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Effects of Fe Dosage in Newborn Pigs on Preweaning and Subsequent Nursery Performance[1]

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Summary

A total of 336 newborn pigs (DNA 241 × 600, initially 3.83 ± 0.114 lb BW) were used in a 63-d study evaluating the effects of increasing injectable Fe dose on preweaning and subsequent nursery pig performance and blood Fe status. GleptoForte (Ceva Animal Health, LLC, Lenexa, KS) contains gleptoferron which is an Fe macro-molecule complex that is used as an injectable Fe source for preweaned piglets. A total of 28 litters were used and on the day of processing (approximately d 3 after birth) all piglets were weighed and six barrows and six gilts per litter were allotted to 1 of 6 treatments in a completely randomized design. Treatments consisted of a negative control receiving no Fe injection and increasing injectable Fe to achieve either 50, 100, 150, 200 mg; or 200 mg plus a 100-mg injection on d 11 post-farrowing. Piglets were weighed and blood samples were taken on d 3, 11, and 21 of age to determine blood Fe status and growth performance. Then pigs were weaned at approximately 21 d of age and allotted to nursery pens based on body weight (BW) and corresponding treatment in a completely randomized design with 5 or 6 pigs per pen and 10 pens per treatment. Common diets were fed throughout the nursery in 3 phases. Blood samples were taken on d 21 (weaning), 35, and 63 to determine blood Fe status.

During the preweaning phase, increasing injectable Fe up to 100 mg improved (quadratic; $P < 0.05$) average daily gain (ADG) and d 21 BW with no further improvement thereafter. There was no evidence of differences ($P > 0.10$) between the 200 mg and 200 mg + 100 mg treatments for growth. For the nursery period, increasing Fe dosage improved (linear; $P < 0.05$) ADG, average daily feed intake (ADFI), and d 63 BW. Also, increasing injectable Fe up to 150 mg improved (quadratic; $P = 0.007$) feed efficiency (F/G) with no further improvement with increased dosage. There was no evidence of differences ($P > 0.05$) between the 200 mg and 200 mg + 100 mg treatments for growth.

[1]Appreciation is expressed to Dr. Andrew Holtcamp, Ceva Animal Health, LLC, Lenexa, KS for technical and financial support.
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Significant treatment × day interactions ($P = 0.001$) were observed for hemoglobin (Hgb) and hematocrit (Hct). The interactions occurred because pigs that had less than 150 mg of injectable Fe had decreased values to d 21 and then increased to d 63 while pigs with 150 or 200-mg of injectable Fe had increased values to d 21 then stayed relatively constant to d 63.

In summary, preweaning and nursery growth performance and blood Fe status were maximized with a 200 mg Fe injection at processing. Providing an additional 100 mg of Fe on d 11 of age increased Hgb, Hct, and serum Fe values at weaning and 14 d into the nursery but did not provide a growth performance benefit in farrowing or nursery.

Introduction

Newborn pigs develop Fe deficiency in the first week of life due to low Fe storage at birth, low levels of Fe in sow colostrum and milk, and the rapid growth rate that occurs during this period of a pig's life.[4] Because of this, an Fe injection within the first week after birth is commonly used in the swine industry to prevent Fe deficiency. The negative consequences of absence of an Fe injection during this period on piglet growth and subsequent nursery performance is well established (2008).[5] Typically, a 200 mg Fe dose sourced from iron dextran is used. Furthermore, Jolliff and Mahan (2014) determined that an extra injection of 100 mg of Fe from iron dextran at d 10 of age can improve Fe status at weaning and initial postweaning performance.[6] Interestingly, Lipinski et al. (2010) determined that a 200 mg injection of Fe from iron dextran in a single dose can reduce the bioavailability of Fe by increasing the expression of hepcidin which suppresses serum Fe circulation and leads to inadequate development of red blood cells compared to a single injection of 100 mg of Fe or 2 injections of 40 mg of Fe.[7]

