Effects of Supplemental Manganese on the Performance and Pork Carcass Composition of Growing-Finishing Swine

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Introduction

Manganese (Mn) is a divalent, transition metal cation that functions as a co-factor of several enzymes crucial for carbohydrate, lipid, and protein metabolism; however, the dietary requirements for Mn in swine diets are quite low and not well established. Until recently, little has been known about the effects of supplemental Mn on pork carcass composition or quality. In the first of two studies, Roberts et al. (2001) found that including 350 ppm Mn from either manganese sulfate (MnSO4) or AvailaMn (a Mn amino acid complex) in diets of growing-finishing swine did not affect ADG, ADFI, or F/G. Yet, when lower dietary Mn inclusion levels (0 to 320 ppm) of AvailaMn were included in swine diets, Apple et al. (2003) noted improvements in pig performance, especially feed efficiency, with 40 and 320 ppm supplemental Mn.

In both previous studies, Mn was removed from the vitamin-mineral premix included in the basal diets, and the use of AvailaMn as the sole source of Mn in the diet may not be cost effective. However, if significant improvements in economically important traits (i.e., performance and pork quality) could be achieved by supplementing diets with Mn from AvailaMn above maintenance levels already in the diet, then it could be a cost-effective production practice. Therefore, the objectives of this study were to determine the effect of supplementing two different basal diets (diets devoid of Mn vs diets formulated to meet Mn maintenance requirements) with 0 or 350 ppm Mn from either MnSO4 or AvailaMn (AvMn) on the performance and carcass composition of growing-finishing swine.

Experimental Procedures

Crossbred barrows and gilts (n = 168) from the mating of line-crossbred barrows and gilts (n = 168) from the mating of line-crossbred barrows and gilts (n = 168) from the mating of line-barrows and gilts (n = 168) from the mating of line-barrows and gilts (n = 168) from the mating of line-(Monsanto Choice Genetics, St. Louis, Mo.) were blocked by weight and randomly allotted within blocks to pens (six pigs/pen in blocks 1, 2, 5, and 6, whereas there were only four pigs/pen in blocks 3 and 4) at an average weight of 48.8 lb. Within blocks, pens were assigned randomly to one of six dietary treatments arranged in a 2 x 3 factorial design: 1) negative control (NC) starter, grower, and finisher diets devoid of Mn in the basal diet; 2) NC diets supplemented with 350 ppm Mn from manganese sulfate (MnSO4); 3) NC diets supplemented with 350 ppm Mn from AvailaMn-80 (AvMn). Pigs were fed a four-phase diet with transition from the grower-I to grower-II, grower-II to finisher-I, and finisher-I to finisher-II phases occurring when the mean block weight reached 80, 150, and 200 lb, respectively. Diets were formulated to be isonitrogenous and isocaloric (Table 1). Grower-I, grower-II, finisher-I, and finisher-II diets contained 1.16, 0.95, 0.72, and 0.57% lysine, respectively. To achieve supplemental levels of 350 ppm Mn, 0.11 and 0.44% MnSO4 and AvMn were added to diets, respectively, at the expense of cornstarch.

Pigs were housed in a curtain-sided building with slatted floors, and each pen was equipped with a single-opening feeder and nipple waterer, which allowed ad libitum access to diets and water throughout the trial. Individual pig weights and feed disappearance were recorded weekly to calculate ADG, ADFI, and feed-to-gain ratio (F/G).

When the lightest block of pigs averaged 250 lb, all pigs were transported to a commercial pork packing plant (Bryan Foods, Inc., West Point, Miss.), and slaughtered according to industry-accepted procedures. Carcass weight was recorded, and 10th rib fat and longissimus muscle (LM) depths were measured online with a Fat-O-Meater® automated probe. Carcasses were subsequently subjected to a conventional spray-chilling system for 24 h. Prior to carcass fabrication, backfat depth opposite the last rib and last lumbar vertebrae were measured.
Data were analyzed as a randomized complete block design with treatments arranged in a 2 x 3 factorial design. Analysis of variance was generated using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) with pen as the experimental unit for performance and pork carcass composition data analyses. Dietary treatment was the lone fixed effect in the model for all performance and carcass composition data. Least squares means were computed, and orthogonal contrasts were used to make specific comparisons between the PC and NC diets, Mn sources (MnSO$_4$ vs AvMn), and presence or absence of Mn in the basal diet.

