



Ractopamine for finishing barrows fed restricted or ad libitum diets: performance and nitrogen balance¹

Vinícius de Souza Cantarelli², Elias Tadeu Fialho², Erin Caperuto de Almeida³, Márcio Gilberto Zangeronimo⁴, Paulo Borges Rodrigues², Rilke Tadeu Fonseca de Freitas²

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² Departamento de Zootecnia da Universidade Federal de Lavras – UFLA – Lavras, Minas Gerais, Brasil, CEP: 37200-000.

³ Departamento de Zootecnia da Universidade Federal de Goiás – UFG.

⁴ Departamento de Medicina Veterinária – UFLA.

ABSTRACT - Supplementation of 5 ppm of ractopamine, associated or not to feed restriction in diets with a high total lysine content (1.04%) was evaluated on performance and nitrogen balance. In experiment 1, 60 hybrid castrated male swine (76.2 ± 2.3 kg) were housed in pairs according to a randomized complete block design in a factorial treatment arrangement (2 × 2 + 1) with or without ractopamine supplementation, two forms of feeding, ad libitum and feed restriction with 1.04% lysine, and an additional treatment (control), with ad libitum feed without ractopamine with 0.8% lysine, amounting to five treatments and six replications. The final live weight, daily weight gain, daily feed intake and feed conversion for 28 days were evaluated. There were improvements in supplementation with ractopamine for final live weight, daily weight gain and feed conversion. The ad libitum feeding improved both final live weight and daily weight gain compared with ractopamine. Compared with the control, there was a decrease in feed conversion with ractopamine supplementation and improvement for final weight (FW) in the treatment with the ractopamine and ad libitum feed. In experiment 2, 30 hybrid castrated male swine (74.1 ± 2.5 kg) were housed in metabolism cages and fed the same experimental treatments to evaluate the percentages of absorbed nitrogen (Nabs), retained nitrogen (Nret), nitrogen retained from the absorbed nitrogen (Nret/Nabs) and the plasma urea concentration at 14 and 28 days. At 14 days, there was an increase in the Nret/Nabs and plasma urea concentration with ractopamine supplementation. Compared with the control, there was a decrease in the plasma urea concentration for feed restriction with ractopamine. At 28 days, there was an increase in the Nret/Nabs with ractopamine supplementation. Thus supplementation with 5 ppm ractopamine improved the performance and efficiency of swine nitrogen use. Feed restriction interfered negatively in weight gain, but it improved the efficiency of the nitrogen use of barrows.

Key Words: additive, carcass modify, fed restricted, nutrition

Ractopamina para suínos em terminação recebendo ração restrita ou à vontade: desempenho e balanço de nitrogênio

RESUMO - Avaliou-se o efeito da suplementação de 5 ppm de ractopamina associada ou não à restrição alimentar em rações com elevado teor de lisina total (1,04%) sobre o desempenho e o balanço de nitrogênio em suínos. No experimento 1, utilizaram-se 60 híbridos machos castrados (76,2 ± 2,3kg) alojados em pares, em delineamento de blocos casualizados em arranjo fatorial 2 × 2 + 1 (0 ou 5 ppm de ractopamina; arrazoamento à vontade ou com restrição; dieta com 1,04% de lisina e uma ração testemunha, sem ractopamina e com 0,8% de lisina, fornecida à vontade) totalizando cinco tratamentos e seis repetições. Foram determinados o peso vivo final, o ganho de peso diário, o consumo diário de ração e a conversão alimentar durante 28 dias. A ractopamina melhorou o peso final, o ganho de peso diário e a conversão alimentar. A alimentação à vontade melhorou o peso final e o ganho de peso diário em relação à restrição. Em comparação à ração testemunha, a conversão alimentar melhorou com a suplementação de ractopamina e o peso final aumentou com a alimentação à vontade associada à suplementação com ractopamina. No experimento 2, utilizaram-se 30 suínos machos castrados híbridos (74,1 ± 2,5kg) alojados em gaiolas de metabolismo, recebendo as mesmas rações experimentais para avaliar as porcentagens de nitrogênio absorvido (%Nabs), retido (%Nret) e retido do absorvido (%Nret/abs) e a concentração plasmática de ureia aos 14 e 28 dias de experimento. Aos 14 dias, a porcentagem de nitrogênio retido do absorvido e a concentração plasmática de ureia aumentaram com a suplementação de ractopamina na ração. Em comparação aos valores obtidos com a ração testemunha, a concentração plasmática de ureia foi menor nos animais sob alimentação restrita com suplementação de ractopamina. Aos 28 dias, a porcentagem de nitrogênio retido do absorvido aumentou com a suplementação desse aditivo. A suplementação com 5 ppm de ractopamina melhora o desempenho e a eficiência de utilização de nitrogênio em suínos em terminação.

