Poultry Science

Chromium propionate in turkeys: effect on performance and animal safety

J. W. Spears,[*] K. E. Lloyd,[*] K. Flores,[†,1] K. Krafka,[‡] J. Hyda,[‡] and J. L. Grimes[†,2]

[*]Department of Animal Science, North Carolina State University, Raleigh, NC 27695-7621, USA; [†]Prestage Department of Animal Science, North Carolina State University, Raleigh, NC 27695-7608, USA; and [‡]Kemin Agrifoods North America, Inc., Des Moines, IA 50317, USA

ABSTRACT Two hundred eighty-eight male Nicholas Large White turkey poults were used to determine the effect of supplementing turkeys with chromium propionate (Cr Prop) from 1 to 84 d of age on performance and animal safety. Treatments consisted of Cr prop supplemented to provide 0, 0.2, or 1.0 mg Cr/kg diet. One mg of supplemental Cr is 5 times (x) the minimal concentration of Cr Prop that enhanced insulin sensitivity in turkeys. Each treatment consisted of 8 floor pens with 12 poults per pen. Turkeys were individually weighed initially, and at the end of the starter 1 (d 21), starter 2 (d 42), grower 1 (d 63), and grower 2 phase (d 84). On d 85, blood was collected from the wing vein in heparinized tubes from 2 turkeys per pen for plasma chemistry measurements. A separate blood sample was collected from the same turkeys in tubes containing K_2EDTA for hematology measurements. Turkey performance was not affected by treatment during the starter 1 phase. Gain was greater (P = 0.024) and feed/gain lower (P = 0.030) for turkeys supplemented with Cr compared with controls during the starter 2 phase. Over the entire 84-d study turkeys supplemented with Cr had greater (P = 0.005) ADG and tended (P = 0.074) to gain more efficiently than controls. Gain (P = 0.180) and feed/gain (P = 0.511) of turkeys supplemented with 0.2 mg Cr/kg did not differ from those receiving 1.0 mg Cr/kg over the entire 84-d study. Feed intake was not affected by treatment. Body weights of turkeys supplemented with Cr were heavier (P = 0.005) than controls by d 84. Chromium supplementation did not affect hematological measurements and had minimal effect on plasma chemistry variables. Results of this study indicates that Cr Prop supplementation can improve turkey performance, and is safe when supplemented to turkey diets at 5x the minimal concentration that enhanced insulin sensitivity.

Key words: chromium propionate, turkeys, performance, animal safety

2024 Poultry Science 103:103195
https://doi.org/10.1016/j.psj.2023.103195

INTRODUCTION

Trivalent chromium (**Cr**) functions to potentiate insulin action in insulin-sensitive tissues (Spears, 2019). Although poultry are more resistant to insulin than mammals (Scanes, 2009), research clearly indicates insulin plays a role in glucose homeostasis in chicks (Akiba et al., 1999; Tokushima et al., 2005; Duport et al., 2008). Chromium propionate (Cr Prop) enhanced insulin sensitivity in broilers (Brooks et al., 2016). In 2016, Cr Prop was approved by the US Food and Drug Administration Center for Veterinary Medicine (FDA), via a food additive petition, as a source of supplemental Cr in broiler diets (FDA, 2016). FDA approval of Cr Prop for broilers was based on a utility study demonstrating increased insulin sensitivity and animal and human food safety studies (Spears et al., 2019). Chromium Prop is the only source of Cr approved for supplementation to broiler diets in the US, and can be supplemented at a concentration up to 0.20 mg Cr/kg diet. Supplementation of Cr Prop increased gain (Van Hoeck et al., 2020) and breast muscle yield in broilers raised under normal conditions (Rajalekshmi et al., 2014; Zheng et al., 2016). Hormones produced during heat stress and other types of stress reduce insulin sensitivity in broilers (Zhao et al., 2009). Chromium Prop improved BW gain (Huang et al., 2016) and duodenal morphology (Huang et al., 2020) in broilers reared under heat stress conditions.

Turkey studies evaluating Cr supplementation are limited, and no Cr source is currently approved for supplementation to turkey diets. Early studies indicated inorganic Cr supplementation at a relatively high level (20 mg Cr/kg diet) increased BW gain in turkeys from 1

Received July 28, 2023.
Accepted October 11, 2023.

[1]Present address: Micronutrients USA, Indianapolis, IN 46421, USA.
[2]Corresponding author: jgrimes@ncsu.edu

to 21d of age (Rosebrough and Steele, 1981; Steele and Rosebrough, 1981). Supplementing turkeys with Cr nicotinate from 9 to 22 wk of age increased BW gain and breast and thigh weights (Chen et al., 2001). Recently, Cr Prop was shown to enhance insulin sensitivity in turkeys following fasting and refeeding (Spears et al., 2023). One component of the FDA food additive petition for Cr Prop regulatory approval involves demonstrating target animal safety when Cr Prop is supplemented at a feeding level above the expected approval level. The present study was conducted to determine the effect of supplementing turkeys with Cr Prop, at 1 and 5 times the minimal concentration shown to increase insulin sensitivity, from 1 to 84 d of age on performance and animal safety.

