Decreasing Preweaning Death Loss in Pigs: Key Management Considerations for Small-Scale Farmers

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Continued improvements in genetic selection and management have enabled the U.S. pork industry to be extremely successful in increasing sows' litter size. A report containing data from over 1.4 million sows on 543 large swine operations revealed that there was a 5.4% increase (12.9 to 13.6) in pigs born alive per litter during the period from 2017 to 2021 (MetaFarms, Inc. and National Pork Board 2022). However, persistently high preweaning death loss, which was greatest (14.4%) in 2021, offset this gain. Table 1 shows data for 2021, divided into the top 10%, middle 50%, and bottom 10% of farms. The top 10% reveals what is attainable and can serve as an aspirational goal for many farms. In contrast, the bottom 10% indicates the amount of progress that many farmers need to make.

Table 1. Key performance indicators for large commercial swine farms in the U.S. achieving different levels of performance in 2021.

	Pigs born alive	Preweaning deaths, %
Top 10%	14.6	8.3
Middle 50%	13.5	14.1
Bottom 10%	12.3	20.2

Source: Meta Farms, Inc. and National Pork Board. 2022.

Note: Data represent production by over 1.4 million sows from 543 large swine operations.

The data clearly suggest that the potential exists to increase sow productivity by decreasing preweaning death loss. Increasing the number of pigs weaned increases revenue and efficiency but does not appreciably increase the fixed and variable costs associated with the sow herd. For example, on a 50-sow farm, weaning one extra pig per litter results in an extra $3,000 in revenue annually (assuming two litters per sow per year and a weaned pig price of $30 per head). This fact sheet describes factors that cause preweaning death loss in pigs and suggests potential mitigation strategies.

Causes of Preweaning Death Loss

Pigs are generally weaned from their sows at an age of 3 to 4 weeks but, in some cases, at 6 to 8 weeks. The number one cause of preweaning deaths is sows lying on pigs. Called maternal overlay, overlay, or crushing, this accounts for 48.1% of deaths. Other major causes of preweaning death include starvation (15.3% of deaths) and scours (13.3% of deaths) (Lay et al. 2002). On sow record cards in the farrowing house, herdsmen often list overlay, starvation, or scours as causes of death. However, preweaning death of a pig often occurs due to a series of related events and interactions among the environment, sow, and pig itself. While it is true that overlay causes the largest number of pig deaths, several related factors contribute to this outcome. For example, pigs that are cold and hungry will huddle close to the sow and be at greater risk of overlay. Possible interactions among the environment, sow, and pig leading to preweaning death are shown in figure 1.

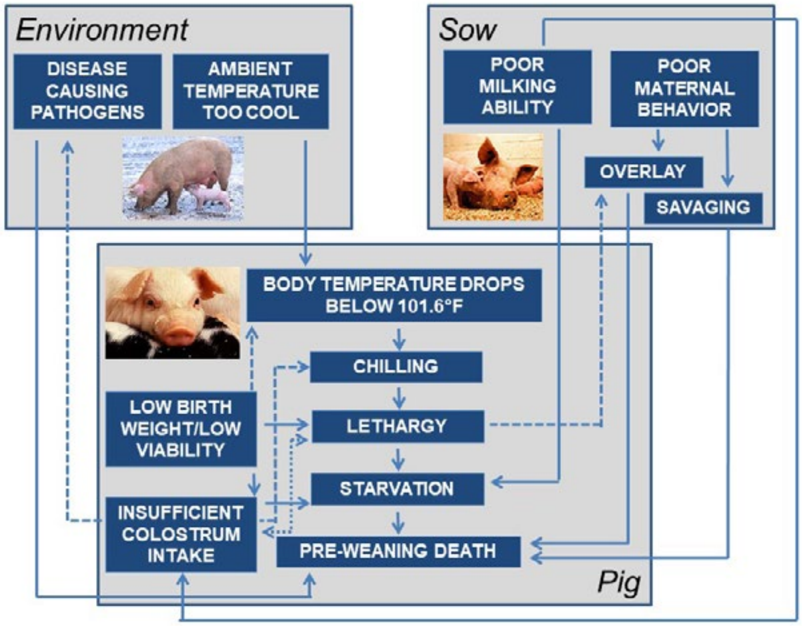

Figure 1. Schematic depiction of events leading to preweaning death of pigs and interactions among the environment, sow, and pig itself. Photographs courtesy of U.S. Department of Agriculture Agricultural Research Service.

