How Alternative Feed Ingredients Affect Poultry Dietary Electrolyte Balance

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Executive Summary

Dried distillers grains with solubles (DDGS, 26-28% crude protein derived primarily from corn in the Midwest, are a byproduct of the ethanol industry that can be used as a source of protein in poultry diets. Turkey producers are concerned that the use of DDGS will result in wet litter (bedding) conditions in the barn and/or change bird performance. Less-dry litter can impact bird performance and welfare. While the potential causes for wet litter are numerous, one possibility is that electrolyte levels or balance in the diet is less than optimal relative to contents of sodium (Na), potassium (K), and chloride (Cl). When assessing dietary electrolyte balance (DEB), sulfur (S) is usually ignored but may need to be considered when alternative feed ingredients are used to replace corn and soybean meal. Use of other feed ingredients or supplements in combination with DDGS may also change or shift the DEB. Two turkey feeding studies were proposed to determine the market turkey response to diets containing DDGS or in combination with canola meal relative to varying levels of dietary chloride.

The goal of the completed research was to develop recommendations based on turkey feeding trials that can be used by poultry nutritionists to improve utilization of DDGS in market turkey diets as it pertains to diet electrolyte balance. The specific objectives of the two research studies were to: 1) Identify a range of dietary electrolyte balance (DEB) values for diets containing distillers dried grains with solubles (DDGS) and canola meal that would not affect market tom turkey performance under practical formulation and typical rearing conditions; 2) Determine if the addition of phytase modifies the DEB in a diet with a high level of alternative feed ingredient inclusion; and, c) Develop, based on information from Objectives 1 and 2, a modified DEB calculation (mDEB) utilizing other electrolyte contributions such as sulfur for use with alternative ingredients. The objectives were not met in their entirety relative to being able to determine and provide some specific dietary electrolyte balance recommendations. However, performance responses relative to diet type and diet chloride were determined and some preliminary recommendations about diet chloride and DEB levels in market turkey tom grow-finish diets were identified.

The overall conclusion reached after completion of the two research projects was that there should be careful consideration in using high levels of both canola meal and DDGS in market turkey diets and that both diet chloride level and electrolyte balance should be considered in order to minimize any potential negative performance effects and wet litter condition in the turkey barn. Levels of chloride in excess of .2 to .3% should be minimized.

Partners

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Introduction

Dried distillers grains with solubles (DDGS, 26-28% CP), derived primarily from corn in the Midwest, are a byproduct of the ethanol industry that can be used as a source of protein in poultry diets. Despite previous research that has indicated that high levels (>10%) of DDGS can be incorporated into poultry diets, in practice DDGS use is usually limited to a lower level. Comments (paraphrased) from industry nutritionists, regarding concerns with the use of DDGS, are usually that of variability in nutrient content and poor amino acid digestibility. In addition, the nutritionists are on occasion told by farm managers and producers that they notice a difference in litter condition when DDGS is fed resulting in wetter conditions which can impact bird performance and welfare. While the potential causes for wet litter are numerous, one possibility is that electrolyte levels or balance in the diet is less than optimal relative to contents of sodium (Na), potassium (K), and chloride (Cl). When assessing dietary electrolyte balance (DEB), sulfur (S) is usually ignored but may need to be considered when alternative feed ingredients are used to replace corn and soybean meal.

The inclusion of alternative feed ingredients such as DDGS in poultry diets can contribute substantial amounts of several minerals – phosphorus, potassium, sodium, chloride and sulfur. Recent analyses of a conventional DDGS sample found Na, Cl, K, and S contents of .27, .2, 1.2, and .9%, respectively, all greater than results found in an earlier survey of DDGS samples. In addition, as the amino acid lysine is limiting in DDGS, lysine supplementation is increased in DDGS diets which also contributes more chloride or sulfur depending on the type of lysine supplement used. And, as DDGS replaces some SBM, potassium levels will be reduced. Other ingredients such as canola meal or bakery by-product may also add electrolytes/minerals to the diet.

