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Comparison of Different Concentrations of Inorganic Trace Minerals in Broiler Diets on Live Performance and Mineral Excretion[1]

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Abstract: Two consecutive experiments compared different concentrations of inorganic trace minerals in broiler production under different ambient temperature. Both experiments had six treatments, consisting of 100, 80, 60, 40, 20 and 0% of normal trace mineral premix (TMP) inclusion rate with eight and four replicates of sixty male broilers in the first and second experiments, respectively. Experiment 1 began on January 9th and finished on February 20th while Experiment 2 began on July 19th and finished on August 29th. Body weight and feed consumption were determined at 14, 35 and 42 days. At 42nd day two birds per pen were killed and the tibia removed for bone ash determination. In Experiment 2, cohort birds were fed in battery pens from 35 to 37 days. with excreta samples collected for trace mineral analysis. In Experiment 1, birds with no TMP had significantly decreased body weight over all growth periods. Birds fed diets with 20% of normal TMP did not differ in performance from those fed higher levels up to 100% of normal addition rates. There was no difference in any growth variables in Experiment 2 when higher environmental temperatures were in effect. Reduction of TMP in broiler diets could reduce mineral excretion to environment. Levels of Fe, Cu, Mn and Zn in broiler excreta decreased when mineral premix levels were reduced.

Key words: Broilers, trace minerals, excreta, environment.

Introduction

Trace minerals such as copper, zinc and manganese are essential elements for development and growth in broilers. In commercial poultry production, trace minerals are commonly added in the form of a premix to diets and used to supply from two to ten times more of these minerals than NRC recommendations (Inal *et al.,* 2001). Data on which NRC recommendations are based are sparse and demonstrate wide variation, with Mn requirements for the chick estimated from 14 (Southern and Baker, 1983a) to 50 mg/kg (Gallup and Norris, 1939) Zn from 14 (Southern and Baker, 1983b) to over 52 mg/kg (Lease *et al.,* 1960) and Fe from 40 (Southern and Baker, 1982) to 80 mg/kg (McNaughton and Day, 1979). Due to growing concerns about environmental pollution, there has been considerable interest in reducing nutrient concentration in poultry litter. In general, nutrient excretion can be reduced by avoiding the overfeeding of specific nutrients or by using nutritional manipulations to enhance nutrient utilization (Ferket *et al.,* 2002). It has recently been reported (Anonymous, 2004) that “remarkably good performance of birds fed successively lower quantities of industry norms, provided the minerals were supplemented in Bioplex form”. However, the only treatments in that study that evaluated reduced quantities of minerals utilized organic mineral complexes and no treatments utilized reduced quantities of minerals from less expensive inorganic forms. Several reports have indicated that broilers could produce well on lower than traditional industry levels during part (Waldroup *et al.,* 1968; Skinner *et al.,* 1992) or all of a growing period (Shelton and Southern, 2006). Current industry cost to supplement diets with conventional inorganic trace minerals is about $ 0.45 per ton of feed[4]. It would be very useful to determine the trace mineral requirement of broiler chickens for reduction of feed cost and environmental risks. Thus, the objective of this study was to compare different concentrations of inorganic trace minerals in broiler production over all growth periods under commercial conditions.

Materials and Methods

Two consecutive experiments were conducted using the same experimental design. The trace mineral mix used in this study (Table 1) is composed completely of inorganic sources of trace minerals and has been used in research studies in our laboratory for many years. Sulfate forms of minerals other than iodine were used to provide the highest bioavailability. Supplemental trace mineral levels in the basal diet are similar to current industry levels (Allard, 2005) and with the exception of iron are in excess of NRC (1994) recommendations. Selenium is added separately and iodized salt used to provide sodium and chloride. Diets were formulated to nutrient levels similar to current industry average. Yellow corn and soybean meal of known moisture and protein content served as principal sources of energy and intact protein. A large batch of feed was prepared for each age period (0-14, 14-35 and 35-42 days) and aliquots used for mixing the experimental diets. The experimental diets were prepared by mixing the trace mineral mix at 100,

Table 1: Trace mineral mix used in Arkansas nutrition research trials

Mineral	Source	Mg/kg diet	U.S. levels[1]	NRC 1994
Manganese	$MnSO_4.H_2O$	100	100-180	60
Zinc	$ZnSO_4.7H_2O$	100	100-150	40
Iron	$FeSO_4.7H_2O$	50	20-40	80
Copper	$CuSO4.5H_2O$	10	5-20	8
Iodine	$Ca(IO_3)_2.H_2O$	1	0.75-1.50	0.35

[1]Allard, 2005.

