Diagnosis and calculation of economic impact of incorrect pharmacologic dosage of zinc oxide supplementation aided by record analysis of nursery performance

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Summary

Piglets weaned from a 1400-sow unit were sent to three different producers in loads of 600 pigs per week. Production records indicated poorer performance and a greater problem with *Escherichia coli* diarrhea in one herd compared to pigs from the other two (394 g versus 436 g of average daily gain (ADG) and 8.0% versus 0.96% mortality for the case herd and other two herds, respectively). No environment and management differences on the sow farm of origin were found to explain the performance differences in these three groups of pigs.

When diet formulations were reviewed, it was discovered that the first two diets fed to the weaned pigs in the case herd contained 612 ppm zinc from zinc oxide, instead of the specified 3000 ppm. Comparable diets for the pigs in the other two locations did contain 3000 ppm zinc. The diet formulation error was corrected, and performance of the next groups of pigs improved. Research has shown that when zinc oxide is added to the weaned pig's diet at a zinc concentration of 3000 ppm rather than at the nutrient requirement (100 ppm), ADG improves and occurrence of diarrhea may diminish. This case study demonstrated the value of closeout records in determining the economic impact of the diet formulation error, which was calculated to be a loss of US$3.13–US$5.88 per weaned pig.

Keywords: swine, zinc, growth, diarrhea, *Escherichia coli*

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All-in–all-out (AIAO), multiple-site swine production has broadened the opportunity to collect accurate growth performance and financial data from distinct groups of pigs. These records, commonly referred to as "closeouts," provide an educational tool for both the producer and the veterinarian. In fact, we believe that the ability to obtain accurate performance records in multiple-site production may be associated with a financial advantage as great as or greater than the advantage derived from improved disease control in these facilities. An example of this financial advantage will be demonstrated in this case study, in which closeout information from the affected group of pigs was compared to peer group data to calculate the economic impact of a nutritional error.

Performance evaluation, or benchmarking, is commonly used in manufacturing industries to identify areas where efficiency and quality can be improved.[1] Benchmarking has been commonly used in the swine industry to evaluate performance in the breeding herd,[2,3] but rarely in the growing pig production phase. However, we are now able to benchmark production records by comparing performance of different groups of pigs in the same facility, or even by making standardized comparisons in different facilities.

This case illustrates how benchmarking records were used in addition to traditional methods to aid in diagnosis and quantification of the economic impact of an outbreak of enteric disease caused by hemolytic *Escherichia coli* and associated with incorrect pharmacologic zinc oxide concentrations in the nursery diet.

Case description

The affected farm receives about 600 weaned pigs (16 ± 3 days of age) once per week for 3 consecutive weeks out of every 8 weeks. All pigs originate from a single 1400-sow farm. The entire nursery facility is emptied before delivery of the next 1800 pigs. For the purposes of this paper, a "group" will refer to 1 week's delivery of approximately 600 pigs and a "cycle" will refer to the 3 consecutive weekly deliveries of approximately 1800 pigs.

The nursery facility was remodeled from a 300-sow, farrow-to-finish farm in September 1998. Existing nurseries were left unchanged, farrowing facilities were converted to nurseries, and finishing facilities were expanded for use as nurseries. The present nurseries have plastic or metal slotted floors over shallow pull-plug pits, and are power-ventilated by a negative pressure system. Nursery pigs are housed on one site and then moved to multiple finishing sites. Prior to the conversion, annual records for the wean-to-finish operation revealed nursery mortality of 2.1% and average daily gains (ADG) in the range of 380–400 g.

Closeout records for each group of 600 pigs weaned from the sow farm included starting weight, death loss, treatments, feed disappearance, and ending weights. These records were submitted to a veterinarian, who entered them into a database

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to compare the performance of these pigs to that of other groups raised on the same farm, and to the performance of other groups of pigs obtained from the same source in the same time period, and raised in two other locations.

The performance records for the second cycle of pigs from the sow farm indicated that pig performance in the case herd was inferior to that of pigs raised in the other two locations during the same time period. Because the three groups of pigs had the same genetic background, we investigated environment, nutrition, and management factors as possible causes for the performance difference. As the performance of other pigs from the same sow farm was excellent, it seemed unlikely that the source of the problem was an infectious disease originating from the sow herd.