Palavras-chave: aditivos, modificador de carcaça, nutrição, restrição alimentar

Introduction

In swine production, the finishing phase shows higher feed:gain ratios than the other phases, with a higher feed intake needed to produce one unit of meat. One of the reasons for this is that the animals' intake capacity exceeds the quantity of nutrients necessary to reach the maximum potential of meat deposition. Thus, it is necessary to provide adequate nutrition and improve feed management to avoid loss of performance during this phase. In this sense, feed conversion has been utilized as the main reference for evaluating performance in large production systems (Losinger, 2000).

Some nutritionists recommend the use of intake restriction in the finishing phase to improve the feed:gain ratio. This restriction is based on the theory that lower energy intake will improve the feed:gain ratio and will decrease carcass fat (Campbell & King, 1982; Bellaver, 1992) and nutrient elimination by excrement (Marcato & Lima, 2005). This nutritional strategy is much utilized by integrated industries that aim for results with lower intake per quantity of meat produced.

An alternative method that is widely used is β -adrenergic agonists, such as ractopamine, that reduce the fat quantity and increase protein in the carcasses. Moreover, ractopamine improves animal performance and the feed:gain ratio, reducing the energetic cost for synthesis and corporal fat deposition (Weber et al., 2006; Stahl et al., 2007). Some authors have observed a reduction in nitrogen except with the use of ractopamine (De Camp et al., 2001; He et al., 2004).

However, there is little knowledge of ractopamine use associated with feed restriction. To address this lack of information, this study was carried out to evaluate the effects of adding ractopamine to different feed managements (free – *ad libitum* – or restricted feed) on the performance, nitrogen balance and plasmatic urea of finish barrows.

Material and Methods

Two experiments – performance and metabolism assays – were carried out from July 2005 to January 2006 using 90 finishing hybrid barrows with a high deposition of lean meat, from a commercial farm. Before the animals were housed, the shed was cleaned and disinfected then maintained in sanitary void for seven days. After this, the animals were housed and underwent a 12-day pre-experimental period to allow them to adapt to the new environment. The experimental plots had 2.30×1.5 m concrete-floor pens and semi-automatic feeders.

During the pre-experimental period, all the pigs were provided with *ad libitum* access to feed and water, following the nutritional requirement recommendations suggested by Rostagno et al. (2005) for this phase. After this the experiments began. The initial weight of the animals was 76.2 ± 2.3 kg (performance), 74.1 ± 2.5 kg (metabolism). They were placed in a randomized block design (two periods of 28 days, with three weight bands, totaling six blocks) in a $2 \times 2 + 1$ factorial arrangement (with or without ractopamine; free feed or feed restricted; and a control diet given *ad libitum* and formulated following the nutritional recommendation for this phase). There was a total of five treatments with two animals per experimental plot to evaluate performance, plus one animal for metabolism.

The experimental diets were formulated with corn and soybean meal and supplemented with vitamins, minerals and amino acids (Table 1). Five combinations were evaluated: a diet with 5 ppm ractopamine and 1.04% total lysine given *ad libitum*; a diet with 5 ppm ractopamine and 1.04% total lysine with a 13.5% feed restriction; a diet without ractopamine with 1.04% total lysine given *ad libitum*; a diet without ractopamine with 1.04% total lysine and a 13.5% feed restriction; and a diet without ractopamine with 0.80% total lysine given *ad libitum*. The feed restriction was calculated on the average intake of the animals that received a free diet the previous day. The provided feed and leftovers were weighed daily to determine the intake of each experimental unit.

After the adaptation period, 60 animals were maintained in stalls in a finishing shed to evaluate the performance, and 30 animals were transferred to metabolic cages adapted for total feces and urine collection. These were situated in a room with air conditioning, permitting the control of the inside temperature at 18 °C. The experimental period lasted 28 days.

To determine weight gain, the pigs were weighed at the beginning and end of the performance assay. The feed conversion was obtained by the intake and weight gain ratio during the experimental period.

