RESEARCH REPORT

ANIMAL SCIENCE

Title: Effects of supplementing transition sow diets with 3 levels of zinc on pre-wean mortality and lifetime productivity of pigs under commercial rearing conditions - **NPB#18-036**

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revised

Industry Summary: Industry-wide, pre-weaning mortality has increased from about 17.7% in 2012 to 22.3% in 2017, especially among pigs < 1 kg in birthweight. Supplementing zinc to gilts from day 85 of gestation until farrowing increased survival of pigs by decreasing stillbirth and pre-weaning mortality. However, there are multiple reasons why this intervention needs testing; the data were collected in a small research farm, there are no data on the impact of zinc supplementation on survival of pigs born from sows across different parities, at current industry number of pigs born, or at commercial management practices such as cross-fostering. Therefore, our project studied the impact of additional zinc in late gestation on pre-weaning mortality at a commercial sow farm following the mentioned criteria. At the end of gestation (day 75), sows (n = 339) were fed diets supplemented with zinc at current farm practice (275 mg/d) and two additional levels (577 or 1,154 mg/d). We observed a decrease in pre-weaning mortality of piglets from sows supplemented with zinc intermediate (13.2%) and high levels (12.2%) when compared with the current practice (15.0%). Among piglets of < 1 kg birthweight, pre-weaning mortality was least in piglets from dams supplemented zinc at high zinc (28.1%), followed by intermediate (36.4%), and highest in the current practice (38.3%). The decrease in pre-weaning mortality of zinc supplemented dams was not affected by the incidence of < 1 kg pigs. Likewise, surviving pigs from zinc supplemented dams had market weights and carcass composition that were not different from other pigs. These observations suggest that piglets saved from the intervention are likely to have similar productivity. A partial budget calculation suggests a decrease in market pig cost by $ 1.5 when sows are supplemented with zinc that cost $ 0.3. In conclusion, transition sow diets supplemented with zinc during the last term of gestation increase survival and productivity of pigs.

Key Findings:

1. Feeding additional zinc (275 mg/d vs. 577 or 1,154 mg/d) in late gestation (day 75) decreased pre-weaning mortality (15.0 vs. 13.2 and 12.2%; respectively).
2. The intervention was effective primarily among low birthweight pigs (< 1 kg) and resulted in about 0.3 additional pigs saved.
3. Pigs from sows fed additional zinc had postweaning growth performance and carcass characteristics that were not difference from other pigs.
4. Feeding additional zinc did not change birthweight or litter weight distribution.

Keywords: include at least 5 keywords
Birthweight, pre-weaning mortality, transition sow diet, zinc

Scientific Abstract

Stillbirths and pre-weaning mortality are the primary cause of suboptimal survival. We tested a dietary intervention to decrease stillbirth and pre-weaning mortality by feeding zinc at the end of gestation. Starting on day 75 of gestation, gilts and sows (n = 333) were assigned randomly to one of three dietary treatments: **1) Control** – sows fed a corn-soybean meal-based diet to supply 275 mg/d of zinc from Zn as 175 ppm diet $ZnSO_4$ and 100 ppm AvailaZn™ (CON); **2) Intermediate** – to supply 577 mg of zinc/d from Control + 240 ppm supplemental Zn as $ZnSO_4$ (INT); and **3) High** – to supply 1,154 mg/d zinc from Control + 470 ppm supplemental Zn as $ZnSO_4$ (HI). At about day 75 of gestation, sows received dietary treatments until the day before farrowing. At farrowing, individual piglets were weighed and identified with an ear-tag. Cross-fostering events were kept within dietary treatments at the current farm management procedures. At weaning, pigs were weigh and counted to calculate average daily gain. The difference between pigs weaned and born alive was recorded as pre-weaning mortality. The statistical model considered the fixed effects of treatment and the random effects of sow parity after data were tested for outliers, equal variances, and normal distribution. There were no noticeable deleterious effects of additional dietary zinc levels on sow feed intake or health. There were no differences ($P > 0.05$) across treatments in total pigs born, born alive, or stillborn. Mortality of low birthweight pigs was greater (38.3%) than normal birthweight pigs (11.4%). Pre-weaning mortality decreased with greater zinc supplementation CON (15.0%), INT (13.2%), and HI (12.2%), while the magnitude of decrease was greatest among low birthweight pigs than normal weight at greater zinc supplementation CON (38.3%), INT (36.4%), and HI (28.1%). This decrease in pre-weaning mortality does not appear to be related to the incidence of low birth weight pigs because this was lower ($P < 0.05$) for sows consuming the intermediate diet (11.6%) when compared to sows fed CON (15.3%) and HI (15.1%). Despite differences in birth weight and pre-weaning mortality, there were no differences in individual piglet gain or weaning weight across treatments. A subset of pigs (n = 450, n ≈ 150/treatment) were selected at weaning to follow post-weaning performance. There were no differences on the final body weight, days to market or carcass characteristics of pigs born from sows on supplemental zinc compared to the current program. In conclusion, zinc for gestation-lactation transition sows may be at greater requirement to decrease pre-weaning mortality but the specific mechanisms of action are still unknown.

Introduction

The total number of pigs born per litter increased from an estimated industry average of 9.1 pigs per litter in 1959, to a modern industry average of 13.9 pigs per litter (Douglas et al., 2014). The increase in total pigs born and concomitant increase in observed pre-weaning mortality represents an unacceptable welfare issue for young pigs and a lost opportunity to further reduce the carbon footprint of modern pork production systems. Therefore, if pork producers could reduce pre-weaning mortality, more pigs could enter the food chain using fewer resources already invested in sows. The increase in pre-weaning mortality in larger litters is a consequence of an increase in the variability of birthweight with low birthweight pigs having greater pre-weaning mortality than littermates of heavier body weight (Zeng et al., 2019). This increase in variability of birthweight has been attributed to *in utero* growth retardation because pig fetuses compete for resources such as space and nutrients (Foxcroft et al., 2006). This competition for nutrients among growing fetuses appears to be greatest towards the last term of gestation when fetuses have the greatest growth rate (Ji et al., 2005).

