

# Effect of the supplementation of biocomplexed minerals in diets for free-range chickens on performance and carcass characteristics

Fábio Loures Cruz<sup>1</sup> , Diogo Alvarenga Miranda<sup>2</sup> , Joanna Oliveira Marçal<sup>1</sup> , Allan Alves Fernandes<sup>3</sup> , Marcos Aurélio Lopes<sup>1\*</sup> , Adriano Geraldo<sup>2</sup> , Peter Bitencourt Faria<sup>1</sup> 

<sup>1</sup> Universidade Federal de Lavras, Departamento de Medicina Veterinária, Lavras, MG, Brasil.

<sup>2</sup> Instituto Federal de Educação, Ciência e Tecnologia de Minas Gerais - Campus Bambuí, Departamento de Ciências Agrárias, Bambuí, MG, Brasil.

<sup>3</sup> Universidade Federal de Lavras, Departamento de Ciências Exatas, Lavras, MG, Brasil.

**ABSTRACT** - We intended to evaluate the influence of supplementation with biocomplexed minerals on the performance and carcass characteristics of Label Rouge broilers of both sexes, as well as on the feed efficiency and feed costs. The experimental design was completely randomized arranged in factorial scheme (3×2) – three experimental diets (control, 0.50 ppm of selenium, and 0.40 ppm of chromium) and two sexes (male and female). Each treatment was composted of three plots, each one represented by 21 birds. The average weight (g/bird), weight gain (g/bird), feed intake (g/bird), and feed conversion in periods of 1 to 7, 1 to 21, 1 to 35, 1 to 49, 1 to 63, and 1 to 90 days were calculated. Weight and yield of carcass and cuts were determined. Both average feed cost (AFC, R\$/bird) and cost per kg of weight gain (CWG, R\$/kg weight gain) as well as economic efficiency index (EEI) were estimated. There was no influence of the diet on performance, carcass characteristics, and feed costs of the birds. The males presented higher means of average weight (3819.2 g/bird), weight gain (3780.9 g/bird), feed intake (11030.2 g/bird), and better feed conversion index (2.9) in the period of 1 to 90 days, besides presenting higher values of live weight at slaughter (3740.2 g), carcass weight (3117.5 g) and carcass yield (83.4%), breast weight (832.4 g), thigh weight (432.5 g), and thigh yield (13.9%); the females presented higher breast yield values (28.1%). The males presented higher AFC and lower CWG. The addition of minerals in the diet does not change performance, carcass characteristics and feed costs. The males present better performance and better carcass characteristics, in addition to being economically more viable.

**Keywords:** biocomplexed chromium, biocomplexed selenium, carcass yield, feed conversion, Label Rouge

\*Corresponding author:  
malopes@ufla.br

Received: November 12, 2019  
Accepted: March 26, 2020

**How to cite:** Cruz, F. L.; Miranda, D. A.; Marçal, J. O.; Fernandes, A. A.; Lopes, M. A.; Geraldo, A. and Faria, P. B. 2020. Effect of the supplementation of biocomplexed minerals in diets for free-range chickens on performance and carcass characteristics. *Revista Brasileira de Zootecnia* 49:e20190224.  
<https://doi.org/10.37496/rbz4920190224>

**Copyright:** This is an open access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.



## 1. Introduction

Nutrition is one of the main factors for the success of any segment of animal production, being fundamental to obtain high production indices. In this context, mineral supplementation, which has been used in broiler farming for promoting improvements both in performance and the main carcass characteristics (Zia et al., 2017) stands out.

Among the minerals used in the broiler diet, we highlight both chromium and selenium, which are essential for animal development and perform various metabolic functions in the organism. Chromium

acts as an active component of glucose tolerance factor (GTF), promoting greater insulin binding to receptors, thus increasing the sensitivity of target cells and, consequently, enhancing insulin action (Carvalho et al., 2002). Selenium promotes increase in the circulating levels of triiodothyronine (T3) due to its action on the activation of the enzymes iodothyronine deiodases (Ahmad et al., 2012). Thus, supplementation with both minerals in the diet may lead to increased protein synthesis in muscle tissue, which may be responsible for performance improvements and increments in the main carcass characteristics (Silva et al., 2019; Ognik et al., 2020). However, for the inclusion of these minerals in the broiler diet, it is necessary to assess the economic viability of the supplementation to verify whether the possible gains in performance and/or in carcass characteristics are economically advantageous.

The real effects of chromium and selenium supplementation in biocomplexed forms on broiler performance and carcass parameters are not yet fully understood. In addition, there are no recent studies in the literature that evaluate the economic viability of supplementation with these minerals and their influence on the growth pattern of broilers.

In view of the exposed, we aimed to check the influence of the inclusion of biocomplexed chromium and selenium in the diet on the performance and carcass characteristics of Label Rouge broiler chickens of both sexes raised in an alternative system, as well as to evaluate the economic efficiency of the mineral supplementation and to estimate the costs with the feeding of the birds according to the experimental diets.

## 2. Material and Methods

The study on animals was conducted according to the institutional Ethics Committee on Animal Use (Protocol Number 29A/2016). The experiment was conducted in Bambuí, Minas Gerais. The municipality is located in the midwestern region of the Minas Gerais state, at an altitude of 706 m, with geographic coordinates 20°00'23" South latitude and 45°58'37" West longitude of Greenwich.

The experimental design was completely randomized arranged in a factorial scheme (3×2), namely, three experimental diets (control - without the addition of biocomplexed minerals; 0.50 ppm of biocomplexed selenium; and 0.40 ppm of biocomplexed chromium) and two sexes, amounting to six treatments. Each treatment consisted of three plots, each one represented by 21 birds, totaling 63 birds per treatment. Therefore, 378 birds were used for evaluations of performance and carcass. The experimental diets were offered throughout the production period, that is, from 1 to 90 days of age. In the diet with chromium, 0.34 g of chromium picolinate was added to 100 kg of feed (concentration of biocomplexed chromium of 12% in the product and 98.64% purity), and for the treatment with selenium, 5.10 g of selenium glycinate to 100 kg of feed (concentrations of 0.98% biocomplexed selenium in the product). The diets between the different treatments were isonutritive. In all the experimental diets, a vitamin premix with inorganic selenium was used, thus providing 0.37 ppm of inorganic selenium in the diet. In addition to the inorganic selenium, there was extra supplementation of biocomplexed selenium and chromium in two of the experimental diets.