To evaluate the nitrogen balance, the intake was determined by metabolic weight ($LW^{0.75}$), measured on the 10th and 24th days of the experiment (immediately before the collection period). It was adjusted by the intake of the animal with lowest ingestion. Thus, all of the animals had a similar nutrient intake in relation to the metabolic weight, with the exception of those submitted to the feed restriction program. For these, a 13.5% restriction was imposed after calculating the feed to be supplied. Feces and urine were collected on the 11th through 14th days and on the 25th through 28th days of the experiment. The feeds were

Table 1 - Calculated composition of experimental diets

Ingredient composition (%)	Experimental diet		
	With ractopamine and 1.04% total lysine	Without ractopamine and 1.04% total lysine	Without ractopamine and 0.80% total lysine
Corn	77.60	77.62	78.02
Soybean meal	19.5	19.5	19.5
Soybean oil	0.65	0.65	0.50
L-lysine- HCl	0.315	0.315	0.073
Dicalcium phosphate	0.8	0.8	0.8
Limestone	0.57	0.57	0.57
Salt	0.3	0.3	0.3
Mineral mix ¹	0.1	0.1	0.1
Vitamin mix ²	0.1	0.1	0.1
Tylan 250 ³	0.04	0.04	0.044
Paylean ⁴	0.025	0.00	0.00
Nutritional composition			
Crude protein (%)	15.45	15.45	15.48
Metabolizable energy (kcal/kg)	3260	3260	3260
Total lysine (%)	1.04	1.04	0.80
Digestible lysine (%)	0.86	0.86	0.69
Digestible methionine (%)	0.231	0.231	0.232
Digestible threonine (%)	0.504	0.504	0.505
Digestible tryptophan (%)	0.154	0.154	0.154
Available phosphorus (%)	0.245	0.245	0.245
Calcium (%)	0.495	0.495	0.495
Ractopamine (ppm)	5.00	0.00	0.00

¹ Composition by kg of product: calcium, 98,800 mg; cobalt, 185 mg; copper, 15,750 mg; iron, 26,250 mg; iodine, 1,470 mg; manganese, 41,850 mg; zinc, 77,999 mg; selenium, 105 mg.

² Composition by kg of product: folic acid, 116.55 mg; pantothenic acid, 2,333.5 mg; biotin, 5.28 mg; niacin, 5,600 mg; pyridoxine, 175 mg; riboflavin, 933.3 mg; thiamine, 175 mg; vit. A, 1,225,000 UI; vit. D₃, 315,000 UI; vit. E, 1,400 mg; vit. K₃, 700 mg; vit. B₁₂, 6,825 mg; antioxidant: 1,500 mg.

³ Antibiotic based on granulated tylosin.

⁴ Ractopamine hydrochloride.

moistened with water (2:1 water:feed) and were supplied at 7 a.m. and 5 p.m. The leftovers were preserved daily to determine the dry matter that was discounted from the supplied feed to evaluate the real intake by the animals. Iron oxide (Fe₂O₃) was used as a fecal marker. It was added to the feed (at 2%) in the first and last meal of the collection period. The other procedures were similar to those described by Fialho et al. (1979).

The dry matter of the feces and ration samples was determined after weighing and drying in a forced ventilation stove at 65 °C to constant weight, then they were put in the stove at 105°C for 24 hours. The nitrogen in the feeds, feces and urine was determined using the Kjeldhal methods (AOAC, 1990), and the gross energy was determined by an adiabatic calorimetric bomb (Parr Instruments Co.).

The dry matter values (with the exception of urine) and total nitrogen were determined following the methodology described by Silva & Queiroz (2002) to evaluate the nitrogen balance. Blood samples were collected for plasmatic urea analysis on the last day of each phase of collection (14th and at 28th days). The samples were taken from the jugular vein and the plasma was obtained by centrifugation (1,600 x g) at 5 °C for 30 minutes. The plasma was stored

at -20°C until the analysis of urea concentration, determined with a lab test enzymatic kit using the colorimetric technique.

The variables analyzed were final weight, average daily weight gain, average daily intake, feed conversion, the percentage of absorbed and retained nitrogen and their ratios and plasmatic urea concentrations.

The statistical analyses were made using the PROC GLMSAS (2001). The global analysis of variance with all the treatments was performed to obtain the average residue square to test the factorial and the treatments. To establish comparisons between each treatment with the control, the Dunnet test (at 5%) was utilized.