Late gestation also represent a period of intense functional change to the sow that changes from nurturing fetuses growing *in utero* to subsequent farrowing of offspring and lactation (Farmer, 2015). These transitions in physiological events may put demand on nutrients at a period when sow feed intake is kept at maintenance (Goodband et al., 2013). Increase in late-gestation feed allowance, bump feeding, is a common industry practice devised under the premise that developing fetuses may benefit from greater nutrient supply from sow feed intake. This practice has proven ineffective and, in some instances, increases stillbirth rate (Gonçalves et al., 2016). Likewise, researchers have considered effects of varying levels of dietary energy or amino acids in gestating sow diets to improve piglet birth weights or survival of low birth weight pigs, but with inconsistent results. Simply more of all nutrients (greater feed allowance) or greater diet energy or amino acid concentrations lead to fatter sows, greater stillbirth rate, and greater feeding cost.

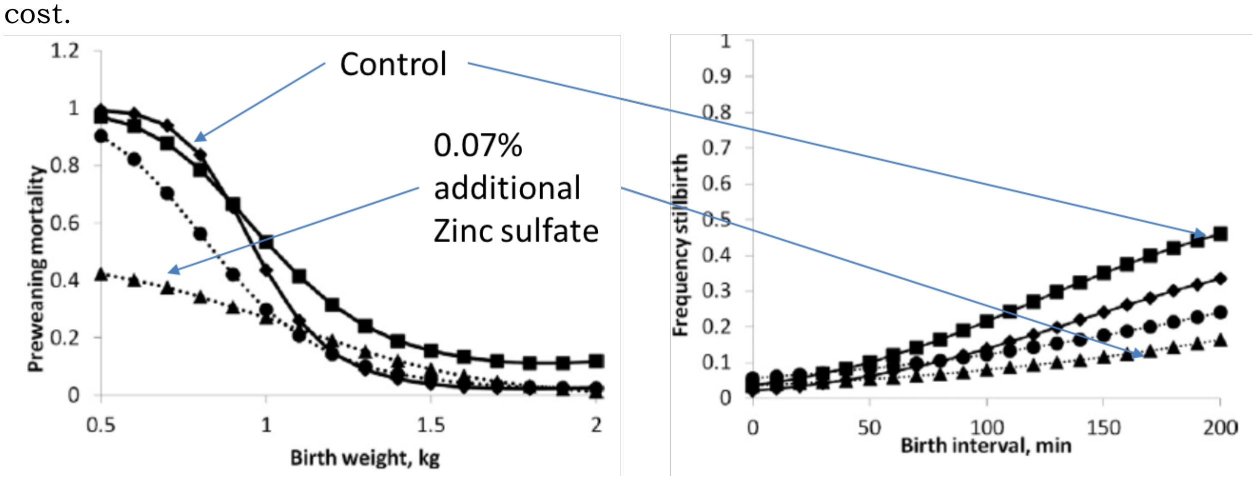

Figure 1. Pre-weaning mortality and frequency of stillbirth of pigs from sows fed diets supplemented with zinc at the end of gestation.

If intrauterine growth retardation is the consequence of competition for nutrients among fetuses, the nutrient may be specific to the stage of growth or the sow physiological transition period. Nutrient deficiencies and associated clinical sings can be separated into two types (Golden, 1989). Type 1 nutrients are associated to deficiencies of one physiological event (e.g. calcium and bone mineralization). Conversely, type 2 nutrients are associated to deficiencies of multiple physiological events and signs of deficiencies are multiple. Zinc is a type 2 nutrient, which deficiencies are not associated with a single physiological event. Researchers have demonstrated that zinc, copper, and manganese accumulate in high concentrations in the conceptus (Hostetler et al., 2003). Likewise, researchers have also demonstrated that during the course of gestation, there is decrease in the zinc concentration of the sow liver that is concomitant to fetal liver zinc concentration. In fact, Vallet et al. (2014) demonstrated, with limited numbers of gilts, that elevated dietary zinc during late gestation reduces stillbirth rate and pre-weaning mortality of low birth weight pigs (Figure 1). However, this research had a relatively small number of sows, smaller average total pigs born, lower pre-weaning mortality than industry average. Likewise, Vallet et al. (2014) only tested one level of supplemental zinc and there are no publications that demonstrate if the effect can be of different magnitude. Therefore, it is not known if the intervention is effective in commercial farms. Therefore, the objectives of this study were to determine pre-weaning survival of piglets and lifetime performance of pigs weighing less than 1.00 kg at birth from sows fed increasing levels of Zn in late gestation.

Objectives

Our hypothesis is that dietary zinc intake may trigger signaling pathways of intrauterine development resulting in decreased IUGR, improved fetal maturation, and consequently, decreased variation in intra-litter birth weight, decreased preweaning mortality, and improved market weight of pigs from sows fed diets supplemented with zinc during transition from gestation to lactation. Therefore, the overall objective of the project is to increase preweaning survival and subsequent lifetime productivity (market weight, days to market, percent lean) of low birth weight pigs. Specifically, we fed late gestating sows (about day 75 diets with three levels of zinc from zinc sulfate and measure sow farrowing performance, individual pig birthweight, and pre-weaning mortality. A second objective is to measure post-weaning mortality, days to market, and carcass characteristics of pigs weaned from sows fed three levels of zinc during late gestation.

