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Chromium and selenium-enriched yeast for castrated finishing pigs: effects on performance and carcass characteristics

Cromo e selênio leveduras para suínos castrados em terminação: efeitos sobre o desempenho e características de carcaça

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Abstract

To evaluate the effect of organic chromium (Cr) and selenium (Se) supplementation on performance and carcass characteristics of finishing pigs, 300 castrated males were distributed in a randomized block design with three treatments and five replications of 20 pigs each. Treatments consisted of different diets, formulated to reach or exceed Rostagno et al. (2011) nutritional requirements, as follows: 1) control - basal diet without organic Cr and Se supplementation from 70 to 130 kg of body weight; 2) CrSe70 - basal diet supplemented with 0.8 mg kg^{-1} of Cr- and 0.6 mg kg^{-1} of Se-enriched yeast from 70 to 130 kg of body weight; 3) CrSe100 - basal diet without organic Cr and Se supplementation from 70 to 100 kg of body weight followed by basal diet supplemented with 0.8 mg kg^{-1} of Cr- and 0.6 mg kg^{-1} of Se-enriched yeast from 100 to 130 kg of body weight. Performance was evaluated by measuring body weight, daily weight gain, daily feed intake and feed conversion ratio. At the end of experimental period, pigs were sacrificed and lean meat percentage, *longissimus dorsi* muscle depth, back fat thickness, and carcass bonus index were determined using prediction equations generated by the software Hennessy System GP4 after carcass scanning with an electronic probe. Data were submitted to one-way ANOVA and in case of significant differences ($P \leq 0.05$), means were compared by SNK multiple-range test. Daily feed intake ($P = 0.008$) and feed conversion ratio ($P = 0.004$) decreased for pigs supplemented with Cr- and Se-enriched yeast from 70 to 100 kg of body weight. Otherwise, pigs supplemented between 100 and 130 kg of body weight increased ($P = 0.032$) daily feed intake in comparison to the control group. Regarding carcass characteristics, Cr- and Se-enriched yeast supplementation increased ($P = 0.019$) *longissimus dorsi* muscle depth in both CrSe70 and CrSe100 treatments. In conclusion, dietary supplementation of Cr- and Se-enriched yeast for castrated male pigs between 70 and 130 kg of body weight increases *longissimus dorsi* muscle depth in carcass without affecting final body weight or daily weight gain of the animals.

Key words: Feed additive. Organic minerals. *Longissimus dorsi*. Weight gain.

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Resumo

Avaliou-se o efeito da suplementação de cromo (Cr) e selênio (Se) orgânico na dieta de suínos de 70 a 130 kg de peso vivo sobre o desempenho e características de carcaça. Foram utilizados 300 suínos machos castrados, distribuídos em um delineamento em blocos casualizados com três tratamentos e cinco repetições de 20 animais. Os tratamentos consistiram em diferentes dietas, formuladas conforme as exigências nutricionais estabelecidas por Rostagno et al. (2011), como segue: 1) controle - dieta basal sem inclusão de Cr e Se orgânicos de 70 a 130 kg de peso vivo; 2) CrSe70 - dieta basal com inclusão de 0,8 mg kg^{-1} de Cr e 0,6 mg kg^{-1} de Se leveduras de 70 a 130 kg de peso vivo; 3) CrSe100 - dieta basal sem inclusão de Cr e Se orgânicos de 70 a 100 kg de peso vivo, seguida de dieta basal com inclusão de 0,8 mg kg^{-1} de Cr e 0,6 mg kg^{1} de Se leveduras de 100 a 130 kg de peso vivo. O desempenho foi avaliado por meio dos parâmetros peso vivo, ganho de peso diário, consumo de ração diário e conversão alimentar. Ao final do período experimental, todos os animais foram abatidos para determinação da percentagem de carne magra, profundidade do músculo *longissimus dorsi*, espessura de toucinho e índice de bonificação das carcaças por meio de equações de predição geradas com auxílio de sonda eletrônica e software Hennessy System GP4 para tipificação de carcaças suínas. Os dados foram submetidos à análise de variância e, em caso de diferença significativa ($P \leq 0,05$), as médias foram comparadas pelo teste SNK. Observou se redução ($P = 0,008$) no consumo de ração e melhora ($P = 0,004$) na conversão alimentar dos suínos suplementados com Cr e Se leveduras entre 70 e 100 kg de peso vivo. De modo contrário, a suplementação de Cr e Se leveduras de 100 a 130 kg de peso vivo aumentou ($P = 0,032$) o consumo de ração dos animais. Em relação às características de carcaça, maior ($P = 0,019$) profundidade do músculo *longissimus dorsi* foi observada independente do período de suplementação. Conclui-se que a suplementação de Cr e Se leveduras em suínos machos castrados de 70 a 130 kg de peso vivo aumenta a profundidade do músculo *longissimus dorsi* sem alterar o peso vivo final e o ganho de peso diário dos animais.

