Effects of Chromium Supplementation on Chicken Broiler Growth and Carcass Characteristics

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Abstract

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The aim of this study was to evaluate the performance and carcass characteristics of broilers after chromium supplementation. One-day-old 90 Hubbard ISA male broiler chicks were divided into one control and two experimental groups. The control group was fed a basal diet, while the two experimental groups were fed a basal diet supplemented with chromium-enriched yeast in doses of 300 or 500 $\mu g \cdot kg^{-1}$ Cr. Supplementation of 500 $\mu g \cdot kg^{-1}$ Cr increased body weight (BW), body weight gain (BWG), and also feed conversion ratio (FCR), ($p < 0.05$) compared to the dose of 300 $\mu g \cdot kg^{-1}$ Cr and to the control diet. The dressing percentage was the highest (75.6%) in the group fed 500 $\mu g \cdot kg^{-1}$ Cr, and differed significantly ($p < 0.05$) compared to the control and 300 $\mu g \cdot kg^{-1}$ Cr groups. The use of chromium yeast in the feeding of chickens caused a decrease of cholesterol level and the content in muscles. The largest differences were observed in breast muscles in the group fed 500 $\mu g \cdot kg^{-1}$ Cr, where the content of cholesterol decreased by approximately 19% ($p < 0.05$). There were no significant differences between the groups in dry matter, protein and in organoleptic traits of the breast and leg muscles.

Cholesterol, BW, BWG, FCR

Chromium (Cr) is a trace element that appears to be an essential micronutrient for animals and humans. Trivalent (Cr^{3+}) and hexavalent (Cr^{6+}) states are biologically active, but some differences in their metabolism are known. Cr^{6+} is more readily absorbed than Cr^{3+}, but its toxicity is higher. In nature, chromium exists mostly in the Cr^{3+} form; it was observed to have antioxidant properties *in vivo* (Tezeuka et al. 1991) as well as to be an integral part of activating enzymes and maintaining the stability of proteins and nucleic acids (Borel and Anderson 1984; Anderson 1994). The primary role of Cr in metabolism is to potentiate the action of insulin through its presence in an organometallic molecule, called the glucose tolerance factor (GTF) (Anderson 1987; Sahin et al. 2001; Pechová et al. 2002; Sahin et al. 2003).

Insulin has been shown to increase the glucose and amino acid uptake into muscle cells, to regulate energy production, muscle tissue deposition, fat metabolism, and cholesterol utilization. If glucose cannot be utilized by body cells due to a low insulin level, it is converted into fat and stored in fat cells. Furthermore, if adequate amino acids cannot enter the cells, muscles cannot be built (Anderson 1987). Moreover, chromium deficiency can disrupt the carbohydrate and protein metabolisms, reduce the insulin sensitivity in peripheral tissues, and also impair the growth rate (Pagan et al. 1995; Sahin and Sahin 2002; Sahin et al. 2003).

Dietary chromium supplementation was found to accelerate body growth and to increase lean body mass in humans, experimental animals, and domestic livestock (Mertz 1993; Hasten et al.1997; Mowat et al. 1993). Dietary chromium supplementation was reported

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to have a positive effect on the growth rate and feed efficiency in growing poultry (Cupo and Donaldson 1987; Lien et al. 1999), particularly in birds reared under heat or cold stress (Sands and Smith 1999; Sahin et al. 2001; Sahin et al. 2003). Research with animals has confirmed that chromium from dietary organic complexes, such as chromium picolinate (CrPic), chromium nicotinate (CrNic) and high-chromium yeast, is absorbed more efficiently than chromium from inorganic forms. The reasons for the low availability of inorganic sources of Cr^{3+} are numerous and probably related to: the formation of insoluble chromic oxide; the binding to natural-chelating agents in feedstuffs (such as phytate); the interference by ionic forms of other elements as well as slow or no conversion of inorganic chromium to the bioactive form (Beitz and Horst 1997).

There is no specification for Cr requirements in poultry diets (NRC 1994), and most poultry diets are basically composed of plant-origin ingredients, usually low in Cr (Giri et al.1990).

The present study was conducted to determine the effects of different doses of chromium from chromium enriched yeast on the growth, body composition, dressing yield and meat quality of broiler chicken.

