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Effect of ractopamine on digestible lysine requirement for finishing pigs under high ambient temperatures

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ABSTRACT

The objective of this research was to study digestible lysine (Lys) levels in diets supplemented or not with ractopamine for finishing pigs in the summer period, where 128 commercial castrated male, hybrid pigs were selected for meat deposition, with an average weight of 81.2 ± 3.3 kg, distributed in an experimental design randomized blocks, in a 4 × 2 factorial arrangement - four digestible Lys levels (0.736; 0.836; 0.937 and 1.038%) and two levels of ractopamine (0 and 10 ppm) – with eight repetitions and two animals per experimental unit. Interaction was observed between the levels of Lys and ractopamine on pork backfat thickness. There was an effect of the levels of Lys with or without the addition of ractopamine on: feed conversion, daily consumption Lys, backfat thickness, loin eye area, loin depth, loss of liquid per cooking and the amount of lean pig meat. The concentrations of Lys when supplemented with ractopamine affected cooking loss of swine longissimus dorsi. Supplementation with ractopamine in the feed improved final weight, daily weight gain, feed conversion, backfat thickness, rib eye area, percentage of lean meat, loin depth and loss of liquid by cooking the animal longissimus dorsi muscle. It was concluded that rations with 10 ppm of ractopamine improve the performance of finishing pigs, and that the level of digestible Lys with 10 ppm of ractopamine in the finishing phase in summer is 1.038% corresponding to 29.3 g of consumption per day, while in rations without ractopamine is 0.945% corresponding to 28.4 g of consumption per day.

INTRODUCTION

Dietary lysine (Lys) is the nutrient that most influences protein deposition in finishing pigs, due to its constancy in body protein and its preferential metabolic destination for muscle tissue deposition (Kessler, 1998). In addition, Lys is the first limiting amino acid in corn and soybean meal for swine (Kim et al., 2001). The pigs in this phase, as the carcass fat and worsening feed efficiency.

Thus, ractopamine is an additive beta-adrenergic agonist used in finishing swine rations for the purpose of weight increases, there is an increase in the content of increasing the deposition of lean meat and still improve the zootechnical indices of finishing pigs (Costa-Lima et al., 2014).

The ractopamine response in pigs can be influenced, among other factors, by sex class, dosage, duration of ractopamine supply and by the level of nutrients and retention of essential amino acids provides increased nitrogen retention in muscles (Apple et al., 2007).

Therefore, according to the literature consulted, Lys levels with ractopamine supplementation ranges from: energy level in the feed. Thus, the use of ractopamine may be more efficient with an increase in Lys intake, since the 0.87% digestible Lys (Marinho et al., 2007a; Pereira et al., 2008), 1.0% digestible Lys (Kiefer and Sanches, 2009),

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1.04% Lys digestible (Corassa, et al., 2013); 1.11% total Lys (Rikard-Bell et al., 2013a) and 1.15% total Lys (Pérez et al., 2005). This variation can also be influenced by several factors such as the environment heat (Sobrinho et al., 2013), swine genetics (Friesen et al., 1994) and the level of protein used in the feed (Ball et al., 2013).

The experiment was carried out with the objective of evaluating the digestible Lys and ractopamine for finishing barrows in the summer period.

MATERIALS AND METHODS

The protocol used in this study was reviewed and approved by the Animal Care and Use Committee of the Federal University of Viçosa (36/2012), complying with the ethical principles of animal experimentation defined by the Colégio Brasileiro de Experimentação Animal (COBEA, 1991).

The experiment was carried out at the Experimental Farm Swine Farm. Vale do Piranga of the Agricultural Research Company of Minas Gerais (EPAMIG), located in the municipality of Oratório – MG, in the summer period of 2012. A total of 128 commercial hybrid swine selected for deposition of meat, castrated males, with an initial weight of 81.2 ± 3.3 kg. The animals were distributed in a randomized block experimental design, in a factorial arrangement 4 × 2, with four levels of digestible Lys (0.736; 0.836; 0.937 and 1.038%) and two levels of ractopamine (0 and 10 ppm), with eight replications and two animals per unit experimental. The experimental unit consisted of the stall and the formation of blocks the initial weight of the animals was considered as a criterion. The experimental period had duration of 28 days.

The environmental conditions inside the pig shed, represented by temperature and relative air humidity, were monitored twice daily (7 am, 12 am and 5 pm) through thermometers of dry bulb and wet bulb, and black globe (Incoterm Ind. de Thermometers Ltda., Porto Alegre, Rio Grande do Sul, Brazil) kept in an empty pen located in the center of the pig shed at half height of the animals' body. Subsequently, those data were converted into the black globe temperature and humidity index (BGTH), as proposed by Buffington et al. (1981), in order to characterize the thermal environment to which the animals were exposed. Thermal variation was also verified daily (7:00 am) through maximum-minimum thermometers ((Incoterm Ind. de Thermometers Ltda., Porto Alegre, Rio Grande do Sul, Brazil).

Treatments consisted of a basal diet supplemented with L-lysine HCl and ractopamine (0 and 10 ppm) in place of starch. The experimental diets were corn-soybean meal based and supplemented with minerals, vitamins and synthetic amino acids in order to meet or exceed barrows' nutritional requirement, according to Rostagno et al. (2011) recommendations, except for digestible Lys.