Palavras-chave: Aditivo. Minerais orgânicos. *Longissimus dorsi*. Ganho de peso.

Introduction

Different feed additives have been investigated for improving swine performance, reducing fat deposition and increasing carcass lean meat percentage (BRUMATTI; KIEFER, 2010). Among them, ractopamine has received great attention because of its energy-repartitioning effect, which favors performance and carcass characteristics during the finishing phase, reducing fat and enhancing lean tissue deposition (KIEFER et al., 2009). However, the use of ractopamine has been questioned in different countries because of its possible effects on the health of human consumers, thus becoming a food safety issue (CENTNER et al., 2014). Some researchers speculate that organic minerals, such as chromium (Cr) and selenium (Se), could act like ractopamine and modify carcass characteristics of animals (SAKOMURA et al., 2014). Nevertheless, the effect of these minerals on performance and carcass characteristics of swine are still inconsistent and inconclusive (CHIBA, 2013).

According to Lien et al. (2001) and Peres et al. (2014), the positive effects of organic Cr on performance and carcass composition of finishing pigs have already been demonstrated. Conversely, no effect of organic Cr supplementation for swine was described by Matthews et al. (2001, 2005). A similar situation occurred with organic Se for pigs: positive effects on performance and carcass characteristics were described in some trials (JANG et al., 2010; MARTINEZ-GOMEZ et al., 2012), but a lack of effect on these characteristics was described in others (STUPKA et al., 2012; CAMPOS, 2013).

Considering the discrepancy among information regarding the effects of organic Cr and Se supplementation for swine, the objective of this

research was to determine if organic Cr and Se supplementation affects performance and carcass characteristics of finishing pigs.

Materials and Methods

General procedures

One trial was conducted in a commercial pig farm located in the Midwest region of Brazil. All experimental procedures were previously approved by the Committee of Ethics in the Use of Animals of the Federal University of Mato Grosso do Sul (process # 840/2017). Pigs were managed according to commercial practices and were raised in an open-sided house provided with fans and sprinklers for environment control. Temperature was checked constantly and recorded once per day.

A total of 300 commercial-hybrid male pigs with similar genetic backgrounds and average weight (66.17 ± 1.62 kg) were divided into groups of 20 animals and allocated in 15 concrete floor pens equipped with semi automatic feeders and nipple drinkers. Each pen was considered a replication in a randomized block design with three treatments and five replications. Treatments consisted of different diets, provided *ad libitum* and in mashed form, according to the following scheme: 1) control - basal diet without organic Cr and Se supplementation from 70 to 130 kg of body weight (BW); 2) CrSe70 - basal diet supplemented with Cr- and Se-enriched yeast from 70 to 130 kg of BW; 3) CrSe100 - basal diet without organic Cr and Se supplementation from 70 to 100 kg of BW, but supplemented with Cr- and Se-enriched yeast from 100 to 130 kg of BW. The basal diet was based on corn, soybean meal and sorgum, and it was formulated to reach or exceed nutritional requirements outlined by Rostagno et al. (2011) (Table 1). Organic Cr and Se were included replacing filler, at 0.8 and 0.6 mg kg^{-1} of feed, respectively. Their source was a commercial additive composed of yeast (*Saccharomyces cerevisiae*) enriched with Cr, Se, dried brewer's yeast, *Schizochitrium sp*., ascorbic acid, and *Aspergillus niger*.

Table 1. Basal diet composition (as-fed basis).