Table 2: Composition (g/kg) and calculated nutrient content of basal diets

Ingredients	0-14d	14-35d	35-42d
Yellow corn	572.71	625.97	690.97
Poultry oil	30.43	28.98	27.37
Soybean meal	346.23	300.32	238.72
Ground limestone	13.95	11.73	11.62
Dicalcium phosphate	17.46	15.59	14.79
Sodium chloride	5.66	5.69	5.72
L-Threonine	0.95	0.31	0.46
L-Lysine HCl	2.19	1.34	1.21
Coban-60	0.75	0.75	0.00
BMD-50	0.50	0.50	0.50
Alimet	3.17	2.82	2.64
Broiler premix[1]	5.00	5.00	5.00
Variable[2]	1.00	1.00	1.00
TOTAL	1000.00	1000.00	1000.00
ME, kcal/lb	1400.00	1425.00	1450.00
Crude protein%	22.40	20.42	17.88
Calcium%	0.98	0.86	0.82
Nonphytate P%	0.45	0.40	0.38
Methionine%	0.60	0.55	0.51
Lysine%	1.38	1.19	1.01
Threonine%	0.94	0.81	0.72
TSAA%	0.99	0.91	0.83
Digestible Met%	0.58	0.53	0.48
Digestible Lys%	1.26	1.07	0.90
Digestible Thr%	0.83	0.70	0.63

[1]Provides per kg of diet: vitamin A (from vitamin A acetate) 7714 IU; cholecalciferol 2204 IU; vitamin E (from dl-alpha-tocopheryl acetate) 16.53 IU; vitamin B_{12} 0.013 mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; menadione (from menadione dimethylpyrimidinol) 1.5 mg; folic acid 0.9 mg; choline 1040 mg; thiamin (from thiamin mononitrate) 1.54 mg; pyridoxine (from pyridoxine HCl) 2.76 mg; d-biotin 0.066 mg; etho1xyquin 125 mg; Se 0.1 mg.
[2]Variable levels of trace mineral mix or washed builders sand.

80, 60, 40, 20 and 0% of normal inclusion rates, resulting in six experimental diets. Composition and calculated nutrient content of basal diets are shown in Table 2. All diets were pelleted with steam (diets for 0-14 days fed as crumbles). Each of the six treatments was assigned to eight (Experiment 1) or four (Experiment 2) replicate pens of 60 male broilers. Male chicks of a commercial strain (Cobb 500) were obtained from a local hatchery where they had been vaccinated in ovo for Marek's disease and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. They were randomly assigned to pens in a house of commercial design with new softwood shavings over concrete floors . Each pen was equipped with two tube feeders and one automatic water fount. Supplemental feeders and waterers were used for the first seven days. Thermostatically controlled gas brooders, exhaust fans and sidewall curtains controlled the temperature. Incandescent lights provided 23 hr light daily. The first experiment started on January 9 and finished on February 20 while the second experiment started on July 19 and finished on August 29, therefore, different environmental conditions occurred in the two experiments. Chicks were managed according to guidelines established by FASS (1999). The Institutional Animal Care and Use Committee of University of Arkansas approved all procedures in this study. Body weight by pen and feed consumption were determined at 14, 35 and 42 days of age. Birds were checked twice daily for mortality, any bird that died or was removed to alleviate suffering was weighed to adjust feed conversion. At the conclusion of the study, two birds per pen were killed by cervical dislocation and the right tibia was removed for bone ash determination. In Experiment 2, cohort birds were fed in battery pens with excreta samples taken from 35-37 days. The fecal samples were frozen, freeze dried and assayed for trace mineral content using Inductively Coupled Plasma Emission Spectroscopy by a commercial laboratory specializing in these assays. Data were subjected to one-way ANOVA using the General Linear Models procedure of SAS (SAS institute, 1991). Pen means were the experimental unit. Mortality data were transformed to the square root of n+1, data are presented as natural numbers. Significant differences among means were separated using the Duncan's Multiple Range Test option of SAS. All statements of significance are based on $P \leq .05$.

