R. Bras. Zootec., 50:e20210141, 2021
https://doi.org/10.37496/rbz5020210141

Non-ruminants
Full-length research article

Revista Brasileira de Zootecnia

Brazilian Journal of Animal Science
e-ISSN 1806-9290
www.rbz.org.br

Dietary chromium yeast supplementation length in diets for growing-finishing pigs

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Received: July 23, 2021
Accepted: October 27, 2021

How to cite: Sanches, D. S.; Garcia, E. R. M.; Rodrigues, G. P.; Kiefer, C.; Marçal, D. A.; Alencar, S. A. S.; Silva, C. M. and Rocha, G. C. 2021. Dietary chromium yeast supplementation length in diets for growing-finishing pigs. Revista Brasileira de Zootecnia 50:e20210141.
https://doi.org/10.37496/rbz5020210141

ABSTRACT - This study aimed to evaluate different periods of chromium yeast (CrY) supplementation on growth performance and quantitative carcass characteristics of growing-finishing pigs. We used eighty barrows (Duroc/Pietran × Large White/Landrace) with an initial body weight of 24.5±2.4 kg. A completely randomized block design was used within four periods of dietary CrY supplementation (control diet: CrY-free, from 25 to 110 kg; Cr25-110 kg: diet with 0.4 mg kg^{-1} of CrY, from 25 to 110 kg; Cr50-110 kg: diet with 0.4 mg kg^{-1} of CrY, from 50 to 110 kg; and Cr70-110 kg: diet with 0.4 mg kg^{-1} of CrY, from 70 to 110 kg), with ten replicates and two animals each. The CrY supplementation did not affect (P>0.05) either the grow performance or the carcass characteristics evaluated. The dietary supplementation of 0.4 mg kg^{-1} of CrY for growing-finishing pigs (25 to 110 kg) does not alter the performance neither the quantitative carcass characteristics.

Keywords: additives, carcass modifier, mineral, swine

1. Introduction

Chromium (Cr) is considered an essential nutrient for acting on the metabolism of carbohydrates, lipids, and protein (Ohh and Lee, 2005). It is a component of the glucose tolerance factor, which increases the insulin signalization and stimulates the uptake of glucose and amino acids by target cells (Amata, 2013). A nutritional Cr deficiency can cause glucose intolerance, increase body fat and blood levels of insulin, cholesterol, and triacylglycerols, and reduce body protein in pigs (Pechova and Pavlata, 2007).

There is evidence that Cr supplementation improves the immune system (Wang et al., 2007; Tian et al., 2014), protein and fat metabolism (Untea et al., 2017), weight gain and feed efficiency (Li et al., 2013; Peres et al., 2014), carcass characteristics (Jackson et al., 2009; Park et al., 2009; Wang et al., 2014), and meat quality in pigs (Li et al., 2013). However, other studies did not show the same effects with dietary Cr supplementation (Tian et al., 2014; Tian et al., 2015; Marcolla et al., 2017). The source and concentration of Cr, supplementation period, nutritional status, stress status, health status, age, and genetics can be involved in the variation of responses observed among the studies (Amata, 2013). The main nutritional requirement guides (NRC, 2012; De Blas et al., 2013; Rostagno et al., 2017) do not present a minimal level of dietary Cr for pigs.

There is evidence that Cr supplementation period may affect the responses of the pigs. In a 29-day trial before slaughter, Rodrigues et al. (2020) did not verify any effect of CrY on growth performance. However, Boleman et al. (1995) observed an increase in carcass muscle percentage and a reduction in carcass fat with a 50-day Cr supplementation; and Caramori Júnior et al. (2017) reported an increase in muscle depth with a Cr supplementation period of 66 days, and Matthews et al. (2001) showed an increase in carcass length with supplementation of 102 days.

These responses raise the hypothesis that increasing the dietary Cr supplementation period may improve the growth performance and carcass characteristics of pigs. Thus, this study aimed to evaluate different CrY supplementation periods on the performance and quantitative characteristics of the carcass of growing and finishing pigs.

2. Material and Methods

The experiment was carried out in an experimental farm located in Terenos, MS, Brazil (20°26'32" S latitude and 54°51'37" W longitude). Research was approved by the Institutional Committee on Animal Use (protocol number 625/2014).

We used eighty barrows (Duroc/Pietran × Large White/Landrace) with an initial body weight of 24.5±2.4 kg. Environmental variables were assessed daily throughout the experimental period, using a dry bulb thermometer, a wet bulb thermometer, and black globe thermometer installed in the center of the room. The black globe temperature and relative humidity index (BGHI) was calculated according to Buffington et al. (1981).

