EFFECTS OF DIETARY PROTEIN, SOURCES AND LEVELS OF ELECTROLYTES ON THE PERFORMANCE OF CHICKS

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SUMMARY

A series of chicken growth assays were conducted to investigate the interactive effects of levels of dietary of protein and electrolyte on chicks performance. Corn-soy diets were fed in all assays, with $NaHCO_3$, $KHCO_3$, $CaCl_2$ or NaCl supplementation to modify the dietary electrolyte balance. The results of this study showed that there was no protein by electrolyte interaction effect on chicks performance. The role of Na^+ K^- Cl levels was influenced by the electrolyte sources added to the diets. The dietary cation excess between 50 and 440 milliequivalent per kilogram, did not affect the chicks performance when a combination of $NaHCO_3$ and $KHCO_3$ was supplemented in the diet. However, when either one was used as the major source of electrolyte, there was an effect. A diet with higher cation excess was needed when using $KHCO_3$ than using $NaHCO_3$, to promote better gain and gain to feed (feed conversion) ratio. Increasing cation excess resulted in the decreased feed efficiency of high protein diet.

Key words : Chicken Growth, Electrolyte, Dietary Protein.

PENGARUH PROTEIN, SUMBER DAN LEVEL ELEKTROLIT RANSUM TERHADAP PERFORMANS ANAK AYAM

RINGKASAN

Suatu seri percobaan telah diadakan untuk menyelidiki pengaruh interaktif kadar protein dan elektrolit di dalam ransum terhadap pertumbuhan dan konversi ransum anak ayam. Ransum yang berbasis jagung-kedelai digunakan dalam percobaan ini, dengan suplementasi $NaHCO_3$, $KHCO_3$, $CaCl_2$, atau NaCl untuk mengubah kadar elektrolit dalam ransum tersebut. Hasil penelitian ini menunjukkan bahwa tidak ditemukan pengaruh interaksi antara kadar protein dan elektrolit terhadap performans anak ayam. Peran kadar Na^+ K^- Cl dipengaruhi oleh sumber elektrolit yang disuplementasikan ke dalam ransum itu. Lebihan kation di dalam ransum yang besarnya antara 50 sampai 440 miliekivalen tiap kg, tidak mempengaruhi performans anak ayam, apabila kombinasi antara $NaHCO_3$ dan $KHCO_3$ disuplementasikan ke dalam ransum. Namun, apabila hanya salah satu saja yang digunakan sebagai sumber utama elektrolit, pengaruh tersebut nampak. Untuk mendorong pertumbuhan dan konversi yang lebih baik, diperlukan ransum yang mengandung banyak lebihan kation asal $KHCO_3$ dan bukannya dari $NaHCO_3$.

Kata kunci: Pertumbuhan anak ayam, Elektrolit, Kadar protein.

INTRODUCTION

Dietary electrolyte imbalance can have important effects upon animals' performance, primarily through its relation to the disturbances in acid-base balance produced by feeding excess chloride relative to the cations sodium and potassium (Leach, 1979).

Mongin (1970) stressed that adjusting mineral content of the diet is important not only to meet the body requirements, but also to maintain an electrolyte balance conducive to optimal performance. Therefore, Mongin (1981) suggested to keep $Na^{+}\ K^{-}\ Cl$ as close as possible to 250 milliequivalent per kg diet and the value of $\frac{K+Cl}{Na}$ is always greater than one, in order to achieve maximum performance of chicks.

Cervantes *et al*. (1982) and Jensen (1982) furthermore, found that an impaired dietary electrolyte balance, namely the decreased $Na^{+}\ K^{-}\ Cl$ value, resulted in an increased anorexia observed in chicks. In their experiment, they supplemented 0.53 percent K_2CO_3 to the diets to increase the $Na^{+}\ K^{-}\ Cl$ from 172 to 249 milliequivalent (meq) per kg.

An earlier report (Melliere and Forbes, 1966) showed that weight gain and feed consumption of chicks were maximized when the cation-anion ratio was in the range of 1.2 to 1.8. The response of the chicks to diets with ratios bigger than 1.8 was dependent upon the cation added. A combination of Na and K was not detrimental but either cation alone, reduced weight gain.

Therefore, it was the purpose of this study to ascertain the effects of different dietary electrolyte sources and levels, expresses in meq of $Na^{+}\ K^{-}\ Cl$, and their interaction with dietary protein level, on the performance of chicks.