Materials and Methods

Animals, diets and experimental design

One-day-old male broiler chicks (90 Hubbard-ISA) were randomly assigned to 3 treatment groups. Each group was replicated 3 times with 10 birds per replicate pen in a battery brooder. All pens were equipped with feeders and waterers. The birds were fed either a control diet or the control diet supplemented with chelated chromium supplied from chromium yeast. Chelated chromium is a nicotinic acid-trivalent chromium-nicotinic acid axis with ligands of glutamic acid, glycine and cysteine. The process was conducted by growing yeast in rich chromium media (chromium chloride) in which the above three amino acids were bound. The type of yeast used was 1026 strain of viable culture of *Saccharomyces cerevisiae* at a concentration of 2.6×10^4 per gram. The yeast then died due to an increased temperature during the drying process (Alltech, Nicholasville, KY 40356, USA).

The birds were fed a starter diet until 21 days of age followed by a finishing diet from day 21 to day 42. The ingredients and chemical composition of the starter and grower basal diets are shown in Table 1. The basal diets were formulated with the use of NRC (1994) guideline, and contained 20-18.5% crude protein (CP) and 12.13-12.55 $MJkg^{-1}$

Metabolizable Energy (ME)

The dietary treatments consisted of the supplementation of the basal diet with 0 (control), 300 or 500 $\mu g \cdot kg^{-1}$ chromium, supplied from chromium yeast containing 1g of Cr per kg of yeast. Small amounts of basal diets were first mixed with the respective amounts of chromium yeast, and then with a larger amount of the basal diet until the total amounts of the respective diets were homogeneous. Birds were kept in electrically heated batteries. Experimental diets were provided *ad libitum*.

Sample collection and laboratory analysis

All chickens per pen were weighed in groups at the beginning (on the 21^{st} day) and at the end of the experiment (42^{nd} day). Body weight gain (BWG) was calculated from these data. The feed - consumed per pen - was recorded, and the feed convention ratio (FCR) was calculated. At the end of the experiment ten chickens per group were taken randomly as a representative sample and were slaughtered. The carcasses were dissected manually and the following criteria were recorded: carcass weight and dressing percentage (carcass weight as percentage of final body weight), weights of breast meat, legs (thigh + shank). These values were expressed as a percentage of the cold carcass weight. Basic chemical analysis of the dry matter (DM), crude protein (CP), crude ash (CA), crude fat (CF) and pH of muscles was conducted by conventional methods described by Pikul (1993). Cholesterol content in muscles was determined by the colorimetric method (Karkalas et al. 1982) by means of a commercially available kit (Boehringer Mannheim, Cat. No 0 139 050), and then it was read with the use of Beckman DU 640 Spectrometer. Colours of muscles were determined with the colorimetric method according to the accepted standards using Minolta Chromameter CR – 200. Results were presented in „Hunter Lab" scale as L*, a*, b* (Uijttenboogaart et al. 1993; Ziołecki and Doruchowski 1989).

Traits of subjective meat quality were recorded by an organoleptic evaluation of roasted samples of breast and thigh meat of 10 chickens per group: a test panel consisting of five people judged the meat with regard to colour, flavour, taste, tenderness, juiciness and the tout ensemble, with grades from 1 (poor) to 5 (very good). Test panel evaluation of the muscles was performed in compliance with the Polish Standard PN-64/A-04022.

Analyses and statistics

The results obtained were processed through the program STATISTICA (data analysis software system) with the application of Windows version 5.0. All the numerical data were analyzed by one-way ANOVA to test the

Table 1. Composition of the starter and grower diets for broiler

Ingredients	Starter (1-21 d)	Grower (22-42 d)
	% of DM	
Corn	37.50	51.00
Wheat	22.00	12.00
Rape	-	30.00
Soybean meal	25.48	18.00
Fodder meal	3.00	5.00
Meat meal	3.31	4.66
Vegetable oil	5.00	3.00
Calcium carbonate	0.20	0.30
Dicalcium phosphate	1.95	1.50
Salt (NaCl)	0.30	0.30
DL-methionine	0.26	0.24
Vitamin-mineral premix *	1.00	1.00
Calculated analyses		
Metabolizable energy (ME), MJ kg^{-1}	12.13	12.55
Crude protein (CP) %	20.00	18.50
Fibre (max) %	4.00	4.00
Lysine	1.22	1.14
Methionine +cystine	0.92	0.86
Tryptophan	0.21	0.19
Available Phoshorus	0.40	0.40
Calcium	1.00	0.85
Chromium analyzed value ($\mu g \cdot kg^{-1}$)	825	855

**Vitamin-mineral premix provided per kg of diet: vitamin 10 000 IU, vitamin D^3 2500 IU, vitamin E, 35 mg, riboflavin 70 mg, panthothenic acid 10 mg, vitamin B_{12} 0.01 mg, niacin 25 mg, choline 950 mg, vitamin K* 1 *mg, biotin 0.15 mg, manganese 60 mg, zinc 50 mg, iron 40 mg, copper 6.0 mg, selenium 0.15 mg.*

effects of the dietary treatments. Significant differences of the obtained means were determined with the use of the Duncan multiple range test at the level of $p < 0.05$. Statistical evaluation of the obtained data is presented in the tables as a mean (x) and a standard deviation (SD).

