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ANIMAL PRODUCTION

Yeast chromium and digestible lysine levels in finishing pigs subjected to high ambient temperatures

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ABSTRACT: *This study evaluated the effects of chromium yeast and digestible lysine levels on the performance and carcass characteristics of finishing pigs. Sixty-four barrows with an initial weight of 72.77 ± 7.20 kg and final weight of 119.44 ± 9.47 kg were used, distributed in a 2 x 2 factorial scheme, with two levels of chromium yeast (Cr0: 0 ppb and Cr800: 800 ppb) and two levels of digestible lysine (L0: recommended level and L+10%: 10%). The recorded air temperature of 30.9 ± 3.7 ºC during the experimental period was considered as heat stress. Performance variables were not influenced (P>0.05); however, L+10% showed an increase (P<0.05) in daily digestible lysine intake. Carcass characteristics of the animals were not influenced (P>0.05) by the chromium or digestible lysine levels. Supplementation with 800 ppb of yeast chromium and a 10% increase in the level of digestible lysine, isolated or associated, did not improve the performance and carcass characteristics of finishing pigs, subjected to high ambient temperatures.*
Key words: *additive, amino acids, nutrition, minerals.*

Níveis de cromo levedura e lisina digestível para suínos em terminação sob temperaturas ambientais elevadas

RESUMO: *Realizou-se este estudo com o objetivo de avaliar os efeitos de níveis de cromo levedura e lisina digestível, desempenho e características de carcaça de suínos em terminação. Foram utilizados 64 machos castrados com peso inicial de 72,77 ± 7,20 kg e final de 119,44 ± 9,47 kg, distribuídos em esquema fatorial 2 x 2, sendo dois níveis (Cr0: 0 ppb e Cr800: 800 ppb) e dois níveis de lisina digestível (L0: nível recomendado e L+10%: 10%). A temperatura do ar registrada de 30,9 ± 3,7 ºC durante o período experimental foi considerada como de estresse por calor. As variáveis de desempenho não foram influenciadas (P>0,05), contudo L+10% aumentou (P<0,05) o consumo de lisina digestível diário. As características de carcaça dos animais não foram influenciadas (P>0,05) pelos níveis de cromo levedura e lisina digestível. A suplementação de 800 ppb de cromo levedura, e o aumento em 10% do nível de lisina digestível, isolados ou associados, não melhoram o desempenho e as características de carcaça de suínos em terminação submetidos a temperaturas ambientais elevadas.*
Palavras-chave: *aditivos, aminoácidos, nutrição, minerais.*

INTRODUCTION

Elevated environmental temperatures are one of the most common stressing agents in swine production systems, which mainly affect the finishing swine. The temperatures adversely affect behavior and hinder swine performance (KIEFER et al., 2010).

In pigs under stress, chromium supplementation in the swine diets improves the immunological status (WANG et al., 2007), minimizes the response to stress agents (LIU et al., 2017), and improves the performance and carcass traits (PARK et al., 2009; WANG et al., 2014). Chromium promotes protein synthesis in skeletal muscle by modulating the anabolic action of insulin (PECHOVA & PAVLATA, 2007). The mTOR signaling pathway functions as a central regulator of cell metabolism (LAPLANTE & SABATINI, 2009).

Growth factors such as insulin and GH activate mTOR complexes, which are essential for protein synthesis; other factors such as leucine and glutamine and the levels of essential amino acids in the diet are also critical for the activation (KIM et al., 2013). Diets containing insufficient levels of amino acids could inhibitor hinder mTOR activation; and consequently, the protein synthesis (ESCOBAR et

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al., 2006; SURYAWAN et al., 2008; LAPLANTE & SABATINI, 2009).

Results from the studies on chromium-related research, regardless of its level or source used in the experimental diets, could possibly be influenced by environmental temperatures. Therefore, this study evaluated the effects of dietary supplementation of chromium yeast and digestible lysine, in terms of the ideal protein concept on the performance and carcass traits of finishing swine, grown under high environmental temperatures.

