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Effect of dietary supplementation with l-carnitine, chromium, and selenium on the performance of finishing pigs

Efeito da suplementação dietética com l-carnitina, cromo e selênio no desempenho de suínos em fase de terminação

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Abstract

This study aimed to assess the combined effect of L-carnitine, chromium propionate, and organic selenium in the diet of pigs at the finishing stage in commercial farms on performance parameters. The sample included 5,456 female and castrated male DB pigs with mean age of 159 days and mean initial weight of 103.33 ± 4.11 kg. The pigs were split into two treatments in a completely randomized design: the control group, free of growth-promoting dietary additives, and the test group, supplemented with Profitilina® (50 mg L-carnitine, 0.2 mg chromium propionate, and 0.3 mg organic selenium kg^{-1} of feed) for 30 days prior to slaughter. The outcomes assessed were daily weight gain (DWG), daily feed intake (DFI), feed conversion (FC), and final body weight (FBW). An improved performance according to all parameters ($P<0.001$) was seen for the test group (2.58 *versus* 2.64 g day^{-1} for DFI; 0.76 *versus* 0.87g day^{-1} for DWG; 3.42 *versus* 3.06 for FC; and 125.7 *versus* 127.7 kg for FBW). Providing a combined dietary supplementation with L-carnitine, chromium propionate, and organic selenium to finishing pigs was effective at improving weight gain, feed intake, feed conversion, and final weight.
Key words: Additives. Efficiency. Growth promoters. Performance.

Resumo

Objetivo deste trabalho foi avaliar a ação combinada da L-carnitina, do propionato de cromo e do selênio orgânico em dietas de suínos em fase final de engorda, em granjas comerciais, sobre os parâmetros de desempenho. Foram avaliados 5.456 suínos (genética DB), machos castrados e fêmeas, com idade média de 159 dias e peso médio inicial de 103,33 ± 4,11 kg. Os animais foram divididos em delineamento inteiramente casualizado, com dois tratamentos, definidos como grupo Controle, isento de aditivos promotores de crescimento na ração; e Teste, suplementados com o produto Profitilina® (50 mg kg^{-1} de L-carnitina; 0,2 mg kg^{-1} de propionato de cromo e 0,3 mg kg^{-1} de selênio) durante 30 dias pré-

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abate. Foram avaliados o ganho diário de peso (GDP), o consumo diário de ração CDR), a conversão alimentar (CA) e o peso vivo final (PVF). Houve melhora do desempenho para todos os parâmetros (P<0,001) a favor do grupo Teste (2,58 versus 2,64 g dia^{-1} para o CDR; 0,76 versus 0,87g dia^{-1} para o GDP; 3,42 versus 3,06 para a CA, e 125,7 versus 127,7 kg de PVF). A suplementação dietética de rações de suínos em fase final de terminação com 50 mg kg^{-1} de L-carnitina; 0,2 mg kg^{-1} de propionato de cromo e 0,3 mg kg^{-1} de selênio foi efetiva na melhora dos índices de desempenho.
Palavras-chave: Aditivos. Eficiência. Performance. Promotores de crescimento.

Introduction

Production efficiency in industrial pig farming is a constant goal. In this cost-benefit relationship, nutritional additives represent a positive tool. However, they must be safe and free of residues to comply with consumer demand. In this context, L-carnitine, chromium propionate, and selenium are resources to achieve these targets. They are often used independently or in pairwise combinations, yielding results that are still somewhat inconsistent (CARAMORI JÚNIOR et al., 2017; OLIVEIRA et al., 2012; OWEN et al., 1996; PIETRUSZKA et al., 2009).

Carnitine (3-hydroxy-4-N-trimethylamine-butyrate) is synthesized by muscle tissue and the liver and comes from the metabolism of the amino acids lysine and methionine. It plays a major role in the transport of fatty acids through the mitochondrial membrane, providing energy to cells (COELHO, 2005; HOPPEL, 2003) and influencing the enzymes involved in the metabolism of proteins and lipids (OWEN et al., 2001). Although it is not considered an essential component in pigs' diet, dietary supplementation with L-carnitine favors the use of fatty acids as energy-producing components, which might increase protein deposition in the body (HEO et al., 2000). Owen et al. (1996) observed that dietary supplementation with 500 or 1,000 mg L-carnitine kg^{-1} of feed led to a linear increase in the dietary efficiency of nursery pigs, suggesting that pigs at the growth and finishing stages might respond similarly (OWEN et al., 2001).

Chromium, as L-carnitine, is also an additive free of legal restrictions and is, therefore, safe to use with no risk to consumers. It is commonly used in growing and finishing pigs and acts by increasing glucose tolerance through the potentialization of insulin, which increases the absorption of this sugar and improves carcass characteristics and meat quality (GOMES et al., 2005). Chromium also functions in protein metabolism by promoting an increased use of amino acids and increasing protein synthesis (CLARKSON, 1997).

