Revista Brasileira de Zootecnia
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ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., v.42, n.5, p.325-333, 2013

Ractopamine levels on performance, carcass characteristics and quality of pig meat[1]

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ABSTRACT - This study evaluated the effect of ractopamine (RAC) on the performance of finishing pigs and the meat quality of these animals. Seventy crossbred pigs (35 barrows and 35 females) selected for high gain of lean meat, with initial weight of 77.1±0.32 kg were distributed in randomized blocks with five treatments (0, 5, 10, 15, and 20 ppm RAC in the diet) and seven replications during 28 days. The experimental unit was represented by a male and a female pig. Regarding the performance variables, there was a linear increase in final weight with increasing levels of RAC, as well as in average daily weight gain. An improvement in feed conversion was observed for animals fed RAC, and the optimal level - estimated by the LRP model - was ~ 5 ppm. For feed intake, no significant effect on intake of digestible lysine and energy intake was observed. Carcass yield responses increased linearly with the RAC dose. Ash content, color component b* and loss drip linearly decreased with increasing doses of RAC. There was also a significant difference in the percentage of ether extract and crude protein in the loin, and treatment with 20 ppm RAC showed a lower amount of protein and larger amounts of lipids. Moisture content, color component L*, weight loss by cooking and defrosting, shear force and pH were not affected by the treatment. Concerning the lipid oxidation, there was no effect of RAC on the concentration of TBARS (thiobarbituric acid reactive substances) under cooling and under freezing. Thus, all ractopamine levels improve performance compared with control and do not negatively affect the quality of fresh, chilled or frozen pig meat.

Key Words: β-adrenergic agonist, lipid oxidation, meat quality, TBARS

Introduction

Historically we have been able to make great strides with regard to the continuous production of food in safe, accessible and in satisfactory quantities. However, according to the Department of Economic and Social Affairs of the UN, the world population will increase from the current 7 billion to over 9 billion in 2050. Along with the increase in the world population is the economic development of regions such as China, India, Eastern Europe and Latin America, creating a scenario of increasing demand for food (Hines, 2008), especially animal protein.

According to FAO (2007), pork represents 39% of total world consumption of animal protein, compared with 30% of chicken, 24% of beef and 7% of other types of meat. In this sense, with pork being the animal protein most consumed in the world, both for its ease of processing and for its various options for marketing, consumers impose different requirements in relation to improvement in carcass quality and meat; therefore, different technologies should be used to maximize production.

Among the technologies, ractopamine (RAC) is one of the most used and has positive results in performance, lean meat production and feed efficiency and lower environmental impact. ractopamine is recognized as a beta-adrenergic agonist (ABA) with action of redirecting nutrients, favoring protein synthesis at the expense of fat deposition in the carcass (Gunawan et al., 2007).

However, although there are known benefits of this class of growth promoter with respect to performance and carcass characteristics (Cantarelli et al., 2009), there are still many questions about the optimal dose for use, and industries are concerned with problems related mainly to the quality of meat processing, because they believe there may be formation of free radicals resulting from the intense metabolism that the beta-agonist may cause.

Therefore, the objective of this study was to determine the optimal dose of ractopamine for performance of

Received June 21, 2012 and accepted November 19, 2012.
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finishing pigs and to evaluate its effect on the quality of meat from animals receiving this additive for 28 days.

Material and Methods

The experiment was conducted at the Swine Experimental Station of Universidade Federal de Lavras. Thirty-five barrows and 35 gilts, which were hybrids selected for high gain lean tissue, with initial weight of 77.1±0.32 kg, were housed in groups of two (one male and one female per pen). The temperature of the barn was 19.12±4.78 °C.

The experimental design was randomized blocks with five treatments (0, 5, 10, 15 and 20 ppm RAC), seven replicates, and two animals per experimental unit. For the pH and lipid oxidation after cooling and freezing, the same design was used, except that the plot was subdivided.

The experimental diets were formulated based on corn and soybean meal supplemented with vitamins, minerals and amino acids to meet the minimum requirements suggested for the strain used, except for lysine, which was increased by 30% due to the use of ractopamine (Mitchell et al., 1990) (Table 1). Diets were fed *ad libitum* and weighed daily to determine intake. The animals were weighed at the beginning and end of the experiment to determine the weight gain.

