THE RESPONSE OF THE GASTROINTESTINAL TRACT OF BROILER CHICKENS TO DIFFERENT DIETARY LEVELS AND SOURCES OF SODIUM

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Abstract. The experiment was performed on 48 male meat-type Ross 308 chickens divided into six experimental groups, each of eight birds. Over a period of five weeks, the birds were fed diets containing sodium at two inclusion levels (0.15% or 0.25%) and from three sources (sodium chloride, sodium bicarbonate or sodium sulfate). The growth performance of chickens and gastrointestinal tract (GIT) parameters were studied. Different inclusion levels and sources of sodium had no effect on the final body weights of broilers and feed conversion. An increase in the sodium content of diets decreased the dry matter content of small intestinal digesta (from 17.1% to 16.1%, p = 0.038) and digesta viscosity (from 2.09 to 1.83 mPas, p = 0.046), but it had no influence on the hydration of the cecal contents. The higher dietary level of sodium enhanced the activity levels of aminopeptidase in the small intestinal mucosa (from 66.8 to 72.6 μmol/min/g of protein, p = 0.030) and microbial α-glucosidase (from 29.7 to 34.4 mol/h/g, p = 0.050), whereas it had no effect on the concentrations of short-chain fatty acids (SCFAs) in the cecal digesta. In comparison with sodium bicarbonate, sodium sulfate reduced the pH of gizzard contents (4.36 vs. 3.80, p = 0.030). Sodium sources had no effect on pH levels in the small intestine and the cecum. Compared with sodium chloride and sodium sulfate, sodium bicarbonate significantly decreased the activity levels of saccharase in the small intestinal mucosa (from 21.1 - 22.5 to 14.4 μmol/min/g of protein, p<0.001) and aminopeptidase (from 71 - 73.6 to 64.5 μmol/min/g of protein, p=0.021). Different sodium sources had no influence on the activities of the analyzed glycolytic enzymes and the production of SCFAs.

Keywords: broiler chickens, Na supplementation, sodium source, gastrointestinal tract.

VIŠČIUKŲ BROILERIŲ VIRŠKINAMOJO TRAKTO REAKCIJA Į NATRIO PRIEDŲ KIEKĮ LESALE IR NATRIO ŠALTINIUS

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Santrauka. Bandymą atlikome su 48 vyriškos lyties Ross 308 veislės viščiukais, suskirstytais į šešias grupes po aštuonis. Penkias savaites paukščiai buvo lesinami lesalais su natrio priedais (0,15 proc. arba 0,25 proc.) iš trijų šaltinių (natrio chlorido, natrio bikarbonato ir natrio sulfato). Ištirti viščiukų augimo ir virškinamojo trakto (GIT) parametrai. Skirtingas natrio kiekis lesaluose ir jo šaltiniai neturėjo įtakos galutiniam viščiukų kūno svoriui ir lesalų pasisavinamumui. Didesnis natrio kiekis lesaluose sumažino sausosios medžiagos kiekį plonosiose žarnose (nuo 17,1 proc. iki 16,1 proc.; p=0,038) ir plonųjų žarnų klampumą (nuo 2,09 iki 1,83 mPas; p=0,046), bet aklosios žarnos turinio drėgniui įtakos neturėjo. Didesnis natrio kiekis lesaluose sustiprino aminopeptidazės kiekį plonųjų žarnų gleivinėje (nuo 66,8 iki 72,6 μmol/min/g proteinų; p=0,030) ir mikrobinę alfa gliukozidazę (nuo 66,8 iki 72,6 μmol/min/g proteinų; p=0,030), tačiau nedarė poveikio mažo molekulinio svorio riebiųjų rūgščių koncentracijai aklojoje žarnoje. Palyginti su natrio bikarbonatu natrio sulfatas sumažinio pH skilvio turinyje (4,36 vs. 3,80; p=0,030). Natrio šaltiniai neturėjo įtakos pH kiekiui plonosiose ir aklojoje žarnose. Palyginti su natrio chloridu ir natrio sulfatu natrio bikarbonatas ženkliai sumažino sacharazės (nuo 21,1–22,5 iki 14,4 μmol/min/g proteinų; p<0,001) ir aminopeptidazės (nuo 71–73,6 iki 64,5 μmol/min/g proteinų; p=0,021) kiekį plonųjų žarnų gleivinėje. Skirtingi natrio šaltiniai neturėjo įtakos glikolitinių fermentų aktyvumui ir mažo molekulinio svorio riebiųjų rūgščių gamybai.