Materials & Methods

This experiment was conducted in a commercial sow facility (1,200 sows) owned by Schwartz Farms, Inc. in Comfrey, Minnesota. The experimental protocol was reviewed and approved by the University of Minnesota Institutional Animal Care and Use Committee (IACUC# 1083-35724A). The experiment began in May, 2018 and concluded in February, 2019.

Animals, Housing, and Treatments

Three consecutive weeks of production incorporating three hundred and thirty-three total females (parity 0 to 7; PIC Camborough, Hendersonville, TN) were randomly assigned to one of three dietary treatments at approximately d 75 of gestation. Parity was balanced across treatments. Treatments were assigned to a block of gestation stalls to avoid cross-contamination of treatments from one sow to her neighbor. One “buffer” sow was placed at the end of each block of stalls to receive the same dietary treatment, but was not included in the experiment. Sows were later moved to farrowing stalls within 3 d of expected farrowing date (Figure 2).

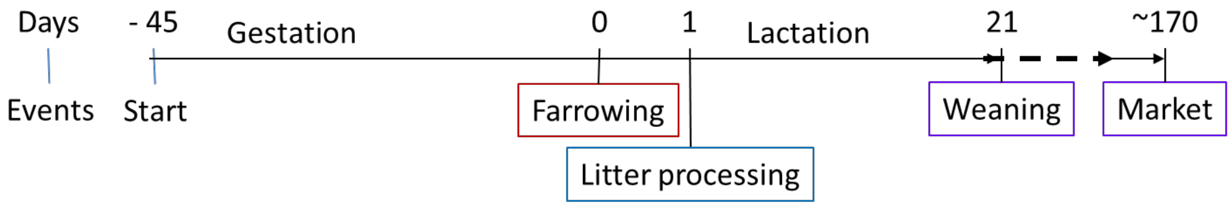

Figure 2. Timeline of experimental events

Dietary treatments consisted of: 1) **Control** – sows fed a corn-soybean meal-based diet containing 125 ppm total supplemental Zn as 75 ppm $ZnSO_4$ and 50 ppm AvailaZn™ (**CON**); 2) **Intermediate** – as Control + 240 ppm supplemental Zn as $ZnSO_4$ (**INT**); and 3) **High** – as Control + 470 ppm supplemental Zn as $ZnSO_4$ (**HI**). Final supplemental Zn concentrations of the three dietary treatments were as follows: 1) **CON** – 125 ppm; 2) **INT** – 365 ppm; and 3) **HI** – 595 ppm. Dietary treatments were imposed by feeding 60 ml (45 g; INT) or 120 ml (90 g; HI) of the zinc topdress providing 518 mg or 1,038 mg, respectively, once daily to the feed hoppers each afternoon prior to feeding only for sows assigned to the INT and HI treatments (Table 1). Gestation and lactation diets were used as per the farm's standard operating procedure (Table 2). Control sows did not receive any topdress. Sows remained on their assigned dietary treatment and received 2.2 kg of feed once daily until farrowing. Immediately after farrowing, all sows were fed a common lactation diet and allowed ad libitum access to feed.

Table 1. Ingredient and zinc composition of topdress (as-fed basis)

Ingredient, %	Topdress
Corn	95.8
Choice white grease	1.0
Zinc sulfate, monohydrat	3.2
TOTAL	100.0
Analyzed composition:	
Zinc total, ppm	11,530

Sows were housed in individual stalls until approximately d 110 of gestation and then moved to individual farrowing stalls. Each farrowing room contained 39 farrowing stalls. Farrowing stalls were equipped with one stainless steel feeder and one nipple waterer on a partially slatted floor over a deep manure collection pit. An independent controller within each farrowing room operated all heaters and ventilation fans. One heat lamp was placed in the creep area of each farrowing stall as a supplemental heat source for piglets.

Sow and Piglet Performance

Sows were identified individually using ear tags. Body condition and lameness scores were recorded at initiation of dietary treatments, approximately d 110 of gestation, within 12 h after parturition, and at weaning. Body condition scores were determined using a body condition caliper placed at the last rib of the sow. Visual lameness scores were recorded and assigned as sows stood up within stalls according to the following scale: 1) Normal: sow standing with weight equally distributed on all feet; or 2) Lame: sow with arched back, weight unequally distributed on feet, difficulty or inability to stand.

Table 2. Ingredient and nutrient composition of sow diets (as-fed basis)

Ingredient, %	Gestation	Lactation
Corn	49.20	52.90
Wheat middlings	15.00	-
Soybean meal	2.50	26.96
DDGS[1]	30.00	15.00
Choice white grease	-	1.00
Limestone	1.70	1.50
Monocalcium phosphate, 21% P	0.45	0.80
Salt	0.45	0.45
L-Lysine HCl	0.23	0.32
L-Threonine	-	0.10
Choline chloride 60%	0.14	0.05
Dyna K	-	0.63
Sow pack[2]	0.08	0.04
Premix[3]	0.25	0.25
TOTAL	100.00	100.00
Analyzed nutrient composition:		
Moisture, %	13.4	15.7
Crude protein, %	16.0	19.2
Crude fat, %	4.3	4.3
Crude fiber, %	3.6	2.1
Ash, %	6.0	8.0
Calcium, %	1.01	1.94
Phosphorus, %	0.63	0.60
Zinc total, ppm	184.6	255.9

[1]Dried distillers grains with solubles

[2]Contains the following: direct-fed microbial (DFM), mycotoxin binder, yeast culture, and carnitine

[3]Contained the following nutrients per kg of premix: vitamin A, 4,409,240 IU; vitamin D_3, 1,587,326 IU; vitamin E, 26,455 IU; menadione, 1,764 mg; riboflavin, 3,307 mg; niacin, 19,842 mg; pantothenic acid, 13,228 mg; pyridoxine, 5,732 mg; vitamin B_{12}, 15 mg; folic acid, 661 mg; biotin, 88 mg; phytase, 132,277 FTU; zinc, 110,231 ppm (60% as $ZnSO_4$, 40% as AvailaZn, Zinpro, Eden Prairie, MN); iron, 97,003 ppm; manganese, 35,274 mg; chromium, 176 ppm; copper, 14,550 ppm; iodine, 485 ppm; selenium, 265 ppm.