GleptoForte (Ceva Animal Health, LLC, Lenexa, KS) is an injectable Fe source that contains gleptoferron. Gleptoferron is a macro-molecule complex that has the potential for increased bioavailability, which allows for improved Fe status at weaning for pigs and potentially improved growth performance. The optimal dose of Fe from iron dextran in pigs is 200 mg provided 3 d after birth to maximize growth and blood iron status (1997).[8] However, research is not available that describes the optimal dosage of Fe from gleptoferron that supports maximum pre- and post-weaning growth performance and Fe status. Therefore, the objective of this study was to determine the effects of increasing injectable Fe dosage in newborn pigs on preweaning and nursery performance as well as blood criteria.

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[4]Kegley, E.B., Spears, J.W., Flowers, W.L., and W.D. Schoenherr. Fe methionine as a source of Fe for the neonatal pig. Nutr. Res. 22:1209-1217. doi:10.1016/S0271-5317(02)00434-7

[5]Peters, J. C., and D. C. Mahan. 2008. Effects of neonatal Fe status, Fe injections at birth, and weaning in young pigs from sows fed either organic or inorganic trace minerals. J. of Anim. Sci. 86:2261-2269. doi:10.2527/jas.2007-0577

[6]Jolliff, J. S., and D. C. Mahan. 2011. Effect of injected and dietary Fe in young pigs on blood hematology and postnatal pig growth performance. J. Anim. Sci. 89:4068-4080. doi:10.2527/jas.2010-3736

[7]Lipinski, P., Starzynski, R.R., Canonne-Hergaux, F., Tudex, B., Olinski, R., Kowalczyk, P., Dziaman, T., Thibaudeau, O., Gralax, M.A., Smuda, E., Wolinski, J., Usinska, A., and R. Zabielski. 2010. Benefits and risks of Fe supplementation in anemic neonatal pigs. Am. J. Pathol. 117:1223-1243. doi:10.2353/ajpath.2010.091020

[8]Murphy, K.A., Friendship, R. M., and C. E. Dewey. 1997. Effects of weaning age and dosage of supplemented iron on the hemoglobin concentrations and growth rate of piglets. J. Swi. Heal. Prod. 5:135-138.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol for this experiment. The study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS.

Farrowing Performance

A total of 336 newborn pigs (DNA 241 × 600, initially 3.83 ± 0.11 lb BW) were used in a 63-d study. A total of 28 litters were used with number of pigs per sow equalized on each day before weaning. On the day of processing (approximately 3 d after birth), all piglets were weighed, and, within litter, six barrows and six gilts were allotted to 1 of 6 treatments in a completely randomized block design. There was 1 barrow and 1 gilt per treatment for each sow. The six treatments consisted of a negative control receiving no injectable Fe, or 50, 100, 150, or 200 mg Fe provided in one injection on d 3, or a treatment with 200 mg provided on d 3 plus another 100 mg injection on d 11. Each 1 mL of Fe dose contained 200 mg of Fe, thus injection dosage was 0, 0.25, 0.50, 0.75, 1.0, or 1.0 plus the additional 0.50 mL to provide the Fe doses. Piglets were weighed at processing (d 3), d 11, and weaning (d 21) to calculate ADG during farrowing. Creep feed was not offered to preweaned pigs.

Nursery Performance

Pigs were weaned at approximately 21 d of age and allotted to pens based on BW and previous Fe treatment in a completely randomized design with 5 or 6 pigs per pen and 10 pens per treatment. Each pen (4 × 4 ft) had metal tri-bar flooring, one 4-hole self-feeder, and a nipple waterer to provide *ad libitum* access to feed and water. Pigs and feeders were weighed on d 10, 17, 24, 31, and 42 after weaning to determine ADG, ADFI, and F/G.