The animals were distributed in a completely randomized block design in one of dietary treatments [control: CrY-free diet for 94 days (25 to 110 kg); Cr25-110 kg: 0.4 mg kg^{-1} of CrY in the diet for 94 days (25 to 110 kg); Cr50-110 kg: 0.4 mg kg^{-1} of CrY in the diet for 65 days (50 to 110 kg); and Cr70-110 kg: 0.4 mg kg^{-1} of CrY in the diet for 43 days (70 to 110 kg)], with ten replicates (pens) of two pigs each. The initial weight was adopted as a criterion for block formation.

Diets (Table 1) were formulated to meet the nutritional requirements of pigs with high genetic potential and medium-superior growth performance according to the recommendations of Rostagno et al. (2011). The CrY was included in diets by adding a commercial product containing 1,600 mg kg^{-1} of CrY replacing the inert ingredient (kaolin).

Pigs received feed and water *ad libitum.* The experimental period lasted 94 days. The animals were weighed at the beginning and at the end of the experimental phases (phase 1: 25 to 50 kg, phase 2: 50 to 70 kg, and phase 3: 70 to 110 kg) to calculate daily feed intake, daily weight gain, and feed conversion. Daily digestible lysine intake, daily crude protein intake, and daily metabolizable energy intake were estimated.

On day 95, all pigs were transported (approximately 1 h) to a commercial slaughterhouse and kept in pens with free access to water for approximately 6 h before slaughter. Hot carcass weight was taken immediately after evisceration. Backfat thickness, *longissimus dorsi* muscle depth, and predicted lean meat percentage were measured using a probe (Hennessy Granding System) inserted between the last thoracic and first lumbar vertebrae 5 cm from the middle line on the left side of the hot carcass). The predicted lean meat amount was calculated by multiplying the hot carcass weight by the predicted lean meat percentage. The bonification index, which is a factor correction that differentiates each hot carcass individually by the predicted lean meat percentage, was determined according to Guidoni (2000).

Table 1 - Centesimal and nutritional composition of the experimental diets

Item	Experimental phase		
	25 to 50 kg	50 to 70 kg	70 to 110 kg
Ingredient (%)			
Corn, 7.88%	73.087	75.691	78.084
Soybean meal, 46.5%	23.410	21.430	19.300
Soybean oil	0.367	0.090	0.000
Dicalcium phosphate	1.181	0.953	0.869
Limestone	0.709	0.648	0.608
Mineral + vitamin premix[1]	0.400	0.400	0.000
Mineral + vitamin premix[2]	0.000	0.000	0.400
Salt	0.405	0.379	0.354
L-Lysine HCl	0.279	0.272	0.256
DL-Methionine	0.074	0.059	0.048
L-Threonine	0.063	0.056	0.053
Chromium yeast[3] or inert[4]	0.025	0.025	0.025
Calculated diet composition (%)[5]			
Crude protein	16.68	15.97	15.16
Metabolizable energy (kcal kg^{-1})	3,230	3,230	3,230
Digestible lysine	0.943	0.891	0.829
Digestible met+cys	0.556	0.526	0.497
Digestible threonine	0.613	0.579	0.555
Digestible triptophan	0.170	0.160	0.149
Digestible valine	0.651	0.615	0.572
Digestible arginine	0.387	0.365	0.265
Digestible histidine	0.311	0.294	0.274
Digestible leucine	0.943	0.891	0.829
Digestible phe+tir	0.943	0.891	0.829
Calcium	0.635	0.552	0.512
Available phosphorus	0.314	0.269	0.250
Sodium	0.180	0.170	0.160

[1] Content per kg of product: iron, 40 g; copper, 4 g; cobalt, 0.08 g; manganese, 12 g; zinc, 40 g; iodine, 0.4 g; selenium, 0.12 g; excipiente q.s.p., 400 g; vitamin A, 2,400,000 IU; vitamin D_3, 400,000 IU; vitamin E, 4,800 IU; vitamin B_1, 0.2 g; vitamin B_2, 1.04 g; vitamin B_6, 0.28 g; pantothenic acid, 4 g; vitamin K_3, 0.6 g; nicotine acid, 8.8 g; vitamin B_{12}, 0.006 g; folic acid, 0.08 g; biotin, 0.02 g; choline, 40 g; excipiente q.s.p., 400 g.
[2] Content per kg of product: iron, 10 g; copper, 1.5 g; manganese, 5 g; zinc, 12.5 g; iodine, 0.1 g; selenium, 0.03 g; vitamin A, 650,000 IU; vitamin D_3, 160,000 IU; vitamin E, 3,000 IU, vitamin B_1, 0.22 g; vitamin B_2, 0.55 g; vitamin B_6, 0.2 g; pantothenic acid, 0.92 g; vitamin K_3, 0.3 g; niacin, 2 g; vitamin B_{12}, 2 g; folic acid, 0.05 g, biotin, 0.003 g; choline, 15 g.
[3] Comercial product containing 1,600 mg kg^{-1} of chromium yeast.
[4] Kaolin.
[5] Values were calculated based on the nutritional composition of raw ingredients following the composition proposed by Rostagno et al. (2011).