MATERIALS AND METHODS

A series of experiments was conducted to evaluate the effects of dietary sodium plus potassium minus chloride level ($Na^+ K^- Cl$) on the performance of chicks. One-week old New Hampshire x Columbian crossed chicks from the University of Illinois poultry farm were housed under continuous lighted, and heated, thermostatically-controlled, starter batteries with raised wire floors, for a two-week experimental period.

A corn-soybean meal starter diet was fed during the first seven days posthatching and during the experimental period. Following an overnight fast, experimental groups of five male chicks were selected to have similar mean initial weights and weight distributions.

In trials 1, two levels of protein in the diet were used, namely, 17 and 24 percent (Table 1), while in trials 2 and 3, only 24 percent protein diets were fed (Tables 3 and 4).

The data, consisting of body weight gain and feed intake were analyzed by the SAS GLM Statistical Package (SAS, 1982) on the Cyber System, University of Illinois. Treatment means were compared by least significant difference method.

Trial 1.

A 2 x 2 x 4 factorial experiment consisting of 2 protein levels (17.45 and 24.42 percent), 2 levels of electrolyte sources ($NaHCO_3$ and $KHCO_3$) and 4 dietary electrolyte levels (50, 180, 310, and 440 meq of $Na^+ K^- Cl$ per kg diet) was conducted. To vary the dietary electrolyte levels, a mixture of equal (1:1) amounts of $NaHCO_3$ and $KHCO_3$ was supplemented into the basal diets which were basal low and high protein diets (Table 2).

Two hundred chicks were used in this trial, which had 8 treatment combinations, 5 replicates per treatment, and 5 chicks per replicate. The average initial weight of the chicks was 69.7 g.

Trial 2.

A completely randomized design experiment using 150 chicks was conducted, which had 5 treatments, 6 replicates per treatment, and 5 chicks per replicate. The treatments were the various levels of dietary electrolytes, namely, 125, 200, 275 and 425 meq Na^+ K^- Cl per kg, with a 24.42 percent protein diet. As shown in trial 1, a mixture of equal (1:1) amounts of $NaHCO_3$ and $KHCO_3$ was used to vary the electrolyte levels in the diet. The basal diet and the treatment compositions are shown in Tables 3 and 4.

Trial 3.

A completely randomized design experiment using 125 chicks was conducted, with 5 treatments, 5 replicates per treatment, and 5 chicks per replicate. The treatments consisted of dietary electrolyte levels of 150, 250 and 350 meq Na^+ K^- Cl per kg. Either $NaHCO_3$ or $KHCO_3$ was used as the only source of diet supplementation to alter the electrolyte level of the basal diet. The composition of the basal diet and the treatments are presented in Tables 5 and 6.

Table 1. Composition of Basal Diets of Trial 1

Ingredient	Basal High protein	Basal Low protein
	%	%
Corn	45.76	65.73
Soybean meal (48% Crude protein)	42.33	24.48
Corn oil	4.00	1.55
Dical-PO_4	2.20	2.20
$CaCl_2$	1.10	0.70
$FeCl_2$	0.05	0.05
NaCl	0.40	0.40
$MnCl_2$	0.05	0.05
ZnCl	0.01	0.01
Choline-Cl (60%)	0.10	0.10
Vitamin mix[a]	0.10	0.10
Na-Se mix (provides 0.1 mg Se/kg diet)	0.01	0.01
DL-Methionine	0.20	0.20
Solka floc	3.69	4.42
Total	100.00	100.00
Calculated: Crude protein (%)	24.42	17.4
Metabolizable energy (Kcal/kg)	2970	2970
$Na^+ + K^+ - Cl$ (meq/kg)	50	50

[a]*Vitamin mix provided per kg of diet: vitamin A, 4400 IU: vitamin D_3, 1000 ICU; vitamin E, 10 IU; vitamin B_{12} ; 0.01 mg; riboflavin, 4.41 mg; d-pantothenic acid, 10.0 mg; niacin 22 mg; menadione sodium bisulfite, 2.33 mg.*

Table 2. Treatment Composition of Trial 1.

