1996

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Summary and Implications

The bioavailability of the iron in iron methionine was compared with that in feed-grade ferrous sulfate. Pigs, which were anemic at weaning, were given diets containing supplements of one of the two iron sources. Iron supplementation increased weight gain and hemoglobin repletion. The increases were greater for ferrous sulfate than for iron methionine. This indicates that the iron in ferrous sulfate is more bioavailable than the iron in the iron methionine source that we investigated.

Introduction

Iron is an essential trace mineral required by swine during all stages of life. Iron needs are particularly high during rapid growth periods. The most critical period is between birth and weaning because of the rapid growth occurring and because of the very low iron content of sows' milk. Most pigs are given an iron injection within the first few days after birth that will usually satisfy their iron needs until weaning. After weaning, iron nutrition is also critical because of the continued rapid growth and the poor feed intake that often occurs during early postweaning.

Several different iron sources can be used in the trace mineral premix for weanling pigs. They can be broadly divided into inorganic sources, such as ferrous sulfate ($FeSO_4 \cdot H_2O$), and organic sources, such as those offered by several commercial manufacturers. Organic sources are generally more expensive than inorganic sources per unit of total iron, but they may confer advantages not offered by the inorganic sources. One potential advantage is higher iron availability to the animal (bioavailability). Higher bioavailability could mean that less supplemental iron from organic sources is needed, and this could partially offset the higher cost.

We have begun a series of experiments to evaluate different organic iron sources and to compare them to a standard inorganic source. We chose as our standard source feed-grade ferrous sulfate ($FeSO_4 \cdot H_2O$), a common source of iron added to swine diets. Two experiments are described in this report. In the first, we established the linear response range of weight gain and blood hemoglobin concentration to ferrous sulfate. In the second, we compared ferrous sulfate and a commercial organic source of iron—iron methionine.

Methods

In each experiment, pigs were given no supplemental iron (either oral or injectable) from birth until weaning. At weaning (approximately 21 days), pigs were bled and their hemoglobin concentrations were measured. Based on their hemoglobin concentration, 72 barrows and 72 gilts were selected for each experiment. The average initial weights and initial hemoglobin concentrations were 9.8 and 10.9 lb and 4.4 and 4.5 g/100 mL in Experiments 1 and 2, respectively. The normal hemoglobin concentration is 8 to 12 g/100 mL.

In the first experiment, pigs were allotted to a basal diet (Table 1) containing 54 mg/kg (or ppm) of iron or to diets containing 12.5, 25, 50, 100, or 200 mg/kg of supplemental iron from feed-grade ferrous sulfate. The basal diet was designed to be deficient in iron, and the purpose of the experiment was to ensure that iron was the limiting nutrient and that performance and hemoglobin concentrations would be increased when supplemental iron was added. There were 36 pens (six per treatment) with two barrows and two gilts per pen. Pigs were allowed continuous access to feed and water, and the experiment lasted three weeks.

Table 1. Composition and nutrient analysis of the basal diet (as-fed basis)[a]

Item	Amount
Ingredient, %	
Corn	51.98
Soybean meal (46.5% CP)	5.00
Dried skim milk	30.00
Spray-dried porcine plasma	6.00
Corn oil	4.00
Monosodium phosphate	1.00
Limestone	.75
Salt and trace minerals[b]	.27
Vitamin premix[c]	1.00
Analyzed nutrient content	
Crude protein, %	20.6
Lysine, %	1.43
Calcium, %	.80
Phosphorus, %	.79
Iron, mg/kg	54
Copper, mg/kg	12
Zinc, mg/kg	115

[a]Composition of the basal diet. The other five diets contained additions of 12.5, 25, 50, 100, and 200 mg/kg iron from $FeSO_4 \cdot H_2O$.
[b]Supplied 2.5 g of NaCl per kilogram of complete diet and the following amounts of trace elements in milligrams per kilogram of complete diet: Cu (as $CuSO_4 \cdot 5H_2O$), 10; I (as $Ca(IO_3)_2$), .2; Mn (as MnO), 20; Se (as Na_2SeO_3), .3; and Zn (as ZnO), 100.
[c]Supplied the following amounts of vitamins per kilogram of complete diet: retinyl acetate, 4,400 IU, cholecalciferol, 550 IU; *all-rac*-α-tocopheryl acetate, 22 IU; menadione (as menadione sodium bisulfite complex), 3.3 mg; riboflavin, 5.5 mg; niacin, 33 mg; *d*-pantothenic acid (as *d*-calcium pantothenate), 22 mg; cyanocobalamin, 22µg; and choline (as choline chloride), 110 mg.

