ORIGINAL RESEARCH

Facility effects on preweaning mortality: A report of the NAHMS National Swine Survey

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Summary: *A producer survey that included 885 facilities was conducted to assess the associations between preweaning mortality and various facility attributes. Using univariate analysis and a multiple regression model, we found a significant association between preweaning mortality and flooring type, heat source, water delivery system, cleaning frequency, cleaning method, and duration of idle time between farrowing groups.*

Preweaning mortality continues to be a source of both biological and financial loss to the swine industry, loss that is becoming increasingly evident as more producers keep detailed records. Nationally, the average for preweaning mortality is about 15% (PigCHAMP = 13.5%, Swine Graphics = 14%, Pigtales = 12.01%).[1-5] However, those farms that rank in the top 90th percentile are achieving preweaning mortality values of about 9% (PigCHAMP = 9.1%, Swine Graphics = 9.0%, and Pigtales = 10.1%), indicating that it is possible to reduce the national preweaning mortality average by 5%–6%.[3-5]

The purpose of this paper is to identify the important risk factors associated with preweaning mortality that could be attributed to facilities. Facilities can influence the number of deaths due to trauma, low viability, and starvation.[6] The primary factors in facilities and facility management that must be considered in preweaning mortality include:

- piglet microenvironment;
- farrowing floor;
- type of farrowing crate design;
- type of water source;
- farrowing room ventilation control;
- cleaning method;
- frequency of cleaning; and
- amount of idle time between groups.

The National Animal Health Monitoring System (NAHMS) conducted a national survey to identify facility attributes correlated with preweaning mortality.[2,7] Using these data, we were able to estimate associations between facility attributes and management and preweaning mortality.

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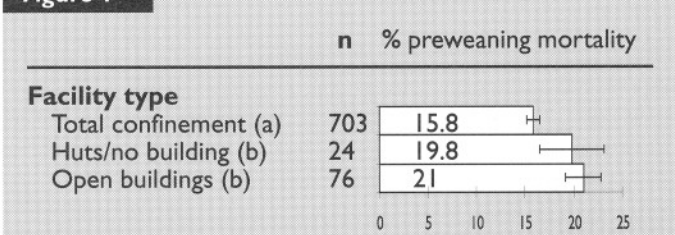
Methods

The study design for the NAHMS Swine Survey has been described previously.[2,7] Briefly, each producer participating in the NAHMS Swine Survey provided detailed farrowing facility information (see Survey questions, next page). Producers also recorded farrowing information (number born live, stillborn, mummies, fostering, illness, and deaths) on diary cards.[2,7]

The study included a total of 21,712 litters from 894 facilities. A total of 885 facilities with 21,540 litters could be classified to a specific facility type. Of these, 750 facilities (19,842 cohort litters) were defined as total confinement. The dependent variable to be analyzed was percent piglet preweaning mortality. Producers were asked to classify the reasons for mortality. Due to the subjectivity of this classification system, we compared their responses to the percentage of total piglet preweaning mortality.[1,2,8,9]

First we focused on the type of facility housing: total confinement, open building, and hut/no building. Because total confinement is the most common housing type (representing 87% of farms in this study) (Figure 1), we then narrowed our analysis to specific attributes of total confinement. Facilities with a very small number of monitored litters can result in either high or low mortality rates that do not necessarily represent the long-term performance of the facility. To reduce the variation associated with facilities with few monitored litters, facilities with fewer than five monitored cohort litters were

Figure 1



Effect of housing type on total preweaning mortality. Facility types with different letters in parentheses are statistically different ($P \leq .05$). Error bars indicate 90% confidence intervals.

Now let's talk about the farrowing facilities in which we are monitoring sows, gilts, and piglets.

What type of facility is this?

Total Confinement
Open Buildings with
—no outside access
—access to dirt/concrete
—access to pasture
Hut or no building
—lot
—pasture

What types of flooring or footing are the swine exposed to?

concrete
slats-concrete
wire or metal
coated metal
wood
other (specify below)

("Concrete" and "slats-concrete" were combined in the statistical analysis as "concrete.")

