds; shelter is 35 ft deep covering the feed alley, bunk, and 20 ft of pen (with concrete floor).
3. Confined: W 90 ft by 40 ft deep; under a mono-slope building with bunks only on the southern exposure; concrete floor with a bedding pack.

There are 4 adjacent pens of each design. All pens hold 80 head, have 80 ft of bunk space, and have similarly sized water fountains. Total capacity of the feedlot is 960 head.

To evaluate the influence of facilities on cattle performance individual animals from incoming Lots were randomly assigned to one pen of each design. These 3 contemporary pens were fed to harvest weight and closed out on a common date. This comparison was replicated 28 times over a period of 7 years involving over 6000 yearling steers and heifers.

Cattle performance

The Open design resulted in lower (P<0.01) ADG and higher (P<0.01) feed/gain (F/G) than the other two designs at closeout (Table 1). There were no differences in cattle performance between the Open w Shelter and Confined systems. The magnitude of performance differences between the systems was less than is often discussed in testimonials. It is important to recognize that the Open pens were constructed with large mounds and extensive packing, and are well drained. Mound height and pen slopes are greater than those found in many planning service recommendations.

The impact of season was evaluated by comparing closeouts on a quarterly basis. Quarters were assigned as the quarter in which the Lot of 3 contemporary pens was marketed. There were 6 or 8 closeout replications available for each quarter of the year. Cattle performed similarly in all 3 pen designs during quarters 2, 3, and 4. Virtually all of the cumulative data set advantage observed for the Open w Shelter and Confined designs is attributable to closeouts occurring during the first quarter of the year (Jan-Mar).

Table 1. A 28-lot comparison of pen design on yearling cattle performance.

<table>
<thead>
<tr>
<th></th>
<th>Open</th>
<th>Open w Shelter</th>
<th>Confined</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BW Initial, lb</td>
<td>805</td>
<td>804</td>
<td>805</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW Final, lb</td>
<td>1365</td>
<td>1382</td>
<td>1377</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADG, lb</td>
<td>3.53a</td>
<td>3.65b</td>
<td>3.62b</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DMI, lb</td>
<td>24.5</td>
<td>24.5</td>
<td>24.3</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F/G</td>
<td>7.01a</td>
<td>6.76b</td>
<td>6.74b</td>
<td>0.003</td>
</tr>
</tbody>
</table>

*a,b* means without common superscripts differ (P<0.05)

Quality and Yield Grade distributions were tracked for 8 Lots of yearling steers and heifers representing >1600 head. Average marbling scores were similar but there was a 5% point increase (P<0.05) in the frequency of Select carcasses if cattle were fed in the Open pens. There were no other notable differences in carcass qualities.
Health records were analyzed for 18 Lot comparisons involving > 4000 head. Pull rates were higher in the Open pens (6.4%) than in the Open w Shelter (2.3%) or Confined (2.2%) designs. Mortality rates were 0.71%, 0.64%, and 0.28% for the Open, Open w Shelter, and Confined designs, respectively.

**Economic efficiency**

Effectiveness of pen designs is a balance of production efficiencies and cost to own/operate the facility. To capture operating cost differences a daily log of activity was recorded continuously for a 3 y period. Activities logged included man hours spent in each system, tachometer hours for equipment used, and the amount of bedding used. Cost of ownership was based on actual facility construction costs (circa 2004) corrected for inflation to a 2010 price. Land was valued at $4680/ac. The land cost was annualized over 20 y and facilities were depreciated over 20 y. Bedding was priced at $35/bale. Published custom rates (2010) were assigned for equipment use. The non-feed costs calculated are not total non-feed costs. It was assumed that the costs to produce and deliver feed to the cattle and for processing cattle were similar regardless of the facility design. Therefore those expenses are not included in the non-feed costs analyzed.

Daily costs were matched with the 28 Lot closeout performance means to calculate the fixed and variable non-feed costs of gain (Table 2). Fixed costs were greatest for the Open w Shelter pens because of the costs to build the shelter and to develop a runoff containment system. Fixed costs were lowest for the Open system. When daily fixed costs were prorated to actual gains in each system, the overall average was $2.82/cwt gain and did not differ (P>0.10) between systems.