The mathematical model for statistical analysis was as follows:

$$Y_{ikl} = \mu + M_i + S_k + MS_{ik} + e_{ikl},$$

in which  $Y_{ikl}$  = effect of mineral supplementation  $i$ , at sex level  $k$ , on repetition  $l$ ;  $\mu$  = constant associated with all data;  $M_i$  = effect of mineral supplementation ( $i = 1, 2, 3$ );  $S_k$  = sex effect ( $k = 1, 2$ );  $MS_{ik}$  = effect of interaction mineral supplementation  $i$  and sex  $k$ ; and  $e_{ikl}$  = error associated with all observations, which, by hypothesis, has a normal distribution with zero mean and sigma squared variance.

The diets were formulated based on corn and soybean meal according to the nutrient allowances of the Manual de Manejo Linha Colonial (Globoaves, 2015), specific to the Label Rouge strain, to meet the requirements of the birds in each production phase (Table 1). The feed compositions were taken from the Brazilian Tables for Poultry and Swine (Rostagno et al., 2011). The calculated values of the experimental diets of each phase are presented in Table 2.

The birds were raised in the period of 1 to 29 days (starter phase), in a conventional experimental shed, without access to grazing area, receiving heating by means of 250 W infrared lamps until 14 days old and artificial lighting 24 h a day; feed and water were supplied *ad libitum*. In the periods of 30 to 49 days (grower phase I), 50 to 77 days (grower phase II), and 78 to 90 days (finisher phase), the birds were reared in an experimental area of free-range poultry production, with access to the grazing area with Tifton 85 (*Cynodon spp*), both feed and water being supplied *ad libitum*. In each experimental unit of 77.35 m<sup>2</sup> of area, 21 birds of the same sex were housed, obtaining a density around one bird for each 3.68 m<sup>2</sup> of free area, discounting the coverage area of the mobile hut and thus meeting the Circular Letter DOI/DIPO number 007/99 of 19/05/1999 (Brasil, 1999).

Regarding performance studies, the average weight, weight gain, feed intake, and feed conversion were evaluated in the periods 1 to 7, 1 to 21, 1 to 35, 1 to 49, 1 to 63, and 1 to 90 days, according to the methodology of Del Castillo et al. (2013). Mortality was monitored daily for correction of feed intake and conversion, as reported by Sakomura and Rostagno (2007). To assess the growth potential of the

**Table 1 - Composition of experimental diets for broilers of the Label Rouge lineage, according to the rearing phases**

Ingredient (kg)	Starter (1 to 29 days)			Grower I (30 to 49 days)		
	Control <sup>a</sup>	Cr <sup>b</sup>	Se <sup>c</sup>	Control <sup>a</sup>	Cr <sup>b</sup>	Se <sup>c</sup>
Corn 7%	63.85	63.85	63.85	65.94	65.94	65.94
Soybean meal 46%	31.90	31.90	31.90	29.50	29.50	29.50
Soy oil	-	-	-	0.50	0.50	0.50
Limestone	1.50	1.50	1.50	1.50	1.50	1.50
Common salt	0.40	0.40	0.40	0.40	0.40	0.40
Bicalcium phosphate	1.85	1.85	1.85	1.70	1.70	1.70
Kaolin	0.03	0.02966	0.0249	0.03	0.02966	0.02
CrPic <sup>1</sup>	-	0.00034	-	-	0.00034	-
Selenium glycinate <sup>2</sup>	-	-	0.0051	-	-	0.0051
DL- Methionine 99%	0.22	0.22	0.22	0.21	0.21	0.21
Choline chloride 60%	0.05	0.05	0.05	0.04	0.04	0.04
Vitamin premix <sup>3</sup>	0.10	0.10	0.10	0.10	0.10	0.10
Mineral premix <sup>4</sup>	0.10	0.10	0.10	0.08	0.08	0.08
Total	100.00	100.00	100.00	100.00	100.00	100.00
Ingredient (kg)	Grower II (50 to 77 days)			Finisher (78 to 90 days)		
	Control <sup>a</sup>	Cr <sup>b</sup>	Se <sup>c</sup>	Control <sup>a</sup>	Cr <sup>b</sup>	Se <sup>c</sup>
Corn 7%	69.24	69.24	69.24	71.25	71.25	71.25
Soybean meal 46%	25.60	25.60	25.60	24.10	24.10	24.10
Soy oil	1.40	1.40	1.40	1.60	1.60	1.60
Limestone	1.30	1.30	1.30	0.95	0.95	0.95
Common salt	0.40	0.40	0.40	0.40	0.40	0.40
Bicalcium phosphate	1.60	1.60	1.60	1.35	1.35	1.35
Kaolin	0.03	0.02966	0.02	0.03	0.02966	0.02
CrPic <sup>1</sup>	-	0.00034	-	-	0.00034	-
Selenium glycinate <sup>2</sup>	-	-	0.0051	-	-	0.0051
DL- Methionine 99%	0.21	0.21	0.21	0.13	0.13	0.13
Choline chloride 60%	0.04	0.04	0.04	0.03	0.03	0.03
Vitamin premix <sup>3</sup>	0.10	0.10	0.10	0.10	0.10	0.10
Mineral premix <sup>4</sup>	0.08	0.08	0.08	0.06	0.06	0.06
Total	100.00	100.00	100.00	100.00	100.00	100.00

<sup>a</sup> Control: diet without the addition of biocomplexed minerals; <sup>b</sup> Cr: diet with 0.40 ppm of biocomplexed chromium; <sup>c</sup> Se: diet with 0.50 ppm of biocomplexed selenium.