Treatment[a]	$Na^+ + K^+ - Cl$
	meq/kg
1. Basal, high protein (Bh)	50
2. Bh + 0.6% $NaHCO_3$ + 0.6% $KHCO_3$	180
3. Bh + 1.2% $NaHCO_3$ + 1.2% $KHCO_3$	310
4. Bh + 1.8% $NaHCO_3$ + 1.8% $KHCO_3$	440
5. Basal, low protein (B1)	50
6. BI + 0.6% $NaHCO_3$ + 0.6% $KHCO_3$	180
7. Bl + 1.2% $NaHCO_3$ + 1.2% $KHCO_3$	310
8. Bl + 1.8% $NaHCO_3$ + 1.8% $KHCO_3$	440

[a] *$NaHCO_3$ and $KHCO_3$ were added in place of solka floc.*

Table 3. Composition of Basal Diet of Trial 2.

Ingredient	%
Corn	45.75
Soybean meal (48% Crude protein)	42.35
Corn Oil	4.00
Dical-PO_4	2.20
$CaCl_2$	1.10
$FeCI_2$	0.05
NaCl	0.40
$MnCl_2$	0.05
$ZnCl_2$	0.01
Choline-Cl 60%)	0.10
Vitamin mix[a]	0.10
Na-Se mix (provides 0.5 mg Se/kg diet)	0.01
DL-Methionine	0.20
Solka floc	3.68
Total	100.00
Calculated: Crude protein (%)	24.42
Metabolizable Energy (kcal/kg)	2970

[a]*Vitamin mix provided per kg of diet: vitamin A, 4400 IU; vitamin D_3, 1000 ICU; vitamin E, 10 IU; vitamin B_{12} 0.01 mg; riboflavin, 4.41 mg; d-pantothenic acid, 10.0 mg; niacin 22 mg; menadione sodium bisulfite, 2.33 mg.*

Table 4. Treatment Composition of Trial 2.

Treatment [a]	$Na^+ + K^+ - Cl$
	meq/kg
1. Basal (B) + 0.35% $NaHCO_3$ + 0.35% $KHCO_3$	125
2. B + 0.70% $NaHCO_3$ + 0.70% $KHCO_3$	200
3. B + 1.05% $NaHCO_3$ + 1.05% $KHCO_3$	275
4. B + 1.40% $NaHCO_3$ + 1.40% $KHCO_3$	350
5. B + 1.75% $NaHCO_3$ + 1.75% $KHCO_3$	425

[a] *$NaHCO_3$ and $KHCO_3$ were added in place of solka floc.*

Table 5. Composition of Basal Diet of Trial 3.

Ingredient	%
Corn	48.50
Soybean meal (48% Crude protein)	42.36
Corn oil	3.00
Dical-PO_4	2.20
$CaCO_3$	0.50
$CaCl_2$	0.52
NaCl	0.40
$FeCl_2$	0.05
$MnCl_2$	0.05
$ZnCl_2$	0.01
Choline-Cl (60%)	0.10
Vitamin mix 0.10	0.10
Na-Se mix (provides 0.1 mg Se/kg diet)	0.01
DL-Methionine	0.20
Solka floc	2.00
Total	100.00
Calculated: Crude protein (%)	24.34
Metabolizable energy (kcal/kg)	2975

[a]*Vitamin mix provided per kg of diet: vitamin A, 4400 IU; vitamin D_3, 1000 ICU; vitamin E, 10 IU; vitamin B_{12} , 0.01 mg; riboflavin, 4.41 mg; d-pantothenic acid, 10.0 mg; niacin, 22.0 mg; menadione sodium bisulfite, 2.33 mg.*

Table 6. Treatment Composition of Trial 3.

Treatment[a]	$Na^+ + K^+ - Cl$
	meq/kg
1. Basal (B)	150
2. B + 1.0% $KHCO_3$	250
3. B + 2.0% $KHCO_3$	350
4. B + 0.84% $NaHCO_3$	250
5. B + 1.68% $NaHCO_3$	350

[a]*$KHCO_3$ or $NaHCO_3$ was added in place of solka floc.*

RESULTS

Trial 1.

Table 7 shows that the dietary protein level greatly influenced body weight gain of the experimental chicks. There was a difference ($p<0.01$) in weight gain average between chicks given 24 and 17 percent protein diets (namely, 17.29 versus 14.81 g per day). However, dietary electrolyte levels of 50, 180, 310, and 440 meq per kg feed, did not affect body weight gain.