Data were analyzed as a completely randomized block design using PROC GLM of SAS (Statistical Analysis System, version 9.4) with dietary treatment as a fixed effect and weight block as a random effect. The experimental unit was the pen for all analyses. The following statistical model was used:

$$Y_{ijk} = \mu + T_i + B_j + \varepsilon_{ijk},$$

in which Y_{ijk} is the quantitative response variable, μ is the overall mean, T is the effect of the i-th treatment, B is the effect of the j-th block, and ε is the random error. Dunnett's test was applied to compare the results of the control diet with the inclusion of chromium at each phase according to Sampaio (1998): for the first phase, three control diets versus one chromium diet; for the second phase, two control diets versus two chromium diets; and for the third phase, a control diet versus three chromium diets. For the performance in the total period and for the carcass results, the degrees of freedom of chromium inclusion period were decomposed into orthogonal polynomials, to get the regression equations. Significance was set at P<0.05.

3. Results

The mean air temperature, relative air humidity, black globe temperature, and BGHI recorded during the experimental period were 27.7±2.0 °C, 75.0±12.0%, 28.1±2.1 °C, and 72.2±1.9 in phase 1; 27.2±2.1 °C, 78.0±9.0%, 27.6±2.1 °C, and 77.5±2.4 in phase 2; and 27.0±2.9 °C, 73.3±10.6%, 27.4±2.9 °C, and 77.0±3.6 in phase 3, respectively (Table 2).

There were no effects (P>0.05) of dietary CrY supplementation on growth performance for any of the evaluated phases (Table 3). The CrY supplementation also did not influence (P>0.05) the quantitative carcass characteristics evaluated (Table 4).

Table 2 - Ambiental condition means inside the barn in each experimental phase

Item	Experimental phases		
	25 to 50 kg	50 to 70 kg	70 to 110 kg
AT (°C)	27.7±2.0	27.2±2.1	27.0±2.9
RH (%)	75.0±12.0	78.0±9.0	73.3±10.6
BGT (°C)	28.1±2.1	27.6±2.1	27.4±2.9
BGHI	72.2±1.9	77.5±2.4	77.0±3.6

AT - air temperature; RH - relative air humidity; BGT - black globe temperature; BGHI - black globe temperature and humidity index.

4. Discussion

In the present study, the recorded mean environmental temperatures (27.7±2.0, 27.2±2.1, and 27.0±2.9 °C for phases 1, 2 and 3, respectively) are considered above the ideal for growing-finishing pigs (Nienaber et al., 1987). One of the primary effects observed in pigs subjected to heat stress is the reduction in feed intake (Campos et al., 2017). However, in the present study, even under air temperatures higher than the ideal, feed intake and weight gain of the animals were not altered and stayed in accordance with the Brazilian table of poultry and swine (Rostagno et al., 2017). This effect may be related to the presence of the water gutter in the pen contributing to heat dissipation.

All experimental diets were formulated to have equal nutrient concentration, except for the Cr level. Once there were no differences in ADFI, nutrient intake was similar for all treatments. A previous study found inconsistent responses of the effects of Cr supplementation on pig's growth performance and carcass characteristics (Gebhardt et al., 2019a).

In pigs, Cr can promote the development of muscle tissue, due to the additional energy generated by the increase in glucose uptake by insulin-sensitive cells, which can later be used for protein synthesis, supporting the muscle growth and cell maintenance (Park et al., 2009). Thus, it was expected that the growth performance of the animals evaluated in the present study would be improved, considering the action of Cr as a digestibility enhancer and nutrient partitioner (Lindemann et al., 2008).