Ingredients (%)	70-100 kg	100-130 kg
Corn (7.88)	43.829	50.757
Soyben meal (46%)	21.495	14.496
Sorgum	29.993	29.993
Meat and bone meal (41%)	2.999	2.999
Vitamin-mineral premix[1]	1.500	1.500
L-Lys	0.140	0.200
L-Thr	0.020	0.030
Filler or Cr+Se supplement	0.050	0.050
Calculated composition (%, unless otherwise indicated)[2]		
Crude protein	17.42	14.80
Metabolizable enregy (Kcal/kg)	3,330	3,330
Calcium	0.480	0.460
Available phosphorus	0.260	0.250
Sodium	0.160	0.140
Digestible Lys	0.830	0.710
Digestible Met+Cys	0.470	0.410
Digestible Thr	0.570	0.490
Digestible Trp	0.200	0.140
Digestible Val	0.730	0.620

[1]Provided in 1 kg of product, 70-100 kg: coline 37.5 g, vit. A 1,625,000 IU, vit. D_3 400,000 IU, vit. E 7,500 IU, vit. K_3 750 mg, vit. B_1 550 mg, vit. B_2 1,375 mg, vit. B_6 500 mg, vit. B_{12} 5,000 mg, niacin 5,000 mg, pantothenic acid 2,300 mg, folic acid 125 mg, biotin 7.5 mg, Fe 25 g, Cu 3,750 mg, Mn 12.5 g, Zn 31.25 g, I 250 mg; Se 75 mg. 100-130 kg: coline 100 g, vit. A 6,000,000 IU, vit. D_3 1,000,000 IU, vit. E 12,000 IU; vit. K_3 1.5 g, vit. B_1 0.5 g, vit. B_2 2.6 g, vit. B_6 0.7 g, vit. B_{12} 0.015 g, pantothenic acid 10 g, folic acid 0.2 g, biotin 0.05 g, nicotinic acid 22 g, Fe 100 g, Cu 10 g, Mn 30 g, Zn 100 g, I 1 g, Se 0.3 g, Co 0.2 g.
[2]Based on ingredient composition by Rostagno et al. (2011).

Performance and carcass characteristics

Pigs were individually weighed three times during the experimental period: in the beginning of the trial at approximately 70 kg (66.17 ± 1.62 kg), when they reached approximately 100 kg (104.35 ± 2.40 kg) and at the end of the experiment at approximately 130 kg (129.67 ± 2.43 kg). Immediately before the pigs were weighed, average feed intake was determined by subtracting feed leftovers from the total amount supplied for each pen. Mortality was checked daily and was used to correct feed conversion calculations.

After the last weighing, pigs were fasted for 12 h before being sacrificed in a commercial processing plant according to the rules established by the Ministry of Agriculture, Livestock and Food Supply in Brazil (BRASIL, 1995). In short, animals were rendered insensible by electrical stunning and terminated via exsanguination by laceration of the great vessels of the neck. Carcasses were then scalded, dehaired, and eviscerated. Immediately after evisceration, lean meat percentage, *longissimus dorsi* muscle depth, and back fat thickness were estimated according to prediction equations generated by the software Hennessy System GP4

after carcass scanning with an electronic probe. Afterwards, the carcass bonus index was calculated according to the processing plant standards.

Statistical analysis

The experimental period was divided into three (70 to 100 kg of BW, 100 to 130 kg of BW, and 70 to 130 kg of BW) for statistical analysis. Data were first tested for normality of studentized residuals and homogeneity of variances. Once these assumptions were reached, data were analyzed in a one-way ANOVA and in the case of significant differences, means were compared by SNK multiple-range test. All statistical procedures were performed in SAS software (SAS, 2004) and statistical significance was set at $P \leq 0.05$.

Results and Discussion

Organic Cr and Se supplementation did not affect final BW or daily weight gain between 70 and 100 kg of BW (Table 2). However, supplemented pigs reduced their daily feed intake ($P=0.008$) and improved their feed conversion rate ($P=0.004$) in comparison to the control group. Between 100 and 130 kg of BW, pigs that received Cr- and Se-enriched yeast supplementation from 100 kg of BW increased daily feed intake ($P=0.032$) in comparison to the control group, but no difference in daily feed intake was detected between the control group and pigs that received organic Cr and Se from 70 kg of BW. Considering the whole experimental period (70 to 130 kg of BW), Cr- and Se-enriched yeast supplementation from 100 kg of BW increased daily feed intake in comparison to the control group.

The average temperature during the experimental period ranged from 20.9 to 33.5 ºC (Figure 1), thus indicating that on most days, pigs were submitted to a moderate to severe heat stress according to the thermal comfort zone of 15 to 21 ºC established by Sampaio et al. (2004). This situation could partially explain the low feed intake observed here, particularly during the final period when pigs weighed more than 100 kg of BW. According to Kiefer et al. (2010), chronic heat stress reduces feed intake, body weight gain and impairs the feed conversion rate of finishing pigs. These responses are highly associated with the reduced capacity of pigs to dissipate heat through body surface in hot environments.