Results and Discussion

The interaction between the ractopamine supplementation and feed management on animal performance was not significant (P>0.05) (Table 2). The animals that received ractopamine, regardless of the feed management, showed an increase of 2.06kg in their final weight (P<0.05). Compared to the other treatments, this corresponded to an increase of 1.96%.

Table 2 - Performance of finishing barrows fed diets supplemented with or without 5 ppm ractopamine, with or without feed restriction, during 28 days

	Feed management		Average ¹
	<i>Ad libitum</i>	Restricted	
Final weight (kg)			
With ractopamine	108.62*	105.32	106.97A
Without ractopamine	105.42	104.40	104.91B
Average ¹	107.02a	104.86b	
Control diet ²	105.09		
Coefficient of variation (%)	1.8		
Average weight gain (kg/day)			
With ractopamine	1.133	1.036	1.084A
Without ractopamine	1.082	0.970*	1.026B
Average ¹	1.107a	1.003b	
Control diet	1.095	-	
Coefficient of variation (%)	4.93		
Average daily feed intake (kg/day)			
With ractopamine	3.250	2.796*	3.023
Without ractopamine	3.232	2.820*	3.026
Average ¹	3.241a	2.808b	
Control diet	3.310	-	
Coefficient of variation (%)	4.07		
Feed:gain			
With ractopamine	2.84*	2.82*	2.83B
Without ractopamine	2.98	2.92	2.95A
Average ¹	2.91	2.87	
Control diet	3.04	-	
Coefficient of variation (%)	5.18		

¹ Averages followed by different lowercase letters in the row and capital letters in the column differ (P<0.05) by the F test.

² Control diet – feed without ractopamine, supplied *ad libitum* and with 0.8% total lysine.

* Differ (P<0.05) from the control diet by the Dunnett test.

Compared to the control diet, only the ractopamine diet supplied *ad libitum* resulted (P<0.05) in an increase of 3.53 kg (3.36%) in body weight. This result was similar to that found by Marinho et al. (2005), who observed an increase of 3.78% in the body weight using diets with 5ppm ractopamine to finish pigs. Others authors have confirmed these results (Weber et al., 2006; Xiong et al., 2006), but some (Carr et al., 2005; Mimbs et al., 2005) did not detect effects of ractopamine in the final weight of the animals.

The *ad libitum* management resulted in a higher final weight (P<0.05) compared to feed restriction. The average weight gain decreased in the animals given this feed program due to a lesser amount of nutrients consumed (Bellaver, 1992). Similar results were reported in others studies (Ellis et al., 1996; Warpechowski et al., 1999).

The average weight gain of the animals that received ractopamine was 5.65 greater (P<0.01) than those fed without the additive, with a deposition of 58 g/day more. These results were similar to those reported by Herr et al. (2000). They worked with ractopamine supplementation in a 0.97 total lysine diet, with a deposition of 68 g/day more

(5.88%) when the animals were supplemented. The positive effect of ractopamine on average weight gain was also observed by Armstrong et al. (2004) and Marinho et al. (2005). However, Pozza et al. (2003), also working with 5 ppm ractopamine over 28 days, did not report a significant effect on the final weight and average daily weight gain. Others have obtained results that did not show the effect of ractopamine on the average daily weight gain of finishing swine (Carr et al., 2005; Mimbs et al., 2005).

The *ad libitum* feed increased (P<0.05) the average daily weight gain of the pigs. Comparing with the control diet, only the restricted diet without ractopamine decreased (P<0.05) the average daily weight gain of the animals, corresponding to a 11.42% of reduction. This can be associated with energetic restriction rather than lysine restriction because the intake of this amino acid submitted to feed restriction management was higher than the control group (1.04% versus 0.80%)

However, the average weight gain was not influenced (P>0.05) by the feed restriction program associated with ractopamine supplementation showing that, even with restricted intake, supplementation with this additive can be efficient to maintain the weight gain of the animals.

Smith et al. (1995) evaluated the supplemented-ractopamine diet in two feed programs, ad libitum and restricted, and observed the best response of this additive when associated with feed restriction. The average daily feed intake was not influenced ($P>0.05$) by ractopamine use but differed ($P<0.01$) with the feed management.

Some studies report a response in intake with ractopamine supplementation. Mimbs et al. (2005) did not find a significant difference in the final weight and weight gain in the animals receiving 10ppm of ractopamine during the 28 days before slaughter. Nevertheless, the intake of the animals fed ractopamine was less and promoted a decrease of 6.89 in the feed:gain ratio. Some studies had proved the same effect when the feed intake for the animals receiving ractopamine was decreased (Yen et al., 1990; Bark et al., 1992), while others did not report the same effect (He et al., 1993; Xiao et al., 1999).

