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ANIMAL PRODUCTION

Chromium and feed restriction as alternative strategies to ractopamine in finishing pigs

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ABSTRACT: This study evaluated chromium and quantitative and qualitative feed restriction as alternative nutritional strategies to ractopamine in finishing barrows. Fifty barrows, genetically similar, with an initial body weight of 99.0 ± 4.3 kg and a final body weight of 117.2 ± 5.8 kg were used. The animals were distributed in a randomized complete block design with five nutritional treatments (Control; Rac = 10ppm ractopamine; Chromium = 0,8mg chromium yeast; Quality = qualitative restriction, 7.5% less net energy in the diet; Quanti = 15% quantitative reduction in feed supply), with five replicates and two animals per replicate. Chromium supplementation and quantitative feed restriction reduced feed, lysine, net energy, and crude protein intakes ($P < 0.05$). Chromium, ractopamine, and quantitative restriction improved feed conversion ($P < 0.05$). Supplementation with chromium and ractopamine and feed restriction did not influence the carcass characteristics of the pigs ($P < 0.05$). Quantitative feed restriction and supplementation of 0.8mg of chromium yeast are presented as potential alternatives to ractopamine in the diet of finishing pigs.
Key words: additives, carcass characteristics, feed management, organic minerals.

Cromo e restrições alimentares como estratégias alternativas a ractopamina para suínos em terminação

RESUMO: O estudo foi conduzido com o objetivo de avaliar o cromo e restrições alimentares quantitativa e qualitativa como estratégias nutricionais alternativas a ractopamina para suínos machos castrados em terminação. Foram utilizados 50 suínos machos castrados, geneticamente similares, com peso inicial de 99,0 ± 4,3 kg e final de 117,2 ± 5,8 kg. Os animais foram distribuídos em delineamento experimental de blocos ao acaso em cinco tratamentos nutricionais (Controle; Rac = 10ppm de ractopamina; Cromo = 0,8mg de cromo levedura; Qualit = restrição qualitativa com menos 7,5% de energia líquida na dieta e Quanti = redução quantitativa de 15% no fornecimento de ração), com cinco repetições e dois animais por repetição. A suplementação de cromo e a restrição alimentar quantitativa reduziram ($P < 0,05$) os consumos de ração, lisina digestível, energia líquida e proteína bruta. O cromo, a ractopamina e a restrição quantitativa melhoraram ($P < 0,05$) a conversão alimentar. A suplementação de cromo, ractopamina e as restrições alimentares não influenciam ($P < 0,05$) as características de carcaça dos suínos. A restrição alimentar quantitativa e a suplementação de 0,8 mg de cromo levedura se apresentam como potenciais alternativas para a substituição da ractopamina nas dietas.
Palavras-chave: aditivos, características de carcaça, manejo alimentar, mineral orgânico.

INTRODUCTION

The use of additives in swine diet has contributed to advances in productive performance in recent years, primarily in terms of feed efficiency and carcass traits. Similar to the actions of additives, feeding management and diet composition can contribute to improve feed efficiency and carcass traits.

Chromium plays a fundamental role in glucose metabolism by enhancing the efficiency of use of circulating glucose (VALENTE JÚNIOR et al., 2021). In swine nutrition, chromium has shown positive effects on performance, including reduced feed intake, increased weight gain, increased carcass muscle depth (ZHANG et al., 2011), and reduced backfat thickness (LIU et al., 2022). Ractopamine has been widely used in the diets of finishing pigs in recent decades, resulting in increased weight gain, improved feed conversion, and reduced carcass fatness (ARMSTRONG et al., 2004; POMPEU et al., 2017). However, several countries have restricted the dietary use of ractopamine (NIÑO et al., 2017), which has stimulated the search for alternatives.

In parallel with the use of feed additives, feed restriction is a technique capable of modifying pig performance by reducing feed intake and carcass backfat thickness (SANTOS et al., 2012). Because feed represents the largest portion of the production costs of finishing pigs, this strategy can also have a positive economic impact. These feeding strategies

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and additives can act alone or together because they have similar goals in terms of performance and carcass characteristics. Therefore, the present study was conducted with the objective of evaluating chromium and quantitative and qualitative dietary restrictions as nutritional alternatives to ractopamine in finishing barrows.

MATERIALS AND METHODS

Fifty genetically similar barrows, with an average initial body weight of 99.0 ± 4.4 kg were used. The pigs were housed in pens measuring 1.15 m × 2.85 m, with a concrete floor and water gutter, equipped with semi-automatic feeders and nipple drinkers.