All experimental diets had the ratio of each essential amino acid to Lys verified to ensure that none of the amino acids became limiting. In the evaluation, the ratios of essential amino acids were maintained as recommended by Rostagno et al. (2011) using the ideal protein concept for finishing barrows. Experimental rations with centenial and nutritional composition are shown in Table 1. Diets chemical analyzes were performed according to Silva and Queiroz (2002) at the Animal Nutrition Lab, Animal Science Department, Universidade Federal de Viçosa, MG, Brazil. The total amino acid analyzes (basal diet) were performed by EVONIK DEGUSSA do Brazil Laboratory and then converted into digestible amino acids using the digestibility coefficients recommended by Rostagno et al. (2011).

The animals were distributed in a completely randomized block design, in a 4 × 2 factorial arrangement consisting of four Lys levels (0.730, 0.830, 0.930 and 1.030%) and two levels of RAC (0 and 10 ppm). There were eight treatments, with two animals per pen and eight pens per treatment.

The experimental period lasted 28 days, in which the animals had ad libitum access to water and experimental diets. At the end of the experimental period, all animals were weighed, fasted for 15 h, weighed again, and then shipped to a commercial facility (Frigorífico Industrial Vale do Piranga SA) to be slaughtered according to the Brazilian legislation (Brasil, 2000). Weight data and feed waste were assessed so as to evaluate growth-performance criteria, which were final body weight (FBW), average daily feed intake (ADFI), average daily Lys intake (ADLI), average daily gain (ADG) and feed conversion ratio (FCR) for the 28 days' experimental period.

At the end of the experimental period, the animals were transported 7.5 km to the slaughter facility. After slaughter, the whole carcasses were individually evaluated with the aid of a typifying pistol inserted at the 3rd dorsal vertebra, trespassing the backfat and the M. Longissimus dorsi, according to the procedures adopted by the slaughter house for carcasses classification, and the results for backfat thickness (BFT) between the tenth and the eleventh rib and loin depth (LD) were measured using an electronic paquimeter, as well as the lean meat percentage (PLM) and quantity of lean meat (QLM) in the carcass. In addition, the carcass yield (CY) was determined by means of the ratio between the hot carcass weight and the fasted weight of the animals.

After classification, carcasses were taken to the cold room where they were stored and cooled to 5°C for 18 h. Subsequently, the right half-carcasses of each animal were sectioned between the 10th and 11th rib for loin eye area (LEA) evaluation according to the methodology described by Bridi et al. (2006).

Subsequently, a sample of approximately 20 cm was taken from the M. Longissimus dorsi from one animal from each experimental unit with weight closest to the treatment average. Samples, after being identified and packed in polyethylene plastic bags, were placed into coolers and

Table 1. Ingredient and chemical composition of experimental diets (%, as-fed basis unless otherwise indicated) varying digestible Lys content, with or without ractopamine (RAC), for finishing barrows under thermoneutral conditions.

Ingredient	Ractopamine supplementation (ppm)							
	0				10			
	Digestible lysine levels (%)							
	0.736	0.836	0.937	1.038	0.736	0.836	0.937	1.038
Ground corn, 7.8 % CP	73.545	73.545	73.545	73.545	73.545	73.545	73.545	73.545
Soybean meal, 45 % CP	23.350	23.350	23.350	23.350	23.350	23.350	23.350	23.350
Salt	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355
Dicalcium phosphate	1.080	1.080	1.080	1.080	1.080	1.080	1.080	1.080
Ground limestone	0.410	0.410	0.410	0.410	0.410	0.410	0.410	0.410
Ractopamine[1]	-	-	-	-	0.050	0.050	0.050	0.050
Inert[2]	0.910	0.771	0.496	0.200	0.860	0.721	0.446	0.150
L-Lysine HCl, 78.5 %	-	0.129	0.258	0.387	-	0.129	0.258	0.387
DL–Methionine, 99.0 %	-	0.010	0.073	0.136	-	0.010	0.073	0.136
L-Threonine	-	-	0.078	0.152	-	-	0.078	0.152
L-Tryptophan	-	-	0.005	0.026	-	-	0.005	0.026
L-Valine	-	-	-	0.009	-	-	-	0.009
Mineral Supplement[3]	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
Vitamin Supplement[4]	0.200	0.200	0.200	0.200	0.200	0.200	0.200	0.200
Growth promoter[5]	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Formulated[6] (analyzed)[7] nutrient content							
Metabolisable energy (MJ/kg)[6]	13.481	13.481	13.481	13.481	13.481	13.481	13.481	13.481
Crude protein[6]	16.66	16.79	16.97	17.25	16.66	16.79	16.97	17.25
Digestible Lysine[7]	0.736	0.836	0.937	1.038	0.730	0.830	0.930	1.030
Digestible Met + cist[7]	0.497	0.507	0.569	0.630	0.497	0.507	0.569	0.630
Digestible Threonine[7]	0.538	0.538	0.614	0.687	0.538	0.538	0.614	0.687
Digestible Tryptophan[7]	0.167	0.167	0.171	0.192	0.167	0.167	0.171	0.192
Digestible Valine[7]	0.694	0.694	0.694	0.703	0.694	0.694	0.694	0.703
Sodium[6]	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
Calcium[6]	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
Non-Phytate Phosphorus[6]	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300