Selenium is a component of some hormones and enzymes. In particular, it is present in glutathione peroxidase, which protects against oxidative stress (ZAVODNIK et al., 2011) and means it is essential in productive and reproductive developmental processes (O'GRADY et al., 2001). However, dietary selenium supplementation for growing and finishing pigs also shows inconsistent results for several reasons, and the effects on performance and carcass characteristics vary from positive (CARAMORI JÚNIOR et al., 2017) to indifferent (MATEO et al., 2007).

Therefore, this study aimed to assess the combined effect of L-carnitine, chromium propionate, and organic selenium in the diet of pigs at the finishing stage in commercial farms on performance parameters.

Material and Methods

All procedures adopted in this research were previously reviewed and approved by the Committee of Ethics on Animal Research and Experimentation of Akei Animal Research under protocol no. 007/2018.

The experiment was carried out on five growth and finishing commercial farms with capacities of 250 to 1,000 pigs associated with a cooperative located in the mid-west portion of the state of Santa Catarina, Brazil, between August and September

2018. The sample included 5,456 female and castrated male DB pigs in a balanced distribution with a mean age of 159 days and mean initial weight of 103.33 ± 4.11 kg.

The pigs were submitted to one of two treatments: the control group was provided a diet free of growth-promoting dietary additives, and the test group was given a diet supplemented with 1 kg Profitilina® per ton of feed (final dose of 50 mg L-carnitine, 0.2 mg chromium propionate, and 0.3 mg organic selenium kg^{-1} of feed) for 30 days prior to slaughter. The animals were housed in masonry barns with pens for 12 to 22 pigs complying with the stocking density of 1 m² per animal featuring a solid floor, nipple double drinking troughs, and linear feeding troughs with free access for all animals simultaneously.

The diets were formulated to meet the minimum recommendations described by Rostagno et al. (2017) for finishing gilts of high genetic potential between 100 and 125 kg (Table 1). The feed was provided *ad libitum* four times a day and the animals had free access to water.

Table 1. Composition (kg t^{-1}) and calculated nutritional value of the baseline experimental feed of finishing pigs.

Ingredients	**%**
Corn kernel	81.333
Soybean meal	13.500
Meat meal	1.400
Animal fat	1.700
Mineral-vitamin premix[1]	0.040
Iodized salt	0.380
Choline	0.015
L-threonine	0.100
L-lysine	0.700
Calcitic lime	0.560
Mycotoxin adsorbent[2]	0.050
Copper sulfate	0.030
Protease[3]	0.020
Phytase[4]	0.002
Liquid methionine[5]	0.035
Rovabio Advance P®[6]	0.005
Emulsifier[7]	0.030
Profitilina®[8]/Inert	0.100
Nutritional levels	
Metabolizable energy (kcal kg^{-1})	3.360
Crude protein (kg^{-1})	14.000
Total calcium (kg^{-1})	0.530
Available phosphorus (kg^{-1})	0.272
Sodium (kg^{-1})	0.170
Total lysine (kg^{-1})	0.955
Digestible lysine (kg^{-1})	0.840
Total methionine (kg^{-1})	0.287

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Digestible methionine (kg^{-1})	0.234
Total methionine+cystine (kg^{-1})	0.554
Digestible methionine+cystine (kg^{-1})	0.496
Total threonine (kg^{-1})	0.618
Digestible threonine (kg^{-1})	0.519

[1]Content per kg of product: Vit A: 6,875 UI; Vit D3: 1,500 UI; Vit E: 55,833.33 UI; Vit K3 (menadione) 1,666.67 mg; Vit B1 (thiamine): 1,666.67 mg; Vit B2 (riboflavin): 5,833.33 mg; Vit B6 (pyridoxine): 3,333.33 mg; Vit B12 (cyanocobalamin): 25.00 mg; niacin: 20,833.33 mg; pantothenic acid: 20,833.33 mg; copper: 8,333.33 mg; iron 58,333.33 mg; manganese: 31,250.00 mg; iodine: 750.00 mg; zinc: 83,333.33 mg; selenium: 291.67 mg; silicon dioxide: 8.33 g; folic acid: 833.33 mg; biotin: 166.67 mg. [1]AjiLys 64; [2]Adtox; [3]Ronozyme ProAct; [4]Ronozyme HiPhos; [5]Rhodimet AT 88; [6]Rovabio Advance P; [7]Liposorb; [8]corresponding to 50 mg L-carnitine; 0.2 mg chromium propionate, and 0.3 mg organic selenium per kg of feed.