Other feed additives may also influence DEB. Phytase is a commonly used enzyme supplement which improves phosphorus utilization in poultry diets. The form of phosphorus as phytate phosphorus or level of phosphorus relative to the requirement can also impact the effective DEB. Ravidran et al. (2008) indicated that phytic acid increased excretion of Na, while supplementation with phytase appeared to increase sodium absorption and/or decrease sodium loss from the gut. Supplementation with phytase resulted in improved amino acid digestibility with lowered DEB. The use of alternative feed ingredients or incorporation of phytase may indicate the need to expand the consideration of DEB to include other elements such as sulfur, calcium and phosphorus and compounds that exert an effect on electrolytes such as phytase.

The goal of the completed research was to develop recommendations based on turkey feeding trials that can be used by poultry nutritionists to improve utilization of DDGS in market turkey diets as it pertains to diet electrolyte balance.

The specific objectives of the two research studies were to:

1. Identify a range of dietary electrolyte balance (DEB) values for diets containing distillers dried grains with solubles (DDGS) and canola meal that would not negatively affect market tom turkey performance under practical formulation and typical rearing conditions
2. Determine if the addition of phytase modifies the DEB in a diet with a high level of alternative feed ingredient inclusion.
3. Develop, based on information from Objectives 1 and 2, a modified DEB calculation (mDEB) utilizing other electrolyte contributions such as sulfur for use with alternative ingredients.

The objectives were not met in their entirety relative to being able to determine and provide some specific dietary electrolyte balance recommendations. This occurred for several reasons. One reason is because the turkey performance response to chloride level per se was more important than the actual dietary electrolyte balance level. The other reason was that each diet series responded differently to the varying chloride levels, and that age period also altered the response. The study was designed to reflect possible scenarios that might occur under commercial conditions, which meant dietary electrolyte balance levels shifted with each feeding period. Although there were limitations to the study in terms of meeting the final objectives, the research that was conducted did result in recommendations of chloride and dietary electrolyte balance levels that should be avoided.

Description of Work Performed - Experiment 1

The objective of the first study was to identify a range of dietary electrolyte balance (DEB) values for diets containing distillers dried grains with solubles (DDGS) and canola meal that would not negatively affect market tom turkey performance under practical formulation and typical rearing conditions.

To determine a range of acceptable DEB values, three different base diets were formulated with three different levels of chloride to form nine diet treatments. The diet formulations were meant to represent DEB ranges under typical feeding conditions. The use of DDGS and canola meal were expected to decrease the DEB levels; likewise increasing the diet chloride content will decrease the diet DEB.

The three diet types were:

1. Control - Corn soybean meal with meat bone meal (CS)
2. As #1 with the addition of 20% DDGS (CS/DDGS)
3. As #2 with the addition of 10% canola meal (CS/DDGS/CM)

The three diet chloride levels were:

1. 0.22%
2. 0.32%
3. 0.42%

Sodium level was kept constant in all diets. Chloride levels were adjusted with salt, sodium bicarbonate and/or ammonium chloride. All diets contained a coccidiostat and growth promotant. Diets were formulated to be isocaloric and to contain similar levels of digestible lysine, sulfur amino acids, and threonine. Example formulations for early and later feeding periods are given in Table 1. Experimental diets were started at 2 wks of age and fed to 14 wks of age. Diets are adjusted for each 3 wk age period so that there were four feeding (age) periods.

Male Nicholas turkey poults were brooded in 50 pens (24/pen) and then randomized by weight at 2 wks of age into 99 pens (10 turkeys/pen) to assure equivalent starting weights. All of the poults were fed the same pre-experimental diet to 2 weeks of age prior to the start of the trial. Turkey body weight and feed consumption were measured at 2, 5, 8, 11, and 14 wks of age. From the above measurements, the following were obtained as pen averages: body weight at the different ages; rate of gain for each time period; feed intake per bird for each time period; feed conversion (ratio of feed per unit of gain). Other measures included sampling of the litter for determination of litter moisture at 11 and 14 wks of age.