Diagnostic history

The first cycle of pigs, arriving in November 1998, were the first from a newly populated sow farm, and their weaning ages and weights were considerably superior to those of subsequent groups. Because of their heavy weaning weights, these pigs required very little of the pelleted SEW and Transition diets (Table 1) and their performance was excellent.

Shortly after receiving the second cycle of 1804 pigs, the producer became concerned about diarrhea, poor performance, and high morbidity and mortality in the newly weaned piglets, and consulted his veterinarian. Environmental parameters, including environmental temperature, humidity, floor space, feeder space and adjustment, water quantity, and air quality, were deemed adequate and appropriate for the size and age of the pigs. A properly collected water sample processed by the laboratory less than 30 hours after collection revealed no coliform bacteria.

Two acutely ill pigs and two chronically ill pigs were necropsied, and tissues were sent to a diagnostic laboratory as well as the veterinarian's in-house laboratory. Gross necropsy findings included watery diarrhea with a pH > 8, which involved both small and large intestines. The more debilitated pigs were dehydrated. Microbiology results revealed a hemolytic *E. coli* resistant to most approved OTC and prescription antibiotics, but sensitive to florenfenicol and amikacin. Hemolytic *E. coli* from the two acutely ill pigs was PCR positive for K88 pilus, heat labile toxin, and heat stable toxin b, and negative for F18 pilus stable and Shigella-like toxin IIe. Hemolytic *E. coli* from the two older, chronically ill pigs was also positive for K88 pilus. Histopathology results were consistent with the diagnosis of *E. coli* infection. Electron microscopy and indirect fluorescent antibody screening did not identify viral pathogens such as porcine coronavirus or rotavirus.

Diarrhea began 7–10 days after the pigs were weaned, and subsided during the fourth week after weaning. Almost all mortality occurred in weeks 2, 3, and 4 after pigs entered the facility (Figure 1). The onset of diarrhea coincided with the switch from the pelleted Transition diet to a meal diet ("Phase 2 diet") manufactured on the farm (Table 1).[4]

Because diarrhea occurred when the Phase 2 diet was fed, the formulation of this diet was changed between the second and third cycles of pigs. Spray-dried blood meal was replaced by select menhaden fishmeal in an attempt to reduce the iron content of the diet and create a less suitable intestinal environment for *E. coli* growth.[5] All ingredient sources and concentrations in the Phase 2 diet were reviewed and found to meet the desired specifications. Finally, an acidifier was added to the diet in an attempt to lower the pH of the gut and make it less suitable for *E. coli* proliferation.[5] The Transition diet was also modified by removing the blood meal and adding an acidifier.

Diarrhea was observed in the third cycle of pigs 7–10 days after they arrived in the herd, and growth performance and mortality were similar to those of the first two groups of pigs.

As the *E. coli* isolated from the pigs necropsied during the second cycle was sensitive to florenfenicol, a prescription was issued for extra-label use of a bovine-approved product, and any third cycle pigs showing clinical signs were treated subcutaneously with a dose of 40 mg per kg. A group of live piglets was submitted to a diagnostic laboratory. A hemolytic *E. coli* was recovered, with an antibiotic sensitivity pattern similar to that of the *E. coli* recovered from the second cycle pigs. Another environmental review was performed, and again all parameters were deemed adequate.

Nursery closeout information from the second and third cycles indicated that performance for this producer's pigs was much inferior to that of pigs from the same sow herd raised by the other shareholder groups (Table 2).

When changes in the Phase 2 diet had no effect on performance, the two pelleted diets fed immediately after weaning and prior to the Phase 2 diet were re-evaluated. The first diet was a complex SEW diet containing 1.6% lysine. An average of only 0.5 kg of this SEW diet was provided per pig. The second diet, a transition diet containing 1.55% lysine, was budgeted at 1.8 kg per pig.

