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Effects of the Age of Newborn Pigs Receiving an Iron Injection on Suckling and Subsequent Nursery Performance and Blood Criteria

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Effects of the Age of Newborn Pigs Receiving an Iron Injection on Suckling and Subsequent Nursery Performance and Blood Criteria

Abstract

A total of 324 newborn pigs (DNA 241 × 600, initially 3.56 ± 0.10 lb body weight (BW)) were used in a 80-d study evaluating the effects of Fe injection timing after birth on suckling and subsequent nursery pig performance and blood criteria. GleptoForte (Ceva Animal Health, LLC., Lenexa, KS) contains gleptoferron, which is an Fe macromolecule complex that is used as an injectable Fe source for suckling piglets. A total of 27 litters were used with the number of pigs per sow equalized on each day of farrowing. Two d after birth, all piglets were weighed, and six barrows and six gilts were allotted to 1 of 6 treatments within litter in a randomized complete block design. Treatments consisted of a negative control receiving no Fe injection or 200 mg of injectable Fe from GleptoForte provided in a single injection on d 2, 4, 6, 8, or 10 after birth. Piglets were weighed on d 2, 12, and weaning (d 21) to calculate average daily gain (ADG) during farrowing. Piglets were bled on d 2, 12, and 21 to determine blood Fe status. The blood criteria evaluated to determine Fe status were: hemoglobin (Hgb), hematocrit (Hct), serum Fe, and total Fe binding capacity (TIBC). Pigs were weaned at approximately 21 d of age and allotted to pens based on previous Fe treatment with BW balanced across all pens within a treatment with 5 or 6 pigs per pen and 10 pens per treatment. Common diets were fed throughout the nursery in 3 phases. Pigs and feeders were weighed on d 28, 35, 42, 48, 55, 62, and 80 after birth to determine ADG, average daily feed intake (ADFI), and feed efficiency (F/G). Pigs were bled on d 21 (weaning) and 35 after birth to determine blood Fe status.

In farrowing, increasing the age that piglets received a 200 mg Fe injection until 4 or 6 d after birth provided marginal evidence for an improvement (quadratic; $P = 0.065$) in ADG. Not providing an Fe injection resulted in marginal evidence for a decrease ($P = 0.070$) in overall ADG and decreased ($P = 0.001$) d 21 BW compared to all other treatments. For the nursery period, increasing the age of piglets receiving a 200 mg Fe injection from 2 to 4 or 6 d after birth improved (quadratic; $P = 0.013$) d 80 ending BW with a decrease in BW when Fe was provided after d 6.

Significant treatment × day interactions ($P = 0.001$) were observed for hemoglobin (Hgb) and hematocrit (Hct). The interactions occurred because pigs injected with 200 mg Fe on d 2, 4, 6, or 8 after birth had increasing values until d 12 after birth, while pigs not receiving an Fe injection or pigs receiving a 200 mg Fe injection on d 10 after birth had decreasing values to d 12 after birth. All pigs receiving a 200 mg Fe injection after birth had increased values from d 12 to 21 and then slightly decreased to d 35 after birth, while pigs not receiving an Fe injection had decreased values from d 12 to 21 and then increasing values to d 35 after birth.

In summary, providing a 200 mg Fe injection on d 4 or 6 after birth provided the greatest preweaning growth performance and body weight at the end of the nursery phase. Providing a 200 mg Fe injection on d 6 after birth provided the greatest blood Fe status up to weaning, but there was no evidence of difference in blood Fe status in the nursery when administering a 200 mg Fe injection within 10 d after birth.

Keywords

Fe, gleptoferron, growth performance, nursery, timing

Cover Page Footnote

Appreciation is expressed to Dr. Andrew Holtcamp, Ceva Animal Health, LLC., Lenexa, KS, for technical and financial support.

