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Manure production and mineral excretion in feces of gilts fed ractopamine

Pedro Henrique Watanabe*, Maria Cristina Thomaz, Leonardo Augusto Fonseca Pascoal, Urbano dos Santos Ruiz, Everton Daniel and Alessandro Borges Amorim

*Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Veterinárias, Rua Prof. Dr. Paulo Donato Castellane, s/n, 14884-900, Jaboticabal, São Paulo, Brazil. *Author for correspondence. Email: pedrowatanabe@ufc.br*

ABSTRACT. A study was conducted to evaluate the feces+urine produced per animal (FUPA), dry matter, mineral matter, organic matter, nitrogen, phosphorus, potassium and sulfur in feces of gilts fed diets with increasing levels of ractopamine (0, 5, 10 and 15 mg kg^{-1} of diet). A total of 468 finishing gilts were allotted into 36 pens. In two days of each week, feces and urine were daily sampled in four pens per treatment, quantifying the feces+urine. To determine the characterization of feces, two samples per week were taken daily, in nine pens per treatment. It was used a split plot design, considering the ractopamine level as the plot and the weeks as the subplots. There was no reduction in nitrogen amount in feces. An interaction was detected between ractopamine concentrations and weeks for FUPA and phosphorus, potassium and sulfur in feces. Ractopamine addition in diets for gilts has reduced the feces+urine production and nitrogen and phosphorus excretion. Higher values estimated for potassium content in feces of animals fed diets with 10 and 15 mg of ractopamine kg^{-1} were found between the second and third week. Increasing levels of ractopamine from 5 to 15 mg kg^{-1} promoted higher excretion of sulfur over the weeks of supply.

Keywords: additive, environmental impact, finishing, mineral, *Sus scrofa*.

Produção de dejetos e excreção mineral nas fezes de fêmeas suínas alimentadas com ractopamina

RESUMO. Objetivou-se avaliar a produção de fezes+urina por animal e teores de matéria seca, matéria mineral, matéria orgânica, nitrogênio, fósforo, potássio e enxofre nas fezes de suínos alimentados com dietas contendo concentrações crescentes (0, 5, 10 e 15 mg kg^{-1} de dieta) de ractopamina. Foram utilizadas 468 fêmeas suínas, alojadas em 36 baias de piso compacto. A cada semana foram realizadas duas colheitas diárias de fezes e urina, de quatro baias por tratamento e duas colheitas semanais, de nove baias por tratamento, para determinação da composição fecal. Utilizou-se o delineamento em blocos, em esquema de parcelas subdivididas, sendo as parcelas as concentrações de ractopamina e as semanas como subparcelas. Não houve redução na quantidade de nitrogênio excretado. Observou-se interação entre concentração de ractopamina e semana, para a produção de fezes+urina por animal e para os teores de fósforo, potássio e enxofre nas fezes. A ractopamina na dieta reduz a produção de fezes+urina e a excreção de nitrogênio e fósforo nas duas semanas iniciais. Foram encontrados maiores valores estimados para o teor de potássio nas fezes de animais alimentados com dietas contendo 10 e 15 mg de ractopamina kg^{-1} entre a segunda e terceira semanas. O aumento na concentração de ractopamina de 5 até 15 mg kg^{-1} promove maior excreção de enxofre em função das semanas.

Palavras-chave: aditivos, impacto ambiental, terminação, minerais, *Sus scrofa*.

Introduction

The quantity of manure produced depends directly on feed composition, age and weight of the swine. Thus, the manure characteristics are also affected by physiology and health status of pigs and diet composition. Due to the lipid anabolism at the finishing phase, the nutrient excretion increases given the low feed:gain ratio of animals in this period (PEET-SCHWERING et al., 1999), whose negative effect increases when the breeding phase extends to weights above 100 kg.

In order to promote the nutrient partition, additives have been tested specifically in finishing phase of pigs, aiming better animal performance by modifying the protein turnover (MIMBS et al., 2005). Beta-adrenergic agonists, as ractopamine, are the main products used for this purpose, promoting leaner animals (BRUMATTI; KIEFER, 2010) and with higher bonification when a classification system of carcasses is established (WATANABE et al., 2011).