<sup>1</sup> Chromium picolinate with 12% concentration of biocomplexed chromium and purity of 98.64%.

<sup>2</sup> Selenium glycinate with 0.98% concentration of biocomplexed selenium.

<sup>3</sup> Guaranteed levels per kg of vitamin premix: folic acid, 900.0 mg; pantothenic acid, 12,000.00 mg; biotin, 77.0 mg; calcium, 130.0-143.7 g; niacin, 40,000.0 mg; selenium, 370.0 mg; vitamin A, 8,800,000.0 IU; vitamin B1, 2500.0 mg; vitamin B12, 0.04 g; antioxidant, 0.02 g; Mn, 75 mg; Zn, 50 mg; Cu, 8 mg; I, 0.75 mg; Fe, 50 mg.

<sup>4</sup> Guaranteed levels per kg of mineral premix: copper, 7.0 g; iron, 50.0 g; iodine, 1.5 g; manganese, 67.5 g; zinc, 45.6 g.

birds fed the experimental diets and of sex, the estimative of the parameters of the Gompertz equation, according to the methodology of Sakomura and Rostagno (2007), was carried out from the data of average weight.

At the end of the experiment, five birds from each plot were selected for slaughter, with live weight close to the plot mean, varying 5% upwards or downwards. They were fasted for an 8-h period and slaughtered at 90 days of age. Slaughter was carried out in a slaughterhouse, and the birds were hung in the overhead rail, followed by sensitization by electronarcosis and bleeding. Afterwards, carcasses were scalded, plucked, eviscerated, and cleaned. They were individually wrapped in duly identified plastic bags, following the distribution of the treatments and plots and refrigerated at 5 °C in a cold room for a period of 24 h for carcass analysis. During evisceration, edible viscera (heart, liver, and gizzard) and abdominal fat (retroperitoneal fat) were collected.

After the cooling period, the carcasses were weighed, considering the carcass with neck, head, and feet and free of abdominal fat and edible viscera. Next, the division of the cuts was carried out, separating the breast, thigh, drumstick, wing, back, neck plus head, and feet. For carcass analysis, live weight at slaughter, weight and carcass yield, the weights and yields of the above-cited cuts, the weights and yields of edible viscera (liver, heart, and gizzard), and abdominal fat were evaluated according to the methodology of Faria et al. (2011).

To survey the economic viability of the mineral supplementation, the average cost (ACD) estimative, represented in Reais per kilogram of feed, of the experimental diets, by means of the mean of the costs of the diets in each production phase (starter, grower I, grower II, and finisher) was carried out. For this, a survey of the prices of the dietary ingredients was conducted during the experimental period, which was in March, April, and May of 2017, practiced in the state of Minas Gerais. Afterwards, the economic efficiency index (EEI) was calculated according to the methodology of Fialho et al. (1992). The average feeding cost (AFC) was estimated during the whole production period (1 to 90 days), by means of the product between the average intake of the birds (kg/bird) and the ACD, the values being expressed in Reais per bird; and the cost per kilogram (kg) of weight gain (CWG) by means of the product between the ACD and the feed conversion, the values being expressed in reais per kg of weight gain.

**Table 2** - Calculated values of experimental diets for broilers of the Label Rouge lineage, according to the rearing phases

Calculated value	Starter <sup>1</sup>	Grower I <sup>2</sup>	Grower II <sup>3</sup>	Finisher <sup>4</sup>
Crude protein (%)	19.43	18.50	17.00	16.42
Crude fiber (%)	3.132	3.031	2.866	2.816
Calcium (%)	1.150	1.100	1.000	0.800
Total phosphorus (%)	0.679	0.643	0.613	0.560
Available phosphorus (%)	0.450	0.420	0.400	0.350
Sodium (%)	0.180	0.180	0.180	0.180
Chlorine (%)	0.296	0.296	0.298	0.299
Metabolizable energy (kcal/kg)	2.889	2.950	3.050	3.100
Lysine (%)	1.030	0.967	0.866	0.828
Digestible lysine (%)	0.940	0.882	0.788	0.753
Methionine (%)	0.508	0.486	0.469	0.380
Digestible methionine (%)	0.485	0.464	0.449	0.361
Methionine + cystine (%)	0.825	0.790	0.753	0.657
Digestible methionine + cystine (%)	0.755	0.723	0.691	0.597
Digestible tryptophan (%)	0.218	0.205	0.184	0.176
Digestible threonine (%)	0.663	0.631	0.578	0.559
Choline (mg)	1.663	1.536	1.415	1.319

<sup>1</sup> Starter rearing phase (1 to 29 days old); <sup>2</sup> Grower phase I (30 to 49 days old); <sup>3</sup> Grower phase II (50 to 77 days old); <sup>4</sup> Finisher phase (78 to 90 days old).

The data were analyzed with the support of the SISVAR® statistical program (Ferreira, 2000). The variables with responses of significant effect in the analysis of variance for treatments and/or interactions were subjected to the Tukey average test (5% significance).

### 3. Results

The birds fed the male sex-control diet presented greater estimated value of live weight at maturity ( $P_m$ ). The birds of the chromium treatment and of the female sex presented higher estimated value of the maturity rate ( $b$ ) and younger age at which the maximum growth rate ( $T^*$ ) is maximum (Table 3).

The statistical analysis revealed no interaction between diet and sex ( $P>0.05$ ) and isolated dietary effect ( $P>0.05$ ) for all variables, regardless of the period (Table 4). There was only an effect of sex ( $P<0.05$ ) for the variables of average weight and weight gain, regardless of the periods, except for 1 to 7 days, and males presented the highest means. Regarding feed intake, males presented higher means ( $P<0.01$ ) in the periods from 1 to 35, 1 to 49, 1 to 63, and 1 to 90 days. In addition, males presented better values ( $P<0.05$ ) of feed conversion in the periods from 1 to 63 and 1 to 90 days.

