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

Danilo de Souza Sanches1, Elis Regina de Moraes Garcia1, Gabriela Puhl Rodrigues1, Charles Kiefer2*, Danilo Alves Marçal2, Stephan Alexander da Silva Alencar2, Camilla Mendonça Silva2, Gabriel Cipriano Rocha3

1 Universidade Estadual de Mato Grosso do Sul, Aquidauana, MS, Brasil.  
2 Universidade Federal de Mato Grosso do Sul, Campo Grande, MS, Brasil.  
3 Universidade Federal de Viçosa, Departamento de Zootecnia, Viçosa, MG, Brasil.

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 25 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
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).
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, \( \mu \) is the overall mean, \( T \) is the effect of the \( i \)-th treatment, \( B \) is the effect of the \( j \)-th block, and \( \varepsilon \) 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   | 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 | 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  |
| 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. | | | |

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 | 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 |    2.90 | 0.125  |
| Loin depth (mm)        |    63.66 |    68.58 |    71.18 |    67.57 |    6.51 | 0.974  |
| 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 (%)  |   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), Gebhardt 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.
Dietary chromium yeast supplementation length in diets for growing-finishing pigs
Sanches et al.

References

Amata, I. A. 2013. Chromium in livestock nutrition: A review. Global Advanced Research Journal of Agricultural Science 2:289-306.

Boleman, S. L.; Boleman, S. J.; Bidner, T. D.; Southern, L. L.; Ward, T. L.; Pontif, J. E. and Pike, M. M. 1995. Effect of chromium picolinate on growth, body composition, and tissue accretion in pigs. Journal of Animal Science 73:2033-2042. https://doi.org/10.2527/1995.7372033x

Buffington, D. E.; Collazo-Arocho, A.; Canton, G. H.; Pitt, D.; Thacher, W. W. and Collier, R. J. 1981. Black globe-humidity index (BGHI) as comfort equation for dairy cows. Transactions of the ASAE 24:711-714. https://doi.org/10.13031/2013.34325

Campos, P. H. R. F.; LeFloch, N.; Noblet, J. and Renaudeau, D. 2017. Physiological responses of growing pigs to high ambient temperature and/or inflammatory challenges. Revista Brasileira de Zootecnia 46:537-544. https://doi.org/10.1590/s1806-92902017000600009

Caramori Júnior, J. G.; Kiefer, C.; Ferreira, E. V.; Vieira, B. S.; Oliveira, H. C.; Silva, C. M.; Abreu, R. C. and Luna, U. V. 2017. Chromium and selenium-enriched yeast for castrated finishing pigs: effects on performance and carcass characteristics. Semina: Ciências Agrárias 38:3851-3860. https://doi.org/10.5433/1679-0359.2017v38n6p3851

De Blas, C.; Gasa, J. and Mateos, G. G. 2013. Necesidades nutricionales para ganado porcino. Normas FEDNA. 2.ed. FEDNA, Madrid.

Gebhardt, J. T.; Woodworth, J. C.; Tokach, M. D.; DeRouchej, J. M.; Goodhand, R. D.; Loughmiller, J. A.; Souza, A. L. P. and Dritz, S. S. 2019a. Influence of chromium propionate dose and feeding regimen on growth performance and carcass composition of pigs housed in a commercial environment. Translational Animal Science 3:389-392. https://doi.org/10.1093/tas/txy104

Gebhardt, J. T.; Woodworth, J. C.; Tokach, M. D.; DeRouchej, J. M.; Goodhand, R. D.; Loughmiller, J. A.; Souza, A. L. P.; Rincker, M. J. and Dritz, S. S. 2019b. Determining the influence of chromium propionate and Yucca schidigera on growth performance and carcass composition of pigs housed in a commercial environment. Translational Animal Science 3:1275-1285. https://doi.org/10.1093/tas/tzx117

Guidoni, A. L. 2000. Melhoria de processos para a tipificação e valorização de carcaças suínas no Brasil. p.221-234. In: 1ª Conferência Internacional Virtual sobre Qualidade de Carne Suína. Embrapa Suínos e Aves, Concórdia. Available at: <http://www.cnpsa.embrapa.br/sgc/sgc_publicacoes/anaisis00e_yuidoni_pt.pdf>. Accessed on: Oct. 15, 2020.