Raktažodžiai: viščiukai broileriai, natrio priedai, natrio šaltiniai, virškinamasis traktas.

Introduction. One of the common problems encountered in intensive broiler production is a high incidence of leg diseases, including foot pad dermatitis, related to inadequate housing conditions, primarily excessive litter moisture (Francesch and Brufau, 2004). The negative consequences of an increased dietary intake of sodium chloride include higher water consumption levels and a higher moisture content of litter (Mushtaq et al., 2007).

Sodium, potassium and chloride are strong ions

responsible for the acid-base equilibrium and the pH of blood and tissue, which play a particularly important role under thermal stress (Borges et al., 2003). Sodium is involved in numerous physiological processes, and it is known to affect enzyme activities and tissue protein synthesis (Olanrewaju et al., 2007). Sodium metabolism disorders and sodium-calcium interactions may contribute to the pathogenesis of skeletal muscles in broiler chickens (Sandercock and Mitchell, 2004).

In recent years, the sodium content of broiler diets has been increased since an adequate intake of dietary sodium has a beneficial influence on feed consumption and the growth rate of birds (Borges et al., 2003; Watkins et al., 2005; Mushtaq et al., 2007). The additional sodium source in chicken diets is usually sodium chloride, while the alternative source, applied during severely hot summer months, is sodium bicarbonate (Branton et al., 1986; Hooge et al., 1999). In most cases, the effects of sodium bicarbonate and sodium chloride in broiler chickens are comparable, both under thermal stress (Ahmad et al., 2006) and optimum temperature conditions (Jankowski et al., 2011a). Sodium sulfate, known as Glauber's salt and used as a laxative, has been tested as an alternative sodium source in a few experiments (Hooge et al., 1999; Ahmad et al., 2006).

Since the synergistic effect of increased levels of sodium and chloride in the ration leads to an increase in water consumption and the moisture content of excreta, there has been a growing interest in alternative sodium sources in broiler nutrition (Kidd et al., 2003; Mushtaq et al., 2005). It seems that high excreta moisture resulting from high dietary sodium intake, noted in previous experiments (Jakowski et al., 2011a, b), may be accompanied by functional gastrointestinal disorders.

The objective of this study was to determine whether a considerable increase in the sodium content of broiler diets, above the NCR recommendations (NRC, 1994), affects gastrointestinal function parameters and whether potential disorders may be prevented by the use of dietary sodium sources alternative to NaCl.

Materials and Methods. The experiment was performed on 48 male meat-type Ross 308 chickens divided into six experimental groups, each of eight birds. Over a period of five weeks, the birds were fed diets containing sodium at two inclusion levels (0.15% or 0.25%) and from three sources (sodium chloride, sodium bicarbonate or sodium sulfate). The composition of experimental diets is given in Table 1.

Table 1. **Composition and nutritional value of basal diets**

Specification	1–14 days	15–35 days
Composition, %		
Wheat	19.60	20.52
Maize	40.00	40.00
Soybean meal	34.15	30.60
Soybean oil	2.24	5.12
Limestone	1.57	1.56
Monocalcium phosphate	1.31	1.12
L-lysine 99 hydrochloride	0.27	0.26
Methionine 99 DL	0.29	0.25
L-threonine	0.07	0.07
Vitamin-mineral premix[1]	0.50	0.50
Calculated content		
ME, MJ/kg	12.35	13.18
Crude protein	21.5	20.0
Crude fiber	3.08	2.03
Lysine, %	1.30	1.20
Methionine, %	0.60	0.55
Met + Cys, %	0.97	0.90
Threonine, %	0.85	0.80
Tryptophan, %	0.26	0.24
Ca, %	0.95	0.90
Available P, %	0.45	0.40
Na, %	0.02	0.02
Cl, %	0.08	0.07
K, %	0.93	0.86

[1]content per kg premix: vitamin A – 5 000 000 IU, vitamin D_3 – 1 400 000 IU, vitamin E – 18 200 mg, vitamin K_3 – 1200 mg, vitamin B_1 – 600 mg, vitamin B_2 – 2 000 mg, vitamin B_6 – 1 200 mg, vitamin B_{12} – 8 000 mg, biotin (H) – 80 000 mg, Fe – 20 000 mg, Mn – 40 000 mg, Zn – 36 000 mg, Cu – 6 000 mg, J – 400 mg, Se – 140 mg, calcium pantothenate – 4 800 mg, nicotinic acid – 20 000 mg, folic acid – 400 mg, choline chloride – 380 mg.