Results and Discussion

Differences in response to reduction of trace mineral premixes were observed between the two experiments. In the first experiment, conducted under environmental conditions with no heat distress, total removal of the trace mineral premixes resulted in a significant reduction in body weight at all ages, compared to birds fed the normal level of supplementation (Table 3). There was also a significant reduction in feed intake in birds fed the diet with no supplemental trace mineral premix, however, there was no significant effect on feed conversion. This suggests that removal of the trace mineral premix influenced the appetite of the birds, resulting in reduced gain. Overall, birds fed diets with as little as 20% of the normal level of trace mineral supplementation did not differ in body weight, feed intake or feed conversion from those fed the diets with 100% of the normal supplemental level. There were no overall effects of dietary treatments on mortality, with no visible leg disorders in surviving birds. No significant differences in tibia ash were observed among the dietary

Table 3: Effect of trace mineral levels on broiler performance in Experiment 1[1]

	% of normal level of supplementation[2]						Statistical analysis		
Items	100	80	60	40	20	0	P-value	SEM	CV %
Body weight (kg)									
14 d	0.425[a]	0.420[ab]	0.429[a]	0.428[a]	0.422[a]	0.404[b]	0.043	0.0056	3.78
35 d	2.164[a]	2.138[a]	2.188[a]	2.183[a]	2.173[a]	2.064[b]	0.002	0.0219	2.69
42 d	2.867[a]	2.833[a]	2.885[a]	2.877[a]	2.848[a]	2.733[b]	0.004	0.0248	2.31
Feed conversion (kg:kg)									
1 to 14d	1.336	1.347	1.330	1.335	1.317	1.331	0.890	0.0166	3.52
1 to 35d	1.651	1.677	1.642	1.653	1.622	1.693	0.124	0.0186	3.17
1 to 42d	1.746	1.763	1.754	1.754	1.746	1.793	0.200	0.0146	2.19
Feed intake (kg)									
1 to 14d	0.504[ab]	0.502[ab]	0.507[a]	0.508[a]	0.493[b]	0.475[c]	<0.001	0.0043	2.46
1 to 35d	3.492[a]	3.505[a]	3.514[a]	3.500[a]	3.448[a]	3.377[b]	0.003	0.0257	1.96
1 to 42d	4.921[a]	4.945[a]	4.976[a]	4.939[a]	4.874[ab]	4.795[b]	0.029	0.0392	2.11
Mortality (%)									
1 to 14d	1.04	0.83	1.25	1.25	0.83	0.83	0.910	0.374	104.92
1 to 35d	2.91	2.71	3.75	5.21	3.13	2.71	0.429	0.964	80.16
1 to 42d	5.21	5.41	5.62	7.29	4.17	4.17	0.660	1.426	75.95
Tibia ash (%)									
42d	42.77	42.22	41.70	41.43	41.38	41.36	0.584	0.656	4.44

[1]Means of eight pens of 60 male broilers per treatment

[2]Normal level provides per kg of diet: 100 mg Mn; 100 mg Zn; 50 mg Fe; 10 mg Cu; 1 mg I.

Table 4: Effect of trace mineral levels on broiler performance in Experiment 2[1]

	% of normal level of supplementation[2]					Statistical analysis			
Items	100	80	60	40	20	0	P-value	SEM	CV (%)
Body weight (kg)									
14 d	0.393	0.394	0.407	0.412	0.419	0.421	0.207	0.0100	4.67
35 d	2.047	2.011	2.018	2.075	2.078	2.021	0.817	0.0450	4.41
42 d	2.615	2.569	2.525	2.663	2.670	2.577	0.621	0.0670	4.17
Feed conversion (kg:kg)									
1 to 14 d	1.258	1.256	1.211	1.232	1.213	1.192	0.238	0.0210	3.50
1 to 35 d	1.528	1.545	1.535	1.520	1.523	1.538	0.693	0.0120	1.60
1 to 42 d	1.675	1.653	1.665	1.648	1.638	1.668	0.485	0.0150	1.76
Feed intake (kg)									
1 to 14 d	0.436	0.438	0.438	0.452	0.452	0.449	0.460	0.0070	3.35
1 to 35 d	3.057	3.037	3.026	3.084	3.096	3.038	0.965	0.0650	4.28
1 to 42 d	4.303	4.170	4.127	4.310	4.301	4.221	0.735	0.1050	4.97
Mortality (%)									
1 to 14 d	2.08	0.83	0.42	1.67	1.25	2.92	0.174	0.680	89.07
1 to 35 d	4.58	2.50	1.67	3.33	1.67	4.58	0.119	0.932	35.65
1 to 42 d	5.00[ab]	2.50[bc]	1.67[c]	3.75[abc]	2.50[bc]	6.25[a]	0.026	0.952	52.74
Tibia ash (%)									
42 d	38.70	35.85	38.17	38.69	37.50	37.71	0.421	1.731	5.52

[1]Means of four pens of 60 male broilers per treatment

[2]Normal level provides per kg of diet: 100 mg Mn; 100 mg Zn; 50 mg Fe; 10 mg Cu; 1 mg I.