The data on daily feed intake also indicated that there was no significant difference in feed intake due to the main effect of protein or electrolyte. However, there was a significant ($p<0.05$) protein by electrolyte interaction affecting feed intake. When a high protein diet was fed, an increase of cation excess tended to increase feed intake, while when a low protein diet was fed, such an increase of cation excess tended to decrease feed intake (Table 7).

There were significant ($p<0.01$) main effects of protein and elctrolyte, and protein by electrolyte interaction on gain/feed, as shown in Table 7. Birds given a 24-percent protein diet utilized feed more efficiently than did the 17 percent group; whereas the chicks receiving 180 meq Na^{+} K^{-} Cl per kg had a better ($p<0.05$) gain/feed, as compared to the group of chicks receiving 440 meq.

A protein by electrolyte interaction ($p<0.05$) affected the efficiency of feed utilization. When the dietary protein was high increasing a cation excess resulted in a decreased feed efficiency. However, when a low protein was given, increasing base excess did not change the efficiency of feed utilization.

Trial 2.

Table 8 shows that there was no significant difference in body weight gain due to electrolyte levels ranging from 125 to 425 meq per kg. However, cation excess of 200 meq per kg diet seems to be superior in promoting growth of chicks, with a daily weight gain of 17.87 g.

Data on feed intake and gain/feed showed that there was no significant difference among the dietary electrolyte treatments. The amounts of feed intake were fairly close to each other. The highest gain/feed of 0.72 was achieved by the groups of chicks receiving the diet supplemented with an equal amount of $NaHCO_3$ and $KHCO_3$ which contained 125 meq per kg. The lowest gain/feed was the group receiving 425 meq cation excess per kg diet.

Trial 3.

The results of trial 3 indicated that a cation excess of 250 meq per kg diet promoted more ($p<0.10$) weight gain than did the 150 meq group, only when $NaHCO_3$ was supplemented in the diet (18.18 g/day). However, this did not occur when $KHCO_3$ was used (Table 9).

It appeared that the cation excess of 250 meq of $NaHCO_3$ supplementation had the highest gain/feed (0.). This was higher ($p<0.10$) than the basal diet (150 meq per kg) which was 0.66, the $KHCO_3$ added diet (250 meq per kg) which was 0.66 and the $NaHCO_3$ added diet (350 meq per kg) which was 0.64.

Data on feed intake, however, did not show any significant difference among the dietary electrolyte levels between electrolyte sources.

Table 7. Performance of Chicks Fed High and Low Protein Diets with Various Levels of Cation Excess (Trial 1)[a]

Ion source		$NaHCO_3$	%	-	0.6	1.2	1.8	Mean	Pooled SEM
		$KHCO_3$	%	-	0.6	1.2	1.8		
Cation-Anion			meq/kg	50	180	310	440		
Gain/day[b]	Dietary protein	24%	g	17.47	17.42	17.13	17.16	17.29	0.20
		17%	g	14.45	15.23	14.52	14.81	14.81	
		Mean	g	15.96	16.32	15.82	15.98		
Feed/ day[c]	Dietary protein	24%	g	26.33	26.00	27.74	28.63	27.17	0.56
		17%	g	27.51	28.07	27.01	27.85	27.61	
		Mean	g	26.92	27.03	27.37	28.24		
Gain/feed [d,e]	Dietary protein	24%		0.66	0.67	0.62	0.60	0.63	0.01
		17%		0.53	0.53	0.54	0.53	0.53	
		Mean		0.60	0.60	0.58	0.56		

[a] *Results represent mean values obtained from five replicates of five chicks during the period of 8 to 22 days posthatching; average initial weight was 67.9 g.*

[b] *Protein main effect was significant ($p<0.01$)*
[c] *Protein x Electrolyte interaction was significant ($p<0.05$)*
[d] *Protein main effet was significant ($p<0.05$)*
[e] *Electrolyte main effect was significant ($p<0.05$)*

Table 8. Performance of Chicks Fed a High Protein Diet with Various Levels of Cation Excess (Trial 2)[a]

Diet			B					Pooled-SEM
Ion source	$NaHCO_3$	%	0.35	0.70	1.05	1.40	1.75	
	$KHCO_3$	%	0.35	0.70	1.05	1.40	1.75	
Cation-Anion		meq/kg	125	200	275	350	425	
Gain/day		g	17.84	17.87	17.64	17.71	16.77	0.38
Feed/day		g	24.83	25.34	24.98	25.37	25.49	0.49
Gain/feed			0.72	0.71	0.78	0.70	0.66	0.02