**Results and Discussion**

Pig performance was not (P > 0.65) affected by dietary or supplemental Mn during the grower-I phase (Table 2). Growth rate was not (P > 0.44) affected by supplemental Mn; however, during the grower-II phase, pigs fed basal diets including Mn consumed less (P < 0.02) feed than pigs fed basal diets devoid of Mn. Additionally, there was a tendency for pigs fed diets including Mn to be more efficient (P < 0.09) during the grower-II phase than those fed basal diets devoid of Mn. Even though pig performance was not affected (P > 0.22) during the early finishing (finisher-I) phase, pigs fed basal diets containing Mn grew faster (higher ADG; P = 0.054) and consumed more (P < 0.047) feed than pigs fed basal diets lacking Mn during the late-finishing (finisher II) phase. Moreover, during the finisher II phase, ADFI tended to be decreased (P < 0.09) in AvMn-supplemented compared to MnSO$_4$-supplemented pigs. Across the entire growing-finishing period, however, ADG, ADFI, and F/G were not (P > 0.22) affected by basal diet Mn level or supplemental Mn source.

Grummer et al. (1950) reported improvements in ADG and F/G in pigs fed supplemental Mn, but neither Plumlee et al. (1956) nor Leibholz et al. (1962) observed an effect of supplemental Mn on ADG or F/G of growing-finishing pigs. In a comparison of supplement levels of 350 and 700 ppm Mn from either MnSO$_4$ or AvMn, Roberts et al. (2001) did not detect an effect of supplementing swine diets with Mn on pig performance, regardless of level or source. On the other hand, Apple et al. (2003) found that supplementing swine diets with 40 and 320 ppm Mn from AvMn increased ADG and reduced F/G during the grower-II phase, which is consistent with results of the present study. In contrast to current results, however, they reported a trend for F/G to be less in pigs fed diets containing 320 ppm Mn from AvMn.

Neither Mn inclusion in the basal diet nor Mn supplementation altered (P > 0.14) backfat depths opposite the last rib, last lumbar vertebrae, or the LM at the 10th rib interface (Table 3). However, carcasses of pigs fed basal diets including Mn tended to be heavier (P = 0.104), and had greater (P < 0.04) 10th rib LM depths, than carcasses of pigs fed basal diets devoid of Mn. Even though fat-free lean yield (FFLY) estimates were numerical higher in carcasses from pigs fed basal diets with Mn, FFLY estimates were not (P > 0.24) affected by dietary or supplemental Mn.

Roberts et al. (2001) found that neither Mn source or supplementation level affected average midline backfat depth or LM area. Moreover, when Mn was included in swine diets, midline backfat depths, 10th rib fat depth, LM depth, and estimated FFLY were similar across the dietary inclusion range of 0 to 320 ppm.

**Implications**

Results of the present study indicate that supplementing swine diets with manganese above their maintenance requirements has no appreciable impact on pig performance. Moreover, feeding manganese to meet maintenance requirements for growing-finishing swine is sufficient to optimize carcass composition.

**Acknowledgments**

The authors wish to express their gratitude to Zinpro Corporation, Eden Prairie, Minn., for financial support of this study. Moreover, the authors are appreciative of Ashley Hays and the staff at the University of Arkansas Swine Research Farm for animal care and assistance with performance data collection.

**Literature Cited**

Table 1. Composition of finisher-II diets (on an as-fed basis).