The performance of animals was evaluated through the final weight (FW), feed intake (DFI), daily weight gain (DWG), and feed conversion (FC). After 28 days of supplementation with RAC, the animals were subjected to a solid fasting period of 12 hours and slaughtered in a commercial abattoir.

After being electrically stunned, the animals were exsanguinated and eviscerated. The carcasses were weighed before and after cooling for 24 hours to obtain the carcass yield. To assess the quality of meat, 24 hours after slaughter, samples of the *longissimus dorsi* muscle were taken from the left side of the carcasses for analysis. From each animal, five samples of *longissimus dorsi* muscle of ~3 cm in thickness were removed, in the longitudinal direction. The first cut was used for evaluation of color and weight loss due to dripping; the second cut was used for determining the weight loss by defrosting, weight loss by cooking, and shear force; the third cut was used to test lipid oxidation under cooling; the fourth cut to test lipid oxidation under freezing; and the fifth for determination of the proximate composition of the meat.

The pH was measured in the *longissimus dorsi* muscle at the region of the last rib of the left-side carcass 45 minutes after slaughter (pH 45 min) and after 24 hours of cooling at 4 °C (final pH).

The water-holding capacity of the meat was evaluated by considering the weight losses by drip, defrosting and cooking. Drip weight loss was evaluated according to the technique described by Boccard et al. (1981), which consists of weighing a ~3 cm thick sample, keeping it suspended and wrapped in plastic bags for 24 hours, and then re-weighing. The loss by defrosting was obtained by the relationship between the weight of the frozen sample and the weight of sample defrosted for 24 hours at 2±2 °C. Cooking loss was obtained according to the method described by Bridi & Silva (2007), which is by the difference between the weight of the defrosted sample and the baked sample (71 °C internal temperature). The same sample used for evaluation of the loss of water by cooking was used to determine the shear force. Sub-samples of 1.3 cm diameter, free of fat and connective tissue, were cut.

The shear force was measured perpendicular to the direction of muscle fibers, using a cutting blade in an inverted "V", connected to the texturometer. The speeds used were 5 mm/s in the pre-test, 2 mm/s in the test, and 5 mm/s in the post-test. The results are expressed as the maximum force required for cutting the samples in kilograms-force (kgf) (Bridi & Silva, 2007).

Table 1 - Proximate composition of diets and calculated values[1]

Ingredients (%)	Doses (ppm)				
	0	5	10	15	20
Corn	71.66	71.66	71.66	71.66	71.66
Soybean meal	23.70	23.70	23.70	23.70	23.70
Soybean oil	1.84	1.84	1.84	1.84	1.84
Dicalcium phosphate	1.08	1.08	1.08	1.08	1.08
Limestone	0.80	0.80	0.80	0.80	0.80
Salt	0.36	0.36	0.36	0.36	0.36
Mineral premix[2]	0.05	0.05	0.05	0.05	0.05
Vitamin premix[3]	0.10	0.10	0.10	0.10	0.10
DL-methionine 99%	0.02	0.02	0.02	0.02	0.02
L-lysine 78%	0.26	0.26	0.26	0.26	0.26
L-threonine 98%	0.11	0.11	0.11	0.11	0.11
Tylosin[4]	0.02	0.02	0.02	0.02	0.02
Ractopamine[5]	0.00	0.025	0.050	0.075	0.100
Calculated composition					
Crude protein (%)	16.06	16.06	16.06	16.06	16.06
Metabolizable energy (kcal/kg)	3300	3300	3300	3300	3300
Digestible lysine (%)	1.002	1.002	1.002	1.002	1.002
Digestible methionine (%)	0.267	0.267	0.267	0.267	0.267
Digestible threonine (%)	0.661	0.661	0.661	0.661	0.661
Available phosphorus (%)	0.300	0.300	0.300	0.300	0.300
Calcium (%)	0.647	0.647	0.647	0.647	0.647

[1] Based on tables of requirements for the strain C40 x Topigs Toppi.
[2] Composition per 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.
[3] Composition per 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; vitamin A - 1,225.000 IU; Vitamin D3 - 315,000 IU; vitamin E - 1,400 mg; vitamin K3 - 700 mg; vitamin B12 - 6,825 mg; selenium - 105 mg; antioxidant - 1,500 mg.
[4] Antibiotic-based granulated tylosin (Tylan).
[5] 2.05% ractopamine hydrochloride (Ractosuin).