MATERIALS AND METHODS

Sixty-four barrows, classified as of high potential for gain according to ROSTAGNO et al. (2017), with initial weight of 72.77 ± 7.20 kg and final weight of 119.44 ± 9.47 kg, were used. Pigs were distributed in a 2 × 2 factorial design comprising of two chromium levels (Cr0: 0 ppb and Cr800: 800 ppb) and two digestible lysine levels (L0: recommended level and L+10%: 10%), totaling four treatments, with eight replicates and two pigs per replicate. The initial weight of the pigs was used as the blocking factor, and the pen was considered as the experimental unit.

Pigs were allotted in a masonry shed with ceramic hoof tiles and fenced sides. Pigpens (1.15 × 2.85 m) were of solid concrete floor with a "shallow pool" at one end of the pen, equipped with feeders and nipple water dispensers. Thermal variables inside the shed were recorded daily at 08h and 16h throughout the experimental period using a portable digital thermometer (model ITWTG2000). The variables recorded were dry bulb temperature, wet-bulb temperature, black globe, and relative humidity. The thermal variables were used to determine the black globe humidity index, according to the equation proposed by BUFFINGTON et al. (1981).

The experimental diets (Tables 1 and 2) were formulated using corn and soybean meal, minerals, and vitamins to meet the nutritional requirements of the pigs (ROSTAGNO et al., 2017). Kaolin was replaced with the necessary quantity of chromium yeast, to correspond to 800 ppb of chromium. Digestible lysine levels were through supplementation of L-Lysine, DL-Methionine, L-Threonine and L-Tryptophan to maintain the ideal protein concept established by ROSTAGNO et al. (2017). There was no need to supplement the other amino acids, because the diet already satisfied the minimal ratio proposed in the ideal protein concept.

The pigs had *ad libitum* access to feed and water throughout the experimental period. Feed leftovers on the floor were collected daily, weighed weekly, and then added to weights of the feed leftovers inside the feeder at the end of every experimental phase, to determine the daily feed intake. The intakes of digestible lysine, crude protein, and metabolizable energy were estimated based on the daily feed intake and according to the estimated concentration of nutrients in the diets. Pigs were weighed using an electronic weighing machine at the beginning of the trial and at the end of each experimental phase (phase I: 70-100 kg; phase II: 100-120 kg), to determine the daily weight gain. The feed: gain ratio was calculated based on the feed intake and weight gain.

For harvesting, animals were desensitized by electronarcosis, then bled, scalded, dehaired, and eviscerated. At the end of the slaughter line, the carcasses were weighed to obtain the hot carcass weight and then split into two halves through a longitudinal cut at the line corresponding to the vertebral column. Backfat thickness, *longissimus dorsi* muscle depth, and lean meat percentage were determined at the P2 measuring point of the left half of the carcass using a Hennessy Grading System GP4/BP4 electronic typification pistol.

The data were analyzed, considering the levels of chromium and digestible lysine as fixed effects and the block as a random effect using the PROC GLIMMIX procedure with SAS 9.1 statistical analysis program (SAS, 2004). The response criteria were evaluated for the primary effects and the potential interactions between chromium and digestible lysine. The significance level was set at 5%.

RESULTS AND DISCUSSION

Mean environmental temperature (30.9 ± 3.7 ºC), globe temperature (31.1 ± 3.6 ºC), relative humidity (59.3 ± 20.4%), and black globe humidity index (80.2 ± 3.9) allow the characterization of the thermal environment as heat stress for finishing pigs. Temperatures above the upper critical temperature of 22 °C (RENAUDEAU et al., 2011) and the black globe humidity index above 82.7 are established as conditions of heat stress for finishing pigs (KIEFER et al., 2010).