Bertechini (2006) stated that growing-finishing pigs might not improve weight gain after organic Cr and Se supplementation, because the associated increase in dietary metabolizable energy level reduces feed consumption. Indeed, when supplementing finishing barrows with 0.4 to 0.8 mg kg^{-1} of Cr-enriched yeast and 0.3 to 0.6 mg kg^{-1} of Se-enriched yeast, Rodrigues (2016) did not find performance differences between supplemented and non-supplemented groups. Similarly, Matthews et al. (2001, 2005) found no effect of 0.2 mg kg^{-1} of Cr tripicolinate or Cr propionate supplementation on pig performance between 23 to 115 kg of BW. However, Peres et al. (2014) showed that 0.2 mg kg^{-1} of Cr methionine supplementation improved the weight gain and feed conversion ratio of finishing pigs. Xu et al. (2017) also showed better feed conversion in swine supplemented with Cr methionine with or without Zn sulfate from 50 to 110 kg of BW. Comparing the effects of 0.3 mg kg^{-1} of Se protein and Se-enriched yeast, Jang et al. (2010) described better performance in pigs supplemented with the first additive, suggesting that Se protein has higher bioavailability to pigs than Se-enriched yeast. Differences in the bioavailability of organic Cr and Se between sources could be the reason for such discrepant results in the literature.

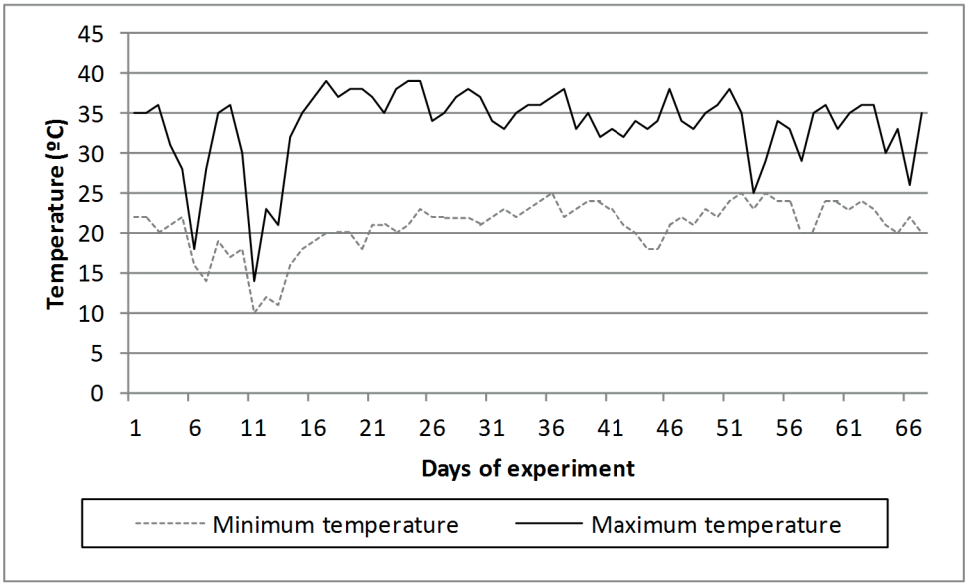
Table 2. Performance of pigs supplemented with Cr- and Se-enriched yeast between 70 and 130 kg of body weight.

Item	Control	CrSe70	CrSe100	Mean	CV (%)	*P* value
70 to 100 kg of body weight						
Initial body weight (kg)	66.24	66.05	-	66.17	2.45	0.837
Final body weight (kg)	104.45	104.14	-	104.35	2.27	0.817
Daily feed intake (kg)	3.50[a]	3.20[b]	-	3.40	4.77	0.008
Daily weight gain (kg)	1.06	1.08	-	1.07	4.25	0.493
Feed conversion rate (kg/kg)	3.29[b]	2.96[a]	-	3.17	4.96	0.004
100 to 130 kg of body weight						
Initial body weight (kg)	103.78	104.14	105.12	104.35	2.30	0.672
Final body weight (kg)	129.52	128.44	131.07	129.67	1.83	0.269
Daily feed intake (kg)	3.21[b]	3.31[ab]	3.50[a]	3.34	4.05	0.032
Daily weight gain (kg)	0.83	0.77	0.83	0.81	6.99	0.670
Feed conversion rate (kg/kg)	3.92	4.29	4.24	4.16	9.19	0.305
70 to 130 kg of body weight						
Initial body weight (kg)	66.46	66.05	66.01	66.17	2.57	0.900
Final body weight (kg)	129.52	128.44	131.07	129.67	1.83	0.269
Daily feed intake (kg)	3.27[b]	3.20[b]	3.49[a]	3.32	2.36	0.001
Daily weight gain (kg)	0.94	0.94	0.97	0.95	3.01	0.158
Feed conversion rate (kg/kg)	3.53	3.45	3.63	3.54	4.89	0.318

