Ann. Anim. Sci., Vol. 11, No. 3 (2011) 405–412

EFFECT OF DIETARY ELECTROLYTE BALANCE ON REARING PERFORMANCE OF BROILER CHICKENS UNDER FARM CONDITIONS*

Jerzy Koreleski[1], Sylwester Świątkiewicz[1],
Anna Arczewska-Włosek[1], Mieczysław Słonecki[2]

[1]Department of Animal Nutrition and Feed Science, National Research Institute of Animal Production, 32-083 Balice n. Kraków, Poland
[2]Experimental Station Rossocha, National Research Institute of Animal Production, 96-204 Kurzeszyn, Poland

Abstract

The aim of the study was to determine the efficiency of adding sodium and chlorine to commercial cereal-soybean starter and grower diets with increased potassium content in broiler chickens raised under farm conditions. A total of 4800 day-old Hubbard Flex broilers were divided into 4 groups with 6 replicates of 200 chickens each and kept in boxes on straw litter. Basal starter and grower diets contained in 1 kg (as analysed): 8.37 and 8.27 g potassium; 1.79 and 1.66 g sodium; and 3.17 and 2.76 g chlorine, respectively. The dietary electrolyte balance (DEB) values were 203 and 206 mEq/kg, respectively. Basal experimental diets were supplemented with 0.3 g Na and/or 0.5 g Cl/kg of diet in the form of sodium carbonate, sodium chloride or ammonium chloride. The dietary supplements had no effect on production parameters during the starter period. In the grower period, the sodium ($NaHCO_3$) supplement increased DEB value to 219 mEq/kg, significantly ($P<0.05$) increasing chickens' body weight gain and feed intake. Sodium added together with chloride as NaCl tended to improve production parameters (non-significantly) without any effect on DEB values. Throughout rearing, the positive effect of sodium supplementation was only observed for increased feed intake ($P<0.05$). Supplementation of chlorine (NH_4Cl) to the starter and grower diets reduced DEB values to 188 and 192 mEq/kg, respectively, without a positive effect on rearing performance, and decreased feed intake ($P<0.05$). The analysed sodium and chlorine supplements had no effect on dressing percentage, abdominal fat content of the carcass and litter moisture.

Key words: broiler chickens, electrolyte balance, sodium, chlorine, performance.

Relatively high potassium levels in plant-based diets may increase the sum of both cations (K^+ and Na^+) while creating a special need for chlorine supplementation to reach the optimum dietary electrolyte balance (DEB) (Mongin, 1981). Dietary potassium may increase chickens' water intake and litter moisture (Vieira and Lima, 2005). In our previous experiment with caged chickens kept on wire floor the starter

*Support by the Ministry of Science and Higher Education, Project No. N 311 0347 34 (2261.5).

diets with high potassium levels (10.7, 12.2 and 12.7 g/kg) and a higher content of sodium (2.0 g) and chloride (3.1 g/kg) increased performance indices (Koreleski et al., 2011 a). The performance also improved at high potassium and chloride (1.73 g) levels when dietary sodium was elevated from very low to 1.61 g/kg (Koreleski et al., 2010). During the starter period, body weight gains and feed conversion ratio were positively affected by the dietary chloride content increased from 2.11 to 2.95 g or 3.16 g Cl per kg (Koreleski et al., 2011 b). At high dietary potassium level excreta moisture was increased (Koreleski et al., 2011 a). As a result of potassium level elevated from 7.8 g to 11.9 g/kg, the dry matter content of excreta decreased and the proportion of breast meat in the carcass increased (Koreleski et al., 2011 b).

In this study performance, litter moisture and carcass indices were investigated in farmed broiler chickens kept on straw floor and fed commercial diets supplemented or not with sodium and chloride added together or separately.

Material and methods

A total of 4800 day-old Hubbard Flex broilers of both sexes were divided into four nutritional groups with 6 replicates of 200 chickens each and kept on straw floor at a stocking density of 14 birds/m^2. Chickens were provided with tap drinking water and feed *ad libitum*. The basal feed mixtures (cereal-soybean starter and grower diets) were bought from the market and their composition was guaranteed. The experimental diets were the basal feeds supplemented with sodium (0.3 g/kg) and chlorine (0.5 g/kg) added together as sodium chloride (NaCl) or separately as sodium bicarbonate ($NaHCO_3$) or ammonium chloride (NH_4Cl).