<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>NC</th>
<th>NC + 350 ppm MnSO₄</th>
<th>NC + 350 ppm AvMn</th>
<th>Basal diet without Mn&lt;sup&gt;a&lt;/sup&gt;</th>
<th>PC</th>
<th>PC + 350 ppm MnSO₄</th>
<th>PC + 350 ppm AvMn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>76.905</td>
<td>76.905</td>
<td>76.905</td>
<td>76.905</td>
<td>76.905</td>
<td>76.905</td>
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<tr>
<td>Wheat midds</td>
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<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
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<tr>
<td>Soybean meal, 48%</td>
<td>5.55</td>
<td>5.55</td>
<td>5.55</td>
<td>5.55</td>
<td>5.55</td>
<td>5.55</td>
<td>5.55</td>
</tr>
<tr>
<td>Calcium carbonate</td>
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<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
<td>0.90</td>
</tr>
<tr>
<td>Vitamin premix&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.125</td>
<td>0.125</td>
<td>0.125</td>
<td>0.125</td>
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<td>Monocalcium phosphate</td>
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<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
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<td>0.44</td>
<td>0.33</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Mineral premix&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>0.10</td>
<td>0.10</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Mineral premix&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>0.10</td>
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<td>Manganese sulfate</td>
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<td>0.11</td>
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<tr>
<td>AvailaMn-80</td>
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<tr>
<td>Salt</td>
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<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Lysine</td>
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<td>0.15</td>
<td>0.15</td>
<td>0.15</td>
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<tr>
<td>Tylan 40</td>
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<tr>
<td>Ethoxiquin</td>
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<td>0.03</td>
<td>0.03</td>
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</table>

Calculated composition, %

<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>NC</th>
<th>NC + 350 ppm MnSO₄</th>
<th>NC + 350 ppm AvMn</th>
<th>Basal diet without Mn&lt;sup&gt;a&lt;/sup&gt;</th>
<th>PC</th>
<th>PC + 350 ppm MnSO₄</th>
<th>PC + 350 ppm AvMn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>11.5</td>
<td>11.5</td>
<td>11.5</td>
<td>11.5</td>
<td>11.5</td>
<td>11.5</td>
<td>11.5</td>
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<tr>
<td>Lysine</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
<td>0.57</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
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<tr>
<td>Tryptophan</td>
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<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
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<td>0.11</td>
</tr>
<tr>
<td>Methionine and cysteine</td>
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<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
</tr>
<tr>
<td>Calcium</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
<td>0.44</td>
</tr>
<tr>
<td>Crude fat</td>
<td>3.78</td>
<td>3.78</td>
<td>3.78</td>
<td>3.78</td>
<td>3.78</td>
<td>3.78</td>
<td>3.78</td>
</tr>
</tbody>
</table>

Manganese, ppm

| Dietary (basal) | 50 | 50       | 50 | 76 | 76 | 76 |
| Supplemental    | 0  | 350      | 350 | 0  | 350 | 350 |

<sup>a</sup>NC = negative control (basal diet devoid of manganese (Mn)); MnSO₄ = manganese sulfate; PC = positive control; and AvMn = AvailaMn-80.

<sup>b</sup>Supplies 3,000 IU vitamin A, 450 IU vitamin D₃, 11.8 IU vitamin E, 1.2 mg vitamin K, 7.5 mg pantothenic acid, 13.6 mg niacin, 2.25 mg riboflavin, and 10.45 µg vitamin B₁₂ per lb of feed.

<sup>c</sup>Supplies 110 ppm iron, 110 ppm zinc, 0.2 ppm selenium, 11 ppm Copper, and 0.2 ppm iodine.

<sup>d</sup>Supplies 26.4 ppm Mn, 110 ppm iron, 110 ppm zinc, 0.2 ppm selenium, 11 ppm copper, and 0.2 ppm iodine.
Table 2. Effect of manganese (Mn) in the basal diet and Mn supplementation on performance of growing-finishing swine.

