Dietary calcium and non-phytate phosphorus requirements of broiler chickens in the prestarter phase

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Objectives

Modern strains of broilers may require greater dietary concentrations of calcium (Ca) and phosphorus (P) to allow for the increased rates of growth being achieved today. The Ca and non phytate P (nPP) requirements vary with growth phase and may be different for depending on broiler strain. Most published research on Ca and P requirements has focused on a starter phase that ranges from hatch (H) to an end age from 16 to 21 days and does not take into account the prestarter (PreSt) phase (H to 7 or 10 d of age), where bone growth rate is most rapid (WILLIAMS et al., 2000, RATH et al., 2000). Deficiencies in dietary Ca and P in the PreSt phase may limit bone mineralization and compromise the structural formation of the skeleton. The aim of this study was to determine requirements for dietary Ca and nPP based on growth performance and bone ash in broilers during the PreSt phase (H to 10 days of age) for two commercial broiler strains (Hubbard 99M × Cobb 500F cross and Ross 708).

Material and Methods

All animal care procedures were approved by University of Maryland Animal Care and Use Committee. In each of the two experiments (Exp I and II), 1 day-old straight-run broiler chicks were placed in artificially lit and environmentally controlled rooms, in modified Petersime batteries cages (99.7 cm long, 68.6 cm wide and 29.2 cm high; Petersime Incubator Company, Gettysburg, Ohio, USA). Each cage had 2 nipple drinkers and 2 feeders (63.5 cm long, 8.9 cm wide and 5.7 cm deep). A photoperiod of 24L:0D was used from hatch to day 4 and 20L:4D from day 5 to 10. Temperature was kept at an average of 32 °C from H to day 4 and then was gradually reduced based on bird observations to 28 °C at day 8. The treatments were randomly pre-assigned to battery pen and pen was the experimental unit. Upon arrival, all birds were weighed, divided into weight groups, such that between and within cage weight variability was minimized. Both experiments were conducted as a completely randomized block design. Birds were offered feed and water for ad libitum consumption. Birds and feed were weighed by pen at 0 and 10 days and were checked twice daily for mortalities with weight of mortality, rest of the birds in the pen and feed determined and this used to determine mortality corrected body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR).

In Exp I, 136 battery cages (6 birds per pen) in each of two blocks (replications in time) to achieve 8 total replicate pens per treatment. Straight-run Hubbard 99 M × Cobb 500 F (HC) and Ross 344 M × Ross 708 F (R) broiler chicks obtained, from 34 and 37 week-old breeder flocks for block 1 and 2, from a local commercial hatchery. There were 17 dietary treatments with 3 Ca and 4 nPP concentrations as follows: at 0.83% Ca nPP tested were 0.25, 0.34, 0.42 and 0.51; at 0.96% Ca nPP tested were 0.29, 0.34, 0.42 and 0.50% nPP and at 1.13% Ca nPP tested were 0.34, 0.42, 0.50 and 0.58% nPP.

A corn-soybean meal basal diet was formulated to meet or exceed NRC (1994) recommendations but also to meet or exceed all average commercial nutrient concentrations used in the USA based on AgriStats (2011) year end summary, excluding Ca and nPP. The
The basal diet was mixed and analyzed in triplicate for tP and Ca (AOAC, 2005) and PP by the method of BLAABJERG et al. (2010) and nPP concentration determined by subtracting analyzed PP from analyzed tP. Based on the concentration of Ca and nPP determined in the basal diet, the basal diet was included at 96% in all 17 experimental diets with analyzed monocalcium phosphate and calcium carbonate were added to the basal diet to obtain the desired concentration of Ca and nPP and 0.2% titanium dioxide added as a marker and variable celite used as a filler to achieve 100%. All final diets were analyzed for Ca and P.

For Exp II, only R strain obtained from the same hatchery as Exp I, were used (49 week-old breeder). Birds were placed into batteries as described for Exp I into 90 battery pens pre-assigned to 15 treatments replicated 6 times and each pen with 20 birds. At 4 days of age, pen weight was determined and 3 birds above and low the mean and 4 birds close to the mean were euthanized and sampled. This data will not be presented in this paper only H to 10 d data will be presented and that reflects 10 birds per pen. The basal diet was mixed and analyzed as described for Exp I but was included at 92.5% in 4 blending basal diets to which analyzed monocalcium phosphate and calcium carbonate were added to achieve the desired Ca and nPP and 0.2% titanium dioxide added as a marker and variable celite used as a filler to achieve 100%. After analysis the 4 blending basals were blended to achieve 15 experimental diets and these diets analyzed as described above. The 15 treatments were obtained from a factorial arrangement of 3 Ca (0.80, 1.00, and 1.15%) and 5 nPP concentrations (0.37, 0.39, 0.48, 0.55 and 0.65%).

