# Role of Dietary Trace Minerals on Mineral Excretion in Pigs

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**ASL-R1797**

### Summary and Implications

Pigs were fed one of four dietary additions of a mixture of trace minerals (copper, iodine, iron, manganese, and zinc). Each incremental addition was formulated to supply 100% of the NRC (1998) estimated trace mineral needs for 5- to 10- kg pigs. In two separate trials, a total of 28 sets of four littermate pigs from a high lean strain were used to determine the effects of trace mineral additions on growth and efficiency of feed utilization. Additionally, these pigs were placed in the barn in such a manner that each of 14 pens of pigs receiving the same dietary treatment were placed over a common excreta pit. Excreta output was collected and weighed each week for a period of 4 weeks resulting in eight replications/trt for the mineral excretion data. Pigs were self-fed the basal diet for 10 days postweaning and then allotted within litter to one of four dietary additions of trace minerals.

In the current experiment, dietary trace mineral additions did not alter growth or efficiency of feed utilization. As dietary trace mineral concentration increased, the excretion (mg/kg of excreta and mg/pig/day) of Cu, Fe, Mn, and Zn increased linearly. Retention of these minerals also increased linearly as dietary trace mineral concentration increased, but the efficiency of retention was not altered except for Fe. When expressing the excretion of these trace minerals relative to P output there also was a linear increase in output.

Based on these data, increasing the dietary concentration of trace minerals above that required to support maximal growth results in greater environmental output. In addition, the ratio of these particular trace minerals to P in pig excreta is not constant but can be altered by dietary regimen.

### Introduction

The database used to establish many of the pigs' trace mineral needs is rather sparse with much of the data obtained in pigs having inferior lean growth rates compared with modern fast-growing, lean genotype pigs. To support this increased rate of lean gain in the modern lean genotype pig, increased concentrations of dietary trace minerals may be needed.

Currently, pork production entities are striving to not only meet the pigs biological demand for minerals but also to reduce environmental mineral excretion with the macroelement phosphorus receiving the most attention. In time, the excretion of certain trace minerals (i.e. zinc, copper, iron, iodine, and manganese) into the environment from pork production units also may be monitored and regulated to prevent excessive soil accumulation. To address these issues, up-to-date data on the effects of trace mineral supplementation on the efficiency and rate of pig growth as well as trace mineral excretion are needed.

### Materials and Methods

The experimental treatments consisted of a basal diet supplemented with four incremental additions (0x, 1x, 2x, and 3x) of a group of five trace minerals (copper, iodine, iron, manganese, zinc) from copper sulfate, potassium iodate, ferrous sulfate, manganese sulfate, and zinc sulfate. Each incremental addition was formulated to supply 100% of the estimated trace mineral needs for 5- to 10- kg pigs (2). The basal diets contained a mixture of corn, soybean meal, casein, and whey protein concentrate supplemented with crystalline amino acids and vitamins (Table 1). The basal ingredients were chosen to create a diet that contained the majority of the feedstuffs present in commercial diets while attempting to minimize the dietary contents of the five test minerals. The desired concentrations (equivalent to 100% of NRC) of Cu and Zn were obtained whereas the concentrations of Mn and Fe in the basal diet exceeded the desired concentrations. All other minerals except the five test minerals were formulated to meet or exceed the estimated requirements. All essential amino acids were at concentrations relative to lysine equivalent to a minimum of 100% of the ideal amino acid ratio (1). All vitamins except choline were supplemented at dietary concentrations equivalent to 600% of the current NRC estimated requirements (2).

Twenty-eight sets (7 barrows, 21 gilts) of four littermate pigs from a high lean strain were evaluated. Pigs were weaned at 18 to 22 days of age, placed in a facility physically isolated from other pigs, and treated with Naxcel for 3 days. Pigs were penned individually on slotted floors in a thermoneutral climate. Postweaning, pigs were fed the basal diet for ten days. Pigs were allowed to consume feed and water ad libitum.

Ten days postweaning, pigs within each litter were randomly allotted to one of the four experimental dietary regimens. In two separate trials, fourteen pens of pigs consuming the same experimental treatment were positioned over a common pit (9.14 m x 1.22 m x 45.7 cm) to collect excreta output. Pig weights, feed consumption, feed wastage, and excreta output were determined every 7 days for 4 weeks. To ensure total excreta removal, each pit was rinsed with a known weight of water during each 7-day period in which excreta was collected. The mineral contribution of this rinse water was later subtracted from total excreta mineral content. Drinking water was also sampled every 7 days to determine the proportion of the pit mineral composition due to water spillage assuming a water disappearance to feed ratio of 4:1. Excreta samples, rinse water, drinking water, and feed samples were analyzed for (Al, B, Ba, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, Si, Sr, Ti, and Zn) using inductively coupled plasma mass spectrometry by the National Soil Tilth Laboratory, Ames, IA.