What types of ventilation are used?

natural
pit fans
wall/ceiling fans

(Positive responses to both "pit fans" and "wall/ceiling fans" were considered separately in the statistical analysis as "pit/wall fans.")

What types of water sources do the sows drink from?

cup
nipple
trough — one sow
trough — many sows
other (specify below)

(The categories "cup only," "nipple only," and "cup and nipple" were used in the statistical analysis. "Trough—one sow," "trough—many sows," and "other" were combined in the statistical analysis as "neither.")

What types of waste management are used?

none
pit-recharge
pit-holding
mechanical scraper/tractor
hand cleaned
flush-under slats/fresh water
flush-under slats/recycled water
flush-open gutter/fresh water
flush-open gutter/recycled water
other (specify below)

("Pit-recharge" and "pit-holding" were combined in the statistical analysis as "deep pit." "Mechanical scraper/tractor" and "hand cleaned" were combined in the statistical analysis as "mechanical removal." All four flush methods were combined in the statistical analysis as "flush type.")

What cleaning methods are used?

none
washed with water
pressure cleaned
disinfected
fumigated
other

("Pressure cleaned" plus "disinfected" or "fumigated" were combined in the statistical analysis as "pressure wash and disinfected." "Washed with water" plus "disinfected" or "fumigated" were combined in the statistical analysis as "cleaned and disinfected [no pressure].")

Are the facilities idle between one farrowing and the next farrowing?

yes/no
(if yes, ask how long they are idle)

How long are the facilities idle?

1–2 days
3–5 days
1 week
2 weeks
1 month or more

(In the statistical analysis, 1-2 days was designated "short." All idle times greater than 2 days were combined in the statistical analysis as "long.")

Are the facilities cleaned after every group farrowed?

yes/no

Is supplemental heat used?

yes/no (If yes, ask what type)

What types of supplemental heat are used?

room heating
heat lamps
radiant heaters
heated floor
heat pads
other (specify below)

("Heat lamps" and "radiant heaters" when combined in the statistical analysis were sometimes called "over heat source." "Heated floor" and "heat pads" were combined in the statistical analysis as "under heat source.")

Is supplemental cooling used?

yes/no (If yes, ask what type).

What types of supplemental cooling are used?

directed forced-air fans (other than for ventilation)
evaporative room coolers (swamp coolers)
mist or spray coolers for group
drip coolers for individuals
head cooling
other (specify below)

("Directed forced-air fans" and "head cooling" were combined in the statistical analysis as "other [fans]." "Mist/Spray coolers" and "Drip coolers" were combined in the statistical analysis as "Drippers.")

The following questions should only be asked if farrowing crates are used:

What types of crates are used?

all metal
wood
wood and metal
other

("Wood" and "wood and metal" were combined in the statistical analysis as "metal/wood.")

Do the crates have special guard rails or bars, in addition to those normally present in the crate structure, to prevent crushing of piglets?

yes/no

deleted. This resulted in a final data set with 703 total confinement facilities (19,732 cohort litters). Even with these limitations, one facility still had 100% mortality and four had 0% mortality.

Herd size is another risk factor for preweaning mortality. In this study, we also evaluated sow inventory herd size. Sow inventories were broken down into the following groups:

- 0–49 sows;
- 50–99 sows;
- 100–199 sows;
- > 200 sows.

We also evaluated preweaning mortality by region to see if there was a significant interaction with facility attributes and region. We grouped the regions by state as follows:

- *Southeast*: Alabama, Georgia, North Carolina, Tennessee, Virginia, Pennsylvania, Maryland.
- *Corn belt*: Iowa, Illinois, Indiana, Michigan, Minnesota, Nebraska, Ohio, Wisconsin.
- *West*: California, Colorado, Oregon.

