

Effects of Iron Supplementation Level in Diets of Growing-Finishing Swine.

I. Pig Performance and Carcass Characteristics

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Story in Brief

A total 210 crossbred barrows and gilts were used to test the effects of supplementation level (50, 100, or 150 ppm) of iron (Fe) from Availa-Fe (an iron-amino acid complex) on performance and carcass characteristics of growing-finishing pigs. During the starter phase, ADG decreased linearly ($P < 0.02$) as supplementary Fe levels increased from 0 to 150 ppm; however, during the grower-I phase, ADG tended to increase linearly ($P < 0.10$) as supplemental Fe from Availa-Fe increased. Pig performance during the grower-II and finisher phases, as well as over the entire trial, was not ($P > 0.10$) affected by supplemental Fe. Carcass muscling and fatness measures were similar ($P > 0.10$) among dietary treatments. The redness of the longissimus muscle (LM) increased linearly ($P < 0.03$) with increasing levels of supplemental Fe. Furthermore, the LM tended to become darker (linear effect; $P < 0.15$), and American color scores tended to increase (linear effect; $P < 0.10$), as dietary Fe from Availa-Fe increased from 0 to 150 ppm. Even though ADG was affected during the early feeding phases, increasing the dietary Fe level had no effects on pig performance or carcass composition. Yet, modest improvements in pork color suggest that feeding diets supplemented with 150 ppm of Fe from Availa-Fe may enhance pork quality.

Introduction

The newborn pig is born with approximately 50 mg of iron (Fe), most of which is as hemoglobin, and sow's milk contains only 1 mg Fe per liter. Therefore, pigs receiving only milk rapidly become anemic, and it is common practice in swine production to supply the newborn pig with Fe, typically via intramuscular injections of 100 to 200 mg of Fe. Post-weaning dietary Fe requirement for pigs is approximately 80 ppm (Pickett et al., 1960), and declines with advancing age and weight (NRC, 1998). Similarly, Harmon et al. (1969) reported that ADG was reduced in pigs fed diets containing less than 29 ppm of Fe, but not at dietary levels ranging from 34 to 147 ppm, indicating the requirement may be somewhat lower than suggested. On the other hand, supplementing diets of weanling and grower pigs with higher (100 to 7,000 ppm) levels of Fe also fails to impact on ADG, ADFI, or F/G (Dove and Ewan, 1990).

Most of the literature focuses on the Fe requirements of newborn and weanling pigs, and very little information is available concerning the effects of supplemental Fe on carcass characteristics. Abdelrahim et al. (1983) indicated that the addition of 5 ppm Fe in the diet of veal calves produced significantly darker meat; however, there are no published reports on the effects of supplemental Fe on pork quality and composition traits. Therefore, the objective of this study was to determine the effect of dietary Fe supplementation level on the performance and carcass characteristics of growing-finishing swine.

Experimental Procedures

A total of 210 crossbred barrows and gilts (DeKalb Choice Genetics, St. Louis, MO), with an average initial live weight of 67 lb, were blocked by weight into seven blocks of 30 pigs/block. Pigs within each block were allotted randomly to pens (six pigs/pen) and stratified across gender and litter origin. Within each block, pens

were randomly assigned to one of five treatments, including a negative control, corn-soybean meal-wheat middlings starter, grower, and finisher diets with no Fe present in the vitamin-mineral premix; a positive control, corn-soybean meal-wheat middlings starter, grower, and finisher diets with iron sulfate present in the vitamin-mineral premix; or the positive control diets supplemented with either 50, 100, or 150 ppm Fe from Availa-Fe (an iron-amino acid complex produced by Zinpro Corp., Eden Prairie, MN). Pigs were fed a four-phase diet with transition from starter to grower-I, from grower-I to grower-II, and grower-II to finisher diets when mean weight of each block was 120, 150, and 200 lb, respectively. Additionally, diets were formulated to be isolysininc (1.00, 0.86, 0.72, and 0.64% lysine in the starter, grower-I, grower-II, and finisher diets, respectively) and isocaloric (1554.3, 1573.6, 1579.4, and 1569.0 Kcal/lb in the starter, grower-I, grower-II, and finisher diets, respectively), and Availa-Fe was added to the trace mineral premix (0, 100, 150, 200, and 250 ppm Fe in the negative control, positive control, 50 ppm supplemental Fe, 100 ppm supplemental Fe, and 150 ppm supplemental Fe diets, respectively; Table 1). All diets were formulated to meet, or exceed, NRC (1998) amino acid, energy, and other nutrient requirements for growing-finishing swine. Individual pig weights were measured weekly, and feed disappearance was recorded at 7-d intervals during each phase to calculate ADG, ADFI, and feed:gain (F/G).