Control - basal diet without organic Cr and Se supplementation from 70 to 130 kg of body weight; CrSe70 - basal diet supplemented with Cr- and Se-enriched yeast from 70 to 130 kg of body weight; CrSe100 - basal diet without organic Cr and Se supplementation from 70 to 100 kg of body weight, but supplemented with Cr- and Se-enriched yeast from 100 to 130 kg of body weight.
Values within a line with the same superscript do not differ significantly at $P \leq 0.05$ (SNK multiple-range test).

According to Lindemann et al. (2008), the bioavailability of Cr tripicolinate in comparison to Cr from propionate, enriched yeast and methionine for growing piglets was 13.1, 22.8 and 50.5%, respectively. However, in a meta-analysis assembling results from 31 studies in which Cr was supplemented for growing-finishing pigs as complexes of Cr methionine chelate, Cr nanocomposite, Cr nicotinate, Cr propionate, Cr tripicolinate, or Cr-enriched yeast, Sales and Jancik (2011) detected positive effects of Cr supplementation, irrespective of its source, on average daily gain and gain:feed ratio. No effect of Cr was detected on feed intake, though. Apparently, sex and age of the animals, in addition of source and level of inclusion of organic Cr and Se, might have an impact on the extent of the response of pigs to these minerals.

Figure 1. Daily variation of environmental temperature during the experimental period.



Organic Cr and Se supplementation increased (*P*=0.019) *longissimus dorsi* muscle depth in both CrSe70 and CrSe100 treatments (Table 3). Nevertheless, lean meat percentage, back fat thickness and carcass bonus index were not affected by treatments. Increases of 17.1% (LIEN et al., 2001) and 7% (WOLTER et al., 1999) in the loin eye area of finishing pigs supplemented with Cr picolinate or Se-enriched yeast were described previously. However, different to the results found here, a significant reduction in back fat thickness due to organic Cr and Se supplementation was also detected by the same authors (13.7 and 15%, respectively). Moreover, Rodrigues (2016) and Stupka et al. (2012) described no effect of organic Cr and Se supplementation on carcass characteristics of finishing pigs.

Table 3. Carcass characteristics of pigs supplemented with Cr- and Se-enriched yeast between 70 and 130 kg of body weight.

Item	Control	CrSe70	CrSe100	Mean	CV (%)	*P* value
Lean meat (%)	59.34	59.83	59.13	59.43	5.89	0.596
Longissimus dorsi muscle depth (mm)	69.15^{b}	73.34^{a}	72.34^{a}	71.66	8.85	0.019
Back fat thickness (mm)	15.66	16.37	17.61	16.52	27.36	0.099
Carcass bonus index	109.23	110.49	110.08	109.93	3.62	0.269

Control - basal diet without organic Cr and Se supplementation from 70 to 130 kg of body weight; CrSe70 - basal diet supplemented with Cr- and Se-enriched yeast from 70 to 130 kg of body weight; CrSe100 - basal diet without organic Cr and Se supplementation from 70 to 100 kg of body weight, but supplemented with Cr- and Se-enriched yeast from 100 to 130 kg of body weight.
Values within a line with the same superscript do not differ significantly at $P \leq 0.05$ (SNK multiple-range test).

Considering that Cr stimulates the uptake of both glucose and amino acids (GOMES et al., 2005), the rule of Cr on carcass muscle and fat deposition is probably a consequence of the increased availability of glucose to energy metabolism, sparing amino acids for protein synthesis. This could explain the greater *longissimus dorsi* muscle depth observed here after Cr- and Se-enriched yeast supplementation. Furthermore, as many discrepant results are found in the literature, one could speculate that factors such as the total period of supplementation, besides the source and the level of inclusion of organic Cr and Se in the diet, might influence the extent of pig responses to these minerals.

Conclusions

Dietary supplementation of Cr- and Se-enriched yeast for castrated male pigs between 70 and 130 kg of body weight increases *longissimus dorsi* muscle depth in the carcass without affecting the final body weight or daily weight gain.

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