[1]RACTOP (Hertape Saúde Animal S.A., Juatuba, Minas Gerais, Brazil). Supplied per kg of product: Ractopamine hydrochloride, 20 g; [2]Starch; [3]Provided per kg of the complete diet: 50 mg of Fe (as FeSO4), 10 mg of Cu (as Cu SO4), 25 mg of Mn (as MnSO4), 70 mg of Zn (as ZnSO4), 0.3 mg of Co (as CoCO3), and 0.8 mg of I (as Ca(IO3)2); [4]Provided per kg of the complete diet: retinyl acetate, 4200 IU; cholecalciferol, 900 IU; DL-α-tocopheryl acetate, 30 mg; thiamin, 0.7 mg; riboflavin, 2.7 mg; pyridoxine, 1.4 mg; pantothenic acid, 10.0 mg; menadione sodium bisulphite, 1.9 mg; folic acid, 0.25 mg; niacin, 18.0 mg; cyanocobalamin, 12 µg; selenium, 240 µg; biotin, 60 µg and choline, 250 mg; [5]ENRADIN® F-80 (Coopers Brasil Ltda., Cotia, São Paulo, Brazil), Supplied per kg of product: Enramicin, 80 g; [6]Formulated nutrient content, according to Rostagno et al. (2011).
[7] Analyzed total amino acid content by EVONIK DEGUSSA, and then converted to digestible amino acids using the digestibility coefficients recommended by Rostagno et al. (2011).

transported to the Meat Science Lab, Department of Animal Science, Universidade Federal de Viçosa, MG, Brazil. At the Meat Science Lab, sampled muscles were sectioned in cross-sections, 2.54 cm thick, and stored at -20°C for further analysis.

The M. Longissimus dorsi coloration was evaluated through the CIELAB system, evaluating the L* (luminosity), a* (red index) and b* (yellow index) parameters and by the saturation index (C*) determination according to the following equation:

$C^* = (a^{*2} + b^{*2})^{1/2}$.

Analyzes for thawing (TLL) and cooking (CLL) liquid loss were determined according to the methodology described by Bridi et al. (2006), shear force (SF) was determined according to the methodology described by AMSA (1995) and myofibrillar fragmentation index (MFI) was performed according to the methodology described by Culler et al. (1978).

After homogenization samples were centrifuged at 1000

g for 15 min at 2°C. The obtained pellet was re-suspended in 20 mL of MFIB at 2°C and centrifuged again at 1000 g for 15 min and at 2°C. The resulting pellet was re-suspended in 10 mL of MFI buffer at 2°C and homogenized in vortex and subsequently filtered through a 1 mm mesh polyethylene sieve. Total myofibrillar proteins quantification was done by the Macro Biuret method (Gornall et al., 1949). For MFI buffer determination, samples were prepared with MFIB for a final volume of 8.0 mL and protein concentration of 0.5 mg/mL.

The samples were then subjected to absorbance reading at 540 nm wavelength. The MFI value was obtained by the following calculation:

MFI = Absorbância × 200*

*Scale factor to convert absorbance values as suggested by Culler et al. (1978).

In order to evaluate the antioxidants effect on the lipid stability of the meat, thiobarbituric acid reactive substances (TBARS) were analyzed. The TBARS analyzes value of each sample were performed in duplicate, using the methodology described by Kang et al. (2001).

In a test tube, approximately 3 g of the meat were weighed, with addition of 18 mL perchloric acid (3.86%), and then the tube was homogenized on a Vortex type stirrer for 15 s. The homogenate was filtered on Whatman 1 filter paper, and 2 mL of the filtrate were placed in duplicate threaded tubes, plus 2 mL of 20 mM TBA aqueous solution. The tubes were kept in a boiling water bath for 30 min. After cooling, the optical density was read in a spectrophotometer at 532 nm. The amount of TBARS in the sample was expressed as mg of malonaldehyde per kg of meat.

Data were analyzed using the GLM procedure of SAS (SAS Institute, 2001). The effects included in the model were: digestible Lys level, ractopamine level and the interaction between those levels (Lys and ractopamine). The interaction was unfolded or not, according to the significance and the estimated digestible Lys requirement for late finishing barrows were established by means of linear and quadratic regression model as the best fit obtained for each variable. F test was applied to the means of the ractopamine factor in order to protect P-values. Significance was declared at $P<0.05$.

RESULTS

During the experimental period, the maximum, minimum and air temperatures in the inside the experimental shed remained at 29.7 ± 2.7; 17.1 ± 3.0 and 28.3 ± 2.5°C, respectively. The performance results of the experiment are presented in Table 2. There was no interaction effect ($P>0.05$) between digestible Lys and ractopamine for none of the performance parameters, carcass characteristics and of meat quality evaluated in the animals, with the exception of backfat thickness (BT).

Digestible Lys levels did not influence ($P>0.05$) the final body weight (FBW) of the animals. However, the addition of ractopamine to the feed improved ($P=0.0250$) 2.29% the FBW of pigs compared to those that did not consume. Lys and ractopamine concentrations did not change ($P>0.05$) the ADFI of the animals. Linear ascending effect ($P=0.0001$) of digestible Lys levels was observed on the ADLI of the animals, according to the equation:

$\hat{Y} = 24.821X + 4,728$; $r^2 = 0.99$.