A completely randomized experimental design with two treatments was employed with an uneven number of replicates (represented by the mixed pens), i.e., 49 for the control group with 2,736 pigs, and 50 for the test group with 2,720 pigs. The pen was considered the experimental unit for weight gain and the farm was the replicate for the data for feed consumption. The number of pigs per pen differed between farms but was similar within a single farm.

The pigs were weighed on the first day of the experiment and on the day of slaughter in order to calculate the daily weight gain. The daily feed intake was obtained by dividing the overall feed provided minus leftovers by the days of evaluation and number of animals, and the feed conversion was calculated by dividing the daily intake by the daily weight gain.

Shapiro Wilk's test was used to evaluate the normality of the distribution of the variables and the data were submitted to an analysis of variance. The averages were compared using an F test at 5% probability using the statistical software R version 3.5.0.

Results and Discussion

The results (Table 2) show the pigs that received dietary supplementation had a better zootechnical performance ($P<0.001$), with a higher daily weight gain and daily feed intake by 105 and 66 g, respectively, than the control group, whereas the feed conversion was 0.36 points lower. The animals in the test group presented a total weight gain 4.42 kg higher than the control group.

Table 2. Mean values of initial weight, daily weight gain (DWG), daily feed intake (DFI), feed conversion (FC), total weight gain (TWG) and final weight of finishing pigs supplemented with L-carnitine, chromium propionate, and organic selenium.

Parameters	**Treatments**		**Difference (%)**	**CV (%)**	**P value**
	Control	Test			
Initial weight (kg)	104.09	102.57	-1.46	3.97	0.06
DWG (kg)	0.77	0.87	+13.76	11.64	<0.001
DFI (kg)	2.58	2.64	+2.56	3.68	<0.001
FC	3.42	3.06	+10.45	11.06	<0.001
TWG (kg)	21.60	26.03	+ 20.51	16.02	<0.001
Final weight (kg)	125.70	127.70	+1.59	0.08	0.08

The results match the findings by Heo et al. (2000), who reported that, even when L-carnitine was the single supplement at 150 mg kg^{-1} of feed a value higher than in the present study a positive effect was seen on the growth rate. In addition, Rekiel and Zackiewcz (2004) adopted supplementation with only L-carnitine at 50 mg kg^{-1} of feed and found improvements in the DWG and FC.

In biochemical processes, L-carnitine forms esters from long-chain fatty acids catalyzed by the enzyme carnitine palmitoyltransferase I (SASEENDRAN et al., 2017), which is able to penetrate the mitochondrial membrane (HEO et al., 2000; JAMES et al., 2013). These esters are then cleaved again through the action of carnitine palmitoyltransferase II and released within the mitochondria to be used for energy production (HEO et al., 2000). That suggests that dietary supplementation with L-carnitine for finishing pigs optimizes the use and transport of fatty acids, thus increasing the production of energy used for animal growth. Therefore, L-carnitine supplementation decreases body fat levels and increases protein deposition (HEO et al., 2000; PIETRUSZKA et al., 2009), a scenario effectively linked to improved FC as found in this research.

Ringseis et al. (2018) demonstrated positive results regarding performance and meat quality by supplementing growing and finishing pigs with doses between 49 and 64 mg kg^{-1}. Nonetheless, there are contrasting observations. Pietruszka et al. (2009), when supplementing pigs with 100 mg L-carnitine kg^{-1} of feed, found no effects on weight gain or feed conversion. Similar results were found by Owen et al. (2001) when using with L-carnitine doses between 25 and 125 mg kg^{-1} of feed and by Chen et al. (2008) when supplementing pigs with 250 mg kg^{-1} of feed for 70 days starting at 59 kg of body weight.

The inconsistent results for the use of L-carnitine can be attributed to several causes, such as the sanitary status; the age of the animals; and environmental, genetic, and nutritional factors (JAMES et al., 2013; RINCKER et al., 2003). In the present study, the dose of 50 mg L-carnitine kg^{-1} of feed was within the values commonly employed in experiments and commercial farming (HARMEYER, 2003; OWEN et al., 2001; RINGSEIS et al., 2018) and proved effective under the conditions of this test. The effect of L-carnitine might be explained by Rincker et al. (2003), who stated that L-carnitine acts in nutrient partition, which modifies the body composition and translates into increased weight gain and improved feed conversion.

The dietary level of lysine in this study can be considered high, surpassing the values proposed by Rostagno et al. (2017) to meet the requirements of boars with high genetic potential and a body weight between 100 and 125 kg. Therefore, the findings align with the reports by James et al. (2013), who suggested the beneficial effects of L-carnitine in finishing pigs might be more noticeable when levels of this amino acid are high in the diet.