<table>
<thead>
<tr>
<th></th>
<th>Basal diet without Mn$^a$ (-Mn)</th>
<th>Basal diet with Mn$^a$ (+Mn)</th>
<th>$P$-value$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NC 350 ppm MnSO$_4$ 350 ppm AvMn</td>
<td>PC 350 ppm MnSO$_4$ 350 ppm AvMn</td>
<td>SEM</td>
</tr>
<tr>
<td>Grower-I (48 to 80 lb)</td>
<td>ADG, lb</td>
<td>1.44</td>
<td>1.38</td>
</tr>
<tr>
<td></td>
<td>ADFI, lb</td>
<td>2.65</td>
<td>2.56</td>
</tr>
<tr>
<td></td>
<td>F/G</td>
<td>1.86</td>
<td>1.86</td>
</tr>
<tr>
<td>Grower-II (80 to 150 lb)</td>
<td>ADG, lb</td>
<td>2.01</td>
<td>1.89</td>
</tr>
<tr>
<td></td>
<td>ADFI, lb</td>
<td>4.64</td>
<td>4.57</td>
</tr>
<tr>
<td></td>
<td>F/G</td>
<td>2.32</td>
<td>2.39</td>
</tr>
<tr>
<td>Finisher-I (150 to 200 lb)</td>
<td>ADG, lb</td>
<td>2.51</td>
<td>2.59</td>
</tr>
<tr>
<td></td>
<td>ADFI, lb</td>
<td>7.39</td>
<td>7.36</td>
</tr>
<tr>
<td></td>
<td>F/G</td>
<td>3.02</td>
<td>3.67</td>
</tr>
<tr>
<td>Finisher-II (200 to 250 lb)</td>
<td>ADG, lb</td>
<td>2.34</td>
<td>2.23</td>
</tr>
<tr>
<td></td>
<td>ADFI, lb</td>
<td>8.40</td>
<td>8.16</td>
</tr>
<tr>
<td></td>
<td>F/G</td>
<td>3.60</td>
<td>3.67</td>
</tr>
<tr>
<td>Overall (48 to 250 lb)</td>
<td>ADG, lb</td>
<td>2.04</td>
<td>1.98</td>
</tr>
<tr>
<td></td>
<td>ADFI, lb</td>
<td>5.48</td>
<td>5.38</td>
</tr>
<tr>
<td></td>
<td>F/G</td>
<td>2.69</td>
<td>2.73</td>
</tr>
</tbody>
</table>

$^a$NC = negative control (basal diet devoid of Mn); MnSO$_4$ = manganese sulfate; PC = positive control; and AvMn = AvailaMn-80.

$^b$Significance of orthogonal contrasts for: positive control (PC) vs. negative control (NC); manganese sulfate (MnSO$_4$) vs. AvailaMn-80 (AvMn); AvailaMn-80 (AvMn); and basal diets containing Mn (+Mn) vs. basal diets absent of Mn (-Mn).
Table 3. Effect of manganese (Mn) in the basal diet and Mn supplementation on carcass composition measures.

<table>
<thead>
<tr>
<th></th>
<th>Basal diet without Mn (−Mn)</th>
<th>Basal diet with Mn (+Mn)</th>
<th>P-value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NC</td>
<td>350 ppm MnSO₄</td>
<td>350 ppm AvMn</td>
</tr>
<tr>
<td>Backfat depth, in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Last rib</td>
<td>1.09</td>
<td>1.09</td>
<td>1.14</td>
</tr>
<tr>
<td>Last lumbar vertebral</td>
<td>0.93</td>
<td>0.96</td>
<td>1.10</td>
</tr>
<tr>
<td>Carcass wt, lb</td>
<td>188.6</td>
<td>187.1</td>
<td>191.1</td>
</tr>
<tr>
<td>10&lt;sup&gt;th&lt;/sup&gt; rib fat depth, in</td>
<td>0.85</td>
<td>0.79</td>
<td>0.86</td>
</tr>
<tr>
<td>LM depth, in&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.1</td>
<td>2.1</td>
<td>2.0</td>
</tr>
<tr>
<td>FFLY, %&lt;sup&gt;d&lt;/sup&gt;</td>
<td>51.4</td>
<td>52.4</td>
<td>51.1</td>
</tr>
<tr>
<td>Marbling&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.8</td>
<td>2.3</td>
<td>2.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> NC = negative control (basal diet devoid of Mn); MnSO₄ = manganese sulfate; PC = positive control; and AvMn = AvailaMn-80.

<sup>b</sup> Significance of orthogonal contrasts for: positive control (PC) vs. negative control (NC); manganese sulfate (MnSO₄) vs. AvailaMn-80 (AvMn); and basal diets containing Mn (+Mn) vs. basal diets absent of Mn (−Mn).

<sup>c</sup> 10<sup>th</sup> rib longissimus muscle depth

<sup>d</sup> Fat-free lean yield = ((15.3098 − (31.2796 x fat depth, in) + (3.8132 x LM depth, in) + (0.5096 x carcass wt, lb)) ÷ carcass wt, lb) x 100.

<sup>e</sup> 1 = devoid to 10 = abundant (NPPC, 1999).