When the lightest block of pigs weighed approximately 260 lb, all pigs were transported approximately 416 miles to a commercial pork packing plant (Bryan Foods, Inc., West Point, MS). After a 12-hr rest period, pigs were electrically-stunned, and harvested according to industry-acceptable procedures. Hot carcass weight was recorded, and 10th rib fat and loin eye depths were measured on-line with a Fat-O-Meater automated probe (SFK Technology A/S, Cedar Rapids, IA). Following a 24-h conventional spray-chill, loins were marked between the 10th and 11th ribs in order to measure loin eye area upon arrival at the University of Arkansas Red-Meat Abattoir. During carcass fabrication, bone-in pork loins from right sides were captured, wrapped in parchment paper, boxed, and transported back

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to the University of Arkansas for pork quality data collection.

At approximately 48 h postmortem, each loin was separated at the mark between the 10th and 11th ribs, and each loin eye was traced onto acetate paper and loin eye area was measured using a compensating planimeter. Then, two 1.5-in thick and one 1-in thick chops were cut anterior to the 11th rib. The two 1.5-in thick chops were used for drip loss determination. A 1.5-in diameter core was removed from each 1.5-in thick chop, weighed, and suspended on a fishhook (barb removed) mounted to the lid of a plastic container (18 in deep x 15 in wide x 24 in long), and stored at 34°F. After 48 h, each core was blotted dry on paper towels and re-weighed. The loss in weight due to drip and evaporation was divided by the initial core weight, multiplied by 100, and reported as drip loss percentage. After a 30-min bloom period, American (1 = pale pinkish gray to 6 = dark purplish red) and Japanese color (Nakai et al., 1975) scores, as well as marbling (1 = devoid to 10 = abundant) and firmness (1 = very soft/very watery to 5 = very firm/very dry) scores, were evaluated by a three-person panel on the 1-in thick loin chop. Also, L* (measure of darkness to lightness; higher number indicates a lighter color), a* (measure of redness; higher number indicates a redder color), and b* (measure of yellowness; higher number indicates a more yellow color) values were determined from the mean of three random readings from a Hunter MiniScan XE (Hunter Associates Laboratory, Inc., Reston, VA) using illuminant C.

All data were analyzed as a randomized complete block design with pen as the experimental unit and blocks based on initial body weight. Analysis of variance was performed using the GLM procedure of SAS (SAS Inst., Inc., Cary, NC). Least-squares means were computed and orthogonal contrasts were used to accurately compare the positive and negative control diets, as well as test the linear, quadratic, and cubic responses to the dietary inclusion level of Availa-Fe.

Results And Discussion

Even though ADFI and F/G were not ($P > 0.10$) affected by dietary treatments during the starter phase, ADG decreased linearly ($P = 0.02$) as supplementary Fe levels increased from 0 (positive control) to 150 ppm (Table 2). During the grower-I phase, however, ADG tended to increase linearly ($P < 0.10$) as supplemental Fe from Availa-Fe increased from 0 (positive control) to 150 ppm, with pigs fed diets supplemented with 150 ppm Fe gaining 0.41 lb/d more than pigs fed the negative control diets. There was also a tendency for F/G to decrease (linear effect; $P = 0.13$) as Fe from Availa-Fe increased in the diet. There were no ($P > 0.10$) differences in ADG, ADFI, or F/G among dietary treatments during the grower-II and finisher phases, as well as over the entire length of the feeding trial. Interestingly, pigs fed the negative control diets tended to have lower F/G values than pigs fed the positive control diets during the grower-II phase ($P = 0.06$) and across the entire trial ($P = 0.07$). The lack

of an effect of dietary Fe on performance during the late grower and finisher phases is consistent with the results of Harmon et al. (1969) and Dove and Ewan (1990), who demonstrated that supplementing pig diets with Fe, at levels greater than NRC (1998) requirements, had no appreciable effects on pig performance.

