Deep bed swine production systems are based upon the concept of providing the animal the ability to select and modify its own microenvironment through the bedding material. There are currently a variety of building designs, bedding schemes and management styles being utilized in the swine industry.

1 Deep bed production opportunities

Deep bed swine finishing offers several opportunities compared to traditional intensive confinement finishing systems. These opportunities are based upon five basic factors: animal performance, animal welfare, environmental issues, marketing options, and initial facility investment:

1. Animal Performance: Deep bed systems, if properly designed and managed, have demonstrated equal if not improved animal performance compared to traditional production methods.

2. Animal Welfare: Animals within deep bed production demonstrate an increased level of play activity and decreased level of anti-social behavior compared to animals reared in confinement. The low incidence of anti-social behaviors indicate that deep bed reared pigs are challenged with fewer stressors, and have a higher level of animal welfare. Properly designed deep bed systems meet the five basic requirements for animal physical and mental well-being, as determined by the RSPCA.

3. Environmental Issues: The deep bed system can be designed to meet or exceed all criteria for a “sustainable” production system. It is commonly more accepted by the general public, due to the solid form of manure and the reduction of odor release. With an active composting process in the bedding pack a valuable soil amendment and fertilizer are provided after removal.

4. Marketing Options: Specialized-marketing systems can be developed for pork from deep bed systems. Currently three major opportunities exist for the development of specialized marketing systems; these include sustainable pork production, animal welfare, and meat quality.

5. Initial Facility Investment: Deep bed facilities require a significant reduction in initial investment compared to traditional confinement systems.
2 Traditional hoop structures for deep bed swine finishing

The original and most common form of deep bed swine finishing facilities are the hoop style production units. The hoop style unit is a quonset-shaped structure, with a woven UV resistant, polypropylene skin pulled over a tubular steel arch frame which is secured to a wooden or concrete pony wall (1.2–1.8 m). These facilities are cold (non-heated, low energy use) structures and animals maintain a proper microenvironment by burrowing into the deep bedding provided. The units have been historically designed to accommodate 180-200 animals (traditional size 9.1x22m), based on 1.1 m² per pig space allowance (0.84 bedded, 0.27 concrete area). Feeders (dry) and waterers (energy free) are located on a raised concrete pad, which extends approximately 1/3 of the building length. Bedding and animal waste is removed from the facility once the group of animals are sold for processing.

The system is based upon natural tunnel ventilation, air enters through the sidewall inlets and is forced out through the endwall openings. Hoop buildings utilized for swine finishing are oriented to intercept the prevailing warm season wind patterns, through the end with the concrete pad. Mister systems are required to maintain animal comfort and performance as far north as the upper Midwestern United States.

The main limitations to traditional style hoop production are the small group sizes (required for ventilation techniques), the decrease in feed efficiency during cold periods, the lack of dunging/bedding area control and the management capabilities required for success.

Due to these limitations, several manufacturers have designed larger and more elaborate hoop buildings. Sizes are now available up to 15.24x36.5 m, designed to accommodate 500 head. However, several problems have developed with these larger buildings including lack of ventilation capacity, increased animal aggression due to the single feeding area, and bedding management issues. These problems have led to the inclusion of ridge vents, circulation fans, dual feed pads, heaters, etc. but with mixed results. This discussion is included to demonstrate the pitfall of altering building design without considering the overall effects on the production system. To optimize animal performance and welfare while minimizing bedding usage and management, all of the building systems must be designed and integrated to meet the specialized requirements of the deep bed production system.

3 Large pen deep bed swine production

The large pen deep bed system is a production model which combines the advantages of straw based production with the technological advances of the confinement system. This results in a environmentally controlled naturally cross-ventilated barn (including heating and misters), which utilizes a multiple station wet/dry feeding system to maximize production, minimize bedding usage and avoid the limitations of the hoop system.

The fastest growing portion of the deep bed segment of the swine industry is through building renovations, this is due to the minimal renovation investment required, the short conversion time and overall animal performance. The majority of renovation
projects have been poultry facilities (turkey and chicken), however confinement cattle finishing buildings, calf housing facilities and older confinement swine finishing units have also been converted.