Analyses of the feed ingredients (corn, soybean meal, poultry byproduct meal, canola meal and DDGS) and diets were made to confirm electrolyte levels. The DDGS utilized was a conventional product with 27% protein and 10% crude fat.

The experimental design was a randomized block design with a factorial arrangement of study factors (type of diet and chloride level) resulting in a total of nine treatments. Each treatment had 11 replicate pens with 10 turkeys per pen. Analyses of variance was conducted to determine the probability of

main effects and diet/chloride interaction, if any, on weight gain, feed intake, feed conversion, and litter moisture.

Diet series had no effect on body weight at 14 wks of age (Table 2). Feed intake and feed efficiency were affected by diet series during 2-14 wks with feed intake of birds fed the corn-soy diet less than the diets containing alternative feed ingredients. Because of the greater feed intake with the DDGS and canola meal diets, feed efficiency was also poorer. While chloride level overall did not affect bird performance, chloride level interacted with diet series during 8 to 14 wks of age, such that feeding the higher levels of chloride (.32 and .42%) in the diet containing both DDGS and canola meal had poorer feed conversion as compared to the diet containing .22% (Figure 1). Litter moisture was increased when DDGS with or without canola was present in the diet (Table 2). Likewise, increasing levels of chloride increased litter moisture content across all diets (Figure 2).

DEB levels for the diets are shown graphically in Figures 3a and 3b. The calculated DEB levels varied with diet series and age period. DEB level decreased with the addition of DDGS and with canola meal. However, there did not appear to be a strong relationship of DEB level with feed conversion and no relationship with body weight. Each diet series had its unique response to the varied chloride levels that could not be explained by DEB value alone.

The results of the trial indicated that higher levels of chloride resulted in increased litter moisture regardless of diet series type and that higher chloride had an effect on grow/finish feed conversion when in excess of .22% of the diet.

Description of Work Performed - Experiment 2

To examine if phytase supplementation exerts an effect on DEB, a factorial design was used with factors of phytase supplement and chloride level. Phytase was either supplemented or not with a commercial enzyme product to provide 500 units/kg. Chloride level was set at four levels .2, .3, .4, and .5 %. The DDGS/canola meal diet was used as the base diet. A control corn-soy diet containing .3% Cl was also included in the study. Supplements of salt, ammonium chloride and sodium bicarbonate were used to achieve the desired chloride and sodium levels in the diet. Diets were formulated to be isocaloric and to contain similar levels of digestible amino acids.

Male Nicholas turkey poults were brooded in 50 pens and then randomized by weight at 2 wks of age into 99 pens (10 turkeys/pen) to assure equivalent starting weights. All of the poults were fed the same pre-experimental diet to 2 weeks of age prior to the start of the trial. Turkey body weight and feed consumption were measured at 2, 5, 8, 11, 14 and 17 wks of age. From the above measurements, the following were obtained as pen averages: body weight at the different ages; rate of gain for each time period; feed intake per bird for each time period; feed conversion (ratio of feed per unit of gain). Other measures included sampling of the litter for determination of litter moisture for each age period, foot pad score and gait score.

The experimental design is a randomized block design with a factorial arrangement of study factors (phytase and chloride level) resulting in a total of 8 treatments. Each treatment had 11 replicate pens with 10 turkey toms per pen. Analyses of variance was conducted to determine main effects and

phytase/chloride interactions on gain, feed intake, feed conversion, litter moisture, foot pad and gait scores.

Chloride level affected bird performance in a number of ways. The highest level of chloride reduced body weight of turkeys starting at 8 wks of age. Reduced weight continued to be observed through 17 wks of age (Table 3). A significant linear trend was observed such that body weight tended to decrease as chloride level increased as a result of decreased feed intake. Foot pad scores and litter moisture increased with increasing chloride level.