Feed

All diets were corn-soybean meal based (Table 1). Common nursery diets were fed in all nursery phases. Phase 1 diets were fed in pellet form and Phase 2 and 3 were fed in meal form. Phase 1 diets were prepared at a commercial mill (Hubbard Feeds, Beloit, KS) and the Phase 2 and 3 diets were prepared at the Kansas State University O.H. Kruse Feed Technology Innovation Center, Manhattan, KS. Each diet contained an added 110 ppm Fe from ferrous sulfate ($FeSO_4$) provided by the trace mineral premix. Phase 2 and 3 diets were formulated to include 50 g/ton of carbadox (Mecadox, Phibro Animal Health Co., Stamford, CT).

Blood, Feed, Fecal, and Water Analysis

Blood was collected via jugular venipuncture from one barrow per treatment per litter on d 3, 11, 21, 35, and 63 after birth. Blood criteria measured included: hemoglobin (Hgb) and hematocrit (Hct) using an ADVIA 2021i Hematology System (Siemens Healthcare Diagnostics, Tarrytown, NY) and serum Fe and total Fe binding capacity (TIBC) using a COBAS C501 Chemistry Analyzer (Roche Diagnostics, Indianapolis, IN). Blood samples were processed at the Kansas State University Veterinary Diagnostic Laboratory, Manhattan, KS.

Diet samples were collected directly from feeders and 6 pooled samples were submitted for analysis of dry matter (DM), crude protein (CP), Ca, P, and Fe content (Ward Laboratories, Inc., Kearney, NE; Table 2).

Fecal samples from 8 sows were also collected on d 3, 11, and 21 of the trial and pooled into a single sample, and then were submitted for duplicate analysis of Fe content (Experiment Station Chemical Laboratories, University of Missouri-Columbia, MO). Water samples from 6 different farrowing crates and 6 different nursery pens were collected on each weigh day and pooled into a single sample and were then submitted for duplicate analysis of Fe content (Ward Laboratories, Inc., Kearney, NE).

Statistical Analysis

Growth data of preweaned piglets were analyzed using the individual pig as the experimental unit and crate and gender as random effects. Nursery growth data were analyzed with pen as the experimental unit and room as a random effect. Blood criteria from preweaned pigs were measured as a repeated measure with individual pig as the experimental unit and crate as a random effect. Blood criteria from nursery pigs were analyzed as a repeated measure with pen as the experimental unit. Growth data were evaluated using linear and quadratic effects of Fe dosage from 0 to 200 mg and a pairwise comparison of the 200 mg vs. 200 + 100 mg treatments using preplanned CONTRAST statements. Blood criteria were evaluated similarly, except accounting for the repeated measures over time. Differences between treatments were determined using least squares means. A P-value ≤ 0.05 was considered significant and 0.05 < P ≤ 0.10 was considered marginally significant. The PROC GLIMMIX procedure of SAS version 9.4 (SAS Institute, Inc., Cary, NC) was used for all statistical models.

Results and Discussion

Chemical Analysis

Results of water analysis collected from farrowing crates averaged 1.22, 0.90, and 0.24 ppm Fe on d 3, 11, and 21, respectively. Results of water analysis collected from nursery pens averaged 0.03, 0.01, and 0.03 ppm Fe on d 0, 14, and 42, respectively. These analyses revealed water contained low Fe concentrations as expected since water originated from a municipal water source. Results of fecal analysis collected from sows during farrowing averaged 1,735; 1,610; and 1,140 ppm Fe on d 3, 11, and 21, respectively. These analyses revealed high levels of Fe were present within the feces of sows, but the Fe may be bound in a form that is unavailable to affect Fe status of preweaned pigs. Analyzed Fe content in the phase 1 nursery diet was higher than formulated values, while phase 2 and 3 analyzed values were slightly lower than expected. All dietary Fe levels were well above the requirement of nursery pigs as indicated by NRC 2012.[9]

Preweaning Growth Performance

From d 3 to 11, ADG of piglets improved (quadratic; P = 0.002) with increasing injectable Fe up to 50 mg with no further improvement thereafter (Table 3). Day 11 BW of piglets increased (quadratic; P = 0.018) with increasing injectable Fe up to 50 mg with no further improvement thereafter. From d 11 to 21, ADG of piglets increased (quadratic; P = 0.001) with increasing dose of Fe up to 100 mg with no further

[9]NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press., Washington D.C.

improvement thereafter. Overall, ADG and d 21 BW increased (quadratic; $P = 0.001$) with increasing injectable Fe dose up to 100 mg with no improvement observed thereafter. Furthermore, there was no evidence for differences in preweaning performance between the 200 mg and 200 mg + 100 mg injectable Fe treatments.