Depending on the improvement of the feed:gain ratio, the possible benefits of ractopamine on manure of pigs are commonly estimated from performance data, resulting in empirical values. Ross et al. (2011) stated that the addition of 10 mg of ractopamine kg^{-1} diet for finishing pigs has reduced feed intake (4.4%) and improved the feed efficiency (20.6%), promoting thus a reduction in 4 days at finishing phase, consequently reducing the manure production. Furthermore, the utilization of ractopamine in diets for pigs can increase the nitrogen retention and reduce the phosphorus excretion (BARK et al., 1992) per animal, also decreasing the concentration of these minerals in manure.

This study evaluated the effect of different ractopamine levels in diets for gilts on the production of feces and urine, dry matter, ash and organic matter of feces and fecal excretion of nitrogen, phosphorus, potassium and sulfur.

Material and methods

For this study, a total of 468 gilts with an initial weight of 84.77 ± 7.20 kg were assigned into a randomized block design with 4 treatments, 9 replicates and 13 animals per experimental unit. The blocks were formed considering the initial weight of the animals. The animals were housed in 36 pens (3.5 × 4 m) with solid floor, fitted with drinkers and feeders.

The treatments consisted of different ractopamine levels in diets (0, 5, 10 and 15 mg kg^{1}) in replacement to kaolin (Table 1). Diets were formulated to meet minimal nutritional and energy requirements, as indicated by Rostagno et al. (2005), considering an energy concentration of 3.23 Mcal ME kg^{-1} diet, 16.20% crude protein and 1.10% digestible lysine for gilts with a high potential for lean deposition. A digestible lysine content of 1.10% was established due to the higher demand of this amino acid when ractopamine is added to diets (XIAO et al., 1999), and the proportions of other amino acids were maintained based on the ideal protein concept (ROSTAGNO et al., 2005).

The experimental period lasted 28 days. Twice a week, the amount of feces+urine produced by animals during 24 hours of four pens per treatment was measured. This procedure was carried out at intervals of 8 hours. Feces+urine were characterized as fecal and urine excretion of animals, removed from pen using a hoe. On the manure output of each pen, the feces+urine were collected and quantified, obtaining the feces+urine produced per animal (FUPA), dividing the total weight of manure by the number of animals on each pen.

For the determination of feces composition, two composite samples of feces of nine pens per treatment were taken twice a week. Aliquots of feces were taken to compose the sample, preventing the contact with ration and urine on the floor. Feces were collected during 12 hours per day. At the end of the day, the feces of each pen were homogenized, obtaining the composite sample. At the end of each collection, samples were stored in plastic containers and frozen.

Samples of feces were dried and ground, for the purpose to determine the dry matter, ash and organic matter content, according to Silva and Queiróz (2002). The nitrogen in feces was determined by Kjeldahl method (SILVA; QUEIRÓZ, 2002). The nitric-perchloric acid wet digestion was used for determination of phosphorus, potassium and sulfur (FERREIRA; CRUZ, 1991; SILVA; QUEIRÓZ, 2002).

Table 1. Percentage and calculated composition of the experimental diet.

Ingredient	%
Corn	77.59
Soybean meal	18.48
Dicalcium phosphate	0.81
Limestone	0.52
Common salt	0.31
L – Lysine.HCl (78.5%)	0.63
DL – Methionine (99%)	0.16
L – Threonine (98.5%)	0.26
L – Tryptophan (98%)	0.05
Vitamin premix[1]	0.15
Mineral premix[2]	0.15
Kaolin	0.89
Total	100.00
Calculated values[3]	
Metabolizable energy, kcal kg^{-1}	3,230.00
Crude protein, %	16.20
Digestible lysine, %	1.10
Digestible methionine+cystine, %	0.62
Digestible threonine, %	0.72
Digestible tryptophan, %	0.19
Available phosphorus, %	0.25
Calcium, %	0.48
Sodium, %	0.16
Potassium, %	0.57
Chlorine, %	0.23

[1]Vitamin premix – amount per kg of product: Vit. A – 2,500,000 UI; Vit. D3 - 500,000 UI; Biotin - 50 mg; Choline - 50 mg; Niacin – 10,000 mg; Calcium pantothenate – 3,000 mg; Vit. B12 - 7 mg; Vit. B2 – 1,800 mg; Vit. E – 7,500 mg; Vit. K3 - 1000 mg; [2]Mineral premix – amount per kg of product: Iron - 40,000 mg; Copper – 35,000 mg; Manganese - 20,000 mg; Zinc - 40,000 mg; Cobalt - 360 mg; Iodine - 840 mg; Selenium - 120 mg; [3]Nutritional value of feed according to Rostagno et al. (2005).