The inclusion of ractopamine in the diet did not change ($P>0.05$) the Lys intake of animals. There was no effect ($P>0.05$) of Lys levels on ADG of swine. However, the growth of the animals was modified ($P=0.0311$) by the inclusion of ractopamine, and the improvement was about 8.51% in relation to those who not ingested. Although there was no effect ($P>0.05$) of interaction between the levels of Lys and ractopamine, there was a divergent response on FCR in relation to ractopamine supplementation or not.

Digestible Lys levels without ractopamine supplementation influenced positively ($P=0.0374$) quadratic FCR up to the estimated level of 0.945% by the equation:

$\hat{Y} = 5.448\ X^2 - 10.300\ X + 7.771$; $r^2=0.99$ (Figure 1).

On the other hand, the increase in Lys levels with the inclusion of ractopamine improved ($P=0.0007$) the FCR linearly with the following equation:

$\hat{Y} = - 0.864\ X + 3,433$; $r^2=0.96$.

The addition of ractopamine in swine rations improved ($P=0.0001$) about 11% the FCR of swine. Although there was no effect ($P>0.05$) of interaction between Lys levels and ractopamine, different responses were found on the parameters of loin eye area (LEA) and LD in relation to the inclusion or not of ractopamine. The results of the carcass characteristics of the experiment are presented in Table 3. Digestible Lys concentrations supplemented or not with RAC in rations modified ($P<0.0070$) the LEA in a linear ascending way according to the equation: $\hat{Y} = 10.717\ X + 34.986$; $r^2=0.93$ and quadratically ($P=0.0170$) to LEA up to the level estimated at: 0.979% according to the equation:

$Y= -107.650x^2 +210.877x – 61.59$; $r^2=0.92$, respectively.

The levels of 0.979% and 1.038% of digestible Lys without and with supplementation, respectively, provided the best results for LEA. An increase ($P=0.0001$) of 11% was observed, which corresponded to 5.1cm² of the LEA of animals when ractopamine was supplemented in the diet. There was an effect ($P<0.05$) of digestible Lys levels, with or without the addition of ractopamine, on the LD in a linear

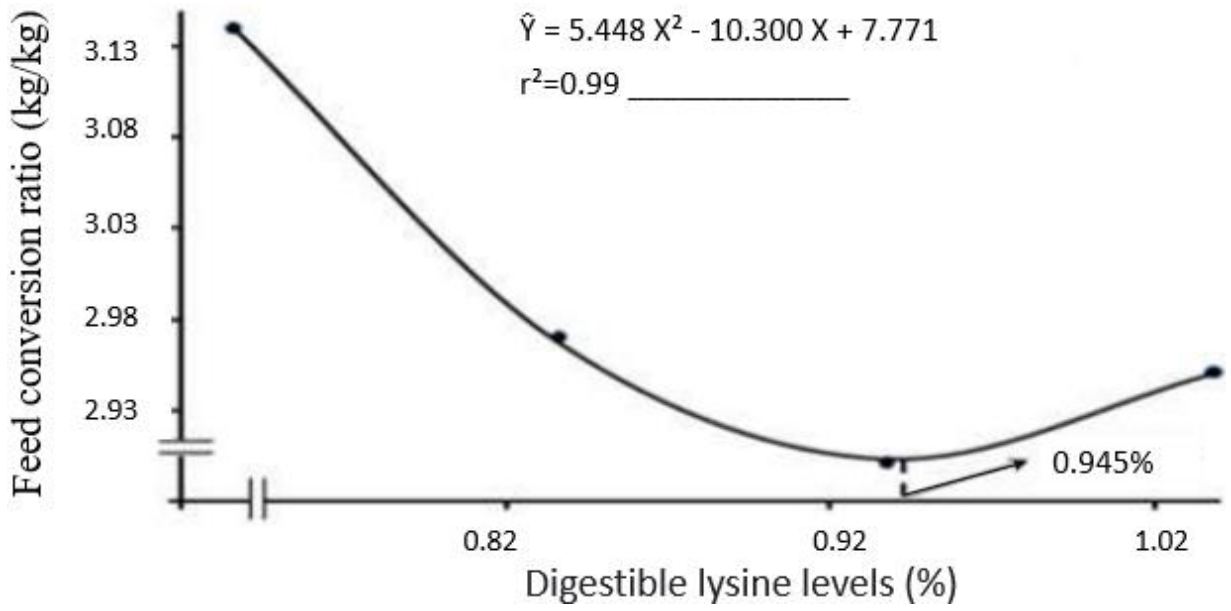

Figure 1 - Feed conversion of finishing pigs with rations containing different digestible lysine levels without ractopamine.

Table 2. Growth performance at the 28th day of experiment of finishing barrows fed diets containing different digestible Lys levels, with or without RAC supplementation.