There was no interaction between diet and sex ( $P>0.05$ ) and any isolated effect of the diet ( $P>0.05$ ) on the carcass variables, but there was sex influence ( $P<0.05$ ) for all the variables, except for drumstick yield (Table 5). Males presented higher values ( $P<0.01$ ) of live weight, carcass weight and yield, breast weight, thigh weight and yield, drumstick weight, wing weight and yield, back weight, weight and yield of head plus neck, and feet weight and yield; however, females presented higher yield values of breast ( $P<0.05$ ) and back ( $P<0.01$ ) (Table 5).

The statistical analysis revealed no interaction between diet and sex ( $P>0.05$ ) for the variables of edible viscera and abdominal fat, but there was an isolated effect of the diet ( $P<0.05$ ) for liver weight and yield (Table 5). For both variables, birds fed the control diet showed a greater mean ( $P<0.05$ ) relative to the selenium-fed birds; however, they were similar to those fed the chromium treatment (Table 5). Regarding sex, there was an effect ( $P<0.05$ ) for all the variables except gizzard yield. Males presented higher means of edible viscera weight ( $P<0.01$ ), heart weight and yield ( $P<0.05$ ), liver weight ( $P<0.05$ ), and gizzard weight ( $P<0.01$ ); females presented higher mean ( $P<0.01$ ) of edible viscera yield, liver yield and weight, and abdominal fat yield (Table 5).

The control treatment presented the best economic efficiency index (EEI), followed by the chromium treatment and, finally, the selenium diet (Table 6). There was no interaction between diet and sex ( $P>0.05$ ) and isolated effect of the diet ( $P>0.05$ ) for any of the variables. Regarding sex, males presented higher value ( $P<0.01$ ) of average feed cost (AFC) and lower value ( $P<0.05$ ) of cost per kilogram of weight gain (CWG), besides the best EEI (Table 6).

**Table 3** - Gompertz equation parameters for live weight of broilers of the Label Rouge lineage, as a function of diet and sex

Parameter	C/M <sup>1</sup>	C/F <sup>2</sup>	Cr/M <sup>3</sup>	Cr/F <sup>4</sup>	Se/M <sup>5</sup>	Se/F <sup>6</sup>
$P_m$ (g)	5314	4522	5174	4089	5223	4295
$b$ (per day)	0.02871	0.02779	0.02944	0.03033	0.02970	0.02883
$t$ (day)	51	51	50	46	50	49
$R^2$	99.99	99.99	99.99	99.99	99.99	99.99

$P_m$  - weight to maturity;  $b$  - maturity rate;  $t$  - age at which growth rate is maximal;  $R^2$  - coefficient of determination.

Gompertz equation:  $P_t = P_m \cdot \exp(-\exp(-b \cdot (\text{age} - t)))$ .

<sup>1</sup> Male birds fed control diet (without supplementation with biocomplexed minerals); <sup>2</sup> Female birds fed control diet (without supplementation with biocomplexed minerals); <sup>3</sup> Male birds fed 0.40 ppm of biocomplexed chromium in diet; <sup>4</sup> Female birds fed 0.40 ppm of biocomplexed chromium in diet; <sup>5</sup> Male birds fed 0.50 ppm of biocomplexed selenium in diet; <sup>6</sup> Female birds fed 0.50 ppm of biocomplexed selenium in diet.



rate and reduced age for maximum growth rate, which can be attributed to the effect of this mineral as an insulin hormone enhancer (Huang et al., 2016). The values of the Gompertz equation parameters of all treatments presented high reliability, with  $R^2$  values above 0.98.

**Table 5 - Carcass variables of broilers of the Label Rouge lineage, according to diet and sex**

Variable	Diet <sup>1</sup> (D)			Sex (S)		P-value <sup>2</sup>			CV (%)
	Control	Cr	Se	Male	Female	D	S	D×S	
LW	3436.4	3389.5	3379.6	3740.2a	3063.4b	0.639	0.001	0.939	3.21
CW	2818.9	2789.9	2779.3	3117.5a	2474.6b	0.755	0.001	0.804	3.34
CY	81.9	82.2	82.1	83.4a	80.8b	0.685	0.001	0.346	0.74
BW	771.2	749.9	768.3	832.4a	693.9b	0.490	0.001	0.731	4.26
BY	27.5	26.9	27.8	26.7b	28.1a	0.400	0.017	0.341	3.85
TW	375.5	365.0	363.7	432.5a	303.6b	0.460	0.001	0.879	4.72
TY	13.2	13.0	13.0	13.9a	12.3b	0.449	0.001	0.764	2.57
DW	450.1	449.5	438.1	498.7a	393.2b	0.487	0.001	0.427	4.28
DY	15.9	16.1	15.7	16.0	15.9	0.400	0.643	0.416	3.05
WW	267.2	263.9	264.3	300.0a	230.3b	0.814	0.001	0.904	3.63
WY	9.5	9.4	9.5	9.6a	9.3b	0.816	0.002	0.921	1.82
BCW	553.4	543.4	539.9	595.8a	495.4b	0.528	0.001	0.756	3.84
BCY	19.7	19.6	19.5	19.1b	20.0a	0.586	0.001	0.711	1.78
HNW	209.5	202.2	205.9	240.8a	171.0b	0.075	0.001	0.932	2.41
HNY	7.4	7.2	7.4	7.7a	6.9b	0.436	0.001	0.725	3.61
FW	111.2	112.9	111.5	134.4a	89.3b	0.754	0.001	0.294	3.91
FY	3.9	4.0	4.0	4.3a	3.6b	0.312	0.001	0.159	3.02
EVW	116.2	111.6	109.5	120.0a	104.8b	0.118	0.001	0.814	4.65
EVY	3.4	3.3	3.2	3.2b	3.4a	0.183	0.005	0.840	10.36
HW	15.2	15.0	14.9	17.2a	12.9b	0.825	0.001	0.544	7.19
HY	0.4	0.4	0.4	0.5a	0.4b	0.973	0.010	0.711	6.53
LIW	59.3a	53.4ab	53.2b	57.4a	53.2b	0.028	0.036	0.601	6.92
LIY	1.7a	1.6ab	1.6b	1.5b	1.7a	0.029	0.001	0.456	6.14
GW	41.6	43.2	41.4	45.4a	38.8b	0.285	0.001	0.629	4.87
GY	1.2	1.3	1.2	1.2	1.3	0.267	0.123	0.690	5.39
AFW	108.3	107.3	109.8	96.8b	120.1a	0.935	0.001	0.228	10.99
AFY	3.2	3.2	3.3	2.6b	3.9a	0.860	0.001	0.203	10.09

