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Dietary Levels of Potassium for Broiler Chickens

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ABSTRACT

Three experiments were conducted to determine the nutritional requirements of potassium (K) for male Ross broiler chickens, from 8 to 21, 22 to 42 and 43 to 53 days of age. The following parameters were evaluated: body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR). In each experiment, a completely randomized experimental design was used, with six treatments (K levels), and six, eight and eight numbers of replicates, and eight, five and four birds per pen, respectively. The experimental diets were basal diets deficient in K but supplemented with K carbonate to result in levels of 0.30, 0.44, 0.58, 0.72, 0.86 and 1.00% K. Estimated requirements for BWG were 0.628, 0.714 and 0.798% K, for the periods 8-21, 22-42 and 43-53 d, respectively.

INTRODUCTION

Potassium is the third more abundant element of the animal body (McDowell, 1992) and the main intracellular cation. It participates on the processes that are essential to the body homeostasis, such as the acid-base equilibrium, osmotic pressure regulation, development of membrane potentials of cells (nerve transmission, muscle activity, cardiac function), activation of numerous intracellular enzymes, and glucose and amino acid absorption and transport (Rinehart *et al.*, 1968; Reece, 1996; Leeson & Summers, 2001). Nevertheless Potassium does not work alone and the correct balance between Na, K and Cl is necessary for best animal performance, bone development, eggshell quality and amino acid use (NRC, 1994).

Mogin (1980; 1981) studied the basic role of cation-anion balance for chickens and pigs and concluded that the electrolyte equilibrium could be described by a formula including the main electrolytes. The abbreviated formula resulted in the so-called electrolytic balance (EB), which is the result of the sum of the positive ions (Na and K) minus the sum of the negative ions (Cl).

According to Murakami (2000), an EB between 150 and 350 mEq/kg is recommended in commercial diets for maximum bird performance. Leeson & Summers (2001) considered 250 mEq/kg as an appropriate level for adequate poultry development.

Hooge & Cummings (1995) stated that the NRC (1994) K dietary requirements for growing poultry were considerably lower than the levels typically present in commercial diets. No increases in K requirements were indicated when environmental temperature, water intake, or stress conditions are increased and neither because. The authors also noted that, due to the lack of published research in refereed journals, many of the K requirements were estimated and presented in italics.

Studies using broilers from 7 up to 21 d estimated 0.824% K as the potassium requirement with 0.15-0.17% Na in a practical-type diet, which indicates approximately a 1:1 Na:K ratio as optimal and with EB around 242 mEq/kg (Hurwitz *et al.*, 1973 cited by Hooge & Cummings, 1995). Thus, this information suggested that the K requirement for maximum BWG could be higher than the 0.30% level recommended by NRC (1994). Rostagno *et al.* (2000) suggested that 0.501, 0.471 and 0.454% K were adequate for EB in the periods from 1 to 21, 22 to 42 and 43 to 49 d, respectively.

It is still unclear how K supplementation improves BW, but it has been shown that diets with high levels of lysine HCL and arginine HCL might need K supplementation as acetate or carbonate to minimize the antagonism between these ions on metabolism (O'Dell & Savage, 1957, O'Dell *et al.*, 1962; Nesheim *et al.*, 1964; Savage, 1972). K salts were also shown to influence lysine catabolism, resulting on lower lysine:arginine ratio (Scott & Austic, 1978). The protein synthesis and BWG reduced tissue lysine concentration. A possible explanation could be a reduced arginase activity in the kidneys and lower urease activity in the intestines (microbial source). The arginine catabolism would be then reduced and this amino acid would become more available for protein synthesis (Stutz *et al.*, 1972).

Young (1995), in personal communication to Hooge & Cummings (1995), stated that K levels in some ingredients were found to be considerably lower than expected compared with standard table values, which would alter K levels and dietary EB calculated by formulas.

Therefore, it is necessary to evaluate the effects of K levels on broiler chickens performance in order to establish the requirements to determine a recommendation for maximum BWG and to evaluate the need of diet supplementation.

MATERIALS AND METHODS

Three experiments were conducted in a metabolism room, each one corresponding to the periods from 8 to 21, 22 to 42 and 43 to 53 days of age. In the first experiment, 288 Ross male chicks with initial average weight of 0.148 kg were reared from 8 to 21 days of age in a completed randomized design with six treatments (K levels) and six replicates, with eight birds per experimental unit. In the second and third experiments, 240 and 192 Ross male broiler chickens with initial average weight of 0.768 kg and 2.295 kg, respectively, were reared from 22 to 42 and 43 to 53 days of age in a completed randomized design with six treatments (K levels) and eight replicates of five and four birds per experimental unit, respectively. In the three experiments, K levels of 0.30, 0.44, 0.58, 0.72, 0.86 and 1.00% K were used.