The body weight (BW) and feed intake (FI) of the chickens were measured and mortality was recorded. The body weight gain (BWG) and feed conversion ratio (FCR) were calculated for the first (1–14 days) and second period of feeding (15–42 days) and for the entire feeding experiment (1–42 days of age). The production index (PI) was calculated for the entire period from the equation: PI = [BW (kg) × × liveability (%) / age (42 days) × FCR] × 100.

At 21 and 35 days of age each box was awarded a subjective litter score in points, where 1 means dry litter, 2 normal litter, 3 wet litter and 4 very damp litter. Moisture, as average percent of measurements made at 5 locations of each floor was determined using a moisture meter for hay and straw (Draminski, Olsztyn).

At the end of the experiment, after 12 hours of starvation, 5 representative cockerels and 5 pullets with body weight close to the respective treatment mean were chosen from each group and decapitated. The live weight and weight of the cooled carcasses with edible giblets were estimated and carcass yield and relative weights of abdominal fat were calculated (Ziołecki and Doruchowski, 1989). The Local Kraków Ethics Committee for Experiments with Animals approved all experimental procedures relating to the use of live animals.

The potassium and sodium content of the diets was analysed by atomic absorption spectrometry (ISO 6869.2000). The chloride content was calculated from wa-

ter soluble chloride (as NaCl), and analysed by the silver nitrate titration method (Volhard, 1874). Basal feed nutrient content was analysed using standard methods (AOAC, 1990) for dry matter (method 930.15), crude protein (984.13, by means of the Kjeldahl method, using Kjeltec Auto 1030, Tecator), crude fat (920.39) and ash (942.05). Crude fibre was estimated with Tecator Fibertec System M.

The data were subjected to a one-way factorial analysis of variance. The significance of differences between means was determined by Duncan's multiple range test and differences were considered significant at $P \leq 0.05$. Statistical analyses were performed using Statistica 5.0 PL software (Statsoft Inc.).

Results

The basal standard mixtures were made as mash by a commercial feed plant. As analysed, the average basal nutrient composition of starter and grower diets was (%): dry matter 88.48 and 88.22, crude protein 21.69 and 20.41, crude fibre 3.61 and 3.39, ether extract 3.99 and 4.33, ash 5.20 and 4.72, respectively. The commercial feed mixtures were declared to contain 8.5 g K, 1.5 g Na and Cl 2.5 g/kg in the starter diet (DEB 212 mEq) and 8.4 g, 1.4 g and 2.1 g/kg in the grower diets (DEB 216 mEq/kg), respectively.

Declared electrolyte content of the commercial basal diets was close enough to the analysed potassium level of 8.37 and 8.27 g/kg for both periods of feeding. In the case of sodium and especially chloride, the analysed values were higher than declared, i.e. 1.79 and 1.66 g Na and 17.0 and 2.76 g/kg Cl, respectively. DEB values from the analysed data were 203 and 206 mEq/kg for the starter and grower diet, respectively. After sodium supplementation and adding sodium together with chloride the electrolyte content increased to 2.09 and 1.96 g Na and 3.67 and 3.26 g/kg Cl, and DEB values in the starter and grower diets ranged from 201 to 216 mEq and from 205 to 219 mEq/kg, respectively (Table 1). Supplementing chloride alone reduced DEB values to 188 and 192 mEq/kg.

Table 1. Design of experiment, electrolyte source added and dietary content*, DEB values

Group	Feeding period	Supplement	Dietary electrolyte content (g/kg)			DEB (mEq/kg)
			K^+	Na^+	Cl^-	
I	starter		8.37	1.79	3.17	203
	grower		8.27	1.66	2.76	206
II	starter	NaCl	8.37	2.09	3.67	201
	grower		8.27	1.96	3.26	205
III	starter	$NaHCO_3$	8.37	2.09	3.17	216
	grower		8.27	1.96	2.76	219
IV	starter	NH_4Cl	8.37	1.79	3.67	188
	grower		8.27	1.66	3.26	192

*analysed.

Table 2. Performance indices of chickens from 1 to 14 days of age

Group*	DEB (mEq/kg)	Body weight gain (g)	Feed intake (g/chick)	Feed conversion ratio (g/g)	Mortality (%)
I	203	340	442	1.30	1.00
II	201	340	442	1.30	0.75
III	216	337	444	1.32	0.83
IV	188	332	437	1.32	1.00
SEM		1.37	1.45	0.004	0.116

P≥0.05.
* 6 replicates of 200 chickens in each group.

