Calcium and phosphorus requirements for maximized growth in modern market poults

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Introduction

Nutrient requirements are expressed in concentrations of the diet. The concentration must be high enough that the bird's need is met; however, the concentration must not be so high that there is more nutrient than the bird can utilize, and is, therefore decreasing the cost effectiveness of the feed. Poultry need phosphorus and calcium in order to build and maintain their skeletons. Phosphorus is also necessary for use in energy utilization and as an important component of cellular parts (NRC, 1994).

When we feed too much of these macro minerals there is an extra cost to add them, but they will simply be excreted. Specifically, phosphorus is the third most expensive feed ingredient, after energy and protein. However, most phosphorus is unavailable to the bird because it is found in the phytate form, resulting in this phytate phosphorus being excreted into the environment (Tahir et al, 2012). This addition of excess phosphorus results in nutrient loading. Under normal conditions, phosphorus concentrations in water are very low. However, human activities have resulted in excessive loading of phosphorus into aquatic environments, including an estimated 4-5 mg/L solely from agriculture-related activity. This introduction of phosphorus into the aquatic environment can spur the growth of algae (Novotony and Olem, 1994 and US EPA, 1999). It has been suggested by some authors (Klopfenstein et al, 2002) that many measures can be taken to reduce phosphorus emissions by livestock including feeding closer to the true requirements of the animal.

The purpose of this study was to determine the correct concentrations of phosphorus and calcium that should be added to turkey starter diets. Little research has examined the proper concentration for maximized growth since 1994 when data were released by the NRC. For poults age 0-4 weeks of age, the accepted calcium requirement is 1.2% and the accepted non-phytate phosphorus (NPP) requirement is 0.6% of the diet (NRC, 1994). However, research in broilers has indicated that that, although the Ca:NPP ratio may be closer to 2.25:1, and the calcium concentration affects the NPP requirement (Latshaw and Pospisil, 2013). If less calcium is present in the diet, then a higher proportion of the phosphorus should dissociate and be available for absorption. This would, in turn, decrease the amount of NPP added to the diet to reach the turkey's requirement (Latshaw and Pospisil, 2013).

Methods

In order to determine the actual calcium and phosphorus concentrations needed for maximized growth in turkey poults, two separate experiments were run. In experiment 1 the 1994 NRC guidelines were used for all categories other than the phosphorus and calcium requirements (see table 1). In this experiment, all poults were fed a diet containing 1.2% calcium. There were four different NPP concentrations based around 0.52%, which corresponds to the 2.25:1 ratio of Ca:NPP. Each group of poults was fed one of the following concentrations: 0.61%, 0.55%, 0.49%, 0.43%, and 0.37%. Atomic absorption methods will be used in order to establish actual concentrations of calcium and phosphorus in the feed.

Female turkey poults were used for this experiment. They were randomly distributed into battery pens, five per pen, and four pens per treatment. Standard management practices were approved by the institutional animal care committee. Poults were fed and watered *ab libitum.*

Growth data were taken at three weeks and feed consumption was established. One bird that represented the average size for the pen was chosen for bone measurement. Poults were then killed by cervical dislocation. The right tibia of each poult was removed, dried and extracted by ether to remove lipids, and ashed in order to determine mineral content.

Statistical analyses were performed with the pen as the experimental unit, providing 16 experimental observations—for weight and feed consumption. Values of one poult were used as a representation for the entire pen. Dried tibia weight, percentage ash in the tibia, and ash relative to body weight. Significant treatment differences were determined by using the General Linear Model of SAS (1996). Least-square means were found and then compared for differences among treatments.

In experiment two, the above procedure was repeated, with the exception that the feed concentrations were changed. The calcium concentration was decreased to 1.0%, and the NPP values dropped to 0.56%, 0.50%, 0.44%, 0.38%, and 0.32%. This was done to test if the turkeys will grow satisfactorily with this calcium concentration and if the NPP requirement was decreased proportionately.