Supplementing diets with Fe from Availa-Fe did not ($P > 0.10$) affect hot carcass weight, 10th rib fat depth, loin eye depth and area, or fat-free lean yield (Table 3). American color scores tended to improve linearly ($P = 0.10$) as supplemental Fe concentrations increased from 0 to 150 ppm; however, dietary Fe did not ($P > 0.10$) affect Japanese color, marbling, or firmness scores. There was a non-significant ($P = 0.15$) linear relationship between L* values and dietary Fe inclusion level, with loin eye muscle becoming darker (lower L* values) as Fe from Availa-Fe increased from 50 to 150 ppm. Pork from pigs fed the negative control diets was redder (higher a* values; $P = 0.03$) than that from pigs fed the positive control diets, and the loin eye became redder (linear effect; $P = 0.04$) as supplemental Fe increased from 0 (positive control) to 150 ppm. Neither b* values (yellowness) or drip loss percentages were affected ($P > 0.10$) by any dietary treatment.

Results from the present study are in line with those of Abdelrahim et al. (1983), who reported that supplementing veal-calf diets with Fe resulted in darker colored veal. Moreover, the linear increase in the redness of pork from Availa-Fe-supplemented pigs confirms the reported increase in redness of skin as dietary Fe, from Availa-Fe, increased from 30 to 120 ppm (Yu et al., 2000).

Implications

Even though daily gain was improved by iron-supplementation during the early-grower phase, results from the present study indicated that increasing the dietary iron content had no appreciable effects on pig performance or carcass composition. However, moderate improvements in pork color were noted, suggesting that feeding diets supplemented with 150 ppm of iron from Availa-Fe may enhance pork quality.

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Table 1. Composition (as-fed basis) of finisher diets (fed from 200 to 260 lb) supplemented with 50, 100, or 150 ppm iron (Fe).

Ingredient, %	Negative control	Positive control	Iron, ppm		
			50	100	150
Corn	70.525	70.525	70.442	70.358	70.275
Wheat middlings	15.00	15.00	15.00	15.00	15.00
Soybean meal (48% CP)	8.50	8.50	8.50	8.50	8.50
Fat	4.00	4.00	4.00	4.00	4.00
Calcium carbonate	1.00	1.00	1.00	1.00	1.00
Salt	0.50	0.50	0.50	0.50	0.50
Lysine hydrochloride	0.15	0.15	0.15	0.15	0.15
Vitamin premix ^a	0.15	0.15	0.15	0.15	0.15
Mineral premix ^b	---	0.09	0.09	0.09	0.09
Mineral premix ^c	0.09	---	---	---	---
Availa-Fe	---	---	0.083	0.167	0.25
Phytase	0.03	0.03	0.03	0.03	0.03
Ethoxyquin	0.03	0.03	0.03	0.03	0.03
Tylosin-40	0.025	0.025	0.025	0.025	0.025
Calculated composition, %					
CP	12.39	12.39	12.39	12.39	12.39
Lysine	0.64	0.64	0.64	0.64	0.64
Methionine + cysteine	0.46	0.46	0.46	0.46	0.46
Threonine	0.44	0.44	0.44	0.44	0.44
Tryptophan	0.13	0.13	0.13	0.13	0.13
Fe from ferrous sulfate, ppm	0	100	100	100	100
Fe from Availa-Fe, ppm	0	0	50	100	150
Calcium	0.45	0.45	0.45	0.45	0.45
Phosphorus	0.40	0.40	0.40	0.40	0.40
ME, Kcal/lb	1569.0	1569.0	1569.0	1569.0	1569.0

^a Vitamin premix contained 14,551 IU of vitamin A, 2,182 IU of vitamin D₃ (D-activated animal sterol), 57 IU of vitamin E, 5.7 mg of vitamin K (menadione sodium bisulfite complex), 36.3 mg of pantothenic acid (D-calcium pantothenate), 65.3 mg of niacin, 11 mg of riboflavin, and 50.6 µg of vitamin B₁₂ per pound of feed (Nutra Blend Corp., Neosho, MO).

^b Mineral premix contains calcium carbonate, 100 ppm Fe (ferrous sulfate), 100 ppm Zn (zinc sulfate), 0.18 ppm Se (sodium selenite), 24 ppm Mn (manganous sulfate), 9.9 ppm Cu (copper sulfate), and 0.18 ppm I (calcium iodate) (Nutra Blend Corp., Neosho, MO).