In the starter period of feeding no differences were noted between the groups (Table 2). The effect of electrolyte added to the diet on broiler performance was found only in the second period of feeding (Table 3). BWG and FI were significantly elevated when sodium was supplemented as $NaHCO_3$ (P≤0.05). A positive effect of sodium added together with chloride as NaCl was also observed but was only numerical (P≤0.05). Throughout the feeding period, the effect of sodium supplementation tended to be positive only for increased FI (Table 4).

Table 3. Performance indices of chickens from 15 to 42 days of age

Group*	DEB (mEq/kg)	Body weight gain (g)	Feed intake (g/chick)	Feed conversion ratio (g/g)	Mortality (%)
I	206	1698 a	3567 ab	2.102	0.57
II	205	1761 ab	3623 ab	2.059	1.70
III	219	1764 b	3629 b	2.058	0.76
IV	192	1712 ab	3559 a	2.078	0.76
SEM		11.4	12.2	0.008	0.186

a, b – means in the same column with different letters differ significantly (P≤0.05).
* 6 replicates of 200 chickens in each group.

Table 4. Performance indices of chickens from 1 to 42 days of age

Group *	Body weight gain (g)	Feed intake (g/chick)	Feed conversion ratio (g/g)	Mortality (%)	Production Index (points)
I	2038	4009 ab	1.967	1.60	248
II	2101	4066 b	1.935	2.45	257
III	2101	4073 b	1.939	1.60	259
IV	2045	3996 a	1.954	1.75	250
SEM	11.7	12.1	0.006	0.220	2.08

a, b – means in the same column with different letters differ significantly (P≤0.05).
* 6 replicates of 200 chickens in each group.

Supplementation with chloride (NH_4Cl) had no positive effect. Throughout the experiment, FI in chickens receiving chloride supplemented feed was lower ($P \leq 0.05$) than in the groups fed the diet with sodium or sodium added together with chloride (Table 4). The highest PI was found when the diet was supplemented with sodium and to a lesser extent when sodium together with chloride were added, but in both cases differences in relation to the other groups were not significant ($P \geq 0.05$). Mortality in both experimental periods was relatively low and random across treatments, and the remaining chickens were in good health. Carcass yield and abdominal fat pad in carcass were not affected by electrolyte supplementation of the diet (Table 5).

Table 5. Results of slaughter analysis and litter moisture

Group	Carcass yield * (%)	Abdominal fat pad * (%)	Litter moisture			
			day 21		day 35	
			%	points	%	points
I	77.1	1.93	33.3	2.00	55.2	2.67
II	76.5	2.09	34.5	2.17	58.8	2.83
III	77.8	1.89	35.2	2.00	55.4	2.83
IV	77.5	1.91	37.1	2.33	58.4	3.00
SEM	0.271	0.066	0.720	0.109	1.12	0.098

$P \geq 0.05$.

* 5 representative cockerels and 5 pullets in each group.

Litter moisture analysed in % or expressed in subjective points was not affected ($P \geq 0.05$), but electrolyte additions (Na and Cl) used in the experiment had a tendency to slightly increase moisture at 21 and 35 day of age (Table 5).

Discussion

All plant diets based on corn and soybean meal with elevated potassium content increase the amounts of excreta due to a higher water intake and larger proportion of indigestible components (Vieira and Lima, 2005). The sodium requirement to achieve maximum growth of chicks has been estimated to be from 2.0 g to 2.2 g for starter period and from 1.5 g to 2.0 g for grower period (NRC, 1994; Murakami et al., 1997). The control commercial feed used in this experiment contained adequate to NRC (1994) amounts of Na, which were lower when compared to the values of 2.8 g or 3.9 g/kg Na recommended by Oviedo-Rondon et al. (2001) or Borges et al. (2003). As reported by Ribero et al. (2008), during the entire period of feeding, broilers fed sodium at the level of 2.5 g and 1.7 g/kg in the starter and grower diet had the best FCR.

In contrast to our earlier findings (Koreleski et al., 2011 a, b), in the present paper the effect of electrolyte supplementation on broiler performance was not observed in the first (starter) period but only in the second period of feeding. BWG and FI in the grower period were significantly elevated when sodium was supplemented sepa-

rately (as $NaHCO_3$). A positive tendency of sodium added together with chloride as NaCl has been also observed but the effect was not significant. During the entire feeding trial, the positive effect of sodium supplementation to the diet was observed only in the case of FI. These findings may suggest that dietary Na content of 1.79 g and 1.66 g/kg was not satisfactory and its increase to 2.32 g and 2.73 g/kg positively affects broiler performance. This result agrees with the content of 2.0 to 2.5 g Na/kg found for a 29- to 42-day phase of feeding by Mushtaq et al. (2007) in subtropical conditions.