Color was examined in the *longissimus dorsi* muscle 24 hours after slaughter using a portable Minolta colorimeter model CR-10, with integrating sphere and angle of view 8º, i.e., lighting d/8 and illuminant C. The components L* (lightness), a* (red-green component), and b* (yellow-blue component) are expressed using the CIELAB color system (Konica Minolta Holdings, 1998). Measurements were obtained by moving the device in three different positions, in such a way that practically the whole surface of the meat was sampled. The average reading was used for statistical analysis.

To study the oxidative stability of meat under cooling, the samples of fresh meat were stored in plastic bags, labeled, and stored under refrigeration at approximately 6 °C, and evaluated 24 hours after slaughter (time zero) and on the 5th, 8th, and 12th days of storage. For the evaluation of oxidative stability of the meat under freezing, samples were stored in the same way but at a temperature of -18 °C and evaluated at time zero, and during the 15th, 30th, 60th, and 90th days.

Analyses of TBARS (thiobarbituric acid reactive substances) were performed according to the methodology described by Tarladgis (1964).

After the test of normality (Shapiro-Wilk), the variables of performance, carcass, and meat were subjected to analysis of variance, which, when significant, were subjected to regression analysis for the doses of ractopamine. For ash, lipids, b* color component, weight loss by cooking, weight loss by drip, and lipid oxidation under cooling and freezing the square root transformation option was used. The split plot design for the assessment of lipid oxidation and pH was used. When the effect was cubic or quartic, the mean doses were compared by the SNK test at 5%. To evaluate the variable feed conversion, the regression discontinuity model LRP (linear response plateau) to estimate the optimal level of RAC was used. All statistical analyses were performed using the computer program SAS (Statistical Analyses System, version 9.1).

Results and Discussion

Supplementation with RAC to pigs resulted in higher ($P<0.05$) final weight and average daily weight gain, and improved feed conversion (Table 2), demonstrating the ability of this additive to improve the performance of finishing pigs. A linear effect was observed for final weight ($P<0.05$); animals fed diets with 20 ppm supplement weighed 4.19% more than animals on control. Similar results were found by Carr et al. (2009), testing levels of 0, 5, 10, and 20 ppm RAC for heavy fattening pigs (133 kg). Moore et al. (2009) observed a higher final weight of the treated animals compared with control when supplementing RAC for 26 days (5 ppm RAC for the first 14 days, and 10 ppm RAC for the12 subsequent days).

However, Rikard-Bell et al. (2009) evaluated animals receiving RAC during 31 days (5 ppm RAC for 14 days and 10 ppm RAC for 17 days) and Sanches et al. (2010) tested 0, 5, 10, and 20 ppm RAC for barrows, and found no difference in final weight. With respect to the average daily weight gain, there was a significant effect of RAC with a linear increase in gain. Compared with control, 20 ppm RAC increased weight gain by 18.87%. Similar results were also reported by Watkins et al. (1990) (0, 5, 10, 15 and 20 ppm RAC for 45 or 50 days) and by Armstrong et al. (2004) (0, 5, 10 and 20 ppm RAC in periods ranging from 6 to 34 days). However, data obtained in this experiment differ from those observed by Brumm et al. (2004) who evaluated 0 and 10 ppm RAC for barrows for 28 days, and those by Mimbs et al. (2005), who tested genetic groups (slightly fat or fat) supplemented with 0 or 10 ppm RAC for 28 days, and did not find a significant increase in weight gain of animals.