Nursery Growth Performance

From d 21 to 31 after weaning, increasing injectable Fe administered during preweaning improved (linear; $P < 0.05$) ADG and ADFI (Table 4). Furthermore, increasing injectable Fe up to 100 mg improved (quadratic; $P = 0.001$) d 31 BW with little improvement thereafter. From d 31 to 45, increasing injectable Fe administered during preweaning improved (quadratic; $P < 0.05$) ADG and F/G. Increasing injectable Fe up to 150 mg also improved (quadratic; $P = 0.009$) d 45 BW with no further improvement with increased dosage. From d 21 to 45, increasing injectable Fe improved (linear; $P < 0.05$) ADG and ADFI. Furthermore, increasing injectable Fe up to 150 mg improved (quadratic; $P = 0.017$) F/G with no further improvement as dosage increased thereafter.

From d 45 to 63, increasing injectable Fe improved (linear; $P < 0.05$) ADG, d 42 ending BW, and marginally improved (linear; $P = 0.071$) ADFI. Overall, increasing injectable Fe improved (linear; $P < 0.05$) ADG and ADFI. Furthermore, increasing injectable Fe up to 150 mg improved (quadratic; $P = 0.007$) F/G with a worsening F/G observed when 200 mg was administered to pigs. There was no evidence of a difference in growth performance ($P > 0.10$) between the 200 mg and the 200 + 100 mg injectable Fe treatments during any phase or overall.

These data suggest that, up to weaning, a 100 mg injection of Fe maximized growth performance, but for subsequent growth performance in the nursery, the 200 mg injection maximized growth performance. A 200 mg Fe dose at processing resulting in greater performance in the nursery is consistent with previous research. The addition of a 100 mg booster of Fe administered at d 11 after birth did not provide a performance benefit in either preweaning or the nursery.

Hematological Criteria

As expected, there was no evidence of difference ($P > 0.10$) observed for any hematological criteria measured on d 3 prior to the Fe injection (Table 5). For Hgb, a significant treatment × day interaction ($P = 0.001$) was observed. The interaction occurred because pigs receiving less than 150 mg of injectable Fe had decreased Hgb values to d 21 and then values increased to d 63 at a faster rate compared to the higher doses. We believe this demonstrates that iron was being absorbed at a faster rate from the diet for the pigs that were provided iron below their requirement prior to weaning. Conversely, for pigs receiving the 150 or 200 mg doses, Hgb values increased to d 21 and then stayed relatively constant to d 63. Hemoglobin values increased in a quadratic manner ($P = 0.001$) on d 11 and 21 and linearly ($P = 0.001$) on d 35 with the 0 mg treatment having the lowest Hgb values and the 200 mg treatment having the greatest values. There was no evidence of treatment differences ($P > 0.10$) observed for Hgb values measured on d 63. On d 21 and 35, pigs that received the 200 mg + 100 mg treatment had increased ($P < 0.05$) Hgb values compared to the 200 mg dose.