Results

For the first experiment, the poults were fed 1.2% Ca with of the following NPP concentrations: 0.61%, 0.55%, 0.49%, 0.43%, or 0.37%. Body weight, feed intake, weight of tibia, and ash/body weight (mg/100g) all increased with increasing amounts of NPP, but the rate of increase slowed between 0.49% and 0.55%NPP (Table 2). Turkeys fed the 0.55%NPP diet yielded the highest percentage of ash in the tibia, with the 0.61% diet yielding the second highest. Upon statistical analysis of these data, it was concluded that in all of the measured categories, there was no significant difference between the 0.55% and 0.61%NPP diets, suggesting an optimal NPP concentration between 0.49% and 0.55%NPP. Table 2 contains the entire set of results from this experiment.

In experiment two, the poults were fed 1.0% Ca and one of the following NPP concetrations: 0.56%, 0.50%, 0.44%, 0.38%, and 0.32%. All measured categories increased with increased NPP concentrations until between 0.38% and 0.44% (Table 3). Upon statistical analysis of these data, it was concluded that in all the measured categories except percentage of ash in tibia, there was no significant difference between 0.44% and the higher concentrations. With the percentage of ash in tibia, 0.44% was significantly different from 0.38%, and 0.50% and 0.56% were not significantly different from each other, but the overall trend of very little growth difference above 0.38% was still evident. The data suggest an optimal NPP concentration between 0.38% and 0.44%. When comparing data from the two experiments, it was noted that the poults in experiment two grew faster than those in experiment one. It was also noted that bone ash was decreased in experiment two as compared to experiment one.

Discussion

As stated in the introduction, having excess NPP and calcium in feed poses a host of problems including nutrient loading in the environment and increasing feed costs (Novotony and Olem, 1994; US

EPA, 1999; Tahir et al, 2012). Previous research in broilers has suggested that the NRC guidelines of feeding a Ca:NPP ratio of 2.25:1 is optimal (Latshaw and Pospisil, 2013). Our data suggest that this is probably not the case for turkeys.

The data collected above indicate that when turkeys are fed a diet containing 1.2% Ca, the optimal NPP concentration is somewhere between 0.49% and 0.55%, resulting in a Ca:NPP ratio of roughly 2.0, coinciding with the NRC guidelines. However, the results from the 1.0% Ca-fed turkeys indicate that the optimal NPP concentration is somewhere between 0.38% and 0.44%. With this being the case, the Ca:NPP ratio is closer to 2.25 in this situation. In addition, the poults grew faster when fed a 1.0% Ca diet than those fed a 1.2% Ca diet, and although they also had decreased ash, did not appear to suffer from any deficiency symptoms above 0.38% NPP. Statistical analyses have not been completed to determine if these differences are significant, but they are expected to be. If a 1.0% Ca diet with a Ca:NPP ratio of 2.25:1 is in fact optimum, then feed prices could be significantly reduced, as well as emissions from manure runoff, by reducing the amount of Ca and NPP that must be added to the feed.

One possible explanation for the lower NPP being sufficient to reach the poult's requirement when 1.0% Ca was fed is the dissociation of mineral containing compounds in the digesting system being reducing by the common ion effect. Using dicalcium phosphate as an example, upon ingestion the following dissolution occurs:

$$CaHPO_4 \dashrightarrow Ca^{2+} + HPO_4^{2-}$$

The K_{sp} of this reaction is $1x10^{-7}$, resulting in approximately 0.2g of dicalcium phosphate dissolved in 1L of water (Brown, et al 2009). When in a more acidic environment, such as the proventriculus of the bird, the dissolution is increased many times. However, the common-ion effect would cause the dissolution of dicalcium phosphate to decrease. The common ion in this case is the Ca^{2+} supplied by the dissolution of limestone in the diet. This idea, proposed by Latshaw and Pospisil (2013) in a broiler study, was used to explain observed phenomena in previous studies, including decreased precaecal absorption of NPP when a high Ca:NPP ratio was in place (Applegate et al., 2003; and Tamim et al., 2004). It seems reasonable to extrapolate this principle to turkeys, as the digestive tracts of turkeys and broilers are very similar. Essentially, due to the common-ion effect, less NPP is produced via dissolution of phosphorus-containing compounds, because of too much Ca^{2+} ion already being present in the solution.