Table 2. A partial accounting of fixed and non-feed variable costs by pen design.

<table>
<thead>
<tr>
<th></th>
<th>Open</th>
<th>Open w Shelter</th>
<th>Confined</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs, $/cwt gain</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td>2.36</td>
<td>3.19</td>
<td>2.90</td>
</tr>
<tr>
<td>Variable non-feed</td>
<td>3.55a</td>
<td>4.12a</td>
<td>9.12b</td>
</tr>
<tr>
<td>Total</td>
<td>5.91a</td>
<td>7.31b</td>
<td>12.02b</td>
</tr>
<tr>
<td><strong>Change from Open</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost, $/cwt gain</td>
<td>--</td>
<td>(1.40)</td>
<td>(6.11)</td>
</tr>
<tr>
<td>F/G</td>
<td>--</td>
<td>(0.25)</td>
<td>(0.27)</td>
</tr>
<tr>
<td>Breakeven Diet Cost, $/T</td>
<td>122</td>
<td>489</td>
<td></td>
</tr>
</tbody>
</table>

*a,b,c means without common superscripts differ (P<0.05)*

The variable non-feed costs were much higher (P<0.05) for the Confined design than for the other two designs. Most of this was attributable to the greater cost for bedding and for managing of the bedding pack and manure.

The higher price of these non-feed costs/cwt gain has to be offset by improved feed cost/cwt gain i.e. improvements in F/G. Using the 28 Lot mean for F/G we can calculate the price of feed at which the observed differences in F/G offset the non-feed costs of production. The Open w Shelter provided enough improvement in F/G over the Open design to reach this offset in costs was reached when dry feed costs were $122/T (Table 2). In other words, when the price of feed exceeds $122/T, it is more profitable to feed cattle in the Open w Shelter designed pens. Doing this same comparison for the Confined system, the offset price for feed became $489/T. One calculation we were unable to make is the difference in value of manure generated in each system. For the Confined design to become cost competitive it will be necessary to gain a substantial offset from manure value.

**Summary**

Facility designs affect the performance, health and carcass traits of cattle. Open w Shelter and Confined designs hold advantages over Open designs and most of this difference occurs when cattle are fed during the period of October
through March. While the Open w Shelter design is the most expensive to build, the upfront costs of construction are much less than the ongoing operating costs of the Confined design. For this region the most cost effective feedlot pen design is the Open w Shelter design.

**Acknowledgements**

These data have been compiled by several individuals over nearly 10 years. Important contributors include Matt Loewe, manager Opportunities Farm, along with faculty Simone Holt, Erik Loe, Ben Holland, and Duane Wulf, and graduate students Tanner Machado and John Mrozinski.
Cattle performance in hoop barns
Dan Loy, professor, Animal Science, Iowa State University; Shawn Shouse, Extension Ag Engineer, Iowa State University

Introduction
Deep bedded housing has become an increasingly popular design for cattle feeding facilities in recent years. Confined housing reduces the need for runoff control by protecting the pen surface from direct exposure to rainfall. Evidence from feedlot closeouts indicate that cattle performance may be improved in these facilities compared to open lots (Pastoor et al., 2012). Hoop buildings are a lower cost alternative for deep bedded housing. Honeyman et al. (2008) estimated the construction costs to be approximately $370 per head capacity at the time. Of course several factors could change this estimate.

Three year performance comparison
Six feeding trials were conducted between 2005 and 2008 at the Iowa State University Armstrong Research farm to compare cattle performance in a bedded hoop-barn system with cattle fed in an open lot with shelter. A 50 X 120 foot hoop barn was constructed at the farm in the fall of 2004. The building housed 120 head per turn in three pens. The performance of cattle fed in this facility was compared to semi-confine ment facility. This facility provided 125 square feet of well-mounded open lot space along with 25 square feet of paved lot under roof, including a covered feedbunk and drive-through feed alley. A detailed description of both facilities has been described by Honeyman et al. (2008). The performance of cattle in this three year study (Honeyman et al., 2010) is summarized in table 1. There were no statistical differences in any of the performance criteria between these two facilities. Cattle fed in the hoop-barn were cleaner with a lower mud score (P<.02) than cattle fed in the semi-confined facility.