A significant treatment × day interaction (*P* = 0.01) was observed for Hct values. The interaction was the result of Hct values for pigs receiving no Fe or 50 mg of injectable Fe decreasing to d 21 and then increasing to d 63 with the feeding of common diets. For pigs receiving the 100 mg dose, Hct values increased to d 11 and then decreased to d 21. From d 21 to 63, Hct values continued to increase with the feeding of common diets. For pigs receiving 150 or 200 mg of injectable Fe, Hct values increased to d 21 and then stayed relatively constant to d 63. Increasing injectable Fe dose, increased Hct values in a quadratic manner (*P* = 0.001) on d 11 and 21, and linearly (*P* = 0.001) on d 35 with pigs receiving no Fe having the lowest Hct value and the 200 mg dose having the greatest Hct value. There was no evidence of treatment differences (*P* > 0.10) observed for Hct values measured on d 63. On d 21 and 35, the 200 mg + 100 mg treatment led to an increase (*P* < 0.05) in Hct values compared to the 200-mg treatment.

For serum Fe, a significant treatment × day interaction (*P* = 0.01) was observed. The interaction was the result of serum Fe values for pigs receiving less than 100 mg of injectable Fe staying relatively constant to d 21 and then increasing to d 63 during the nursery period. Meanwhile, for pigs receiving 100 mg of injectable Fe, serum Fe values increased to d 11 and then decreased to d 21. From d 21 to 63, serum Fe values increased for these pigs with the feeding of common diets. For the 150 and 200 mg treatments, serum Fe values increased to d 11 and then decreased until d 21. Serum Fe values for pigs receiving these treatments increased from d 21 to 35 and then stayed relatively constant to d 63 with the feeding of common diets. Increasing injectable Fe dose increased serum Fe values on d 11 (linear; *P* = 0.001), d 21 (quadratic; *P* = 0.002), and d 35 (linear; *P* = 0.001) with the 0 mg treatment having the lowest serum Fe values and the 200 mg treatment having the greatest serum Fe values. There was no evidence of treatment differences (*P* > 0.10) observed for serum Fe values measured on d 63. On d 21, the 200 mg + 100 mg treatment had an increase (*P* = 0.030) in serum Fe values compared to the 200-mg treatment.

A significant treatment × day interaction (*P* = 0.01) was observed for TIBC values. Total iron binding capacity is a measurement of blood's capacity to bind to transferrin, an iron-binding blood glycoprotein that transports iron to body tissues. The interaction was the result of TIBC values increasing for all treatments from d 3 to 21 except for the 200 mg dose, which stayed constant from d 11 to 21. From d 21 to 35, TIBC values decreased for all treatments, while pigs receiving 0 or 50 mg of injectable Fe continued to decrease to d 63 with the feeding of common diets. From d 35 to 63, pigs receiving 100 mg of injectable Fe had relatively constant TIBC, while pigs receiving 150 or 200 mg of injected Fe increased with the feeding of common diets. Increasing injectable Fe decreased TIBC values on d 11 (quadratic; *P* = 0.001) and on d 21 and 35 (linear; *P* = 0.001) with the 0 mg treatment having the greatest TIBC values and the 200 mg treatment having the lowest TIBC values. There was no evidence of difference (*P* > 0.10) between the treatments on d 63. There was no evidence of differences (*P* > 0.10) between the 200 mg and 200 + 100 mg treatments at any of the blood collection time points.

The results suggest that 200 mg of Fe is the optimal dosage for the greatest Fe status at weaning and in the nursery. The improvement in blood Fe status during the nursery stage to increasing Fe up to a 200 mg dose is consistent with previous research.

A 100 mg additional dose midway through preweaning has the ability to improve blood Fe status through weaning and the first phase of the nursery, but no additional benefits are observed for growth performance. Also, we observed that by d 42 in the nursery, feeding diets that are sufficient to meet the pig's Fe requirement restored blood Fe measurements in pigs that received low doses of supplemental Fe at processing during preweaning, with hematological indicators at the end of the nursery stage being similar to those that received the high doses of Fe. Although blood Fe status is recaptured at the end of the nursery stage, final body weight and nursery growth performance of these pigs receiving the low Fe injection was still poorer than that of the pigs receiving the 200 mg dose.