Table 2 - Performance and carcass traits of fattening pigs receiving different doses of ractopamine in the diet (0, 5, 10, 15, and 20 ppm) for 28 days

Variable	Doses (ppm)					Mean	CV (%)
	0	5	10	15	20		
Final weight (kg)[2]	102.70	105.30	106.50	105.60	107.00	105.40	2.52
Daily weight gain[1,3]	901	1023	1050	1012	1071	1011	8.22
Daily feed intake[1]	2823	2741	2871	2746	2919	2820	8.55
Feed conversion[4]	3.15	2.68	2.73	2.76	2.87	2.84	4.47
Daily intake of digestible lysine[1]	29.08	28.24	29.58	28.28	30.06	29.00	8.55
Daily intake of metabolizable energy (kcal/day)	9118	8855	9275	8869	9427	9109	8.55
Carcass yield (%)[2]	80.70	81.00	81.10	81.80	81.70	81.30	1.16

CV - coefficient of variation.
[1] g/day.
[2] Significant linear regression ($P<0.05$).
[3] Significant linear regression ($P<0.01$).
[4] Linear response plateau.

The average daily feed intake of animals supplemented with RAC did not differ between treatments (P>0.05), similar to the observed by Aalhus et al. (1992) (0, 5, 10, 15 and 20 ppm RAC for barrows and gilts) and Marinho et al. (2007) (5 ppm RAC for 21 or 28 days for barrows). However, this behavior was not observed by Carr et al. (2005a) and Mimbs et al. (2005), suggesting that these differences in responses may be related to the different genetic strains used.

Regarding the variable feed conversion, the optimum supplementation of ractopamine estimated by the LRP model was 3.88 ppm, resulting in a feed conversion value of 2.78 (P<0.05). Using the optimal level estimated by the LRP model, the improvement in feed conversion compared with the control treatment was 29%. Similar results were found by Ferreira et al. (2011) (0, 5, 10, 15 and 20 ppm RAC for barrows and gilts), who estimated the optimal level of 4.41 ppm RAC for better feed conversion. Similar results were also found by Schinckel et al. (2001), who concluded that to gain weight, most of the animal response to RAC can be achieved with supplementation of 5 ppm in the diet. Other authors, however, observed different responses: Armstrong et al. (2004) (0, 5, 10, and 20 ppm RAC) observed a significant response to the improvement in feed conversion in all treatments, although more efficiently for 10 and 20 ppm RAC; Stites et al. (1991) observed that the effect of RAC in pigs does not necessarily present a dose-dependent behavior, which may partly explain the results obtained in this work.

Some researchers, such as Kessler (2001), claim that the feed conversion is highly correlated with variables representing the gain of lean tissue and, on that basis, persists as a performance measure and is used as the main reference for evaluating the efficiency of pig production systems. By presenting a lower energy value aggregate, the greater gain of lean tissue improves the response in relation to feed conversion.

The greater feed conversion observed in animals receiving RAC may explain their better performance compared with the higher final weight and better average daily weight gain. This is because RAC is recognized as a splitter of nutrients, favoring a lower fat deposition and increased deposition of lean tissue in the carcass, whereas the muscle tissue is rich in water, and so demands fewer nutrients for their formation. The energetic deposition of muscle tissue is approximately three times lower than the cost of body fat deposition (English et al., 1988).

In general, divergent responses observed in the literature can be explained by different studies using varied strains and duration of use of the additive as well as the nutritional management (Dunshea et al., 1993; Smith et al., 1995).

No differences (P>0.05) were observed for consumption of digestible lysine and energy intake, demonstrating that the differences observed were not influenced by these factors.

For carcass yield, there was a linear increase (P<0.05) with increased doses of RAC in the diet. The animals fed 20 ppm RAC had a yield 1.24% higher than the control treatment. According to Mills (2002), and Stahly & Barck (1991), ractopamine and other phenylethanolamines that increase the percentage of meat are capable of increasing the proportion of nutrients deposited on the carcass in relation to the deposition on the internal organs. One of the reasons for this improvement in carcass yield is the occurrence of a higher weight at slaughter with low relative weight of the viscera, generating an increase in muscle mass and a decrease in visceral weight. Adeola et al. (1990) (supplementing barrows and gilts with 20 ppm RAC for 28 days) and Stites et al. (1991) (48 days of 0, 5, 10, or 20 ppm RAC for finishing pigs) observed the same effect on an increase in the carcass weight for animals receiving the additive.

However, when evaluating the supplementation of 20 ppm RAC to barrows and gilts from 64 to 100 kg, Carr et al. (2005a) and Uttaro et al. (1993) found no significant difference for animals receiving the additive. However, in order for comparisons of carcass yield values obtained in different scientific studies to be valid, the income must have been determined under similar conditions, since this variable is highly affected by the duration of pre-operative fasting before slaughter, as well as by the diet of animals (Oliveira, 2005).