MATERIALS AND METHODS

Experimental Design

Two hundred eighty-eight (288) male 1-day-old turkey poults (Nicholas Large White; sourced from Prestage Farms, Inc., Clinton, NC 28328) were used in this study. The poults were identified with wing bands and randomly assigned to treatments. Treatment pens were set up in the house as a completely randomized design. Treatment consisted of: 1) control (no supplemental Cr), 2) 0.20 mg of supplemental Cr (from KemTRACE Cr Prop) per kg of diet and 3) 1.0 mg of supplemental Cr (from Cr Prop) per kg of diet. One mg of supplemental Cr per kg of diet is 5 times (x) the minimal level of Cr Prop that increased insulin sensitivity in turkeys (Spears et al., 2023).

Each treatment consisted of 8 replicate floor pens, and 12 poults were housed per pen. Floor pens were covered with fresh Pine wood shavings. Turkeys that died the first 6 d of the study were replaced with birds that had received the control diet. Birds that died or were euthanized after d 6 were necropsied at the North Carolina Veterinary Diagnostic Laboratory in Raleigh, NC. Turkeys were fed experimental diets for 84 d.

Housing and Diets

Pens had individual dimensions of 4.57 m x 1.83 m, and were set-up with individual waterers, feeders, heat lamps, and fresh Pine wood shavings covering the floor. The house was set up with a 24:0 (light:dark) cycle for the first 9 d of the study and then a 23:1 cycle thereafter. The initial house temperature was set at 35.5°C when poults were placed. House temperature settings were reduced to 27°C on d 14, 23°C on d 22, 21°C on d 30, and 18.5°C on d 42 of the study. Due to outside ambient temperature, house temperatures ranged from 37°C to 16°C over the course of the study.

Ingredient composition of the basal diets is shown in Table 1. Calculated levels of nutrients in diets are shown in Table 2. The diets were formulated to meet or exceed National Research Council (NRC, 1994) requirements for turkeys. The starter 1 diet was fed from 1 to 21 d, the starter 2 diet from 21 to 42 d, the grower 1 diet from 42 to 63 d, and the grower 2 diet was fed from 63 to 84 d. One base mix of each basal diet was produced for each phase of the study. Treatment diets were then prepared by mixing 1% of a corn-Cr Prop premix with 99% base mix. Chromium propionate was mixed with finely ground corn to provide 0, 0.20, or 1.0 mg Cr/kg of diet, when added at 1% to the base mix. Diets were offered ad libitum in crumble form for the starter 1 and starter 2 phases, and in pellet form for the grower 1 and grower 2 phases. Feed was provided in self-feeders, and feed disappearance was measured each time diets were changed. Water was available ad libitum throughout the study.

Turkeys were individually weighed on d 1, 21, 42, 63, and 84 of the study. Birds were observed daily for general health. Turkeys that died or were euthanized because of leg abnormalities, dropped crop, breathing

Table 1. Ingredient composition of basal turkey diets.[1]

Ingredient	Starter 1 %	Starter 2 %	Grower 1 %	Grower 2 %
Ground corn	22.2	28.8	33.0	36.3
Ground wheat	15.0	15.0	15.0	15.0
Soybean meal 47%	48.0	41.5	38.0	35.0
Poultry fat	7.42	7.8	7.7	8.02
Limestone	2.5	2.3	2.1	1.90
Mono-dicalcium phosphate	2.9	2.65	2.4	2.15
L-Lysine	0.35	0.375	0.275	0.20
DL-Methionine	0.40	0.35	0.325	0.26
Threonine	0.075	0.075	0.05	0.025
Sodium bicarbonate	0.25	0.25	0.25	0.25
Selenium premix (0.06% Se)	0.05	0.05	0.05	0.05
Sodium chloride (salt)	0.25	0.25	0.25	0.25
Choline chloride (60%)	0.20	0.20	0.20	0.20
Trace mineral premix[2]	0.20	0.20	0.20	0.20
Vitamin premix[3]	0.20	0.20	0.20	0.20

[1]Chromium propionate will be added at the appropriate levels for the various treatments after basal diets are mixed and split.

[2]Provided per kg of diet: 120 mg Zn (from $ZnSO_4$), 120 mg Mn (from $MnSO_4$), 80 mg Fe (from $FeSO_4$), 10 mg Cu (from $CuSO_4$), 2.5 mg I (from $CaIO_4$).