Jackson, A. R.; Powell, S.; Johnston, S. L.; Matthews, J. O.; Bidner, T. D.; Valdez, F. R. and Southern, L. L. 2009. The effect of chromium as chromium propionate on growth performance, carcass traits, meat quality, and the fatty acid profile of fat from pigs fed no supplemented dietary fat, choice white grease, or tallow. Journal of Animal Science 87:4032-4041. https://doi.org/10.2527/jas.2009-2168

Li, Y. S.; Zhu, N. H.; Niu, P. P.; Shi, F. X.; Hughes, C. L.; Tian, G. X. and Huang, R. H. 2013. Effects of dietary chromium methionine on growth performance, carcass composition, meat colour and expression of the colour-related gene myoglobin of growing-finishing pigs. Asian-Australasian Journal of Animal Sciences 26:1021-1029. https://doi.org/10.5713/ajas.2013.13012

Lindemann, M. D.; Cromwell, G. L.; Monegue, H. J. and Purser, K. W. 2008. Effect of chromium source on tissue concentration of chromium in pigs. Journal of Animal Science 86:2971-2978. https://doi.org/10.2527/jas.2008-0888

Lindemann, M. D. and Lu, N. 2019. Use of chromium as an animal feed supplement. p.79-125. In: The nutritional biochemistry of chromium (III). 2nd ed. Vicent, J. B., ed. Elsevier. https://doi.org/10.1016/B978-0-444-64121-2.00003-9

Marcolla, C. S.; Holanda, D. M.; Ferreira, S. V.; Rocha, G. C.; Serão, N. V. L.; Duarte, M. S.; Abreu, M. L. T. and Saraiva, A. 2017. Chromium, CLA, and ractopamine for finishing pigs. Journal of Animal Science 95:4472-4480.

Matthews, J. O.; Southern, L. L.; Fernandez, J. M.; Pontif, J. E.; Bidner, T. D. and Oggaard, R. L. 2001. Effect of chromium picolinate and chromium propionate on insulin and insulin kinetics of growing barrows and on growth and carcass traits of growing-finishing barrows. Journal of Animal Science 79:2172-2178. https://doi.org/10.2527/2001.7992172x

Nienaber, J. A.; LeRoy Hahn, G. and Yen, J. T. 1987. Thermal environment effects on growing-finishing swine Part I:Growth, feed intake and heat production. Transactions of the ASAE 30:1772-1775. https://doi.org/10.13031/2013.30635

NRC - National Research Council. 2012. Nutrient requirements of swine. 11th ed. National Academies Press, Washington, DC.

Ohh, S. J. and Lee, J. Y. 2005. Dietary chromium-methionine chelate supplementation and animal performance. Asian-Australasian Journal of Animal Sciences 18:898-907. https://doi.org/10.5713/ajas.2005.898

Park, J. K.; Lee, J. Y.; Chae, B. J. and Ohh, S. J. 2009. Effects of different sources of dietary chromium on growth, blood profiles and carcass traits in growing-finishing pigs. Asian-Australasian Journal of Animal Sciences 22:1547-1554. https://doi.org/10.5713/ajas.2009.80633
Dietary chromium yeast supplementation length in diets for growing-finishing pigs
Sanches et al.

Pechova, A. and Pavlata, L. 2007. Chromium as an essential nutrient: a review. Veterinarni Medicina 52:1-18. https://doi.org/10.17221/2010-VETMED

Peres, L. M.; Bridi, A. M.; Silva, C. A.; Andreo, N.; Barata, C. C. P. and Dário, J. G. N. 2014. Effect of supplementing finishing pigs with different sources of chromium on performance and meat quality. Revista Brasileira de Zootecnia 43:369-375. https://doi.org/10.1590/0100-09392014000700005

Rodrigues, G. P.; Kiefer, C.; Nascimento, K. M. R. S.; Corassa, A.; Garcia, E. R. M.; Marçal, D. A.; Silva, C. M. and Rocha, G. C. 2020. Combined supplementation of chromium-yeast and selenium-yeast on finishing barrows. Ciência Rural 50:e20190406. https://doi.org/10.1590/0103-8478cr20190406