Variable	Digestible lysine levels (%)				Ractopamine levels (ppm)	Average	P-value			s.e.m.[A]
	0.736	0.836	0.937	1.038			Lys	RAC	Lys x RAC	
IBW (kg)	81.12	81.07	81.05	81.07	0	81.04	n.s.	n.s.	n.s.	0.43
					10	81.12				
FBW (kg)	110.05	110.49	110.86	110.94	0	109.33[a]	n.s.	<0.025	n.s.	2.30
					10	111.84[b]				
ADFI (kg)	3.097	2.964	2.936	2.919	0	3.037	n.s.	n.s.	n.s.	7.98
					10	2.921				
ADLI (g)	23.22	25.19	27.89	30.65	0	26.85	L**	n.s.	n.s.	7,88
					10	25.81				
ADG (kg)	1.033	1.051	1.065	1.067	0	1.011[a]	n.s.	<0.031	n.s.	8,53
					10	1.097[b]				
FCR. (Kg/kg)	3.14	2.97	2.90	2.95	0	2.99[a]	Q*	<0.001	n.s.	4.27
	2.82	2.68	2.62	2.55	10	2.67[b]	L**			6.17

Lys, lysine; RAC, ractopamine; Lys × RAC = interaction lysine x ractopamine; IBW, initial body weight; FBW, final body weight; ADFI, average daily feed intake; ADLI, average daily lysine intake; ADG, average daily gain; FCR, feed conversion ratio. Within the average row, means followed by different capital letters are statistically different by Fisher-Snedecor distribution (P<0.05). *P<0.05; **P<0.01; Q, quadratic effect; L, linear effect; n.s., non-significant effect.

ascending way with the following equations: $\hat{Y}$ = 7.014 X + 48.498; r^2=0.84 and $\hat{Y}$ = 19.896 X + 21.750; r^2=0.74, respectively. The animals that ingested ractopamine increased(P=0.0001) approximately 9.11% at LD compared to those who did not consume the additive.

Difference (P<0.05) was observed between Lys levels, with or without addition of ractopamine, in relation to backfat thickness (BFT), both linearly descending according to the equations: $\hat{Y}$ = -4.257 X + 17.777; r^2=0.91 and $\hat{Y}$ = -6.646 X + 21.826; r^2=0.91, respectively. In addition, the BFT was reduced (P=0.0010) by 13.78% which corresponded to 1.93 mm when the animals ingested ractopamine. Digestible Lys and ractopamine levels did not influence (P>0.05) the CY of the animals. The lean meat quantity (QLM) was modified (P=0.032) linearly ascending by the concentration of digestible Lys in

Table 3. Carcass characteristics at the 28th day of experiment of finishing barrows fed diets containing different digestible Lys.

Variable	Digestible lysine levels (%)				Ractopamine levels (ppm)	Average	P-value			s.e.m
	0.736	0.836	0.937	1.038			Lys	RAC	Lys × RAC	
LD (mm)	45.65	49.18	52.45	52.34	0	50.15A	L*	<0.001	n.s.	4.30
	53.30	54.90	55.07	55.60	10	54.72B	L*			3.76
LEA (mm)	35.64	38.46	42.49	40.98	0	39.39B	Q*	<0.01	n.s.	6.88
	42.50	44.45	45.14	45.87	10	44.49A	L**			5.90
BFT (mm)	16.80	16.61	15.32	15.00	0	15.93A	L**	<0.001	n.s.	9.21
	14.81	13.99	13.75	13.46	10	14.00B	L*			10.48
CY (%)	74.10	75.06	75.26	76.44	0	74.70	n.s.	n.s.	n.s.	4.27
					10	75.42				
QLM (kg)	44.48	44.86	45.18	46.51	0	44.74B	L*	<0.016	n.s.	6.12
					10	45.98A				
PLM. (%)	56.50	56.72	56.84	57.18	0	55.22A	ns	<0.025	n.s.	3.97
					10	57.24B				

(Lys) levels, with or without ractopamine (RAC) supplementation, under thermoneutral conditions; Lys, lysine; RAC, ractopamine; Lys × RAC = interaction lysine × ractopamine; LD, loin depth; LEA, loin eye area; BFT, backfat thickness; CY, carcass yield; QLM, lean meat quantity; PLM, lean meat percentage. Within the average row, means followed by different capital letters are statistically different by Fisher-Snedecor distribution (P<0.05). *P<0.05; **P<0.01; Q, quadratic effect; L, linear effect; n.s., non-significant effect.

Table 4. Meat quality at the 28th day of experiment of finishing barrows fed diets containing different digestible Lys levels, with or without RAC supplementation.

Variable	Digestible lysine levels (%)				Ractopamine levels (ppm)	Average	P-value			s.e.m.[A]
	0.736	0.836	0.937	1.038			Lys	RAC	Lys x RAC	
TL (%)	12.08	13.40	12.36	12.27	0	12.50A	n.s.	<0,002	n.s.	19.41
					10	13.53B				
CL (%)	19.49	20.40	22.18	22.10	0	21.78	L*	n.s.	n.s.	9.45
					10	21.45				
SF (kgf)	3.10	2.84	3.14	3.07	0	3.06	n.s.	n.s.	n.s.	12.83
					10	3.08				
MFI (%)	61.71	62.97	63.54	62.69	0	61.87	n.s.	n.s.	n.s.	8.57
					10	59.87				
LO, MDA (mg/kg)	0.517	0.532	0.538	0.521	0	0.528	n.s.	n.s.	n.s.	16.79
					10	0.526				
B*	6.52	6.23	6.41	6.37	0	6.51A	n.s.	n.s.	n.s.	12.11
					10	6.15[B]				
A*	2.01	2.10	2.29	1.99	0	2.11[A]	n.s.	<0.05	n.s.	24.89
					10	1.86[B]				
L*	45.21	43.63	43.32	44.02	0	44.32	n.s.	n.s.	n.s.	7.79
					10	44.09				