[3]Provided per kg of diet: vitamin A, 26,455 IU; vitamin D, 7,937 IU; vitamin E, 132 IU; vitamin B_{12}, 0.08 mg; riboflavin, 26.4 mg; niacin, 220 mg; d-pantothenate, 44 mg; menadione, 7.9 mg; folic acid, 4.4 mg; thiamine, 7.9 mg; pyridoxine, 15.8 mg; d-biotin, 0.50 mg.

Table 2. Calculated composition of diets.

Nutrient	Starter 1	Starter 2	Grower 1	Grower 2
DM, %	88.9	88.7	88.6	88.5
CP, %	28.2	25.3	23.7	22.3
Crude fat, %	9.5	10.4	10.5	10.4
Crude fiber, %	2.6	2.5	2.5	2.4
ME, kcal/kg	2,899	3,011	3,069	3,139
Total methionine, %	0.74	0.66	0.62	0.55
Total cystine, %	0.35	0.32	0.31	0.30
Total lysine, %	1.74	1.60	1.43	1.30
Total tryptophan, %	0.35	0.32	0.29	0.28
Total threonine, %	1.03	0.93	0.86	0.79
Total isoleucine, %	1.14	1.02	0.95	0.90
Total histidine, %	0.62	0.56	0.54	0.51
Total valine, %	1.23	1.11	1.04	0.99
Total leucine, %	1.95	1.79	1.71	1.64
Total arginine, %	1.78	1.58	1.48	1.40
Total phenylalanine, %	1.26	1.13	1.06	1.00
Ca, %	1.54	1.42	1.30	1.18
Available P, %	0.74	0.68	0.86	0.56
Na, %	0.19	0.18	0.19	0.18

problems, or general unthriftiness were necropsied at the North Carolina Veterinary Diagnostic Laboratory in Raleigh, NC.

Sampling

Samples of experimental diets were collected weekly and composited by phase for Cr analysis. Water samples were also collected weekly for Cr analysis. At the termination of the study (d 85), blood was collected from the wing vein in heparinized tubes from 2 representative turkeys per pen (closest to mean d 84 weight). Turkeys were harvested by block with each block consisting of 1 pen per treatment. Heparinized blood samples were placed on ice until centrifuged at 1,200 x g for 20 min at 10°C and plasma was obtained for blood chemistry analysis. A separate sample of whole blood was collected from the same turkeys in tubes containing K_2EDTA for hematology measurements.

Analysis

Plasma was analyzed for an avian chemistry panel that included glucose, uric acid, phosphorus, calcium, sodium, potassium, chloride, HCO_3, total protein, albumin, globulin, cholesterol, hemoglobin, alkaline phosphatase (**ALP**), aspartate aminotransferase (**AST**), lactate dehydrogenase (**LD**), lipase, and creatine kinase (**CK**). The whole blood sample was used for determination of packed cell volume, total leukocyte, lymphocyte, monocyte, eosinophil, basophil, and heterophil counts. Chemistry panel measurements (Roche Diagnostics, Cobas 6000 c501, Indianapolis, IN) and hematology measurements (Siemens, Advia 120, Malvern, PA) were performed at the Clinical Pathology Laboratory at the NCSU Veterinary School. Feed samples were prepared for Cr analysis by wet ashing with trace metal grade nitric acid using a hot-plate procedure (Lloyd et al., 2010). Water samples were acidified with a small amount of 6N HCl on the day of collection and later analyzed for chromium without ashing.

Chromium concentrations in diets and water were measured by electrothermal atomic absorption spectrophotometry (Shimadzu, Model GFA 7000A, Kyoto, Japan). The method of standard addition was used for each tissue sample to remove matrix effects as described by Lloyd et al. (2010).

Statistical Analysis

Performance data were analyzed statistically as a completely randomized design by analysis of variance using the Proc Mixed procedure of SAS (2016). Plasma chemistry and hematology data were analyzed as a randomized complete block design using the MIXED procedure of SAS. Sampling block served as the block. Differences among treatments were determined using single degree of freedom orthogonal contrasts. Comparisons made were: 1) control (0 added Cr) vs. the 2 Cr-supplemented treatments, and 2) 0.20 vs. 1.0 mg Cr/kg diet.

Table 3. Analyzed chromium concentrations in experimental diets from composite samples.