Table 1. Performance of finishing steers managed in a bedded hoop-barn or a semi-confined facility (open lot with shelter)\(^1\)

<table>
<thead>
<tr>
<th>Item</th>
<th>Hoop</th>
<th>Feedlot</th>
<th>SEM</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pens</td>
<td>18</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>712</td>
<td>716</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days on feed</td>
<td>103</td>
<td>103</td>
<td>0.9</td>
<td>0.62</td>
</tr>
<tr>
<td>Initial weight, lb.</td>
<td>904</td>
<td>905</td>
<td>11</td>
<td>0.94</td>
</tr>
<tr>
<td>Final weight, lb.</td>
<td>1311</td>
<td>1350</td>
<td>11</td>
<td>0.32</td>
</tr>
<tr>
<td>ADG, lb.</td>
<td>4.0</td>
<td>4.1</td>
<td>0.6</td>
<td>0.19</td>
</tr>
<tr>
<td>DMI, lb</td>
<td>27.5</td>
<td>27.5</td>
<td>0.3</td>
<td>0.98</td>
</tr>
<tr>
<td>Feed/gain (DM)</td>
<td>6.9</td>
<td>6.7</td>
<td>0.1</td>
<td>0.17</td>
</tr>
<tr>
<td>Mud score(^2)</td>
<td>1.9</td>
<td>2.2</td>
<td>0.1</td>
<td>0.02</td>
</tr>
</tbody>
</table>

\(^1\) Honeyman et al. (2010)
\(^2\) 1=Clean, 5=Dirty.
Table 2 compares the carcass characteristics of the cattle in this study. There were no differences in any of the carcass parameters measured between cattle fed in the two facilities.

**Table 2.** Carcass characteristics of finishing steers managed in a bedded hoop-barn or a semi-confined facility (open lot with shelter)

<table>
<thead>
<tr>
<th>Item</th>
<th>Hoop</th>
<th>Feedlot</th>
<th>SEM</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot carcass wt., lb.</td>
<td>813</td>
<td>818</td>
<td>6</td>
<td>0.59</td>
</tr>
<tr>
<td>Dressing %</td>
<td>62.0</td>
<td>60.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat thickness, in.</td>
<td>0.43</td>
<td>0.43</td>
<td>0.01</td>
<td>0.92</td>
</tr>
<tr>
<td>KPH fat, %</td>
<td>2.4</td>
<td>2.4</td>
<td>0.01</td>
<td>0.99</td>
</tr>
<tr>
<td>Ribeye area, sq. in.</td>
<td>13.2</td>
<td>13.1</td>
<td>0.1</td>
<td>0.38</td>
</tr>
<tr>
<td>Marbling score(^2)</td>
<td>1031</td>
<td>1027</td>
<td>0.5</td>
<td>0.61</td>
</tr>
<tr>
<td>% Choice and up</td>
<td>75.4</td>
<td>74.3</td>
<td>2.7</td>
<td>0.78</td>
</tr>
<tr>
<td>% YG 1 and 2</td>
<td>63.4</td>
<td>62.9</td>
<td>2.7</td>
<td>0.94</td>
</tr>
</tbody>
</table>

\(^1\) Honeyman et al. (2010)

\(^2\) Marbling score scale: slight = 900, small = 1,000, modest = 1,100.

