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Effects of Iron Injection Timing on Suckling and Subsequent Nursery and Growing-Finishing Performance and Hematological Criteria under Commercial Conditions¹

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Summary

A total of 1,892 newborn pigs (PIC 359 × C40; initially 3.3 lb body weight [BW]) within 172 litters were used in a 168-d study to evaluate the effects of Fe injection timing after birth on suckling and subsequent nursery and growing-finishing growth performance and hematological criteria. One day after birth, piglets were weighed, and 11 pigs within each litter were allotted to 1 of 6 treatments consisting of no Fe injection or 200 mg of injectable Fe provided on d 1, 3, 5, or 7 of age, or 200-mg on d 1 plus 200-mg on d 12 of age. Piglets were weighed individually and bled at weaning (19 d of age) to determine blood Fe status and lactation growth performance. Pigs were weaned and placed in a commercial wean-to-finish facility in a total of 15 pens with equal representation of treatments in each pen. Pigs were individually weighed on d 72 and 168 after birth to determine subsequent nursery and growing-finishing average daily gain (ADG).

During the lactation phase, marginal significance for a decrease (linear; $P = 0.080$) in preweaning ADG was observed with increasing the age at which pigs received a 200-mg Fe injection; however, there was no evidence for a difference ($P > 0.10$) in d 19 BW. The absence of an Fe injection decreased ($P = 0.0001$) preweaning ADG and d 19 BW compared to pigs receiving an Fe injection. Providing a 200-mg Fe injection on d 1 plus d 12 of age showed no evidence of a difference ($P > 0.10$) in preweaning ADG or d 19 BW compared to pigs receiving a 200-mg Fe injection on d 1 only.

During the nursery (d 19 to 72 d of age) or finishing (d 72 to 168) phases, increasing the age at which pigs received a 200-mg Fe injection after birth provided no evidence for a difference ($P > 0.10$) in subsequent nursery or finishing ADG. The absence of an Fe injection post-farrowing decreased ($P = 0.0001$) subsequent nursery ADG and ending BW on d 72.

¹ Appreciation is expressed to Ceva Animal Health, LLC., Lenexa, KS for technical and financial support, and JBS USA (Greeley, CO) for providing animals and facilities and technical assistance.

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Overall (d 1 to 168 d of age), increasing the age at which pigs received a 200-mg Fe injection provided no evidence for a difference ($P > 0.10$) in overall ADG. The absence of an Fe injection post-farrowing decreased ($P = 0.0001$) overall ADG. Providing a 200-mg Fe injection on d 1 plus d 12 of age showed no evidence of a difference ($P > 0.10$) in overall ADG compared to pigs receiving a 200-mg Fe injection on d 1 of age only. Furthermore, there was no evidence ($P > 0.10$) that Fe injection treatments influenced preweaning or wean-to-finish mortality. The absence of an Fe injection post-farrowing provided no evidence for a difference ($P > 0.10$) in preweaning or wean-to-finish mortality.

For hematological criteria, increasing the age at which pigs received an Fe injection decreased (linear: $P < 0.05$) hemoglobin (Hb) and hematocrit (Hct) values at d 19 of age. The absence of an Fe injection post-farrowing decreased ($P = 0.0001$) Hb and Hct values at d 19 of age compared to pigs receiving an Fe injection after birth. Providing a 200-mg Fe injection on d 1 plus d 12 of age increased ($P = 0.0001$) Hb and Hct values at weaning compared to pigs receiving a 200-mg Fe injection on d 1 only.

In summary, this study provides evidence that administering 200 mg of Fe from gleptoferron within 7 d after birth optimizes preweaning and subsequent nursery and grow-finisher growth performance. Not administering 200 mg of Fe after birth significantly reduces preweaning and subsequent growth performance and blood Fe status at weaning compared to pigs receiving a 200-mg Fe injection, regardless of timing after birth.

Introduction

Iron is an indispensable micromineral due to its involvement in numerous biological functions. Iron deficiency and anemia develop prior to weaning because of low Fe storages at birth, rapid growth rate, and low sow colostrum and milk Fe content.^{5,6} Because of this, supplemental injectable Fe is provided to suckling piglets to prevent Fe deficiency and anemia. Efficacy of supplemental injectable Fe after birth on suckling and subsequent nursery pig performance is well established.^{7,8} A single 200-mg intramuscular (IM) injection of Fe is commonly used in the swine industry to prevent Fe deficiency.