	Analyzed Cr, mg/kg diet (DM basis)			
Treatment	Starter 1	Starter 2	Grower 1	Grower 2
Control	2.92	2.90	2.70	3.38
Cr 0.2	3.11	3.14	2.93	3.63
Cr 1.0	4.11	4.09	3.86	4.62

RESULTS AND DISCUSSION

Diet Analysis

Analyzed Cr concentrations in composite samples of treatment diets are presented in Table 3. The control diets ranged from 2.70 to 3.38 mg Cr/kg. Chromium concentrations in the control diets were considerably higher than those observed in our broiler safety study (Spears et. al., 2019). Mono-dicalcium phosphate was used as the phosphate source in the present study. We have used food grade phosphoric acid in previous studies (Brooks et al., 2016; Spears et al., 2019,2023) to minimize Cr concentrations in the control diets. Chromium concentrations in 5 feed grade phosphate sources averaged 135 mg Cr/kg, with a range of 112 to 163 mg Cr/kg (Spears et al., 2017). Therefore, the addition of 2% mono-dicalcium phosphate to the diet would provide approximately 2.7 mg Cr/kg diet. The amount of mono-dicalcium phosphate supplemented in the present study ranged from 2.15% to 2.9%. Analyzed Cr concentrations in Cr Prop supplemented treatments were in line with expected values. Water samples obtained averaged 0.78 ng Cr/ml.

Mortality

Two turkeys in the control and 1.0 mg Cr/kg treatments, and one bird in the 0.2 mg Cr/kg treatment were found dead the first 6 d. After the initial 6-d replacement period, 3 control turkeys, one in the 0.2 mg Cr group, and 2 in the 1.0 mg Cr/kg treatment were necropsied. The report for the 3 control turkeys indicated: 1) pendulous crop, 2) small for its age and postmortem autolysis made it difficult to evaluate, and 3) undetermined. The turkey in the 0.20 mg Cr treatment died from liver cirrhosis and heart failure. The report for the 2 turkeys in the 1.0 mg Cr treatment necropsied indicated: 1) pendulous crop, and 2) mild dyschondroplasia of the tibiotarsi with internal bleeding.

Turkey Performance

Turkey BW were greater ($P = 0.005$) in Cr-supplemented turkeys compared to controls by d 63 and remained heavier ($P = 0.005$) on d 84 (Table 4). Final

Table 4. Effect of dietary chromium on turkey body weights.[1]

	Supplemental Cr, mg/kg diet[2]				*P*-value		
	0	0.2	1.0	SEM	Treatment	0 vs. Cr	0.2 vs. 1.0
BW, g							
Day 1	59.5	59.6	59.8	0.46	0.854	0.643	0.759
Day 21	616	617	616	16.9	0.999	0.996	0.966
Day 42	2,144	2,249	2,250	45.7	0.194	0.073	0.997
Day 63	4,883	5,152	5,379	98.4	0.007	0.005	0.117
Day 84	8,623	9,026	9,304	141.7	0.010	0.005	0.179

[1]Means represent the average of 8 pens.
[2]Provided from KemTRACE chromium propionate.

BW did not differ ($P = 0.179$) amount turkeys supplemented with 0.20 and 1.0 mg Cr/kg diet.

Turkey performance by period is shown in Table 5. Intake, ADG, and feed/gain were similar across treatments during the starter 1 period (d 1−21). During the starter 2 period (d 21−42) ADG was greater ($P = 0.024$) and feed/gain lower ($P = 0.030$) for turkeys supplemented with Cr compared with controls. Gain of turkeys supplemented with Cr was greater than controls ($P = 0.006$) during the grower 1 period (d 42−63). Turkeys supplemented with 1.0 mg Cr/kg also had greater ($P = 0.040$) ADG than those supplemented with 0.20 mg Cr/kg during the grower 1 period. Performance was not significantly affected by treatment during the grower 2 period (d 63−84).

Over the entire 84-d study ADFI was not affected by treatment (Table 5). Turkeys supplemented with Cr had greater ($P = 0.005$) ADG and tended ($P = 0.074$) to gain more efficiently than controls. Feed/gain ($P = 0.511$) and ADG ($P = 0.180$) did not differ amount the Cr-supplemented treatments. In our insulin sensitivity study Cr supplementation did not affect turkey performance during the 34-d study (Spears et al., 2023). Chromium supplementation did not affect gain until after 21 d in the present study. The insulin sensitivity study was conducted in battery cages with 6 to 7 birds per cage. The current study was conducted under more practical conditions in floor pens, covered with wood shavings, and 12 birds housed per pen.

We have avoided using feed grade sources of phosphorus in previous poultry studies because of their high Cr content. In the present study feed grade mono-dicalcium phosphate was used as the supplemental phosphorus source, because we were not attempting to get the control diet as low as possible in Cr. Using feed grade phosphorus in the present study greatly increased Cr concentrations in the control diets. Although the control diets analyzed over 2.5 mg Cr/kg, the addition of supplemental Cr, from Cr Prop, increased ADG and final BW. This suggests that the Cr in the control diets was poorly bioavailable.