The animals were distributed in a randomized block experimental design in five nutritional treatments (Control; Rac:10 ppm of ractopamine; Chromium:0.8 mg of chromium kg^{-1} of feed; Quality: qualitative restriction, with a reduction of 7.5% in net energy in the diet, and Quanti: quantitative reduction of 15% in the supply of feed) divided into two daily feedings, with five replicates of two animals per treatment. The inclusion levels of the evaluated feed additives were based on the best economic response to ractopamine (BRUMATTI & KIEFER, 2010) and the best technical response to chromium (CARAMORI Jr. et al., 2017). Dietary restrictions were established, with adjustments based on the results of previous studies (SANTOS et al., 2012; FARIAS et al., 2022). The initial weight of the animals was used as the criterion for block formation. Quantitative restriction was calculated based on the feed intake of animals in the control treatment and corrected daily.

The experimental diets (Table 1) were formulated based on corn and soybean meal supplemented with vitamins and minerals to meet the nutritional requirements established by ROSTAGNO et al. (2011) for pigs weighing 100–120 kg with high genetic potential and average performance.

The experiment lasted for 16 days. The animals were weighed individually at the beginning and the end of the experimental period. The feed provided and the leftovers were weighed daily to determine the daily feed intake. Crude protein, digestible lysine, and net energy intake were calculated by multiplying the concentration of these dietary components by the daily feed intake.

At the end of the experimental period, the animals were fasted for 12 h and subsequently transported to an abbattoir, where they were kept in waiting pens for eight hours with free access to water. The animals were slaughtered in accordance with the management standards and slaughter procedures in Brazil. At the end of the slaughter line, the carcasses were weighed and divided into two halves by making a longitudinal cut along the back lumbar line corresponding to the spine. Carcass length was measured from the cranial edge of the first rib to the cranial edge of the pubic symphysis using a tape measure, according to the method of BRIDI & SILVA (2007). Cuts were made in the left half of the carcass between the last thoracic vertebra and the first lumbar vertebra to measure the depth of the *Longissimus dorsi*muscle and backfat thickness with the aid of a digital caliper, according to the method of BRIDI & SILVA (2007).

The percentage of lean meat in the carcass was determined according to the following equation proposed by BRIDI & SILVA (2007):

$$\text{Lean meat yield (\%)} = 60 - (\text{backfat thickness} \times 0.58) + \text{muscle depth} \times 0.10 \quad (1)$$

Performance data and quantitative carcass traits were subjected to an analysis of variance using the general linear model procedure (PROC GLM, SAS Institute, Inc., Cary, NC, USA). When significant differences were observed, means were compared using the Scott–Knott test. Statistical analyzes were performed using the statistical analysis system SAS (version 9.4) at a 5% level of significance.

RESULTS AND DISCUSSION

Compared to the control treatment, supplementation of diets with chromium and quantitative feed restriction reduced ($P < 0.05$) the average daily intake of feed, digestible lysine, net energy, and crude protein, and improved ($P < 0.05$) feed conversion (Table 2). Animals fed a diet supplemented with ractopamine had better feed conversion than the control group ($P < 0.05$). There was no effect ($P > 0.05$) of the treatments on the final weight and average daily gain.

Pigs subjected to quantitative feed restriction showed a lower average daily feed intake, which was an expected result because daily control of the feed provided for this group of animals was performed. Even without feed restriction, pigs fed a diet containing chromium showed reduced feed intake.

The observed effects of the treatments on the average daily intake of digestible lysine, net energy, and crude protein were consistent with the responses observed for the average daily feed intake,

Table 1 - Centesimal and nutritional composition of experimental diets.

Ingredients, %	-----Control-----	----Cromium----	--------Rac-------	-----Quality-----	------Quant------
Corn 7.86%	84.96	84.96	84.96	77.78	84.96
Soybean meal 46.5%	11.84	11.84	11.84	13.14	11.84
Inert (kolin)	0.962	0.912	0.912	6.865	0.962
Dicalcium phosphate	0.751	0.751	0.751	0.759	0.751
Limestone	0.544	0.544	0.544	0.536	0.544
Salt	0.329	0.329	0.329	0.332	0.329
Supl. vit.+min[1]	0.200	0.200	0.200	0.200	0.200
L-Lysine HCl	0.306	0.306	0.306	0.280	0.306
DL-Methionine	0.032	0.032	0.032	0.038	0.032
L-Threonine	0.062	0.062	0.062	0.060	0.062
L-Thyptophan	0.014	0.014	0.014	0.010	0.014
Chromium	0.000	0.050	0.000	0.000	0.000
Ractopamine	0.000	0.000	0.050	0.000	0.000
----------*Nutritional composition calculated*[2]----------					
Crude protein, %	12.39	12.39	12.39	12.39	12.39
Met. energy, Kcal kg^{-1}	3.230	3.230	3.230	3.003	3.230
Net. energy, Kcal kg^{-1}	2.500	2.500	2.500	2.312	2.500
Digestible lysine, %	0.691	0.691	0.691	0.691	0.691
Digestible met+cist., %	0.415	0.415	0.415	0.415	0.415
Digestible threonine, %	0.463	0.463	0.463	0.463	0.463
Digestible tryptophan, %	0.124	0.124	0.124	0.124	0.124
Digestible arginine, %	0.221	0.221	0.221	0.221	0.221
Digestible valine, %	0.477	0.477	0.477	0.477	0.477
Calcium, %	0.733	0.733	0.733	0.733	0.733
Digestible phosphorus, %	0.215	0.215	0.215	0.215	0.215
Sodium, %	0.150	0.150	0.150	0.150	0.150