Low Birth Weights

Koketsu, Takenobu, and Nakamura (2006) reported a greater risk of preweaning death in larger litters. The pork industry's focus on increasing litter size has unintentionally led to an increase in the proportion of low birth-weight pigs. This is depicted in figure 2, which shows the proportion of pigs with birth weights less than 2.2 pounds in 111 litters farrowed at the Tidewater Agricultural Research and Extension Center. As litter size increased from three to 18 pigs, so did the proportion of pigs that weighed 2.2 pounds or less.

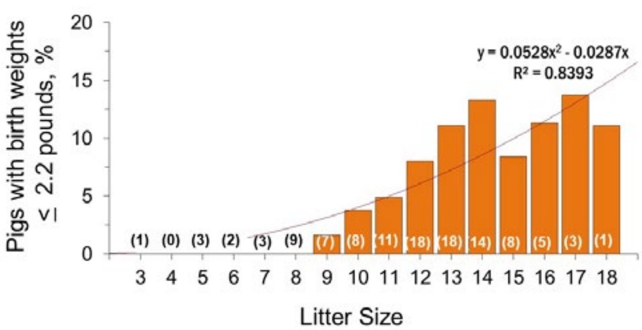

Figure 2. Relationship of total litter size and the proportion of pigs weighing ≤ 2.2 pounds. Data is for 111 litters farrowed at Virginia Tech's Tidewater Agricultural Research and Extension Center in Suffolk, Virginia. The number of litters for each litter size category appears in parentheses.

The threshold of 2.2 pounds is typically used to define runt pigs at greatest risk of preweaning death. These pigs may have a disproportionately small body relative to the head size and are identified by their dolphin-shaped heads and ears that point backwards. Compared with normal birth-weight offspring, light birth-weight pigs have greater rates of preweaning deaths and lower postnatal growth rates. Moreover, at slaughter, these pigs have less muscle, are fatter, and have poorer meat quality (Rehfeldt and Kuhn 2006).

Low Body Temperatures

The newborn pig, with a body temperature of 102 to 104 F, relies almost entirely on shivering to produce heat. Shivering is very energy-inefficient and can rapidly deplete already low energy reserves. Thus, pigs are at a high risk for hypothermia, which occurs when the body loses heat faster than it is produced. If severe enough, the pig becomes lethargic and susceptible to starvation or overlay or both. Newborn pigs are at risk for hypothermia because they lack a full hair coat, because their small size encourages heat loss, and because, unlike many other domestic farm animals, sows do not dry their newborns by licking away birth-associated membranes and fluids. Furthermore, pigs have a very small amount of white fat, which does have insulating properties but is primarily structural and has little potential to be utilized as an energy source. Brown fat, which uses energy to produce heat, is present in newborns of several animal species, including calves, but is not present in pigs.

The pig's lower critical temperature is 94.3 F, which is the lowest ambient temperature at which normal body metabolism occurs. Below this temperature, metabolism must increase to maintain normal body temperature. Recent data has shown that, even in optimal farrowing environments with supplemental heating, the transition from the sow's reproductive tract to the outside world results in a decline in pig body temperature from 102 to 95 F within the first 30 minutes of life (Vande Pol et al. 2020). Hence, all newborn pigs should be assumed to be at least near hypothermia immediately after birth.

Low Colostrum Intake

Colostrum is the first milk a sow secretes during lactation and is produced for just 24 hours following the onset of farrowing. The substance is rich in energy and contains antibodies (immunoglobulins). At birth, energy reserves in pigs are very low and the immune system is extremely immature. Colostrum provides energy and the passive immunity critical for fighting diseases.

Newborn pigs require a minimum of 9 ounces of colostrum within the first 24 hours of life, although approximately 33% of sows do not produce enough to provide this amount to each individual in a litter (Quesnel, Farmer, and Devillers 2012). Figure 3 shows the amount of colostrum consumed during the first 24 hours of life by pigs surviving to weaning and by pigs that died during the nursing period. Although these data do not necessarily indicate a cause-and-effect relationship, they are consistent with the concept that adequate colostrum consumption is critical for preweaning survival in swine.