Statistical analysis

To determine which variables to include in a multiple regression model, we analyzed preweaning piglet mortality for each facility attribute and management procedure by using SAS's General Linear Model (GLM) procedure, least squares means option.[10] We chose the least squares means option because the survey design resulted in attributes with different numbers of observations. In some cases, the differences in the mean values of piglet mortality may be very large, though not statistically significant because there was a low number of observations for some facility attributes.

Next, to simultaneously adjust for multiple facility attributes, we constructed a regression model. The different total confinement facility attributes that we found to be significant using univariate analysis and that we used in the model included:

- flooring type;
- piglet supplemental heating (under-heat source was defined as a heated floor or heating pad in the creep area with no additional supplemental heating [i.e., heat lamps or radiant heaters]);
- supplemental cooling (data for summer cooling included 262 facilities monitored during the summer months, [Southeast: May-September, and for the rest of the country: June-August]);
- ventilation system;
- waste management system;
- crate type;
- protective guardrails (i.e., whether or not a guardrail was present and the basic construction material of the crate); and
- sow water source.

All facility attributes types were discrete variables (i.e., either the facility had the attribute type or it did not). In regression modeling of discrete variables, one attribute type is considered the base parameter by which all other types of that attribute are compared. For example, the flooring attribute has five possibile types: wire only, any wood, coated wire, concrete, and other. Wire only was chosen as the base type and therefore had a parameter estimate of 0.00. The parameter estimates for the other types measure their impact on preweaning mortality relative to wire only. A positive coefficient means that the specific flooring type increased mortality relative to that of wire only.

The choice of base type is arbitrary and is usually the type with the most observations, the one of greatest interest to the researcher, or the least/greatest if a size variable. For our analysis, we chose as base parameters those attribute types with the largest number of observations for each attribute except for ventilation (pit fans), waste management (mechanical removal), and herd size (1–49 sows).

We also included various facility management procedures in the model:

- cleaning frequency;
- cleaning method; and
- amount of idle time.

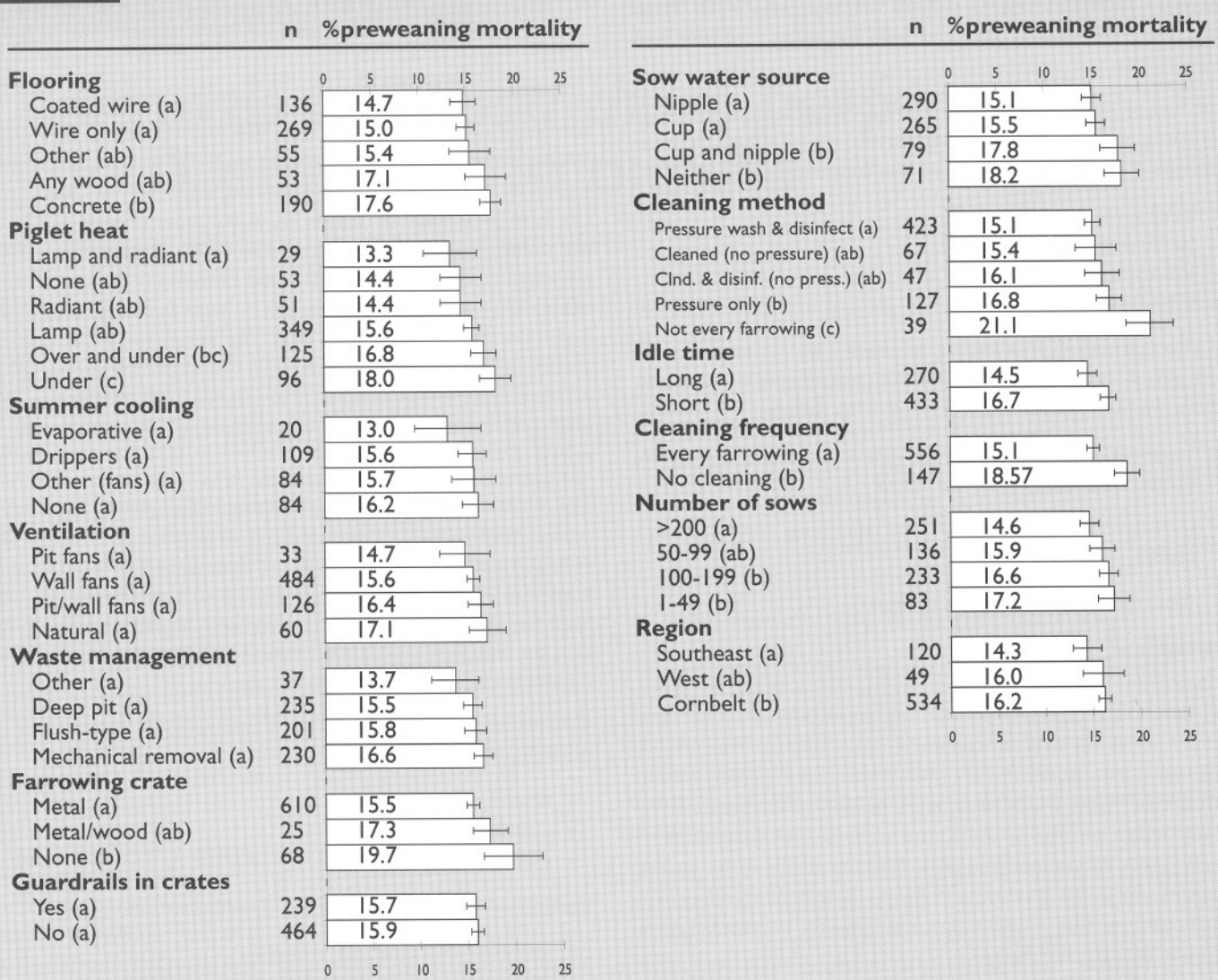
We considered several selected interactions in the model:

