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Thermogenic oils as a substitute for ractopamine in the production of heavy pigs

Óleos termogênicos em substituição a ractopamina na produção de suínos em fase de pós-terminação

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ABSTRACT: This study aimed to assess the effects of thermogenic oils (safflower and coconut oils) as a replacement for ractopamine in heavy pig diets. A total of 24 mix-breed barrows with an average weight of 98.70 ± 1.63 kg were distributed in a randomized block design with four treatments and six replicates. Treatments were as follows: basal diet, modified basal diet + 10 ppm ractopamine, basal diet + safflower oil, and basal diet + coconut oil. Animal performance, organ weights, meat quality, carcass traits, and economic viability were determined. Data were analyzed using Duncan's test at the 5% significance level. The safflower oil diet resulted in the highest carcass meat and ham weights, whereas the coconut oil diet provided the highest loin eye area and the lowest fat area, resulting in the highest meat/fat ratio. Analysis of economic viability indicators revealed that vegetable oil treatments differed significantly from other treatments in feed cost, feed cost per kilogram of live weight, economic viability index, and cost index, given that oil inclusion increased the price of diets. Supplementation of heavy pig diets with thermogenic oils is a viable alternative to enhance lean meat production, but its use depends on market availability and product price.

KEYWORDS: feed additive; carcass; vegetable oil; pig farming; economic viability.

RESUMO: Este estudo visou avaliar os efeitos dos óleos termogênicos (óleos de cártamo e de coco) como substitutos da ractopamina em dietas de suínos pesados. Um total de 24 suínos machos castrados com um peso médio de 98,70 ± 1,63 kg foram distribuídos em um modelo de blocos aleatorizados com quatro tratamentos e seis repetições. Os tratamentos foram os seguintes: dieta basal (RB), RB modificada + 10 ppm de ractopamina, RB + óleo de cártamo, e RB + óleo de coco. Foram determinados o desempenho animal, pesos dos órgãos, qualidade da carne, características da carcaça, e viabilidade económica. Os dados foram analisados utilizando o teste de Duncan ao nível de 5% de significância. A dieta de óleo de Cártamo resultou na maior quantidade de carne de carcaça e pesos de pernil, enquanto que a dieta de óleo de coco forneceu a maior área do olho do lombo e a menor área de gordura, resultando na maior relação carne/gordura. A análise dos indicadores de viabilidade económica revelou que os tratamentos com óleo vegetal diferiram significativamente de outros tratamentos no custo da alimentação, custo da alimentação por quilograma de peso vivo, índice de viabilidade económica, e índice de custo, dado que a inclusão do óleo aumentou o preço das dietas. A suplementação de dietas de suínos pesados com óleos termogênicos é uma alternativa viável para aumentar a produção de carne magra, mas a sua utilização depende da disponibilidade no mercado e do preço do produto.

PALAVRAS-CHAVE: aditivo alimentar; carcaça; óleo vegetal; suinocultura; viabilidade econômica.

INTRODUCTION

Pork is one of the most consumed foods in the world due to its nutritional value. Its composition includes amino acids, B vitamins, a low concentration of sodium and polyunsaturated fatty acids (RESENDE and CAMPOS, 2015). In Brazil, pigs are generally slaughtered with up to 100 kg live weight

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(lean pigs), but the international market prefers heavier animals (≥130 kg) (PINTO, 2018). However, for these animals it is observed that after 100kg there is a decay in the production of lean tissue, so that most of the nutrients deposited in the carcass are made in the form of fat. Therefore, nutritional strategies are important to reduce this physiological process. (BERTOL et al., 2019).

With the goal of lean meat from heavier animals, pork production invested in technologies to enhance its production. One of these strategies was the use of beta-adrenergic such as ractopamine (MOREIRA et al., 2018).

Ractopamine is one of the most used additives in Brazil, USA and Canada, with the purpose of reducing fat deposition, but in the main importing countries of this meat such as Europe, China and Russia, ractopamine is banned (FERREIRA et al., 2011).