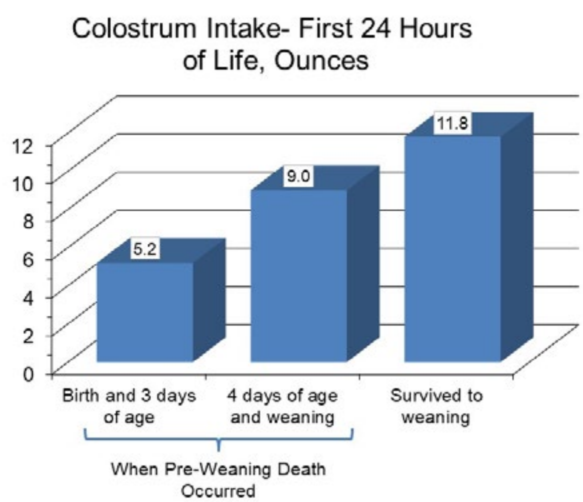

Figure 3. Amount of colostrum ingested during the first 24 hours of birth by pigs that either survived until or died prior to weaning at 25 to 31 days. (Data source: Devillers, Le Dividich, and Prunier 2011.)

Several factors can influence the amount of colostrum intake in pigs. In a recent study, Quesnel et al. (2023) demonstrated greater colostrum intake in heavy birth-weight pigs compared with smaller littermates. In contrast, an inverse relationship exists between pig colostrum intake and both the litter size and the cumulative birth interval (elapsed time between the birth of a particular pig and the first pig born). In other words, as litter size increases, the average colostrum intake of each pig born in the litter is decreased. Further, pigs born late receive less colostrum than do pigs born early.

The amount of colostrum consumed by a pig shortly after birth not only determines preweaning survival but may also have profound effects on future growth and reproduction. Vallet et al. (2015) noted that low colostrum intake on the first day of life was associated with a significantly reduced growth rate through 200 days of age in both gilts and barrows. Further, reproductive traits in females, including age at puberty and pigs born live through four parities, were positively associated with colostrum intake on the first day of life — in other words, the greater the colostrum intake as a newborn, the greater the reproductive performance as an adult.

Management to Decrease Preweaning Deaths of Pigs

Although the trait responds to selection, heritability for pig survival to weaning is low and on average is 0.04 (Knol, Leenhouwers, and van der Lende, 2002). That means that only 4% of the variation seen for preweaning survival of pigs among sows is due to genetics, with the other 96% being due to environment. Nevertheless, the females chosen to enter or remain in the breeding herd largely influence the number of preweaning pig deaths. Although the benefits of attending farrowing (decreased stillborn pigs, decreased preweaning deaths, and so forth) have been documented (Holyoake et al. 1995), this practice may not be feasible for many small pig farms, particularly those that farrow outdoors or in small huts. Thus, the small pig farmer should select females that are hardy, have good mothering ability, and have at least 12 well-spaced, functional teats. The farmer should choose sows that produce more modest size litters rather than sows that were developed to farrow extremely large litters and that consequently have numerous low birth-weight pigs. Highly prolific sows, along with suckling pigs, require considerable labor in more pristine facilities. Moreover, higher parity sows (those with seven or more parities) have greater preweaning death loss rates than lower parity sows (Koketsu, Takenobu, and Nakamura, 2006). On the farm, maintaining an average parity of 3.5 is recommended.

In general, gestating sows require a maintenance level of 5 to 6 pounds of feed daily. Rather than feeding a predetermined level, it is better to base the amount of feed offered on sow body condition score (BCS), a key indicator of management and animal well-being. On a five-point scale, a score of 3 is optimum (fig. 4) and indicates an appropriately fed sow.