The administration of a single 200-mg Fe dose is commonly practiced within the first week post-farrowing. However, limited research exists on the specific day of age when the Fe injection is administered to optimize performance and blood Fe status. Egeli and Framstad determined that administering a 180-mg injection of Fe dextran to suckling pigs 1, 3, or 4 days after birth showed no evidence of difference in Hb values 14 or 21 d after birth.⁹ Furthermore, Kernkamp et al. observed that increasing the age at which a 150-mg Fe dextran injection was administered from 7 to 14 or 21 d of age decreased hemoglobin (Hb) and hematocrit (Hct) values at 21 and 28 d after birth but showed no evidence of a difference in BW up to 56 d of age.¹⁰

⁵ Kegley, E.B., J.W. Spears, W.L. Flowers, 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 Hurley, W. 2015. Composition of sow colostrum and milk. In: C. Farmer, editor, *The gestating and lactating sow*. Wageningen Academic Publishers. Wageningen, The Netherlands, p. 193-229.

⁷ Chevalier, T. 2019. Improved iron status in weanling pigs leads to improved growth performance in the subsequent nursery period. M.S. Thesis. University of Kentucky, Lexington.

⁸ Williams, H.E., J.C. Woodworth, J. M. DeRouchey, S.S. Dritz, M.D. Tokach, R.D. Goodband, and A. Holtkamp. 2019. PSV-12 Effects of increasing iron dosage in newborn pigs on preweaning performance and hematological criteria. *J. Anim. Sci.* 97:195-196 (Supplement_2). doi:10.1093/jas/skz122.344.

⁹ Egeli, A.K. and T. Framstad. 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

¹⁰ Kernkamp, H.C.H., A.J. Clawson, and R.H. Ferneyhough. 1962. Preventing iron-deficiency anemia in baby pigs. *J. Anim. Sci.* 21:527-532. doi:10.2527/jas1962.213527x.

Gleptoferron is a commercially available injectable Fe source. The optimal dose of Fe from gleptoferron in pigs was previously determined to be 200 mg to optimize growth and blood Fe status.⁸ In that study, all pigs were administered the Fe injection on d 3 after farrowing. Recent research suggests that providing a single 200-mg injection of Fe 4 or 6 d after birth improves preweaning growth performance and BW at the end of the nursery phase.^{11,12} Therefore, the objective of this study was to evaluate the effects of increasing the age when newborn pigs receive a 200-mg Fe injection provided from gleptoferron on preweaning and subsequent nursery and growing-finishing performance and hematological criteria under commercial conditions.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocols for this experiment. The study was conducted at a commercial sow facility in north-west Texas and a wean-to-finish facility in central Iowa.

A total of 1,892 newborn pigs (PIC 359 × C40; initially 3.3 ± 0.04 lb BW) within 172 litters were used in a 168-d study. One d after birth, all piglets were individually weighed, and 11 piglets within each litter were allotted to 1 of 6 treatments in a completely randomized design. One pig per litter received no Fe injection and 2 pigs per litter were used on all other treatments. Thus, there were 172 replications for the no Fe injection treatment and 344 replications for all other treatments. Treatments consisted of pigs receiving no Fe injection or 200 mg of injectable Fe (GleptoForte, Ceva Animal Health, Lenexa, KS) provided on d 1, 3, 5, or 7 of age, or 200 mg on d 1 plus 200 mg on d 12 of age. Piglets were individually weighed on d 1 and weaning (d 19) to determine preweaning ADG. Creep feed was not offered to suckling pigs. At weaning, pigs were placed in a commercial wean-to-finish facility in a total of 15 pens with equal representation of treatments in each pen. Each pen (31.5 × 25 ft) was equipped with a 5-hole stainless steel wet-dry feeder and 2 nipple waterers to provide *ad libitum* access to feed and water. Pigs were individually weighed on d 72 and 168 after birth to determine subsequent nursery and growing-finishing ADG.