Earlier studies with turkeys supplemented with relatively high concentrations of Cr (20 mg Cr/kg diet), from inorganic $CrCl_3$, indicated that performance responses to Cr supplementation were affected by CP and niacin content of the diet (Steele and Rosebrough., 1979; Rosebrough and Steele, 1981). Gain from 7 to 21 d of age was increased by Cr supplementation in turkeys

Table 5. Effect of supplemental chromium on turkey performance by period.[1]

	Supplemental Cr, mg/kg diet[2]				*P*-value		
Item	0	0.2	1.0	SEM	Treatment	0 vs. Cr	0.2 vs. 1.0
Starter 1 (d 1−21)							
ADFI, g/d	52.6	49.7	49.6	1.54	0.324	0.138	0.959
ADG, g/d	26.5	26.5	26.5	0.80	0.999	0.995	0.958
Feed/gain	1.99	1.88	1.90	0.08	0.607	0.337	0.815
Starter 2 (d 21−42)							
ADFI, g/d	145.0	144.8	137.7	5.4	0.560	0.579	0.361
ADG, g/d	72.8	77.8	77.8	1.7	0.074	0.024	0.980
Feed/gain	1.99	1.87	1.77	0.06	0.053	0.030	0.258
Grower 1 (d 42−63)							
ADFI, g/d	269.1	276.3	284.0	7.4	0.383	0.237	0.476
ADG, g/d	130.4	138.2	149.0	3.5	0.004	0.006	0.040
Feed/gain	2.06	2.01	1.91	0.05	0.100	0.098	0.158
Grower 2 (d 63−84)							
ADFI, g/d	425.1	428.8	441.6	10.6	0.523	0.443	0.404
ADG, g/d	178.1	184.5	186.9	3.3	0.173	0.074	0.610
Feed/gain	2.38	2.33	2.36	0.05	0.761	0.580	0.632
Overall (d 1−84)							
ADFI, g/d	222.9	224.9	228.2	5.5	0.794	0.596	0.679
ADG, g/d	101.9	106.7	110.1	1.6	0.010	0.005	0.180
Feed/gain	2.18	2.11	2.08	0.04	0.162	0.074	0.511

[1]Means represent an average of 8 pens.
[2]Provided from KemTRACE chromium propionate.

fed a control diet supplemented with 100 mg niacin/kg diet (Steele and Rosebrough, 1979). However, Cr supplementation did not affect gain when the control diet was supplemented with an additional 250 mg niacin/kg (Steele and Rosebrough, 1979). In the present study niacin was supplemented at 220 mg/kg diet. Chromium supplementation also increased gain and feed intake from 7 to 21 d of age in turkeys fed diets low in CP (23%) but not in those receiving diets containing 30% CP. The starter 1 diet used in the present study contained 31.6% CP on a DM basis. More recent studies also indicate that Cr addition to turkey diets can improve performance. Supplementing male turkeys, 8 wk of age, with 1.0 mg Cr/kg diet, from Cr nicotinate, increased gain from 9 to 18 wk of age (Chen et al., 2001). Supplementing 16-wk-old male turkeys for 24 wk with 0.75 mg Cr/kg, from Cr picolinate, increased eviscerated yield, and breast, thigh, and liver weight, while decreasing shrinkage loss (Biswas et al., 2014). Furthermore, compared with controls, male turkeys receiving 0.75 mg Cr/kg had greater sperm concentration, sperm motility, and fertility (Biswas et al., 2014).

Plasma Chemistry Variables

Plasma biochemical measurements at the end of the 84-d study are presented in Table 6.