Table 2 presents the levels of diet supplementation with different sodium sources and the content of sodium, potassium and chloride in grower diets. Sodium chloride, sodium bicarbonate and sodium sulfate were added to basal diets in the form of a 1% premix prepared under laboratory conditions, which was mixed thoroughly with feed.

Table 2. **Supplementation of grower diets with different sodium sources and the content of sodium, potassium and chloride in the diet**

Na source	Supplemented Na source, %	Supplemented Na, %	Content in the diet, %		
			Na	K	Cl
NaCl	0.382	0.15	0.16	0.96	0.36
$NaHCO_3$	0.548		0.16	0.96	0.11
Na_2SO_4	0.463		0.16	0.97	0.12
NaCl	0.636	0.25	0.29	0.91	0.52
$NaHCO_3$	0.913		0.28	0.96	0.10
Na_2SO_4	0.772		0.31	0.98	0.11

All experimental diets were prepared using identical components whose nutritive value corresponded to the nutrient requirements of broiler chickens aged 1–14 and 15–35 days (NRC, 1994). Detailed information on the composition of basal diets, analysis of the mineral content of diets and broiler management conditions can be found in our previous paper (Jankowski et al., 2011b) describing an experiment which involved three sources and three dietary inclusion levels of sodium.

Broilers representing the average body weight of each group were selected for an evaluation of gastrointestinal function and development. Birds were sacrificed by cervical dislocation. After laparatomy, segments of the digestive tract (small intestine and cecum) were removed and weighed. As soon as possible after euthanasia (ca. 20 min), ileal and cecal pH was measured using a microelectrode and a pH/ION meter (model 301, Hanna Instruments, Vila do Conde, Portugal). The small intestine was divided into four equal sections, and the second section (jejunum) from the duodenum end was rinsed with ice-cold physiological saline and cut open. Mucosal samples were collected by scraping with glass slides on an iced glass plate, weighed and subsequently stored at -20ºC. Digesta taken from the last two sections of the small intestine were used for an immediate analysis of dry matter, viscosity and pH. Cecal contents, after storage at 70°C, were used for determination of microbial enzyme activity and SCFA concentrations. The ceca were flushed with water, blotted on filter paper and weighed.

For digesta viscosity measurements, the contents of the small intestine were collected, mixed on a vortex mixer, and centrifuged at 7.211 x g for 10 min at 21^0C. The supernatant (0.5 ml) was placed in a Brookfield LVDV-II+ cone-plate rotational viscometer (CP40; Brookfield Engineering Laboratories Inc., Stoughton, MA) and viscosity was measured at a fixed temperature of 39ºC and a shear rate of 60 per minute.

Mucosal sucrase and maltase activities were assayed by the method of Dahlqvist (1964). The amount of liberated glucose was measured spectrophotometrically and the enzyme activity was expressed as µmol disaccharide hydrolyzed per minute and gram of protein. The protein content of ileal mucosa was determined by the method proposed by Lowry (Lowry et al., 1951) using bovine serum albumin as a standard.

Bacterial glycolytic activity in the cecal digesta was measured as the rate of *ρ*- or *o*- nitrophenol release from nitrophenylglucosides, as described by Juśkiewicz and Zdunczyk (2004). The following substrates were used: *ρ*-nitrophenyl-*α*-D-glucopyranoside (for *α*-glucosidase), *ρ*-nitrophenyl-*β*-D-glucopyranoside (for *β*-glucosidase), *ρ*-nitrophenyl-*α*-D-galactopyranoside (*α*-galactosidase), *o*-nitrophenyl-*β*-D-galactopyranoside (*β*-galactosidase), and *ρ*-nitrophenyl-*β*-D-glucuronide (for *β*-glucuronidase). The reaction mixture contained 0.3 mL of a substrate solution (5 mM) and 0.2 mL of a 1:10 (w/w) dilution of the cecal sample in 100 mM phosphate buffer (pH 7.0) after centrifugation at 7.211 × g for 15 minutes. Incubation was carried out at 39ºC and *ρ*-nitrophenol was quantified at 400 nm and at 420 nm (*o*-nitrophenol concentration) after the addition of 2.5 mL of 0.25 M cold sodium carbonate. Enzymatic activity (*α*- and *β*-glucosidase, *α*- and *β*-galactosidase, and *β*-glucuronidase) was expressed as µmol product formed per min (IU) per g of digesta.