Lys, lysine; RAC, ractopamine; Lys × RAC = interaction lysine x ractopamine; TL, Thaw water loss; CL, cooking water loss; SF, shear force; MFI, myofibrillar fragmentation index; LO, lipid oxidation; B*, meat color score for yellow index; A*, meat color score for red index; L*, meat color score for luminosity index. Within the average row, means followed by different capital letters are statistically different by Fisher-Snedecor distribution (P<0.05). *P<0.05; **P<0.01; Q, quadratic effect; L, linear effect; n.s., non-significant effect.

the ration, according to the following equation: $\hat{Y}$ =6.369X + 39.609, r^2=0.88. The addition of ractopamine in the diet improved (P=0.016) at QLM in the carcass of the animals compared to those that did not consume. There was no significant difference (P>0.05) in digestible Lys levels over PLM of the animals. However, when assessing the addition of ractopamine in the diet over PLM, an increase was observed (P=0.0250) of 1.81%. The thaw water loss

(TL) in the meat was not influenced (P>0.05) by the levels of digestible Lys in the diets. However, the inclusion of ractopamine increased (P=0.002) 8.24% the TL of meat compared to those who did not eat. As the digestible Lys concentrations in the diets increased (P=0.001) the cooking water loss (CL) linearly, with the following equation: $\hat{Y} = 9.541X + 12.582$, $r^2=0.88$. Meat PLC not verified significant difference (P>0.05) when ractopamine was included in the diet. The meat quality results are presented in Table 4. The SF of Longissimus dorsi was not changed (P>0.05) by the digestible Lys and ractopamine concentrations in the swine feed.

Digestible Lys and ractopamine levels did not affect (P>0.05) the MFI of the muscle. The TBARS of animal meat was not altered (P>0.05) by Lys levels digestible and ractopamine in the diets.Staining values (A*, B* and L*) were not affected by Lys levels of the ration.

However, the inclusion of ractopamine reduced (P<0.05) the B* values of Longissimus dorsi muscle of the animals that ingested the additive.

DISCUSSION

Considering the average air temperature obtained, it can be inferred that the animals were subjected to heat stress, as they were above the critical temperature maximum of 26°C for the category, as established by Moura et al. (2011). In addition, the UGTI obtained was close to that found by Sobrinho et al. (2013) from 81.9 for finishing pigs kept under high ambient temperatures. The absence of interaction between the factors (Lys and ractopamine) were also observed by some researchers (Ross et al., 2011; Webster et al., 2007), which evaluated the performance and carcass characteristics of finishing pigs fed diets containing different levels of digestible Lys and ractopamine.

In opposition, Apple et al. (2004) and Armstrong et al. (2004) verified the effect of interaction between Lys and ractopamine levels on pig performance. The possible difference in results found in the literature may be due to the swine genetics, differences in Lys and ractopamine concentrations in rations and also the duration of ractopamine used in the different studies. In relation to the increase in final body weight (FBW) of pigs fed rations containing ractopamine, were also observed by Marinho et al. (2007b) and Sanches et al. (2010) who working with pigs fed different doses of ractopamine (5 and 10 ppm) obtained an improvement of 2.7 and 2.8% in FBW, respectively Voluntary feed intake was not altered by Lys concentrations digestible, a fact also verified by Almeida et al. (2010) that assessing levels of digestible Lys ranging from 0.68 to 1.08% with or without the addition of ractopamine (5 ppm) for barrows and finishing females, there was no difference significant impact on voluntary animal consumption. In opposition, Corassa et al. (2013) evaluating digestible Lys levels varying from 0.94 to 1.04% in diets with the addition of ractopamine (5 ppm), found a reduction in the ADFI of finishing pigs as the Lys level.

According to Souza et al. (2011) the diversity of responses can be explained by the level of energy used and by the imbalance of essential amino acids in the rations, among other factors. As in a study there was no significant variation in the ADFI of pigs, it can be inferred that the increase in the daily intake of digestible Lys was due to its concentration in the feed. The increase in Lys concentrations was not enough to change the ADG of pigs. Rikard-Bell et al. (2013b) evaluating total Lys levels ranging from 0.56 to 1.01% with or without the addition of ractopamine at concentrations of 5 and 20 ppm for barrows and finishing female pigs, also not found a significant variation in the GPD in relation to the increase in the concentration of Lys.

Still consistent with these results, Almeida et al. (2010) and Souza et al. (2011) did not find changes in the swine's average daily gain ADG due to the different Lys levels. In opposition, Kiefer and Sanches (2009) carried out a meta-analysis based on the result of 18 experiments with 2,991 finishing pigs on the influence of digestible Lys levels ranging from 0.65 to 1.0% supplemented or not with ractopamine (5, 10 and 20 ppm), reported an increase in the ADG of the animals when increased Lys concentrations in the diet.

The difference in results found in the literature may possibly be related to the thermal environment (Sobrinho et al., 2013), swine genetics (Friesen et al., 1994) and the level of protein used in the feed (Ball et al., 2013). In the present study, an increase of 8.5% in the swine's ADG was observed when added ractopamine to the feed. Recent studies conducted by Peterson et al. (2015) with pigs in termination, studied three levels of ractopamine (0, 5 and 7.5 ppm) and the behavior of the animals (sociable, moderate and aggressive), showed an increase of 9.9 and 9.0% in the ADG when they consumed ractopamine at concentrations of 5 and 7.5 ppm, respectively, compared to the control treatment.