Hemoglobin, potassium, and lipase activity were the only plasma variables affected by treatment. Turkeys supplemented with Cr had greater ($P = 0.023$) hemoglobin concentrations than controls. Hemoglobin concentrations did not differ among turkeys receiving 0.20 and 1.0 mg Cr/kg. Reference ranges for serum or plasma biochemical parameters are not available for turkeys. Hemoglobin concentrations in turkeys supplemented with Cr would appear to be in the normal range based on hemoglobin concentrations reported by Huff et al. (2008) in 16-wk-old turkeys. Supplementing Cr concentrations (from Cr Prop) up to 1000 mg Cr/kg diet did not affect hemoglobin concentrations in rats (Staniek et al., 2016). Plasma potassium concentrations tended to be greater ($P = 0.083$) in turkeys supplemented with Cr compared with controls. Turkeys supplemented with 1.0 mg Cr/kg had greater ($P = 0.048$) plasma potassium concentrations than those receiving 0.20 mg/kg. Pigs supplemented with 5 mg Cr/kg, from Cr Prop, had higher serum potassium concentrations than control pigs (Lindemann et al., 2008). Previous studies have reported serum potassium concentrations of 4.2 mmol/L in 12-wk-old turkeys (Szabo et al., 2005) and 3.64 mmol/L in 6-wk-old turkeys (Cason and Teeter, 1994). The greater plasma potassium concentrations in Cr-supplemented turkeys may be due to their heavier BW. Breast meat yield is highly correlated with final BW and weight gain in turkeys (Hiscock et al., 2022). Lean body mass is highly correlated with total body potassium in humans (Corcoran et al., 2000), and plasma potassium is correlated with total body potassium in humans (Patrick, 1977). Plasma lipase activity was greater ($P = 0.020$) in turkeys supplemented with Cr compared with controls. Lipase activity did not differ ($P = 0.173$) among turkeys supplemented with 0.20 and 1.0 mg Cr/kg. We are not aware of previous studies that have reported plasma or serum lipase activity in turkeys. Plasma lipase catalyzes the hydrolysis of triglycerides to 2 fatty acids and a 2'- monoglyceride. Serum lipase is primarily derived from the pancreas with a much smaller amount coming from the gastric mucosa (Rallis et al., 1996). In acute pancreatitis serum lipase activity is greatly elevated. The serum lipase values observed in Cr-supplemented turkeys would not be considered high compared to serum lipase activity in dogs. In dogs serum lipase activity above 500 U/L is considered elevated (Rallis et al., 1996).

Table 6. Plasma clinical chemistry parameters in turkeys.[1]

	Supplemental Cr, mg/kg diet[2]				*P*-value			
Item	0	0.20	1.0	SEM	Block	Treatment	0 vs. Cr	0.2 vs. 1.0
Glucose, mg/dL	279.6	283.6	284.3	4.7	0.688	0.752	0.463	0.919
Uric acid, mg/dL	2.94	3.27	3.61	0.31	0.148	0.360	0.224	0.458
Hemoglobin, mg/dL	10.0	11.9	11.1	0.47	0.004	0.042	0.023	0.241
Phosphorus, mg/dL	6.9	7.1	6.9	0.16	0.272	0.658	0.795	0.388
Calcium, mg/dL	11.1	11.1	11.1	0.07	0.088	0.931	0.726	0.903
Sodium, mmol/L	152	151	152	0.4	0.642	0.347	0.947	0.153
Potassium, mmol/L	3.44	3.51	3.76	0.08	0.012	0.040	0.083	0.048
Chloride, mmol/L	112	111	112	0.4	0.195	0.300	0.569	0.152
Total protein, g/dL	3.51	3.45	3.43	0.04	0.149	0.336	0.162	0.676
Albumin, g/dL	1.11	1.06	1.06	0.02	0.173	0.153	0.057	1.000
Globulin, g/dL	2.41	2.39	2.37	0.04	0.451	0.791	0.609	0.658
Cholesterol, g/dL	109	108	103	2.6	0.015	0.262	0.282	0.213
Bicarbonate, mmol/L	23.6	24.2	25.1	0.50	0.016	0.156	0.122	0.233
Anion gap[3]	20.1	19.4	18.8	0.77	0.185	0.505	0.296	0.619
Lipase, IU/L	11.3	14.6	17.6	1.5	0.003	0.031	0.020	0.173
ALP, IU/L	1909	1908	1946	51.3	0.284	0.839	0.776	0.610
AST, IU/L	281	290	294	12.3	0.676	0.754	0.484	0.810
LD, IU/L	565	545	578	39.1	0.777	0.825	0.951	0.545
CK, IU/L	5392	6080	6930	795.9	0.857	0.415	0.273	0.463

[1]Each mean represents the mean of 8 pens with 2 turkeys sampled per pen.
[2]Provided from KemTRACE chromium propionate.
[3]Sodium + potassium − (chloride + bicarbonate).

Table 7. Hematological parameters in turkeys.[1]

	Supplemental Cr, mg/kg diet[2]				———— *P*-value ————			
Item	0	0.2	1.0	SEM	Block	Treatment	0 vs. Cr	0.2 vs. 1.0
WBC, $\times 10^3/\mu L$[3]	23.2	24.5	23.9	1.9	0.845	0.885	0.663	0.829
Packed cell volume, %	34.1	33.4	33.3	0.7	0.008	0.651	0.367	0.903
Lymphocytes, $10^3/\mu L$	8.33	8.87	9.24	1.03	0.686	0.820	0.570	0.801
Monocytes, $10^3/\mu L$	1.79	1.89	2.41	0.36	0.629	0.447	0.433	0.321
Eosinophils, $10^3/\mu L$	0.48	0.38	0.67	0.12	0.563	0.260	0.750	0.110
Basophils, $10^3/\mu L$	1.76	1.64	1.29	0.30	0.548	0.526	0.428	0.424
Heterophils, $10^3/\mu L$	10.74	11.80	10.44	0.99	0.220	0.606	0.754	0.350

[1]Each mean represents an average of 8 pens with 2 turkeys sampled per pen.
[2]Provided from KemTRACE chromium propionate.
[3]White blood cell count.