LW - live weight (g); CW - carcass weight (g); CY - carcass yield (%); BW - breast weight (g); BY - breast yield (%); TW - thigh weight (g); TY - thigh yield (%); DW - drumstick weight (g); DY - drumstick yield (%); WW - wing weight (g); WY - wing yield (%); BCW - back weight (g); BCY - back yield (%); HNW - head plus neck weight (g); HNY - head plus neck yield (%); FW - feet weight (g); FY - feet yield (%); EVW - edible viscera weight (g); EVY - edible viscera yield (%); HW - heart weight (g); HY - heart yield (%); LIW - liver weight (g); LIY - liver yield (%); GW - gizzard weight (g); GY - gizzard yield (%); AFW - abdominal fat weight (g); AFY - abdominal fat yield (%).

Means followed by distinct letters (ab), in the row, indicate difference between diets and sex.

<sup>1</sup> Control: diet without addition of minerals; Cr: diet with 0.40 ppm of biocomplexed chromium; Se: diet with 0.50 ppm of biocomplexed selenium.

<sup>2</sup> Tukey's test at 5% probability.

**Table 6 - Economic efficiency of diets and feed costs for broilers of the Label Rouge lineage during the period from 1 to 90 days, according to diet and sex**

Variable	Diet <sup>1</sup> (D)			Sex (S)		P-value <sup>2</sup>			CV (%)
	Control	Cr	Se	Male	Female	D	S	D×S	
ACD	0.6947	0.6961	0.6997	-	-	-	-	-	-
EI	100.0000	99.8036	99.2911	100.0000	95.2463	-	-	-	-
AFC	7.1242	7.1965	7.2579	7.6862a	6.6994b	0.735	0.001	0.473	4.05
CWG	2.0468	2.1080	2.0987	2.0337b	2.1352a	0.300	0.010	0.481	3.36

ACD - average cost of diet (R\$/kg of feed); EI - economic efficiency index (%); AFC - average food cost (R\$/bird); CWG - cost per kilogram (kg) of weight gain (R\$/kg of weight gain).

<sup>1</sup> Control: diet without addition of minerals; Cr: diet with 0.40 ppm of biocomplexed chromium; Se: diet with 0.50 ppm of biocomplexed selenium.

<sup>2</sup> Tukey's test at 5% of probability.

Means followed by distinct letters (ab), in the row, indicate difference between sexes.

Supplementation with chromium and selenium minerals in broiler diets may cause physiological changes in poultry, which may generate performance response. Chromium has a reduction effect on the secretion of catecholamine (Samanta et al., 2008) and corticosterone (Sahin et al., 2003), which, when at high levels, may cause a reduction in feed intake (Huang et al., 2016). Thus, chromium can increase feed intake and, consequently, weight gain. In addition, due to the fact that chromium acts as a potentiator of insulin action, it may lead to an increase in the utilization rate of glucose, which results in an improvement in feed efficiency, which may lead to an increase in weight gain and, consequently, an improvement in feed conversion (Sahin et al., 2003). Selenium supplementation, in turn, may increase circulating levels of T3, which stimulates protein synthesis in muscle tissue and may be responsible for increased weight gain and improved conversion food index (Ahmad et al., 2012).

However, in the present study, there were no changes in bird performance with supplementation with both minerals. This can be attributed to the fact that in the vitamin premix, used in the composition of the experimental diets, there was inorganic selenium. Therefore, this element was present in all the experimental diets, which may have interfered in the response of biocomplexed selenium supplementation, preventing changes in the performance of birds. Regarding chromium, this element is present in the main dietary ingredients such as corn and soybean, which would probably be enough to meet the nutritional requirements of the birds. In addition, since the birds were raised in a semi-intensive system with access to grazing areas, chromium and selenium could be present in the soil and, consequently, in plants. This may have increased the birds' intake of these minerals, preventing the response of supplementation with these minerals in biocomplexed form on performance. A great part of the works in the literature has also not observed the influence of the supplementation with chromium (Perai et al., 2014; Zheng et al., 2016; Brooks et al., 2016; Trivedi et al., 2019) and biocomplexed selenium (Ahmad et al., 2012; Göçmen et al., 2016; Safdari-Rostamabad et al., 2017; Li et al., 2018; Silva et al., 2019) in broiler diets on weight gain, feed intake, and feed conversion, regardless of mineral source and inclusion levels.

With advancing age, males showed higher values of average weight, weight gain, and feed intake. Variations in performance between birds of different sex may be related to differences in growth rates. According to Mitrovic et al. (2011) and Sarica et al. (2014), males have higher growth potential and higher weight gain rates, due to higher production of anabolic hormones, especially androgens, which stimulate growth and muscle mass gain in animals. Thus, males have higher feed intake, which may be due to their higher demand for nutrients to express their higher growth potential (Santos et al., 2005). The results of the present study are in agreement with those of Santos et al. (2005), Faria et al. (2011), and Del Castilho et al. (2013), who observed higher average weight gain for males, and with Santos et al. (2005) and Dourado et al. (2009), in which males presented higher values of feed intake.