Ractopamine supplementation influenced ($P<0.05$) the feed:gain ratio, which decreased (7.5%) compared to the diet without the supplement and the control diet. Similar results were reported by Marinho et al. (2005) and Weber et al. (2006). In the literature, feed gain is the performance characteristic that most improves with ractopamine supplementation.

The improvements obtained in the animals fed the supplemented ractopamine diet can be linked to the deviation of the nutrients to muscle tissue deposition, which requires fewer nutrients to synthesize one tissue unit compared to fat tissue (Moser et al., 1986). Moreover, the increase in protein deposition (due to a 35% water aggregate) is the main factor that justifies the increase in daily weight gain associated with the improved feed:gain ratio. Thus, the addition of ractopamine in finishing pig diets improves the efficiency of nutrient use (Marinho et al., 2005).

The interaction between ractopamine supplementation and feed management on metabolism parameters was not significant ($P>0.05$) at the 14th day (Table 3). The animals that received ractopamine showed a 4.73% increase ($P<0.05$) in the absorbed retained nitrogen ratio and a 10.78% reduction in the plasmatic urea concentration on the 14th day compared to the group without the ractopamine diet.

The ractopamine supplied to the restricted diet resulted in a lower ($P<0.05$) plasmatic urea concentration than the control group. This result was consistent with the reduced values obtained with the feed:gain ratio of the animals fed the ractopamine-supplemented diets. Dunshea et al. (1993) and See et al. (2004) also observed that pigs receiving

Table 3 - Nitrogen and urea plasmatic concentrations in finishing barrows fed diets supplemented with or without 5 ppm ractopamine, with or without feed restriction, for 14 days

	Feed management		Mean ¹
	<i>Ad libitum</i>	Restricted	
Absorbed nitrogen (%)			
With ractopamine	91.36	91.41	91.39
Without ractopamine	90.83	90.47	90.65
Mean ¹	91.10	90.94	
Control diet ²	90.15		
Coefficient of variation (%)	1.43		
Retained nitrogen (%)			
With ractopamine	70.30	69.76	70.03
Without ractopamine	64.93	68.95	66.94
Mean ¹	67.61	69.35	
Control diet	67.45		
Coefficient of variation (%)	5.94		
Retained/absorbed nitrogen ratio (%)			
With ractopamine	76.93	76.31	76.62A
Without ractopamine	71.51	74.81	73.16B
Mean ¹	74.22	74.56	
Control diet	73.67		
Coefficient of variation (%)	4.78		
Urea (mg%)			
With ractopamine	23.21	20.41*	21.60B
Without ractopamine	25.83	22.48	24.21A
Mean ¹	24.41a	21.40b	
Control diet	24.73		
Coefficient of variation (%)	9.98		

¹ Means followed by different lowercase letters in the row and capital letters in the column differ ($P<0.05$) by the F test.

² Control diet – feed without ractopamine, supplied *ad libitum* and with 0.8% total lysine.

* Differ ($P<0.05$) from the control diet by the Dunnett test.

ractopamine showed a lower plasmatic urea concentration. However, Yen et al. (1990) did not find a positive effect in the plasmatic urea concentration when supplying the additive.

The decrease in the plasmatic urea concentration induced by ractopamine is consistent with the action mechanism of this molecule, which results in an increase of protein synthesis in the muscle (Helfrich et al., 1990; Adeola et al., 1992). This increase in protein synthesis denotes an increase in nitrogen use, which decreases plasmatic urea. It is known that feed restriction induces increase in protein synthesis efficiency by reducing oxidation and increasing nitrogen use efficiency (Reeds et al., 1981; Fabian et al., 2002). In the present study, the feed restriction reduced ($P<0.05$) the plasmatic urea concentration by 12.33% with regard to the *ad libitum* feed management.

Thus, the results showed that supplementing with ractopamine for 14 days interfered positively in protein use efficiency, especially when associated with feed restriction.