At 10 d of age, 6 birds in the Exp I and 10 birds in the Exp II were weighed, euthanized by cervical dislocation and samples taken from all birds left in the pen. Middle toes from both feet of each bird were cut at the third metatarsal and right tibias with all tissue including distal cartilaginous cap removed. Toes and tibias, by pen, were oven dried at 100°C for 24 h, defatted for 16 hours in a Soxhlet apparatus in refluxing petroleum ether, oven-dried at 100 ºC overnight and weighed for determination of dry defatted weight. Dry defatted toes and tibias were ashed for 16 h at 600 ºC. Dry defatted ash content was determined (AOAC, 2005) and expressed as percentage of the defatted bone weight.

Data were analyzed as a completely randomized design using proc MIXED (LITTELL et al., 1996) of SAS (SAS INSTITUTE INC., 2008). All analyses were done based on analyzed Ca and determined nPP concentrations. Strain and dietary treatments were considered as fixed effects and block (time) and interactions between block (time) and dietary treatments as random effects in the Exp I. When effects were significant ($P < 0.05$) treatment means were separated using Tukey-Kramer test (TUKEY, 1991). Multiple regression analyses using proc REG were done where block (time) effect was used as a dummy variable to test for the linear, quadratic, and interactions effects for the response variables. Predicted values were obtained and used to generate the surface graphs (KHURI AND CORNELL, 1996).

**Results**

*Experiment I.* Dietary treatment affected all traits studied ($P < 0.05$). The relationships between dietary Ca and nPP concentrations (%) and BWG (g/ bird) and bone ash (%) and between mg Ca and nPP intake per g BW gain and bone ash content could be explained by the significant ($P < 0.05$) quadratic regression models. Quadratic response of nPP but not Ca concentration affected BWG for both strains. Birds fed diets with low concentrations of Ca and low nPP (0.84% Ca and 0.24% nPP) had severely depressed BWG regardless of strain. One main difference between strains was the interaction ($P < 0.05$) of Ca and nPP on BWG in R (Figure 1.a) but not HC strain (Figure 1.b). At low Ca, the response to lower nPP was greater than at higher Ca and at high Ca the response to high nPP was greater than at lower Ca in the R strain and while this effect was similar for the HC strain the effect was not significant.
Based on surface analysis, BWG, the requirements for Ca ranged between 0.83 and 1.15% for R and 0.95 and 1.15% for HC. The requirements for nPP ranged between 0.51 and 0.60% for both R and HC. The maximal average BW of R birds was of 250 g with a FI of 240 g whereas average BW of HC birds were of 258 g and FI was 240 g. Based on ANOVA analysis with Tukey’s separation of means a requirement value was estimated. The estimated requirements were 0.95% Ca for R and HC and 0.57 and 0.55% nPP for R and HC.

Ash data were analyzed based on percent Ca and nPP analyzed in the diet as well as mg Ca and nPP intake per g of BWG and the effects had similar significance. Data on percent toe ash is presented both for percent Ca and nPP (Figures 1.c and 1.d) as well as mg Ca and nPP intake per g BWG (Figure 1.e and 1.f). Only data for toe ash will be presented in the graphs because toe ash was a more sensitive measure than tibia ash at this age. The range and estimated requirement was similar regardless of whether toe or tibia ash was used.

Based on ANOVA, birds fed diets with low Ca and low nPP (0.84% Ca and 0.25% nPP) had lower percent toe and tibia ash. Based on surface analysis, the response to nPP on bone ash for both strains was quadratic while that for Ca was neither linear nor quadratic and was very flat. Similar to what was seen in BWG, there was an interaction (P < 0.05) of Ca and nPP on toe and tibia ash in R strain but not in HC strain. At low Ca, the response to lower nPP was greater than at higher Ca and at high Ca the response to high nPP was greater than at lower Ca in the R strain. Based on toe and tibia ash surface analysis, the requirements for R and HC for Ca ranged between 0.95 and 1.15% and nPP ranged between 0.51 and 0.60% nPP. Requirements for Ca and nPP expressed as mg Ca and nPP intake per g of BWG were the same for both HC and R strains, with the Ca requirements ranged from 11.0 to 13.3 and nPP from 5.9 to 6.9. Based on ANOVA analysis with Tukey’s separation of means toe and tibia ash, the estimated Ca requirements expressed as percent were 1.10 and 1.15 for R and HC strain, respectively and nPP 0.60 for both strains. The estimated Ca and nPP requirements expressed as mg Ca or nPP intake per g BWG for toe and tibia ash were 13.3 and 6.9 for Ca and nPP, respectively in both strains.