Regarding the feed conversion index, males presented better values throughout the production period (1 to 90 days), which indicates that they are more efficient in converting the consumed feed into weight gain. This result is in agreement with those of Santos et al. (2005), Faria et al. (2011), and Del Castilho et al. (2013), who observed better indices of feed conversion for males.

In general, the supplementation with biocomplexed minerals in broiler diets may cause changes in tissue metabolism, especially in muscle tissue (Zia et al., 2017). Chromium is an active component of glucose tolerance factor (GTF) and, therefore, is responsible for promoting greater insulin-binding to cell receptors, thereby increasing the sensitivity of target cells and enhancing insulin action (Huang et al., 2016). Selenium, in turn, acts on the activation of the enzymes iodothyronine deiodases, which promote dehydration of the phenolic or tyrosine ring of the thyroxine molecule (T4), increasing the production and circulating levels of T3 (Ahmad et al., 2012).

Thus, the supplementation with both minerals in the diet may cause increased protein synthesis in muscle tissue, which may be responsible for an increase in the main carcass characteristics. However, in the present study, there were no changes in carcass characteristics with biocomplexed chromium and selenium supplementation. Other authors found no influence of the supplementation of biocomplexed chromium (Souza et al., 2010; Zheng et al., 2016; Huang et al., 2016; Arif et al., 2019;



Ognik et al., 2020) and selenium (Oliveira et al., 2014; Safdari-Rostamabad et al., 2017; Silva et al., 2019) on the main carcass characteristics, either. The effectiveness of supplementation basically depends on the levels and bioavailability of the source of minerals to be added to the diet, and these factors may be insufficient to promote alterations in tissue metabolism that allow an increase in the main carcass characteristics (Huang et al., 2016; Li et al., 2018).

In a great part of the works in the literature, males presented higher values of live weight (Mitrovic et al., 2011; Sarica et al., 2014; Cruz et al., 2018) and carcass yield (Del Castillo et al., 2013), which is in agreement with the results observed in the present study. This behavior is related to sexual dimorphism, in which males present a higher growth potential, with greater muscle deposition capacity due to the synthesis of androgen hormones, responsible for protein anabolism, in addition to better developed bone structure (Rondelli et al., 2003).

The fact of that females present higher mean of breast yield and males higher thigh yield and drumstick weight may be related to the effect of sexual dimorphism, and this behavior has been observed in other studies (Dourado et al., 2009; Faria et al., 2011; Del Castillo et al., 2013; Sarica et al., 2014; Cruz et al., 2018). Males presented greater development of the secondary parts of the carcass, such as wing, back, head plus neck, and feet. This is due to the fact that males have greater muscle tissue growth potential as well as better developed bone structure with greater limb development (Rondelli et al., 2003; Mitrovic et al., 2011; Sarica et al., 2014). According to Madeira et al. (2006), males present more intense physical activity, which is responsible for greater development of the leg muscles.

In general, sex differences in relation to the edible viscera weight can be attributed to differences in body proportions between males and females, since males have higher live weight and proportionally higher internal organ weight (Mitrovic et al., 2011). This justifies the fact that, in the present study, males showed higher values of heart, liver, and gizzard weight. However, regarding yield values, females presented the highest means of yield of liver and total edible viscera (heart, liver, and gizzard). This may be due to the lower live weight values found for female birds, since the edible viscera yield was calculated in relation to the values of live weight.

Regarding the weight and yield of abdominal fat, females showed higher means, which are probably due to hormonal differences and growth rates between the sexes. According to Rondelli et al. (2003), females show earlier maturity and, thus, there is a reduction in muscle tissue growth, concomitantly with an increase in the deposition of fat in the carcass, compared with males at the same age. In addition, female hormones, especially estrogen, increase body fat deposition (Kessler and Silva, 2017). With similar results, Santos et al. (2005), Faria et al. (2011), Mitrovic et al. (2011), Sarica et al. (2014), and Cruz et al. (2018) found higher values of abdominal fat yield for females.

The inclusion of biocomplexed sources of chromium and selenium in the diet did not cause changes in the average feed cost (AFC) and in the cost per kilogram of weight gain (CWG), considering the entire production period (1 to 90 days). However, from the point of view of the manager, the inclusion of any ingredient that burdens the slightest the dietary costs is interesting as long as it promotes production gains in the stock. The control treatment was more economically efficient; however, its difference in relation to the chromium and selenium treatments, based on the economic efficiency index (EEI) values, was lower than 1%. Regarding sex, males presented higher AFC, lower CWG, and better economic efficiency, based on the EEI values. This indicates that males, despite presenting the highest feed cost during the growing period, are more economically efficient, since the cost to gain one kilogram of live weight is lower when compared with females.

## 5. Conclusions

The addition of biocomplexed chromium and selenium in broiler diets does not affect performance, carcass characteristics, and feed costs. Regarding sex, males present better performance and carcass characteristics, in addition to being economically more viable.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

Conceptualization: F.L. Cruz. Data curation: F.L. Cruz, D.A. Miranda, J.O. Marçal, A.A. Fernandes, M.A. Lopes and A. Geraldo. Formal analysis: M.A. Lopes and A. Geraldo. Funding acquisition: A. Geraldo and P.B. Faria. Investigation: F.L. Cruz. Methodology: F.L. Cruz, D.A. Miranda, J.O. Marçal, A.A. Fernandes, M.A. Lopes and A. Geraldo. Project administration: F.L. Cruz, A. Geraldo and P.B. Faria. Supervision: M.A. Lopes, A. Geraldo and P.B. Faria. Writing-original draft: F.L. Cruz and A. Geraldo. Writing-review & editing: F.L. Cruz.

## Acknowledgments

We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for granting a scholarship for a doctorate in Veterinary Sciences to the author F.L. Cruz.