- idle time and cleaning method;
- frequency of cleanup and cleaning method;
- cleaning method and flooring type;
- flooring type and supplemental heating type; and
- ventilation system and waste management system.

In order to account for any confounding by herd size or location, size of breeding herd and region of the country were forced into the model.

All attributes and selected interactions were entered in a multi-variable forward stepwise regression model. We used an iterative procedure in which the "best" attribute category of type variables, as measured by its F statistic, is entered into the model first. Then the next best attribute category is entered and the process continues until all significant attribute categories have been entered. The minimum F value for being included in the model had a significance level of $P = .1$. If it found a particular type variable significant, the model pulled in the entire attribute category. Using this model allowed us to identify the most important attributes associated with piglet preweaning mortality.

Figure 2



For total confinement facilities only, the effects of various management practices and design factors on preweaning mortality. Within each attribute category, types with different letters in parentheses are statistically different ($P \leq .10$). Types within each category are sorted by percent preweaning mortality. Error bars indicate 90% confidence intervals.

Results

Most facilities included in the NAHMS Swine Survey where a facility type could be determined were classified as total confinement (Figure 1). There were significant differences in piglet preweaning mortality by facility type. Lowest piglet preweaning mortality occurred in total confinement facilities.

Univariate analysis indicated that the following attributes (Figure 2) were significantly associated with preweaning mortality:

- Flooring: Plastic-coated wire was associated with the lowest piglet preweaning mortality, but was not significantly better than wire floor. Both plastic-coated wire and wire flooring were significantly better than concrete floors.
- Supplemental heating: Under-heat sources, such as heat pads or heated floors in the creep area, were associated with the highest mortality rates. All other possible combinations of supplemental heat, including no supplemental heat, had significantly fewer deaths than underheat by itself. The combination of heat lamp and radiant heaters had the lowest preweaning mortality, but was not better statistically than heat lamps or radiant heaters independently.
- Cooling: There were no significant differences in piglet preweaning mortality by type of supplemental cooling system.
- Ventilation and Waste management: Preweaning mortality did not vary significantly by type of ventilation used in a facility, nor did this study identify a significant difference

in preweaning mortality based on type of waste management system.