The interaction between ractopamine supplementation and feed management on metabolism parameters was not significant ($P>0.05$) at 28 days (Table 4). The use of ractopamine resulted, regardless of the feed management, in an approximate increase of 4.40% ($P<0.05$) in the

retained/absorbed nitrogen ratio, similar to the first 14 days of the experiment. Compared to the control diet, only the *ad libitum* ractopamine diet improved ($P<0.05$) by 8.49% this variable. This result was not observed at 14 days, showing that the ractopamine effect is more evident after 28 days use. De Campet et al. (2001) also observed an increase in the nitrogen retention in pigs receiving 20 ppm ractopamine.

The urea plasma concentration at 28 days only differed ($P<0.05$) between the feed managements, and it was lower in the animals given the feed restriction, with a reduction of 11.61%. Considering that the ractopamine did not influence ($P>0.05$) the plasmatic urea concentration at 14 days, but did have a positive effect at 28 days, it is suggested that this additive acts more efficiently in the protein metabolism in the first 14 days of use. This is probably because of its efficiency in reducing oxidation and improving amino acid use efficiency. However, the *ad libitum* ractopamine diet aided nitrogen retention more significantly at 28 days of use. These results also indicated that after this period, the effects of ractopamine appear be lesser in pigs of the same weight.

He et al. (2004) have already suggested that ractopamine acts more efficiently in the first days of use.

Table 4 - Nitrogen and urea plasmatic concentrations in finishing barrows fed diets supplemented with or without 5 ppm ractopamine, with or without feed restriction, for 28 days

	Feed management		Mean ¹
	<i>Ad libitum</i>	Restricted	
Absorbed nitrogen (%)			
With ractopamine	90.96	91.24	91.14
Without ractopamine	91.79	92.00	91.90
Mean ¹	91.41	91.62	
Control diet	90.95		
Coefficient of variation (%)	1.50		
Retained nitrogen (%)			
With ractopamine	69.71	68.35	69.07
Without ractopamine	66.44	67.90	67.17
Mean ¹	68.12	68.12	
Control diet ²	66.46		
Coefficient of variation (%)	4.12		
Retained/absorbed nitrogen ratio (%)			
With ractopamine	77.26*	75.34	76.30A
Without ractopamine	72.38	73.78	73.08B
Mean ¹	74.82	74.56	
Control diet	71.21		
Coefficient of variation (%)	4.45		
Urea (mg%)			
With ractopamine	21.20	19.60	20.40
Without ractopamine	23.60	20.00	21.80
Mean ¹	22.40a	19.80b	
Control diet	22.83		
Coefficient of variation (%)	10.29		

¹ Means followed by different lowercase letters in the row and capital letters in the column differ ($P<0.05$) by the F test.

² Control diet – feed without ractopamine, supplied *ad libitum* and with 0.8% total lysine.

* Differ ($P<0.05$) from the control diet by the Dunnett test.

These authors worked with ractopamine in two periods with six-day intervals and observed an increase in nitrogen retention percentages mainly in the first period. The results of the present study confirm the improvement in this variable in the first period (14 versus 28 days).

In general, the literature describes a peak in nitrogen use efficiency followed by a decline, with the best response during the first 14 days (Williams et al., 1994). In cells, the change in response over time can be linked to a decreased regulation of β -adrenergic receptors with partial activity of the ractopamine agonists (Liu et al., 1994; Mills, 2001). Nevertheless, more studies should be conducted to evaluate the period of highest efficiency of this molecule.

Conclusions

The use of 5 ppm ractopamine in diets with 1.04% total lysine, supplied in restricted feed management (13.5%) or ad libitum feed, resulted in a higher final weight, higher average daily weight gain and a lower feed:gain ratio in finishing barrows. The use of 5 ppm ractopamine reduced the plasmatic urea concentration at 14 days and improved nitrogen use efficiency at 28 days. The feed restriction, despite improving the nitrogen use efficiency, decreased average daily weight gain of the pigs.

