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UK University of Kentucky College of Agriculture

Compost-Bedded Pack Barns in Kentucky

Jeffrey M. Bewley, Animal and Food Sciences, and Joseph L. Taraba, Biosystems and Agricultural Engineering

Choosing the environment in which lactating dairy cows will spend the majority of their time is an important decision for dairy producers. This choice has considerable influence on productivity, health, milk quality, reproduction, animal well-being, and farm profitability. Dairy producers should consider the system that will work best for them given their climate, construction and building costs, labor availability, long-term maintenance costs, and return on investment. In Kentucky, dairy cows are often provided access to pasture during mild weather or even throughout the year. While pasture generally allows for excellent cow comfort, bad weather and muddy conditions can make cow cleanliness and milk quality a challenge and result in heat or cold stress. Lactating dairy cows have traditionally been housed in loose-housing bedded pack, tie-stall, or freestall barns. Innovative dairy producers in Virginia and Minnesota have introduced a variation on the loose-housing system. It is generally referred to as a compost-bedded pack barn. Its key component is a large, open resting area, usually bedded with sawdust or dry, fine wood shavings. The compost-bedded pack barn is a relatively new housing system. Very little controlled research has taken place, so most recommendations are based on producer experience. Currently, there are several compost-bedded pack barns in Kentucky, and many more are under construction.

Compost-bedded pack barns can be the primary housing in smaller herds or provide special needs housing in larger herds. Cows can be managed in a single group within the barn or in multiple groups subdivided within the barn. These barns are intensively managed to encourage composting of manure and organic material, unlike more traditional straw-based bedded packs. Composting increases the bedding temperature, which reduces disease-causing microorganisms. It also decreases the bedding moisture by increasing the drying rate. Air is added to the bedded pack twice a day, generally while the cows are being milked, using various types of cultivators. Facility design, ventilation, frequent and deep stirring, and avoidance of overcrowding are the keys to a good working compost-bedded pack barn (Figure 1).

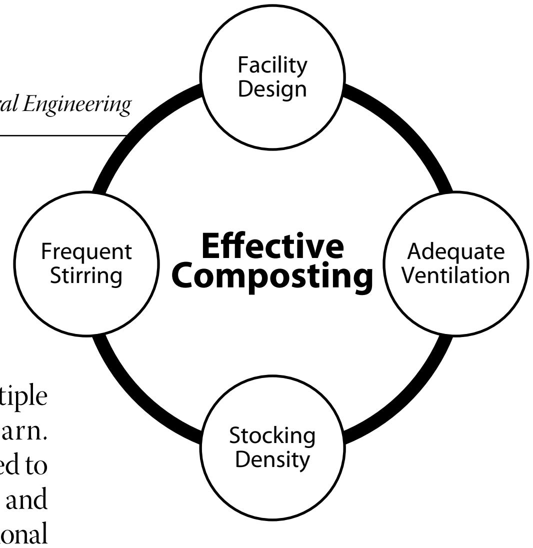


Figure 1. Keys to maintaining a well-managed compost-bedded pack barn.