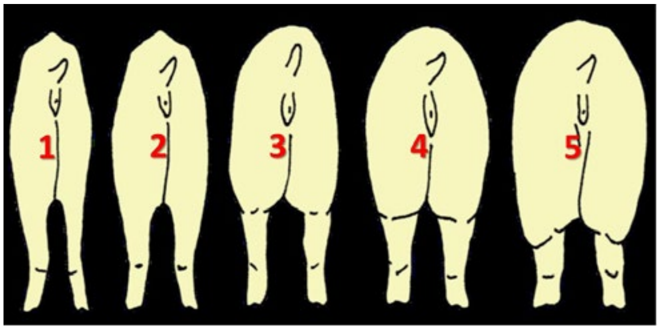

Figure 4. Body condition scale for sows: 1 = emaciated (shoulders, individual ribs, hips, and backbone visually apparent), 2 = thin (shoulders, ribs, hips, and backbone can be easily felt when pressure is applied by hand, 3 = ideal (shoulders, ribs, hips, and backbone can only be felt when pressure is applied by hand), 4 = fat (shoulders, ribs, hips, and backbone cannot be felt even when pressure is applied), and 5 = obese (fat deposits clearly visible). Photograph courtesy of the National Pork Board.

Emaciated and thin sows (BCS = 1 and 2, respectively) do not have the protein or energy stores necessary to support optimum pig growth and development. Emaciated sows need the maintenance level of feed plus 2 pounds (BCS = 1), and thin sows (BCS = 2) need the maintenance level plus 1 pound. Fat or obese sows (BCS = 4 and 5, respectively) may have greater fat deposition in the uterus and mammary glands, suffer more incidences of farrowing difficulties, and generally display higher preweaning death loss. Sows that are overfed during gestation also consume less feed during lactation than medium-conditioned or thin sows. Overfeeding during gestation negatively affects milk production and subsequent reproduction (Estienne et al. 2000). Gestating sows with a BCS of 4 or 5, should receive the maintenance level of feed daily minus 0.5 pounds or 1 pound, respectively. The direct economic impact of overfeeding sows can be substantial. For example, feeding a herd of 50 sows each day during gestation an extra 0.5 pounds to 1 pound of feed costing $240 per ton increases annual feed costs by $1,067 to $2,133.

When sows are fed as a group, invariably one animal becomes the "boss sow" and monopolizes feed resources. This sow overconsumes and becomes fat or obese. More timid subordinate sows do not consume enough feed and become too thin. Keeping all sows at a BCS of 3 is less difficult when sows are penned individually for feeding. At the very least, sows should be sorted into pens of animals with similar BCS and fed accordingly.

Farrowing Accommodations

Farrowing crates that limit sows to standing, sitting, and lying, are widely used in the commercial swine industry and generally increase pig survivability compared to pens that allow more freedom of movement (Glencorse et al. 2019). To some farmers, the increased survival of newborn pigs outweighs the potential compromise of sow welfare caused by confinement in farrowing crates. To others, especially those with animal welfare-driven production goals, the end (potentially lowering preweaning death loss) does not justify the means (confining sows in crates), and they employ alternative farrowing systems. Common examples of alternative farrowing systems include pasture (or "free-range") farrowing and farrowing huts.

In a pasture or free-range farrowing system, sows choose sites to construct nests in which to farrow. This is an option for many small pig farmers, yet it will likely result in greater pig deaths as the pigs are more exposed to the elements and the producers are less able to provide supplemental care. Other farmers with extensive pig farms elect to provide sows with farrowing huts. A farrowing hut is a small, roofed enclosure that is deep bedded with straw and allows sows to express normal maternal behavior, such as nest building. The amount of floor space in the farrowing hut is closely associated with pig survivability. Researchers from Iowa State University showed that pig survivability to weaning was 75% to 89% in farrowing huts with a floor space allowance of 37.5 square feet or less but increased to 92% to 94% when floor space allowance was 42 square feet or more (Honeyman and Roush 1997). The authors of that study suggested that guardrails inside the hut increase preweaning survival of pigs as well. Recently, Conrad et al. (2022) reported that the proportion of sows with at least one pig dying from overlay was significantly less for sows farrowing in ark metal huts (43%), such as the one shown in figure 5, compared with A-frame plywood (93%) or round polyethylene (86%) calf huts.

Figure 5. An example of an ark metal farrowing hut. Note the guardrails placed along the bottom of walls of the hut designed to provide pigs with protection from sow overlay. Photograph courtesy of Ayrshire Farm.