**Effects of pen density on performance of cattle fed in bedded hoop barns**

The previous study was conducted with a pen density of 50 square feet per head. In an effort to reduce construction and operating costs on a per head basis, feeders have been reducing the space allowance. A study was conducted utilizing 4 trials over the period 2008 to 2011 to evaluate the effects of pen density in a hoop barn on cattle performance and carcass characteristics (Honeyman et al., 2012). This was also conducted at the Armstrong Research farm near Lewis, Iowa. The densities compared in this trial were 40, 45 and 50 square feet per head. The results of this experiment are shown in Table 3. There were no statistical differences in performance or carcass characteristics across the pen densities measured in this study. However a numerical trend in ADG and Feed/gain would suggest that a reduction in performance with increased stocking density may exist but was not within the power of this study to measure. Our conclusion is that space allowance less than 50 square feet per head is feasible but some reduction in performance cannot be ruled out.
Table 3. Performance and carcass characteristics of steers fed at various stocking densities in bedded hoop barns

<table>
<thead>
<tr>
<th>Item</th>
<th>Stocking Density (square feet per head)</th>
<th>SEM</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>Pens</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Head</td>
<td>160</td>
<td>180</td>
<td>200</td>
</tr>
<tr>
<td>Days on feed</td>
<td>115</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Initial weight, lb.</td>
<td>887</td>
<td>882</td>
<td>886</td>
</tr>
<tr>
<td>Final weight, lb.</td>
<td>1304</td>
<td>1285</td>
<td>1276</td>
</tr>
<tr>
<td>ADG, lb.</td>
<td>3.81</td>
<td>3.68</td>
<td>3.56</td>
</tr>
<tr>
<td>DMI, lb.</td>
<td>27.6</td>
<td>27.4</td>
<td>27.4</td>
</tr>
<tr>
<td>Feed/gain (DM)</td>
<td>7.3</td>
<td>7.48</td>
<td>7.79</td>
</tr>
<tr>
<td>Mud score</td>
<td>2.14</td>
<td>1.94</td>
<td>2.3</td>
</tr>
<tr>
<td>Hot carcass wt., lb.</td>
<td>806</td>
<td>799</td>
<td>794</td>
</tr>
<tr>
<td>Dressing %</td>
<td>61.8</td>
<td>62.2</td>
<td>62.3</td>
</tr>
<tr>
<td>Fat thickness, in.</td>
<td>.45</td>
<td>.45</td>
<td>.44</td>
</tr>
<tr>
<td>KPH fat, %</td>
<td>2.15</td>
<td>2.16</td>
<td>2.08</td>
</tr>
<tr>
<td>Ribeye area, sq. in.</td>
<td>12.87</td>
<td>12.79</td>
<td>13.01</td>
</tr>
<tr>
<td>Marbling score3</td>
<td>1030</td>
<td>1036</td>
<td>1025</td>
</tr>
<tr>
<td>% Choice and up</td>
<td>68</td>
<td>71</td>
<td>63</td>
</tr>
<tr>
<td>% YG 1 and 2</td>
<td>46</td>
<td>49</td>
<td>57</td>
</tr>
</tbody>
</table>

1 Honeyman et al. (2012)
2 1=Clean, 5=Dirty.
3 Marbling score scale: slight = 900, small = 1,000, modest = 1,100.

References


Evaluation of rubber mats over concrete slats in cattle confinement facilities
Russ Euken, Livestock Field Specialist, Iowa State University Extension and Outreach

Introduction

Confinement housing of beef cattle is becoming more common due to increased environmental concerns and the desire to capture potential efficiencies in cattle performance and manure value. Deep pit facilities with concrete slatted floors were first being used in the upper Midwest in the 1970's and in the last five years more of these facilities are being constructed as is the case with bedded confinement facilities. Potential disadvantages of concrete slats may be the effect on feet and legs and performance consequences for cattle being on concrete slats for extended periods of time.

Rubber mats manufactured to be installed on top of the concrete slats are being promoted to overcome these issues. The mats have been used in European countries for several years and lately producers in the United States with concrete slat barns have installed rubber mats. Anecdotal reports from producers report increased performance and improved wellbeing of cattle when rubber mats are used on top of slats. A few European studies have reported on welfare and performance of beef cattle on rubber mats or concrete slats. In addition, there has been some research work on using the rubber mats in the United States.

