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In this issue:

A. Influence of different levels of calcium and phosphorus on young broiler performance

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Influence of different levels of calcium and phosphorus on young broiler performance

Broiler production has changed and improved over recent decades. Bird growth has accelerated and there has been an increase in leg problems in the barn and bone fractures during processing. Research has found that the newer, fast-growing strains have lower bone-ash content and weaker skeletal integrity (Williams et al., 2000).

Nutrient requirements (NRC, 1994), especially for Ca and P, are based on published research conducted between 1952 and 1983. The changes in bird strains and management changes, which include phytase supplementation, dictate more research and information about the nutrient effects and interactions must be undertaken. Calcium can be a limiting factor in bone mineralization and macromineral absorption (Driver et al, 2005; Simpson and Wise, 1990). Changing the amount of dietary calcium may improve or limit phosphorus utilization. Phosphorus amounts, which come from both organic and inorganic sources, can be varied to sustain broiler requirements (Adeolo and Walk, 2013). Phosphorus amounts over threshold requirements in the birds also create environmental and economic concerns for producers. Plus, the effects of Ca and P on broiler performance are not exclusive of each other, and their interactions can be significant.

The requirements for Ca and nonphytate phosphorus (NPP) in the modern poultry industry are becoming a major issue. There are economic, environmental and animal welfare implications. Hamdi et al., (2015) recently published results of their research to establish the optimum dietary Ca and NPP levels for starting broilers, using a range of diets with varying levels of Ca and NPP plus a high dose of phytase.

Experiment

In total, 420 1-day-old male broilers were used in this experiment. They were divided among 12 dietary treatments with 5 replications. Three calculated levels of Ca (0.5, 0.7 and 0.9%, respectively) and 4 calculated levels of NPP (0.25, 0.31, 0.38 and 0.45%, respectively) were used in the treatments. All the treatment diets met or exceeded the nutrient requirements for broilers (Fundación Española Desarrollo Nutrición Animal, 2008), except for Ca

Continued on p.2

Continued from p. 1

and available P. The birds were individually wing-tagged in order to monitor individual body weight (BW) and the group BW at the start (0d), middle (7d) and end of the experiment (14d post-hatch). From the BW values, feed intake (FI), weight gain (WG) and growth:finish (G:F) from d1to d14 were calculated. Three birds from each cage were euthanized, and measurements were taken for gizzard and proventriculus pH and bone-ash determination. The rest of the chicks were then euthanized to determine the Ca and P content of the birds' whole bodies. Diets were analyzed for dry matter (DM), Ca, and P.

Results

Table 1 shows the nutrient breakdown of the diets. Calcium levels (0.62, 0.79 and 0.96%) were actually higher than what was formulated, as a result of Ca being present in some ingredients. Analyzed P levels (from 0.64-0.84%) and phytase activity (1,150 FTU/kg) were also higher than calculated values.

Table 2 shows the influence of Ca and P on feed intake (FI) and weight gain (WG). Increasing the level of NPP from 0.25 to 0.38% increased FI in birds on the high-Ca diet (0.9%) but not on the lower Ca diets (0.5 and 0.7%). From 7d to 14d, there was a similar pattern for growth performance. Increasing levels of P also increased growth performance. Results were higher for birds fed 0.38% NPP over birds fed the 0.25% diet.

Tibia weight was greatest in birds on the 0.9% Ca diets and 0.38% NPP diet. The greatest Ca:P imbalance (0.5% Ca with 0.45% NPP in the diet) presented the lowest tibia weight and ash content in birds. Fractional retention of Ca decreased from 74% on the 0.5% Ca to 46% on the 0.9% Ca diets. Whole body Ca content decreased as the level of dietary calcium increased from 0.5% to 0.7%.

The P content tended to decrease as dietary Ca increased. The fractional retention of P decreased from 66% to 52% as NPP increased from the 0.25% to the 0.45% diets. As dietary P increased (0.25 to 0.45%), the fractional retention of Ca increased from 53% to 61%. Whole-body Ca content was higher on the 0.31, 0.38 and 0.45% NPP diets than on the 0.25% NPP diets in the birds.