Data were analyzed in a split plot design, considering levels of ractopamine in the diet as plots and the four weeks as subplots. The experimental unit was composed by the average of the two samples per week. After analysis of error distribution using Cramer Von-Mises test, with

5% of probability, (EVERITT, 1998), data were subjected to analysis of variance using the GLM procedure of statistical software SAS (1998), performing a polynomial procedure up to the third degree to the main effects and significant interactions.

Results and discussion

Evaluating the feces+urine produced per animal (PUFA), was observed an interaction between ractopamine levels in diets and weeks (Table 2). However, no effects ($p < 0.05$) of ractopamine addition in diets or weeks were observed on the ash content of feces. Ractopamine inclusion in diets for gilts had not affected the dry matter and organic matter of feces ($p > 0.05$). A quadratic trend was observed ($p < 0.05$) along the weeks for dry matter ($Y=26.773+0.713X-0.190X^2$; $R^2=0.6092$) and organic matter ($Y=23.056+0.299X-0.110X^2$; $R^2=0.5022$) in feces, presenting higher values in the second (1.87) and first (1.33) weeks, respectively.

Table 2. Feces+urine produced per animal (FUPA), on a natural matter basis, and dry matter (DM), ash and organic matter (OM) of feces of gilts, on dry matter basis, according to levels of ractopamine in diets, during the experimental period.

		Variable			
Ractopamine level (RL), mg kg^{-1}		FUPA, kg	DM, %	Ash, %	OM, %
0		5.04	26.87	3.93	22.90
5		4.71	27.13	4.17	23.00
10		4.82	27.37	4.21	23.08
15		4.68	27.26	4.22	22.85
Weeks (W)					
1		4.70	27.16	4.03	23.11
2		4.67	27.84	4.10	23.60
3		4.88	26.84	4.17	22.54
4		4.96	26.79	4.23	22.57
	RL	NS	NS	NS	NS
Effect	W	NS	Quadratic	NS	Quadratic
	RL x W	*	NS	NS	NS
CV[1], %		17.11	5.11	9.42	4.85

[1]Coefficient of variation; *$p < 0.05$; NS – non-significant.

The higher water content in feces of pigs may be due to the lower ractopamine effects on the protein deposition, with longer supply of this additive. According to Willians et al. (1994), better performance and muscle deposition of pigs fed diets with ractopamine occurs during the first 14 days of feeding diets containing this beta-adrenergic agonist.

In relation to the effect of 20 mg of ractopamine kg^{-1} diet for pigs, Sutton et al. (2001) observed lower efficiency on nitrogen retention after the second week of feeding, stating that the excess of protein intake but not retained, led to a higher ingestion of water and, consequently increasing the water content in feces.

For feces+urine produced per animal (Table 3) there was a linear effect ($p < 0.05$) of the four experimental weeks for ractopamine inclusion at the level of 5 mg kg^{-1} ($Y=4.640+0.087X$; $R^2=0.7344$), 10 mg kg^{-1} ($Y=4.568+0.157X$; $R^2=0.8695$) and 15 mg kg^{-1} ($Y=4.403+0.155X$; $R^2=0.5544$). For the first two weeks, there was a linear effect ($p < 0.05$) of ractopamine inclusion in diets with the respective equations: $Y=4.834-0.025X$; $R^2=0.7883$ (first week) and $Y=4.850-0.022X$; $R^2=0.8346$ (second week), however for the third and fourth weeks there was no effect ($p > 0.05$).

An increase in FUPA was verified during the experimental weeks when used 5, 10 and 15 ppm of ractopamine. Over the first two experimental weeks, the increasing ractopamine levels in diets promoted a linear reduction on FUPA, demonstrating that higher levels could decrease the manure of pigs at finishing phase. Sutton et al. (2001) also stated that the addition of 20ppm in diet has reduced the manure of pigs with 90 kg of weight, observing a decrease in the water intake and urine excretion of animals fed diets with this additive, causing a reduction on manure from finishing pigs. Similarly, Ross et al. (2011) also found that supplementing 10 mg ractopamine kg^{-1} in finishing pig diets could decrease the requirements for water consumption in finishing hogs.

Ractopamine inclusion has not reduced the nitrogen excreted in feces (Table 4). However, evaluating weeks, a quadratic effect ($p < 0.05$) was detected, with low excretion on the second week (2.10) of the experiment ($Y=4.072-0.223X+0.053X^2$; $R^2=0.6982$).

Table 3. Feces+urine produced per animal (FUPA), on natural matter, based on ractopamine level in diets and weeks.