Research

A research project reported by the Agricultural Research Institute in Northern Ireland in (Lowe et al., Animal Welfare 2001) compared concrete slats, mats covering slats, solid concrete floor with straw bedding or wood shavings. One project compared 1179 lb steer preference for the flooring types by measuring the time over a 72 hour period spent in pens with the various flooring types and their behavior while in those pens. Cattle spent the most time on the solid concrete with straw bedding followed by solid concrete with wood shavings, then the rubber mat pens and finally concrete slat pens. In addition the time spent lying or standing on straw bedded pens was higher than the slat pens. Another trial comparing rubber mats or rubber strips on concrete slats indicated no preference for either flooring type.

In another trial (Lowe et al., Livestock Production Science 2001) at the same location, comparisons of floor type effects on performance cleanliness, carcass composition and meat quality were made. Floor types were concrete slats, rubber mats on top of concrete slats and solid concrete floor bedded with straw. In a second trial, rubber strips on top of the slots was included as a floor type. Five continental cross steers weighing 990 lbs in trial 1 and 930 lbs in trial 2 were assigned per pen with five pens of each floor type. 160 sq. ft. per head were allocated on the slatted floor pens and 285 sq. ft. per head was allowed on the solid floor pens. Cattle were on feed for 140 days in trial 1 and 142 days in trial 2.

There was no significant effect on feed intake or gain in either year as shown in table 1 and 2. The same was true for carcass composition and meat quality.

Table 1 - The effect of floor type on feed intake and animal performance in year one.
Lowe et al., Livestock Production Science, 2001

<table>
<thead>
<tr>
<th>Trait</th>
<th>Concrete slats</th>
<th>Rubber mat</th>
<th>Solid concrete with straw bedding</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed intake (kg/hd/day)</td>
<td>9.2</td>
<td>9.4</td>
<td>8.9</td>
<td>.14</td>
</tr>
<tr>
<td>Gain (kg/day)</td>
<td>1.03</td>
<td>1.11</td>
<td>1.06</td>
<td>.033</td>
</tr>
</tbody>
</table>
Table 2 - The effect of floor type on feed intake and animal performance in year two.
Lowe et al., Livestock Production Science, 2001

<table>
<thead>
<tr>
<th>Trait</th>
<th>Concrete slats</th>
<th>Rubber mat</th>
<th>Rubber strips</th>
<th>Solid concrete with straw bedding</th>
<th>S.E.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed intake (kg/hd/day)</td>
<td>8.8</td>
<td>8.8</td>
<td>9.0</td>
<td>8.9</td>
<td>.18</td>
</tr>
<tr>
<td>Gain (kg/day)</td>
<td>1.10</td>
<td>1.16</td>
<td>1.16</td>
<td>1.17</td>
<td>.052</td>
</tr>
</tbody>
</table>

The Grange Research Center in Ireland in 2006 and 2007 (Earley B. et al.) reported on research with rubber mat flooring on top of concrete slats, concrete slats with wood shavings on top, and concrete slats. In one trial, 4 pens with nine, 1100 lb. steers at 29 sq ft. per head were on feed for 148 days during which feed intake, performance, hoof lesions, and behavior were evaluated. There were beef breed and a small number of Holstein Friesian cattle in this trial. In table 3 the results are reported. No differences were found on feed intake and performance across all cattle types. Hoof lesions were higher for cattle on mats or wood chips but no laminitis was observed in any of the cattle.

Table 3. Performance and welfare characteristics of finishing beef steers values are expressed as mean ± s.e.m.
Earley B. Grange et al., Research Center