Sow performance measurements included total number of piglets born, born alive, stillborn, mummified, and weaned per litter. Within 12 h of birth and prior to cross-fostering, all piglets were weighed and ear tagged, individually. Litter sizes were standardized to 12 or 13 piglets per sow by cross-fostering within 24 h of farrowing. Cross-fostering within treatment was attempted, but was not controlled throughout lactation to reflect current farm practices. All piglets were processed according to the standard operating procedure established by the farm within 24 to 48 h of birth. Piglet processing included tail docking, needle teeth clipping, iron shots, and castration of males. Incidence of stillborn and mummified piglets were recorded, but were not weighed. Any pigs that died shortly before or during parturition likely due to asphyxia or dystocia were classified as stillborn.

One day before weaning, pigs were inventoried and individual bodyweights were recorded to determine body weight gain during nursing. Piglets were weaned at approximately 18.1

± 0.1 d of age. A subset of about 15 litters per treatment (n = 150 pigs/treatment) of both low birth weight (n = 50 pigs/treatment) and normal/heavy birth weight (n = 100 pigs/treatment) pigs were selected at weaning to monitor post-weaning growth and carcass performance. Selected pigs did not receive any dietary treatments throughout the entire growing/finishing phase. Pigs were tattooed individually before shipment and were harvested at JBS Pork in Worthington, MN. Individual pig tattoo numbers were used to collect hot carcass weight, backfat depth measured between the third and fourth from last rib, and loin depth data. An optical probe (Fat-O-Meat'er™, Frontmatec Group, Denmark) was used to determine backfat and loin depth of all carcasses. The following equation determined by JBS Pork was used to calculate percent lean:

Percent lean = 58.86 - 0.61 × (backfat depth) + 0.12 × (loin depth).

The following equations reported by NPPC (2000) were used to calculate percent fat-free lean, and lean gain:

Percent fat-free lean (FFL) = [15.31 – (31.277 × backfat depth) + (3.813 × loin depth) + (0.51 × HCW)] / HCW × 100; and

Lean gain = (FFL at ending weight - FFL in feeder pig) / days on test.

Sample Analysis

Two random samples of the zinc topdress and gestation diet were collected at initiation and throughout feeding of dietary treatments for each farrowing group. All samples were stored until shipment for analysis at -20°C. Diet and topdress samples were sent to Minnesota Valley Testing Laboratories, Inc. (New Ulm, MN) for proximate analysis and determination of zinc concentration. Standard procedures (AOAC, 2016) were followed for analysis of moisture (Method 930.15), ash (Method 942.05), fat (Method 2003.05), crude fiber (Method BA6A-05), crude protein (Method 990.03), calcium (Method 985.01), phosphorus (Method 985.01), and zinc (Method 985.01) concentrations.

Statistical Analysis

Experimental data were analyzed using the PROC GLIMMIX procedure of SAS (Version 9.4, SAS Institute Inc., Cary, NC) with a Gaussian distribution. Sow was considered the experimental unit. Post-weaning data considered pig as the experimental unit. The statistical model considered fixed effects of dietary treatment, farrowing group, and their interaction. Farrowing group was tested as a fixed effect for all variables but did not influence performance or mortality variables, so it was removed from the final statistical model. Treatment means were separated using the PDIFF option with the Tukey-Kramer adjustment for multiple comparisons.

Chi square analyses were used to determine the influence of gestation treatments on categorical response variables such as pre-weaning and post-weaning piglet mortality, lameness scores, and incidence of stillbirths and mummies. All data were reported as least square means and considered statistically significant at $P < 0.05$ with $P < 0.10$ considered a trend.

Results

Effects of sow zinc supplementation of survival of suckling pigs

Regardless of the birthweight, pre-weaning mortality decreased when sows were fed increasing levels of supplemental Zn in late gestation ($P < 0.10$; Figure 3). This decrease in pre-weaning mortality was of greatest magnitude among light birthweight pigs which decreased by 10 percentage points (38.3% in CON vs 28.1% in HI; $P = 0.05$). Not only did mortality of low birth weight piglets decline, mortality of heavy birth weight pigs also decreased, yet at lesser magnitude ($P < 0.10$). Although we hypothesized that survival of low birth weight pigs would improve, we did not expect to observe improvements in survival of heavy piglets, as well.