The role of chromium must also be taken into account when analyzing the results. According to Zhang et al. (2011) and Oliveira et al. (2012), chromium doses between 0.2 and 0.4 mg kg^{-1} of feed lead to increased glucose tolerance by potentializing insulin, which increases the absorption of this carbohydrate and improves performance indices and carcass characteristics (GOMES et al., 2005).

Chromium as a performance-enhancing additive, despite variable results for its supplementation in the literature (PERES et al., 2014), led to an improvement of 6.08% in weight gain and 3.30% in feed conversion when supplemented at 0.2 mg kg^{-1} of feed for 35 days prior to slaughter (ZHANG et al., 2011). Nevertheless, when Matthews et al. (2005) used the same dose, no effect was found on the performance parameters of growing and finishing pigs. According to Gebhardt et al. (2018), the exclusive use of chromium as a feed additive in rations of growing and finishing pigs produced only a modest effect. The results obtained in this research

using the same dose as Zhang et al. (2011) were even higher than those reported by those authors, which suggests that the effects of chromium were potentialized when in association with L-carnitine. Li et al. (2013) obtained better zootechnical performance values for pigs supplemented for 28 days with 0.3, 0.6, and 0.9 mg chromium propionate kg^{-1} of feed than those fed the control diet. Another possible reason for the benefits of chromium supplementation is its association with the reduction in body fat (BOLEMAN et al., 1995) attributed to its ability of increasing glucose absorption by target cells, which prevents excess plasma glucose from converting into fat (GOMES et al., 2005).

Some studies have assessed the association of L-carnitine with chromium propionate, particularly for sows. Real et al. (2008), when studying pregnant and lactating sows provided with diets supplemented with L-carnitine (90 and 250 mg day^{-1}) and chromium (360 to 1,000 µg day^{-1}) using a factorial design, reported that such combinations at higher doses improved reproductive indices, particularly the number of live births in the first two parities, which suggests an additive effect of the supplements. The dietary association of chromium propionate (0.2 mg kg^{-1} of feed) with L-carnitine (500 mg kg^{-1} of feed) for piglets 21 days post-weaning led to improvements in performance characteristics (CHO et al., 2000). According to Woodworth et al. (2007), the proposed mechanism of this joint action is based on the influence of chromium on glucose and insulin levels immediately after feeding and of carnitine on non-esterified fatty acids (an important metabolic fuel) 6 to 24 h after feeding, as well as the IGF concentration, which reduces body fat, changes lipid oxidation, and increases protein synthesis.

Organic selenium is a component of several hormones and enzymes involved in animal performance (ZAVODNIK et al., 2011), however, its use in pigs' diets has shown inconsistent results. Mateo et al. (2007) found no improvement in the performance parameters of growing and finishing pigs when supplementing the diets with 0.2 mg selenium kg^{-1} of feed. Stupka et al. (2012), when exclusively supplementing diets with selenium at 1 mg kg^{-1} of feed for finishing pigs over different pre-slaughter periods (0, 30, and 60 days) also found no difference in the performance between the control and test groups.

In contrast, Jang et al. (2010) used three organic sources of selenium (all at 0.3 mg kg^{-1} feed *versus* a control diet) for growing and finishing pigs, and Martinez-Gomez et al. (2012) provided organic and inorganic selenium (9.45 mg kg^{-1} feed *versus* a control diet) and both found positive zootechnical performance results.

Oliveira et al. (2017), when evaluating supplementation with organic and inorganic selenium at two levels for the inorganic source (0.30 and 0.60 mg kg^{-1} of feed) and four levels for the organic source (0.15, 0.30, 0.45, and 0.60 mg kg^{-1} of feed) for 35 days after weaning, found improved feed conversion but no impact on the weight gain of the piglets. In the same study, the authors confirmed the superiority of the organic selenium over the inorganic selenium, and, irrespective of the source, the dose of 0.30 mg kg^{-1} of feed (the same as in the present study) was the most appropriate for piglets.

When providing dietary supplementation with chromium (0.8 mg kg^{-1} of feed) and selenium (0.6 mg kg^{-1} of feed) for pigs between 70 and 130 kg of body weight, Caramori Júnior et al. (2017) obtained a significant improvement in lumbar muscle depth, an indicator of lean meat deposition in the carcass, thus demonstrating the effectiveness of such a combination. Although the level of selenium supplementation was low in the studies by Stupka et al. (2012) and Son et al. (2018), the positive results obtained reiterate the role of selenium in animal metabolism, especially its role in enzyme and hormone composition, and indicate a potentialization effect of this element with chromium and L-carnitine on animal performance.

Conclusion

Dietary supplementation of finishing pigs with 50 mg L-carnitine, 0.2 mg chromium propionate, and 0.3 mg organic selenium kg^{-1} of feed for 30 days prior to slaughter led to improvements in weight gain, feed intake, feed conversion, and the final weight.

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