		Weeks				
		1	2	3	4	
		FUPA, kg				Effect
Ractopamine level, mg kg^{-1}	0	4.89	4.86	5.05	5.07	-
	5	4.65	4.71	4.82	4.91	Linear
	10	4.62	4.64	4.89	5.05	Linear
	15	4.51	4.50	4.77	4.92	Linear
Effect		Linear	Linear	NS	NS	

NS – non-significant.

Table 4. Mean values of nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) content in feces of gilts, on dry matter basis, according to the levels of ractopamine in the diets, during the experimental period.

Ractopamine level (RL), mg kg^{-1}		Variable N, %	P, %	K, %	S, mg kg^{-1}
0		3.92	1.96	1.17	2981
5		3.80	2.02	1.14	2990
10		3.76	2.03	1.22	3073
15		3.80	2.04	1.12	3277
Weeks (W)					
1		3.93	2.04	1.11	2893
2		3.79	1.95	1.19	3045
3		3.96	2.01	1.20	3093
4		4.03	2.05	1.14	3290
	RL	NS	NS	NS	NS
Effect	W	Quadratic	NS	NS	NS
	RL x W	NS	*	*	*
CV[1], %		5.26	9.70	17.34	11.67

[1]Coefficient of variation; *$p < 0.05$; NS – non-significant.

Although the ractopamine inclusion in finishing pig diets increases nitrogen utilization (ROSS et al., 2011), some researches registered that the ractopamine effect on muscle deposition of pigs is not constant during the supply of this additive in diets, and observed an immediate response, followed by a *plateau* then a decrease on muscle growth (DUNSHEA et al., 1993; WILLIANS et al., 1994). Moody et al. (2000) reported that the ractopamine response on muscular tissue decreases over time, due to a desensitization of beta-adrenergic receptors of cells, thus amino acids were not used for muscle deposition, leading to an elimination of protein consumed in the form of nitrogen compounds.

Interactions between levels of ractopamine in diets and weeks, to phosphorus, potassium and sulfur content in feces of gilts are listed in Table 5. During the experimental period, it was noted a linear increase ($p < 0.05$) on phosphorus excretion in feces of animals fed 5 mg of ractopamine kg^{-1} diet ($Y=1.835+0.071X$; $R^2=0.8091$). A quadratic trend was observed ($p < 0.05$) on phosphorus content in feces from those animals fed 10 mg of ractopamine kg^{-1} diet ($Y=2.312-0.277X+0.065X^2$; $R^2=0.6563$), with reduced excretion of this mineral on the second experimental week (2.12).

Woods et al. (2011) observed that 18 mg of ractopamine kg^{-1} diet has not modified the phosphorus excreted in feces, though a reduction on phosphorus excreted in urine was verified, concluding that this beta-adrenergic agonist can change the phosphorus retention in pigs at finishing phase.

When analyzed the excretion of phosphorus in feces per week, in the second week of the experimental period the increasing levels of ractopamine in diets resulted in higher content of this mineral in feces ($Y=1.857+0.049X$; $R^2=0.7213$). For the fourth week, it was observed a quadratic effect ($Y=1.921+0.062X-0.003X^2$; $R^2=0.6543$), with higher excretion of phosphorus in feces to an estimated concentration of 8.70 mg of ractopamine kg^{-1} diet. A linear effect was observed on phosphorus content in feces of animals fed diets with 5 mg of ractopamine kg^{-1} diet ($Y=1.835+0.0714X$, $R^2=0.8091$). At level of 10 mg kg^{-1}, a quadratic effect was noted ($Y=2.312-0.277X+0.065X^2$, $R^2=0.6563$), with lower excretion of phosphorus estimated for the second week.

By evaluating the potassium excretion in feces per week according to the different levels of ractopamine in diets, a linear reduction ($p < 0.05$) was observed in the first week ($Y=1.264-0.059X$; $R^2=0.7214$) and a quadratic effect ($p < 0.05$) in the second ($Y=1.125+0.057X-0.003X^2$; $R^2=0.8773$), third ($Y=1.204-0.038X+0.002X^2$; $R^2=0.6778$) and fourth weeks ($Y=0.949+0.027X-0.003X^2$; $R^2=0.6990$). Higher excretions of potassium were estimated for the second, third and fourth weeks with levels of 9.50; 10.45 and 4.50 mg of ractopamine kg^{-1} diet, respectively. It was observed a quadratic effect ($p < 0.05$) on potassium content in feces of animals fed diets with 10 and 15 mg of ractopamine kg^{-1} ($Y=0.900+0.336X-0.069X^2$; $R^2=0.8113$ and $Y=0.471+0.659X-0.135X^2$; $R^2=0.8799$, respectively), being estimated higher excretion of potassium between the second and third weeks (2.43 and 2.44).