The birds were housed in metabolism cages, grouped in batteries that corresponded to the experimental units. The diets for each replicate were kept in individual buckets and feed and water intakes were recorded. Birds were reared under conventional conditions until the initial day of each experiment. Diets were formulated according to the age and the nutritional requirements reported by Rostagno *et al.* (2000).

In all experiments, treatments consisted of a basal diet formulated to fulfil nutritional requirements for all nutrients except for potassium, according to age, based on levels recommended by Rostagno *et al.* (2000). It was necessary to replace the washed soybean meal for other ingredients with smaller K content in order to formulate the basal diet deficient in K. The composition of the basal diets used in each experiment are shown in Table 1. Washed soybean meal, used as protein source, was obtained after three washes of the soybean meal with acid solution adjusted to pH 4.6 with hydrochloric acid (HCl), followed by two washes with distilled water, drying in stove at 55°C for 24 hours and grinding. The final product contained 90% DM, 56% CP and 0.70% K. This procedure was an adaptation of the technique used in the 50's and 60's to produce isolated soybean protein and it results in partial loss of K during the washing steps (Supple & Combs, 1959; Leach *et al.,* 1959). Then, increasing levels of K were obtained by replacing washed sand for potassium carbonate (K_2CO_3) (56.5% of K). Laboratory analyses were performed to determine K levels in the experimental diets, which were compared with calculated values.

The diet from each experimental unit was weighed at the beginning and the end of each experiment, and data were corrected for mortality. The birds were individually weighed at the beginning and the end of each experiment. These data were used to obtain feed intake (FI), body weight gain (BWG) and feed conversion rate (FCR) The maximum and minimum temperatures were daily recorded and the means are shown in Table 2.

The statistical analyses were accomplished by the statistical program SAEG (System for Statistical and Genetic Analyses) (Universidade Federal de Viçosa, 1999), and K requirements were estimated using polynomial regression models. A 5% probability level was used in all comparisons.

Table 1 - Composition of basal diets according to age.

Ingredient	8 to 21 d	22 to 42 d	43 to 53 d
Corn, meal %	58.500	63.000	66.730
WSM[1], %	13.500	14.083	11.734
Gluten meal (60% CP), %	10.950	9.972	8.054
Starch, %	3.974	2.792	4.000
Meat meal, %	5.660	1.790	2.000
Limestone, %	0.188	0.016	0.652
Dicalcium phosphate, %	0.050	2.190	0.824
Soybean oil, %	1.000	1.000	1.653
DL-Met, %	0.171	0.145	0.123
L-Lys HCl, %	0.632	0.567	0.527
L-Arg, %	0.217	0.300	0.226
L-Thr, %	0.070	0.060	0.012
L-Trp, %	0.066	0.042	0.048
Choline Chlorine 60%, %	0.100	0.100	0.100
Salt, %	0.394	0.300	0.381
Vitamin/mineral and additive mix*, %	0.238	0.238	0.238
Washed sand, %	4.290	3.405	2.698
Total	**100.000**	**100.000**	**100.000**
Calculated nutrient composition			
ME (kcal ME/kg)	3.096	3.102	3.200
CP (%)	21.605	20.000	18.000
Lys (%)	1.263	1.156	1.050
Met (%)	0.542	0.494	0.437
Met+cys	0.897	0.825	0.742
Trp (%)	0.230	0.202	0.190
Thr (%)	0.798	0.747	0.634
Arg (%)	1.290	1.265	1.101
Gly+ser, %	2.093	1.804	1.642
Calcium, %	0.960	0.874	0.800
Total P(%)	0.632	0.797	0.544
Available P (%)	0.450	0.609	0.365
Potassium (%)	0.305	0.306	0.300
Analyzed potassium, %	0.334	0.315	0.320
Sodium (%)	0.222	0.192	0.192
Chlorine (%)	0.305	0.277	0.278
EB (mEq/kg)[2]	88.53	83.64	81.82