The purpose of the second experiment was to compare the bioavailability of iron in iron methionine with that in ferrous sulfate. Iron methionine is a commercial source of organic iron in which the iron molecule is complexed with the amino acid methionine. Pigs were allotted to the same basal diet or to diets containing 75 or 150 mg/kg iron from ferrous sulfate or 50, 100, or 150 mg/kg iron from iron methionine. Other features of the second experiment were similar to those of the first.

Results and Discussion

The results of the first experiment are in Table 2. Average daily feed intake, average daily gain, and feed efficiency all increased linearly as supplemental iron increased from 0 to 200 mg/kg. The results for average daily gain are illustrated in Figure 1. Pigs fed the basal diet without supplemental iron performed very poorly and became progressively more anemic as the experiment progressed. Some pens of pigs lost weight during the experiment and could not be included in the summary of results. Pigs fed diets with 12.5 or 25 mg/kg of supplemental iron were also unable to increase their hemoglobin concentration as the experiment progressed. However, pigs fed diets with the three highest levels of supplemental iron increased in hemoglobin concentration from the beginning to the end of the experiment. As a result, at the end of the experiment there was an increase in hemoglobin concentration as supplemental iron concentration increased. Thus, the results of the first experiment demonstrated that the basal diet was indeed limiting in iron and that performance could be improved by iron supplementation. Based on these findings, we decided to use the same basal diet with supplements of iron up to 150 mg/kg in the second experiment.

In the second experiment, weight gain increased in response to supplemental iron intake from both ferrous sulfate and iron methionine. However, the increases were greater for ferrous sulfate than for iron methionine supplementation. As shown in Figure 2, the ratio between the slopes of the two response lines was 81.4%. This indicates that, based on weight gain, the iron in iron methionine was approximately 81% as bioavailable as the iron in ferrous sulfate. Similar findings were observed when blood hemoglobin con-

Table 2. Effects of iron supplementation on growth and blood hemoglobin of weanling pigs[a]

	Supplemental Fe, mg/kg[b]						
Item[c]	0[d]	12.5	25.0	50.0	100.0	200.0	P-value[e]
ADFI (0 to 3 wk), lb	.311	.331	.417	.439	.551	.710	L<.01
ADG (0 to 3 wk), lb	.075	.097	.187	.212	.344	.494	L<.01
Gain/Feed (0 to 3 wk)[f]	.282	.323	.427	.485	.621	.695	L<.01 Q<.07
Hemoglobin (wk 0), g/dL	4.28	4.57	4.35	4.63	4.41	4.40	NS
Hemoglobin (wk 1), g/dL	4.21	4.13	4.15	4.67	4.72	5.22	L<.01
Hemoglobin (wk 2), g/dL	4.11	4.24	3.88	4.73	5.31	6.40	L<.01
Hemoglobin (wk 3), g/dL	3.85	4.29	4.23	5.18	6.61	8.34	L<.01

[a]Data represent least squares means of six pens per treatment (each pen contained two barrows and two gilts). Three-week experiment. Average initial weight 9.8 lb; average final weight 14.9 lb.
[b]Supplemental Fe was provided as $FeSO_4 \cdot H_2O$.
[c]ADFI = average daily feed intake, ADG = average daily weight gain, and Gain/Feed = feed efficiency.
[d]One pen removed after 2 wk because of considerable weight loss.
[e]L = linear effect, Q = quadratic effect, and NS = nonsignificant effect.
[f]Does not include data from three pens (two with 0 added iron and one with 12.5 mg/kg added iron) that lost weight.