The levels of chromium and digestible lysine did not influence ($P>0.05$) the performance of pigs (Table 3); however, there was an increase ($P<0.05$) in the daily estimated digestible lysine intake. The increased amino acid supply in L+10% diets led to a higher intake in Phase I ($P<0.05$), Phase

Table 1 - Centesimal and nutritional composition of experimental diets from 70 to 100 kg.

Ingredients	Diets			
	Cr0L0	Cr0L+10%	Cr800L0	Cr800L+10%
Corn	79.815	79.815	79.815	79.815
Soybean meal, 46.5%	15.693	15.693	15.693	15.693
Soy oil	1.700	1.700	1.700	1.700
Dicalcium phosphate	0.863	0.863	0.863	0.863
Limestone	0.594	0.594	0.594	0.594
Salt	0.368	0.368	0.368	0.368
L-Lysine HCl, 77.5%	0.339	0.444	0.339	0.444
DL-Methionine, 99.5%	0.071	0.120	0.071	0.120
L-Treonine, 96.8%	0.076	0.132	0.076	0.132
L-Tryptophan, 99.0%	0.032	0.048	0.032	0.048
Premix vitamin and mineral[1]	0.150	0.150	0.150	0.150
Inert (kaolin)	0.300	0.074	0.250	0.024
Yeast chromium[2]	0.000	0.000	0.050	0.050
Nutritional composition[3]				
Crude protein, %	14.145	14.285	14.145	14.285
Net energy, Mcal kg^{-1}	2.570	2.570	2.570	2.570
Calcium, %	0.497	0.497	0.497	0.497
Disponible phosphorus, %	0.242	0.242	0.242	0.242
Sodium, %	0.165	0.165	0.165	0.165
Digestible lysine, %	0.805	0.886	0.805	0.886
Digestible meth + cyst, %	0.483	0.532	0.483	0.532
Digestible treonine, %	0.523	0.576	0.523	0.576
Digestible tryptophan, %	0.161	0.177	0.161	0.177
Digestible valine, %	0.563	0.563	0.563	0.563

[1]Content per kilogram of product: vit. A: 1,250,000 UI, vit. D3: 250,000 UI, vit. E: 6,250 UI, vit. K3: 750 mg, vit. B1: 375 mg, vit. B2: 1,000 mg, vit. B6: 375 mg, vit. B12: 4,500 mg, pantothenic acid: 2,300 mg, folic acid: 125 mg, iron: 25 mg, copper: 3,750 mg, manganese: 12.5 g, zinc: 31.25 g, iodine: 250 mg, selenium: 75 mg, and excipient.
[2]Supplementation of 50 g of yeast chromium to obtain diets with 800 ppb of yeast chromium.
[3]Values calculated based on the nutritional composition of raw materials (ROSTAGNO et al., 2017).

II ($P< 0.05$), and for the total experimental period ($P<0.05$). This is an expected response, because there was no difference between the daily feed intake and the increase in amino acid supply, following the ideal protein concept.

In this study, none of the performance variables were affected by chromium supplementation; however, the possible effects of elevated environmental temperatures, during the experimental period, needs to be considered. Finishing pigs are extremely sensitive to high environmental temperatures (KIEFER et al., 2010), and for the entire experimental period, temperatures were much higher than the upper critical limit of 22 °C, as recommended for finishing swine (RENAUDEAU et al., 2011), and maximum temperatures of up to 39 °C were frequently observed.

The primary effects that are often observed and measured in pigs under heat stress conditions are decreased feed intake and modifications in carcass composition (ROSS et al., 2015; MARTÍNEZ-MIRÓ et al., 2016; CAMPOS et al., 2017). A decrease in feed intake is influences weight gain and the feed:gain ratio (KIEFER et al., 2010). However, both feed intake and weight gain of the pigs did not decrease, in response to the elevated temperatures recorded during the experimental period. Therefore, they were classified as high-performance pigs, according to the Brazilian requirement tables (ROSTAGNO et al., 2017). This could be attributed to the adaptability of the lineage used in this study to heat stress conditions (ROSS et al., 2015).