* Vitamin, mineral and additive levels provided per ton of feed: vit A 10,000,000 IU, vit D_3 2,000,000 IU, vit E 30,000 IU, vit K_3 3,000 mg, vit B_1 2,000 mg, vit B_2 6,000 mg, vit B_6 4,000 mg, vit B_{12} 15,000 mcg, nicotinic acid 50,000 mg, pantothenic acid 12,000 mg, biotin 100 mg, folic acid 1,000 mg, selenium 250 mg, manganese 160,000 mg, Iron 100,000 mg, zinc 100,000 mg, copper 20,000 mg, cobalt 2,000 mg, iodine 2,000 mg, vehicle for 1,000 g.1 - Washed soybean meal: 90% DM, 56% CP and 0.70% K.2 - Electrolytic balance: [Na]+[K] – [Cl].

Table 2 - Maximum and minimum mean temperatures (°C) in each trial.

Age (days)	Maximum	Minimum	Mean
8 to 21	25.00	17.31	21.16
22 to 42	27.11	21.32	24.21
43 to 53	27.22	19.11	23.17

RESULTS AND DISCUSSION

The results obtained for the performance parameters in each experiment are given in Table 3. A quadratic effect on BWG and on FI was observed in the period from 8 to 21 d. The estimated requirements were 0.628% of K for BWG and 0.640% of K for FI (Table 4). There was no significant effect of K level on FCR.

Table 3 - Effect of potassium levels on bird performance at 8-21, 22-42 and 43-53 d.

Potassium levels (%)	Feed intake (g)	Body weight gain (g)	Feed conversion ratio
8 to 21 d			
0.30	883	616	1.432
0.44	926	639	1.451
0.58	933	646	1.445
0.72	932	650	1.435
0.86	917	634	1.448
1.00	879	604	1.457
Mean	911	631	1.445
Regression	Q	Q	NS
CV (%)	3.42	4.02	3.36
22 to 42 d			
0.30	2,622	1,467	1.791
0.44	2,751	1,575	1.749
0.58	2,843	1,625	1.749
0.72	2,861	1,626	1.802
0.86	2,962	1,646	1.800
1.00	2,791	1,553	1.799
Mean	2,805	1,582	1.782
Regression	Q	Q	NS
CV (%)	3.46	4.08	3.94
43 to 53 d			
0.30	1,293	539	2.421
0.44	1,316	615	2.153
0.58	1,402	599	2.364
0.72	1,457	652	2.257
0.86	1,385	616	2.251
1.00	1,439	627	2.302
Mean	1,383	608	2.293
Regression	Q	Q	NS
CV (%)	8.16	12.46	8.36

L - linear effect. Q - quadratic effect. NS – not significant.

Table 4 - Estimates of potassium requirements and regressions for weight gain and feed intake for broiler chickens from 8-21, 22-42 and 43-53 d.

	Requirement (%)	EB[1]	Regression	r^2
8 to 21 d				
Weight gain	0,628	161	$y=522,164^*+406,81^*x-323,511^*x^2$	0,99
Feed intake	0,640	174	$y=754,471^*+570,886^*x-445,821^*x^2$	0,98
22 to 42 d				
Weight gain	0,714	188	$y=1119,05^*+1475,65^*x-1033,64^*x^2$	0,96
Feed intake	0,767	201	$y=2131,11^*+1993,64^*x-1299,43^*x^2$	0,87
43 to 53 d				
Weight gain	0,798	209	$y=404,724^*+577,567^*x-361,598^*x^2$	0,77
Feed intake	0,924	241	$y=1111,48^*+687,004^*x-371,363^*x^2$	0,78

1- EB= electrolytic balance, mEq/kg. *significant.