- Farrowing crates: In this study, litters farrowed in metal crates had a significant advantage in surviving over those not farrowed in crates. However, adding a guardrail to crates did not significantly reduce preweaning mortality.
- Feed and Water delivery: Certain methods of water delivery to the sow and piglets are associated with lower piglet preweaning mortality. Facilities with nipple waterers only and cup waterers only had significantly lower piglet preweaning mortality than those water delivery systems that combine a cup and nipple or a water source other than a cup or a nipple. However, mortality was not significantly different between facilities with nipples only or cups only.
- Cleaning method/frequency/idle time: Facility cleaning was significantly associated with preweaning mortality. Any form of cleaning was better than no cleaning, and cleaning after every farrowing was better than not cleaning after every farrowing. Facilities that were pressure washed and disinfected had the lowest levels of preweaning mortality, significantly better than pressure washing only. Also, farms that waited more than 2 days to refill the crates were associated with significantly lower preweaning mortality.
- Farm size: Herds with more than 200 sows had numerically the lowest preweaning mortality, significantly lower than herds with 1–49 and 100–199 sows.
- Region: The southeastern region had significantly lower piglet preweaning mortality than the corn belt region.

Table 1

Multivariate analysis of facility attributes on total preweaning mortality

Category	Parameter estimate	Partial r-square	Model r-square	Prob > F
Farm size and region		**.0151**	**.0151**	-----
1-49 sows	0.00			na.
50-99 sows	-.073			.5743
100-199 sows	-0.11			.9297
> 200 sows	-2.20			.0828
Corn belt	0.00			na
Southeast	-1.67			.0816
West	-0.82			.5678
Idle time		**.0177**	**.0328**	**.0004**
Short idle	0.00			na
Long idle (>2d)	-2.01			.0098
Flooring		**.0195**	**.0524**	**.0069**
Wire only	0.00			na
Any wood	1.86			.1911
Coated wire	-0.64			.5174
Concrete	2.95			.0015
Other	0.30			.8253
Cleaning frequency		**.0082**	**.0606**	**.0141**
Every time	-1.87			.0538
Supplemental piglet heating		**.0142**	**.0747**	**.0636**
Heat lamp	0.00			na
Under heat	2.62			.0149
Over & under heat	0.92			.3356
None	-1.68			.2166
Radiant heat	-0.33			.8124
Lamp & radiant heat	-1.06			.5562
Cleaning method		**.0114**	**.0861**	**.0764**
Pressure wash & disinfect	0.00			na
Not every farrowing	3.11			.0648
Washed with water	-1.63			.2171
Cleaned and disinfected (no pressure)	-0.67			.6471
Pressure wash only	1.27			.1795

Multivariate analysis

Facility attributes

When the above variables were entered into the regression model, flooring type and heat source were the two facility characteristics that were significantly associated with lower preweaning mortality levels (Table 1).

Flooring type—Among the flooring variables, concrete floors had a mortality rate almost 3 percentage points higher than wire floors. The other types of flooring were not statistically different from wire.

Heat source—Using an under-heat source of supplemental heat (i.e., hot water heat in floor, electric pads, etc.) had a significantly higher piglet preweaning mortality—nearly 2.6 percentage points higher than heat lamps alone. Other supplemental heat sources were not significantly different.

Facility management

Idle time, cleaning frequency, and cleaning method also entered into the model as significant categories. Farrowing barn idle time greater than 2 days had the greatest impact on piglet preweaning mortality. Failing to clean the farrowing barn was associated with preweaning mortality more than 3 percentage points higher than that associated with pressure washing and

disinfecting or fumigation. All other cleaning methods were not significantly different.