There was no interaction ($P>0.05$) between the levels of chromium and digestible lysine and

Table 2 - Centesimal and nutritional composition of experimental diets from 100 to 120 kg.

Ingredients	Diets			
	Cr0L0	Cr0L+10%	Cr800L0	Cr800L+10%
Corn	85.271	85.271	85.271	85.271
Soybean meal, 46.5%	11.152	11.152	11.152	11.152
Soy oil	1.000	1.000	1.000	1.000
Dicalcium phosphate	0.758	0.758	0.758	0.758
Limestone	0.546	0.546	0.546	0.546
Salt	0.349	0.349	0.349	0.349
L-Lysine HCl, 77.5%	0.336	0.426	0.336	0.426
DL-Methionine, 99.5%	0.042	0.085	0.042	0.085
L-Treonine, 96.8%	0.062	0.110	0.062	0.110
L-Tryptophan, 99.0%	0.033	0.047	0.033	0.047
Premix vitamin and mineral[1]	0.150	0.150	0.150	0.150
Inert (kaolin)	0.300	0.104	0.250	0.054
Yeast chromium[2]	0.000	0.000	0.050	0.050
Nutritional composition[3]				
Crude protein, %	12.270	12.397	12.270	12.397
Net energy, Mcal kg^{-1}	2.570	2.570	2.570	2.570
Calcium, %	0.444	0.444	0.444	0.444
Disponible phosphorus, %	0.216	0.216	0.216	0.216
Sodium, %	0.158	0.158	0.158	0.158
Digestible lysine, %	0.697	0.767	0.697	0.767
Digestible meth + cyst, %	0.418	0.460	0.418	0.460
Digestible treonine, %	0.453	0.499	0.453	0.499
Digestible tryptophan, %	0.139	0.153	0.139	0.153
Digestible valine, %	0.492	0.492	0.492	0.492

[1]Content per kilogram of product: vit. A: 1,250,000 UI, vit. D3: 250,000 UI, vit. E: 6,250 UI, vit. K3: 750 mg, vit. B1: 375 mg, vit. B2: 1,000 mg, vit. B6: 375 mg, vit. B12: 4,500 mg, pantothenic acid: 2,300 mg, folic acid: 125 mg, iron: 25 mg, copper: 3,750 mg, manganese: 12.5 g, zinc: 31.25 g, iodine: 250 mg, selenium: 75 mg, and excipient.
[2]Supplementation of 50 g of yeast chromium to obtain diets with 800 ppb of yeast chromium.
[3]Values calculated based on the nutritional composition of raw materials (ROSTAGNO et al., 2017).

the carcass traits (Table 4). The levels of chromium and digestible lysine did not influence (P>0.05) the carcass traits of the pigs.

Pigs under heat stress conditions showed decreased protein deposition and increased fat tissue deposition (ROSS et al., 2015), which was also observed in this study. There was a tendency for both an increase in backfat thickness (P=0.102) and a decrease in lean meat percentage (P=0.109). In addition, heat stress may increase insulin sensitivity in pigs (FERNANDEZ et al., 2015). Therefore, the increase in the backfat thickness of pigs receiving diets with a 10% increase in amino acid, compared to that fed recommended dietary digestible lysine levels, could be attributed to the deamination and utilization of amino acids in excess as energy, resulting in deposition as lipids in the adipose tissue (VAN MILGEN & DOURMAD, 2015).

The most important function of chromium as a modulator of protein synthesis in pigs under heat stress is probably because of its influence on the mTOR mechanism and on the expression of heat shock proteins (HSPs) (GANESAN et al., 2017). The mTOR mechanism is essential for the synthesis of HSPs under heat stress conditions. The activation of factors inducing the synthesis of HSPs under heat stress conditions is dependent on the mTOR signaling pathway. In cells that have an inactivated mTOR pathway, HSPs are not expressed in response to the heat stress. In others, heat stress activates the

Table 3 - Levels of yeast chromium and digestible lysine on the performance of finishing pigs.

