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Bioavailability of Iron in Iron Proteinates

Austin Lewis
University of Nebraska - Lincoln, alewis2@unl.edu

Phillip S. Miller
University of Nebraska - Lincoln, pmiller1@unl.edu

Hsin-Yi Chen
University of Nebraska - Lincoln

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Phillip S. Miller
Hsin-Yi Chen[1]

Summary and Implications

The bioavailability of the iron in two different sources of iron proteinate was compared with that in feed-grade iron sulfate ($FeSO_4 \cdot H_2O$). Pigs, which were iron deficient and anemic at weaning, were given diets with no supplemental iron or supplements, of iron sulfate or iron proteinate. During the three-week study, weight gain and hemoglobin increased as the iron supplementation increased. When hemoglobin repletion was compared, there were no significant differences between iron sulfate and either of the iron proteinate sources. These results indicate the iron in iron sulfate and the two iron proteinate sources were similar in bioavailability. Thus, price per unit of total iron should be the primary criterion when selecting among these iron sources.

Introduction

Iron is a critical trace mineral for young pigs because the iron content of sows' milk is very low. Most newborn pigs are given an iron injection to meet their needs until weaning. After weaning, supplemental iron must be provided because the iron content of most diet ingredients is not adequate to meet needs, especially during periods of rapid growth.

The most commonly used source of supplemental iron, iron sulfate ($FeSO_4 \cdot H_2O$), is relatively inexpensive and in a form readily available to the animal (bioavailable). However, other iron sources are available. Many of which are referred to as "organic" because the iron is combined with an organic molecule such as an amino acid or protein. Organic sources are usually more expensive per unit of total iron than inorganic sources and therefore must offer some advantage to justify including them in swine diets. Increased bioavailability of the iron in organic sources would justify their purchase and inclusion in swine diets.

In a previous experiment (Nebraska Swine Report 1996), we evaluated the bioavailability of iron in iron methionine. In the following report, we discuss experiments designed to determine the bioavailability of iron in two different sources of iron proteinate relative to the iron in iron sulfate.

Methods

The methods were the same in both experiments. Pigs selected for the experiments were given no supplemental iron (either oral or injectable) from birth until weaning at approximately 21 days post-farrowing. At weaning, blood hemoglobin concentrations were measured and, based on hemoglobin concentration, 72 barrows and 72 gilts were selected for each experiment. The average initial weights and initial hemoglobin concentrations were 11.6 and 11.1 pounds and 4.5 and 4.0 g/100 mL in Experiments 1 and 2, respectively. The selected pigs were iron deficient and anemic at the start of the experiments, as the normal hemoglobin concentration is 8 to 12 g/100 mL.

During the experimental periods, pigs were allotted to a basal diet (Table 1) or to diets formulated to contain 75 or 150 mg/kg (ppm) of supplemental iron from feed-grade iron sulfate or diets formulated to contain 50, 100 or 150 mg/kg of supplemental iron from iron proteinate. The same source of iron sulfate was used in both experiments. Thus in each experiment there were six dietary treatments. There were 36 pens (six per treatment) with two barrows and two gilts per pen. Pigs were allowed ad libitum access to feed and water throughout the three-week experiment. Pigs were bled at the end of each week and hemoglobin concentrations were determined. Hemoglobin repletion was calculated as ((final weight × 0.088) × final hemoglobin) - ((initial weight × 0.088) × initial hemoglobin). The factor of 0.088 was used because blood volume was assumed to be 8.8 percent of body weight.

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

Item	Amount
Ingredient, percent	
Corn	51.98
Soybean meal, 46.5% CP	5.00
Dried skim milk	30.00
Spray-dried plasma protein	6.00
Corn oil	4.00
Monosodium phosphate	1.00
Limestone	.75
Salt	.25
Trace mineral premix[a]	.02
Vitamin premix[b]	1.00
Analyzed nutrient content	
Crude protein,%	20.9
Lysine, %	1.31
Calcium, %	.82
Phosphorus, %	.77
Iron, mg/kg	65
Copper, mg/kg	10
Zinc, mg/kg	139

[a]Supplied the following amounts of trace elements in milligrams per kilogram of complete diet: Cu (as $CuSO_4 \cdot 5H_2O$), 10; I (as $Ca(IO_3)_2$),m .2; Mn (as MnO), 20; Se (as Na_2SEO_3), .3; and Zn (as ZnO), 100.

[b]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; niacine, 33 mg; *d*-pantothenic acid (as *d*-calcium pantothenate), 22 mg; cyanocobalamin, 22µg; and choline (as choline chloride), 110 mg.

Table 2. Effects of iron source and iron supplementation on growth, blood hemoglobin and hemoglobin repletion of weanling pigs (Exp. 1)[a].