Designs have ranged to accommodate from 500 to over 2800 head, depending on building size, animal flow, pen arrangement and stocking density. Many times compromises are required with renovation projects due to the original building design (such as using circulation fans on a wider building or buildings with limited sidewall ventilation, smaller cleanout equipment due to barn height, etc.), however these ultimately will affect production and operating cost and must be considered carefully. Each building must be evaluated individually for quality, structural integrity, and adaptability prior to renovation. Renovation cost vary considerably depending upon the quality and design of the facility, cost have ranged from US $15–85.

The success of these renovated facilities has demonstrated the potential of the large pen deep bed swine production system. Recently new facilities have been designed and constructed for deep bed swine finishing. By properly designing and constructing a facility for deep bed swine production producers hope to improve animal performance, ease animal management requirements, decrease bedding usage and management, and better utilize the manure produced from the facilities for its nutrient value. Construction cost of new facilities have varied considerably, the reported range has been US $80–125.

3.1 Animal density

The current recommendation for large pen deep bed facilities is 1.4 m$^2$ per pig, but range from 1.15 to 1.5 m$^2$. These recommendations are based on animal performance, bedding usage and bedding management requirements. Commercial research indicates that animal performance is not significantly different from 1.15 to 1.5 m$^2$, but as area per pig decreases bedding usage and management requirements increase significantly.

3.2 Pen layout

The initial renovations of buildings for deep bed swine production divided the building into pens (usually ranging from 300–500 head) either arranged crossways, lengthways or a combination thereof. This division of the building into pens creates a multitude of problems within the deep bed production system. If divided crossways, the middle pens are very difficult to bed, and a dunging problems occur along the fenceline. Whereas dividing the building down the midline results in significant fenceline dunging, which eventually results in an inverted dunging pattern.

Due to the importance of bedding management and the difficulties caused by pen divisions, the majority of the pen dividers have been removed and more recent building renovations/construction have utilized a single pen design (normal range from 1000–1500+/-head). Industry data indicates that the large pen design has no negative consequences on animal welfare or performance. In fact, the majority of industry reports indicate improved animal welfare/performance due to superior bedding pack quality with its corresponding improvement in the building environment.
3.3 Pen space utilization

Research and field data have indicated that encouraging distinct lying and dunging patterns are beneficial in large pen deep bed finishing facilities. The data indicates that a 60% lying area along the midline of the building, a 15% transition area, and 25% dunging area along the sidewall eases bedding management, reduces overall bedding usage, improves the building environment and maximizes animal performance/welfare.

3.4 Building design

Ideally a facility should be constructed as clear-span building, this is to allow maximum maneuverability of bedding and cleannout equipment and avoid disruption of a proper lying/dunging pattern. A minimum 3.7 m clearance height within the facility and a minimum 3.1 m sidewall height are necessary to provide adequate facility clearance for bedding/cleannout equipment and to obtain the necessary ventilation capacity. The most common sidewall design is to utilize a short ponywall with an interior mounted hog panel on the top to protect the curtain and bird netting from the animals.

To obtain the necessary ventilation capacity and proper airflow distribution patterns approximately 10–12 m is the recommended building width for naturally ventilated deep bed swine finishing facilities. Wider buildings normally lack the necessary ventilation capacity and therefore require mechanical assistance. However, a minimum building width is required to maintain separate lying, dunging and feeding areas. Extremely narrow buildings do not allow adequate separation distances between these areas and therefore extensive cross contamination of the bedding occurs. Due to specific site location, wind patterns, obstacles, etc. building widths may vary considerably.

3.5 Feed/water system

Hoop buildings rely upon a centralized feeding area located at one end of the building to provide feed and water. Due to the combination of large group sizes, and a large total area for which the pigs can travel, investigate, and explore a centralized feeding/waterer location is not an option for large pen deep bed finishing units.

Several types of feeders/waterers, feeder placement, mounting systems, and feed line locations have been investigated by the industry. Feeders should be selected which are designed for maximum animal welfare and performance, are easy to adjust and operate, do not require an external water source, and are not subject to trough flooding. Higher capacity feeders help limit the number of required feeding stations, thereby limiting the number of obstacles for proper bedding distribution. However, there are functional limits to feeder length and capacity, concerns for increased animal aggression, and effects on surrounding bedding pack quality which must be considered.

The feeder platform must not only allow for a strong and durable feeder attachment, but should provide adequate area for the animal to maintain a natural, comfortable eating posture on a stable and level surface. This will maximize animal performance and feed efficiency while limiting feeder contamination from bedding materials.
4 Bedding management

Bedding is the most single critical determining factor for success or failure in all types of deep bed production systems. It effects animal performance, animal behavior, animal health and the quality of the building environment.