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Effects of the Age of Newborn Pigs Receiving an Iron Injection on Suckling and Subsequent Nursery Performance and Blood Criteria[1]

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Summary

A total of 324 newborn pigs (DNA 241 × 600, initially 3.56 ± 0.10 lb body weight (BW)) were used in a 80-d study evaluating the effects of Fe injection timing after birth on suckling and subsequent nursery pig performance and blood criteria. GleptoForte (Ceva Animal Health, LLC., Lenexa, KS) contains gleptoferron, which is an Fe macromolecule complex that is used as an injectable Fe source for suckling piglets. A total of 27 litters were used with the number of pigs per sow equalized on each day of farrowing. Two d after birth, all piglets were weighed, and six barrows and six gilts were allotted to 1 of 6 treatments within litter in a randomized complete block design. Treatments consisted of a negative control receiving no Fe injection or 200 mg of injectable Fe from GleptoForte provided in a single injection on d 2, 4, 6, 8, or 10 after birth. Piglets were weighed on d 2, 12, and weaning (d 21) to calculate average daily gain (ADG) during farrowing. Piglets were bled on d 2, 12, and 21 to determine blood Fe status. The blood criteria evaluated to determine Fe status were: hemoglobin (Hgb), hematocrit (Hct), serum Fe, and total Fe binding capacity (TIBC). Pigs were weaned at approximately 21 d of age and allotted to pens based on previous Fe treatment with BW balanced across all pens within a treatment with 5 or 6 pigs per pen and 10 pens per treatment. Common diets were fed throughout the nursery in 3 phases. Pigs and feeders were weighed on d 28, 35, 42, 48, 55, 62, and 80 after birth to determine ADG, average daily feed intake (ADFI), and feed efficiency (F/G). Pigs were bled on d 21 (weaning) and 35 after birth to determine blood Fe status.

In farrowing, increasing the age that piglets received a 200 mg Fe injection until 4 or 6 d after birth provided marginal evidence for an improvement (quadratic; $P = 0.065$) in ADG. Not providing an Fe injection resulted in marginal evidence for a decrease ($P = 0.070$) in overall ADG and decreased ($P = 0.001$) d 21 BW compared to all other

[1]Appreciation is expressed to Dr. Andrew Holtcamp, Ceva Animal Health, LLC., Lenexa, KS, for technical and financial support.
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treatments. For the nursery period, increasing the age of piglets receiving a 200 mg Fe injection from 2 to 4 or 6 d after birth improved (quadratic; $P = 0.013$) d 80 ending BW with a decrease in BW when Fe was provided after d 6.

Significant treatment × day interactions ($P = 0.001$) were observed for hemoglobin (Hgb) and hematocrit (Hct). The interactions occurred because pigs injected with 200 mg Fe on d 2, 4, 6, or 8 after birth had increasing values until d 12 after birth, while pigs not receiving an Fe injection or pigs receiving a 200 mg Fe injection on d 10 after birth had decreasing values to d 12 after birth. All pigs receiving a 200 mg Fe injection after birth had increased values from d 12 to 21 and then slightly decreased to d 35 after birth, while pigs not receiving an Fe injection had decreased values from d 12 to 21 and then increasing values to d 35 after birth.

In summary, providing a 200 mg Fe injection on d 4 or 6 after birth provided the greatest preweaning growth performance and body weight at the end of the nursery phase. Providing a 200 mg Fe injection on d 6 after birth provided the greatest blood Fe status up to weaning, but there was no evidence of difference in blood Fe status in the nursery when administering a 200 mg Fe injection within 10 d after birth.

Introduction

Young pigs have more rapid growth rates that can lead to greater body blood volume.[4] Because of this rapid growth rate and sow colostrum containing low levels of Fe, newborn pigs are more susceptible to developing iron deficiency in the first week of life.[5] Due to this, intramuscular (IM) administration of 200 mg of Fe after birth is common in the swine industry and it is well established this practice prevents iron deficiency and anemia.[6] However, there are discrepancies in the optimal time after birth to provide the Fe injection to maximize growth and hematological criteria. Research has shown that providing a 180 mg Fe injection 1 d compared to 3 or 4 d after birth resulted in greater hematological criteria in the first week of life.[7] Kernkamp et al., on the other hand, observed that delaying a 150 mg Fe injection to 21 d after birth compared to administering a 150 mg Fe injection 7 d after birth revealed no evidence of difference in body weight or hematological criteria when pigs were weaned at 28 d of age.[8]