## References

- Ahmad, H.; Tian, J.; Wang, J.; Khan, M. A.; Wang, Y.; Zhang, L. and Wang, T. 2012. Effects of dietary sodium selenite and selenium yeast on antioxidant enzyme activities and oxidative stability of chicken breast meat. *Journal of Agricultural and Food Chemistry* 60:7111-7120. <https://doi.org/10.1021/jf3017207>
- Arif, M.; Hussain, I.; Mahmood, M. A.; Abd El-Hack, M. E.; Swelum, A. A.; Alagawany, M.; Mahmoud, A. H.; Ebaid, H. and Komany, A. 2019. Effect of varying levels of chromium propionate on growth performance and blood biochemistry of broilers. *Animals* 9:935. <https://doi.org/10.3390/ani9110935>
- Brasil. 1999. Ministério da Agricultura, Pecuária e Abastecimento. Ofício circular DOI/DIPOA nº 007/99, de 19 de maio de 1999. Normatização e comercialização do frango Caipira ou frango Colonial, também denominado “Frango Tipo ou Estilo Caipira” ou “Tipo ou Estilo Colonial”. *Diário Oficial da União, Brasília, DF, 1999.*
- Brooks, M. A.; Grimes, J. L.; Lloyd, K. E.; Krafka, K.; Lamptey, A. and Spears, J. W. 2016. Chromium propionate in broilers: effect on insulin sensitivity. *Poultry Science* 95:1096-1104. <https://doi.org/10.3382/ps/pew018>
- Carvalho, J. B. C.; Zecchin, H. G. and Saad, M. J. A. 2002. Vias de sinalização da insulina. *Arquivos Brasileiros de Endocrinologia & Metabologia* 46:419-425. <https://doi.org/10.1590/S0004-27302002000400013>
- Cruz, F. L.; Saraiva, L. K. V.; Silva, G. E.; Nogueira, T. M.; Silva, A. P. and Faria, P. B. 2018. Growth and carcass characteristics of different crosses of broiler chickens reared under an alternative system. *Semina: Ciências Agrárias* 39:317-328. <https://doi.org/10.5433/1679-0359.2018v39n1p317>
- Del Castilho, C. C.; Santos, T. T.; Rodrigues, C. A. F. and Torres Filho, R. A. 2013. Effects of sex and genotype on performance and yield characteristics of free range broiler chickens. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* 65:1483-1490. <https://doi.org/10.1590/S0102-09352013000500029>
- Dourado, L. R. B.; Sakomura, N. K.; Nascimento, D. C. N.; Dorigam, J. C.; Marcato, S. M. and Fernandes, J. B. K. 2009. Crescimento e desempenho de linhagens de aves pescoço pelado criadas em sistema semi-confinado. *Ciência e Agrotecnologia* 33:875-881. <https://doi.org/10.1590/S1413-70542009000300030>
- Faria, P. B.; Vieira, J. O.; Silva, J. N.; Rodrigues, A. Q.; Souza, X. R.; Santos, F. R. and Pereira, A. A. 2011. Performance and carcass characteristics of free-range broiler chickens fed diets containing alternative feedstuffs. *Brazilian Journal of Poultry Science* 13:211-216. <https://doi.org/10.1590/S1516-635X2011000300009>
- Ferreira, D. F. 2000. Análises estatísticas por meio do Sisvar para Windows versão 4.0. p.255-258. In: 45ª Reunião Anual da Região Brasileira da Sociedade Internacional de Biometria. UFSCar, São Carlos.
- Fialho, E. T.; Barbosa, H. P.; Ferreira, A. S.; Gomes, P. C. and Giroto, A. F. 1992. Utilização da cevada em dietas suplementadas com óleo de soja para suínos em crescimento e terminação. *Pesquisa Agropecuária Brasileira* 27:1467-1475.
- Globoaves. 2015. Manual de manejo linha colonial. Globo Aves Agropecuária Ltda., Cascavel.
- Göçmen, R.; Yazgan, O. and Cufadar, Y. 2016. Effect of different organic and inorganic selenium levels on performance, selenium concentrations of some tissues, glutathione peroxidase enzyme activity and meat quality in broilers. *The Journal of Animal & Plant Sciences* 26:916-923.