Common diets were fed in all nursery and growing-finishing phases. The phase 1 nursery diets were fed in pellet form. Phase 2 and 3 nursery diets and all growing-finishing diets (3 total) were fed in meal form. All nursery diets were supplemented with 110 mg/kg Fe from iron sulfate (FeSO_4) provided by the trace mineral premix. Inclusion rate of the trace mineral premix in growing-finishing diets was reduced in a stepwise manner and diets contained 92, 73, and 55 mg/kg supplemental Fe from FeSO_4 . All diets were formulated according to the Nutrient Requirements of Swine (NRC, 2012) to be at or above the pig's daily nutrient requirements to not limit growth performance.¹³ Complete diet samples for each nursery dietary phase were taken directly from feeders and stored at -4°F. Diet samples were pooled, subsampled, and sent to a commercial laboratory (Ward Laboratories, Kearney, NE) for analysis of Fe.¹⁴

¹¹ Roubicek, C., H.E. Williams, J.M. DeRouchey, J.C. Woodworth, S.S. Dritz, M.D. Tokach, R.D. Goodband, and A. Holtcamp. 2019. Evaluating the effects of day of iron injection after farrowing on preweaning performance and hematological criteria. *J. Anim. Sci.* 97:151-152. doi:10.1093/jas/skz122.268.

¹² Williams, H.E., C. Roubicek, J.M. DeRouchey, J.C. Woodworth, S.S. Dritz, M.D. Tokach, R.D. Goodband, and A. Holtcamp. 2019. PSVI-19 Evaluating the effects of day of iron injection after farrowing on nursery performance and hematological criteria. *J. Anim. Sci.* 97:209-210. doi: 10.1093/jas/skz122.369.

¹³ NRC. 2012. Nutrient requirements of swine. 11th rev. ed. Natl. Acad. Press., Washington D.C.

¹⁴ AOAC International. 2012. Official Methods of Analysis of AOAC Int. 19th ed. Assoc. Off. Anal. Chem., Gaithersburg, MD.

Whole blood samples were collected via jugular venipuncture in 5 mL lithium heparin (Becton, Dickinson and Company, Franklin Lakes, NJ) vacutainer tubes using 22-gauge, 2.54 cm needles from 30 barrows per treatment at weaning (d 19). Whole blood samples were immediately analyzed for Hb and Hct on a handheld iSTAT portable clinical analyzer (iStat Alinity, Abbott Point of Care Inc.; Princeton, NJ).

Growth data of suckling piglets were analyzed as a completely randomized design with individual pig as the experimental unit and sow $\times$ gender serving as the random effect. Nursery and growing-finishing growth and lifetime growth data were analyzed with individual pig as the experimental unit. Sow $\times$ gender and pen served as random effects in the model. In addition, hematological criteria data were analyzed as a repeated measure. Heterogeneous variance was accounted for where appropriate. The BIC was used to determine best fit, with a lower number indicating an improved fit. A decrease in BIC greater than 2 among models for a hematological criterion was considered a significant improvement in fit.¹⁵ All growth and hematological criteria were analyzed assuming a normal distribution, and mortality data were analyzed using a binomial distribution. Pre-planned contrasts were utilized to evaluate linear and quadratic effects of Fe injection timepoint after birth and a pairwise comparison of the negative control vs. all other treatments. A pairwise comparison was utilized to evaluate pigs receiving a 200 mg injection on d 1 after birth vs. pigs receiving a 200 mg injection on d 1 after birth plus 200 mg on d 12 after birth. Differences between treatments were determined by using least squares means. Data were analyzed using the GLIMMIX procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC). Results were considered significant at $P \leq 0.05$ and marginally significant at $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

Iron analysis of the nursery diets indicated that diets either met or exceeded the pig's Fe requirement estimate.¹³ The analyzed Fe content of phase 1, phase 2, and phase 3 were 113, 110, and 98 ppm, respectively.

From d 1 to 19 of age, marginal significance for a decrease (linear; $P = 0.080$) in preweaning ADG was observed with increasing the age at which pigs received a 200-mg Fe injection (Table 1). However, there was no evidence for a difference ($P > 0.10$) in d 19 BW with increasing age at which pigs received a 200-mg Fe injection. The absence of an Fe injection decreased ($P = 0.0001$) preweaning ADG and d 19 BW compared to pigs receiving an Fe injection. Providing a 200-mg Fe injection on d 1 plus d 12 of age showed no evidence of a difference ($P > 0.10$) in preweaning ADG or d 19 BW compared to pigs receiving a 200-mg Fe injection on d 1 only.

From d 19 (weaning) to 72 of age, increasing the age at which pigs received a 200-mg Fe injection after birth provided no evidence for a difference ($P > 0.10$) in subsequent nursery ADG. However, marginal significance for a decrease ($P = 0.077$) in d 72 ending BW was observed with increasing age post-farrowing when pigs received a 200-mg Fe injection. The absence of an Fe injection post-farrowing decreased ($P = 0.0001$) subsequent nursery ADG and ending BW on d 72. Providing a 200-mg Fe injection on d 1 plus d 12 of age decreased ($P < 0.05$) subsequent nursery ADG and d 72 ending BW compared to pigs receiving a 200-mg Fe injection on d 1 of age only.

