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Scientists are continually seeking ingredients to be added to common swine rations which will increase gain and feed efficiency. During recent years there has been some interest in copper as a growth promoting factor when fed at high levels. Several reports have indicated that copper is an effective growth stimulant when added to swine rations at a level of approximately 250 ppm. However, its widespread usage as a feed additive has been restricted by reports of toxicity at levels generally recommended for improving rate of gain and feed efficiency.

Experimental Procedure

Seventy-two crossbred pigs were used in trial I and randomly allotted from outcome groups on the basis of litter, weight, and sex into 12 lots of six pigs each. Three lots of pigs received each of the following treatments:

1. Basal ration
2. Basal ration plus 250 ppm copper
3. Basal ration plus 100 ppm iron and 100 ppm zinc
4. Basal ration plus 250 ppm copper, 100 ppm iron, and 100 ppm zinc

The pigs were confined on concrete with feed and water supplied ad libitum. Blood samples were obtained after the pigs had been on trial 26 days and at the end of the experiment. Composition of the basal ration is presented in table 1.

In trial II, which was conducted during the summer of 1969, 120 crossbred pigs weighing approximately 50 lb. were allotted, five pigs per lot, three barrows and two gilts, into three replicated groups of eight lots each. The basal ration was the same as for trial I but the treatments were changed as follows:

1. Basal ration
2. Basal ration plus 50 ppm molybdenum
3. Basal ration plus 100 ppm iron and 100 ppm zinc
4. Basal ration plus 50 ppm molybdenum, 100 ppm iron and 100 ppm zinc
5. Basal ration plus 500 ppm copper
6. Basal ration plus 500 ppm copper and 50 ppm molybdenum
7. Basal ration plus 500 ppm copper, 100 ppm iron and 100 ppm zinc
8. Basal ration plus 500 ppm copper, 50 ppm molybdenum, 100 ppm iron and 100 ppm zinc

The pigs were confined on concrete with feed and water supplied ad libitum in outside lots. Bi-weekly weights were obtained for progress studies. Blood samples were obtained when the pigs had been on trial 23 days and at the termination of the trial and analyzed for hemoglobin, hematocrit, and copper and zinc concentration in the blood serum.

Results

A summary of the results of trial I is presented in table 2. Pigs receiving rations containing either supplemental copper alone, iron and zinc combined or a combination of copper, iron, and zinc gained faster and consumed more feed than the pigs fed the basal ration. Average daily gains were 1.27, 1.63, 1.64 and 1.72 lb. per day and feed consumption averaged 4.51, 5.95, 5.78, and 5.76 lb. per day for pigs fed the (1) basal, (2) copper, (3) iron and zinc or (4) copper, iron and zinc rations, respectively. The pigs in the first replicate were heavier at the beginning of the trial and gained faster than the other two replicates except when the combination of copper, iron and zinc was fed.

A higher incidence of parakeratosis was observed in the pigs fed the basal ration alone, which may have accounted for the lower feed intake and reduced gain. Pigs with a heavier initial weight were less severely affected than those of a lighter starting weight. Copper in the ration reduced the severity of skin lesions associated with the disease, while iron and zinc completely prevented these lesions.

Pigs receiving rations with copper had slightly higher serum copper concentrations and considerably higher liver copper levels. Pigs fed rations without added copper had approximately 20 ppm copper in the liver compared to 446 ppm for those pigs receiving 250 ppm copper in their rations. When zinc and iron were included in the ration along with copper, the average copper level of the liver was reduced to 175 ppm. No visible signs of copper toxicity were observed in this trial. Zinc concentrations in blood serum and liver also increased when supplemental zinc was fed.

Table 3 summarizes the available data of trial II. All the chemical analyses have not been completed and will be reported at a later date.

Pigs fed zinc and iron alone had the highest average daily gains. Gains were slightly less when molybdenum was added with the zinc and iron and they were approximately 12% less when 500 ppm copper were included with these minerals. Copper alone, or in combination with molybdenum, resulted in pigs gaining slightly less than those fed the basal ration. It appears that copper fed at 500 ppm is slightly toxic. Necropsy examinations on the three pigs which died revealed large gastric ulcers which had bled profusely. The stomachs were filled with large blood clots and the entire intestinal tract was filled with free blood. These conditions may have been caused by the high copper levels as all three of these pigs were receiving rations containing 500 ppm copper. Molybdenum in the diet gave no growth response nor did it offset the symptoms of copper toxicity, which it has been shown to do in other species.

As in trial I, a higher incidence of parakeratosis occurred in the basal ration and also in the molybdenum-treated diet. Copper added to the ration reduced the severity of gross skin lesions and zinc completely eliminated the symptoms associated with the disease.

Although some variability was observed between pens in daily feed consumption and feed efficiency, average differences were small. Ranges of 5.19 to 5.98 lb. for feed consumption and 3.31 to 3.73 lb. feed per pound gain were noted with no definite trend apparent due to any of the minerals fed.

Hematocrit and hemoglobin values were decreased by the inclusion of copper in the diet. When iron was added to the diets already containing copper, slight increases in the hemotocrit and hemoglobin values were observed. However, they did not reach the levels present in pigs fed rations without copper.