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

[4]Jolliff, J.S. and D. C. Mahan. 2011. Effect of injected and dietary iron in young pigs on blood hematology and postnatal pig growth performance. J. Anim. Sci. 89:4068–4080. doi: 10.2527/jas.2010-3736
[5]Kegley, E.B., Spears, J.W., Flowers, W.L., and W.D. Schoenherr. 2002. Fe methionine as a source of Fe for the neonatal pig. Nutr. Res. 22:1209-1217. doi:10.1016/S0271-5317(02)00434-7
[6]Perri, A.M., Friendship, R.M., Harding, J.C. and T.L. O'Sullivan. 2016. An investigation of iron deficiency and anemia in piglets and the effect of iron status at weaning on post-weaning performance. J. Swi. Heal. Prod. 24:10-20.
[7]Egeli, A.K. and T. Farmstad. 1999. An evaluation of iron-dextran supplementation in piglets administered by injection on the first, third or fourth day after birth. Res. Vet. Sci. 66:179-184. doi:10.1053/rvsc.1998.0223
[8]Kernkamp, H.C.H., Clawson, A.J. and R.H. Ferneyhough. 1962. Preventing iron-deficiency anemia in baby pigs. J. Anim. Sci. 21:527-532.

and potentially improved growth performance. Williams et al.[9] previously determined that a 200 mg Fe injection provided from GleptoForte on d 2 after birth maximized farrowing and nursery performance and Fe status. However, research is not available that describes the optimal injection timing of Fe from gleptoferron after birth 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 Fe injection time after birth in newborn pigs on preweaning and subsequent nursery performance and blood criteria.

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 324 newborn pigs (DNA 241 × 600, initially 3.56 ± 0.10 lb BW) were used in a 80-d study. A total of 27 litters were utilized with number of pigs per sow equalized on each day of farrowing. Two days after birth, all piglets were weighed, and six barrows and six gilts were allotted in a randomized complete block design to 1 of 6 treatments such that there was 1 barrow and 1 gilt per treatment for each sow. Thus, there were 54 replications per treatment. The six treatments consisted of a negative control receiving no Fe injection or 200 mg of injectable Fe (GleptoForte, Ceva Animal Health, LLC., Lenexa, KS) provided in a single injection on d 2, 4, 6, 8, or 10 after birth. Piglets were weighed on d 2, 12, and weaning (d 21) to calculate ADG before weaning. Creep feed was not offered to suckling pigs.

Nursery Performance

Pigs were weaned at approximately 21 d of age and allotted to pens based on previous Fe treatment with BW balanced across all pens within a treatment 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 28, 35, 42, 48, 55, 62, and 80 after birth to determine ADG, ADFI, and F/G.

Feed

Common diets were fed in all nursery phases (Table 1). The phase 1 diet was prepared at a commercial feed mill located in central KS (Hubbard Feeds, Inc., Beloit, KS) and contained specialty protein ingredients fed in pellet form. Phase 2 and 3 diets were prepared at the Kansas State University O.H. Kruse Feed Technology and Innovation Center (Manhattan, KS). Phase 2 and 3 diets were formulated to include 50 mg/kg of carbadox (Mecadox, Phibro Animal Health Co., Stamford, CT) and were fed in meal form. All diets contained 110 mg/kg Fe from ferrous sulfate ($FeSO_4$) provided by the trace mineral premix. All diets were formulated according to the Nutrient Requirements of Swine[10] to be at or greater than the pigs' daily nutrient requirements so as not

[9]Williams, H.; Woodworth, J.C.; DeRouchey, J.M.; Dritz, S.S.; Tokach, M.D.; Goodband, R.D.; and Holtcamp, A. 2018. "Effects of increasing Fe dosage in newborn pigs on suckling and subsequent nursery performance." *Kansas Agricultural Experiment Station Research Reports.* Vol. 2: Iss. 10.

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

to limit growth performance. Feed samples in each dietary phase were collected directly from feeders and 6 pooled samples for each dietary phase were submitted for analysis of dry matter (DM), crude protein (CP), Ca, P, and Fe content (Ward Laboratories, Inc., Kearney, NE; Table 2).

Blood and Feed Analysis

Blood was collected via jugular venipuncture from one barrow per treatment per litter on d 2, 12, and 21 after farrowing as well as d 35 after birth. Blood criteria measured included Hgb and 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 Veterinary Diagnostic Laboratory, College of Veterinary Medicine, Kansas State University, Manhattan, KS.