Analysis revealed an error in the formulation of each of these diets. The specifications called for 2700 g per ton (2970 ppm) zinc from zinc oxide, but both diets contained only 612 ppm, due to a mathematical error made by the feed supplier when converting kg to lb. The discovery of the formulation error was made between the second and third weeks of delivery, and the diets were reformulated correctly for the fourth cycle of pigs. Pigs in the fourth cycle still experienced some clinical signs of diarrhea and there was a 1.98% death loss attributed to *E. coli*. However, changing the source of the pelleted diets dramatically improved the performance of these pigs and appeared to improve their responsiveness to treatment when the disease was present.

Table 1: Zinc concentration from zinc oxide and feed budgets in the case herd diets. Diet formulations are similar to those listed in the 1997 Kansas State Nutrition Guide[25]

Diet	Feed budget, kg/pig	Acid zinc concentration, ppm Specified	Actual
Segregated early weaning	0.45	2970	612
Transition	1.80	2970	612
Phase 2	5.40	2000	2000
Phase 3	20.00	165	165

Figure 1: Comparison of cumulative nursery deaths

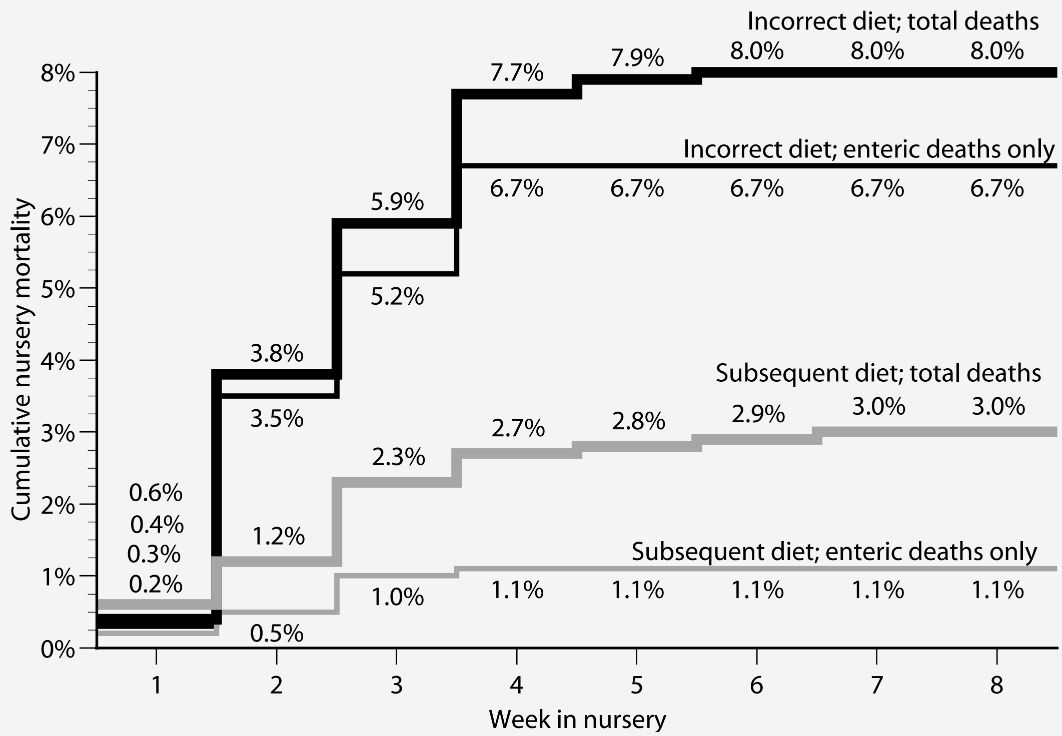

Table 2: Impact of pharmacologically incorrect zinc oxide concentration on pig performance and medication cost

	Pigs received in cycles 2 and 3		Pigs received in cycles 5 and 6	
	case herd	**peer herds**	**case herd**	**peer herds**
Number of groups	6	10	6	10
Pigs per group	602	615	681	701
Total pigs	3613	6154	4085	7009
Zinc concentration, ppm*	612	2970	2970	2970
Mortality	8.00%	0.96%	3.00%	2.22%
Initial weight (kg/pig)	5.24	5.19	5.04	5.04
Final weight (kg/pig)	23.5	25.5	23.3	22.0
ADG, g/d	394	436	396	367
Medication cost:				
$/group	$131.76	$60.00	$21.25	$37.97
$/pig	$.021	$0.10	$0.03	$0.05

*Dietary zinc concentration from zinc oxide

Between the fourth and fifth cycles, cleaning and disinfecting procedures were intensified. The pigs in cycles five and six showed no signs of diarrhea and the mortality rate decreased (Table 2).