[1]Content per kg of product: pantothenic acid: 2,300 mg kg^{-1}; niacin: 4,500 mg kg^{-1}; folic acid: 125 mg kg^{-1}; copper: 3,750 mg kg^{-1}; iron: 25 g kg^{-1}; zinc: 31.25 g kg^{-1}; iodine: 250 mg kg^{-1}; selenium: 75 mg kg^{-1}; manganese: 12.5 g kg^{-1}; vitamin A: 1,250,000 IU kg^{-1}; vitamin D3: 250,000 IU kg^{-1}; vitamin E: 6,250 IU kg^{-1}; vitamin K3: 750 mg kg^{-1}; vitamin B1: 375 mg kg^{-1}; vitamin B2: 1,000 mg kg^{-1}; vitamin B6: 375 mg kg^{-1} and vitamin B12: 4,500 mcg kg^{-1}.
[2]Values calculated based on the nutritional composition of the raw materials (ROSTAGNO et al., 2011).
Rac = Ractopamine; Quality = Qualitative dietary restriction; Quant = Quantitative dietary restriction.

in which the treatments with lower feed ingestion also resulted in lower nutrient consumption. It is still possible to infer that, even with the reduction of 188 kcal of net energy in the diet with qualitative restriction, the pigs adjusted their daily feed intake according to their energy requirements, a fact proven in studies such as that of GONÇALVES et al. (2016), and thus were able to maintaina nutrient intake similar to that of the control group. Even with the reduction in nutrient intake, these treatments did not show a substantial reduction in weight gain; therefore, it is possible to infer that these treatments showed better feed efficiency, as did the animals fed the diet containing ractopamine.

In the literature, the reported effects of dietary Cr supplementation on performance vary. Some studies observed an increase only in weight gain (ZHANG et al., 2011), others observed an increase in weight gain and feed intake (LI et al., 2013), improvement in weight gain and feed conversion (PERES et al., 2014), or improvement only in feed conversion (WANG & XU, 2004). Cr supplementation has also been reported to have no effect on performance (MARCOLLA et al., 2017; FARIAS et al., 2022).

Chromium can improve the dry matter digestibility of the diet (OLIVEIRA et al., 2007) and; consequently, increase the amount of nutrients absorbed and available for metabolism. The greater supply of nutrients associated with the presence of chromium can potentiate insulin action (LIU et al., 2017) and result in better performance.

Although, ractopamine supplementation did not provide a marked effect on the daily gain of

Table 2 - Performance of castrated male pigs in finishing supplemented with chromium, ractopamine and quantitative and qualitative dietary restrictions.

Variables	Experimental diets						
	--Control--	--Cromium--	---Rac---	---Quality---	---Quant---	---CV %---	---P-value---
Initial weight, kg	99.05	99.79	99.37	98.76	99.18	1.91	0.909
Final weight, kg	116.81	117.83	120.6	116.54	116.59	2.42	0.109
DFI, kg*	3.84[a]	3.42[b]	3.63[a]	3.94[a]	3.24[b]	7.91	0.002
DWG, kg	1.11	1.13	1.33	1.11	1.09	12.95	0.067
FC*	3.52[a]	3.07[b]	2.76[b]	3.56[a]	2.99[b]	9.98	0.001
LI, g dia^{-1}*	26.5[a]	23.6[b]	25.1[a]	27.2[a]	22.4[b]	7.91	0.002
NEI, Kcal dia^{-1}*	9.605[a]	8.558[b]	9.080[a]	9.109[a]	8.116[b]	7.91	0.002
CPI, g dia^{-1}*	476[a]	424[b]	450[a]	489[a]	402[b]	7.91	0.002

Rac = Ractopamine; Quality = Qualitative dietary restriction; Quant = Quantitative dietary restriction; DFI = Daily feed intake; DWG = Daily weight gain; FC = Feed conversion; LI = Lysine intake; NEI = Net energy intake; CPI = Crude protein intake.
*Different letters on the same line differ according to the Scott-Knott test.

the animals in the present study, increased weight gain is one of the effects frequently observed in studies that evaluate ractopamine supplementation (POMPEU et al., 2017).