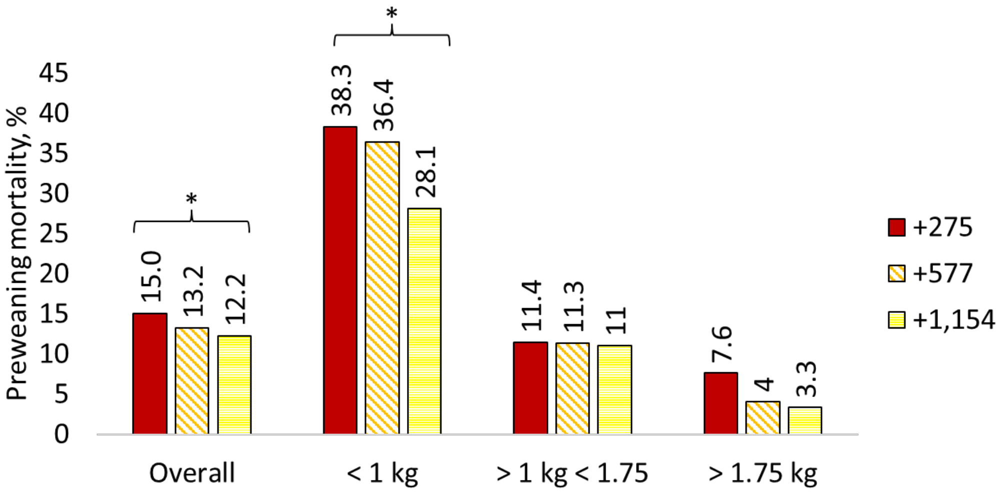

Figure 3. Feeding additional zinc to sows during late gestation decreases pre-weaning mortality

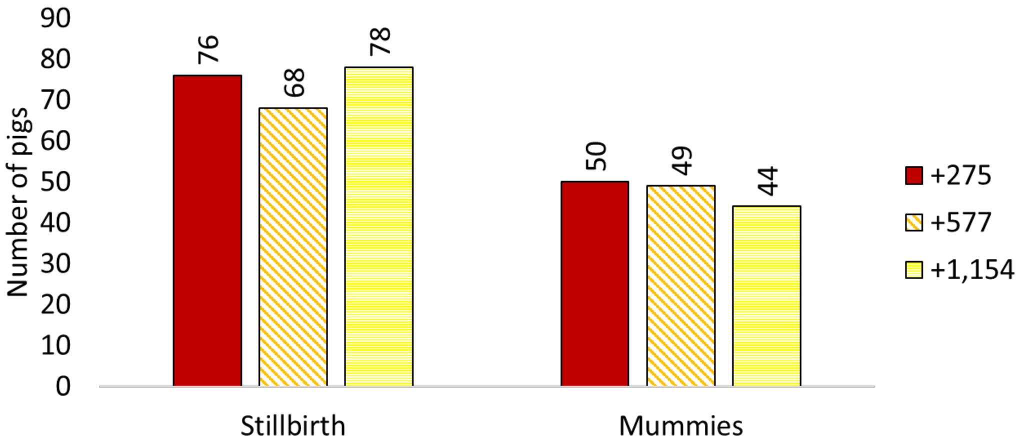

Figure 4. Effect of maternal zinc supplementation during late gestation on the number of stillbirth and mummies

In contrast to the previous experiment of Vallet et al. (2014), we did not observe differences in the number of pigs stillbirth or number of mummies after the dietary intervention.

Effect of sow zinc supplementation of weigh of newborn pigs

A common observation is that pre-weaning mortality is associated to an increase in the variability of birthweight among littermates and subsequent greater pre-weaning mortality among light (< 1 kg) pigs. We had the hypothesis that maternal zinc supplementation would decrease the incidence of light weight pigs and subsequently increase survival. However, in this study, maternal zinc supplementation decreased ($P < 0.05$) the incidence of low birth weight pigs in INT (11.6%) compared with CON (15.3%) and HI (15.1%). Likewise, piglet birthweight was greater ($P < 0.05$) in INT (1.42 kg) than CON (1.38 kg) and HI (1.40 kg).

Post-weaning growth performance

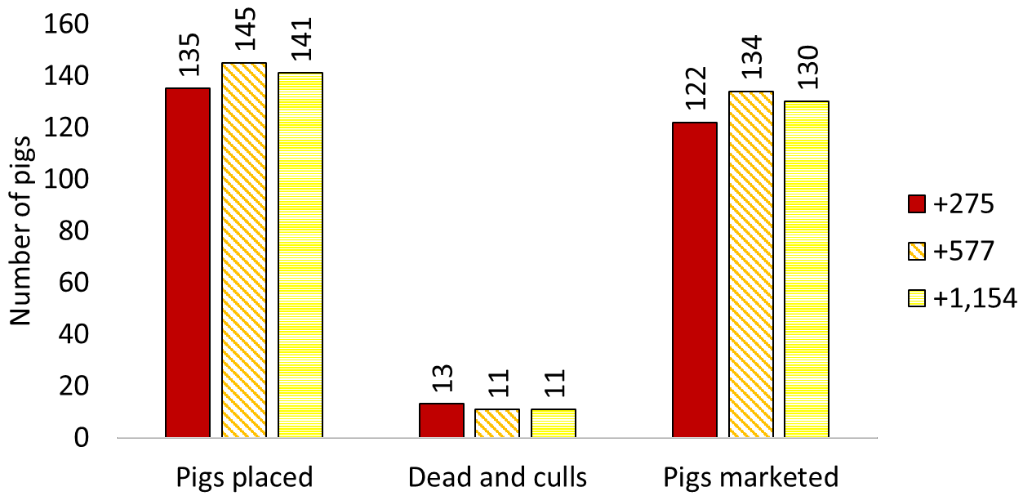

Figure 5. Effect of maternal zinc supplementation in late gestation on post-weaning survival of the offspring

An unfavorable effect of decreasing pre-weaning mortality of low birth weight pigs, is that low birthweight pigs have greater post-weaning mortality and grow slower than heavier littermates. The percentages of pigs that were marketed were not different among dietary treatments (CON: 90, INT: 92, and HI: 92%).