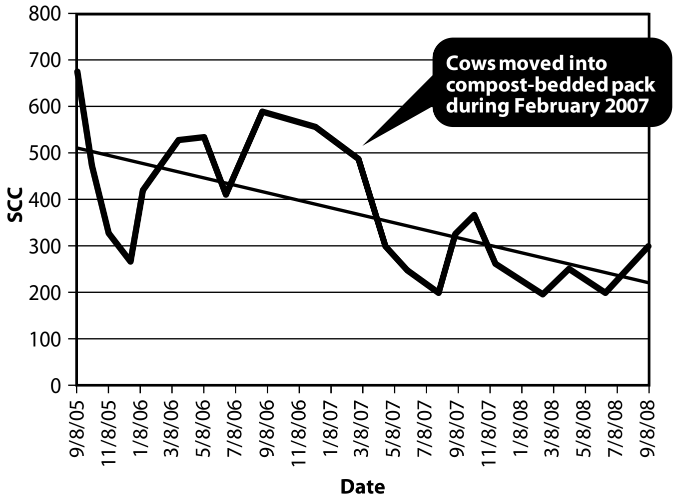
Reported Possible Benefits

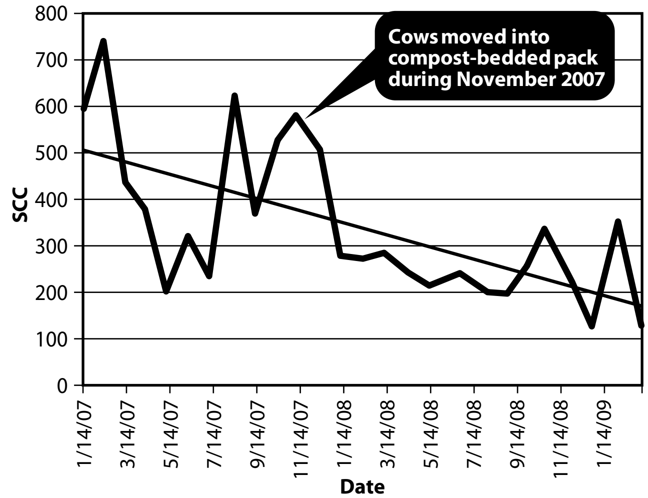
Producers should be cautious about expecting the same benefits that other producers have experienced with compost-bedded pack barns. The dairy is a dynamic environment, which makes it difficult to evaluate the impact of several management changes made simultaneously or how those changes will impact a particular dairy operation. However, here are six potential benefits:

- Most dairy producers build a compost-bedded pack barn to improve cow comfort. Compared to freestalls, cows have more freedom of movement in the compost-bedded pack barn and are able to lie down more naturally (Figure 2), which in theory should lead to cows spending more time lying down. Furthermore, even when cows are standing, they are on a softer surface than if they were standing in concrete alleys within freestall barns.

Figure 2. Two well-managed Kentucky compost-bedded pack barns with excellent cow comfort.

Figure 3. Somatic cell count (SCC) trends for two Kentucky dairies before and after construction of a compost-bedded pack barn.





- Producers report reduced incidence of lameness and improved hoof health as a result of more time lying down and a softer surface for standing. In a Minnesota study, the percentage of clinically lame cows (7.8%) was considerably lower than in other recent studies examining lameness in freestall herds (19.6 to 27.8%; (Barberg et al., 2007b).
- With improved footing on a softer surface, cows may be more likely to exhibit signs of estrus, leading to improved heat detection rates. In the Minnesota study, heat detection rates for seven dairies increased from 36.9% to 41.4%, and pregnancy rates increased from 13.2 to 16.5% (Barberg et al., 2007b).
- Improved milk quality, as evidenced by reduced somatic cell counts (SCC) and reduced clinical incidence of mastitis, is another commonly discussed benefit. This improved quality is particularly evident in herds in which cows had previously been pastured year-round without access to any housing. Three of seven Minnesota dairies with historical SCC data saw a reduced bulk-tank SCC, while six of nine dairies had reduced mastitis infection rates (average reduction of 12.0%; Barberg et al., 2007b). Two Kentucky dairy producers who constructed compost-bedded pack barns saw considerable reductions in herd SCC levels after moving into their new facilities (Figure 3). While this result may seem to contradict conventional wisdom, most producers believe that keeping the cows dry and clean minimizes exposure to pathogens and thus improves milk quality (Figure 4). Additionally, the stress level for cows in a comfortable environment will be lower, which strengthens their immune systems and enables them to better fight off infections.
- Ultimately, all the cow-based benefits cited above contribute to potential for increased milk yield, reduced culling rates, and increased cow longevity. In the Minnesota study, eight of 12 dairies moving to a compost-bedded pack barn had an increase in 305-day mature equivalent milk production (Barberg et al., 2007b).
- Producers have also indicated that their new barns have resulted in less flies and odor.

Figure 4. Examples of clean udders in compost-bedded pack barns, which can be maintained by providing cows with a clean, dry surface to lie on.

Design Considerations

As with any dairy facility, site selection is critical. To maximize natural ventilation, the barn should be located to take advantage of summer winds. It should also be elevated slightly to minimize rain and snow runoff into the pack. Although it's unlikely the pack will be wet enough for drainage from the bottom, selecting a location with minimal potential for contamination through pack seepage is also important.

The pack base should be either clay or concrete. A concrete base has no real advantages, so new facilities are generally constructed using a clay base, which is cheaper. Most newly constructed compost-bedded pack barns are built by modifying existing designs for two-, three-, or four-row freestall barns with wooden, steel, or hoop frames. Some Kentucky producers have even built their barns with dimensions that allow flexibility for adding concrete alleys, freestall platforms, dividers, and waterers. These modifications allow flexibility in case the producers find the facility does not meet their needs or a changing market makes modifications necessary.