<table>
<thead>
<tr>
<th>Trait</th>
<th>Concrete slats</th>
<th>Mat 1</th>
<th>Mat 2</th>
<th>Wood chips over slats</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM intake (kg/day)</td>
<td>9.8 ± 0.30</td>
<td>9.9 ± 0.06</td>
<td>9.8 ± 0.17</td>
<td>10.1 ± 0.09</td>
</tr>
<tr>
<td>Gain (kg/hd/day)</td>
<td>1.160 ± .050</td>
<td>1.140 ± .050</td>
<td>1.110 ± .040</td>
<td>1.180 ± .050</td>
</tr>
<tr>
<td>Feed efficiency (DMI/ live wt. gain kg)</td>
<td>8.6 ± 0.38</td>
<td>8.8 ± 0.38</td>
<td>8.8 ± 0.15</td>
<td>8.6 ± 0.26</td>
</tr>
<tr>
<td>Lying %</td>
<td>49.6± 0.38</td>
<td>51.2± 0.39</td>
<td>51.0 ± 0.38</td>
<td>49.5± 0.39</td>
</tr>
<tr>
<td>Standing %</td>
<td>50.1± 0.38</td>
<td>48.3± 0.39</td>
<td>48.8 ± 0.39</td>
<td>50.2± 0.39</td>
</tr>
<tr>
<td>Hoof lesions(^1)</td>
<td>40.9± 2.91</td>
<td>65.8± 2.92</td>
<td>71.9 ± 2.92</td>
<td>55.6± 2.92</td>
</tr>
<tr>
<td>White line lesions(^1)</td>
<td>22.5± 2.29</td>
<td>35.3± 2.19</td>
<td>41.0 ± 2.22</td>
<td>33.8± 2.22</td>
</tr>
<tr>
<td>Dirt scores(^2)</td>
<td>31.9± 1.20</td>
<td>32.0± 1.22</td>
<td>31.8± 1.20</td>
<td>49.4± 1.20</td>
</tr>
</tbody>
</table>

\(^{a,b,c}\) Within row, means with the same superscripts are not significantly different (P ≥ 0.05).

\(^1\) The total number of lesions/animal at the end of the study; 2Dirt scores; sum of 16 body parts each on a cleanliness scale of 1 (clean) to 5 (dirty).

In another trial, 3 types of rubber mats over slats, concrete slats and outside solid concrete pens (OWP) were compared. 1125 lb steers were on feed for 153 days. The slat pens had 29 sq ft. per head and the outside pens had 129 sq ft. per head. The outside pens had higher intake and higher live weight gain than the other treatments. One mat treatment had better feed conversion than the slats. All the mat treatments and outside pens had higher dressing percent than the concrete slat treatment. The mat treatments all had more hoof lesions as compared to the concrete slats or outside pens.

There was no difference in animal performance and dirt scores among the mat treatments. Although carcass weight was greater in animals housed on OWP’s and Mat 1 than those on slats it was not significantly different from Mat 2 or 3. There were a greater number of lesions on the hooves of animals housed on mats compared with slats and OWP treatments.
Table 4. Intake, performance, slaughter traits, hoof condition and dirt scores of finishing beef steers on slats, slats plus mats and out-wintering pads (Mean ± s.e.m.), Earley B. Grange Research Center

<table>
<thead>
<tr>
<th>Trait</th>
<th>Concrete slats</th>
<th>Mat 1</th>
<th>Mat 2</th>
<th>Mat 3</th>
<th>Outside pads</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM intake (kg/day)</td>
<td>9.2 ± 0.05</td>
<td>9.5 ± 0.29</td>
<td>9.4 ± 0.06</td>
<td>9.2 ± 0.07</td>
<td>10.1 ± 0.07</td>
</tr>
<tr>
<td>Gain (kg/hd/day)</td>
<td>1.016 ab ± .047</td>
<td>1.072 ab ± .053</td>
<td>0.964 a ± .051</td>
<td>0.969 a ± .042</td>
<td>1.112 b ± .059</td>
</tr>
<tr>
<td>Feed efficiency (DM/carcass gain kg)</td>
<td>15.4 b ± 0.4</td>
<td>13.5 a ± 0.6</td>
<td>14.7 ab ± 0.4</td>
<td>14.3 ab ± 0.7</td>
<td>14.0 ab ± 0.4</td>
</tr>
<tr>
<td>Hoof lesions</td>
<td>22 a ± 1.8</td>
<td>38 b ± 2.4</td>
<td>37 b ± 2.5</td>
<td>33 b ± 1.4</td>
<td>20 a ± 2.3</td>
</tr>
<tr>
<td>Dirt scores</td>
<td>39.4 ± 0.69</td>
<td>37.6 ± 0.76</td>
<td>39.3 ± 0.74</td>
<td>39.3 ± 0.71</td>
<td>37.4 ± 0.75</td>
</tr>
</tbody>
</table>

abc Within row, means with the same superscripts are not significantly different (P ≥ 0.05).
1 The total number of lesions/animal at the end of the study
2 Dirt scores; sum of 16 body parts each on a cleanliness scale of 1 (clean) to 5 (dirty).