The observed requirement levels were 57% and 109% higher than the K levels of 0.40 and 0.30% recommended by NRC (1984 and 1994, respectively). One of the possible reasons for such difference is that the levels recommended by NRC (1994) were determined using birds Vantress x White Plymouth Rock (Leach *et al.*, 1959), which have smaller growth potential than the strain used in the present study, mainly in muscle mass. Another reason could be attributed to the protein level of the diets. In the study of Leach *et al.* (1959), protein levels of 25.8 to 37.9% CP were used, whereas in the current study the level used in the initial phase was 21.4% of CP, as recommended by Rostagno *et al.* (2000). Nevertheless, this effect was not expected, since theoretically, K requirements would increase with the excess of nitrogen (Leach *et al.,* 1959; Sullivan, 1963; Chavez *et al.,* 1979; Austic, 1983; Hooge & Cummings, 1995). The levels of 0.628% and 0.640% of K determined in the present study are similar to the level of 0.501% recommended by Rostagno et al. (2000), although this level has been suggested for an appropriate EB. In the period from 22 to 42 d, a quadratic effect was also observed for BWG and for FI (Table 3) and estimated levels were 0.714% and 0.767% of K, respectively (Table 4). These values are higher than those obtained in the first experiment. Such requirement increase indicates that muscle development was still occurring, and more K was necessary because of the relation between K and protein syntheses. The observed levels were 104% and 138% higher than those recommended by NRC for this phase, i.e., 0.35 and 0.30% of K (NRC, 1984 and 1994, respectively). Environmental temperature was very close to the threshold of thermal comfort (Table 2), which could increase K requirements due to poorer intestinal blood irrigation (Bottje & Harrison, 1986; Wolfenson *et al.*, 1987). As observed in the first experiment, there was no significant difference for FCR.

In the last period, from 43 to 53 d, quadratic effects were also observed for BWG and for FI (Table 3). The estimated levels were 0.798% and 0.924% of K for BWG and for FI respectively (Table 4). These results confirmed the tendency of increase in the requirements, though less markedly, probably due to the decrease in the growth rate. As in the previous experiments, the requirement was higher (166%) than the recommendation of 0.30 for this period (NRC, 1984; 1994). There was no significant difference for FCR in the period.

The requirement of K for maximum BWG was preferentially used to determine nutritional requirements. The behavior of the estimated values for this parameter in this study was in agreement with the curves of body composition for K observed by Kravis & Kare (1960). They reported that newly hatched chicks had low K levels and high Na levels, which oscillated until 12 d of age. Afterwards, K levels were high and Na levels were low, and showed little variation. The behavior was common to almost all tissues, but occurred mainly in muscles, where the content of K at hatching was 30 mEq/kg, reaching a peak of 110 mEq/kg at 12 d of age, and was constant at about 90 mEq/kg afterwards. These findings supports the hypothesis of decreasing requirements with age increase. Conversely, this was not observed in the present experiments; possibly due to the EB of the diets, the reduced lifespan of the modern broiler or even because the renal regulation system was still in development. In any case, the higher K requirements for broilers nowadays could be explained by the largest potential of muscle mass accumulation in comparison to the birds used in the previous studies.

The estimated K requirements for largest BWG were used to calculate EB values in the three phases (8 to 21, 22 to 42 and 43 to 53 d). The calculated EB values were 161, 188 and 209 mEq/kg, respectively, and are above the minimum value (150 mEq/kg) recommended by most studies (Murakami, 2000). This finding evidences a need for better understanding the involved processes and the individual effect of each electrolyte. As the levels of Na and Cl in these experiments were constant and in agreement with the recommendations for each phase (Rostagno *et al.*, 2000), it should be considered that the differences observed in this study probably resulted from the interactions among Na, Cl and K.

Based on the requirements estimated for each phase, it was possible to establish a prediction equation for K requirements as a function of age, for each Mcal of ME. The curve and the equation are shown in Figure 1. The equation confirmed the increasing tendency of K requirement levels with age until birds were 53 days old. The level of 0.72% K showed the best BWG in the three periods. Further studies are needed to confirm if the requirements can be maintained or even decreased after the period of intense muscle development.

The potassium levels assessed in the present study affected bird performance. The nutritional requirements of potassium for maximum BWG of birds in the periods from 8 to 21, 22 at 42 and 43 to 53 d were of 0.628, 0.714 and 0.798% of K, respectively.

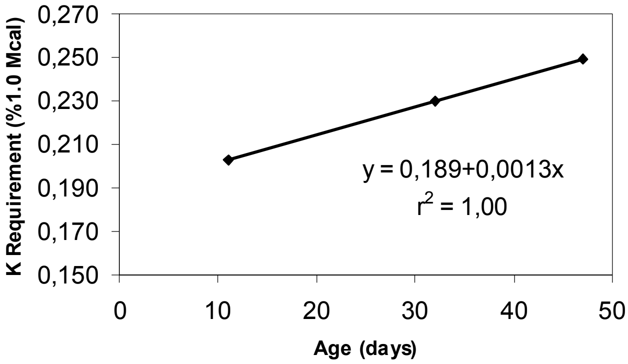

Figure 1 - Estimated potassium requirements for male Ross broilers as a function of age (% for Mcal ME).

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