¹⁵ Gonçalves, M. A. D., N. M. Bello, S. S. Dritz, M. D. Tokach, J. M. DeRouchey, J. C. Woodworth, and R. D. Goodband. 2016. An update on modeling dose-response relationships: Accounting for correlated data structure and heterogeneous error variance in linear and nonlinear mixed models. *J. Anim. Sci.* 94:1940-1950. doi:10.2527/jas.2015-0106.

From d 72 to 168 of age, increasing the age at which pigs received a 200-mg Fe injection provided no evidence for a difference ($P > 0.10$) in subsequent growing-finishing ADG or d 168 ending BW. The absence of an Fe injection post-farrowing decreased ($P < 0.05$) subsequent growing-finishing ADG and d 168 ending BW. Providing a 200-mg Fe injection on d 1 plus d 12 of age showed no evidence of a difference ($P > 0.10$) in subsequent growing-finishing ADG and d 168 ending BW compared to pigs receiving a 200-mg Fe injection on d 1 of age only.

Overall from d 1 to 168 of age, increasing the age at which pigs received a 200-mg Fe injection provided no evidence for a difference ($P > 0.10$) in overall ADG. The absence of an Fe injection post-farrowing decreased ($P = 0.0001$) overall ADG. Providing a 200-mg Fe injection on d 1 plus d 12 of age showed no evidence of a difference ($P > 0.10$) in overall ADG compared to pigs receiving a 200-mg Fe injection on d 1 of age only.

There was no evidence ($P > 0.10$) that Fe injection treatments influenced preweaning or wean-to-finish mortality. The absence of an Fe injection post-farrowing provided no evidence for a difference ($P > 0.10$) in preweaning or wean-to-finish mortality.

For hematological criteria, increasing the age at which pigs received an Fe injection decreased (linear; $P < 0.05$) Hb and Hct values at d 19 of age (Table 2). The absence of an Fe injection post-farrowing decreased ($P = 0.0001$) Hb and Hct values at d 19 of age compared to pigs receiving an Fe injection after birth. Providing a 200-mg Fe injection on d 1 plus d 12 of age increased ($P = 0.0001$) Hb and Hct values at weaning compared to pigs receiving a 200-mg Fe injection on d 1 only.

In summary, increasing the age at which pigs received a 200-mg Fe injection within the first week after birth provided no evidence for an improvement in preweaning or subsequent growth performance. These results disagree with Roubicek et al.¹¹ and Williams et al.¹² The discrepancies in the results are unknown at this time. Furthermore, the results are in agreement with previous research that absence of an Fe injection after birth decreases preweaning and subsequent nursery growth performance and blood Fe status at weaning compared to pigs receiving a single 200-mg Fe injection after birth regardless of timing. Not providing an Fe injection after birth also reduces growing-finishing growth performance compared to pigs receiving a single 200-mg Fe injection after birth regardless of timing. To our knowledge, this is the first study evaluating the absence of an Fe injection after birth and its effects on growing-finishing pig performance in a commercial setting. The results also suggest that providing a 200-mg injection of Fe from gleptoferron 1 d and 12 d after birth increases Hb and Hct values at weaning but does not improve preweaning or subsequent growth performance compared to pigs receiving a single 200-mg injection of Fe from gleptoferron on 1 d after birth. Therefore, administering 200 mg of Fe from gleptoferron within 7 d after birth optimizes preweaning and subsequent nursery and grow-finishing growth performance. The inconsistencies in responses between studies warrant further research.

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Table 1. Effects of injectable Fe timing on preweaning and subsequent nursery and growing-finishing growth performance¹