Discussion

Although producers who participated in this study were trained to collect valid data, one should keep in mind that recording errors were possible. Producers responding to the survey could have misinterpreted our questions, or have been unclear about our definitions of some of the facility attributes. For example, although use of guardrails in farrowing crates has been shown to be effective in reducing preweaning mortality,[1] in this study there was no significant association between use of guardrails and lower preweaning mortality. Perhaps producers weren't sure what should be reported as guardrails in this survey. A more detailed survey would be necessary to provide specific information suggesting an optimal crate design (i.e., whether or not to include bow bars and/or fingers, whether guardrails are effective, ideal crate width, ideal height of first bar, and whether the crate should be hydraulic or conventional). It is important, therefore, to interpret the findings of this study in light of the fact that they represent data generated with a producer survey.

Facility attributes

With the use of a regression model, we found flooring material and supplemental heat source to be the most important facility attributes identified in this study.

Flooring type

The type of floor chosen is not too critical as long as it is not concrete. Because it is porous, concrete flooring material is much more difficult to clean. Piglets are exposed to more pathogens, resulting in illness and higher mortality. In our experience, piglets on total concrete floors or concrete combinations experience more scouring problems.

Heat source

In our study, litters with no supplemental heating were primarily from southern operations and farrowed during the summer months, which may explain the low preweaning mortality. There were not enough facilities without supplemental heating during the nonsummer months to allow us to thoroughly compare whether supplemental heating per se was significantly associated with lower preweaning mortality.

Environmental management in the farrowing barn is a dilemma. Ideally, one must maintain a macroenvironment that will keep the sow comfortable so that she maintains her appetite and will continue optimal lactation (i.e., 15–22°C),[1] while maintaining a microenvironment that avoids chilling the piglets (i.e., >38°C).[1] Piglets, especially in early life, have a poor ability to thermoregulate. In the absence of an external heat source in areas with cool or cold ambient temperatures, piglets can become chilled resulting in poorer colostrum intake, lower viability, greater potential for diarrhea, and greater likelihood of traumatic (crushing) injury. All these factors can result in higher piglet preweaning mortality.

Summer is one of the most challenging seasons to manage. This is when it becomes very difficult to maintain the sows' macroenvironment *and* the piglets' microenvironment. Although in this study supplemental cooling was not significantly associated with lower preweaning mortality, the literature reports that drip cooling, evaporative cooling, and the combination of drip cooling and forced air are significantly better in terms of preweaning mortality than forced air cooling systems.[11,12] However, preweaning mortality may not be the best parameter against which to measure the impact of summer heat in farrowing barn performance. Other parameters to evaluate would be: litter weight gain, weaning-to-first-service interval, and subsequent total-born litter size. More work needs to be done in this area to clearly define which system performs best.

The R^2 value of heat source and flooring type (.0861—8.6% of the variation explained by the model) is relatively low, indicating that the role of facilities in explaining preweaning mortality is directly influenced by other variables. Low R^2 values are not unusual in survey research, even when management variables are included. It is impossible to truly measure the thought processes of producers while they are handling pigs. However, we can measure the facilities and management practices they use. Thus, even with low R^2 values, our results do provide information as to which facility attributes contribute the most to reducing preweaning mortality. Indeed, this study suggests that the way facilities are managed is as important as such facility characteristics as flooring type and heat source.

Facility management

For example, the multiple regression model identified some key facility management issues (idle time, frequency of cleaning, and cleaning method). Cleaning the facility between farrowings is associated with a significant reduction in piglet preweaning mortality, suggesting that cleaning will help reduce preweaning mortality. Facility cleaning is facilitated by all-in—all-out production flow no matter which cleaning method is used.

Farrowing facility idle time varies widely by farm. Those farms that push for ultimate pigs weaned per crate per year generally have very short idle times. However, some of the batching systems allow more idle time between groups.