Results and Discussion

The effects of supplemental chromium on the performance of broiler chickens are summarized in Table 2. All chickens were growing normally. Supplementation of 500 $\mu g \cdot kg^{-1}$ Cr either for 21 or 42 days increased BW, BWG, and also FCR ($p < 0.05$) compared to the dose of 300 500 $\mu g \cdot kg^{-1}$ Cr and the control diet. A small supplement of yeast protein to the chicken diet (dilution 1:1000) should not affect the results among the experimental and control groups. Results of the present study are in agreement with the results of other authors. Lien et al. (1999) reported that dietary supplements of 1 600 or 3 200 500 $\mu g \cdot kg^{-1}$ Cr as chromium picolinate markedly improved the weight gain of broiler chicken ($p < 0.05$). In addition, Sands and Smith (1999) also showed that the supplementation of chromium picolinate increased the growth rate without affecting the feed intake in broilers reared under environmental stress. Chen et al. (2001) indicated that 1 mg/kg chromium supplementation significantly improved the weight gain and food intake in turkeys from 9 to 18 weeks of age, but did not significantly influence performance in the period from 19 to 22 weeks of age. In other studies, supplemental chromium in the dose of 200, 400, 800, and particularly of 1 200 $\mu g \cdot kg^{-1}$, resulted in the increase in body weight, feed intake, egg production and also feed efficiency of Japanese quails (Sahin et al. 2001). Moreover, Mooney and Cromwell (1997) suggest that chromium in the organic form as picolinate is more effective than chloride, and that Cr must be supplemented throughout the growing–finishing period to improve the carcass composition in swine.

Table 2. Effects of supplementary chromium yeast on the body weight (BW), body weight gain (BWG) and feed conversion ratio (FCR) of chicken broilers from 1 to 42 days of age. * O = basal diet; 300 = basal diet+300 µg·kg^{-1} Cr of diet; and 500 = basal diet+500 µg·kg^{-1} Cr of diet (n = 30), (mean ± SD)

	Dietary Treatments*		
	Control	300	500
BW (g)			
1 d	40.09 ± 3.15	40.03 ± 3.19	39.32 ± 3.58
21 d	647.22 ± 42.15^{a}	638.50 ± 70.88^{a}	655.88 ± 54.91^{b}
42 d	2009.16 ± 102.68^{a}	1948.75 ± 113.76^{a}	2085.41 ± 138.07^{b}
BWG (g)			
1 to 21 d	607.13 ± 9.04^{a}	598.47 ± 7.68^{a}	616.56 ± 4.60^{b}
22 to 42 d	1362.94 ± 16.04^{a}	1310.29 ± 21.45^{a}	1429.53 ± 18.40^{b}
1 to 42 d	1969.07 ± 76.40^{a}	1908.72 ± 89.46^{a}	2046.09 ± 98.70^{b}
FCR (g:g)			
1 to 21 d	1.57 ± 0.03	1.59 ± 0.01	1.60 ± 0.02
22 to 42 d	1.87 ± 0.04^{a}	1.92 ± 0.08^{a}	1.81 ± 0.06^{b}
1 to 42 d	1.78 ± 0.04^{a}	1.81 ± 0.02^{a}	1.72 ± 0.03^{b}
Mortality (%)			
1 to 42 d	1.14 ± 0.01	1.12 ± 0.01	1.17 ± 0.02

Means in the same column with different superscript a, b are significantly different (p< 0.05)

Results of the slaughter analysis of broiler chickens fed a diet containing different chromium doses are presented in Table 3. The proportion of breast and leg muscles in the carcass was the highest in 300 µg·g^{-1} Cr group (52.19%), followed by the group 500 µg·kg^{-1} Cr (51.44%) and the control group (51.39%). The dressing percentage was the highest (75.67%) in the group fed 500 µg·kg^{-1} Cr, and differed significantly ($p < 0.05$) compared to the control group and 300 µg·kg^{-1} Cr. No information is available in literature on the effect of Cr on the carcass characteristics of market age broilers.