[a]*Results represent mean values obtained for six replicates of five male chicks during the period of 8 to 22 days posthatching; average initial weight was 69.1 g.*

Table 9. Performance Of Chicks Fed a High Protein Diet with Various Levels of Cation Excess (Trial 3).[a]

Diet			Basal					Pooled-SEM
Ion source	$NaHCO_3$	%	-	-	-	1.0	2.0	
	$KHCO_3$	%	-	1.0	2.0	-	-	
Cation-Anion		meq/kg	150	250	350	250	350	
Gain/day		g	16.82^{y}	17.28^{xy}	17.33^{xy}	18.18^{x}	17.26^{xy}	0.31
Feed/day		g	25.62	26.23	25.91	26.13	26.84	0.47
Gain/feed			0.66	0.66	0.67	0.70	0.64	0.01

[a] *Results represent mean values obtained for five replicates of five chicks during the period-of 8 to 22 days posthatching; average initial weight was 68.3 g.*
[x,y] *Means with different superscripts differ statistically ($p<0.05$).*

DISCUSSIONS

The results of this study clearly indicated that the dietary electrolyte expressed as sodium plus potassium minus chloride (Na+ K– Cl) ranging from 50 to 440 meq per kg did not significantly affect body weight gain of chicks when a mixture of equal amounts of $NaHCO_3$ and $KHCO_3$ was used as a supplement to modify the electrolyte level. This was demonstrated in two levels of protein diets (low and high) in trials 1, and using only high protein diets in trials 2 and 3.

The fact that a higher protein level of the diet promoted a more rapid growth, was evidenced in trials 1. In those trials, higher protein level (24 percent) resulted in more gain ($p<0.01$ in trial 1) when compared with the lower protein level (17 percent).

When either $NaHCO_3$ or $KHCO_3$ was used separately, the electrolyte levels ranging from 150 to 350 meq per kg diet, clearly affected gain (Table 9). Chicks receiving 150 meq of cation excess per kg diet, gained less ($p<0.10$) than did the chicks receiving 250 meq per kg of either $NaHCO_3$ or $KHCO_3$ added diet. The data in Table 9 show that the level of 250 meq kg diet from a $NaHCO_3$ source resulted in the highest gain of 18.18 g per day which was 1.36 g gain per day greater than the basal diet group. On the other hand, when the cation excess was increased from 250 to 350 meq per kg using $NaHCO_3$, no additional response was observed.

The level of feed intake, did not appear to be affected by dietary electrolyte level as observed in Tables 7, 8 and 9. However, in trial 1, (Table 7) a significant protein by electrolyte interaction was noted ($p<0.05$) to have affected feed intake. When a high protein diet was fed, an increasing base excess tended to increase feed intake. This happened when an equal weight of $NaHCO_3$ and $KHCO_3$ was used as the electrolyte source. This result was confirmed in Trial 2 (Table 8) where there was a tendency of increasing from 125 to 425 meq per kg diet.

Interactions between dietary electrolyte and protein level observed in trial 2, did not exist when $KHCO_3$ was used as the major electrolyte source (Table 6) and when the proportion of $NaHCO_3$: $KHCO_3$ inclusion was 1 : 2. Furthermore, trial 3 (Table 9) also supported the fact than when $NaHCO_3$ was used as the major electrolyte source, an increase in cation excess from 150 to 350 meq per kg diet resulted in an increase of feed intake. This did not occur when $KHCO_3$ was used for supplementation instead of $NaHCO_3$.

Since HCO^-_3 may have a significant role in acid-base balance in the body, future experiments which take this ion into account when predicting the acid-base status of diets and drinking water,are needed.

CONCLUSION

The role of Na+ K– Cl levels was influenced by the electrolyte sources added to the diets. The dietary cation excess between 50 and 440 milliequivalent per kilogram, did not affect chick performance when a combination of $NaHCO_3$ and $KHCO_3$ were supplemented in the diet. However, if either one was used as the major source of electrolyte, there was an effect. A diet with higher cation excess was needed when using $KHCO_3$ than using $NaHCO_3$, to promote better gain and gain to feed ratio. Increasing cation excess resulted in the decreased feed efficiency when high protein diet was fed.

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