The centesimal composition of *longissimus dorsi* shows that there was no difference (P>0.05) between treatments for moisture (Table 3). On average, the muscle showed 72.5% moisture, which is in accordance with Estevez et al. (2003) and Virgili et al. (2003), who found average moisture of 73%. There was no significant difference (P>0.05) in mean percentage of crude protein and ether extract for the *longissimus dorsi* muscle from pigs that received the control diet or diets containing 5, 10 or 15 ppm RAC. However, pigs fed diets containing 20 ppm RAC had a lower average percentage of crude protein and a higher average percentage of lipids (P<0.05) in this muscle compared with animals receiving other treatments. The decrease in the percentage of protein in the muscle of animals receiving the highest level of ractopamine was consistent since there was a concomitant increase in the ether extract.

The deposition of water is related to muscle protein synthesis, and inversely related to fat deposition. Dunshea et al. (1993) and Uttaro et al. (1993) found more protein deposition and higher moisture content with the inclusion of ractopamine in the diet.

Since the effect of ractopamine on lipid metabolism and protein synthesis occurs by binding to membrane receptors, it can be inferred that these results occurred due to the phenomenon of "down-regulation" or desensitization of β-adrenergic receptors, in excess of the additive, but it must be emphasized that this behavior is not similar in other muscles.

Evaluating the use of 0, 10 and 20 ppm RAC for barrows, Carr et al. (2005b) observed an increase in the amount of ether extract of the *longissimus dorsi* muscle of pigs, comparing the treatment of 20 ppm RAC with others. Some other researchers (Apple et al., 2008; Xiao et al., 1999) found that animals supplemented with 20 ppm RAC had a greater marbling score of the *longissimus dorsi* muscle, which is consistent with the observed in this experiment.

The ash content of the *longissimus dorsi* muscle was influenced by the use of ractopamine. There was a linear effect (P<0.05), in which the animals treated with higher doses of the additive had lower percentages of ash. Comparing the dose of 20 ppm RAC with the control, there was a decrease of ~10.35% of ash. Adeola et al. (1990) also observed a decrease in the levels of ash in animals supplemented with 20 ppm RAC when compared with untreated control. However, Uttaro et al. (1993) and Xiao et al. (1999) observed an increase in ash content of the muscle of fattening pigs with an initial weight of 64 kg and a final weight of 90 kg supplemented with 20 ppm RAC.

There were no significant differences (P>0.05) between treatments for initial and final pH (Table 4). These values are within the normal reported in the literature and are similar to those of Bridi et al. (2006), Carr et al. (2005b, 2009) and Stites et al. (1991). More specifically in relation to the final pH, the mean values were very close to those considered optimal by Dalla Costa (2010) for fresh meat of pigs (pH between 5.5 and 5.8). However, Warris et al. (1990) found that the final pH of the meat from pigs treated with β-adrenergic agonist was higher, and these results justify the fact that these animals consumed muscle glycogen, which can result in lower production and accumulation of lactic acid in the carcass after slaughter, thereby making it difficult to reduce the pH.

Regarding the variables of color, there was no significant difference (P>0.05) for L*. Carr et al. (2005a,b) and Uttaro et al. (1993) also found no significant difference for this variable. All values of L* found in this study were higher than 50, indicating that the lighter meats were considered normal (Joo et al., 1995, 1999), including those

Table 3 - Centesimal composition of the *longissimus dorsi* muscle of finishing pigs receiving different doses of ractopamine in the diet (0, 5, 10, 15, and 20 ppm) for 28 days

Variable	Doses (ppm)					Mean	CV (%)
	0	5	10	15	20		
Moisture	72.47	72.61	72.49	72.16	72.74	72.50	1.06
Crude protein[1]	18.03a	18.16a	17.91a	19.85a	15.91b	17.97	7.96
Ether extract[1]	6.26a	5.57a	6.27a	5.04a	11.34b	6.90	9.38
Ash[2]	3.96	3.80	3.75	3.82	3.55	3.78	3.37

CV - coefficient of variation.
[1] Means followed by different letters in the same row differ by the SNK test (P<0.05).
[2] Significant linear regression (P<0.05).