Table 3. Results of slaughter analysis of broilers fed a diet containing different chromium doses from 0 to 42 days of age. * O = basal diet; 300 = basal diet+300 µg·kg^{-1} Cr of diet; 500 = basal diet+500 µg·kg^{-1} Cr of diet (n = 30), (mean ± SD)

	Supplementary Cr* levels (µg·kg^{-1})		
	0	300	500
Dressing percentage (%)	73.74 ± 3.09a	73.04 ± 5.86a	75.67 ± 5.78b
Breast muscles (%)	18.5 ±1.69	20.04 ±1.64	19.25 ±2.41
Leg muscles (with bone) (%)	32.89 ±1.69	32.15 ±1.41	32.19 ±0.83

Means in the same row with different superscript a, b are significantly different ($p < 0.05$)

The estimations of chemical qualities of the breast and leg muscles of the chickens are presented respectively in Tables 4 and 5.

Table 4. The chemical composition of breast muscles of broiler chicken (DM-dry matter, CP-crude protein, CF-crude fat, CA-crude ash), * O = basal diet; 300 = basal diet+300 µg·kg^{-1} Cr of diet; 500 = basal diet+500 µg·kg^{-1} Cr of diet (n =10), (mean ± SD)

Supplementary Cr* levels (µg·kg^{-1})	DM (g·kg^{-1})	CP (g·kg^{-1})	CF (g·kg^{-1})	CA (g·kg^{-1})	pH
0	267.2 ± 1.89	237.6 ± 1.51	21.48 ± 1.18^{a}	12 ± 1.03	5.632 ± 0.007
300	259.1 ± 1.35	232.8 ± 1.09	18.34 ± 1.05^{b}	12 ± 1.00	5.828 ± 0.116
500	262.5 ± 1.98	232.8 ± 1.48	20.88 ± 1.81^{a}	13 ± 0.80	5.850 ± 0.141

Means in the same column with different superscript a, b are significantly different ($p < 0.05$)

Table 5. The chemical composition of leg muscles of broiler chicken (DM-dry matter, CP-crude protein, CF- crude fat, CA-crude ash). * O = basal diet; 300 = basal diet + 300 μg·kg^{-1} Cr of diet; 500 = basal diet+500 μg·kg^{-1} Cr of diet (n = 10), (mean ± SD)

Supplementary Cr* levels (μg·kg^{-1})	DM (g·kg^{-1})	CP (g·kg^{-1})	CF (g·kg^{-1})	CA (g·kg^{-1})	pH
0	244.8 ± 3.52	188.0 ± 4.79	52.52 ± 2.88	7.9 ± 0.66	5.996 ± 0.101
300	247.3 ± 17.3	187.0 ± 2.00	53.06 ± 1.81	9.9 ± 0.85	6.222 ± 0.016
500	242.9 ± 3.5	181.4 ± 2.88	53.56 ± 2.04	9.5 ± 0.81	6.370 ± 0.015

The use of chromium yeast in the feeding of chickens caused the lowering of the cholesterol level (Table 6) and fat content in muscles. The largest differences were observed in the case of breast muscles in the group fed 500 μg·kg^{-1} Cr, where the content of cholesterol got smaller by approximately 19% ($p < 0.05$) compared to the control group. Fat content in this group was lower (by approximately 10%) only in breast muscles. No essential differences were observed in the protein level in breast muscles, and its content ranged from 23.76 to 23.28%, and leg muscles (18.80 – 18.14%) (see Table 4 and 5).

Table 6. Total cholesterol content (mg/100 g) in muscles. * O = basal diet; 300 = basal diet + 300 μg· kg^{-1} Cr of diet; 500 = basal diet + 500 μg·kg^{-1} Cr of diet (n = 10), (mean ± SD)

Supplementary Cr* levels (μg·kg^{-1})	Muscles	
	Breast	Leg
0	70.480 ± 0.725^{a}	88.820 ± 0.349^{a}
300	63.820 ± 0.376^{c}	79.900 ± 0.115^{b}
500	57.375 ± 0.170^{b}	78.450 ± 0.057^{b}

Means in the same column with different superscript a, b, c are significantly different (P<0.05)

When analyzing other parameters influencing the quality of meat, e.g. pH, it was demonstrated that the pH value of the breast muscles was comprised in the range from 5.6 to 5.8, and in the leg muscles it oscillated from 5.9 to 6.3. Breast muscles possess larger quantities of glycogen with regard to their functionality; after slaughter, these muscles show lower pH than leg muscles, which was demonstrated in the present investigations. There were no essential changes in the dry matter of breast and leg muscles after the supplementation of chromium, although the dry matter content was higher in the breast muscles and oscillated from 25.91 to 26.72% in comparison with the leg muscles – oscillating between 24.29 and 24.73%.