What this means for the Industry

Higher levels of calcium can have negative effects on broiler performance for a variety of reasons. Calcium forms insoluble complexes with phytate-phosphorus and inorganic P (Angel et al., 2002). The pH increases in the crop and gizzard conditions arise where Ca, phytate and P become bound up (precipitate). Shifts in pH may also reduce Ca and P digestibility (Walk, et al., 2012). Calcium has the ability to form insoluble soaps with the free fatty acids and bile acids in the birds. Research has shown that these types of soaps can limit the absorption of fat in vivo (Shahkalili, et al., 2001).

This research follows earlier studies and finds that bone-mineral content, bone-mineral density, and percentage of ash increased linearly as dietary calcium concentrations increase (Onyango, et al., 2003). However, there was an interaction between Ca and NPP on the percentage of tibia ash, which shows that high levels of calcium may influence the availability of P for bone mineralization. There is a physiological response by the chicken to overcome a Ca deficiency by up-regulating the nutrient transfer and how the nutrients are deposited in the bird's infrastructure. At NPP levels of 0.38%, the growth of chicks at d 14 was improved. The increased levels of NPP up to 0.38% in the 0.7 and 0.9% calcium treatments also increased bone mineralization in birds. In this study, the high dose of supplemental phytase (at 1,150 U/kg), may explain the positive responses at lower NPP values in the diet that were observed.

Increasing levels of NPP from 0.25 to 0.31% NPP allows for increases in the fractional retention of Ca and is reflected

Continued on p.3

Continued from p. 2

Table 1. Calculated composition of study diets

Ca (%)	0.9				0.7				0.5			
NPP (g/kg)	0.25	0.31	0.38	0.45	0.25	0.31	0.38	0.45	0.25	0.31	0.38	0.45
Ingredients (%)												
Corn	23.87	23.87	23.87	23.87	23.87	23.87	23.87	23.87	23.87	23.87	23.87	23.87
Wheat	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Soybean Meal	27.15	27.15	27.15	27.15	27.15	27.15	27.15	27.15	27.15	27.15	27.15	27.15
Extruded full-fat soybean	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27	13.27
Na phosphate	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
L-Lysine	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
DL-Methionine	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
L-Threonine	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Soy oil	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Salt	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Trace mineral-vitamin premix[1]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Celite	1.10	0.93	0.77	0.61	1.601	1.45	1.29	1.13	2.13	1.97	1.81	1.65
Limestone[2]	1.90	1.76	1.63	1.49	1.38	1.24	1.10	0.97	0.85	0.72	0.58	0.44
Monocalcium phosphate[3]	0.03	0.55	0.85	1.14	0.26	0.55	0.85	1.14	0.26	0.55	0.85	1.14
Calculated Composition												
ME, kcal/kg	2,960	2,960	2,960	2,960	2,960	2,960	2,960	2,960	2,960	2,960	2,960	2,960
CP, %	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
Lys, %	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
TSAA, %	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Thr, %	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
Na, %	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Ca, %	0.90	0.90	0.90	0.90	0.70	0.70	0.70	0.70	0.50	0.50	0.50	0.50
P, %	0.49	0.55	0.62	0.69	0.49	0.55	0.62	0.69	0.49	0.55	0.62	0.69
Available P, %	0.24	0.31	0.37	0.44	0.24	0.31	0.37	0.44	0.24	0.31	0.37	0.44
Analyzed Composition												
Ca, %	0.96	0.96	0.96	0.96	0.79	0.79	0.79	0.79	0.62	0.62	0.62	0.62
P, %	0.64	0.68	0.78	0.84	0.66	0.70	0.80	0.84	0.64	0.68	0.76	0.84