During the period when zinc oxide was provided at 612 ppm instead of 3000 ppm, the client experienced 8.0% death loss, compared to death loss of only 0.96% for other shareholders (Table 2). When the appropriate pharmacologic concentration of zinc oxide was added to the diet, death loss decreased dramatically for the next groups of pigs raised in the same nursery facility, and their performance was comparable to that of groups of pigs raised in the other facilities during the same time frame.

Calculating economic impact

The veterinarian played an important role for this client by calculating the economic loss caused by the error in feed formulation. As no control group is available for retrospective data, it may be difficult to select the appropriate peer group to use as the standard for benchmarking and making economic calculations. Because of this difficulty, two economic calculations were performed in this case:

- The data from the period when 612 ppm zinc oxide was fed were compared to data for pigs received by the other shareholders during the same time period (Table 3); and
- The data from the period when 612 ppm zinc oxide was fed was compared to the next two cycles of pigs through the same nursery after the zinc concentration was increased to 2970 ppm (Table 3).

A partial-budget economic analysis was performed to calculate the economic loss.[6] This calculation included the cost of additional death loss, medication, labor, lost performance, lost profit potential from the dead pigs, and increased veterinary consultation and diagnostics (Table 3).

Table 3: Calculation of lost profit due to error in feed formulation (data from Table 2 used for calculations).

	Cycles 2 and 3 in case herds compared to… cycle 2 and 3 in peer herds	Cycles 2 and 3 in case herds compared to… cycles 5 and 6 in case herd
Extra dead pigs in cycles 2 and 3 of case herd	254	181
Cost factors for partial budget analysis		
a. Additional death loss (Cost invested in a dead pig × number dead) cost of weaned pig (includes investment in sow farm) + diet fed to pigs that died + facility cost = \$32.89 + \$1.00 + (8 days × \$0.10/day) = \$34.69	\$8811.26	\$6266.75
b. Performance loss (ADG of comparison group–ADG case groups) × days on feed × number of pigs × market price = (436–394 g/d) × 50 days × 3613 pigs × \$0.88/kg	\$6677.82	\$0.00
c. Lost profit potential from increased mortality Additional pigs lost × (market price–cost of production) = number of pigs × (\$0.88/kg–\$0.77/kg) × 113.8 kg	\$3179.57	\$2258.13
d. Additional medication cost Difference in medication costs per group × number of groups = \$71.76 × 6 groups or \$110.51 × 6 groups	\$430.56	\$663.06
e. Additional labor cost (Extra hours of labor × value of labor) × number of groups = (8 hours x \$10/hr) × 6 rounds	\$480.00	\$480.00
f. Extra diagnostics and veterinary fees Diagnostics cost = \$756.30 Consultation cost = \$900.00	\$1656.30	\$1656.30
Performance cost difference: Total for 3613 pigs	**\$21,235.51**	**\$11,324.23**
Per pig placed in the nursery	\$5.88	\$3.13

The case herd and two other facilities (peer herds) received weaned pigs from the same sow farm. Groups of approximately 600 pigs were received by the case herd for three consecutive weeks in an 8-week cycle. The other two facilities received groups of 600 pigs on the other 5 weeks of the cycle.

Additional death loss was calculated as the cost invested in a dead pig times the number of pigs that died. For this situation, the cost of a weaned pig was \$32.89. This value includes the \$28 paid by the producer on the day pigs were received plus \$4.89 per pig invested in the sow farm. This additional investment is the cost of the producer's original investment in the sow farm amortized over a 10-year period. The other costs incurred in a dead pig included cost of the diet consumed by the pig before it died and the facility cost for the time that the pig spent in the nursery before dying.