^c Mineral premix devoid of ferrous sulfate (Nutra Blend Corp., Neosho, MO).

Table 2. Effects of iron-supplementation level on performance of growing-finishing swine.

Item	Negative control	Positive control	Supplemental iron, ppm			SE
			50	100	150	
Starter phase (67 to 120 lb)						
ADG, lb ¹	1.96	1.99	1.93	1.95	1.86	0.033
ADFI, lb	4.36	4.50	4.52	4.48	4.22	0.136
F/G	2.22	2.28	2.33	2.38	2.27	0.058
Grower I phase (120 to 150 lb)						
ADG, lb ²	1.73 ^y	1.88 ^{xy}	1.92 ^{xy}	1.92 ^{xy}	2.14 ^x	0.097
ADFI, lb	5.34	5.55	5.40	5.44	5.56	0.198
F/G ³	3.12	2.98	2.90	2.90	2.60	0.164
Grower II phase (150 to 200 lb)						
ADG, lb	2.26	2.18	2.32	2.13	2.09	0.081
ADFI, lb	6.00	6.29	6.43	6.25	6.30	0.191
F/G ⁴	2.66	2.99	2.80	2.95	3.02	0.118
Finisher phase (200 to 260 lb)						
ADG, lb	1.97	2.02	2.00	1.94	2.01	0.053
ADFI, lb	5.98	6.33	6.34	6.24	6.22	0.156
F/G	3.04	3.15	3.17	3.21	3.10	0.059
Overall trial (67 to 260 lb)						
ADG, lb	2.00	2.01	2.04	1.98	2.00	0.024
ADFI, lb	5.39	5.62	5.66	5.57	5.52	0.119
F/G ⁵	2.70	2.81	2.76	2.84	2.76	0.040

¹ Linear effect of supplemental iron (P = 0.02).

² Linear effect of supplemental iron (P = 0.10).

³ Linear effect of supplemental iron (P = 0.13).

⁴ Negative control is different from the positive control (P = 0.06).

⁵ Negative control is different from the positive control (P = 0.07).

Table 3. Effects of iron-supplementation level on carcass characteristics of growing-finishing swine.

Item	Negative control	Positive control	Supplemental iron, ppm			SE
			50	100	150	
Hot carcass wt, lb	197.7	203.5	201.4	206.6	199.1	3.33
10th rib fat depth, in	0.77	0.78	0.81	0.82	0.80	0.052
Loin eye depth, in	2.2	2.3	2.3	2.2	2.2	0.05
Loin eye area, sq in	8.2	7.6	7.4	8.0	7.3	0.29
Fat-free lean yield, %	52.89	53.06	52.64	52.16	52.71	0.893
American color score ^{a,1}	3.2	3.2	3.0	3.3	3.4	0.13
Japanese color score ^b	3.3	3.2	3.4	3.4	3.4	0.12
Marbling score ^c	1.9	1.8	1.9	1.9	2.1	0.14
Firmness score ^d	3.2	3.3	3.4	3.4	3.4	0.10
Lightness (L*) ^{e,2}	51.18	50.87	51.54	50.63	50.20	0.438
Redness (a*) ^{e,3,4}	8.11	7.63	7.41	7.95	7.94	0.149
Yellowness (b*) ^e	14.83	14.42	14.54	14.41	14.32	0.232
Drip loss, %	2.4	2.4	2.6	3.1	2.9	0.39

^a American color score: 1 = pale pinkish gray and 6 = dark purplish red (NPPC, 1999).

^b Japanese color score: 1 = pale gray and 6 = dark purple (Nakai et al., 1975).

^c Marbling score: 1 = devoid and 10 = abundant (NPPC, 1999).

^d Firmness score: 1 = very soft/very watery and 5 = very firm/very dry (NPPC, 1991)

^e L* = measure of darkness to lightness (larger number indicates a lighter color); a* = measure of redness (larger number indicates a more intense red color; and b* = measure of yellowness (larger number indicates a more yellow color).

¹ Linear effect of supplemental iron (P = 0.10).

² Linear effect of supplemental iron (P = 0.15).

³ Negative control is different from the positive control (P = 0.03).

⁴ Linear effect of supplemental iron (P = 0.04).