Statistical Analysis

Growth data of suckling piglets were analyzed as a randomized complete block design using the individual pig as the experimental unit and crate and gender as random effects. Nursery growth data were analyzed as a randomized complete block design using the PROC GLIMMIX procedure of SAS (version 9.4 SAS Institute, Inc., Cary, NC) with pen as the experimental unit and block as a random effect. Blood criteria from suckling and nursery pigs were measured as a repeated measure within pig with the individual pig as the experimental unit and crate as a random effect. Growth data and blood parameters were evaluated using linear and quadratic effects of Fe injection time point from d 2 to 10 after birth and a pairwise comparison of the negative control vs. all other treatments using preplanned CONTRAST statements. Blood criteria were also evaluated for treatment and day interactions using the PROC GLIMMIX procedure of SAS. Differences between treatments were determined by using least squares means. A P-value ≤ 0.05 was considered significant and 0.05 < P ≤ 0.10 was considered marginally significant.

Results and Discussion

Chemical Analysis

Results of the diet analysis indicated that DM, CP, calcium, and phosphorus met the pigs' nutrient requirement.[10] Iron analysis of the diets indicated that diets either met or exceeded the pigs' iron requirement.[10]

Preweaning Growth Performance

From d 2 to 12, there was marginal evidence for an improvement (linear; $P = 0.066$) in ADG when increasing the age of piglets when receiving a 200 mg Fe injection (Table 2). From d 12 to 21, increasing the age that piglets receive a 200 mg Fe injection from 4 or 6 d after birth increased (quadratic; $P = 0.024$) ADG with a decrease in performance observed when the Fe injection was delayed until d 8 or 10. From d 12 to 21, pigs that did not receive an Fe injection after birth had decreased ($P = 0.001$) ADG compared to all other treatments. Overall, marginal evidence for a difference (quadratic; $P = 0.065$) in ADG was observed when increasing the age piglets received a 200 mg Fe injection to 4 or 6 d after birth, with a decrease in performance observed when delaying Fe injection until d 8 or 10. Not providing an Fe injection resulted in marginal evidence for a decrease ($P = 0.070$) in overall ADG and decreased ($P = 0.001$) d 21 BW compared to all other treatments.

Nursery Growth Performance

From d 21 to 35, there was marginal evidence for a difference (linear; $P = 0.059$) with increasing age after birth of a 200 mg Fe injection for an increase in ADFI (Table 3). Increasing the age when piglets that received a 200 mg Fe injection to d 4 after birth improved (quadratic; $P = 0.028$) d 35 BW with no further improvement observed when injections were provided at either d 6, 8, or 10 after birth. Also, the absence of a Fe injection after birth worsened ($P = 0.001$) ADG, ADFI, F/G, and d 35 BW compared to all other treatments.

From d 35 to 48, there was no evidence of a difference ($P > 0.10$) in growth performance by increasing the age when piglets received a 200 mg Fe injection. However, increasing time of a 200 mg Fe injection up to 4 d after birth improved (quadratic; $P = 0.019$) d 48 BW. Furthermore, not providing a Fe injection after birth decreased ($P < 0.05$) ADG, ADFI, and d 48 BW compared to all other treatments.

From d 48 to 80, there was marginal evidence for a difference (quadratic; $P = 0.076$) with increasing age after birth of a 200 mg Fe injection for an increase in ADFI. Increasing age when piglets received a 200 mg Fe injection from 2 to 4 or 6 d after birth improved (quadratic; $P = 0.013$) d 80 ending BW with a decrease in BW when pigs received Fe on d 8 or 10 of age. Marginal evidence for a reduction ($P = 0.061$) in ADFI was observed in pigs not receiving a Fe injection after birth compared to all other treatments. The absence of an Fe injection decreased ($P = 0.001$) d 80 ending BW compared to all other treatments.

Overall, there was no evidence of a difference ($P > 0.10$) in nursery growth performance by increasing the age when piglets received a 200 mg Fe injection. The absence of an Fe injection after birth decreased ($P < 0.05$) ADG and ADFI compared to all other treatments.