Purdue University researchers (Elmore, M. R. et al.) at the 2009 American Society of Animal Science meetings reported on a trial comparing cattle performance and feet and leg issues on rubber mats (solid or slatted rubber mats) over slats to concrete slats in small pens of 6 head per pen for an 84 day period. They did not find any performance differences but knee and hock swelling were less for cattle on rubber mats versus concrete. The number of times cattle changed posture which was used as an indicator of floor traction and comfort was higher for the cattle on slatted rubber mats. The floor surface of the rubber mats was dirtier than the concrete slats but cattle cleanliness between rubber mats and concrete slats was the same.

University of Wisconsin researchers (Plaster, S et al. and Wagner, D. et al.) reported on two trials at the 2011 Fifth International Conference on Assessment of Animal Welfare at the farm level and the 2012 Beef Cattle Welfare symposium. The trials compared cattle preferences, knee joint circumference, and performance of cattle on concrete slats or rubber mats laid over the slats.

Four pens 19.7 feet wide by 11.5 ft. deep with 4 head of cattle were used with a 56 sq. ft. per head pen space. Two pens were covered with rubber mats and two pens had concrete waffle slats. In the first part of one study 8 cattle had access to both the rubber mats and concrete slats. The cattle were observed to be on the rubber mats 78 % of the time during an 18 day period. When the pens were split the cattle on rubber mats spent less time lying down, had increased feed intake, improved gain, and better feed efficiency than cattle on concrete slats in two different trials. Cattle were started on feed at 820 lbs. or 640 lbs. and on feed for 29 or 24 days in the two trials. Knee swelling was less for cattle on mats. Cattle cleanliness was also evaluated during the feeding period and found to be the same for mats or slats.

Table 5. Trial 1 Comparison of concrete slats and rubber mats University of Wisconsin (unpublished data)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Concrete slat</th>
<th>Rubber mat</th>
<th>SEM</th>
<th>P=</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lying time in minutes per bout</td>
<td>61</td>
<td>49.9</td>
<td>1.4</td>
<td>.03</td>
</tr>
<tr>
<td>Feed intake</td>
<td>20.83</td>
<td>21.43</td>
<td>.28</td>
<td>.07</td>
</tr>
<tr>
<td>Average daily gain</td>
<td>3.59</td>
<td>4.34</td>
<td>.22</td>
<td>.03</td>
</tr>
<tr>
<td>Feed DM/lb. gain</td>
<td>5.82</td>
<td>4.95</td>
<td>.13</td>
<td>.04</td>
</tr>
</tbody>
</table>
Table 6. Trial 2 Comparison of concrete slats and rubber mats University of Wisconsin (unpublished data)

<table>
<thead>
<tr>
<th>Trait</th>
<th>Concrete slat</th>
<th>Rubber mat</th>
<th>SEM</th>
<th>P=</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in knee circumference (cm)</td>
<td>2.55</td>
<td>1.7</td>
<td>.19</td>
<td>.03</td>
</tr>
<tr>
<td>Feed intake</td>
<td>15.83</td>
<td>16.14</td>
<td>.44</td>
<td>.68</td>
</tr>
<tr>
<td>Average daily gain</td>
<td>2.73</td>
<td>3.31</td>
<td>.13</td>
<td>.10</td>
</tr>
<tr>
<td>Feed DM/lb. gain</td>
<td>5.83</td>
<td>4.88</td>
<td>.12</td>
<td>.03</td>
</tr>
</tbody>
</table>

In the summer of 2011 Summit Farms, Alden, Iowa was building two new deep pit beef confinement buildings and considering placing rubber mats over the slats in some of the pens. Iowa State University Extension and the Iowa Beef Center offered to help conduct a study and Summit Farms installed three different types of mats in 9 pens with 3 pens of concrete slats with no mat. Each pen is approximately 80 ft. by 40 ft. and is designed to hold 140 head at 22.5 sq. ft. per head with 6.75 in bunk space per head. Comparisons of cattle performance, slips and falls, pulls, behavior, and death loss are being made.