Literature data suggest that dietary chloride requirement for maximum performance in the grower period is 2.3 g/kg with DEB of 161 mEq/kg (Murakami et al., 2001), or 3.0 g/kg (Mushtaq et al., 2007). Supplementation with chloride (NH_4Cl) in our experiment had no positive effect on performance. Throughout the experiment, FI in chickens fed ammonium chloride supplemented diet was even lower ($P \leq 0.05$) than in groups fed the diet with added sodium or sodium together with chloride as NaCl. As a result of chloride supplementation the DEB value decreased to 188 mEq and 192 mEq/kg.

An adverse effect on excreta scores and dry matter content of increasing DEB value as a result of higher Na content and lower Cl content in the diets was reported by Ravindran et al. (2008). The excess of dietary cations (K^+ and Na^-) promotes the increase in litter moisture and water intake whereas the increase of chloride anions seems to be unrelated to the moisture of droppings (Oviedo-Rondon et al., 2001). The results of our experiment did not confirm the existence of this effect on litter quality when diets contained 8.37 and 8.27 g of potassium; 1.79–2.09 and 1.66–1.96 g of sodium; and 3.17–3.67 and 2.76–3.26 g of chloride per kg of starter and grower diet.

Mushtaq et al. (2007) reported that high dietary sodium content (3 g/kg) tended to increase breast yield and decrease abdominal fat but diets with high chloride content (4 g/kg) increased dressing percentage in chickens. In our field experiment the different content of dietary electrolytes did not affect the slaughter results in chicks.

In conclusion, in the field experiment with broiler chickens receiving commercial feed mixtures with elevated potassium content, the BWG and FI were significantly elevated when 0.3 g sodium was supplemented separately as $NaHCO_3$ to the diet. As analysed, dietary sodium content increased from 1.66 g to 1.96 g/kg and DEB from 206 mEq to 219 mEq/kg. A tendency towards a positive effect of sodium added together with chloride as NaCl (DEB values were not changed as compared to the control feed) has been also observed. In contrast, 0.5 g chloride added as NH_4Cl to the commercial feed mixture (containing 2.76 g/kg Cl), decreased DEB to 188 mEq and 192 mEq/kg in the starter and grower period while having no positive effect on performance.

References

AOAC (1990). Association of Official Chemists. Official methods of analysis. 15th Ed. Arlington, VA.

Borges S.A., Fisher Da Silva A.V., Ariki J., Hooge D.M., Cummings K.R. (2003). Dietary electrolyte balance for broiler chickens under moderately high ambient temperatures and relative humidities. Poultry Sci., 82: 301–308.

Koreleski J., Świątkiewicz S., Arczewska-Włosek A. (2010). The effect of dietary potassium and sodium on performance, carcass traits, nitrogen balance and excreta moisture in broiler chicken. J. Anim. Feed Sci., 19: 244–256.

Koreleski J., Świątkiewicz S., Arczewska-Włosek A. (2011 a). The effect of sodium and chloride supplements on performance, balance indices and excreta dry matter in broiler chickens fed high potassium diets. Archiv Gefluegelk., 75: 30–35.

Koreleski J., Świątkiewicz S., Arczewska-Włosek A. (2011 b). The effect of different dietary potassium and chloride level on performance and excreta dry matter in broiler chicken. Czech J. Anim. Sci., 56: 53–60.

Mongin P. (1981). Recent advances in dietary anion-cation balance applications in poultry. Proc. Nutr. Soc., 40: 285–294.

Murakami A.E., Saleh E.A., England J.A., Dickney D.A., Watkins S.E., Waldroup P.W. (1997). Effect of level and source of sodium on performance of male broilers to 56 days. J. Appl. Poult. Res., 6: 128–136.

Murakami A.E., Rondon E.O.O., Martins E.N., Pereira M.S., Scapinello C. (2001). Sodium and chloride requirements of growing broiler chickens (twenty-one to forty-two days of age) fed corn-soybean diets. Poultry Sci., 80: 289–294.