Table 5. Phosphorus (P), potassium (K) and sulfur (S) content in feces of gilts, on a dry matter basis, in the ractopamine level in diets and weeks.

		Weeks wW 1	2	3	4	
				P, %		Effect
Ractopamine level, mg kg^{-1}	0	2.03	1.81	2.01	1.91	-
	5	1.92	1.95	2.03	2.14	Linear
	10	2.05	1.95	2.10	2.15	Quadratic
	15	2.07	1.97	2.03	2.06	-
Effect		NS	Linear	NS	Quadratic	
				K. %		
Ractopamine level, mg kg^{-1}	0	1.21	1.01	1.04	1.15	-
	5	1.10	1.19	1.18	1.21	-
	10	1.15	1.33	1.23	1.15	Quadratic
	15	0.99	1.24	1.23	0.94	Quadratic
Effect		Linear	Quadratic	Quadratic	Quadratic	
				S. mg kg^{-1}		
Ractopamine level, mg kg^{-1}	0	3275	3651	3089	3181	-
	5	3033	3384	3401	3388	Quadratic
	10	3211	3042	3313	4020	Quadratic
	15	3399	3560	3657	3708	Linear
Effect		NS	Quadratic	Linear	Quadratic	

NS – non-significant.

Although Marcato and Lima (2005) have noted that the potassium content accounted to about 9% of ash excreted in feces of male finishing pigs, in the present work we observed a higher contribution of this mineral, with values close to 29% ash in feces. According to NRC (1998), the apparent availability of potassium is from 5 to 20% of mineral intake, but the excretion of this mineral could be affected by feed ingredients and animal age.

Ractopamine inclusion in diets affected the sulfur excretion in feces during the experimental weeks, with a quadratic effect with levels of 5 mg of ractopamine kg^{-1} diet ($Y=2227+942X-161X^2$; $R^2=0.5662$) and 10 mg of ractopamine kg^{-1} diet ($Y=3824-836X+221X^2$; $R^2=0.7732$), and also a linear increase with 15 mg kg^{-1} ($Y=3326+109X$; $R^2=0.8235$). By estimating the sulfur excretion in feces of gilts fed diets with 5 and 10 mg of ractopamine kg^{-1}, it was detected a higher excretion on the third (2.93) and lower excretion on the second (1.89) weeks, respectively. According to the ractopamine levels in diets, there was a reduction in the sulfur content in feces during the second week ($Y=3701-109X+6X^2$; $R^2=0.7899$), with an estimated level of 8.93 mg of ractopamine kg^{-1} diet and high excretion during the fourth week ($Y=3007+130X-6X^2$; $R^2=0.5662$), at an estimated level of 10.87 mg kg^{-1}. In the third week it was noted an increase in sulfur excretion ($Y=3143+121X$; $R^2=0.7003$) due to the rising level of ractopamine.

The modulation in sulfur content in feces due to addition of different levels of ractopamine has demonstrated that this beta-adrenergic agonist in swine diets does not depend only on lysine level in diets (KIEFER; SANCHES, 2009), but also the sulfur amino acids supply is important. Marinho et al. (2007) evaluated the ractopamine inclusion and different diet formulations, and observed that beyond lysine, an adjustment of other essential amino acids is necessary in diets to potentiate the ractopamine effect. According to Arnink and Verstegen (2007), the appropriate supply of amino acids in diets is a nutritional strategy to optimize the performance of pigs and reduce the nitrogen and others minerals excretion. Thus, nutritional tools aiming better feed efficiency as well as using protein levels in diets based on the ideal protein concept consist in procedures to reduce the excess of amino acids, which would be catabolized, consequently resulting in higher excretion of nitrogen by finishing pigs.

Conclusion

Increasing levels of ractopamine up to 15 mg kg^{-1} reduce the feces+urine produced per animal and nitrogen and phosphorus content in feces, during the first two weeks of supply. Higher values estimated for potassium content in feces of animals fed diets with 10 and 15 mg of ractopamine kg^{-1} were found between the second and third weeks. Increasing levels of ractopamine from 5 to 15 mg kg^{-1} promoted higher excretion of sulfur over the weeks of supply.

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