Hematological Criteria

As expected, there was no evidence of difference ($P > 0.10$) observed for any hematological criteria measured on d 2 prior to the Fe injection (Table 4). For Hgb, a significant treatment × day interaction ($P = 0.001$) was observed. The interaction occurred because pigs receiving a 200 mg Fe injection on d 2, 4, 6, or 8 after birth had increasing Hgb values to d 12 after birth, while pigs not receiving a 200 mg Fe injection or pigs receiving a 200 mg Fe injection on d 10 after birth had decreasing Hgb values to d 12 after birth. All pigs receiving a 200 mg Fe injection had increased Hgb values from d 12 to 21 and then slightly decreased to d 35 after birth, while pigs not receiving a Fe injection had decreased values from d 12 to 21 and then increasing Hgb values to d 35 after birth. On d 12, administering a 200 mg Fe injection up to d 4 after birth increased (quadratic; $P = 0.001$) Hgb values with a decrease in Hgb values observed with later injections. On d 21, administering a 200 Fe mg injection after d 6 of birth decreased (linear; $P = 0.047$) Hgb values. On d 35, there was no evidence of difference ($P > 0.10$) in Hgb values among the treatments. The absence of an Fe injection after birth resulted in decreased ($P = 0.001$) Hgb values on d 12, 21, and 35 after birth compared to all other treatments.

A significant treatment × day interaction ($P = 0.001$) was observed for Hct values. This interaction occurred because pigs receiving a 200 mg Fe injection on d 2, 4, 6, or 8 after birth had increasing Hct values to d 12 after birth, while pigs not receiving a Fe injection or pigs receiving a 200 mg Fe injection on d 10 after birth had decreasing Hct values to d 12 after birth. All pigs receiving a 200 mg Fe injection after birth had increased Hct values from d 12 to 21 and then slightly decreased to d 35 after birth, while pigs not receiving an Fe injection had decreased values from d 12 to 21 and then increasing Hct values to d 35 after birth. On d 12 post-farrowing, piglets receiving a 200 mg Fe injection up to d 4 after birth had increased (quadratic; $P = 0.001$) Hct values with a decrease in Hct values observed thereafter. On d 21 post-farrowing, marginal significance for a decrease (linear; $P = 0.094$) in Hct values was observed for administering a 200 mg Fe injection after d 6 of birth. On d 35 post-farrowing, there was no evidence of difference ($P > 0.10$) in Hct values amongst the pigs receiving a 200 mg Fe injection. The absence of a Fe injection after birth decreased ($P = 0.001$) Hct values on d 12, 21, and 35 after birth compared to all other treatments.

For serum Fe, a significant treatment × day interaction ($P = 0.01$) was observed. The interaction was a result of serum Fe values in pigs receiving a 200 mg Fe injection after birth increasing from d 2 to 12, decreasing from d 12 to 21, and then increasing from d 21 to 35 while pigs not receiving an Fe injection had decreasing serum Fe values to d 21, then increasing values from d 21 to 35. On d 12 post-farrowing, serum Fe values increased (quadratic; $P = 0.001$) when the 200 mg of Fe injection was administered up to d 10 with a larger increase in values from d 8 to 10 when Fe was administered. On d 21 and 35, there was no evidence of difference ($P > 0.10$) in serum Fe values amongst the pigs receiving a 200 mg Fe injection. The absence of a Fe injection decreased ($P = 0.001$) serum Fe values on d 12, 21, and 35 compared to all other treatments.

A significant treatment × day interaction ($P = 0.001$) was observed for TIBC values. This interaction occurred because pigs receiving a 200 mg Fe injection on d 2, 4, or 6 after birth had increased TIBC values up to d 21 then decreased to d 35 while pigs receiving a 200 mg Fe injection on d 8 or 10 after birth had increasing TIBC values up to d 12 then decreasing values from d 12 to 35. Pigs not receiving an Fe injection after birth had increasing TIBC values up to d 21 and then decreased to d 35. On d 12 post-farrowing, TIBC values increased (quadratic; $P = 0.001$) when the 200 mg Fe injection was administered to d 10 after birth with a larger increase in values observed when Fe was administered from d 6 to 10. On d 21 and 35, there was no evidence of difference ($P > 0.10$) observed for TIBC values in pigs receiving a 200 mg Fe injection. The absence of an Fe injection decreased ($P = 0.001$) TIBC values on d 12, 21, and 35 after birth compared to all other treatments.

These results suggest that administering an injection of 200 mg Fe on d 4 or 6 after birth results in the greatest suckling and subsequent nursery performance. Up to weaning (d 21 post-farrow), there was no evidence of a difference in blood Fe status when a 200 mg Fe injection was administered up to d 6 of age with a decrease in blood Fe status observed thereafter. There was no evidence of difference in blood Fe status in the early nursery period among the pigs receiving a 200 mg Fe injection. The negative impact on growth performance and blood Fe status in pigs not receiving an Fe injection after birth is in agreement with previous research. These results suggest that producers should consider extending the time after birth before administering an Fe injection to maximize post-farrowing and subsequent nursery performance. In this study, providing a 200 mg Fe injection on d 4 after birth provided the greatest preweaning growth performance and ending nursery body weight.