Discussion

Our working hypothesis was that dietary zinc intake of sows during late gestation increases survival (e.i. decrease stillbirth and pre-weaning mortality) of the offspring by decreasing intrauterine growth retardation (IUGR). We measured intra-litter birthweight and the prevalence of pigs born less than 1 kg because these are associated with IUGR and pre-weaning mortality in past research (Edwards, 2002; Zeng et al., 2019).

The current observation that zinc supplementation decreased overall pre-weaning mortality is encouraging and well in agreement with the observation from Vallet et al. (2014). This is remarkable given the differences in experimental and environmental conditions between the two experiments. The sows from the experiment in Vallet et al. (2014) had an average of 9.5 pigs born alive which is comparatively less than 14.7 in the current farm. It is generally accepted that pre-weaning mortality and the prevalence of low birth weight pigs increases with larger litter size. In addition, pre-weaning mortality in the control group in the Vallet et al. (2014) experiment was 7.4% while in the current experiment was 15%, which is closer to U.S. industry average. In the current experiment, cross-fostering was restricted to sows within the same dietary treatment. In previous research, cross-fostering was observed to increase growth of small disadvantaged pigs. In spite of active cross-fostering, we did observe a decrease in pre-weaning mortality suggesting that the effect of zinc can be effective under cross-fostering conditions, which is a common practice in commercial farms. Taken together, the observations of the current experiment in reference to Vallet et al. (2015) suggest that the impact of zinc on pre-weaning mortality could be independent of the underling pre-weaning mortality and number of pigs born per litter.

The effect of zinc on pre-weaning mortality may be dose dependent because the effect of zinc on overall mortality appears to increase with greater intake of zinc; decreasing by 12% when sows were fed the intermediate level and 19% when fed the high level of zinc. Therefore, testing for additional feeding levels of zinc and determining an optimal level of dietary zinc intake may be necessary. In addition, there may be a limited number of farms that could feed a different diet or a supplement to sows in late gestation on a regular basis. Therefore, future research may be needed to determine if the intervention can be fed thought gestation, if shorter feeding period, or if there are alternative nutrients that also decrease pre-weaning mortality.

The current experiment only demonstrated the benefit of the additional zinc intake in late gestation. However, we did not collect any data that could indicate a potential mechanism of action. Knowing this mechanism of action could be useful to determine potential interaction with other nutrients in the diet or help to determine alternative interventions that can improve the effectiveness of feeding zinc. It is worth noting that sow diet zinc supplementation decreased pre-weaning mortality but did not affect birthweight of the litter or did not decrease the incidence of lightweight pigs. This observation suggest that maternal zinc supplementation causes a developmental change in the lightweight pigs that better prepares them for postnatal growth environment.

Conclusion

The observation that supplementation of zinc in late gestation decreased the pre-weaning mortality is an encouraging finding for U.S. pork producers who may need to find practical means to feed the treatment to sows in late gestation.

Presentations and dissemination of information

The results of this project are under review for publication in a peer review journal. A summary was submitted to the National Hog Farmer and will be presented at the Allen D. Leman Swine Conference in 2019. The research team also briefed Schwartz farm employees about the final data analysis and major finding of the report.

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Appendix 1. Additional data collected during the experiment

Table 1. Effect of supplemental zinc in late gestation on farrowing performance of sows

	Treatment				
Item	CON[1]	INT[2]	HI[3]	SE	*P*-value
No. of sows	112	112	115	-	-
No. of litters	108	104	110	-	-
No. of piglets	1,565	1,424	1,525	-	-
Parity	2.9	3.0	2.9	0.2	0.92
Days on trial	35.8	36.0	36.1	0.4	0.70
Gestation length, d	115.2[a]	115.2[a]	115.6[b]	0.1	< 0.01
Lactation length, d	22.4	21.9	22.3	0.3	0.45
Days to service	6.9	7.1	5.8	0.9	0.43
Sows mated within 7d post-weaning[4], %	85.9	83.3	89.8	-	0.48
Body condition score[5]					
D79 Gestation[6]	14.9[a]	15.5[b]	15.5[b]	0.2	0.03
Pre-Farrow[7]	13.1	13.3	13.3	0.6	0.68
Weaning	11.4	11.8	11.8	0.4	0.32
Farrowing performance					
Total pigs born/litter	14.7	13.8	14.2	0.4	0.23
Pigs born alive/litter	14.0	13.1	13.4	0.4	0.25
Pigs weaned/litter	10.7	10.3	10.7	0.3	0.26

[ab]Means within a row with different superscripts differ ($P < 0.05$)

[1]Diets containing 125 ppm supplemental Zn as AvailaZinc and $ZnSO_4 \cdot H_2O$

[2]Diets containing 365 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$

[3]Diets containing 595 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$

[4]Calculated as: (number of sows mated within 7 d of weaning divided by total sows at weaning) x 100; Chi square = 1.46, df = 2

[5]Body condition scores evaluated at last rib via caliper

[6]Initiation of dietary treatments

[7]One day before expected farrowing date

Table 2. Effect of supplemental zinc in late gestation on prevalence of lameness of sows

Item	Treatment			Chi square[4]	*P*-value
	CON[1]	INT[2]	HI[3]		
D79 Gestation				0.49	0.78
Lame	1	1	2		
Not lame	113	114	114		
Pre-farrow[5]				2.02	0.36
Lame	2	1	0		
Not lame	104	106	106		
Weaning				1.88	0.39
Lame	2	0	1		
Not lame	99	94	96		

[1]Diets containing 125 ppm supplemental Zn as AvailaZinc and $ZnSO_4 \cdot H_2O$
[2]Diets containing 365 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$
[3]Diets containing 595 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$
[4]df = 2
[5]Presence of lameness evaluated one day before expected farrowing date

Table 3. Effect of supplemental Zn in late gestation on total number of stillbirths and mummified piglets

Item	Treatment			Chi square	*P*-value
	CON[1]	INT[2]	HI[3]		
Stillbirths	76	68	78	8.56[4]	0.20
Mummies	50	49	44	6.37[5]	0.61

[1]Diets containing 125 ppm supplemental Zn as AvailaZinc and $ZnSO_4{\cdot}H_2O$.
[2]Diets containing 365 ppm supplemental Zn as Control + $ZnSO_4{\cdot}H_2O$.
[3]Diets containing 595 ppm supplemental Zn as Control + $ZnSO_4{\cdot}H_2O$.
[4]df = 6.
[5]df = 8.