Source:		Iron sulfate[b]		Iron proteinate[c]		
Item[d] Supplemental Iron, mg/kg:	0	60.2	163.3	44.8[e]	86.8	141.6
ADG (0 to 3 wk), lb	.004	.238	.379	.128	.287	.337
ADFI (0 to 3 wk), lb	.300	.483	.551	.346	.485	.567
Gain/Feed (0 to 3 wk)	.015	.482	.673	.336	.595	.606
Hb concentration (wk 0), g/dL	4.61	4.36	4.74	4.50	4.59	4.22
Hb concentration (wk 1), g/dL	4.66	4.71	4.82	4.58	4.80	4.62
Hb concentration (wk 2), g/dL	4.11	5.12	5.91	4.42	5.19	5.74
Hb concentration (wk 3), g/dL	4.10	5.78	7.36	4.79	5.95	7.61
Hb repletion (O to 1 wk), g	.46	3.66	2.13	.66	2.69	3.28
Hb repletion (O to 2 wk), g	-2.31	7.72	12.48	1.70	7.39	12.52
Hb repletion (0 to 3 wk), g	-2.12	18.76	36.72	6.24	20.52	37.14

[a]Data represent means of six pens per treatment (each pen contained two barrows and two gilts). Three-week experiment: average initial weight 11.57 lb; average final weight 16.45 lb.
[b]Supplemental iron was provided as feed-grade $FeSO_4 \cdot H_2O$.
[c]Supplemental iron was provided as iron proteinate (OPTiMIN® FE, NutriBasics, Highland, IL).
[d]ADG = average daily gain, ADFI = average daily feed intake, Gain/Feed = feed efficiency, and Hb = hemoglobin.
[e]Mean of five pens because of weight loss in the other pen.

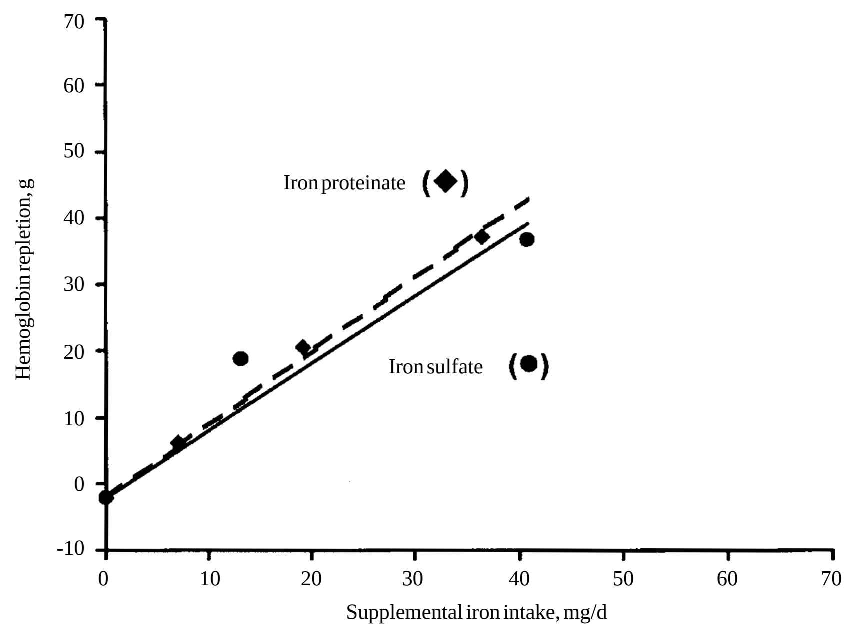

Figure 1. Slope ratio comparison of the effect of iron sulfate and iron proteinate on hemoglobin repletion in weanling pigs (Experiment 1).

Results and Discussion

The results of the first experiment are in Table 2. Chemical analysis of the diets for iron content established the analyzed supplemental iron content differed somewhat from the calculated content. The analyzed contributions from the supplemental sources are shown in Table 2 and these values were used in the analysis of the data. Pigs fed the diet without iron supplementation gained very little weight and their hemoglobin concentration declined as the experiment progressed. Addition of supplemental iron increased weight gain, feed intake and feed efficiency linearly ($P < .001$) regardless of whether the supplemental iron was from iron sulfate or iron proteinate. The changes in growth performance per unit of supplemental iron were approximately equal as well.

Blood hemoglobin concentrations in the first experiment were also affected by iron intake. At the end of the experiment (week three) blood hemoglobin increased linearly ($P < .001$) as the supplemental iron concentration increased. As for the growth traits, the increase in hemoglobin concentration was relatively similar, regardless of supplement source. Hemoglobin repletion, which combines both weight gain and hemoglobin concentration, also increased linearly (P .001) as dietary iron content increased. The effects were particularly evident at the end of the experiment.

To calculate relative bioavailabilities, hemoglobin repletion was related to supplemental iron intake. The relationship at the end of Experiment 1 is illustrated in Figure 1. For simplicity, mean values are shown,

Table 3. Effects of iron source and iron supplementation on growth, blood hemoglobin and hemoglobin repletion of weanling pigs (Experiment 2)[a].