Phytase had no effect on body weight, and, on an overall basis, feed conversion with phytase was similar to the diet series without phytase. Feed intake and feed conversion response to phytase was modified depending on chloride level, which also varied with age period. During the grow finish period (8-17 wks of age), feed conversion tended to be similar among turkeys fed the diets without phytase regardless of dietary chloride level. In diets with phytase, a curvilinear response was observed with feed conversion minimized at .3% chloride (Figure 4).

A relationship of bird performance to dietary electrolyte balance was not established due to a lack of a strong response to varying levels of dietary chloride and differing response within feeding period. DEB levels associated with decreased body weight with the higher chloride level were 188, 172, and 143 meq/kg of diet during 8-11, 11-14 and 14-17 wks of age.

Overall Results

High levels of alternative feed ingredients were used as a model under a worst case scenario to examine the influence of changing the dietary electrolyte balance in the diet through the use of DDGS and canola meal and by varying the dietary chloride level. Inclusion of DDGS (20%) in market turkey tom diets resulted in similar body weight to turkeys fed corn-soy control diets to 14 wks of age. With the addition of canola meal at 10% in combination with DDGS, gains were either equivalent or less after 8 wks of age in comparison to a corn-soy control diet (Experiment 1 vs. Experiment 2).

Feed conversion in Experiment 1 was poorer in diets containing DDGS or in combination with canola meal because of greater feed intake and not decreased growth, suggesting the metabolizable energy content of the DDGS was overestimated. The poorer feed conversion in Experiment 2 in the DDGS/canola meal diets in comparison to the corn soy control was due to poorer gain and feed intake after 8 wks of age when chloride level increased above 0.2% chloride.

Chloride level had different effects on market turkey performance depending on experiment. Feed efficiency for each diet type in Experiment 1 was influenced by chloride level where increasing chloride level negatively impacted feed conversion in the combination diet of DDGS/canola meal when chloride level was in excess of .22%. In Experiment 2, where the chloride response to the combination diet was explored further, the highest chloride level of .5% was growth depressing primarily through a reduction in turkey feed intake. A significant linear trend was observed for decreased body weight as chloride level increased from .2 to .5% of the diet. In contrast to the results in Experiment 1, feed conversion was only impacted by chloride level during the 14-17 wk feeding period and the response was modified by the presence or absence of phytase.

For Experiment 1, all dietary electrolyte balance levels were acceptable with the corn-soy diet series. For the DDGS diet series, since no negative performance effect attributable to chloride was observed, it is assumed that the decrease in dietary electrolyte balance associated with DDGS inclusion in the diet also resulted in acceptable DEB levels. However, these values overlap somewhat with the DEB levels associated with negative effects on feed conversion of turkeys fed the higher chloride levels in the combination diet (DDGS/canola meal) in Experiment 1. DEB levels associated with poorer feed conversion in the combination diet were 253 and 223 meg/kg of diet for the respective age periods of 8-11 and 11-14 wks of age. In Experiment 2 with the combination diet (DDGS/canola meal), dietary electrolyte balance levels that resulted in the poorest growth were 215, 219, 189, 172, and 143 meq/kg of diet for the respective age periods of 2-5, 5-8, 8-11, 11-14, and 14-17 wks of age.

Conclusions

Inclusion of DDGS (20%) in market turkey tom diets, while resulting in similar body weight to turkeys fed corn-soy control diets to 14 wks of age, had poorer feed efficiency indicating that assignment of the appropriate metabolizable energy value to DDGS is needed in order to achieve optimal feed efficiency.

In corn-soy diets and diets with 20% DDGS, chloride levels of .42% were without effect on market tom turkey performance.

Under conditions of increasing chloride level, inclusion of both canola meal (10%) and DDGS (20%) resulted in either poorer feed conversion and/or growth. Chloride levels in excess of .22% of the diet should be avoided.

Litter moisture increased as chloride level increased above .3% of the diet.

Supplementation of the diet with phytase (500 ftu/kg) allowed reductions in expensive ingredients of dicalcium phosphate and supplemental fat and provided similar performance to that of non- phytase supplemented diets.

Increasing diet chloride content in combination with phytase produced a curvilinear response in feed efficiency, where minimum feed efficiency was obtained at .3% chloride.