Systems of bedding management for large pen deep bed swine finishing

Currently there are two categories of bedding systems utilized in the US swine industry: the carbon based bedding system (straw, cornstalks, paper, etc.), and the sand based system. The carbon based bedding system is utilized in the vast majority of deep bed production systems, whereas the use of the sand based system is very limited. These two systems are based on different physical, chemical and biological processes.

Carbon based bedding systems

There are currently two bedding management approaches in the US within the category of carbon based bedding systems. The most common is the continuous addition approach which utilizes less bedding for the initial bedding pack, but provides timely additions of bedding to the facility to maintain the proper bedding environment. The quantity of bedding used for each addition is based upon environmental factors (weather, humidity, etc.), quality of the bedding pack, bedding material type and quality, and animal factors (animal size, gender, etc.). The continuous approach provides more control of the building environment, maximizes animal performance, encourages greater composting and reduces pollution concerns, but increases production cost and labor requirements.

The alternative to the continuous addition program is the single addition approach which is characterized by utilizing a large initial volume of bedding prior to pigs entering the facility, with no further additions of bedding material during the growout phase. This limits labor, and reduces overall bedding requirements. However, there are concerns with this system regarding animal welfare, animal performance, air quality within the building and the potential for environmental pollution.

Selection of bedding materials

There are a minimum of ten basic factors which must be considered for selection of bedding materials. These include; absorbency, water retention/evaporation rate, carbon content, carbon availability, structure, structural integrity, effects on animal health (is it carcinogenic, does it cause skin rashes, lesions, blisters, etc.), handling systems, availability of supply, and cost. Table 1 is a partial listing of materials currently utilized for deep bed swine finishing (Hill, 1999).

A bedding management plan can utilize a combination of materials to improve bedding pack characteristics, improve animal performance, reduce availability issues, and reduce cost. These combinations are normally based on combining physical...
characteristics of the bedding material to improve the bedding pack, or scheduling bedding materials to better match the needs of the animal (based on size, gender, etc.)

One of the pitfalls for large pen deep bed swine facilities is that bedding materials are routinely evaluated based only on cost and availability, with little or no consideration for the remaining factors.

**Table 1 — Bedding materials**

<table>
<thead>
<tr>
<th>Bedding Type</th>
<th>Absorbency</th>
<th>C/N Ratio</th>
<th>Structure/Texture</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat straw</td>
<td>210</td>
<td>125</td>
<td>Excellent</td>
<td>Standard for industry</td>
</tr>
<tr>
<td>Oat straw</td>
<td>244</td>
<td>60</td>
<td>Compaction concern</td>
<td>Skin rash</td>
</tr>
<tr>
<td>Corn stalks</td>
<td>Medium*</td>
<td>65</td>
<td>Poor for young pigs*</td>
<td>Dust and mold</td>
</tr>
<tr>
<td>Ground corn cobs</td>
<td>210</td>
<td>90</td>
<td>Compaction problem</td>
<td>Dust</td>
</tr>
<tr>
<td>Whole corn cobs</td>
<td>120</td>
<td>90</td>
<td>Poor–due to large size</td>
<td>leg Injury/leeching</td>
</tr>
<tr>
<td>Soybean stubble/straw</td>
<td>*</td>
<td>*</td>
<td>Intertwines</td>
<td>Puncture wounds to small pigs</td>
</tr>
<tr>
<td>Grass straw</td>
<td>100–200**</td>
<td>15–50**</td>
<td>Compaction and intertwines</td>
<td>Dust and mold</td>
</tr>
<tr>
<td>Recycled paper</td>
<td>**</td>
<td>150</td>
<td>Poor structure–compaction</td>
<td>Dust and handling</td>
</tr>
<tr>
<td>Wood shavings</td>
<td>175</td>
<td>500</td>
<td>Little structure/body</td>
<td>Positive testing for TB</td>
</tr>
<tr>
<td>Rice hulls</td>
<td>171</td>
<td>120</td>
<td>Little structure/body</td>
<td>Compaction and dust</td>
</tr>
<tr>
<td>sand</td>
<td>25</td>
<td>//////////</td>
<td>Muck</td>
<td>Dust and leeching</td>
</tr>
</tbody>
</table>

*Depends on harvesting technique; **Depends on type and variety