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, 47% crude protein	20.29	29.62	33.75
Corn DDGS, 6-9% oil[2]	5.00	---	---
HP 300[3]	7.50	5.00	---
Fish meal	4.00	---	---
Choice white grease	3.00	---	---
Limestone	0.75	1.05	0.95
Monocalcium phosphate, 21% phosphorus	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, 60% liquid	0.04	---	---
Phytase[5]	---	0.02	0.02
Zinc oxide	0.39	0.25	---
Mecadox-2.5[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) amino acids, %			
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
Net energy, kcal/lb	1,170	1,081	1,077
Chemical analysis,[7] %	23.7	22.8	21.6
Dry matter	90.6	89.3	88.4
Crude protein	20.2	22.9	20.5
Calcium	0.94	0.87	0.89
Phosphorus	0.60	0.60	0.56
Iron, ppm	101.1	112.2	87.8

[1]Phase 1 diets were fed from d 0 to 14 (13 to 20 lb), Phase 2 diets fed from d 14 to 27 (20 to 32 lb), and Phase 3 diets fed from d 27 to 42 (32 to 78 lb).
[2]Dried distillers grains with solubles.
[3]Hamlet Protein, Inc., Findlay, OH.
[4]Trace mineral premix contained 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]Complete diet samples (6 per phase) were obtained from each dietary phase directly at the feeder (Ward Laboratories, Inc., Kearney, NE).

Table 2. Effects of injectable Fe timing on preweaning pig growth performance[1]

		Fe injection day[2]						Probability, $P <$		
Item[3]	0[4]	2	4	6	8	10	SEM	Linear[5]	Quadratic[5]	0 vs. Others
BW, lb										
d 2[6]	3.6	3.5	3.6	3.6	3.6	3.5	0.10	0.667	0.360	0.677
d 12[7]	8.4	8.4	8.8	8.7	8.2	8.3	0.23	0.191	0.239	0.723
d 21	12.0	13.0	13.7	13.6	12.8	13.0	0.36	0.327	0.113	0.001
ADG, lb										
d 2 to 12	0.48	0.49	0.52	0.50	0.46	0.48	0.018	0.066	0.350	0.461
d 12 to 21	0.40	0.52	0.57	0.58	0.52	0.54	0.020	0.688	0.024	0.001
d 2 to 21	0.48	0.51	0.54	0.59	0.49	0.50	0.029	0.446	0.065	0.070

[1]A total of 324 suckling pigs (DNA 241 × 600) were used with 12 pigs per sow and 2 replications of treatment within sow.
[2]200 mg of Fe (Gleptoforte, Ceva Animal Health, LLC., Lenexa, KS) administered on d 2, 4, 6, 8, or 10 after farrowing.
[3]BW = body weight. ADG = average daily gain.
[4]Negative control with pigs receiving no iron injection.
[5]Comparison of d 2 to 10 injection treatments.
[6]Represents 2 d after farrowing.
[7]Represents 12 d after farrowing.

Table 3. Effects of injectable Fe timing on nursery pig performance[1]