Table 1. Nursery diet composition (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Corn	32.18	50.68	61.85
Soybean meal, 48% crude protein	20.29	29.63	33.75
Corn DDGS, 6-9% oil[2]	5.00	---	---
Enzymatically processed soy protein[3]	7.50	5.00	---
Fish meal	4.00	---	---
Choice white grease	3.00	---	---
Limestone	0.75	1.05	0.95
Monocalcium phosphate, 21% P	0.70	1.05	1.15
Sodium chloride	0.30	0.30	0.35
L-Lysine-HCl	0.23	0.30	0.30
DL-Methionine	0.15	0.18	0.12
L-Threonine	0.09	0.15	0.12
Trace mineral premix[4]	0.15	0.15	0.15
Vitamin premix	0.25	0.25	0.25
Choline chloride	0.04	---	---
Phytase[5]	---	0.02	0.02
Zinc oxide	0.39	0.25	---
Antimicrobial[6]	---	1.00	1.00
Total	100	100	100

continued

Table 1. Nursery diet composition (as-fed basis)[1]

Ingredient, %	Phase 1	Phase 2	Phase 3
Calculated analysis			
Standardized ileal digestible (SID) AA, %			
Lysine	1.40	1.35	1.24
Methionine:lysine	35	35	33
Methionine and cysteine:lysine	58	58	57
Threonine:lysine	63	66	63
Tryptophan:lysine	19	19	18.7
Valine:lysine	69	67	68
Total lysine, %	1.55	1.49	1.39
Metabolizable energy, kcal/lb	1,574	1,475	1,468
Net energy, kcal/lb	1,170	1,081	1,077
Crude protein, %	23.7	22.8	21.6
Calcium, %	0.86	0.78	0.70
Phosphorus, %	0.76	0.68	0.65
STTD P,[7] %	0.53	0.52	0.48
Fe, ppm[8]	321	354	357

[1]Phase 1 diets from d 0 to 10 (12.4 to 14 lb), Phase 2 diets fed from d 10 to 24 (14 to 25 lb), and Phase 3 diets fed from d 24 to 42 (25 to 50 lb).

[2]DDGS = dried distillers grains with solubles.

[3]HP 300, Hamlet Protein, Inc., Findlay, OH.

[4]Trace mineral premix containing 110 ppm Fe from $FeSO_4$.

[5]HiPhos 2700 (DSM Nutritional Products, Inc., Parsippany, NJ), provided 184.3 phytase units (FTU)/lb and an estimated release of 0.10% available P.

[6]Mecadox-2.5 (Phibro Animal Health, Teaneck, NJ) is a source of carbadox.

[7]Standardized total tract digestible phosphorus.

[8]Fe levels based on NRC (2012) ingredient loading values.

Table 2. Chemical analysis of nursery diets (as-fed)[1,2]

Item	Phase 1	Phase 2	Phase 3
Dry matter, %	92.0	90.8	89.3
Crude protein, %	21.47	23.4	20.9
Calcium, %	0.90	0.96	0.97
Phosphorus, %	0.70	0.67	0.66
Fe, ppm	420	273	255

[1]Phase 1, 2, and 3 diets were fed from d 0 to 10, 10 to 24, and 24 to 42, respectively.
[2]Complete diet samples were obtained from each dietary phase directly at the feeder. Samples of diets were then submitted for analysis of DM, CP, Ca, P, and Fe content (Ward Laboratories, Inc., Kearney, NE).

Table 3. Effects of injectable Fe dosage on preweaning pig performance[1]

	Fe, mg[2]							Probability, *P* <		
Item	0	50	100	150	200	200 + 100[3]	SEM	Linear[4]	Quadratic[5]	200 vs. 200 + 100[6]
Body weight, lb										
d 3[7]	3.8	3.8	3.8	3.9	3.8	3.9	0.11	0.793	0.943	0.556
d 11[8]	7.2	7.9	7.8	7.9	7.8	7.7	0.21	0.012	0.018	0.702
d 21	10.4	12.5	12.9	12.7	12.7	12.6	0.32	0.001	0.001	0.800
Average daily gain, lb										
d 3 to 11	0.42	0.51	0.50	0.50	0.50	0.49	0.018	0.002	0.002	0.409
d 11 to 21	0.34	0.49	0.54	0.51	0.52	0.51	0.018	0.001	0.001	0.881
d 3 to 21	0.38	0.50	0.52	0.50	0.51	0.50	0.016	0.001	0.001	0.605