Cecal digesta samples were subjected to a short-chain fatty acid (SCFA) analysis using gas chromatography (Shimadzu GC-2010; Shimadzu, Kyoto, Japan). The samples (0.2 g) were mixed with 0.2 mL formic acid, diluted with deionized water and centrifuged at 7.211 × g for 10 min. The supernatant was loaded onto a capillary column (SGE BP21, 30 m × 0.53 mm) using an on-column injector. The initial oven temperature was 85^oC, and it was raised to180ºC by 8ºC/min and held for 3 minutes. The temperatures of the flame ionization detector and the injection port were 180ºC and 85ºC, respectively. The sample volume for GC analysis was 1 µL. The cecal SCFA pool size was calculated as the sum of SCFA concentrations in the digesta and cecal digesta weight.

The STATISTICA software package version 8.0 (StatSoft Corp., Cracow, Poland) was used to determine whether variables differed among treatment groups. Two-way ANOVA was performed to assess the effects of the inclusion level of sodium from the applied sodium (0.15 and 0.25%), the type of sodium salt (NaCl, $NaHCO_3$ and Na_2SO_4) and the interaction between sodium dosage and sodium salt type (D×S). Differences were considered to be significant at $p \leq 0.05$.

Results. The final body weights of chickens were similar in all groups, irrespective of the experimental factors (Table 3).

Table 3. **Final body weight (FBW) and feed conversion ratio** (FCR)

Supplemented Na, %	Na source	FBW, kg	FCR, kg/kg
0.15	NaCl	1.89 ± 0.18	1.79 ± 0.17
	$NaHCO_3$	1.95 ± 0.12	1.69 ± 0.10
	Na_2SO_4	1.89 ± 012	1.67 ± 0.06
0.25	NaCl	1.91 ± 0.18	1.69± 0.04
	$NaHCO_3$	1.88 ± 0.16	1.79 ± 0.07
	Na_2SO_4	1.93 ± 0.10	1.70 ± 0.05
Na addition			
0.15%		1.91 ± 0.14	1.72 ± 0.12
0.25%		1.90 ±0.14	1.73 ± 0.07
p		0.908	0.797
Na source			
NaCl		1.90 ± 0.17	1.74 ± 0.13
$NaHCO_3$		1.91 ± 0.14	1.74 ± 0.09
Na_2SO_4		1.91 ± 0.11	1.69 ± 0.05
p		0.977	0.349

There were no differences between groups with respect to small intestinal weight and the amount of cecal digesta (Table 4). The dry matter content of small intestinal digesta was lower in chickens fed diets with higher sodium content, whereas it remained at a similar level in birds fed diets supplemented with different

sodium sources. The experimental factors had no effect on the dry matter content of cecal digesta. Lower pH in the gizzard contents was observed in chickens fed sodium sulfate, and the noted difference was significant relative to sodium bicarbonate (p = 0.030). Birds fed diets with a higher sodium content, regardless of sodium sources, were characterized by lower viscosity of small intestinal digesta (p = 0.046) and higher activity of aminopeptidase in the intestinal mucosa (p = 0.030). Lower activity levels of aminopeptidase and saccharase were observed in chickens fed sodium bicarbonate (p = 0.021 and p < 0.001, respectively), compared with the other sodium sources.