Thermally treated breast and leg muscles did not show any differences in organoleptic characteristics (Table 7). Breast muscles as well as leg muscles were characterized by significantly lower ($p < 0.05$) all colour parameters in the group fed 500 μg·kg^{-1} Cr (Table 8), compared to the remaining groups.

The addition of chromium yeast to the feed of broiler chickens did not cause any significant changes in the organoleptic parameters compared to the control group. Mean results of a sensory evaluation of tout ensemble for breasts amounted to 4.3 points, and for leg muscles - from 4.3 to 4.5 points.

In conclusion, the performance of broiler chicken and poultry meat quality depends mainly on the composition of diets. The results of the present study show that chromium supplementation of 500 μg·kg^{-1} Cr has a beneficial effect on the growth and quality of meat of broiler chickens; it particularly influences the cholesterol content.

Table 7. Organoleptic evaluation of breast and leg muscles with grades from 1 (poor) to 5 (very good).* O = basal diet; 300 = basal diet + 300 μg·kg^{-1} Cr of diet; 500 = basal diet + 500 μg·kg^{-1} Cr of diet. (n = 10)

Supplementary Cr* levels (μg·kg^{-1})	Colour	Flavour	Taste	Tenderness	Juiciness	Tout ensemble
0 B	4.3	4.2	4.1	3.7	3.7	4.3
300 B	4.6	4.4	4.3	3.7	3.7	4.3
500 B	4.5	4.4	4.1	3.8	3.8	4.3
0 L	4.5	4.6	4.3	4.1	4.1	4.5
300 L	4.5	4.5	4.1	4.2	4.2	4.5
500 L	4.5	4.2	4.2	4.2	4.0	4.2

B - Breast muscle, L - Leg muscle

Table 8. Colorimetric evaluation of muscle colour.* O = basal diet; 300 = basal diet + 300 μg·kg^{-1} Cr of diet; 500 = basal diet + 500 μg·kg^{-1} Cr of diet (n = 30), (mean ± SD)

Groups	Colour[1]	Supplementary Cr* levels (μg·kg^{-1})		
		0	300	500
Breast muscle	L	71.06 ± 1.08^a	74.06 ± 2.57^a	63.82 ± 2.40^b
	a	3.12 ± 0.30^a	3.70 ± 0.40^a	2.16 ± 0.14^b
	b	25.20 ± 0.98^a	26.48 ± 1.09^a	22.5 ± 1.44^b
Leg muscle	L	70.16 ± 0.94^a	69.20 ± 0.34^a	64.52 ± 0.40^b
	a	16.60 ± 2.33	14.28 ± 1.26	14.40 ± 0.86
	b	26.36 ± 0.76^a	26.54 ± 0.29^a	24.02 ± 0.50^b

Means in the same row with different superscript a, b are significantly different ($P < 0.05$)
[1] L – lightness scale 0-100, a – redness, b-yellow

Účinek aplikace chrómu na růst a užitkovost brojlerů kuřat

Cílem studie bylo vyhodnotit růst a užitkovost brojlerů kuřat po aplikaci chrómu. Devadesát jednodenních kuřat Hubbard ISA bylo rozděleno na kontrolní a dvě experimentální skupiny. Kontrolní skupina byla krmena základní krmnou směsí, zatímco dvě experimentální skupiny byly krmeny základní krmnou směsí s přídavkem chrómu v obohacených kvasnicích v dávkách 300 nebo 500 μg·kg^{-1} Cr. Přídavek 500 μg·kg^{-1} Cr zvýšil BW, BWG a také FCR ($p < 0,05$) ve srovnání s dávkou 300 μg·kg^{-1} a s kontrolním krmivem. Nejvyšší výtěžnost (75.6%) byla ve skupině krmené 500 μg·kg^{-1} Cr, která se významně lišila ($p < 0,05$) od kontrolní skupiny a skupiny krmené 300 μg·kg^{-1} Cr. Využití chrómem obohacených kvasnic v krmení kuřat snížilo koncentraci cholesterolu a obsah tuku ve svalovině. Největší rozdíly byly zjištěny u prsní svaloviny ve skupině krmené 500 μg·kg^{-1} Cr, kde se obsah cholesterolu snížil přibližně o 19% ($p < 0,05$). Nebyly zjištěny žádné významné rozdíly v obsahu sušiny, proteinů a v organoleptických vlastnostech prsních a stehenních svalů.

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