A guide for sizing a compost-bedded pack barn is in Worksheet 1. First you need to decide how much space to allocate per animal. In general, the pack area should provide at least 85 square feet of resting space per cow (65 square feet for Jerseys). Because Kentucky's heat and humidity alter the amount of moisture in the composting environment, Kentucky producers should provide at least 95 to 100 square feet of resting space per cow. In facilities for special needs cows, producers may need more than 100 square feet of resting space.

You should not be tempted to shortcut feed and water access in an effort to build a low-cost facility. For optimum animal performance and health, feed and water should be easily accessible and readily available at all times.

Worksheet 1. Calculating compost-bedded pack barn dimensions.

Step	Calculation		Formula	Example Inputs[a]		Example Answer
1	Required Pack Area	=	RC x NC	100 x 100	=	10,000 sq ft
2	Barn Length	=	(MC x NC)/12	(24 x 100)/12	=	200 ft
3	Pack Width	=	RPA/BL	10,000 x 200	=	50 ft
4	Total Barn Width	=	PW + FAW + EW	50 + 12 + 1	=	63 ft
5	Total Barn Area	=	TBW X BL	63 x 200	=	12,600 sq ft

Key: BL = barn length; MC = manger space/cow; RC = resting space/cow; EW = exterior walls; NC = no. of cows; RPA = required pack area; FAW = feed alley width; PW = pack width; TBW =total barn width

[a] *Recommendations: RC = 100 sq ft/cow, MC = 24 in/row, FAW = 12 ft, EW = 1 ft.*

Feed bunks may be located in the barn or outside under a roof. Feed bunks in the barn are preferred to encourage more feed intake. Provide a minimum of 24 to 30 inches of feed bunk space per cow and 2 feet of water tank perimeter per 15 to 20 cows. Cows will generally use the space provided more efficiently when they have entry access along the long side of the rectangular barn. If the entrance to the barn is on the short side, a wet, dirty area may develop there.

Adequate ventilation is essential. It removes heat and moisture created by the cows and the extra heat and moisture created by the composting process. Proper ventilation includes not only air movement through the barn but circulation within the building to prevent both stagnant and excessively breezy areas. Proper ventilation can improve cows' overall health and immunity by eliminating respiratory problems, keeping them cool in the summer, and keeping the pack surface dry, which minimizes bacterial growth and keeps cows clean.

Sidewalls in a compost-bedded pack barn should be 16 feet, higher than in freestalls because the pack and wall depth block some of the air flow. The barn should have an east-west orientation to take advantage of prevailing winds and reduce levels of direct sunlight entering the barn. A ridge vent opening of 2 inches for each 10 feet of building width is recommended. The basic air movement in a compost-bedded pack barn flows into the barn through the open sidewalls and is exhausted through the ridge vent.

Without fans, cows may congregate in areas where natural air flow is higher. Congregation of animals in one area leads to excessive moisture accumulation and ineffective composting. Mixing fans (ceiling or big box) are recommended to help keep the pack dry and ensure even air flow throughout the barn. Many Kentucky farms have installed high volume/low speed ceiling fans in their compost-bedded pack barns. They seem to be working well. When you install fans, take care to ensure that they are high enough for tillage equipment to work underneath them at maximum pack depth.

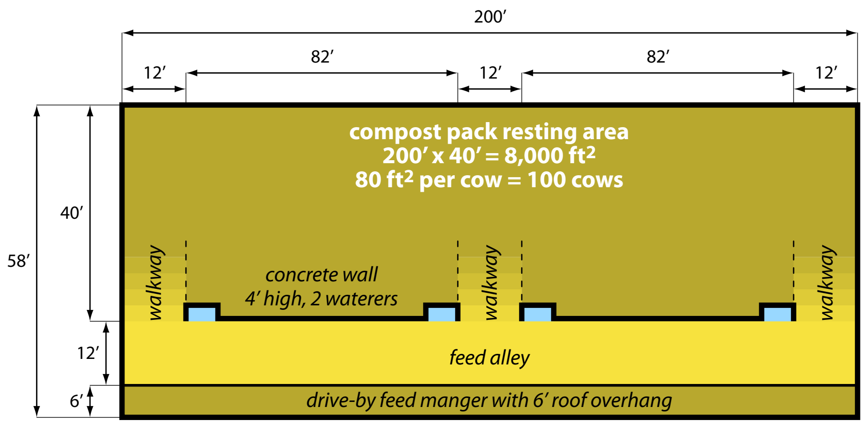
You should build 3-foot eave overhangs to prevent rain from reaching the pack. You can also install roof gutters to reduce runoff from blowing into the pack. Sidewall curtains may also help block winter winds and bad weather.