Three replications were on fed from October 2011 to March 2012. Due to difficulty sourcing cattle only one replicate was fed from March of 2012 to Aug of 2012 and one more was fed from May of 2012 to Sept of 2012. So far, 5 replicates or 20 pens of cattle over three different feeding periods are included in the analysis. All of the cattle in the 5 replications were heifers that were on feed from 130 – 164 days.

The only information being reported in Table 7 (Euken et al., 2013 ISU Animal Science Animal Industry report) is the daily gain, feed efficiency, and feed intake information from the five replications to date. Additional close out information will be added to the analysis when available. The data on slips and falls and cattle behavior has not been summarized or analyzed at this point in time.

For the first 3 replications cattle pulled for feet and leg issues were recorded. Over the 3 pens fed on concrete slats mechanical pulls averaged 5.9% ±2.9% standard error of the cattle during the feeding period. On 9 pens fed on rubber mats the average number of pulls was 1.8% ±.6% standard error. There was a wide variation in number of pulls per pen on both concrete slats and rubber mats. The effect of pulling on performance or marketing of those individual animals was not recorded. Death loss on the 5 pens of cattle fed on concrete averaged 1.25% ±.55% standard error and for the 15 pens fed on rubber mats the death loss was .74% ±.21% standard error. From data available cause of death was not able to be determined.

In table 7, all mat types are combined and compared to concrete slats. There were no statistical differences between the concrete slats or rubber mat in this analysis.

Table 7. Comparison of feed intake, daily gain, and feed efficiency between rubber mat flooring and concrete slats (Mean ± S. E.) Summit Farms and Iowa State University

<table>
<thead>
<tr>
<th>Trait</th>
<th>Rubber Mats</th>
<th>Concrete Slats</th>
<th>Probability &gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily feed intake (lbs feed/hd/day)</td>
<td>20.79±.48</td>
<td>20.19±.83</td>
<td>0.5399</td>
</tr>
<tr>
<td>Daily Gain (lbs/hd/day)</td>
<td>3.08±.13</td>
<td>2.86±.22</td>
<td>0.4132</td>
</tr>
<tr>
<td>Feed Efficiency (lbs feed/lb gain)</td>
<td>6.76±.17</td>
<td>7.04±.30</td>
<td>0.4214</td>
</tr>
</tbody>
</table>

Summary

Research thus far has been inconclusive if cattle gain or feed efficiency is changed on rubber mats versus concrete slats. From two studies it does appear that rubber mats are preferred by cattle versus concrete slats but one of those studies would indicate cattle prefer straw bedding on solid concrete over rubber mats and concrete slats. There does to be appear to be less joint swelling and possibly improvement in animal movement and behavior on rubber mats as compare to concrete slats. A trend toward less pulls for feet and leg issues has been observed, but needs to be analyzed further. If rubber mats can help prevent injuries that limit individual cattle performance or marketability that would be a benefit and contribute to economic gain.
The research trials have mainly used small numbers of animals per pen and it is not known if the results from these data would be the same with more animals in larger pens. Other questions related to the use of mats include their effect with longer feeding periods, what is optimum cattle density with mats, and does the whole pen area need to be covered with a rubber mat to gain any potential improvement.

References

1Walsh Fellow, UCD School of Agriculture, Food Science and Veterinary Medicine, Belfield, Dublin
2Supervisor, UCD School of Agriculture, Food Science and Veterinary Medicine, Belfield, Dublin


aResearch Institute of Northern Ireland, Large Park, Hillsborough, Co. Down, BT26 6DR, Northern Ireland, UK
bDepartment of Agriculture for Northern Ireland, Belfast, Northern Ireland, UK
cThe Queen’s University of Belfast, Belfast, Northern Ireland, UK