Hematological Parameters

Hematological measurements are shown in Table 7. Chromium supplementation did not affect any of the hematological variables.

CONCLUSIONS

The present study indicates that Cr Prop is safe when supplemented to turkey diets at 5x the minimal concentration that enhanced insulin sensitivity. Supplementation of 0.20 or 1 mg Cr/kg diet, from Cr Prop, for 12 wk increased ($P = 0.005$) ADG compared with controls. Chromium supplementation did not affect hematological measurements, and had minimal effect on plasma chemistry measurements. The concentration of Cr Prop (1.0 mg Cr/kg) supplemented in the present study was well below the maximum tolerable level for poultry that has been estimated, based on broiler data, at 500 mg Cr/kg (NRC, 2005). The highest concentration of Cr previously supplemented to turkeys was 200 mg Cr/kg, from $CrCl_3$, to turkey hen diets (Anderson et al., 1989). No adverse effects were reported in this study following 5 wk of Cr supplementation.

ACKNOWLEDGMENTS

The authors acknowledge Matt Newhouse (Kemin Agrifoods North America, Inc.) for support in monitoring this study and associated data with the use of good laboratory-like practices. This research was partially supported by a grant from Kemin Agrifoods North America, Inc.

DISCLOSURES

The authors declare that they have no conflict of interest in this study.

REFERENCES

Akiba, Y., Y. Chida, T. Takahashi, Y. Ohtomo, K. Sato, and K. Takahashi. 1999. Persistent hypoglycemia induced by continuous insulin infusion in broiler chickens. Br. Poult. Sci. 40:701–705.

Anderson, R. A., N. A. Bryden, M. M. Polansky, and M. P. Richards. 1989. Chromium supplementation of turkeys: effects on tissue chromium. J. Agric. Food Chem. 37:131–134.

Biswas, A., S. Divya, A. B. Mandal, S. Majumdar, and R. Singh. 2014. Effects of dietary supplementation of organic chromium (picolinate) on physical and biochemical characteristics of semen and carcass traits of male turkeys. Anim. Reprod. Sci. 151:237–243.

Brooks, M. A., J. L. Grimes, K. E. Lloyd, K. Krafka, A. Lamptey, and J. W. Spears. 2016. Chromium propionate in broilers: effect on insulin sensitivity. Poult. Sci. 95:1096–1104.

Cason, J. J., and R. G. Teeter. 1994. Feed access effects on serum metabolites of hybrid large white male turkeys. Poult. Sci. 73:1348–1351.

CFR Part 573.304, *Federal Register*, 81 (No. 107), 2016. 21. https://www.govinfo.gov/content/pkg/FR-2016-06-03/pdf/2016-11971.pdf

Chen, K. L., J. J. Lu, T. F. Lien, and P. W. S. Chiou. 2001. Effects of chromium nicotinate on performance, carcass characteristics and blood chemistry of growing turkeys. Br. Poult. Sci. 42:399–404.

Corcoran, C., E. J. Anderson, B. Burrows, T. Stanley, M. Walsh, A. M. Poulos, and S. Grinspoon. 2000. Comparison of total body potassium with other techniques for measuring lean body mass in men and women with AIDS wasting. Am. J. Clin. Nutr. 72:1053–1058.

Dupont, J., S. Tesseraud, M. Derouet, A. Collin, N. Rideau, S. Crochet, E. Godet, E. Cailleau-Audouin, S. Métayer-Coustard, M. J. Duclos, C. Gespach, T. E. Porter, L. A. Cogburn, and J. Simon. 2008. Insulin immune-neutralization in chicken: effects on insulin signaling and gene expression in liver and muscle. J. Endocr. 197:531–542.

Hiscock, H. M., E. M. Leishman, R. J. Vanderhout, S. M. Adams, J. Mohr, B. J. Wood, C. F. Baes, and S. Barbut. 2022. Describing the relationships among meat quality traits in domestic turkey (Meleagris gallopavo) populations. Poult. Sci. 101:102055.

Huang, Y., J. Yang, F. Xiao, K. Lloyd, and X. Lin. 2016. Effects of supplemental chromium source and concentration on growth performance, carcass traits, and meat quality of broilers under heat stress conditions. Biol. Trace Elem. Res. 170:216–223.

Huang, Y. L., Q. H. Luo, F. Xiao, X. Lin, and J. W. Spears. 2020. Responses of growth performance, immune traits, and small intestinal morphology to dietary supplementation of chromium propionate in heat-stressed broilers. Poult. Sci. 99:5070–5073.