[1] Provides per kg feed: vitamin, A (from retinol), 13,500 IU; vitamin D_3 (from cholecalciferol), 4,800 IU; vitamin E (from alfa-tocopherol), 49.5 IU; vitamin B_1, 3mg; vitamin B_2, 9mg; vitamin B_6, 4.5mg; vitamin B_{12}, 16.5µg; vitamin K_3, 3mg; calcium pantothenate, 16.5mg; nicotinic acid, 51mg; folic acid, 1.8mg; biotin, 30µg; Fe (from $FeSO_4 \cdot 7H_2O$), 54mg; I [from $Ca(I_2O_3)_2$], 1.2mg; Co [from $2CoCO_3 \cdot 3Co(OH)_2 \cdot H_2O$], 0.6mg; Cu (from $CuSO_4 \cdot 5H_2O$), 12mg; Mn (from MnO), 90mg; Zn (from ZnO), 66mg; Se (from Na_2SeO_3), 0.18mg; Mo [from $(NH_4)_6Mo_7O_{24}$], 1.2mg; phytase, 1,000 FTU/kg; Endo-1,4-beta-xylanase EC 3.2.18, 150 Farbe xylanase unit.
[2] Limestone supplied 38% Ca
[3] Monocalcium phosphate supplied 22.6% P and 17.8% Ca.

Table 2. Influence of Ca and NPP[1] levels in diets containing phytase at 1,150 FTU/kg on feed intake and growth performance of broilers from d1 to 14[2].

Treatment	NPP, %	BW, d 14, g	FI[3], d1 to 14, g/d	WG[4], d1 to 14, g/d	WG, d7 to 14, g/d	G:F, d1 to 14
0.5	0.25	428	37.6[a]	27.4	34.7	0.732
	0.31	436	36.6[a,b]	28.0	35.5	0.766
	0.38	431	35.7[a,b]	27.7	35.3	0.776
	0.45	408	35.7[a,b]	25.9	34.0	0.736
0.7	0.25	428	37.7[a]	27.4	35.4	0.731
	0.31	444	37.3[a]	28.5	37.0	0.765
	0.38	460	39.2[a]	29.7	39.0	0.770
	0.45	440	36.6[a,b]	28.3	36.0	0.771
0.9	0.25	391	30.3[a]	24.7	30.9	0.821
	0.31	417	34.6[a,b]	26.6	33.5	0.770
	0.38	445	37.5[a]	28.7	36.6	0.766
	0.45	446	35.3[a,b]	28.7	37.9	0.815
Ca level, %						
0.5		426	36.3	27.2	34.8[a,b]	0.752
0.7		443	37.7	28.4	36.8[a]	0.759
0.9		425	34.4	27.1	34.7[b]	0.793
NPP level, %						
	0.25	416[b]	35.1	26.5[b]	33.6[b]	0.761
	0.31	432[a,b]	36.1	27.7[a,b]	35.3[a,b]	0.767
	0.38	446[a]	37.4	28.7[a]	36.9[a]	0.770
	0.45	431[a,b]	35.8	27.6[a,b]	35.9[a,b]	0.774
SEM		12.7	1.3	0.9	1.3	0.033
P value[5]						
Ca level x NPP level		0.122	0.048	0.107	0.068	0.614
Ca level		0.086	0.005	0.086	0.045	0.185
NPP level		0.050	0.242	0.045	0.025	0.969

[1] Nonphytate P
[2] Data are means of 5 pens with 7 chicks each
[3] Average daily feed intake
[4] Average daily weight gain
[5,a,b] Values in the same column with different letters are significantly different ($P<0.05$)

Continued on p.4

Continued from p. 3

in the body growth and bone mineralization response to the improved Ca:P in the diet. The increase in NPP levels also reduces the fractional retention of P, opposite the reaction to Ca. When P levels are higher than physically required for maximum utilization and retention, the extra P is most likely to be excreted. Knowing the required nutrient thresholds is important to avoid wasting P in the flock.

The interaction of P and Ca needs to be evaluated at each growth phase. The effects of the nutrients must be considered together and not solely evaluated on an individual basis. Hamdi et al. (2015) found that young chicks responded to changing NPP levels in the diet, both in growth performance and bone mineralization. As dietary calcium increases, young chick growth decreases and might affect bone formation during this early period. Levels of dietary NPP can modify the negative effects of Ca. This recent research makes a strong argument for formulating diets meeting or exceeding P requirements of broilers, particularly when diets are high in calcium. This research may also add to a future foundation of study evaluating the interaction of Ca and P at later stages of broiler growth and development.

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