Literature Cited

- ADEOLA, O.; BALL, R.O.; YOUNG, L.G. Porcine skeletal muscle myofibrillar protein synthesis is stimulated by ractopamine. **Journal of Nutrition**, v.122, p.488-495, 1992.
- ARMSTRONG, T.A.; IVERS, D.J.; WAGNER, J.R. et al. The effect of dietary ractopamine concentration and duration of feeding on growth performance, carcass characteristics, and meat quality of finishing pigs. **Journal of Animal Science**, v.82, p.3245-3253, 2004.
- ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS - AOAC. **Official methods of analysis**. 15.ed. Arlington, 1990. 1230p.
- BARK, L.J.; STAHLY, T.S.; CROMWELL, G.L. et al. Influence of genetic capacity for lean tissue growth on rate and efficiency of tissue accretion in pigs fed ractopamine. **Journal of Animal Science**, v.70, p.3391-3400, 1992.
- BELLAVER, C. **Restrição da alimentação para suínos**. Suinocultura dinâmica. Concórdia: EMBRAPA-CNPISA. Ano 1, n.2, 1992, p.1-4.
- CAMPBELL, R.G.; KING, R.H. The influence of dietary protein and level of feeding on the growth performance and carcass characteristics of entire and castrated male pigs. **Animal Production**, v.35, p.177-184, 1982.
- CARR, S.N.; RINCKER, P.J.; KILLEGER, J. et al. Effects of different cereal grains and ractopamina hydrochloride on performance, carcass characteristics, and fat quality in late-finishing pigs. **Journal of Animal Science**, v.83, p.223-230, 2005.
- DECAMP, S.A.; HANKINS, S.L.; CARROLL, A.L. et al. Effects of ractopamine and level of dietary crude protein on nitrogen and phosphorus excretion from finishing pigs. **Purdue University Swine Research Report**, 2001. 6p.
- DUNSHEA, F.R.; KING, R.H.; CAMPBELL, R.G. et al. Interrelationships between sex and ractopamine on protein and lipid deposition in rapidly growing pigs. **Journal of Animal Science**, v.71, p.2919-2930, 1993.
- ELLIS, M.; WEBB, A.J.; AVERY, P.J. et al. The influence of terminal sire genotype, sex, slaughter weight, feeding regime and slaughter-house on growth performance and carcass and meat quality in pigs and on the organoleptic properties of fresh pork. **Journal of Animal Science**, v.62, p.521-530, 1996.
- FABIAN, J.; CHIBA, L.I.; KUHLLERS, D.L. et al. Degree of amino acid restrictions during the grower phase and compensatory growth in pigs selected for lean growth efficiency. **Journal of Animal Science**, v.80, p.2610-2618, 2002.
- FIALHO, E.T.; ROSTAGNO, H.S.; FONSECA, J.B. et al. Efeito do peso vivo sobre o balanço energético e protéico de rações à base de milho e de sorgos com diferentes conteúdos de tanino para suínos. **Revista Brasileira de Zootecnia**, v.8, p.386-397, 1979.
- HE, P.F.; AHERNE, X.; THOMPSON, J.R. et al. Effect of ractopamine on carcass characteristics and joint-cartilage soundness in finishing pigs. **Canadian Journal of Animal Science**, v.73, p.169-176, 1993.
- HE, G.; BAIDOO, S.K.; YANG, Q. Interactive effect of ractopamine and protein/lysine level on growth performance, carcass characteristics and nutrient utilization in finishing pigs. **Swine Research Project List**, 2004. Disponível em: <<http://sroc.cfans.umn.edu/research/swine/projects/2004SwineNutrition.pdf>>. Acesso em: 20/2/2007.
- HELFRICH, W.G.; JUMB, D.B.; ANDERSON, D.B. et al. Skeletal muscle α -actin synthesis is increased pretranslationally in pigs fed the phenethanolamine ractopamine. **Endocrinology**, v.126, p.3096-3100, 1990.
- HERR, C.T.; YAKE, W.; ROBSON, C. et al. Effect of nutritional level while feeding Paylean™ to late-finishing swine. **Swine Day**, Purdue University, p.89-95, 2000.
- LIU, C.Y.; GRANT, A.L.; KIM, K.H. et al. Limitations of ractopamine to affect adipose-tissue metabolism in swine. **Journal of Animal Science**, v.72, p.62-67, 1994.
- LOSINGER, W.C. Feed-conversion ratio of finisher pigs in the USA. **Preventive Veterinary Medicine**, 36, 287-305, 2000.
- MARCATO, S.M.; LIMA, G.J.M.M. Efeito da restrição alimentar como redutor do poder poluente dos dejetos de suínos. **Revista Brasileira de Zootecnia**, v.34, n.3, p.855-863, 2005.
- MARINHO, P.C.; FONTES, D.O.; SILVA, F.C.O. et al. Efeito da ractopamina e de métodos de formulação sobre o desempenho de suínos machos castrados em terminação. **Revista Brasileira de Zootecnia**, v.36, p.1061-1068, 2007.
- MILLS, S.E. Biological basis of the ractopamine response. **Journal of Animal Science**, v.79 (suppl. 1), p.238, 2001 (Abstr.).
- MIMBS, K.J.; PRINGLE, T.D.; AZAIN, M.J. et al. Effects of ractopamine on performance and composition of pigs phenotypically sorted into fat and lean groups. **Journal of Animal Science**, v.83, p.1361-1369, 2005.
- MITCHELL, A.D.; SOLOMON, M.B.; STEELE, N.C. Influence of level of dietary protein or energy on effects of ractopamine in finishing swine. **Journal of Animal Science**, v.69, p.4487-4495, 1991.
- MOSER, R.L.; DALRYMPLE, R.H.; CORNELIUS, S.G. et al. Effect of cimaterol (CL 263,780) as a repartitioning agent in the diet for finishing pigs. **Journal of Animal Science**, v.62, p.21-26, 1986.
- POZZA, P.C.; NUNES, R.V.; SANTOS, M.S. et al. Efeito da ractopamina sobre o desempenho e características de carcaça de suínos machos castrados na fase de terminação. In: CONGRESSO BRASILEIRO DE VETERINÁRIOS ESPECIALISTAS EM