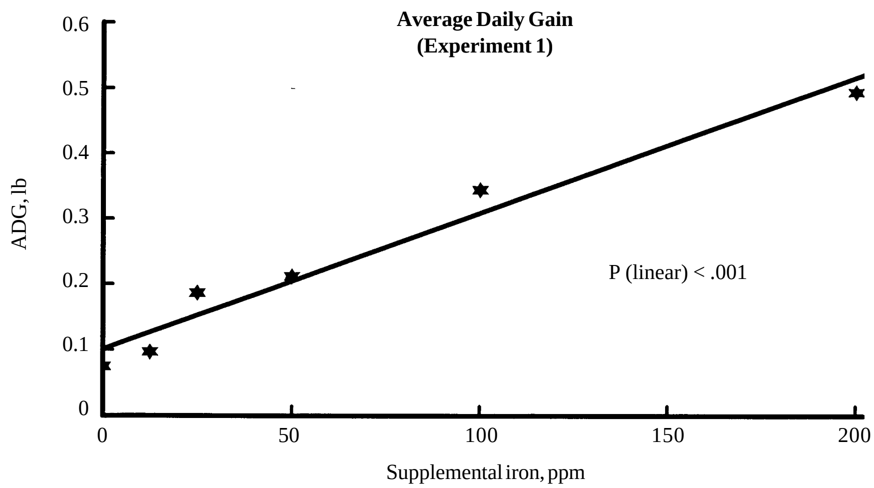

Figure 1. The effect of supplemental iron intake from feed-grade ferrous sulfate on weight gain of weanling pigs.

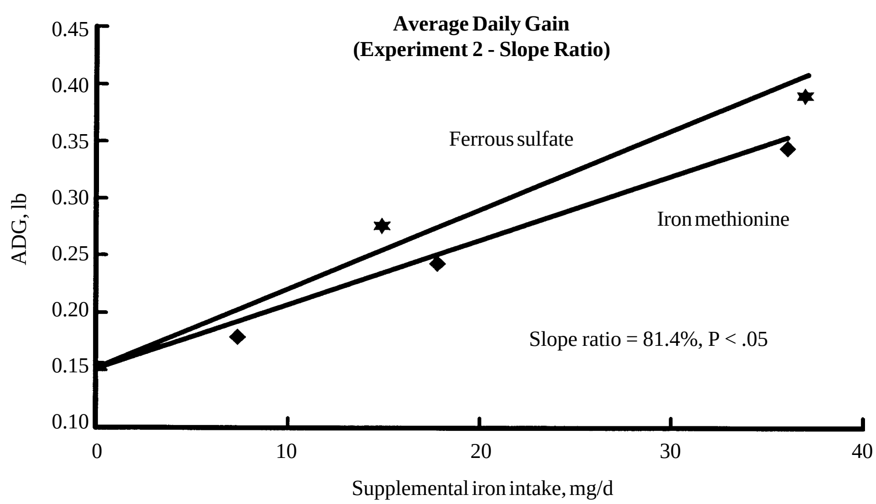

Figure 2. Slope ratio comparison of the effect of ferrous sulfate and iron methionine on weight gain of weanling pigs.

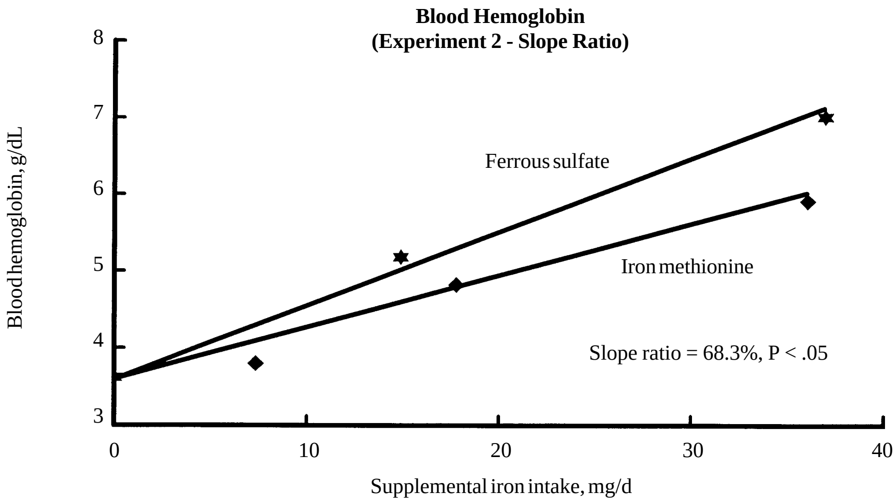

Figure 3. Slope ratio comparison of the effect of ferrous sulfate and iron methionine on blood hemoglobin concentration of weanling pigs.

centrations were measured (Figure 3). Based on hemoglobin concentration, the iron in iron methionine was 68% as bioavailable as the iron in ferrous sulfate.

Thus, using procedures described in these studies (hemoglobin repletion assays) we conclude that the iron in iron methionine is less bioavailable than the iron in ferrous sulfate. The reason for the difference between bioavailability estimates based on weight gain and hemoglobin are unknown, but similar findings have been reported in previous research.

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