Table 4. **Parameters of gastrointestinal function**

	Na addition, %			Na source			
	0.15	0.25	p	NaCl	$NaHCO_3$	Na_2SO	p
Intestinal weight, g/kg BW							
entire small intestine	34.8±3.3	35.2±3.7	0.678	33.7±3.2	35.8±4.6	35.5±2.1	0.297
cecal digesta	3.85±1.17	3.99±1.27	0.744	3.41±1.47	4.19±1.01	4.16±1.00	0.230
Dry matter content of digesta, %							
small intestine	17.1^{a}±1.5	16.1^{b}±1.3	0.038	16.6±1.6	16.7±1.5	16.6±1.4	0.991
cecum	17.0±2.88	17.0±3.20	0.976	16.9±3.79	17.3±2.49	16.9±2.83	0.934
pH of digesta							
gizzard	4.23±0.50	3.99±0.72	0.164	4.17^{ab}±0.49	4.36^{a}±0.20	3.80^{b}±0.88	0.030
small intestine	5.68±0.25	5.71±0.29	0.767	5.67±0.42	5.68±0.15	5.73±0.17	0.848
cecum	6.42±0.21	6.49±0.23	0.309	6.48±0.28	6.42±0.22	6.48±0.15	0.741
Viscosity of SI, mPas	2.09^{a}±0.4	1.83^{b}±0.3	0.046	2.03±0.6	2.04±0.2	1.80±0.3	0.238
Mucosal enzyme activity, μmol/min/g of protein							
saccharase	18.8±5.9	19.8±3.4	0.346	22.5^{a}±3.7	14.4^{b}±3.5	21.1^{a}±2.5	<0.001
maltase	93.2±14.2	98.5±13.2	0.243	97.2±12.3	89.9±14.6	100.5±13.2	0.156
aminopeptidase	66.8^{b}±10.6	72.6^{a}±8.1	0.030	73.6^{a}±6.3	64.5^{b}±11.7	71.0^{a}±8.9	0.021

Table 5. **Parameters of cecal ecosystem function**

	Na addition, %			Na source			
	0.15	0.25	p	NaCl	$NaHCO_3$	Na_2SO	p
Microbial enzyme activity, mol/h/g							
α-glucosidase	29.7^{b}±6.8	34.4^{a}±7.3	0.050	31.8±10.6	31.3±4.9	32.9±5.6	0.852
β -glucosidase	6.86±2.2	8.23±1.9	0.063	7.30±2.7	7.39±2.2	7.95±1.5	0.727
α-galactosidase	36.9±11.8	42.5±13.4	0.180	39.7±16.7	36.8±9.7	42.6±11.4	0.518
β-galactosidase	45.7±16.5	42.9±16.1	0.571	42.0±19.4	42.2±10.6	48.6±17.5	0.469
β-glucuronidase	33.1±10.9	35.6±10.4	0.496	34.8±11.6	32.9±12.5	35.4±7.8	0.855
SCFA concentrations, μmol/g							
acetic acid	74.6±8.1	68.9±9.2	0.065	70.4±9.7	72.2±9.0	72.7±9.0	0.804
propionic acid	11.0±2.5	10.4±2.1	0.456	10.8±1.9	10.3±2.1	11.0±2.9	0.749
iso-butyric acid	2.15±0.44	2.06±0.32	0.502	2.11±0.39	2.20±0.24	2.01±0.50	.531
butyric acid	18.5±4.6	21.0±7.5	0.127	17.8±4.9	21.2±9.1	20.3±3.3	0.216
iso-valeric acid	2.45±0.71	2.31±0.62	0.539	2.41±0.45	2.49±0.65	2.24±0.85	0.650
valeric acid	4.46±1.46	4.00±0.65	0.220	3.97±0.65	4.15±0.82	4.56±1.68	0.417
Total SCFAs	113.2±13.9	108.7±17.1	0.383	107.5±16.3	112.5±16.9	112.8±14.0	0.633

Higher activity of α-glucosidase (p = 0.050) and lower concentrations of acetic acid (p = 0.065) were noted in the cecal digesta of broilers fed diets with an increased sodium content (Table 5). No significant differences were found in the activity levels of the other enzymes in the cecal microflora and the concentrations of the other SCFAs.

Discussion. Based on the nutrient requirements of chickens (NRC, 1994), the sodium and chloride content of diets should be 0.20% at the beginning and 0.12% towards the end of fattening, whereas the recommended potassium content of the ration should not be lower than 0.30%. In the present study, the lower inclusion levels of sodium chloride, sodium bicarbonate and sodium sulfate were similar to the average values recommended by NRC (1994) for the starter and grower period. As a result of the higher sodium addition, the recommended dietary sodium intake for broiler chickens was exceeded by nearly a half in the starter period, and over twofold in the grower period. In all diets, the concentrations of potassium

coming from feed components exceeded the recommended dietary allowance threefold. The inclusion of sodium chloride in experimental diets resulted in exceeding the recommended chloride intake, whereas in the other groups the chloride content of diets corresponded to the NRC recommendations (1994). The differences in the electrolyte content of diets had no effect on the final body weights of chickens and feed conversion. In many experiments (Watkins et al., 2005; Mushtaq et al., 2007), the growth performance of birds was improved when the sodium content of feed was increased to 0.2–03%. No such trend was noted in our study (Jankowski et al., 2011a, b).