**Table 1. Basal diet composition.**

| Ingredient | % |
|---|---|
| Corn | 60.20 |
| Soybean meal | 19.05 |
| Whey protein concentrate | 8.00 |
| Casein | 3.64 |
| L-Lysine·HCl | .21 |
| D,L-Methionine | .07 |
| Soybean oil | 3.00 |
| Mono-dicalcium phosphate | 1.72 |
| Phytase | .10 |
| $CaCO_3$, reagent grade | 2.29 |
| Salt | .40 |
| Vitamin premix[a] | .64 |
| Trace mineral premix[b] | .10 |
| Corn starch | .45 |
| Antimicrobial agent[c] | .13 |

[a]Contributed the following per kg of diet: biotin, .30 mg; riboflavin, 21 mg; pantothenic acid, 60 mg; niacin, 90 mg; folic acid, 1.8 mg; pyridoxine, 9 mg; thiamin, 6 mg; vitamin $B_{12}$, .105 mg; vitamin E, 96 IU; vitamin A, 13200 IU; vitamin $D_3$, 1320 IU; vitamin K, 3 mg; choline, 1561 mg.
[b]Contributed the following per kg of diet: Zn, 75 mg; I, .14 mg.
[c]Contributed per kg of diet: 110 mg tylosin.

The experiment was analyzed as a completely randomized block design with the pen considered as the experimental unit (28 replications/trt) for body growth data and excreta pit (fourteen pens/pit; 8 replications/trt) considered as the experimental unit for mineral excretion data. Orthogonal comparisons were made to test for linear and quadratic diet effects. Least-square means are reported.

## Results and Discussion

The basal diet was analyzed to contain 67, 220, 465, and 110% of the estimated NRC (1998) requirement for copper, iron, manganese, and zinc, respectively, for the 5- to 10- kg pig. Dietary iodine was not analyzed in the current experiment. The mean incremental levels of addition of the five test minerals were formulated to be 6, .14, 100, 4, and 100 mg/kg of diet for copper, iodine, iron, manganese, and zinc, respectively (Table 2). These incremental levels of inclusion were to be equivalent to 100% of the estimated NRC (1998) requirement for 5- to 10- kg pigs. The mean incremental additions for Cu, Fe, Mn, and Zn averaged 95, 27, 120, and 115% of the targeted increment. The cause of the lower than desired incremental addition of Fe is not known. Dietary concentrations of phosphorus and calcium also are included in Table 2 to represent the dietary concentration consistency of nontest minerals.

**Table 2. Analyzed composition of experimental diets.**

| Criteria | Dietary trace mineral addition 0x | 1x | 2x | 3x |
|---|---|---|---|---|
| Mineral content, ppm | | | | |
| Copper | 4.3 | 10.1 | 15.9 | 22.5 |
| Iodine[a] | nd | nd | nd | nd |
| Iron | 220 | 262 | 311 | 316 |
| Manganese | 18.6 | 21 | 26.5 | 33.0 |
| Zinc | 110 | 250 | 295 | 457 |
| Phosphorus | 7,212 | 7,267 | 7,291 | 7,272 |
| Calcium | 15,759 | 14,914 | 15,401 | 15,108 |

[a]Not determined.

Dietary trace mineral concentration did not alter daily feed intake or body weight gain, or the efficiency of feed utilization (Table 3).

**Table 3. Effect of dietary trace mineral concentration on pig growth and feed utilization.**

| Criteria | Dietary trace mineral addition 0x | 1x | 2x | 3x | SEM |
|---|---|---|---|---|---|
| Body weight, kg | | | | | |
| Initial | 7.3 | 7.3 | 7.4 | 7.4 | .2 |
| Final | 23.8 | 24.4 | 24.1 | 24.3 | .5 |
| Growth and feed utlization | | | | | |
| Gain, g/d | 567 | 587 | 575 | 582 | 12 |
| Feed, g/d | 795 | 796 | 801 | 804 | 19 |
| G/F, g/kg | 722 | 744 | 727 | 731 | 13 |

As dietary trace mineral concentration increased, total excreta output decreased linearly. However, the concentrations of Cu, Fe, Mn, and Zn in the excreta (mg/kg of excreta) increased linearly and the amount of trace mineral excreta output per pig per day increased linearly as dietary trace mineral concentration increased (Table 4). The retention of these four trace minerals also increased linearly as dietary trace mineral concentration increased. However, the efficiency of mineral retention was not altered by dietary regimen with the exception of Fe retention.