Table 5: Mineral concentration (mg/kg dry matter) in broiler excreta collected from 35 to 37 d of age from male broilers housed in battery cages (Experiment 2)

% of normal[1]	Fe	% of normal	Mn	% of normal	Zn	% of normal	Cu	% of normal
100	552[a]	100	454[a]	100	458[a]	100	51.73[a]	100
80	570[a]	103.2	414[b]	91.1	434[b]	94.7	53.21[a]	102.8
60	494[b]	89.5	326[c]	71.8	341[c]	74.4	43.60[b]	84.2
40	394[c]	71.3	212[d]	46.6	240[d]	52.4	32.62[c]	63.0
20	391[c]	70.8	172[e]	37.8	200[e]	43.7	29.82[c]	57.6
0	377[c]	68.3	142[f]	31.2	172[f]	37.5	23.71[d]	45.8
SEM	62.39		35.71		30.48		9.06	
P value	<0.0001		<0.0001		<0.0001		<0.0001	

[1]Normal Level Provides Per kg of diet;100 mgZn;50 mg Fe;10 mg Cu;1 mg l.

treatments, although tibia ash tended to decline as trace mineral levels decreased. The second experiment was conducted under environmental temperatures that induced some degree of heat distress. The average weekly temperature was a low of 80.74± 7.09 with average weekly high temperature of 87.79 ±5.25. In this experiment, reduction or total removal conversion (Table 4). As observed in Experiment 1, tibia ash tended to decline as trace mineral levels decreased but the differences were not statistically significant. Over the entire 42 days feeding period, there were significant differences in mortality among the treatments, but they did not follow the trend of trace mineral reduction. Although the chicks fed the diets with all trace mineral removed had the highest mortality during the study, they did not differ significantly from those fed the diet with 100% supplementation. Variability in mortality data is extensive so caution must be taken in evaluating these results. Few data have been reported on mineral excretion when mineral premix was reduced or removed from the diet. Mineral concentration in broiler excreta collected from 35 to 37 days of age is shown in Table 5. There were significant reductions in all the minerals in the excreta associated with reduction in the diet. Reducing the amount of trace minerals in the diet of broilers would therefore reduce mineral excretion to environment. In a 45 days experiment by Burrell *et al*. (2004) broilers were given a maize-soybean meal basal diet supplemented with 0, 20, 40 and 80 mg/kg of Zn from zinc sulphate or an organic zinc source and reported that increased supplemental zinc concentration significantly increased zinc excretion. Removal of both TMP and vitamin in broilers has been reported in several previous researches. Nilipour *et al*. (1994) reported that reduction of vitamin and mineral premix up to 50% of recommended level had no adverse effect on broiler chickens. Removal of vitamin and trace mineral mixes reduced growing costs with no adverse effects on performance in broilers from 28 to 49 days (Skinner *et al.,* 1992). Maiorka *et al*. (2002) reported that withdrawal of vitamin mix affected feed conversion and resulted in more deleterious growth than withdrawal of mineral mix during the final period of broiler chicken. In a 43-days floor pen study that included diets with and without phytase and with and without supplemental

trace minerals, Shelton and Southern (2006) reported that growth performance was not affected in chicks fed diets with or without the trace minerals, but adding phytase had positive effects on growth performance. Removal of the trace minerals had a negative effect on bone strength. Recent reports on trace mineral needs for growing broilers are limited. Batal *et al.* (2001) reported that the bioavailable zinc requirement for chicks 1 to 3 wk of age was estimated at 22.4 mg/kg. However, Burrell *et al.* (2004) found the zinc requirement of male broilers grown to 45 days of age was 80 mg/kg supplemental zinc. In this study, they found no significant effect of dietary zinc supplementation on body weight gain, feed conversion or mortality during the first 20 days of age. Therefore, it appears that more research is needed to accurately define the requirements for various trace minerals for broilers over the entire growth period. In conclusion, the results of the present study indicate that trace mineral levels in broiler diets could be markedly reduced compared to current industry levels without any significant effects on live performance. Comparison of inorganic and organic sources at these lower levels should be considered in these studies. A reduction in supplemental trace mineral levels would be reflected in reduced trace mineral excretion.

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