Further work can be performed to narrow the ranges needed for optimum poult growth. The work performed here indicates that turkeys grow faster with 1.0% Ca concentrations, as long as fed in approximately a 2.25 Ca:NPP ratio. Further studies are planned to test if a 0.8% Ca diet with this same ratio can also lead to comparable growth curves. Further studies are also planned to narrow the range from between 0.38% and 0.44% NPP to a more definite concentration when 1.0% Ca is fed.

Literature Cited

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Table 1. Composition (%) of the diets.

	1.20% calcium		1.00% calcium	
Ingredient	**0.37 NPP**	**0.61 NPP**	**0.32 NPP**	**0.56 NPP**
Corn	47.94	47.40	48.42	47.84
Soybean meal (47.5 CP)	37.40	37.40	37.40	37.40
Corn gluten meal (60% CP)	7.00	7.00	7.00	7.00
Vegetable oil	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.30	2.59	1.08	2.46
Limestone	2.09	1.34	1.83	1.03
Salt	0.40	0.40	0.40	0.40
Vitamin and trace mineral mix	0.20	0.20	0.20	0.20
Methionine	0.17	0.17	0.17	0.17
Lysine (50%)	0.28	0.28	0.28	0.28
Lysine.HCl	0.19	0.19	0.19	0.19
Threonine	0.03	0.03	0.03	0.03
Calculated nutrients				
Protein (%)	26.00	26.00	26.00	26.00
Methionine (%)	1.05	1.05	1.05	1.05

Lysine (%)	1.60	1.60	1.60	1.60
Threonine (%)	1.00	1.00	1.00	1.00
Calcium (%)	1.20	1.20	1.00	1.00
NPP (%)	0.37	0.61	0.32	0.55

Table 2. Responses to graded levels of NPP when turkeys were fed 1.20% calcium.

NPP %	**Body Wt kg**	**Feed kg**	**Wt of tibia g**	**Ash in tibia %**	**Ash/ BW mg/100 g**
0.37	0.481[a]	0.544[a]	1.644[a]	30.9[a]	105.4[a]
0.43	0.510[b]	0.594[b]	1.804[ab]	32.7[a]	115.9[ab]
0.49	0.528[bc]	0.624[bc]	1.857[abc]	35.8[b]	125.7[b]
0.55	0.540[cd]	0.622[bc]	1.977[c]	38.8[c]	141.8[c]
0.61	0.560[d]	0.650[c]	2.079[c]	38.6[c]	143.1[c]
P	<0.01	<0.01	<0.01	<0.01	<0.01
SEM	0.007	0.010	0.008	0.8	3.7

Table 3. Responses to graded levels of NPP when turkeys were fed 1.00% calcium

NPP %	Body wt kg	Feed kg	Wt of tibia g	Ash in tibia %	Ash/ BW mg/100 g
0.32	0.549[a]	0.658[ab]	1.916[a]	28.1[a]	98.1[a]
0.38	0.553[a]	0.626[a]	2.007[a]	30.7[b]	111.3[a]
0.44	0.604[b]	0.701[b]	2.441[b]	32.8[c]	132.4[b]
0.50	0.612[b]	0.685[ab]	2.376[b]	35.9[d]	139.5[b]
0.56	0.604[b]	0.700[b]	2.356[b]	36.6[d]	142.3[b]
P	<0.01	<0.01	<0.01	<0.01	<0.01
SEM	0.008	0.010	0.060	0.8	4.3

Stat procedure used PROC GLM for fixed effect of NPP.

Stat procedure used PROC MIXED for the default output of LSMEANS DIFF to separate means.