Item ³	Fe injection day ²						Probability, <i>P</i> =			
	0 ⁴	1	3	5	7	1 and 12 ⁵	Linear ⁶	Quadratic ⁶	0 vs. others ⁷	d 1 vs. d 1 and 12 ⁸
BW, lb										
d 1	3.3	3.3	3.3	3.3	3.3	3.3	0.799	0.855	0.930	0.633
SEM	0.05	0.04	0.04	0.04	0.04	0.04				
d 19	11.2	13.5	13.3	13.4	13.2	13.5	0.146	0.607	<0.0001	0.729
SEM	0.18	0.13	0.13	0.13	0.14	0.13				
d 72	51.9	63.7	62.9	63.1	62.1	61.8	0.077	0.840	<0.0001	0.024
SEM	1.16	1.00	1.00	1.01	1.00	1.01				
d 168	257.9	276.6	275.1	275.3	273.3	273.8	0.155	0.846	<0.0001	0.205
SEM	2.79	2.30	2.31	2.32	2.32	2.33				
ADG, lb										
d 1 to 19	0.42	0.55	0.54	0.54	0.53	0.55	0.080	0.533	<0.0001	0.699
SEM	0.010	0.006	0.006	0.006	0.006	0.006				
d 19 to 72	0.77	0.95	0.94	0.94	0.92	0.91	0.126	0.904	<0.0001	0.010
SEM	0.018	0.015	0.015	0.016	0.015	0.015				
d 72 to 168	2.15	2.22	2.21	2.21	2.20	2.21	0.370	0.895	0.001	0.546
SEM	0.024	0.020	0.020	0.020	0.020	0.020				
d 1 to 168	1.51	1.62	1.61	1.61	1.60	1.61	0.154	0.837	<0.0001	0.197
SEM	0.016	0.013	0.013	0.014	0.014	0.014				
Prewean mortality, %	8.0	7.4	8.6	9.8	10.1	9.0	0.181	0.725	0.676	0.445
SEM	2.07	1.42	1.53	1.62	1.65	1.57				
Wean-to-finish mortality, %	2.7	3.0	3.0	2.3	5.2	4.3	0.258	0.209	0.634	0.361
SEM	1.34	1.00	1.00	1.00	1.35	1.24				

¹A total of 1,892 suckling pigs (PIC 359 × PIC C40) were used in a 72-d experiment with 11 pigs per sow. Two replications of injectable Fe treatments and 1 replication of the negative control were used within each sow's litter. Pigs were weaned at 19 d after farrowing and placed in a commercial wean-to-finish facility with approximately 125 pigs per pen in a total of 15 pens. Each treatment was equally represented in each pen. Common diets were fed throughout the nursery phase and contained 110 ppm added Fe from FeSO₄ provided from the vitamin and trace mineral premix.

²200 mg of Fe (GleptoForte, Ceva Animal Health, LLC., Lenexa, KS) administered on d 1, 3, 5, and 7 after farrowing.

³BW = body weight. ADG = average daily gain. Each timepoint represents days after farrowing. Days 1 and 19 represent timepoints in farrowing and d 72 represents timepoints in the nursery.

⁴Negative control with pigs receiving no Fe injection.

⁵Pigs were administered 200 mg of Fe at 1 d and 12 d after farrowing.

⁶Comparison of d 1 to d 7 injection treatments.

⁷Comparison between mean of pigs receiving no Fe injection and mean of all other pigs.

⁸Pairwise comparison between mean of pigs receiving injection on d 1 and pigs receiving injection on d 1 and d 12.

Table 2. Effects of injectable Fe timing on suckling pig blood criteria¹

Item ³	Fe injection day ²						Probability, <i>P</i> <			
	0 ⁴	1	3	5	7	1 and 12 ⁵	Linear ⁶	Quadratic ⁶	0 vs. Others ⁷	d 1 vs. d 1 and 12 ⁸
Hgb, g/dL										
d 19	5.0	11.1	11.3	10.7	10.3	12.2	0.001	0.113	<0.0001	<0.0001
SEM	0.32	0.20	0.20	0.20	0.20	0.20				
Hct, %										
d 19	15.2	32.6	33.3	31.7	30.4	36.1	0.002	0.101	<0.0001	<0.0001
SEM	1.06	0.64	0.63	0.64	0.65	0.64				

¹A total of 1,892 suckling pigs (PIC 359 × PIC C40) were used in a 72-d experiment with 11 pigs per sow. Two replications of injectable Fe treatments and 1 replication of the negative control were used within each sow's litter.

²200 mg of Fe (GleptoForte, Ceva Animal Health, LLC., Lenexa, KS) administered on d 1, 3, 5, and 7 after farrowing.

³Hgb = hemoglobin. Hct = hematocrit. Day 19 represents weaning.

⁵Pigs were administered 200 mg of Fe at 1 d and 12 d after farrowing.

⁶Comparison of d 1 to d 7 injection treatments.

⁷Comparison between mean of pigs receiving no Fe injection and mean of all other pigs.

⁸Pairwise comparison between mean of pigs receiving injection on d 1 and pigs receiving injection on d 1 and d 12.