While a number of different barn designs exist, a suggested layout from the University of Minnesota is depicted in Figure 5. With this design, 4-foot walls surround the bedded pack on all sides, including a wall to separate the bedded pack from the feed alley. These walls may be cast-in-place concrete, moveable concrete panels, or wooden panels. Consider how much pressure manure and cows will place on the walls when choosing which material to use.

Figure 5. Compost barn layout for 100 cows.

Layout has three walkways to access the pack, drive-by feeding, and 6-ft overhang. Waterers are against the concrete wall, separating the bedded pack from the feed alley. They are accessed from the feed alley only. Not drawn to scale.

Source: University of Minnesota (Endres and Janni, 2008).



The concrete feed alley on one long side of the barn allows cows access to feed and water without traveling long distances. Because cows defecate and urinate more around feed and water, they should have access to waterers only on the alley side. Alley-only access minimizes excess moisture in the pack and keeps water cleaner. It also eliminates the need to alter waterer height as the pack depth changes.

Concrete feed alleys should be 12 to 14 feet wide, with walkways located every 120 to 160 feet and at each end. To prevent cows from falling into the feed alley, a fence should be built on top of the 4-foot wall next to the pack area.

Understanding Composting

Composting relies on microorganisms to break down organic matter and produce carbon dioxide, moisture, and heat. In a compost-bedded pack barn, the manure and urine released by cattle provide the essential nutrients (carbon, nitrogen, moisture, and microorganisms) needed for the composting process.

Composting is an aerobic process—oxygen is required. In a compost-bedded pack barn, the oxygen comes from stirring the bedding and from the air that filters into the bedding surface, which should be fluffy to encourage the air infiltration. How well the compost-bedded pack works depends on maintaining the appropriate balance of oxygen, moisture, temperature, amount of organic matter, and size and activity of microbial populations. As long as the proportions of carbon, nitrogen, oxygen, and moisture are balanced, the microorganism population will thrive and produce sufficient heat to dry the pack and kill pathogens, viruses, fly larvae, and weed seeds.

The pack's temperature provides a good indication of the level of microbial activity. Temperatures near the surface of the pack will be closer to the air temperature because moisture, evaporation, and air movement dissipate heat. The bedding-surface temperature under a resting cow will rise, however.

The ideal pack temperature, measured at approximately 12 inches beneath the surface, is between 130 and 150° F. Cow comfort would be a concern with packs at temperatures above the range, particularly on hot, humid days. A temperature in that range indicates that organic materials are breaking down fairly rapidly. When the temperature is below the 130-150° range, the composting process is too slow. When it is above this range, the beneficial bacteria that are necessary for composting are killed.

Temperatures can be measured with a long cooking thermometer. If a thermometer is not available, you can feel the material (at 12 inches beneath the surface) with your bare hands. If the pack is hot almost to the point that you do not want to touch it, the temperature is likely high enough. Packs at varying temperatures are shown in Figure 6.

Manure, urine, and microbial activity produce a pack's moisture, which should be between 50 and 60%. When moisture is too low, the microbes won't have enough water, and the compost will be too cool, resulting in a compost rate that's too slow. If the moisture level is too high, the pack becomes anaerobic (lacking oxygen); the rate of micro-

Figure 6. Examples of compost-bedded packs of varied temperatures.

Light and fluffy compost with ideal temperature (134.6º) is shown at left.
Wet and chunky compost with below-optimal temperature (99.6º) is shown at right.

bial decomposition will slow; and again, composting will be too slow.

As a simple moisture check, grab a handful of compost and squeeze it. If you can squeeze water out or if water droplets drip from or appear on the surface of squeezed bedding, the pack is too wet. If you can't form a ball, the pack is too dry. When the pack is working well, the bedding material will appear loose and fluffy, not compacted and chunky.

Generally, you'll see higher temperatures when the pack is fluffy because air promotes microbial activity. When the pack is compacted and has excessive moisture, you'll see reduced temperatures.

Excessively high temperatures in the compost bed (more than 150° F) occur when there is high microbial activity due to the presence of easily digestible organic matter and moisture near the low end of the optimal range. Under these conditions, the pack doesn't have enough water for evaporative cooling. Lack of water may occur when cow density is low, when air movement dries the pack more quickly, or in warm, dry weather.