Regardless of whether sows farrow in crates or pens indoors or in nests or huts outdoors, newborn pigs require an ambient temperature of 95 to 100 F. With outdoor systems, bedding within the nest or hut and the warmth of the sow and littermates (huddling) maintain a suitable microenvironment for the pigs. With farrowing crates or pens, heat mats, or hanging heat lamps approximately 18 inches above pig sleeping areas provides a suitable temperature. Alternatively, in the case of pens, adding straw or other bedding materials will provide warmth to pigs.

Attending Farrowing

Pig farmers who are present when sows farrow and assist when necessary will generally decrease preweaning deaths by nearly one pig per litter (Holyoake et al. 1995). Attendance at farrowing allows farmers to do four things: (1) remove the placenta from around pigs and clear airways to prevent suffocation, (2) towel dry and position pigs under a heat lamp immediately after birth to prevent chilling (fig. 6), (3) prevent savaging of pigs by the sow — most likely one with its first litter, and (4) ensure that pigs consume an adequate amount of colostrum.

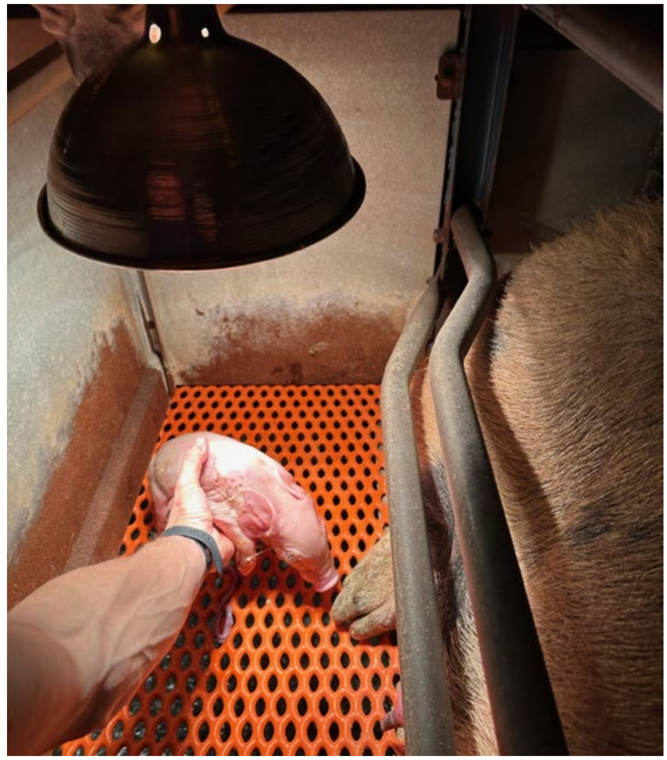

Figure 6. Being present when a sow farrows allows placement of newborn pigs under a heat lamp. Photograph by R. Tyler Niblett.

Stillbirth rates increase with increasing litter size, duration of farrowing, and interval between births. Attendance at farrowing provides the farmer with the opportunity to manually deliver pigs when the birth interval becomes longer than 40 minutes. The duration of farrowing and the interval between pigs can be decreased by administering 0.5 milliliter (10 international units) of oxytocin intramuscularly, but this practice has been shown to increase stillborn rate (Hill et al. 2022). Oxytocin for obstetrical use requires a veterinarian prescription, and producers should consult the herd veterinarian for best practices.

Recently, Tucker, Petrovski, and Kirkwood (2022) demonstrated that intraperitoneal injection of 15 milliliters of 0.9% sterile saline warmed to 113 F improved body temperature, colostrum intake, and survival in pigs with low birth weights. For the injections, pigs were held head down by their hocks and the saline administered using a 20-milliliter syringe and a ½ inch-long, 20-gauge needle (fig. 7). This procedure is a potential option to increase body temperature in chilled pigs.

Figure 7. For proper intraperitoneal injection, baby pigs are held head down. The injection site is as shown. Photograph by R. Tyler Niblett.