Mushtaq T., Aslam Mirza M., Athar M., Hooge D.M., Ahmad T., Ahmad G., Mushtaq M.M.H., Noreen U. (2007). Dietary sodium and chloride for twenty-nine- to forty-two-day-old broiler chickens at constant electrolyte balance under subtropical summer conditions. J. Appl. Poult. Res., 16: 161–170.

NRC (1994). Nutrient Requirements of Poultry. National Research Council. 9th Edition. National Academy Press. Washington, DC.

Oviedo-Rondon E.O., Murakami A.E., Furlan A.C., Moreira I., Macari M. (2001). Sodium and chloride requirements of young broiler chickens fed corn-soybean diets (one to twenty-one days of age). Poultry Sci., 80: 592–598.

Ravindran V., Cowieson A.J., Selle P.H. (2008). Influence of dietary electrolyte balance and microbial phytase on growth performance, nutrient utilization and excreta quality of broiler chickens. Poultry Sci., 87: 677–688.

Ribeiro A.M.I., Kessler A.M., Viola T.H., Silva I.C.M., Rubin M., Raber M., Opinheiro C., Lecznieski L.F. (2008). Nutritional interaction of methionine sources and sodium and potassium levels on broiler performance under Brazilian summer conditions. J. Appl. Poult. Res., 17: 69–78.

Vieira S.L., Lima I.L. (2005). Live performance, water intake and excreta characteristics of broilers fed all vegetable diets based on corn and soybean meal. Internat. J. Poult. Sci., 4: 365–368.

Volhard J. (1874). Ueber eine neue Methode der Massanalytischen Bestimmung des Silbers. J. Practical Chem., 9: 217–224.

Ziołecki J., Doruchowski W. (1989). The method for evaluation of poultry carcass (in Polish). COBRD, Poznań, pp. 1–30.

Accepted for printing 4 V 2011

JERZY KORELESKI, SYLWESTER ŚWIĄTKIEWICZ, ANNA ARCZEWSKA-WŁOSEK, MIECZYSŁAW SŁONECKI

Wpływ zmiany równowagi elektrolitów w mieszance paszowej na efekty odchowu brojlerów w warunkach fermowych

STRESZCZENIE

Celem pracy było sprawdzenie w fermowym żywieniu brojlerów skuteczności dodatku sodu i chloru (chlorków) do komercyjnej mieszanki paszowej zbożowo-sojowej typu starter i grower o

podwyższonym poziomie potasu. Do doświadczenia wzięto 4800 jednodniowych kurcząt Hubbard Flex, które przydzielono do 4 grup z 6 podgrupami po 200 sztuk i trzymano w boksach na ściółce słomiastej. Standardowa mieszanka paszowa na starterowy i growerowy okres żywienia zawierała w 1 kg (wg analizy): 8,37 i 8,27 g K; 1,79 i 1,66 g Na oraz Cl 3,17 i 2,76 g/kg, a wskaźnik równowagi elektrolitów DEB wyniósł 203 i 206 mEq/kg. Doświadczalne mieszanki paszowe uzupełniono dodatkiem 0,3 g Na i/lub 0,5 g Cl w postaci dwuwęglanu sodu, chlorku sodu lub chlorku amonu.

W starterowym okresie odchowu nie stwierdzono wpływu stosowanych dodatków na wskaźniki produkcyjne. W growerowym okresie żywienia dodatek sodu ($NaHCO_3$) podwyższył wartość DEB do 219 mEq/kg, istotnie zwiększając ($P \leq 0,05$) przyrost masy ciała i pobranie paszy. Niepotwierdzoną statystycznie tendencję do poprawy wskaźników produkcyjnych wykazał także równoczesny dodatek do mieszanki paszowej sodu i chloru w postaci NaCl – bez wpływu na wartość DEB. W całym okresie odchowu pozytywny efekt dodatku sodu został potwierdzony jedynie w przypadku zwiększonego pobrania paszy ($P \leq 0,05$).

Dodatek chloru (NH_4Cl) do mieszanki paszowej typu starter i grower obniżył wartość DEB do 188 i 192 mEq/kg, nie wykazując korzystnego wpływu na wskaźniki odchowu brojlerów oraz zmniejszając pobranie paszy ($P \leq 0,05$). Badane dodatki sodu i chloru nie miały wpływu na wydajność rzeźną kurcząt i zawartość tłuszczu sadełkowego w tuszce oraz nie zwiększyły stopnia zawilgocenia ściółki.