The C:N ratio ideally should be between 25:1 and 30:1 If you can smell ammonia in the barn, the C:N ratio is likely below 25:1. The optimum range for pH is from 6.5 to 8.0. Both the C:N ratio and pH are challenging to measure.

Bedding Material

Minnesota researchers and dairy producers suggest that dry, fine wood shavings or sawdust, preferably from pine or other softwoods, are the bedding materials of choice in compost-bedded pack barns.

The theory is that such fine, coarse material provides a large ratio of surface area to volume, is easier to till, and absorbs and holds liquids well. The size of bedding particles is particularly important for regulating microbial access to the food source—manure and urine. At the same time, the high lignin content of these wood materials provides some resistance to microbial breakdown, which makes it last longer. Kiln-dried sawdust is preferred, but the pack will perform well as long as the moisture content for sawdust when it is put in the compost-bedded pack is less than 18%. Green sawdust is generally too wet. Products from softwoods such as pine seem to work best. Cedar should be avoided because it contains oils and organic materials that inhibit the microbial activity necessary for composting. Black walnut has been shown to cause laminitis in horses, though there is no research to support this theory in dairy cattle.

In early research studies, finely processed corn cobs, soy straw, or flax straw, ground through a 3/4-inch screen, have performed well. Such fine materials may be used in a mix with sawdust to stretch sawdust supply.

Some innovative producers continue the composting by stockpiling compost material after the pack is cleaned out. They turn this material to accelerate drying and then re-introduce this dry product into the pack along with new sawdust to stretch the sawdust supply.

Bedding materials with large particles do not work well at all. Corn stalks; waste hay; and oat, barley, and wheat straw tend to support bacterial growth and retain too much water. If you use these bedding materials, you may find it hard to stir and aerate the pack, or you may create a pulp or chunks. Moreover, the waxy coating on straw makes it difficult for microorganisms to penetrate.

Management Essentials

To start a compost-bedded pack, 1.5 to 2 feet of bedding is applied to the barn floor. Depending on the size of the barn, two to four semi-loads of sawdust may be required to start the pack. Make sure you add enough sawdust so that the barn floor is not disturbed when mixing begins. New bedding (4 to 8 inches) is added to the pack when existing bedding is moist enough to stick to the cows when they get up. How often bedding should be added depends on how much evaporation occurs. Generally, the composted bedding pack is top-dressed every two to five weeks. Some producers add smaller amounts of bedding more frequently. More bedding may be used during humid or wet weather or if the barn is overcrowded. The packs may reach 4 feet before cleaning. Most producers leave 6 to 12 inches of old material to help start microbial activity in the new pack.

The bedding area is generally cleaned out in the fall, with the used bedding applied to the land. Some producers also clean the packs in the spring. As with any facility, the success of a compost-bedded pack barn hinges largely on how well it is managed. Maintaining proper aeration and stocking density are key. If you stir and mix the pack often and uniformly, you'll stir in manure and urine from the surface and incorporate oxygen and moisture. The result will be better aerobic decomposition of organic material.

Uniform stirring and mixing also provide a clean, soft, dry surface for cows to lie on. You should stir the compost during every milking, while cows are out of the barn. Most producers start stirring about a day after new sawdust is added to the pack. A variety of methods can be used to stir. Most producers use a cultivator, tines, or a rotary tiller attached to the rear of a skid steer or small tractor (Figure 7). If you use heavy equipment, wheel tracks won't be broken up, or if the pack is too wet, the pack may become too compacted, limiting oxygen and causing lower temperatures. Compaction also leads to higher bed moisture, with negative impacts related to inadequate aeration as cited above.

You should aerate the compost bed to a depth of at least 10 to 12 inches and up to 16 to 18 inches. Use of a chisel plow will reduce the amount of bedding you'll need and increase pack temperatures. Some producers plow the pack twice, both lengthwise and crosswise, to aerate even more.

Figure 7. Examples of equipment used to stir compost-bedded pack barns.

If you overcrowd the barn, you may have too much moisture in the pack, dirtier cows, and higher somatic cell counts. The following can occur:

- Manure and urine going into the pack increase, which causes the pack's moisture level to rise too high and the composting process to slow considerably.
- Physical packing of the bedding material increases, which reduces airflow in the pack.
- The amount of fecal contamination (non-ag Streps and Coliforms) in the lying space increases as a result of more manure, which can lead to greater incidence of environmental mastitis.