Table 4. Effect of supplemental Zn in late gestation on incidence of low birth weight piglets

	Treatment				
Item	CON[1]	INT[2]	HI[3]	Chi square[4]	*P*-value
Low birth wt. (≤ 1.00 kg)	240	165	231	10.78	< 0.01
Normal birth wt. (≥ 1.01 kg)	1325	1259	1294		
Total pigs born	1565	1424	1525		
Incidence of low birth wt., %[5]	15.3	11.6	15.1		

[1]Diets containing 125 ppm supplemental Zn as AvailaZinc and $ZnSO_4 \cdot H_2O$.
[2]Diets containing 365 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$.
[3]Diets containing 595 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$.
[4]df = 2.
[5]Calculated as incidence of low birth wt. pigs / total pigs born.

Table 5. Effect of supplemental Zn in late gestation on piglet performance

Item	Treatment			SE	*P*-value
	CON[1]	INT[2]	HI[3]		
Overall					
Piglet birth wt., kg	1.38[a,x]	1.42[b]	1.40[ab,y]	< 0.01	< 0.01
Piglet gain, g/d	227.0	226.5	229.7	1.5	0.28
Piglet weaning wt., kg	5.52	5.59	5.51	0.03	0.14
Piglet age at weaning, d	18.2	18.1	18.1	< 0.1	0.44
Total piglet gain, g	4,100	4,140	4,080	30	0.23
Low birth wt. (≤ 1.00 kg)					
Piglet birth wt., kg	0.83	0.84	0.83	< 0.01	0.75
Piglet gain, g/d	187.3	190.1	187.9	3.6	0.86
Piglet weaning wt., kg	4.41	4.44	4.34	0.06	0.58
Piglet age at weaning, d	18.9	18.8	18.5	0.1	0.12
Total piglet gain, g	3,532	3,559	3,475	67	0.66
Normal birth wt. (1.01 to 1.75 kg)					
Piglet birth wt., kg	1.38[a]	1.41[b]	1.38[a]	< 0.01	< 0.01
Piglet gain, g/d	227.0	230.1	225.6	1.7	0.16
Piglet weaning wt., kg	5.50[ab]	5.58[a]	5.46[b]	0.03	0.02
Piglet age at weaning, d	18.2	18.2	18.1	< 0.1	0.42
Total piglet gain, g	4,112[xy]	4,168[x]	4,073[y]	31	0.09
Heavy birth wt. (≥ 1.76 kg)					
Piglet birth wt., kg	1.94	1.94	1.96	0.01	0.26
Piglet gain, g/d	255.9	250.2	254.9	39	0.58
Piglet weaning wt., kg	6.42	6.29	6.44	0.07	0.28
Piglet age at weaning, d	17.6	17.5	17.6	0.1	0.75
Total piglet gain, g	4,485	4,349	4,473	69	0.33

[ab]Means within a row with different superscripts differ ($P < 0.05$).
[xy]Means within a row with different superscripts differ ($P < 0.10$).
[1]Diets containing 125 ppm supplemental Zn as AvailaZinc and $ZnSO_4 \cdot H_2O$.
[2]Diets containing 365 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$.
[3]Diets containing 595 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$.

Table 6. Effect of supplemental Zn in late gestation on mortality of pigs by treatment and weight classification[1]

Item	Treatment			Chi square[5]	*P*-value
	CON[2]	INT[3]	HI[4]		
Piglet Mortality					
Overall				5.41	0.07
Dead[6]	235	188	186		
Alive[7]	1,330	1,236	1,339		
Total pigs	1,565	1,424	1,525		
Mortality, %	15.0	13.2	12.2		
Low birth wt. (≤ 1.00 kg)				5.94	0.05
Dead[6]	92	60	65		
Alive[7]	148	105	166		
Total pigs	240	165	231		
Mortality, %	38.3	36.4	28.1		
Normal birth wt. (1.01 to 1.75 kg)				0.11	0.94
Dead[6]	127	120	112		
Alive[7]	987	938	909		
Total pigs	1,114	1,058	1,021		
Mortality, %	11.4	11.3	11.0		
Heavy birth wt. (≥ 1.76 kg)					
Dead[6]	16	8	9	5.20	0.07
Alive[7]	195	193	264		
Total pigs	211	201	273		
Mortality, %	7.6	4.0	3.3		

[1]Data presented as counts of pigs.
[2]Diets containing 125 ppm supplemental Zn as AvailaZinc and $ZnSO_4 \cdot H_2O$.
[3]Diets containing 365 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$.
[4]Diets containing 595 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$.
[5]df = 2.
[6]Represents dead pigs from birth to weaning; does not include stillborn pigs.
[7]Represents live piglets from birth to weaning.