Peres, L. M.; Bridi, A. M.; Silva, C. A.; Andreo, N.; Barata, C. C. P. and Dário, J. G. N. 2014. Effect of supplementing finishing pigs with different sources of chromium on performance and meat quality. Revista Brasileira de Zootecnia 43:369-375. https://doi.org/10.1590/0100-09392014000700005

Rodrigues, G. P.; Kiefer, C.; Nascimento, K. M. R. S.; Corassa, A.; Garcia, E. R. M.; Marçal, D. A.; Silva, C. M. and Rocha, G. C. 2020. Combined supplementation of chromium-yeast and selenium-yeast on finishing barrows. Ciência Rural 50:e20190406. https://doi.org/10.1590/0103-8478cr20190406

Pechova, A. and Pavlata, L. 2007. Chromium as an essential nutrient: a review. Veterinarni Medicina 52:1-18. https://doi.org/10.17221/2010-VETMED

Peres, L. M.; Bridi, A. M.; Silva, C. A.; Andreo, N.; Barata, C. C. P. and Dário, J. G. N. 2014. Effect of supplementing finishing pigs with different sources of chromium on performance and meat quality. Revista Brasileira de Zootecnia 43:369-375. https://doi.org/10.1590/0100-09392014000700005

Rodrigues, G. P.; Kiefer, C.; Nascimento, K. M. R. S.; Corassa, A.; Garcia, E. R. M.; Marçal, D. A.; Silva, C. M. and Rocha, G. C. 2020. Combined supplementation of chromium-yeast and selenium-yeast on finishing barrows. Ciência Rural 50:e20190406. https://doi.org/10.1590/0103-8478cr20190406

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.

Rostagno, H. S.; Albino, L. F. T.; Hannas, M. I.; Donzele, J. L.; Sakomura, N. K.; Perazzo, F. G.; Saraiva, A.; Abreu, M. L. T.; Rodrigues, P. B.; Oliveira, R. F.; Barreto, S. L. T. and Brito, C. O. 2017. Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais. 4.ed. UFV, Viçosa, MG.

Sampaio, I. B. M. 1998. Estatística aplicada à experimentação animal. FEPMZ, Belo Horizonte.

Tian, Y. Y.; Gong, L. M.; Xue, J. X.; Cao, J. and Zhang, L. Y. 2015. Effects of graded levels of chromium methionine on performance, carcass traits, meat quality, fatty acid profiles of fat, tissue chromium concentrations, and antioxidant status in growing finishing pigs. Biological Trace Element Research 168:110-121. https://doi.org/10.1007/s12011-015-0352-1

Tian, Y.Y; Zhang, L. Y.; Dong, B.; Cao, J.; Xue, J. J. and Gong, L. M. 2014. Effects of chromium methionine supplementation on growth performance, serum metabolites, endocrine parameters, antioxidant status, and immune traits in growing pigs. Biological Trace Element Research 162:134-141. https://doi.org/10.1007/s12011-014-0147-9

Untea, A. E.; Varzary, I.; Panait, T. D.; Habeau, M.; Ropota, M.; Olceanu, M. and Carnescu, G. M. 2017. Effects of chromium supplementation on growth, nutrient digestibility and meat quality of growing pigs. South African Journal of Animal Science 47:332-341. https://doi.org/10.4314/sajas.v47i4.10

Wang, M. Q.; Xu, Z. R.; Zhai, L. Y. and Lindermann, M. D. 2007. Effects of chromium nanocomposite supplementation on blood metabolites, endocrine parameters and immune traits in finishing pigs. Animal Feed Science and Technology 139:69-80. https://doi.org/10.1016/j.anifeedsci.2006.12.004

Xu, X.; Liu, L.; Piao, X. S.; Ward, T. L. and Ji, F. 2017. Effects of chromium methionine supplementation with different sources of zinc on growth performance, carcass traits, meat quality, serum metabolites, endocrine parameters, and the antioxidant status in growing-finishing pigs. Biological Trace Element Research 179:70-78. https://doi.org/10.1007/s12011-017-0935-0

Zhang, H.; Dong, B.; Zhang, M. and Yang, J. 2011. Effect of chromium picolinate supplementation on growth performance and meat characteristics of swine. Biological Trace Element Research 141:159-169. https://doi.org/10.1007/s12011-010-8727-9