[1]A total of 336 preweaned pigs (DNA 241 × 600) were used with 12 pigs per sow and 2 replications of treatment within sow.
[2]Fe (Ceva Animal Health, LLC, Lenexa, KS) dosage administered 3 d after birth.
[3]Pigs were administered 200 mg at 3 d after birth and 100 mg 11 d after birth.
[4]Linear comparison of 0 to 200 mg doses.
[5]Quadratic comparison of 0 to 200 mg doses.
[6]Pairwise comparison between mean of 200 mg and 200 + 100 mg treatments.
[7]Represents 3 d after farrowing.
[8]Represents 11 d after farrowing.

Table 4. Effects of Fe dosage on nursery pig performance[1]

	Fe, mg[2]							Probability, *P* <		
	0	50	100	150	200	200 + 100[3]	SEM	Linear[4]	Quadratic[5]	200 vs. 200 +100[6]
BW, lb										
d 21	10.7	12.5	12.9	12.8	12.8	12.8	0.17	0.001	0.001	0.997
d 31	11.4	13.0	13.8	14.1	14.1	14.5	0.59	0.001	0.001	0.339
d 45	20.6	23.3	24.8	25.7	25.7	26.6	0.60	0.001	0.009	0.277
d 63	42.7	46.5	47.6	50.1	50.5	49.9	1.17	0.001	0.209	0.730
d 21 to 31										
ADG, lb	0.07	0.05	0.09	0.13	0.14	0.18	0.051	0.005	0.524	0.263
ADFI, lb	0.24	0.23	0.25	0.29	0.31	0.31	0.038	0.010	0.375	0.881
F/G	6.05	4.95	1.82	2.94	2.95	-0.02	3.08	0.402	0.577	0.499
d 31 to 45										
ADG, lb	0.63	0.72	0.78	0.83	0.80	0.83	0.034	0.001	0.036	0.563
ADFI, lb	1.12	1.12	1.11	1.20	1.18	1.24	0.051	0.198	0.674	0.353
F/G	1.85	1.59	1.43	1.43	1.48	1.51	0.07	0.001	0.006	0.773
d 21 to 45										
ADG, lb	0.39	0.44	0.49	0.54	0.53	0.55	0.025	0.001	0.136	0.430
ADFI, lb	0.75	0.75	0.75	0.82	0.82	0.85	0.032	0.048	0.609	0.524
F/G	1.98	1.75	1.53	1.52	1.57	1.56	0.088	0.001	0.017	0.913
d 45 to 63										
ADG, lb	1.18	1.29	1.27	1.31	1.36	1.29	0.043	0.003	0.704	0.246
ADFI, lb	1.94	2.02	2.02	2.03	2.18	2.06	0.101	0.071	0.632	0.322
F/G	1.65	1.56	1.60	1.55	1.60	1.59	0.039	0.368	0.147	0.835
d 21 to 63										
ADG, lb	0.72	0.80	0.83	0.86	0.87	0.87	0.030	0.001	0.212	0.794
ADFI, lb	1.25	1.29	1.30	1.33	1.39	1.36	0.051	0.029	0.740	0.666
F/G	1.75	1.61	1.57	1.54	1.59	1.58	0.036	0.002	0.007	0.803

BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency.
[1]A total of 308 nursery pigs (DNA 241 × 600) were used with 5 or 6 pigs per pen and 10 replications per treatment. Common diets were fed throughout the nursery phase and contained 110 ppm added Fe from $FeSO_4$ from the trace mineral premix.
[2]Fe (Ceva Animal Health, LLC, Lenexa, KS) dosage administered 3 d after birth.
[3]Pigs were administered 200 mg at 3 d after birth and 100 mg 11 d after birth.
[4]Linear comparison of 0 to 200 mg doses.
[5]Quadratic comparison of 0 to 200 mg doses.
[6]Pairwise comparison between mean of 200 mg and 200 + 100 mg treatments.