**Table 4. Effect of dietary trace mineral concentration on trace mineral excretion and retention.**

| | Dietary trace mineral addition | | | | |
|---|---|---|---|---|---|
| Criteria | 0x | 1x | 2x | 3x | SEM |
| Daily excreta output, kg/pig[a] | | | | | |
| | 10.97 | 6.36 | 4.91 | 4.86 | 1.24 |
| Excreta mineral concentration, mg/kg of excreta | | | | | |
| Cu[a] | .17 | .47 | .65 | 1.06 | .14 |
| Fe[a] | 9.04 | 15.32 | 17.29 | 24.13 | 2.90 |
| Mn[a] | .58 | 1.07 | 1.18 | 1.61 | .22 |
| Zn[a] | 4.02 | 9.93 | 14.70 | 21.43 | 3.20 |
| Daily mineral intake, mg/pig | | | | | |
| Cu[a] | 4.68 | 8.45 | 13.61 | 18.56 | .97 |
| Fe[a] | 198 | 222 | 266 | 275 | 11 |
| Mn[a] | 16.22 | 17.13 | 22.39 | 28.42 | 1.33 |
| Zn[a] | 110 | 210 | 249 | 390 | 20 |
| Daily mineral excretion, mg/pig | | | | | |
| Cu[a] | 1.59 | 3.05 | 3.80 | 6.92 | .84 |
| Fe[a] | 94 | 101 | 100 | 159 | 14 |
| Mn[a] | 5.98 | 7.19 | 7.04 | 10.60 | 1.03 |
| Zn[a] | 39 | 68 | 86 | 142 | 18 |
| Daily mineral retention, mg/pig | | | | | |
| Cu[a] | 3.09 | 5.40 | 9.81 | 11.63 | .96 |
| Fe[a] | 104 | 120 | 165 | 117 | 13 |
| Mn[a] | 10.25 | 9.94 | 15.35 | 17.82 | 1.27 |
| Zn[a] | 71 | 142 | 163 | 248 | 19 |
| Efficiency of mineral retention, % | | | | | |
| Cu | 59 | 63 | 71 | 66 | 5 |
| Fe[b] | 45 | 50 | 60 | 39 | 4 |
| Mn | 60 | 59 | 68 | 64 | 3 |
| Zn | 53 | 67 | 66 | 66 | 5 |

[a]Linear trace mineral effect, P<.05.
[b]Quadratic trace mineral effect, P<.05.

Dietary trace mineral concentration did not alter the concentration of Ca or P in pig excreta (Table 5). When expressing Ca and P output on a g/pig/day basis, P excretion declined quadratically. This was mainly due to a large drop in P excretion in pigs fed the 2x concentration of trace minerals. Because of this lowered P excretion, the efficiency of P retention was also quadratically improved. As environmental excretion regulations move towards a P based system, it is important to realize that the composition of excreta can vary even at the same level of P output. For example, as dietary trace mineral concentration increased, the proportion of Cu, Fe, Mn, and Zn increased linearly relative to P excretion (Table 5).

**Table 5. Effect of dietary trace mineral concentration on phosphorus and calcium excretion and retention.**

| | Dietary trace mineral addition | | | | |
|---|---|---|---|---|---|
| Criteria | 0x | 1x | 2x | 3x | SEM |
| Excreta mineral concentration, mg/kg of excreta | | | | | |
| P | 100 | 152 | 130 | 172 | 23 |
| Ca | 334 | 522 | 457 | 511 | 70 |
| Daily mineral intake, g/pig | | | | | |
| P | 6.06 | 6.10 | 6.18 | 6.12 | .09 |
| Ca | 13.08 | 12.51 | 13.00 | 12.68 | .21 |
| Daily mineral excretion, g/pig | | | | | |
| P[a] | 1.09 | 1.04 | 0.83 | 1.12 | .08 |
| Ca | 3.47 | 3.27 | 2.52 | 3.24 | .26 |
| Daily mineral retention, g/pig | | | | | |
| P | 4.97 | 5.06 | 5.35 | 5.00 | .12 |
| Ca | 9.62 | 9.24 | 10.48 | 9.43 | .34 |
| Efficiency of mineral retention, % | | | | | |
| P[a] | 81 | 83 | 87 | 82 | 1 |
| Ca | 72 | 73 | 80 | 75 | 2 |
| Excreta trace mineral:P ratio, mg trace mineral/g P excreted | | | | | |
| Cu[b] | 1.39 | 2.99 | 4.82 | 5.76 | .30 |
| Fe[b] | 88 | 100 | 133 | 139 | 8 |
| Mn[b] | 5.44 | 6.93 | 8.98 | 9.07 | .54 |
| Zn[b] | 35 | 65 | 110 | 116 | 8 |

[a]Quadratic trace mineral effect, P<.05.
[b]Linear trace mineral effect, P<.05.

**References**


1. Chung, T. K. and D. H. Baker. 1992. Ideal amino acid pattern for 10-kilogram pigs. J. Anim. Sci. 70: 3102–3111.
2. NRC. 1998. Nutrient Requirements of Swine (10th Ed.). National Academy Press. Washington, DC.