Source:		Iron sulfate[b]		Iron proteinate[c]		
Item[d] Supplemental Iron, mg/kg:	0	60.2	163.3	44.8[e]	86.8	141.6
ADG (O to 3 wk), lb	.132	.262	.465	.337	.384	.467
ADFI (0 to 3 wk),lb	.494	.567	.791	.628	.697	.769
Gain/Feed (0 to 3 wk)	.263	.455	.581	.533	.552	.607
Hb concentration (wk 0), g/dL	3.84	4.27	3.73	4.25	3.80	4.16
Hb concentration (wk 1), g/dL	3.78	4.50	4.07	4.55	4.42	5.52
Hb concentration (wk 2), g/dL	3.93	5.03	6.55	5.09	5.80	7.40
Hb concentration (wk 3), g/dL	4.04	6.29	9.28	5.86	7.95	9.45
Hb repletion (0 to 1 wk), g	.92	2.43	9.61	3.98	5.25	10.32
Hb repletion (0 to 2 wk), g	2.50	8.14	24.84	10.72	18.39	28.42
Hb repletion (0 to 3 wk), g	5.29	23.01	62.27	24.71	44.16	60.03

[a]Data represent means of six pens per treatment (each pen contained two barrows and two gilts). Three-week experiment: average initial weight 11.11 lb; average final weight 18.28 lb.
[b]Supplemental iron was provided as feed-grade $FeSO_4 \cdot H_20$.
[c]Supplemental iron was provided as iron proteinate (BUFFERMIN®, JH Biotech, Inc., Ventura, CA).
[d]ADG = average daily gain, ADFI = average daily feed intake, Gain/Feed = feed efficiency, and Hb = hemoglobin.

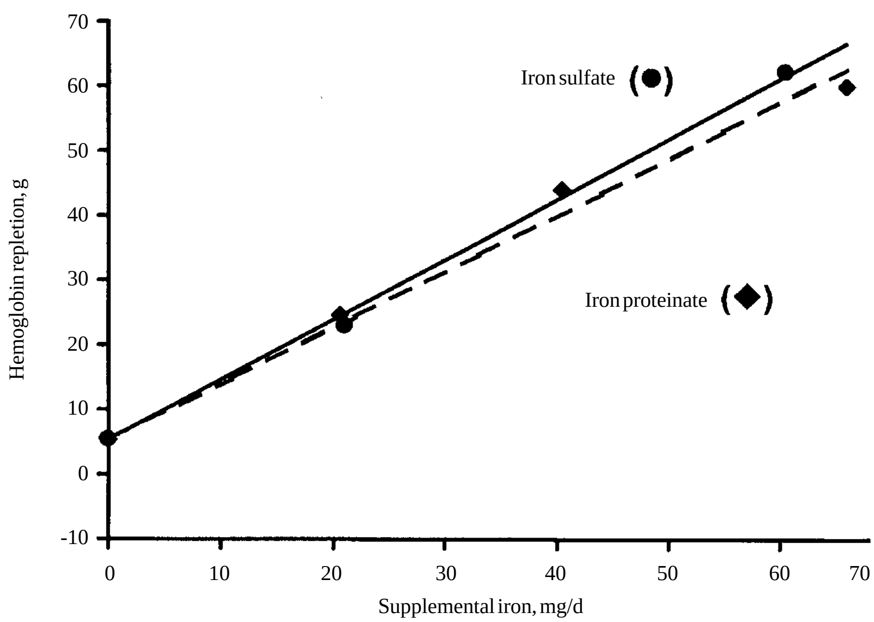

Figure 2. Slope ratio comparison of the effect of iron sulfate and iron proteinate on hemoglobin repletion in weanling pigs (Experiment 2).

although statistical calculations were done on individual pens. The increases in hemoglobin repletion were slightly greater for iron proteinate than for iron sulfate. Statistical analysis revealed the ratio of the two slopes was 1.03, meaning iron proteinate was 103 percent as bioavailable as iron sulfate. However, 103 percent was not statistically different from 100 percent, indicating the two sources were similar in iron bioavailability.

Results of the second experiment are in Table 3 and Figure 2. These results were very similar to Experiment 1. Both growth performance and blood hemoglobin concentration increased linearly ($P < .001$) as supplemental iron increased. As shown in Figure 2, the increase was somewhat lower for iron proteinate than for iron sulfate. The ratio of the slopes of the two lines was 0.92, revealing this source of iron proteinate was 92 percent as bioavailable as iron sulfate. As in Experiment 1, this value was not statistically different from 100 percent, indicating the two sources are similar in iron bioavailability.

The results of these two experiments indicate iron sulfate and the two sources of iron proteinate contain iron equally bioavailable to meet the needs of weanling pigs.

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[1]Austin J. Lewis is a professor, Phillip S. Miller is an associate professor, and Hsin-Yi Chen is a research technologist in the Department of Animal Science.