The absence of differences in the final body weights of chickens fed diets supplemented with sodium chloride, sodium bicarbonate and sodium sulfate is consistent with the findings of Hooge et al. (1999). In the cited study, the above sodium sources supplied 0.20% dietary sodium. Similar fattening performance of broilers was observed by Damron et al. (1986) in an experiment involving two dietary sodium sources, sodium chloride and sodium bicarbonate. In another study, sodium bicarbonate improved the growth rate of heat-stressed broiler chickens more effectively than other sodium sources (Ahmad et al., 2006).

In our experiment, different electrolyte composition of feed affected selected parameters of the upper GIT. The higher sodium supplementation level increased the hydration of the small intestinal contents and decreased digesta viscosity, most probably due to increased water consumption. Such relationships were also reported by other authors (Murakami et al., 2001; Borges et al., 2003; Mushtaq et al., 2007) who studied the effects of increased dietary sodium intake by broiler chickens. In the present study, the higher sodium inclusion level had no influence on the activity of glycolytic enzymes, but it enhanced the activity of aminopeptidase in the intestinal mucosa. This accords with the results of an earlier experiment where an increase in dietary sodium intake enhanced the activity of intestinal ATPases (Gal-Garber et al., 2003).

Sodium bicarbonate reduced the activity of saccharase in the small intestinal mucosa and aminopeptidase, in comparison with sodium chloride and sodium sulfate. This could result from differences in the electrochemical properties of ions released from additional sodium sources. In the dietary electrolyte balance, sodium is balanced by chloride and, to a lesser extent, by bicarbonate (Mongin, 1981). Divalent anions, such as anion sulfate (SO_4^{2-}), have weaker effects than monovalent elements (Hooge, 1995).

A drop in the pH of the gizzard contents was noted in chickens fed diets containing sodium sulfate, which was the only difference between this sodium source and sodium chloride. The water content of intestinal digesta did not increase. This is an important consideration since sodium sulfate (Glauber's salt) is an osmotic laxative used in both veterinary and human medicine to accelerate the passage and excretion of drugs in the case of an overdose (Cocchetto and, 1981). An analysis of the dry matter content of excreta revealed that the applied amount of sodium sulfate decreased the moisture content of the droppings, compared with sodium chloride and sodium bicarbonate (Jankowski et al. 2011b).

The higher dietary inclusion level of sodium chloride had an insignificant effect on cecal parameters. It enhanced the activity of microbial α-glucosidase, but it did not increase the concentrations of SCFAs in the cecal contents. Similar results were obtained in our previous experiment (Jankowski et al., 2011a) where chickens were fed diets with 0.17% and 0.26% sodium. In the current study, no differences were found in the cecal parameters of broilers receiving diets supplemented with sodium chloride, sodium bicarbonate and sodium sulfate. The administered dose of sodium sulfate had no effect on the activity of cecal microflora. As demonstrated by medical analyses, dietary sulfate may affect colonic pathophysiology because sulfate availability determines in part the activity of sulfate reducing bacteria in the bowel (Florin et al., 1991). In poultry, the caecal fermentation processes may significantly be affected by the dietary presence of carbohydrates not digested in the small intestine, like mannanoligosaccharide (Juskiewicz et al., 2003; Zdunczyk et al., 2005), inulin (Juskiewicz et al., 2005; Zdunczyk et al., 2005), fructooligosacharides (Juskiewicz et al., 2006, 2008), and α-galactosides (Jankowski et al., 2009; Zdunczyk et al., 2010; Juskiewicz et al., 2010).

Conclusions. The results of this study show that an increase in the sodium content of broiler diets, from 0.16% to approximately 0.30%, led to minor changes in the gastrointestinal tract of birds, limited to increased hydration and decreased viscosity of small intestinal digesta and enhanced activity of aminopeptidase in the intestinal mucosa, whereas that it had no considerable influence on fermentation processes in the cecum. Alternative sodium sources, other than sodium chloride, had an insignificant effect on the analyzed parameters: sodium bicarbonate reduced the activity levels of saccharase and aminopeptidase in the intestinal mucosa, and sodium sulfate decreased the pH of the gizzard contents. The noted differences did not affect the final body weights of chickens.

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