In the present study, the nutrient concentration of the diet supplemented with ractopamine was similar to that of the control diet, and no adjustments were made as proposed by ROSTAGNO et al. (2011; 2017). This may be a reason why there was no increase in weight gain with the use of ractopamine, only in feed conversion. Considering the minimum daily recommendation of 21.9 g of digestible lysine and 8,070 Kcal of net energy, according to ROSTAGNO et al. (2017), we can infer that all treatments provided adequate daily intake of nutrients so that the animals could express their maximum gain potential, which is why we did not observe significant differences in this variable in the present study.

In the present study, it was possible to confirm that finishing pigs adapted feed intake according to the energy level of the diet because there was no difference in net energy consumption between animals in the control treatment and animals subjected to qualitative feed restriction (with a reduction in the net energy level of 7.5%). FRAGA et al. (2008) used up to 20% qualitative feed restriction in finishing pigs and did not observe any effect on daily feed intake. However, they reported a linear reduction in the daily digestible energy intake and daily weight gain with worsening feed conversion, which was not observed in the present study. MOREIRA et al. (2007) did not verify any effects of qualitative restrictions (7.5 and 15% of metabolizable energy) on the performance of finishing pigs, which is similar to the results observed in the present study.

There was no effect ($P < 0.05$) of diet on the carcass traits evaluated (Table 3). In the literature, there are studies with chromium supplementation that show positive effects in reducing the backfat thickness and increasing the loin eye area (OLIVEIRA et al., 2007; ZHANG et al., 2011). The differences between these results and those observed in the current study may be associated with the dose of chromium used and duration of Cr administration.

The effects of ractopamine on carcass traits are well documented. Studies evaluating the use of ractopamine in the diet of finishing pigs generally indicate positive effects on the loin eye area, reduced backfat thickness, and increased amounts of lean meat (POMPEU et al., 2017). Ractopamine inhibits the binding of insulin to the β-adrenergic receptor, antagonizing its action, and reducing fat synthesis and deposition (ARMSTRONG et al., 2004). Thus, the efficacy of ractopamine is believed to be related to its ability to block lipogenesis and increase lipolysis. However, these effects were not observed in the current, and other, studies (SANCHES et al., 2010; SILVA et al., 2015).

Several factors can influence the response of pigs to ractopamine supplementation, including different genetic lineages, inclusion levels, supplementation periods, and amino acid adjustment of the diets. In the current study, 10 ppm ractopamine, associated with a reduced period of supplementation, can be considered to be the main factor responsible for the lack of significant responses in carcass traits. These hypotheses were confirmed by SEE et al. (2004), who

Table 3 - Carcass characteristics of castrated male pigs in finishing supplemented with chromium, ractopamine and quantitative and qualitative dietary restrictions.

Variables	----------Experimental diets----------						
	---Control---	---Cromium---	---Rac---	---Quality---	---Quant---	---CV%---	---P value---
MD, mm	86.26	81.17	83.52	82.55	89.15	9.13	0.340
FT, mm	9.71	10.89	10.20	13.10	11.38	26.95	0.281
HCW, kg	87.86	85.57	90.83	87.83	86.00	5.45	0.289
CL, cm	96.51	97.46	97.13	96.60	97.53	2.22	0.849
LM, kg	62.99	61.80	62.44	60.66	62.31	3.37	0.319
LMP, %	55.37	52.83	56.71	53.28	53.59	6.33	0.214
CY, %	76.28	74.27	75.50	75.57	74.27	1.39	0.401

Rac = Ractopamine; Quality = Qualitative dietary restriction; Quant = Quantitative dietary restriction; MD = Muscle depth; FT = Fat thickness; HCW = Hot carcass weight; LC = Carcass length; LM = Lean meat in kilograms; LMP = Lean meat percentage; CY = Carcass yield.

observed satisfactory performance at 5 and 10 pap and better quantitative characteristics of pig carcasses at 20 ppm; and by OLIVEIRA et al. (2013), who observed a linear improvement in carcass characteristics with an increase in the supplementation period.

CONCLUSION

Supplementation of 0.8 mg chromium yeast kg^{-1} of feed and quantitative feed restriction reduced the average daily feed intake of finishing pigs. Supplementation of 0.8 mg of chromium yeast kg^{-1} of feed, ractopamine (10 ppm), and quantitative feed restriction improved the feed conversion in pigs. However, these treatments did not improve the carcass traits of the pigs. Quantitative feed restriction of 15% and supplementation of 0.8 mg of chromium kg^{-1} of feed are potential alternatives for replacing ractopamine in diets.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The funding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

The project was approved by the ethics committee in the use of animals, protocol number 0651/2014 – Universidade Federal de Mato Grosso do Sul (UFMS).

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