- SUÍNOS, 2003, Goiânia. **Anais...** Goiânia: ABRAVES, 2003. p.289-290.
- REEDS, P.J.; FULLER, M.F.; CADENHEAD, A. et al. Effect of changes in the intakes of protein and non - protein energy on whole - body protein turnover in growing pigs. **British Journal Nutrition**, v.45, p.539-546, 1981.
- ROSTAGNO, H.S.; ALBINO, L.F.T.; DONZELE, J.L. et al. **Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais**. 2.ed. Viçosa, MG: Universidade Federal de Viçosa, 2005. 186p.
- SEE, M.T.; ARMSTRONG, T.A.; WELDON, W.C. Effect of a ractopamine feeding program on growth performance and carcass composition in finishing pigs. **Journal of Animal Science**, v.82, p.2474-2480, 2004.
- SILVA, D.J.; QUEIROZ, A.C. **Análises de alimentos: métodos químicos e biológicos**. Viçosa, MG: Universidade Federal de Viçosa, 2002. 235p.
- SMITH, W.C.; PURCHAS, R.W.; VAN ENKEVORT, A. et al. Effects of ractopamine on the growth and carcass quality of entire Male and female pigs fed ad libitum or at a restricted level. **New Zealand Journal of Agricultural Research**, v.38, p.373-380, 1995.
- STAHL, C.A.; CARLSON-SHANNON, M.S.; WIEGAND, B.R. The influence of creatine and a high glycemic carbohydrate on the growth performance and meat quality of market hogs fed ractopamine hydrochloride. **Meat Science**, v.75, p.143-149, 2007.
- STATISTICAL ANALYSES SYSTEM - SAS. **System for Microsoft Windows**. Release 8.2. Cary: 2001. (CD-ROM).
- XIAO, R.J.; XU, Z.R.; CHEN, H.L. Effect of ractopamine at different dietary protein levels on growth performance and carcass characteristics in finishing pigs. **Animal Feed Science and Technology**, v.79, p.119-127, 1999.
- XIONG, Y.L.; GOWER, M.J.; LI, C. et al. Effect of dietary ractopamine on tenderness and postmortem protein degradation of pork muscle. **Meat Science**, v.73, p.600-604, 2006.
- WARPECHOWSKI, M.S.; FEDALTO, L.M.; GUARESCHI NETO, A.R. et al. Efeito da restrição alimentar quantitativa sobre o desempenho e as características de carcaça de suínos em terminação. **Archives Veterinary Science**, v.4, n.1, p.73-75, 1999.
- WEBER, T.E.; RICHERT, B.T.; BELURY, M.A. et al. Evaluation of the effects of dietary fat, conjugated linoleic acid, and ractopamine on growth performance, pork quality, and fatty acid profiles in genetically lean gilts. **Journal of Animal Science**, v.84, p.720-732, 2006.
- WILLIAMS, N.H.; CLINE, T.R.; SCHINCKEL A.P. et al. The impact of ractopamine, energy intake and dietary fat on finisher pig growth performance and carcass merit. **Journal of Animal Science**, v.72, p.3152-3162, 1994.
- YEN, J.T.; MERSMANN, H.J., HILL, D.A. et al. Effects of ractopamine on genetically obese and lean pigs. **Journal of Animal Science**, v.68, p.3705-3712, 1990.