The results of the present study corroborate with Tian et al. (2014), who found no effect on growth performance for growing pigs (30 to 50 kg) fed diets supplemented with Cr methionine (0.8 mg kg^{-1}) during 35 days, and Matthews et al. (2005), who reported no improvement in growth performance for finishing pigs (73 to 115 kg) supplemented with 0.2 mg kg^{-1} of Cr propionate for 54 days.

On the other hand, when investigating the supplementation of increasing dietary levels of Cr methionine (0.3, 0.6, and 0.9 mg kg^{-1}) for 28 days in barrows from 75 to 100 kg, Li et al. (2013) observed a linear increase in weight gain and feed intake, 20 and 26% greater than the control diet, respectively. The increase in daily feed intake was also observed by Gebhardt et al. (2019b), when evaluating the isolated effect of Cr picolinate (0.2 mg kg^{-1}) in pigs from 27 to 130 kg.

Table 3 - Growth performance of barrows from 25 to 110 kg fed chromium yeast-supplemented diets for different periods

Variable	Period of chromium yeast supplementation[1]				CV (%)	P-value
	Control	Cr25-110	Cr50-110	Cr70-110		
IBW (kg)	25.34	24.28	24.30	24.16	-	-
BW 50 (kg)	47.65	47.28	44.36	45.26	5.64	0.144
BW 70 (kg)	72.60	73.78	70.08	71.74	4.95	0.344
FBW (kg)	112.56	111.60	110.37	110.19	4.23	0.385
25 to 50 kg						
ADFI (kg)	1.617	1.638	1.437	1.458	10.01	0.094
CP intake (g day^{-1})	269.9	273.4	239.7	243.1	11.77	0.165
SID Lys intake (g day^{-1})	15.26	15.46	13.55	13.74	11.77	0.165
ME intake (kcal day^{-1})	5,225	5,295	4,641	4,707	11.77	0.165
ADG (kg)	0.698	0.718	0.625	0.668	10.85	0.197
F:G	2.340	2.285	2.295	2.166	5.35	0.172
50 to 70 kg						
ADFI (kg)	2.842	2.990	2.907	3.008	15.88	0.638
CP intake (g day^{-1})	454.1	477.2	464.2	528.3	16.18	0.441
SID Lys intake (g day^{-1})	25.34	26.62	25.90	29.47	16.18	0.441
ME intake (kcal day^{-1})	9,185	9,651	9,389	10,681	16.18	0.441
ADG (kg)	1.040	1.105	1.073	1.104	6.36	0.557
F:G	2.742	2.705	2.698	2.992	13.45	0.511
70 to 110 kg						
ADFI (kg)	3.472	3.338	3.487	3.498	6.56	0.574
CP intake (g day^{-1})	526.2	506.2	529.0	530.0	7.52	0.621
SID Lys intake (g day^{-1})	28.77	27.68	28.93	28.98	7.52	0.621
ME intake (kcal day^{-1})	11,211	10,785	11,270	11,291	7.52	0.621
ADG (kg)	1.050	0.997	1.060	0.984	8.42	0.875
F:G	3.310	3.385	3.330	3.560	8.05	0.443
25 to 110 kg						
ADFI (kg)	2.680	2.671	2.642	2.755	6.42	0.632
CP intake (g day^{-1})	420.5	419.5	414.0	431.9	7.42	0.824
SID Lys intake (g day^{-1})	23.29	23.25	22.92	23.92	7.46	0.818
ME intake (kcal day^{-1})	8,656	8,626	8,533	8,895	7.34	0.838
ADG (kg)	0.928	0.929	0.916	0.915	4.61	0.572
F:G	2.895	2.876	2.891	3.007	5.01	0.147

IBW - initial body weight; BW50 - body weight at the end of phase 1 (25 to 50 kg); BW70 - body weight at the end of phase 2 (50 to 70 kg); FBW - final body weight; ADFI - average daily feed intake; CP - crude protein; SID Lys - standardized ileal digestible lysine; ME - metabolizable energy; ADG - average daily gain; F:G - feed-to-gain ratio.

[1] Control: diet without chromium yeast supplementation; Cr25-110: diet supplemented with 0.4 mg kg^{-1} of chromium yeast, from 25 to 110 kg; Cr50-110: diet supplemented with 0.4 mg kg^{-1} of chromium yeast, from 50 to 110 kg; Cr70-110: diet supplemented with 0.4 mg kg^{-1} of chromium yeast, from 70 to 110 kg.