**Experiment II.** Based on surface analysis, BWG of R birds was affected by Ca and nPP concentration. As the Exp I, increasing nPP in the diet increased BWG quadratically (P < 0.001) (Figure 2.a). There was no BWG response to Ca (linear; P = 0.416, quadratic; P = 0.076) but there was an interaction of Ca and nPP concentration on BWG (P < 0.001). As in Exp I, the response to low nPP was greater at low Ca while the response to high nPP was greater at high Ca. However, it is important to note that there was a lack of fit of the model (P = 0.035). Based on BWG, Ca requirements for R birds weighing 258 g and with a FI of 258 g from H to 10 d of age, ranged from 0.85 to 1.20% and for nPP requirements ranged from 0.55 to 0.69%. Estimated Ca and nPP requirements were 1.05 and 0.55%, respectively.

Toe and tibia percent ash were affected quadratically by percent Ca and nPP in the diet (Figure 2.b) as well as when FI and BWG were taken into consideration (mg Ca or nPP intake per g BWG, Figure 2.c). Interactions between Ca and nPP expressed as percentage and mg Ca and nPP intake per g of BWG were observed for toe (P < 0.01) and tibia ash (P < 0.001). At low Ca, the response to lower nPP was greater than at higher Ca and at high Ca the response to high nPP was greater than at lower Ca in the R strain. Based on surface analysis, Ca and nPP requirements were the same for both toe and tibia ash and ranged from 1 to 1.20% for Ca and 0.56 to 0.69% for nPP. Requirements for mg Ca intake per g of BWG based on toe and tibia ash ranged from 12.4 to 14.5 and nPP from 7.0 to 8.4, respectively. Based on ANOVA analysis with Tukey’s separation of means, the estimated requirement, based on tibia and toe ash, for Ca was 1.10% and nPP, 0.63% while the estimated requirements expressed as mg Ca or nPP intake per g BWG were 13.6 and 7.8, respectively.
Figure 1. Surface plot of BW gain (g/bird) for Ross 344 M × Ross 708 F birds (a) and Hubbard 99 M × Cobb 500 F birds (b) from H to day 10, toe ash (%) vs. Ca and nPP percent in 10 day-old Hubbard 99 M × Cobb 500 F birds (c) and Ross 344 M × Ross 708 F birds (d) and toe ash (%) vs. Ca intake and nPP intake per BW gain (mg/g) in 10 day-old Hubbard 99 M × Cobb 500 F birds (e) and Ross 344 M × Ross 708 F birds (f) (Exp I).

Figure 2. Surface plot of a) BW gain (g/bird) in Ross 344 M × Ross 708 F birds (H to day 10), b) toe ash (%) in 10 day-old Ross 344 M × Ross 708 F birds vs. Ca and nPP percent and
c) toe ash (%) in 10 day-old Ross 344 M × Ross 708 F birds vs. mg Ca and nPP intake per g of BWG (Exp II)

Conclusions

The requirements for Ca and nPP from H to 250 g of BW (10 days of age) and a FI of 250 g from H to 10 days of age varied depending on strain and trait studied. For HC broilers Ca requirements based on BWG ranged from 0.95 to 1.15% and nPP from 0.51 to 0.60% with requirement estimates of 0.95 and 0.55% for Ca and nPP, respectively. For bone ash the Ca requirements ranged from 0.95 and 1.15% with an estimated requirement of 1.15% and for nPP the range was 0.51 to 0.60% and the estimate was 0.60%. Estimated requirements expressed as mg Ca or nPP intake per g BWG were 13.3 and 6.9, respectively for HC. For R broilers, requirements based on Exp II, that had a greater range of concentrations studied, for BWG were 0.85 to 1.20% with an estimated requirement of 1.05% and for nPP the range was 0.55 to 0.69% with an estimated requirement of 0.55%. For bone ash the Ca requirement ranged from 1.0 to 1.20% and the estimated requirement was 1.10% and for nPP the range was 0.56 to 0.69% with an estimated requirement of 0.63%. Estimated requirements expressed as mg Ca or nPP intake per g BWG were 13.6 and 7.8, respectively for R.

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References