		Fe injection day[2]						Probability, $P <$		
Item[3]	0[4]	2	4	6	8	10	SEM	Linear[5]	Quadratic[5]	0 vs. Others
BW, lb										
d 35[6]	16.7	19.1	20.8	20.5	19.8	20.0	0.45	0.001	0.028	0.001
d 48	27.7	31.3	34.0	33.2	32.7	32.6	0.74	0.001	0.019	0.001
d 80	72.6	76.1	81.1	81.8	80.1	78.9	1.62	0.001	0.013	0.001
d 21 to 35										
ADG, lb	0.34	0.44	0.50	0.49	0.51	0.49	0.030	0.196	0.241	0.001
ADFI, lb	0.46	0.52	0.58	0.59	0.58	0.60	0.030	0.059	0.375	0.001
F/G	1.50	1.21	1.18	1.23	1.14	1.24	0.074	0.895	0.636	0.001
d 35 to 48										
ADG, lb	0.84	0.91	1.02	0.94	0.99	0.97	0.034	0.373	0.321	0.001
ADFI, lb	1.18	1.32	1.41	1.33	1.33	1.34	0.052	0.748	0.675	0.003
F/G	1.40	1.45	1.38	1.43	1.35	1.39	0.044	0.250	0.612	0.997
d 48 to 80										
ADG, lb	1.39	1.40	1.47	1.48	1.47	1.44	0.053	0.497	0.140	0.153
ADFI, lb	2.38	2.41	2.55	2.58	2.50	2.50	0.064	0.463	0.076	0.061
F/G	1.72	1.73	1.73	1.74	1.71	1.74	0.031	0.831	0.992	0.579
d 0 to 80										
ADG, lb	1.01	1.06	1.14	1.11	1.13	1.11	0.030	0.346	0.185	0.003
ADFI, lb	1.64	1.71	1.83	1.79	1.78	1.78	0.043	0.499	0.193	0.004
F/G	1.63	1.62	1.60	1.63	1.57	1.61	0.023	0.439	0.619	0.363

[1]A total of 311 nursery pigs (DNA 241 × 600) were used with 5 or 6 pigs per pen and 10 replicate pens with 5 or 6 pigs 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]200 mg of Fe (Gleptoforte, Ceva Animal Health, LLC., Lenexa, KS) administered on d 2, 4, 6, 8, or 10 after farrowing.

[3]BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed efficiency.

[4]Negative control with pigs receiving no iron injection.

[5]Comparison of d 2 to d 10 injection treatments.

[6]Values represent time after birth.

Table 4. Effects of injectable Fe timing on suckling and nursery pig blood criteria[1]

		Fe injection day[2]						Probability, $P <$		
Item[3]	0[4]	2	4	6	8	10	SEM	Linear[5]	Quadratic[5]	0 vs. Others
Hgb, g/dL[6]										
d 2[7]	8.3	8.2	8.4	8.2	8.4	8.1	0.21	0.843	0.337	0.675
d 12[8]	5.6	10.4	11.0	10.5	9.0	7.0	0.22	0.001	0.001	0.001
d 21	4.1	11.4	11.5	11.4	11.2	10.9	0.21	0.047	0.187	0.001
d 35	7.2	10.4	10.6	10.9	10.1	10.5	0.22	0.583	0.313	0.001
Hct, %[6]										
d 2	28.7	28.2	29.2	28.8	28.9	27.9	0.75	0.709	0.168	0.859
d 12	19.6	35.4	37.0	36.5	31.2	23.5	0.69	0.001	0.001	0.001
d 21	14.1	39.0	38.9	38.9	38.4	37.4	0.71	0.094	0.376	0.001
d 35	26.9	35.1	35.9	37.2	34.5	35.4	0.73	0.638	0.126	0.001
Serum Fe, μg/dL[6]										
d 2	45	47	44	40	51	43	9.4	0.958	0.881	0.976
d 12	17	149	169	170	184	299	9.2	0.001	0.001	0.001
d 21	14	102	79	105	102	108	9.3	0.228	0.401	0.001
d 35	92	145	125	146	142	131	9.4	0.667	0.852	0.001
TIBC, μg/dL[6]										
d 2	203	184	193	190	193	205	17.9	0.458	0.847	0.610
d 12	694	363	402	427	476	648	17.6	0.001	0.001	0.001
d 21	816	411	440	444	419	441	17.7	0.478	0.527	0.001
d 35	540	379	386	404	375	382	17.8	0.944	0.465	0.001

[1]A total of 336 pigs (DNA 241 × 600) were used in a 80-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 farrowing. Day 2 and d 12 represent time points in farrowing and d 21 and d 35 represent time points 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]200 mg of Fe (Gleptoforte, Ceva Animal Health, LLC., Lenexa, KS) administered on d 2, 4, 6, 8, or 10 after farrowing.

[3]Hgb = hemoglobin. Hct = hematocrit. TIBC = total iron binding capacity.

[4]Negative control with pigs receiving no iron injection.

[5]Comparison of d 2 to d 10 injection treatments.

[6]Treatment × day interaction ($P < 0.001$).

[7]Represents 2 d after farrowing. Blood was drawn prior to Fe injection.

[8]Represents 12 d after farrowing. Blood was drawn prior to Fe injection.