To provide more opportunity for the farmer to be available to attend farrowing, the process can be induced (Monteiro et al. 2022). Injection of prostaglandin products such as dinoprost tromethamine (10 milligrams intramuscularly) results in farrowing in approximately 31 hours in most treated sows. Thus, the drug could be administered at 8 a.m. on one day, with farrowing likely occurring during the afternoon of the next day. It is extremely important that prostaglandins not be administered earlier than three days prior to the normal predicted farrowing or pig viability and survivability will be compromised. Thus, excellent records must be maintained for (1) the average length of gestation for the animals on a specific farm, and (2) the breeding and projected farrowing dates for each animal. As an example, for a herd with an average gestation length of 115 days, prostaglandin should not be administered before day 112 of gestation. Like oxytocin, prostaglandins for obstetrical purposes require a prescription, and farmers are encouraged to consult their veterinarians for assistance.

Increasing Colostrum Intake

Pig farmers can increase the likelihood of newborn pigs consuming the minimum level of colostrum (9 ounces) within 24 hours of birth by using one of four methods: (1) assisting pigs onto the teat to suckle, (2) providing supplemental colostrum using a bottle with a Pritchard teat (fig. 8) or a syringe with or without a tube, (3) cross-fostering, and (4) split-suckling. All of these require more labor in the farrowing house. Regardless of method, pigs must consume the colostrum within 24 hours after birth. During this period, the gastrointestinal tract is “open” and large molecules such as immunoglobulins can be absorbed. After 24 hours, the gut is “closed,” blocking this absorption.

Figure 8. A Pritchard teat, available at most farm supply dealers, attached to a soda bottle for feeding colostrum to pigs. Photograph by R. Tyler Niblett.

The colostrum used for supplemental feeding of a pig can be collected from the sow by milking one or more teats. Colostrum can be collected, frozen, and stored for six months. It can be thawed in warm water, but temperatures should not exceed 140 F or immunoglobulins may be inactivated. Commercial colostrum replacers and supplements are available. Colostrum replacers have a higher level of immunoglobulins than do colostrum supplements; however, neither is as effective as colostrum collected from the sow.

The newborn pig’s stomach capacity is approximately 1.7 ounces per 2.2 pounds body weight. Therefore, pigs of differing body weight require a different number of supplemental feedings to consume 9 ounces of colostrum in 24 hours. For example, a 2-pound pig, with a stomach capacity of 1.5 ounces, would require five to six feedings. In contrast, a 3.5-pound pig, with a stomach capacity of 2.7 ounces, would require three to four feedings. Wait an hour between feedings if possible.

Cross-fostering is the practice of moving pigs from a sow with a large litter to a sow with a smaller litter to equalize pig numbers among sows. This allows equitable access to colostrum among pigs. However, when groups of sows produce more pigs than they have teats to support, the technique is limited. Pigs should be cross-fostered as soon after birth as possible, and it is better to transfer the larger pigs in a litter. Only cross-foster pigs to sows that are still likely to be producing colostrum and are less than 12 to 16 hours after farrowing. Using prostaglandins (previously discussed) to induce a synchronous farrowing among appropriate sows is an effective tool to better facilitate cross-fostering.

The split-suckling technique involves the temporary removal of larger piglets from the udder for several milking events. This provides smaller pigs the opportunity to consume colostrum.

Preventing Disease

Although most preweaning death losses are not due to disease but rather noninfectious causes such as overlay, deaths due to disease still occur. Disease challenges are common and possibly deadly, particularly if coupled with other stressors, such as inadequate colostrum intake or cold environments. As previously discussed, ingestion of colostrum is critical for pig survival. Moreover, when pig diseases are considered, the adage "an ounce of prevention is worth a pound of cure" is apropos.

Vaccinating sows prior to farrowing will increase transfer of passive immunity from dam to pigs. Consult a veterinarian to customize a vaccination protocol specific to your farm. The protocol may also include vaccinations that must be administered to pigs at initial processing (usually 24 hours or so after farrowing). Also consider treating sows for internal and external parasites prior to farrowing.

Maintaining good hygiene in the farrowing accommodations, be it a hut in the field or a room with pens or crates in a barn, will help prevent disease and decrease preweaning death loss. To prevent high levels of preweaning death loss, a new group of pigs should have limited or no exposure to the pathogens of their predecessors. Methods of reducing exposure of pigs to pathogens include using an "all-in, all-out" rather than continuous flow system, cleaning the facility (power-washing and disinfecting a farrowing room or removing old bedding and relocating farrowing huts), having a long idle time or period of vacancy between farrowing groups, and washing sows before farrowing.