Variables	Cr0	Cr0	Cr800	Cr800	SEM	P value		
	L0	L+10%	L0	L+10%		Cr	L	Cr x L
Initial weight	72.72	72.66	72.84	72.85	2.687	0.802	0.968	0.955
Final weight phase I	98.25	97.98	97.34	97.96	2.963	0.721	0.894	0.732
Final weight phase II	120.22	119.71	118.32	120.50	3.053	0.746	0.629	0.434
Phase I, 70-100 kg								
DFI, kg	3.26	3.33	3.20	3.32	0.127	0.864	0.611	0.884
DWG, kg	1.02	1.01	0.98	1.00	0.028	0.546	0.844	0.684
FC	3.19	3.28	3.26	3.32	0.075	0.603	0.487	0.853
DDLI, g	26.28	29.51	25.80	29.46	1.056	0.861	0.031	0.889
DNEI, Mcal	8.39	8.58	8.24	8.57	0.328	0.867	0.582	0.885
Phase II, 100-120 kg								
DFI, kg	3.25	3.19	3.18	3.39	0.099	0.628	0.572	0.341
DWG, kg	1.04	1.03	1.00	1.07	0.030	0.913	0.447	0.297
FC	3.12	3.11	3.18	3.18	0.098	0.624	0.988	0.962
DDLI, g	22.63	24.45	22.16	26.05	0.729	0.599	0.011	0.334
DNEI, Mcal	8.35	8.22	8.17	8.75	0.254	0.627	0.536	0.341
Phase I+II, 70-120 kg								
DFI, kg	3.25	3.26	3.19	3.36	0.103	0.902	0.558	0.582
DWG, kg	1.03	1.02	0.99	1.04	0.022	0.646	0.542	0.360
FC	3.16	3.20	3.22	3.25	0.071	0.510	0.685	0.938
DDLI, g	24.61	27.21	24.14	27.90	0.829	0.928	0.013	0.626
DNEI, Mcal	8.37	8.42	8.21	8.65	0.268	0.927	0.528	0.610

Cr: chromium, L: lysine, DFI: daily feed intake, DWG: daily weight gain, FC: feed conversion, DDLI: daily digestible lysine intake, DNEI: daily net energy intake.

mTOR pathway for the expression of HSPs; however, the downstream factors that are crucial for protein synthesis via mTOR are blocked.

Therefore, under heat stress conditions, there is a potential for chromium to promote protein synthesis via the mTOR-signaling pathway. However, there is a probability of decrease in the resulting anabolism, because the amino acids from the diets are redirected for synthesizing HSPs for acclimatizing the animal to the stress resulting from high temperatures (CHOU et al., 2012).

Table 4 - Levels of yeast chromium and digestible lysine on the carcass characteristics of finishing pigs.

Variables	Cr0	Cr0	Cr800	Cr800	SEM	P value		
	L0	L+10%	L0	L+10%		Cr	L	Cr x L
HCW, kg	89.30	90.07	89.21	89.88	2.474	0.932	0.646	0.977
CY, %	74.82	76.02	75.69	75.28	0.548	0.878	0.328	0.067
BT, mm	17.28	19.59	17.03	19.30	1.071	0.843	0.102	0.988
LD, mm	65.95	65.95	64.27	64.67	1.095	0.355	0.899	0.898
LM, %	55.03	53.02	54.82	53.11	0.919	0.960	0.109	0.894

Cr: chromium, L: lysine, HCW: hot carcass weight, CY: carcass yield, BT: backfat thickness, LD: loin depth, LM: lean meat.

CONCLUSION

Supplementation with 800 ppb of chromium yeast and an increase of 10% in digestible lysine levels, either in isolation or in concurrence, does not improve the performance and carcass traits in finishing pigs under elevated environmental temperatures.

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BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

The project was approved by the ethics committee in the use of animals, protocol number 625/2014 – Universidade Federal de Mato Grosso do Sul (UFMS).

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.

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