Table 4 - Initial pH, final pH, color components (L*, a* and b*) and physical characteristics of *longissimus dorsi* muscle of fattening pigs receiving different doses of ractopamine in the diet (0, 5, 10, 15, and 20 ppm) for 28 days

Variable	Doses (ppm)					Mean	CV (%)
	0	5	10	15	20		
Initial pH	6.06	5.90	6.13	6.03	6.11	6.04	3.44
Final pH	5.83	5.76	5.83	5.84	5.75	5.80	1.95
L*	52.2	51.7	51.2	51.8	51.7	52.0	3.43
a*[1]	7.86	6.88	6.91	6.79	6.98	7.08	6.82
b*[2]	1.16	0.75	0.46	0.62	0.57	0.71	24.82
Drip loss (%)[2]	1.16	1.11	0.93	0.95	0.95	1.02	7.75
Weight loss by defrosting (%)	2.79	2.91	3.20	3.00	3.05	2.99	30.36
Weight loss by cooking (%)	26.8	26.7	27.4	29.6	27.7	28.0	4.49
Shear force (Kgf)	7.36	7.61	6.64	7.00	8.08	7.34	8.83

CV - coefficient of variation.
[1] Significant quadratic regression (P<0.05).
[2] Significant linear regression (P<0.05).

from the control treatment. This fact alone is not sufficient to consider them as PSE (pale, soft, and exudative), since to be regarded as such, the following also needs to be present: initial pH lower than 5.8, final pH below 5.6 and loss of water by freezing greater than 5% (Joo et al., 1995, 1999). This finding is of extreme importance, since it reaffirms that supplementation of ractopamine to finishing pigs does not favor the production of meat as PSE. This defect of pork has great economic impact, since it is unsuitable for industrialization and is unpleasant for the consumer. Increased values of L* are related to the low final pH of the meat, characteristic of animals with rapid anaerobic consumption of glycogen, resulting in greater lactic acid production. The accumulation of lactic acid starts the denaturation of meat proteins, resulting in greater loss of water and greater reflection of light, giving it a pale appearance (Juncher et al., 2001).

For a*, a quadratic effect was observed (P<0.05) and for b* a linear effect (P<0.05) was observed, i.e., the value of a* decreased close to the treatment with 15 ppm ractopamine inclusion in the diet and at the level of 20 ppm RAC increased again, showing behavior similar to that presented for the percentage of lipids in the *longissimus dorsi* muscle. Higher values for a* can be explained by the amount of iron present in the tissue, where samples with the highest amount of potassium show higher values of a* (Juncher et al., 2001), which is associated with this quantity of myoglobin in muscle. Several studies have shown that ractopamine promotes significant reductions in the a* values (Uttaro et al., 1993; Carr et al., 2005b). Regarding the b* values, they decreased linearly with the inclusion of ractopamine in the diet. In general, the value of b* indicates carotenoid pigments that are deposited in fat (Bressan et al., 2004).

Due to the tendency of pigs to have higher fat deposition in the subcutaneous layer and later in muscle, the slaughter of heavier animals can result in changes in the values of b* (Cisneros et al., 1996). In addition, changes in the b* value can be indicative of changes in fatty acid composition of intramuscular fat (John et al., 2005). Aalhus et al. (1990), Carr et al. (2005a) and Uttaro et al. (1993) reported similar results, with increased levels of ractopamine leading to a decrease in the b* value. According to Apple et al. (2007), although there were significant differences in the color of pig meat, these differences are usually not visibly noticeable to consumers in most cases. Moreover, there are studies showing that supplementation of pigs with 5, 10, or 20 ppm RAC did not affect the color of meat (Stites et al., 1991; Armstrong et al., 2004).

Drip weight loss decreased linearly (P<0.05) with the use of increasing doses of ractopamine. Treatment with 20 ppm RAC led to a decrease in weight loss of 18.10% when compared with control. Apple et al. (2004), Bridi et al. (2006) and Stoller et al. (2003) observed no change in this variable. However, it is interesting to note that the drip loss influences the industrial processing of meat (Roça, 2010). The amount of water loss is a problem for industries as the exudate contains soluble proteins, vitamins and minerals (Bonagurio et al., 2003). Thus, the result of this research indicates that ractopamine favors the production of noble products such as cooked and raw ham, and also that after the cuts for the sale, the product looks better to consumers for presenting a lower accumulation of water in containers. Agostini et al. (2011) found no effect of ractopamine dose used on drip loss.