Ractopamine acts on lipid and protein metabolic pathways, as well has been shown to have an effect on carbohydrate metabolism, and thus redirects the nutrients present in the ration favoring the synthesis of proteins in detriment of fat deposition on the carcass (Gunawan et al., 2007), consequently increasing the ADG of the animals. The feed conversion ratio (FCR) response obtained in this study was also observed by Sobrinho et al. (2013) evaluating digestible Lys levels ranging from 0.66 to 1.24% for swine subjected to heat stress, found a quadratic improvement up to the estimated level of 0.98%.

Based on the findings found by these authors, one can suggest that heat stress increases the requirement of digestible Lys due to physiological and behavioral responses attributed to stress. Consistent with this finding, Corassa et al. (2013) evaluating levels of Lys ranging from 0.94 to 1.04% containing 5 ppm of ractopamine for male pigs castrated and finishing females, also obtained a linear

improvement in the FCR of the animals as a function of the increase in Lys concentration in the diets.

In contrast, Souza et al. (2011) did not observe changes in FCR in function of increased Lys levels with 20 ppm ractopamine supplementation in rations of finishing barrows. Based on the FCR results of the animals, it can be inferred that there was an approximately 9% increase in Lys requirement with ractopamine supplementation. However, Marinho et al. (2007b) and Smits and Cadogan (2003) reported that when the ractopamine is included in rations, the requirement for essential amino acids, especially Lys, is increased by about 30%. However, other factors such as: the Lys and energy (Apple et al., 2004), the swine genotype (Friesen et al., 1994) and the environment heat (Sobrinho et al., 2013) can influence the nutritional requirement of pigs.

The results found in the present study corroborate the findings of Apple et al. (2004), Almeida et al. (2010), Moraes et al. (2010) and Garbossa et al. (2013) that verified an improvement in the FCR of the pigs when they were fed with rations containing ractopamine. The observed response can be attributed to increased protein deposition provided by the inclusion of ractopamine, and the deposition of fat in the carcass has a high energy cost (in terms of weight) compared to deposition of meat (Weatherup et al., 1998). The swine LEA was modified by the Lys concentration, resulting similar was found by researchers (Andretta et al., 2011; Kiefer and Sanches 2009) who performed a meta-analysis and reported a positive influence of Lys levels on the loin area of pigs fed rations containing 10 and 20 ppm of ractopamine.

On the other hand, Webster et al. (2007) did not observe a significant variation of the digestible Lys levels with or without ractopamine supplementation (5 and 10 ppm) in relation to the animals' LEA. The inclusion of ractopamine improved the AOL of the animals that is within the LEA range of 1.4 to 7.3 cm² observed in other studies with finishing pigs fed 10 mg ractopamine compared to untreated animals with the additive in rations (Crome et al., 1996; Stoller et al., 2003; Armstrong et al., 2004; James et al., 2013a). The LD of pigs was increased with the inclusion of ractopamine, a fact also observed by Mendoza et al. (2015) and Almeida et al. (2013) also found increase of 5.6 and 11%, when the animals ingested 5 and 10 ppm of ractopamine in the rations for finishing pigs, respectively.

In contrast, Fernández-Dueñas et al. (2008) evaluating levels of ractopamine (0, 5 and 7.4 ppm) in the diets of castrated males and females did not significant difference over the LD. The BFT parameter was influenced by the Lys and ractopamine interaction, this finding is consistent with that found by Kiefer et al. (2009) who performed a meta-analysis of several studies, and also verified an interaction between the levels of Lys and ractopamine. Marinho et al. (2007a) evaluating two levels of digestible Lys (0.67 and 0.87%) with and without the inclusion of ractopamine (5 ppm) for barrows in finishing, found a reduction in the BFT of the animals as the Lys concentration. However, Souza et al. (2011) evaluating digestible Lys levels ranging from 0.80 to 1.10% containing 20 ppm of ractopamine in rations for barrows in termination, no significant difference was observed in the levels on the BFT of the animals.

Several researchers have demonstrated a reduction in BFT when the animals ingested different doses of ractopamine (5, 7.4, 10 and 20 ppm) in rations for finishing pigs: 1.30 mm Mendoza et al. (2015); 1.05 mm (Hinson et al., 2012); 0.6 mm (James et al., 2013b) and 2.30 mm Rikard-Bell et al. (2013b), respectively. Araújo et al. (2014) evaluating the effect of ractopamine on metabolism lipid content of finishing pigs, found that ractopamine acts on the lipid metabolism in order to stimulate lipolysis and inhibit lipogenesis. Based on this assumption, it can be inferred that ractopamine acts on the reduction of BFT (subcutaneous) as it is the most representative adipose tissue for swine. The lack of effect of Lys concentration on swine CY was also verified by Kiefer et al. (2009) who performed a meta-analysis of several studies, and concluded that different concentrations of digestible Lys containing ractopamine at levels of 5, 10 and 20 ppm in rations did not affect the CY of pigs.