- Huang, Y.; Yang, J.; Xiao, F.; Lloyd, K. and Lin, X. 2016. Effects of supplemental chromium source and concentration on growth performance, carcass traits, and meat quality of broilers under heat stress conditions. *Biological Trace Element Research* 170:216-223. <https://doi.org/10.1007/s12011-015-0443-z>
- Kessler, A. M.; Snizek, P. N. and Brugalli, I. 2000. Manipulação da quantidade de gordura na carcaça de frangos. p.107-133. In: *Anais da Fundação Apinco de Ciência e Tecnologia Avícolas. Fundação de Ciência e Tecnologia Avícolas, Campinas.*
- Kessler, A. M. and Silva, M. F. R. 2017. Crescimento do tecido adiposo. p.558-568. In: *Fisiologia das aves comerciais. Macari, M. and Maiorka, A., eds. FUNEP/UNESP, Jaboticabal.*
- Li, J. L.; Zhang, L.; Yang, Z. Y.; Zhang, Z. Y.; Jiang, Y.; Gao, F. and Zhou, G. H. 2018. Effects of different selenium sources on growth performance, antioxidant capacity and meat quality of local Chinese subei chickens. *Biological Trace Element Research* 181:340-346. <https://doi.org/10.1007/s12011-017-1049-4>
- Madeira, L. A.; Sartori, J. R.; Saldanha, E. S. P. B.; Pizzolante, C. C.; Silva, M. D. P.; Mendes, A. A.; Takahashi, S. E. and Solarte, W. V. N. 2006. Morfologia das fibras musculares esqueléticas de frangos de corte de diferentes linhagens criados em sistema de confinamento e semiconfinamento. *Revista Brasileira de Zootecnia* 35:2322-2332. <https://doi.org/10.1590/S1516-35982006000800018>
- Mitrovic, S.; Bogosavljevic-boskovic, S.; Stanisic, G.; Djermanovic, V.; Doskovic, V. and Rakonjac, S. 2011. Carcass characteristics of two strains of native broilers (White Naked Neck and Black Svrljig) fattened under a semi-intensive system. *African Journal of Biotechnology* 10:15813-15818.
- Ognik, K.; Dražbo, A.; Stepniowska, A.; Kozłowski, K.; Listos, P. and Jankowski, J. 2020. The effect of chromium nanoparticles and chromium picolinate in broiler chicken diet on the performance, redox status and tissue histology. *Animal Feed Science and Technology* 259:114326. <https://doi.org/10.1016/j.anifeedsci.2019.114326>
- Oliveira, T. F. B.; Rivera, D. F. R.; Mesquita, F. R.; Braga, H.; Ramos, E. M. and Bertechini, A. G. 2014. Effect of different sources and levels of selenium on performance, meat quality, and tissue characteristics of broilers. *The Journal of Applied Poultry Research* 23:15-22.
- Perai, A. H.; Kermanshahi, H.; Nassiri Moghaddam, H. and Zarban, A. 2014. Effects of supplemental vitamin C and chromium on metabolic and hormonal responses, antioxidant status, and tonic immobility reactions of transported broiler chickens. *Biological Trace Element Research* 157:224-233. <https://doi.org/10.1007/s12011-013-9879-1>
- Rondelli, S.; Martinez, O. and García, P. T. 2003. Sex effect on productive parameters, carcass and body fat composition of two commercial broilers lines. *Brazilian Journal of Poultry Science* 5:169-173. <https://doi.org/10.1590/S1516-635X2003000300002>
- Rostagno, H. S.; Albino, L. F. T.; Donzele, J. L.; Gomes, P. C.; Oliveira, R. F.; Lopes, D. C.; Ferreira, A. S.; Barreto, S. L. T. and Euclides, R. F. 2011. *Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais*. 3.ed. UFV, Viçosa, MG.
- Safdari-Rostamabad, M.; Hosseini-Vashan, S. J.; Perai, A. H. and Sarir, H. 2017. Nanoselenium supplementation of heat-stressed broilers: effects on performance, carcass characteristics, blood metabolites, immune response, antioxidant status, and jejunal morphology. *Biological Trace Element Research* 178:105-116. <https://doi.org/10.1007/s12011-016-0899-5>
- Sahin, K.; Sahin, N. and Kucuk, O. 2003. Effects of chromium, and ascorbic acid supplementation on growth, carcass traits, serum metabolites, and antioxidant status of broiler chickens reared at a high ambient temperature (32 °C). *Nutrition Research* 23:225-238. [https://doi.org/10.1016/S0271-5317\(02\)00513-4](https://doi.org/10.1016/S0271-5317(02)00513-4)
- Sakomura, N. K. and Rostagno, H. S. 2007. *Métodos de pesquisa em nutrição de monogástricos*. 2.ed. Funep, Jaboticabal.
- Samanta, S.; Haldar, S.; Bahadur, V. and Ghosh, T. K. 2008. Chromium picolinate can ameliorate the negative effects of heat stress and enhance performance, carcass and meat traits in broiler chickens by reducing the circulatory cortisol level. *Journal of the Science of Food and Agriculture* 88:787-796. <https://doi.org/10.1002/jsfa.3146>
- Santos, A. L.; Sakomura, N. K.; Freitas, E. R.; Fortes, C. M. L. S.; Carrilho, E. N. V. M. and Fernandes, J. B. K. 2005. Estudo do crescimento, desempenho, rendimento de carcaça e qualidade de carne de três linhagens de frango de corte. *Revista Brasileira de Zootecnia* 34:1589-1598. <https://doi.org/10.1590/S1516-35982005000500020>
- Sarica, M.; Yamak, U. S.; Turhan, S.; Boz, M. A.; Saricaoğlu, F. T. and Altop, A. 2014. Comparing slow-growing chickens produced by two- and three-way crossings with commercial genotypes. 2. Carcass quality and blood parameters. *European Poultry Science* 78. <https://doi.org/10.1399/eps.2014.30>
- Silva, V. A.; Clemente, A. H. S.; Nogueira, B. R. F.; Carvalho, A. C.; Freitas, L. F. V. B.; Ramos, A. L. S. and Bertechini, A. G. 2019. Supplementation of selenomethionine at different ages and levels on meat quality, tissue deposition, and selenium retention in broiler chickens. *Poultry Science* 98:2150-2159. <https://doi.org/10.3382/ps/pey569>
- Souza, L. M. G.; Murakami, A. E.; Fernandes, J. I. M.; Guerra, R. L. H. and Martins, E. N. 2010. Influência do cromo no desempenho, na qualidade da carne e no teor de lipídeos no plasma sanguíneo de frangos de corte. *Revista Brasileira de Zootecnia* 39:808-814. <https://doi.org/10.1590/S1516-35982010000400016>
- Trivedi, S. P.; Patil, S. S.; Garg, D. D.; Savsani, H. H.; Pawar, M. M. and Gohel, B. C. 2019. Effect of dietary supplementation of organic chromium on feed intake, growth performance and economics in commercial broiler chickens. *Journal of Entomology and Zoology Studies* 7:374-378.

Zheng, C.; Huang, Y.; Xiao, F.; Lin, X. and Lloyd, K. 2016. Effects of supplemental chromium source and concentration on growth, carcass characteristics, and serum lipid parameters of broilers reared under normal conditions. *Biological Trace Element Research* 169:352-358. <https://doi.org/10.1007/s12011-015-0419-z>

Zia, W. M.; Khaliq, A.; Naveed, S.; Hussain, J.; Muhammad, I.; Khan, T. M. and Rehman, S. M. 2017. Exploring the effect of selenium forms on final body weight, slaughter characteristics and tissue selenium concentration in Aseel cockerels. *Indian Journal of Animal Research* 51:881-886. <https://doi.org/10.18805/ijar.10764>