Table 4 - Carcass characteristics of barrows from 25 to 110 kg fed chromium yeast-supplemented diets for different periods

Variable	Period of chromium yeast supplementation[1]				CV (%)	P-value
	Control	Cr25-110	Cr50-110	Cr70-110		
Hot carcass weight (kg)	82.12	81.97	82.27	80.00	3.90	0.632
Carcass length (cm)	101.42	103.05	101.00	102.26	3.62	0.847
Backfat thickness (mm)	12.80	13.30	11.88	14.61	24.04	0.672
Loin depth (mm)	63.06	68.58	71.18	67.57	6.51	0.071
Predicted lean meat (%)	58.88	59.15	60.23	58.28	3.32	0.499
Predicted lean meat (kg)	48.31	48.47	49.54	46.58	3.83	0.125
Bonification index (%)[2]	105.97	106.19	107.35	104.76	1.64	0.182

[1] Control: diet without chromium yeast supplementation; Cr25-110: diet supplemented with 0.4 mg kg^{-1} of chromium yeast, from 25 to 110 kg; Cr50-110: diet supplemented with 0.4 mg kg^{-1} of chromium yeast, from 50 to 110 kg; Cr70-110: diet supplemented with 0.4 mg kg^{-1} of chromium yeast, from 70 to 110 kg.

[2] Factor correction that differentiates each hot carcass individually by the predicted lean meat percentage.

In turn, Peres et al. (2014) observed an improvement of approximately 5% in weight gain and 7% in feed conversion in pigs from 60 to 107 kg fed diets with 0.2 mg kg^{-1} of Cr methionine. Xu et al. (2017) also found an improvement in feed conversion with Cr methionine supplementation in diets for pigs from 50 to 110 kg.

The results observed for carcass characteristic are accordance with the responses observed by Matthews et al. (2001, 2005), Zhang et al. (2011), Peres et al. (2014), Gebhardt et al. (2019a), Gebardht et al. (2019b), and Rodrigues et al. (2020), who also did not observe the effect of supplementing organic sources of Cr on the quantitative carcass characteristics in the growth and finishing phases.

In the present study, it was expected that the Cr supplementation would provide a positive effect on carcass traits due to its mechanisms of action in maintaining glucose homeostasis, potentiating insulin in metabolizing fat, and increasing the uptake of glucose and amino acids for protein synthesis (Amata, 2013).

It can be inferred that the supplementation period was not a critical factor for the lack of a significant effect on the carcass characteristics in the present study, but probably the level of Cr supplementation. Caramori Júnior et al. (2017) reported an increase in muscle depth when evaluating a higher level of CrY (0.8 mg kg^{-1}) in the diet for finishing pigs for a shorter period (66 days).

It is important to note that there is no nutritional recommendation for minimal Cr requirements for finishing pigs (Rostagno et al., 2017), and that the level of 0.4 mg kg^{-1} of Cr supplemented over a long period was not sufficient to promote positive effects on carcass characteristics. This hypothesis is corroborated by Lindemann and Lu (2019), who pointed out that the variability of the effects of Cr supplementation on carcass characteristics can be associated with the supplementation level and period, as well as body weight of pigs. For this reason, further studies are suggested to elucidate not only the period, but also the level of supplementation to better understand the results of the present and other studies.

5. Conclusions

The supplementation of 0.4 mg kg^{-1} of CrY in diets for growing and finishing pigs from 25 to 110 kg does not affect growth performance and quantitative carcass characteristics.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: E.R.M. Garcia, C. Kiefer and G.C. Rocha. Investigation: D.S. Sanches, E.R.M. Garcia, G.P. Rodrigues, C. Kiefer, S.A.S. Alencar and C.M. Silva. Methodology: D.S. Sanches, E.R.M. Garcia, G.P. Rodrigues, C. Kiefer and D.A. Marçal. Supervision: E.R.M. Garcia and C. Kiefer. Visualization: D.A. Marçal, S.A.S. Alencar, C.M. Silva and G.C. Rocha. Writing-original draft: D.S. Sanches, E.R.M. Garcia, G.P. Rodrigues, C. Kiefer, D.A. Marçal, S.A.S. Alencar, C.M. Silva and G.C. Rocha. Writing-review & editing: D.S. Sanches, E.R.M. Garcia, G.P. Rodrigues, C. Kiefer, D.A. Marçal, S.A.S. Alencar, C.M. Silva and G.C. Rocha.

Acknowledgments

The authors thank the Fundação de Apoio ao Desenvolvimento do Ensino, Ciência e Tecnologia do Estado de Mato Grosso do Sul (FUNDECT), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Universidade Federal de Mato Grosso do Sul (UFMS), and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES; Finance Code 001) for the financial support in the execution of the research project.

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