Lost performance cost was calculated as the difference in average daily gain from the expected level of gain × the number of pigs and days that they were in the nursery. Finally, this value was multiplied by the market price for the pigs to determine the economic value of the lower weight gain. No consideration was given to the fact that decreased weight gain may extend into the finisher phase.

Calculation of the cost of death loss is not complete unless consideration is given to the lost profit potential of not having those pigs available. The calculation is derived from determining net profit per pig × the number of pigs that died above the expected number.

Calculations of the additional labor and medication costs were possible because the producer kept records of injections and increased labor time associated with treating and managing the pigs. Diagnostic and veterinary costs were calculated from bills paid by the producer.

The total cost of the diet formulation error was \$11,324 when compared to subsequent groups produced through the same nursery facility, or \$21,236 when compared to pigs raised by the other producers receiving pigs from the same sow farm during the same time period. These costs equalled \$3.13–\$5.88 per pig entering the nursery.

Discussion

Although this was not a scientifically controlled research trial, there was a striking difference in mortality of the piglets compared with either peer group from the same sow farm. This suggests that dietary zinc oxide might be useful pharmacologically for preventing mortality associated with *E. coli*. Subsequent performance of other shareholder's pigs was inferior to that of the original performance of their pigs. This may have been because the early groups entered the nursery in the winter and spring, whereas later groups entered during the humid summer months. Another possible reason for the superior performance of the original groups was that they were placed in new or newly remodeled facilities that had not had a chance to build up environmental pathogens (laymen commonly refer to this as the "honeymoon period"). Although pig performance in the case herd was considerably poorer than that for other shareholders during the time when the lower zinc oxide concentration was fed, it was better than performance for other shareholders during the subsequent performance period. We believe this provides further evidence that the zinc oxide concentration was affecting performance in the case herd.

The dietary nutrient requirement of zinc in the newly weaned pig is 100 ppm.[7] However, feeding higher concentrations of zinc (3000 ppm) from zinc oxide in the diet for the first 14–21 days after weaning has been shown to improve daily gain whether *E. coli* diarrhea is present[8,9] or not.[10–14] In a series of experiments, Woodworth, et al.,[15] confirmed earlier work of Hahn and Baker[10] showing that the oxide form of zinc was more effective in producing the growth-promotion response than zinc sulfate or a zinc amino acid complex. Woodworth, et al.,[16] also discovered that the source of zinc oxide, although important for bioavailability,[17] did not influence the pharmacologic growth-promotion response.

Other researchers also have demonstrated that high concentrations of zinc oxide can reduce occurrence of diarrhea in pigs[18,19] and humans.[20] The mode of action for zinc oxide in the control of *E. coli* is not fully known. Kasahara and Anraku[21] suggested that zinc ions react with specific residues of bacterial dehydrogenases and interfere with the respiratory chain of the *E. coli*. In a challenge study, adding 2500 ppm of zinc from zinc oxide to the diet prevented post-weaning diarrhea without affecting the numbers of *E. coli* excreted in the feces.[22] In another challenge study, high concentrations of zinc from any of four zinc oxide sources reduced the occurrence of *E. coli* diarrhea without affecting fecal shedding of the *E. coli*.[23] In these experiments, a high prevalence of diarrhea occurred in pigs that did not receive high concentrations of zinc oxide when challenged. Other research demonstrated that supplementing starter diets with 3000 ppm zinc oxide reduced the degree of bacterial translocation from the small intestine to the ileal mesenteric lymph node.[24] As noted in a review by Woodworth,[25] these experiments suggest that zinc does not reduce the number of *E. coli* present, but interferes with the ability of the *E. coli* to produce a toxic environment in the gut.

Implications

- Incorrect pharmacologic dietary zinc oxide concentration may be associated with increased mortality in weaned pigs.
- Closeout records can facilitate diagnosis of errors in the formulation of diets.
- Closeout records can be used to quantify the economic impact of impaired growth performance and increased mortality.

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