Iron is used to produce hemoglobin, a substance in red blood cells critical for carrying oxygen to the various tissues of the body. Pigs are born with very little stored iron, and sow colostrum and milk have low iron concentrations. Thus, pigs are prone to developing anemia, characterized by rough hair coats, pale mucous membranes, and poor growth. To prevent anemia, farmers should provide pigs with intramuscular injections of 100 to 200 mg of iron (usually in the form of iron dextran) within 24 to 72 hours after farrowing. It may be valuable to retreat pigs with iron at 17 to 18 days of age, particularly if weaning occurs at older ages (equal to or greater than 28 days). This is important, regardless of the type of farrowing accommodation pigs are born in.

Traditionally, pigs raised outdoors were thought to not need iron treatment, because they could meet requirements by eating soil. However, a study by Szabo and Bilkei (2002), demonstrated that treatment of pigs raised outdoors with 150 mg iron dextran resulted in greater preweaning survival rates and weaning weights compared to untreated control pigs (table 2).

Table 2. Hemoglobin levels, weaning weight, morbidity, and mortality in pigs raised outdoors and treated with iron dextran.

	Control	**Iron-treated[1]**	***P*[2]**
Number of pigs	2,344	2,347	---
Hemoglobin, grams per deciliter	5.1 ± 1.2	10.1 ± 1.4	< 0.01
Weaning weight, pounds	24.1 ± 0.04	26.6 ± 0.04	0.05
Morbidity[3], %	15.9	8.9	< 0.01
Mortality, %	16.4	9.1	< 0.01

Source: Szabo and Bilkei, 2002.

[1]150 mg iron dextran.

[2]Values less than or equal to 0.05 are statistically significant.

[3]Reduced feed intake, rough hair coat, wrinkled skin, diarrhea, fever, joint swellings, or signs of respiratory illness.

Summary

- The percentage of live-born pigs that die before weaning continues to increase in the U.S., and the potential exists to increase animal welfare, sow reproductive efficiency, and farm profitability.
- Sows lying on a pig (called overlay) is the most common cause of preweaning death, followed by starvation and scours, and most pig deaths occur during the first 72 hours after birth, with the first 24 hours being most critical.
- With increasing litter size, the proportion of pigs born at a low birth-weight increases, and these pigs are very susceptible to preweaning death.
- For most small pig farms, breeding females should be from breeds or lines that are hardy, have good mothering ability, possess at least 12 functional teats, and produce more modest size litters.
- Attendance at farrowing generally decreases pre-weaning deaths by an average of nearly one pig per litter.
- Preventing pigs from becoming chilled or exposed to disease-causing pathogens will decrease preweaning mortality.
- Consumption of adequate amounts of colostrum soon after birth is critical for pig survival and future performance.
- Treat pigs, even those raised outdoors, with iron shortly after birth to prevent anemia.

References

Conrad, L., L. Aube, E. Heuchan, S. Conte, R. Bergeron, and N. Devillers. 2022. "Effects of Farrowing Hut Design on Maternal and Thermoregulatory Behaviour in Outdoor Housed Sows and Piglets." *Applied Animal Behaviour Science* 251:105616. https://doi.org/10.1016/j.applanim.2022.105616.

Devillers, N., J. Le Dividich, and A. Prunier. 2011. "Influence of Colostrum Intake on Piglet Survival and Immunity." *Animal* 5:1605-12.

Estienne, M. J., A. F. Harper, C. R. Barb, and M. J. Azain. 2000. "Concentrations of Leptin in Serum and Milk Collected from Lactating Sows Differing in Body Condition." *Domestic Animal Endocrinology* 19:275-80.

Glencorse D., K. Plush, S. Haze, D. D'Souza, M. Hebart. 2019. "Impact of Non-confinement Accommodation on Farrowing Performance: A Systematic Review and Meta-analysis of Farrowing Crates Versus Pens." *Animals* 9:957. https://doi.org/10.3390/ani9110957.