The values for shear force were not significantly different (P>0.05) when using increasing doses of ractopamine in the diet of pigs. Bridi et al. (2006) and Agostini et al. (2011) found no effect of ractopamine on this variable, showing that the use of ractopamine did not affect the tenderness of the meat. Other studies have shown differences (Warris et al., 1990; Wood et al., 1994), i.e., it was observed that pigs that had consumed ractopamine showed meat with a higher shear force, possibly as a result of the increasing diameter of muscle fibers or by reducing the activity of the proteolytic enzyme calpain.

TBARS values were not affected by different levels of ractopamine, and there was no interaction between ractopamine and storage time (Table 5). However, the storage time led to an increase (P<0.01) in TBARS values, agreeing with the results observed by Apple et al. (2008), who evaluated the *longissimus dorsi* muscle of animals receiving 0 or 20 ppm RAC, and no difference between the levels of ractopamine for this variable was observed. However, there was an increase in TBARS values in relation to storage time. Likewise, Leick et al. (2010) tested the levels of 0 or 5 ppm RAC and observed no difference in TBARS values of the *longissimus dorsi* muscle packaged under modified atmosphere (80% O_2/20% CO_2) for 0, 7, 14 and 21 days.

As occurred with the meat under cooling, a significant linear effect (P<0.01) of the variable time was observed, i.e., TBARS also increased with time (Table 6). However, TBARS values were lower than the literature cites as being detectable by the consumer, thus determining that the meat from RAC-supplemented pigs could be stored for a period of 90 days without having its quality compromised in terms of lipid oxidation.

Table 5 - Lipid oxidation (malonic dialdehyde concentration in mg/kg) of *longissimus dorsi* muscle of fattening pigs receiving different doses of ractopamine in the diet (0, 5, 10, 15, and 20 ppm) and stored under refrigeration for 0, 5, 8, and 12 days

Day of evaluation	Doses of ractopamine (ppm)					Mean[1]	P		
	0	5	10	15	20		Ractopamine	Time	R*T
0	0.117	0.128	0.106	0.099	0.124	0.115	0.3879	≤0.0001	0.9893
5	0.269	0.267	0.254	0.241	0.216	0.249			
8	0.458	0.424	0.431	0.361	0.384	0.412			
12	0.598	0.618	0.505	0.513	0.482	0.543			
Mean	0.360	0.359	0.324	0.304	0.301				
CV (%)	16.18								

CV - coefficient of variation; R*T - ractopamine × time interaction.
[1] Significant linear regression (P<0.05).

Table 6 - Lipid oxidation (malonic dialdehyde concentration in mg/kg) of *longissimus dorsi* muscle of finishing pigs receiving different doses of ractopamine in the diet (0, 5, 10, 15, and 20 ppm) and frozen for 0, 15, 30, 60, and 90 days

Day of evaluation	Doses of ractopamine (ppm)					Mean[1]	P		
	0	5	10	15	20		Ractopamine	Time	R*T
0	0.117	0.128	0.106	0.134	0.114	0.120	0.8208	≤0.0001	0.6239
15	0.104	0.101	0.096	0.083	0.096	0.096			
30	0.138	0.137	0.144	0.116	0.130	0.133			
60	0.173	0.169	0.163	0.140	0.158	0.161			
90	0.225	0.229	0.217	0.196	0.239	0.221			
Mean	0.151	0.153	0.145	0.134	0.148				
CV (%)	9.91								

CV - coefficient of variation; R*T - ractopamine × time interaction.
[1] Significant linear regression (P<0.05).

Conclusions

All ractopamine levels improve feed conversion in the same way compared with control. For the variables daily gain, final weight and carcass yield, linear effect was observed with increasing doses up to 20 ppm of ractopamine. Ractopamine does not negatively affect the quality of pork, bringing benefits to both producers and slaughterhouses.

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