Extrapolating from the research diets, minimum dietary electrolyte balance in market turkey tom diets with high levels of alternative feed ingredients, in this case canola meal and DDGS, changed with bird age. Minimum dietary electrolyte balance based on observed growth should not be less than 217, 200, and 171 meg/kg of diet during 8-11, 11-14 and 14-17 wks of age when using both DDGS and canola meal.

The overall conclusion reached was that there should be careful consideration in the level of use of both canola meal and DDGS in market turkey diets and that both diet chloride level and electrolyte balance should be considered in order to minimize any potential negative performance effects and wet litter condition in the turkey barn.

Future research needs

The research results limited the extent that the stated objectives could be met for reasons stated earlier in the introduction section. While the results differed between the two studies, results of both studies indicated that excessive chloride can have a negative effect on bird performance in the combination diet of DDGS and canola meal. But there were also several dissimilarities. For Experiments 1 and 2, there were different conclusions relative to identifying levels of DEB that resulted in negative performance. Supplementation with phytase appeared to shift the response to electrolyte balance in one feeding period and potentially for body weight gain as well. At a minimum, confirming the phytase response relative to DEB would be one area to follow-up. Likewise some further manipulation of the electrolyte content of the diet at different ages in order to confirm acceptable DEB levels for the various age periods of the turkey.

Table 1. Composition of diets containing .22% chloride for Experiment 1.

	2-5 wks			11-14 wks		
Ingredients	***Trt 1**	**Trt 4**	**Trt 7**	**Trt 1**	**Trt 4**	**Trt 7**
Corn	44.26	31.91	26.13	57.66	47.31	41.20
Soybean meal 47% CP	45.17	36.83	31.07	30.88	20.47	15.01
Distillers Dried Grain with solubles	0	20.0	20.0	0	20.0	20.0
Poultry ByProduct Meal	5.0	5.0	5.0	5.0	5.0	5.0
Canola Meal	0	0	10	0	0	10.0
Dicalcium phosphate	1.97	1.68	1.61	1.13	0.86	0.79
Calcium carbonate	1.18	1.39	1.30	0.82	1.05	0.96
Salt	0.148	0.060	0.070	0.179	0.085	0.099
Scarb	0.226	0.270	0.260	0.177	0.267	0.260
L-Lysine · HCL	0.160	0.320	0.330	0.083	0.268	0.267
DL-Methionine	0.222	0.170	0.130	0.137	0.118	0.070
Threonine	0.050	0.050	0.030	0.028	0.038	0.016
Vit/min mix	0.41	0.41	0.41	0.275	0.275	0.275
Animal Fat	1.12	1.82	3.57	3.57	4.20	6.00
Total	100.0	100.0	100.0	100.00	100.00	100.00

*Trt1: corn soy diet with 0.22% Cl; Trt 4: corn soy DDGS diet with 0.22% Cl; Trt 7: corn soy DDGS canola meal diet with 0.22% Cl

Table 2. Response of market toms to 14 wks of age fed different diet types (corn-soy-poultry byproduct meal (CSM), CSM+20% DDGS, or CSM+20% DDGS+10% canola meal) during 2 to 14 wks of age. Diet response averaged over chloride level. (Experiment 1).

Diet Type	BW (lbs), 14 wks of age	Feed/gain 2-14 wks of age	Litter moisture (%), Average
CSM	28.6	2.16[b]	38.60[b]
CSM+20% DDGS	28.8	2.21[a]	41.09[a]
CSM+ 20% DDGS + 10% canola	28.9	2.23[a]	41.68[a]

Table 3. Response of market toms at 17 wks of age fed different chloride levels in a diet containing 20% DDGS and 10% canola meal) during 2 to 17 wks of age. Diet response averaged over main effect of phytase.(Experiment 2).