Even when the compost process works well, cows in a compost-bedded pack barn are not in a sterile environment. Minnesota research showed large numbers (9,122,700 cells/cc) of mastitis pathogens on the surface of compost-bedded packs, including coliforms, environmental *Staphylococcus* species, and *Bacillus* (Barberg et al., 2007a). If bacterial populations are high in the bedding, they also will be high on the surface and end of the teat. Consequently, maintaining healthy teat ends is necessary. If you prepare cows well in the parlor, you will further minimize potential mastitis problems. Vaccination of cows with an *E. coli* vaccine may also prove beneficial. Furthermore, if you provide cows with feed after they leave the parlor, you'll allow more time for the teat end to close after milking.

Economic Considerations

Before building a compost-bedded pack barn, you should consider the costs of construction, annual maintenance, and bedding and the profitability of a new barn. Building costs vary because concrete, steel, and wood prices fluctuate. How much of the barn you build yourself and what options you add are also cost factors. Still, construction costs for a compost-bedded pack barn are generally less than for a freestall barn, despite more space per cow and higher sidewalls. You use less concrete, and do not need to invest in freestall partitions and bases. Reported construction costs have ranged from $600 to $1,800 per cow space, though more recent estimates have been on the higher end of that range.

While initial investment is lower than for a freestall barn, annual maintenance is typically higher. For a 100-cow herd, you can assume that a semi-truckload of sawdust (about 18 tons) will be used every two to five weeks. At these rates, bedding costs have ranged from $0.35 to $0.85 per cow per day.

You should also consider the cost of handling manure. Compost-bedded pack barns reduce the amount of manure storage, but you may need equipment to handle both liquid and dry manure. Keep in mind that dry manure can be easier to handle and does not have to be applied as frequently.

In calculating labor costs, assume that five to 15 minutes is required for stirring and scraping the feed alley, which is generally accomplished twice daily during milkings. It may cost you more if you build a facility for on-farm storage of sawdust (to assure availability and enable you to buy it when prices are lower). To offset costs, you may find a market for selling the final compost.

Table 1. Changes in bedding costs with changing sawdust prices for a 100-cow herd adding a new load of sawdust every 3 weeks (on average).

Price Per Semi-Load of Sawdust	Total Annual Bedding Costs	Monthly Bedding Costs	Annual Per-Cow Bedding Costs	Bedding Costs Per Cow, Per Day
$200	$ 3,466.67	$ 288.89	$ 34.67	$ 0.09
$300	$ 5,200.00	$ 433.33	$ 52.00	$ 0.14
$400	$ 6,933.33	$ 577.78	$ 69.33	$ 0.19
$500	$ 8,666.67	$ 722.22	$ 86.67	$ 0.24
$600	$ 10,400.00	$ 866.67	$ 104.00	$ 0.28
$700	$ 12,133.33	$ 1,011.11	$ 121.33	$ 0.33
$800	$ 13,866.67	$ 1,155.56	$ 138.67	$ 0.38
$900	$ 15,600.00	$ 1,300.00	$ 156.00	$ 0.43
$1,000	$ 17,333.33	$ 1,444.44	$ 173.33	$ 0.47
$1,100	$ 19,066.67	$ 1,588.89	$ 190.67	$ 0.52
$1,200	$ 20,800.00	$ 1,733.33	$ 208.00	$ 0.57
$1,300	$ 22,533.33	$ 1,877.78	$ 225.33	$ 0.62
$1,400	$ 24,266.67	$ 2,022.22	$ 242.67	$ 0.66
$1,500	$ 26,000.00	$ 2,166.67	$ 260.00	$ 0.71

Potential Limitations

The primary limitation for compost-bedded pack barns so far has been sawdust availability. These barns require three to four times the amount of bedding of a typical freestall. In on-farm experiments, alternative materials have not performed as well as sawdust. If you're considering a compost-bedded pack barn, make sure you have a reliable, timely supply of sawdust available. Demand for sawdust will go up and prices will continue to rise as more people build these barns and increased demand for sawdust comes from the biofuel, dark-fire tobacco, and charcoal industries.

You should consider how sawdust prices affect daily and annual bedding costs (Table 1). If the pack is not managed well, the higher risk of exposure to environmental mastitis pathogens can add to your costs, as would eye and respiratory infections that can result from dust created when the pack is being aerated.

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