Table 7. Mortality of pigs by weight classification[1]

Item	
Overall	
Total deaths[2]	609
Total alive[3]	3905
Total pigs	4514
Mortality, %	13.5
Low birth wt. (≤ 1.00 kg)	
Total deaths[2]	217
Total alive[3]	419
Total pigs	636
Mortality, %	34.1
Normal birth wt. (1.01 to 1.75 kg)	
Total deaths[2]	359
Total alive[3]	2,834
Total pigs	3,193
Mortality, %	11.2
Heavy birth wt. (≥ 1.76 kg)	
Total deaths[2]	33
Total alive[3]	652
Total pigs	685
Mortality, %	4.8

[1]Data presented as counts of pigs.
[2]Represents dead pigs from birth to weaning; does not include stillborn pig
[3]Represents live piglets from birth to weaning.

Table 8. Effects of supplemental Zn in late gestation on post-weaning mortality of pigs[1]

	Treatment				
Item	CON[2]	INT[3]	HI[4]	Chi-square[5]	*P*-value
Overall					
Dead[6]	13	11	11	0.46	0.80
Alive[7]	122	134	130		
Total pigs	135	145	141		
Mortality	9.6%	7.6%	7.8%		
Low birth wt. (≤ 1.00 kg)					
Dead[6]	3	4	1	2.50	0.29
Alive[7]	26	23	31		
Total pigs	29	27	32		
Mortality	10.3%	14.8%	3.1%		
Normal birth wt. (1.01 to 1.75 kg)					
Dead[6]	7	6	8	1.48	0.48
Alive[7]	61	100	77		
Total pigs	68	106	85		
Mortality	10.3%	5.7%	9.4%		
Heavy birth wt. (≥ 1.76 kg)					
Dead[6]	3	1	2	< 0.01	0.99
Alive[7]	35	11	22		
Total pigs	38	12	24		
Mortality	7.9%	8.3%	8.3%		

[1]Data presented as counts of pigs
[2]Offspring from sow diets containing 125 ppm supplemental Zn as AvailaZn and $ZnSO_4 \cdot H_2O$
[3]Offspring from sow diets containing 365 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$
[4]Offspring from sow diets containing 595 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$
[5]df = 2
[6]Represents piglets that died from weaning to market
[7]Represents live piglets from weaning to market

Table 9. Carcass characteristics of pigs from sows by treatment and weight classification

Item	Treatment			SE	*P*-value
	CON[1]	INT[2]	HI[3]		
Overall					
No. of pigs	122	134	130	-	-
Wean to slaughter, d	168.6	168.3	167.1	1.1	0.59
Hot carcass weight, kg	99.9	101.2	100.1	0.6	0.19
Backfat depth, mm	16.3	16.3	16.0	0.4	0.74
Loin depth, cm	6.9[xy]	6.8[x]	7.0[y]	< 0.1	0.07
Lean[4], %	57.2	57.1	57.5	0.2	0.42
FFL[5], %	53.5	53.5	53.8	0.2	0.54
Lean gain[6], g/day	314.5	319.4	320.3	2.6	0.23
Low birth wt. (≤ 1.00 kg)					
No. of pigs	26	23	31	-	-
Wean to slaughter, d	174.0	169.5	171.8	2.1	0.41
Hot carcass weight, kg	97.7	99.8	98.4	1.3	0.57
Backfat depth, mm	15.7	15.9	16.7	0.7	0.55
Loin depth, cm	6.7	6.5	6.8	0.1	0.26
Lean[4], %	57.3	56.9	56.8	0.5	0.76
FFL[5], %	53.8	53.5	53.1	0.5	0.62
Lean gain[6], g/day	301.5	315.3	305.1	6.0	0.25
Normal birth wt. (1.01 to 1.75 kg)					
No. of pigs	61	100	77	-	-
Wean to slaughter, d	169.1	168.3	167.2	1.4	0.66
Hot carcass weight, kg	100.1	101.6	101.1	0.8	0.39
Backfat depth, mm	16.7	16.5	15.9	0.5	0.46
Loin depth, cm	7.0	6.9	7.1	0.1	0.35
Lean[4], %	57.1	57.1	57.7	0.3	0.31
FFL[5], %	53.4	53.4	53.9	0.3	0.35
Lean gain[6], g/day	313.7	319.8	323.5	4.8	0.13
Heavy birth wt. (≥ 1.76 kg)					
No. of pigs	35	11	22	-	-
Wean to slaughter, d	163.7	165.8	160.2	2.2	0.28
Hot carcass weight, kg	101.0	101.3	98.8	1.3	0.33
Backfat depth, mm	16.3	14.9	15.2	0.9	0.53
Loin depth, cm	7.0	6.7	7.2	0.1	0.19
Lean[4], %	57.3	57.8	58.2	0.6	0.55
FFL[5], %	53.5	54.2	54.3	0.4	0.47
Lean gain[6], g/day	325.3	324.2	330.1	4.3	0.74

[xy]Means within a row with different superscripts differ ($P < 0.10$)
[1]Offspring from sow diets containing 125 ppm supplemental Zn as AvailaZn and $ZnSO_4 \cdot H_2O$
[2]Offspring from sow diets containing 365 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$
[3]Offspring from sow diets containing 595 ppm supplemental Zn as Control + $ZnSO_4 \cdot H_2O$
[4]Lean calculated as: 58.86 - 0.61 × (backfat depth) + 0.12 × (loin depth); JBS Pork

[5]Fat-free lean calculated as: [15.31 – (31.277 × backfat depth) + (3.813 × loin depth) + (0.51 × HCW)] / HCW × 100; NPPC (2000)
[6]Lean gain calculated as: (FFL at ending weight - FFL in feeder pig) / days on test; NPPC (2000)