Diet Chloride Level (%)	BW (lbs), 17 wks of age	Foot pad Scores	Litter moisture (%),
.2	38.3[a]	2.53[ab]	44.50[bc]
.3	37.9[ab]	2.44[b]	41.70[c]
.4	38.2[a]	2.73[a]	47.17[bc]
.5	37.6[b]	2.68[a]	51.16[a]

Chloride *(P<.05)*

Figure 1. Feed efficiency (8-14 wks of age) response of market tom turkeys to chloride level (% of diet) in diets containing 20% DDGS and 10% canola meal (Experiment 1). Interaction of chloride level and diet series (P<.0017).

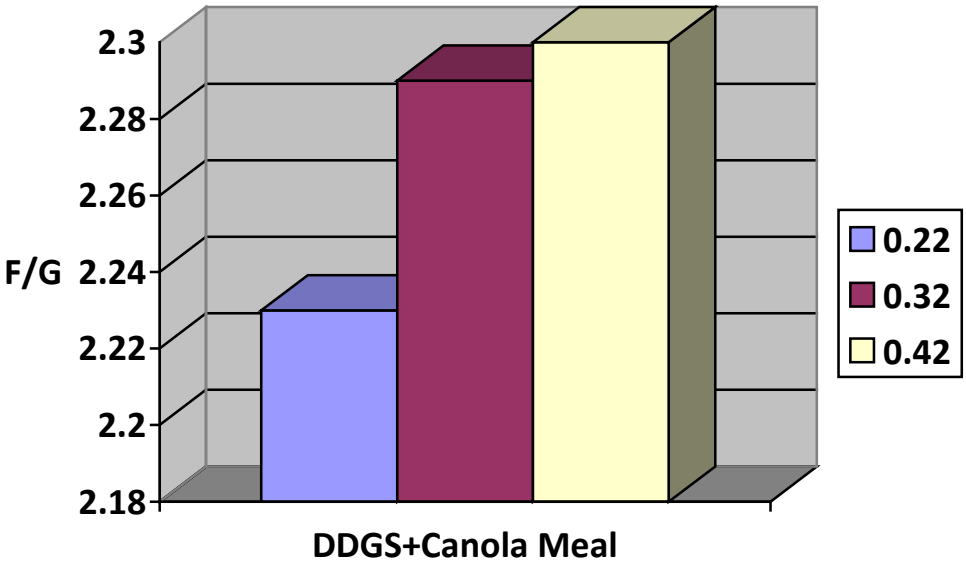

Figure 2. Litter moisture (average of samples taken at 11 and 14 wks of age) in response to diet chloride levels (P<.055). Values are averaged overall diet types. (Experiment 1)

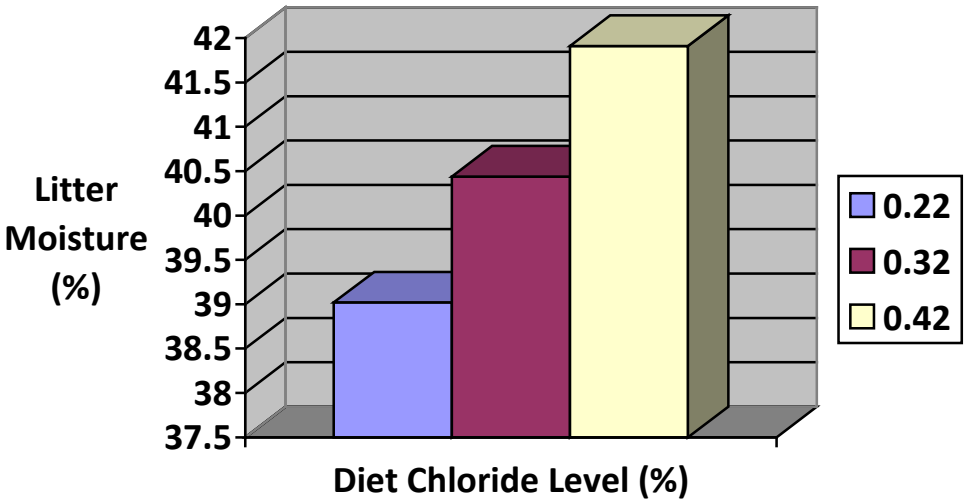

Figure 3a. Dietary electrolyte balance (DEB) of the different diet types (corn-soy-poultry byproduct meal (CSM), CSM+20% DDGS, or CSM+20% DDGS+10% canola meal) for 2-5 wks of age (Experiment 1).