Table 5. Effects of Fe dosage on preweaned and nursery pig hematological criteria[1]

	Fe, mg[2]							Probability, $P <$		
Item	0	50	100	150	200	200 + 100[3]	SEM	Linear[4]	Quadratic[5]	200 vs. 200 + 100[6]
Hgb, g/dl[7]										
d 3[8]	8.4	8.3	8.3	8.3	8.2	8.5	0.24	0.636	0.816	0.512
d 11[9]	5.7	8.3	9.9	10.1	10.7	10.5	0.22	0.001	0.001	0.731
d 21	4.6	6.8	9.3	11.3	12.0	12.8	0.22	0.001	0.001	0.012
d 35	7.4	8.4	10.0	10.8	11.6	12.7	0.23	0.001	0.150	0.001
d 63	12.0	11.8	12.0	12.1	12.0	12.4	0.24	0.610	0.789	0.287
Hct, %[7]										
d 3	28.0	27.1	27.6	27.4	27.4	28.0	0.72	0.688	0.684	0.567
d 11	20.0	29.2	34.4	35.8	36.5	36.2	0.71	0.001	0.001	0.782
d 21	16.0	23.4	30.9	37.3	38.8	40.9	0.71	0.001	0.001	0.038
d 35	26.4	30.0	33.6	35.5	37.2	40.6	0.72	0.001	0.072	0.001
d 63	40.9	39.4	40.1	40.4	39.7	41.1	0.76	0.612	0.669	0.204
Serum Fe, μg/dl[7]										
d 3	26	24	30	29	25	24	8.8	0.920	0.744	0.927
d 11	19	29	101	149	163	157	8.7	0.001	0.558	0.675
d 21	22	15	25	53	86	113	8.7	0.001	0.002	0.030
d 35	88	99	121	150	138	147	9.4	0.001	0.267	0.481
d 63	143	142	130	144	136	128	8.9	0.690	0.711	0.547
TIBC, μg/dl[7,10]										
d 3[8]	252	248	216	236	242	223	19.9	0.594	0.324	0.507
d 11	698	536	442	417	406	421	19.6	0.001	0.001	0.606
d 21	726	667	519	479	415	398	19.7	0.001	0.174	0.546
d 35	631	536	468	442	394	378	20.1	0.001	0.090	0.588
d 63	500	495	478	496	495	490	22.4	0.896	0.607	0.883

[1]A total of 336 pigs (DNA 241 × 600) were used in a 63 d experiment with 12 pigs per sow and 2 replications of each treatment within sow. Pigs were weaned at 21 d and placed in pens with 5 or 6 pigs per pen and 10 replications per treatment. All barrows were bled at each of the time points to measure hematological criteria. Each time point represents days after birth. Day 3 and 11 represent time points in farrowing and d 21, 35, and 63 represent t in the nursery. Common diets were fed throughout the nursery phase and contained 110 ppm added Fe from $FeSO_4$ from the trace mineral premix.

[2]Fe (Ceva Animal Health, LLC, Lenexa, KS) dose administered 3 d after birth.

[3]Pigs were administered 200 mg at beginning of trial and 100 mg 11 d after birth.

[4]Linear comparison of 0 to 200 mg doses.

[5]Quadratic comparison of 0 to 200 mg doses.

[6]Pairwise comparison between mean of 200 mg and 200 + 100 mg treatments.

[7]Treatment × day interaction ($P < 0.001$). Hgb = hemoglobin. Hct = hematocrit. TIBC = total Fe binding capacity.

[8]Represents 3 d after farrowing. Blood was drawn prior to Fe injection.

[9]Represents 11 d after farrowing. Blood was drawn prior to Fe injection.

[10]Total Fe binding capacity.