Huff, G. R., W. E. Huff, N. C. Rath, N. B. Anthony, and K. E. Nestor. 2008. Effects of *Escherichia coli* challenge and transport stress on hematology and serum chemistry values of three genetic lines of turkeys. Poult. Sci. 87:2234–2241.

Lindemann, M. D., G. L. Cromwell, H. J. Monegue, and K. W. Purser. 2008. Effect of chromium source on tissue concentration of chromium in pigs. J. Anim. Sci. 86:2971–2978.

Lloyd, K. E., V. Fellner, S. J. McLeod, R. S. Fry, K. Krafka, A. Lamptey, and J. W. Spears. 2010. Effects of supplementing dairy cows with chromium propionate on milk and tissue chromium concentrations. J. Dairy Sci. 93:4774–4780.

NRC. 1994. Nutrient Requirements of Poultry. 9th. Rev. ed. National Academic Press, Washington, DC.

Patrick, J. 1977. Assessment of body potassium stores. Kidney Int 11:476–490.
Rajalekshmi, M., C. Sugumar, H. Chirakkal, and S. V. Ramarao. 2014. Influence of chromium propionate on the carcass characteristics and immune response of commercial broiler birds under normal rearing conditions. Poult. Sci. 93:574–580.
Rallis, T. S., A. F. Koutinas, M. G. Kritsept, and K. T. Moraitou. 1996. Serum lipase activity in young dogs with acute enteritis or gastroenteritis. Vet. Clin. Path. 25:65–68.
Rosebrough, R. W., and N. C. Steele. 1981. Effect of supplemental dietary chromium or nicotinic acid on carbohydrate metabolism during basal, starvation, and refeeding periods in poults. Poult. Sci. 60:407–417.
SAS Institute. 2016. Version 9.4 of the SAS System for Windows. SAS Institute Inc., Cary, NC.
Scanes, C. G. 2009. Perspectives on the endocrinology of poultry growth and metabolism. Gen. Comp. Endocrinol. 163:24–32.
Spears, J. W. 2019. Boron, chromium, manganese, and nickel in agricultural animal production. Biol. Trace Elem. Res. 188:35–44.
Spears, J. W., K. E. Lloyd, and K. Krafka. 2017. Chromium concentrations in ruminant feed ingredients. J. Dairy Sci. 100:3584–3590.
Spears, J. W., K. E. Lloyd, C. A. Pickworth, Y. L. Huang, K. Krafka, J. Hyda, and J. L. Grimes. 2019. Chromium propionate in broilers: human food and broiler safety. Poult. Sci. 98:6579–6585.
Spears, J. W., K. E. Lloyd, K. Krafka, J. Hyda, and J. L. Grimes. 2023. Chromium propionate in turkeys: effects on insulin sensitivity. Poult. Sci., doi:10.1016/psj.2023.103215.
Staniek, H., Z. Krejpcio, and D. Wieczorek. 2016. The effects of high dietary doses of chromium (III) complex with propionic acid on nutritional and selected blood indices in healthy female rats. Biol. Trace Elem. Res. 171:192–200.
Steele, N. C., and R. W. Rosebrough. 1981. Effect of trivalent chromium on hepatic lipogenesis by the turkey poult. Poult. Sci. 60:617–622.
Steele, N. C., and R. W. Rosebrough. 1979. Trivalent chromium and nicotinic acid supplementation for the turkey poult. Poul. Sci. 58:983–984.
Szabo, A., M. Mezes, P. Horn, Z. Suto, Gy. Bazar, and R. Romvari. 2005. Developmental dynamics of some blood biochemical parameters in the growing turkey. Acta Vet. Hungar. 53:397–409.
Tokushima, Y., K. Takahashi, K. Sato, and Y. Akiba. 2005. Glucose uptake in vivo in skeletal muscles of insulin-injected chicks. Comp. Biochem. Physiol. B 141:43–48.
Van Hoeck, V., M. Sonawane, A. L. Gonzalez Sanchez, I. Van Dosselaer, C. Buyens, and D. Morisset. 2020. Chromium propionate improves performance and carcass traits in broilers. Anim. Nutr. 6:480–487.
Zhao, J. P., H. Lin, H. C. Jiao, and Z. G. Song. 2009. Corticosterone suppresses insulin- and NO-stimulated muscle glucose uptake in broiler chickens (*Gallus gallus domesticus*). Comp. Biochem. Physiol. C 149:448–454.
Zheng, C., Y. Huang, F. Xiao, X. Lin, and K. Lloyd. 2016. Effects of supplemental chromium source and concentration on growth, carcass characteristics, and serum lipid parameters of broilers reared under normal conditions. Biol. Trace Elem. Res. 169:352–358.