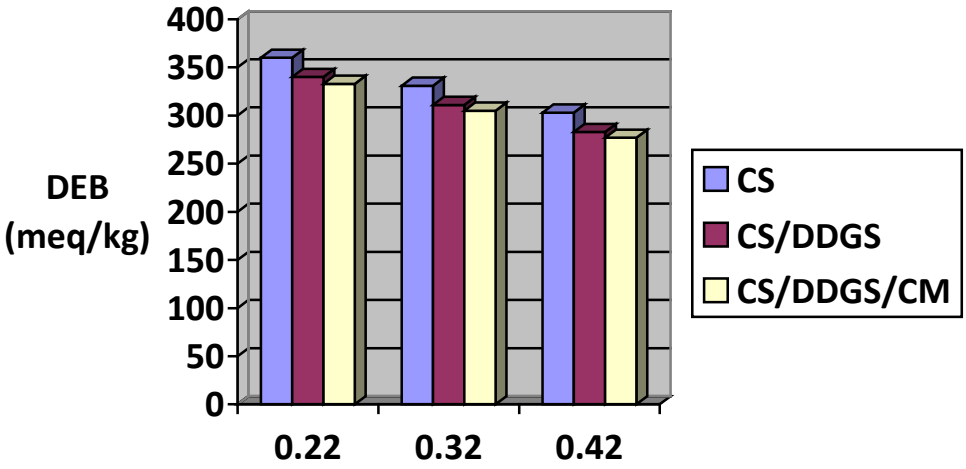

Figure 3b. Dietary electrolyte balance (DEB) of the different diet types (corn-soy-poultry byproduct meal (CSM), CSM+20% DDGS, or CSM+20% DDGS+10% canola meal) for 11-14 wks of age (Experiment 1).

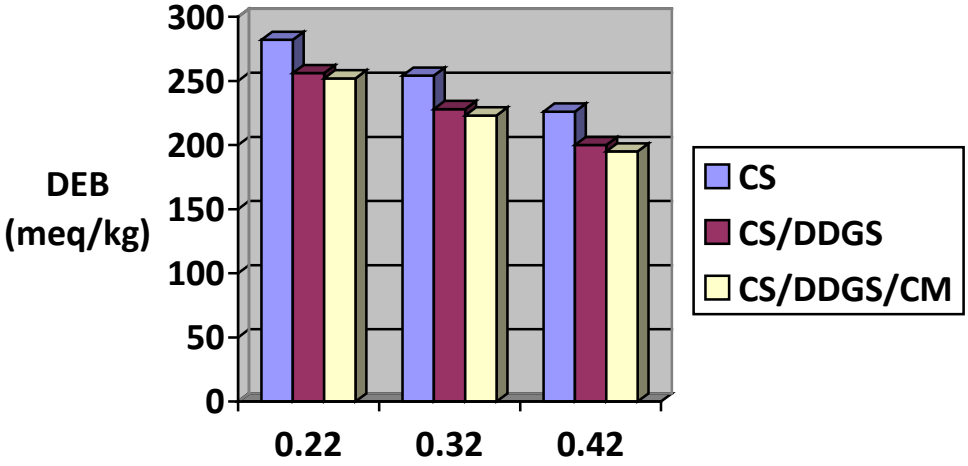
DEB
(meq/kg)
300
250
200
150
100
50
0
0.22
0.32
0.42
CS
CS/DDGS
CS/DDGS/CM

Figure 4. Feed efficiency (8-17 wks of age) response of market tom turkeys to chloride level (% of diet) in diets containing 20% DDGS and 10% canola meal with and without phytase supplementation (Experiment 2). Interaction of chloride level and phytase (P<.10).