Hill, S. V., M. del Rocio Amezcua, E. S. Ribeiro, T. L. O'Sullivan, and R. M. Friendship. 2022. "Defining the Effect of Oxytocin Use in Farrowing Sows on Stillbirth Rate: A Systematic Review with a Meta-analysis." *Animals* 12(14):1795. https://doi.org/10.3390/ani12141795

Holyoake, P. K., G. D. Dial, T. Trigg, and V. L. King. 1995. "Reducing Pig Mortality Through Supervision During the Perinatal Period." *Journal of Animal Science* 73(12):3543-51 https://doi.org/10.2527/1995.73123543x.

Honeyman, M. S., and W. B. Roush. 1997. Pig Crushing Mortality by Hut Type in Outdoor Farrowing. https://lib.dr.iastate.edu/handle/20.500/12876/91016.

Knol, E. F., J. I. Leenhouwers, and T. van der Lende. 2002. "Genetic Aspects of Piglet Survival." *Livestock Production Science* 78(1):47-55.

Koketsu, Y., S. Takenobu, and R. Nakamura. 2006. "Preweaning Mortality Risks and Recorded Causes of Death Associated with Production Factors in Swine Breeding Herds in Japan." *Journal of Veterinary Medical Science* 68(8): 821-6.

Lay, D. C., Jr., R. L. Matteri, J. A. Carroll, T. J. Fangman, and T. J. Safranski. 2002. "Preweaning Survival in Swine." *Journal of Animal Science* 80(E-supplement 1):E74-86.

MetaFarms, Inc. and National Pork Board. 2022. Production Analysis Summary for U.S. Pork Industry: 2017-2021. Des Moines, Iowa: National Pork Board. https://porkcheckoff.org/research/production-analysis-summary-for-u-s-pork-industry-2017-2021/.

Monteiro, M. S., B. B. D. Muro, A. P. Poor, D. F. Leal, R. F. Carnevale, M. P. Shiroma, G. W. Almond, C. A. P. Garbossa, A. M. Moreno, C. H. C. Viana. 2022. "Effects of Farrowing Induction with Prostaglandins on Farrowing Traits and Piglet Performance: A Systematic Review and Meta-analysis." *Theriogenology* 180:1-16. https://doi.org/10.1016/j.theriogenology.2021.12.010.

Quesnel, H., C. Farmer, and N. Devillers. 2012. “Colostrum Intake: Influence on Piglet Performance and Factors of Variation.” *Livestock Science* 146:105-14.

Quesnel, H., R. Resmond, E. Merlot, M.-C. Père, F. Gondret, and I. Louveau. 2023. “Physiological Traits of Newborn Piglets Associated with Colostrum Intake, Neonatal Survival, and Preweaning Growth.” *Animal* 17:100843. https://doi.org/10.1016/j.animal.2023.100843.

Rehfeldt, C., and G. Kuhn. 2006. “Consequences of Birth Weight for Postnatal Growth Performance and Carcass Quality in Pigs as Related to Myogenesis.” *Journal of Animal Science* 84 (E-supplement): E113-23.

Szabo, P., and G. Bilkei. 2002. “Iron Deficiency in Outdoor Pig Production.” *Journal of Veterinary Medicine Series A*, 49:390-1. https://doi.org/10.1046/j.1439-0442.2002.00448.x.

Tucker, B. S., K. R. Petrovski, and R. N. Kirkwood. 2022. “Neonatal Piglet Temperature Changes: Effect of Intraperitoneal Warm Saline Injection.” *Animals* 12:1312. https://doi.org/10.3390/ani12101312.

Vallet, J. L., J .R. Miles, L. A. Rempel, D. J. Nonneman, and C. A. Lents. 2015. “Relationships Between Day One Piglet Serum Immunoglobulin Immunocrit and Subsequent Growth, Puberty Attainment, Litter Size, and Lactation Performance.” *Journal of Animal Science* 93: 2722-29.

Vande Pol, K. D., A. F. Tolosa, C. M. Shul, C. B. Brown, S. A. S. Alencar, and M. Ellis. 2020. “Effect of Method of Drying Piglets at Birth on Rectal Temperature over the First 24 h After Birth.” *Translational Animal Science* 4:1-12. https://doi.org/10.1093/tas/txaa183.

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