Summary

Two trials were conducted to study the effects of copper levels in the ration on performance of growing-finishing swine. Pigs receiving copper in the diet at 250 ppm (trial I) had a faster rate of gain than those fed the basal ration. The addition of zinc and iron with copper in the diet produced no added response. When copper was raised to 500 ppm (trial II), it appeared that the toxic level was reached and a slight depression in gain was observed when compared to the basal ration. Zinc and iron added to the basal diet resulted in pigs gaining 13% faster than those receiving the basal ration. When zinc and iron were added to a ration containing 500 ppm of copper, a slight increase in gains was noted. In both trials, feed per unit of gain was not greatly affected. Serum copper and zinc levels were increased when these minerals were added to the rations. Liver copper levels increased approximately twentyfold and liver zinc levels doubled when 250 ppm copper and 100 ppm zinc were added to the rations. Zinc additions to the copper-supplemented ration reduced copper levels in the liver. Pigs receiving 500 ppm copper had lower hematocrit and hemoglobin values than those not receiving the mineral.

Table 1. Composition of Basal Rations (Percent)

	To 120 lb.	120 lb. to market
Ground yellow corn	79.4	89.8
Soybean meal (50%)	17.7	7.9
Limestone	0.5	0.5
Dicalcium phosphate	1.7	1.1
White salt	0.5	0.5
Premix[a]	0.2	0.2
Calculated analysis		
Protein, %	16.0	12.0
Calcium, %	0.65	0.5
Phosphorus, %	0.65	0.5

[a] Provided 1350 I.U. vitamin A, 200 I.U. vitamin D, 2 mg. riboflavin, 4 mg. calcium pantothenate, 9 mg. niacin, 10 mg. choline chloride and 7 mcg. vitamin B_{12} per pound of ration.

Table 2. Performance of Pigs Fed Supplemental Copper, Iron and Zinc (Trial I)

	Rep	Basal	Basal plus 250 ppm Cu[b]	Basal plus 100 ppm Fe[b] and 100 ppm Zn[b]	Basal plus 250 ppm Cu 100 ppm Fe and 100 ppm Zn
No. of pigs[a]		18	18	17	18
Av. init. wt., lb.		39.9	40.0	39.8	39.9
Av. final wt., lb.		169.8	205.9	206.5	216.2
Av. daily gain, lb.	1	1.45	1.77	1.74	1.69
	2	1.22	1.69	1.65	1.79
	3	1.15	1.44	1.53	1.68
	Av.	1.27	1.63	1.64	1.72
Av. daily feed, lb.	Av.	4.51	5.95	5.78	5.76
Av. feed per lb. gain, lb.	1	3.25	3.57	3.49	3.33
	2	3.61	3.38	3.57	3.25
	3	3.79	4.04	3.51	3.33
	Av.	3.55	3.66	3.52	3.30
Serum copper, ppm					
26 days	Av.	1.47	1.81	1.61	1.78
End of trial	Av.	1.84	2.18	2.15	2.31
Serum zinc, ppm					
26 days	Av.	0.54	0.70	1.44	1.34
End of trial	Av.	0.83	0.76	1.17	1.24
Liver copper, ppm	Av.	17	446	22	175
Liver zinc, ppm (Dry basis)	Av.	177	167	318	344

[a] Three lots of 6 pigs each per treatment. One pig died in treatment 3, data not included. Initial weights averaged approximately 46, 40 and 34 lb. for replicates 1, 2 and 3, respectively.

[b] Cu = copper, Fe = iron, Zn = zinc.

Table 3. Results of Feeding High Levels of Copper, Molybdenum, Zinc and Iron (Trial II)

	Rep	Basal	Mo	Zn+Fe	Mo, Zn+Fe	Cu	Cu +Mo	Cu, Zn+Fe	Cu,Mo, Zn+Fe
No. of pigs[a]		15	15	15	15	14	13	15	15
Av. init. wt., lb.		51.5	51.4	51.5	51.7	51.4	52.5	50.5	51.2
Av. final wt., lb.		194.8	194.6	212.5	207.8	187.8	186.1	192.7	191.6
Av. daily gain, lb.	1	1.55	1.55	1.87	1.75	1.62	1.57	1.70	1.66
	2	1.38	1.46	1.63	1.67	1.40	1.49	1.31	1.60
	3	1.69	1.61	1.72	1.63	1.40	1.27	1.61	1.29
	Av.	1.54	1.54	1.74	1.68	1.47	1.44	1.54	1.52
Av. daily feed, lb.	Av.	5.38	5.34	5.98	5.57	5.21	5.36	5.43	5.19
Av. feed/lb. gain, lb.	1	3.55	3.49	3.47	3.31	3.41	3.48	3.50	3.47
	2	3.59	3.60	3.27	3.34	3.69	3.66	3.39	3.30
	3	3.36	3.34	3.58	3.29	3.52	4.06	3.69	3.50
	Av.	3.50	3.48	3.44	3.31	3.54	3.73	3.53	3.42
Hematocrit (%)									
23 days	Av.	39.3	40.3	40.2	41.5	35.3	35.3	37.3	36.7
At slaughter	Av.	45.1	44.1	44.1	43.8	38.1	38.4	40.6	40.2
Hemoglobin (gm. %)									
23 days	Av.	11.91	11.92	12.07	12.48	10.14	10.32	10.75	10.47
At slaughter	Av.	13.75	13.47	13.70	14.00	11.05	11.14	11.93	11.94
Blood serum, 23 days									
Copper, ppm	Av.	1.66	1.79	1.70	1.71	2.21	2.25	2.15	2.03
Zinc, ppm	Av.	0.27	0.32	1.05	1.04	0.49	0.56	1.02	0.95

[a] Three replicate lots of 5 pigs each per treatment. Three pigs died and data not included. Initial weights averaged approximately 62, 44 and 48 lb. for replicates 1, 2 and 3, respectively.