However, operations that try to maximize pigs weaned per crate per year to reduce fixed cost per pig and maximize profit will often use other management procedures that may affect preweaning mortality as well as the amount of idle time. Procedures that maximize pigs weaned per crate per year include:

- using crates at greater than 100 percent capacity;
- early weaning sows with small litters; and
- cross fostering their pigs on remaining litters (i.e., every sow suckles 11–12 piglets).

These practices don't allow for long idle time but do lend themselves to higher intensity in the farrowing barn. This higher intensity may come at the price of a higher piglet preweaning mortality. Ultimately, one must analyze the cost : benefit of increasing intensity in the farrowing barn, because the end goal of maximizing pigs weaned per crate per year is to improve profitability.

Farm size and region

Interestingly, farm size and region were significantly associated with preweaning mortality as univariate attributes, but as part of the multivariate analysis, each accounted for only 1.5 percent of the variation ($R^2 = .0151$). The lower preweaning mortality associated in the univariate analysis with larger herds (200 sows) may be because owners of large herds are more committed to the swine operation and have more management time and labor available in the farrowing barn to reduce preweaning mortality. Herds with 50–99 sows are often owned by a single producer very dedicated to the operation, whereas in operations with 1–50 sows the swine operation may not be the major enterprise and may suffer from the lack of labor available to devote to farrowing barn management. Herds with 100–199 sows may not have adequate labor resources to commit to managing the farrowing barn. More work needs to be done in this area to help understand the influence of herd size on preweaning mortality.

A number of characteristics of the southeastern region could explain the relatively lower preweaning mortality values there. The swine industry in this region has been developed more recently and has newer, more modern facilities. Many of these units also have more than 200 sows. The warmer climate in this region may also have a significant impact on lowering preweaning mortality.

Other considerations

Some of the facility attributes we included in this study may actually be more significant when measured against other parameters than preweaning mortality. For example, because of its impact on air quality, waste management is often a major consideration when building or remodeling. Waste management strategies also guide the choice of ventilation system. The lack of significant associations among waste handling/ventilation systems and preweaning mortality in this study should not, however, prompt one to conclude that neither is an important facility consideration. Rather, it may be that preweaning mortality is not the parameter of hog production most significantly influenced by these factors. Air quality, equipment, longevity, and production workers' environmental health are important concerns that warrant a careful decision about ventilation type and manure-handling system.

Understanding how facilities affect overall production performance, not only preweaning mortality, is very important—facilities are the most capital-intensive portion of production units, and many different options exist. Today many suppliers sell products based on anecdotal information rather than scientific experimentation. We must continue to challenge the suppliers of equipment and facilities to scientifically test the facilities that we help our clients choose.

To understand the full economic impact of facility type and management, more controlled studies are needed to answer specific facility questions that remain in the industry. Other outcomes should be evaluated as well: litter rate of gain, weaning-to-first-service interval, subsequent total born, and cost of production.

Implications

- Good managers are able to make any system work.[2,13] There is no magic in facility design to reduce preweanng mortality.
- Break the disease cycle with longer idle times between farrowings and by cleaning the farrowing area after every farrowing. Before increasing idle time, first analyze to see whether the extra piglets you save per litter compensate for the fewer litters farrowed, i.e., select the idle time that results in the most piglets weaned per crate per year.
- Switching from concrete floors to some other type of flooring system (e.g., wire) should help improve performance.
- Use some type of creep heat source (i.e., heat lamps or radiant heat) for the piglets, but don't use an under heat source.
- Controlling preweaning mortality is one way all producers can improve their performance and be more competitive within the industry.

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Practice tip

A Brief Quiz on Training

Here are four ways that firms determine how well their training efforts pay off. Check the method that is most typical of your approach. Do you:

- Monitor employee reactions?
- Conduct attitude surveys and ask for reactions?
- Use some kind of measuring approach to determine whether employees produce the desired results?
- Measure, but see if results are consistent with company values?

The last is the best approach, followed in decreasing order as you go back up the list.

Source: Kenneth E. Carlisle and Dan Henrie, writing in Training &Development, 1640 King St., Alexandria, Virginia 22313.