Corassa et al. (2013) also found an ascending linear effect of the QLM of the animals as the digestible Lys concentration increased with the addition of 5 ppm of ractopamine. In line with these findings, Webster et al. (2007) reported that the use of adequate digestible Lys levels containing ractopamine favors protein deposition in the carcass. Sainz et al. (1993) reported that ractopamine supplementation in swine increased the amount of lean meat in the carcass, possibly due to the lesser action of calpain on muscle proteolysis. There was no significant difference in digestible Lys levels in in relation to the PLM of the animals' carcass. These results corroborate those found by Almeida et al. (2013) that evaluating different periods of use of ractopamine (0, 7, 14 and 28 days) and with two levels of ractopamine (0 and 10 ppm), obtained a 3% increase in PLM in relation to the control treatment. In opposition, Fernández-Dueñas et al. (2008) assessing ractopamine levels (0, 5 and 7.4 ppm) in rations of castrated males and females showed no difference significant effect on the PLM in the carcass.

According to the assumption of Spurlock et al. (1993) ractopamine is a ß adrenergic agonist that, when administered in swine rations, increases the amount of lean carcass meat by increasing muscle deposition and reducing fat, improving the fat: meat ratio in the carcass. This action occurs due to increase in muscle protein synthesis or decreasing its degradation and the Protein degradation is mediated by the activity of proteases present in the muscle. Longissimus dorsi TL was altered by ractopamine supplementation, similar results were found by Garbossa et al. (2013) that evaluating different concentrations of ractopamine, also did not observe difference in the TL of swine meat. In opposition, Leal et al. (2014) studying ractopamine levels ranging from 0 to

15 ppm in male and female castrated pigs, demonstrated that the increase in ractopamine in the rations provides a decrease in the loss of liquid in the thawing.

And yet, Silva et al. (2015) evaluating the association of ractopamine and antioxidant vitamins for finishing pigs, found no difference effect of ractopamine supplementation on meat TL. The diversity of response of the addition of ractopamine to meat TL, may show that this variable is influenced by other factors such as genotype and swine stress during slaughter. Witte et al. (2000) evaluating two levels of Lys (0.48 and 0.64%) for swine in termination under different thermal environments, did not observe significant variation of Lys concentrations versus CL longissimus dorsi.

The difference in results found in the studies may have been influenced by animal genetics (Lim et al., 2014). Several researchers Apple et al. (2004) and Silva et al. (2015) did not observe changes in the longissimus dorsi CL due to the addition of ractopamine. It can be suggested that the addition of ractopamine in the ration did not modify the loss of water, which is one of the main meat quality criteria observed by consumers. According to Paulk et al. (2014) the increase in water loss during the cooking could have a negative effect on consumer palatability due to reduced moisture in the cooked product and the loss of associated benefits such as increased succulence. The meat quality parameter SF was not altered by the levels of Lys and ractopamine. Boler et al. (2011) evaluating different digestible Lys concentrations for castrated, intact and immunocastrated male pigs, there was no variation SF significance.

Several researchers, Stoller et al. (2003) and Fernández-Dueñas et al. (2008) also found no effect of ractopamine supplementation on shear force values for the levels (5, 7.4 and 10 ppm of ractopamine) in different sexual categories (whole males, castrated, immunocastrated and females). On the other hand, Patience et al. (2009), Rocha et al. (2013) and Iocca et al. (2015) verified the effect of feeding with ractopamine on the strength of the loins of swine (higher shear values) for barrows, intact, immunocastrated and females. In opposition, Leal et al. (2014) studying ractopamine levels ranging from 0 to 15ppm in male and female castrated pigs, demonstrated that the increase in ractopamine in the rations provides a decrease in the loss of liquid in the thawing. And yet, Silva et al. (2015) evaluating the association of ractopamine and antioxidant vitamins for finishing pigs, found no difference effect of ractopamine supplementation on meat TL.

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However, according to Fernández-Dueñas et al. (2008) the differences in ractopamine concentrations, duration, or both may influence the meat quality response (tenderness). Pérez et al. (2005) working with digestible Lys levels ranging from 0.95 to 1.05% and containing or not ractopamine (10 ppm) in rations for finishing pigs, observed a reduction in MFI as the concentration of digestible Lys increased in the ration, a fact not observed in the present work. Absence of Lys effect on the IMF can be explained by the genetics of the swine (Lim et al., 2014) and the energy level of the feed (Cameron et al., 2000). Similarly, there was no significant difference in supplementation with ractopamine on IFM. Stoller et al. (2003) also did not verify the influence of addition of ractopamine on the intramuscular fat of the animals' longissimus dorsi.

However, these same researchers also reported that the genotype of animals (Berkshire and Duroc) obtained divergent responses regarding fat intramuscularly, confirming that genetics interfere with the response. Dunshea et al. (2005) and Trindade et al. (2008), correlated values of TBARS with sensory analysis results with trained and untrained judges (Trindade et al., 2008) to evaluate “rancid odor” in pork. According to the authors, the odor detection threshold corresponds to values between 0.5 and 1.0 mg MDA/kg for trained panelists and

0.6 and 2.0 mg MDA/kg for untrained panelists.

Thus, considering the average value of lipid oxidation found in this study (0.53 mg MDA/kg sample) and the report by Drehmer (2005), that the product can be considered of good quality when TBARS levels are between 0.5 to 1.0 mg of MDA/kg.

Conclusion

The best performance and carcass characteristics of pigs neutered males in the summer period were obtained with the levels of 1.038 and 0.945% of digestible Lys, corresponding to an estimated daily consumption of 29.3 and 28.4 g, respectively, with 10 ppm ractopamine supplementation or not in the feed.

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