One of the alternatives to replace ractopamine is the use of vegetable oils, which act in the animal metabolism helping to reduce the deposition of fat in the carcass, just as it occurs in humans (COSTA et al., 2020), in addition to being a source of health-promoting fatty acids (BERTOL et al., 2015, SOUZA et al., 2020). Coconut and safflower oils, for instance, are capable of decreasing body fat in humans, rodents, and pigs (APPLETOON et al., 2015, COSTA et al., 2020). Research has shown that dietary intake of oils can help control blood cholesterol in nonruminant animals, including humans, increasing high-density lipoprotein levels while decreasing low-density lipoprotein levels (HANN et al., 2014).

In this context, research aimed at finding alternatives to the use of ractopamine may bring important contributions. Brazil is one of the major exporters of pork meat, so research with natural additives that have the same property as ractopamine has been developed to find an alternative compound to ractopamine.

Therefore, the objective of this research is to evaluate the effects of the use of thermogenic oils coconut and safflower oils as replacers of ractopamine on animal performance, meat quality, carcass yield, organ weights, and economic viability.

MATERIAL AND METHODS

The experiment was conducted at the Swine Research and Management Center (5°53'7"S 35°21'38"W). The project was approved by the Animal Research Ethics Committee (CEUA) under protocol number 002-2016.

A total of 24 male, castrated, mixed-breed (Pietrain, Large White, and Landrace) pigs, with an initial mean weight of 98.70 ± 1.63 kg, were used in the experiments, and for this purpose one animal per pen was used. Pigs were housed in an experimental shed divided into pens (2.76 m long × 1.85 m wide) with concrete floor, semi-automatic feeders, and nipple drinkers. The minimum and maximum temperatures recorded during the experimental period were 23 and 37 °C, respectively. The mean relative humidity was 54%.

The experiment was arranged in a randomized block design with four treatments and six replications. Initial body weight was used as the blocking factor, according to the following statistical model (Eq. 1):

$$X_{ij} = \mu + \alpha_i + \beta_i + \varepsilon_{ij} \quad (1)$$

Where:

X_{ij} is the observed value of the *i*-th treatment in the *j*-th block;

μ is the overall mean of all observations;

α_i is the effect of the *i*-th treatment;

β_j is the effect of the *j*-th block;

ε_{ij} is the experimental error associated with the *i*-th treatment in the *j*-th block.

Treatments consisted of a basal diet based on corn, soybean meal, and a commercial vitamin–mineral premix for finishing pigs (T_1), a modified basal diet supplemented with 10 ppm ractopamine (T_2), the basal diet supplemented with coconut oil (T_3), and the basal diet supplemented with safflower oil (T_4). The basal diet (Table 1) was formulated according to Rostagno et al. (2017).

Table 1. Ingredient and nutrient composition of experimental diets for late-finishing pigs.

Ingredient (g/kg)	Basal diet	Ractopamine diet
Corn	823.962	788.874
Soybean meal	148.969	177.941
Premix[1]	25.000	25.000
L-Lysine	1.900	4.885
L-Threonine	0.168	1.800
L-Methionine	0.001	0.000
L-Tryptophan	0.000	1.000
Ractopamine (10 ppm)	0.000	0.500
Calculated composition (g/kg)	1000	1000
Crude protein	140	155
Metabolizable energy (kcal/kg)	3246	3232
Calcium	6.61	6.66
Available phosphorus	1.59	1.63
Sodium	1.65	1.64
Chlorine	2.55	2.55
Lysine	6.91	9.88
Methionine	2.14	2.25
Threonine	4.63	6.47
Tryptophan	1.25	2.33
Valine	5.78	5.78

[1]Provided per kilogram of product: calcium 240 g, calcium 245 g, phosphorus 24.00 g, sodium 55 g, iron 3.2 mg, copper 5 mg, manganese 1.275 mg, zinc 2.235 mg, iodine 25.50 mg, cobalt 12.70 mg, selenium 9.50 mg, vitamin A 182.800 IU, vitamin D3 33 IU, vitamin E 722 IU, vitamin K3 36 mg, vitamin B1 28.0 mg, vitamin B2 105.00 mg, niacin 630 mg, pantothenic acid 360 mg, vitamin B6 35.0 mg, folic acid 18 mg, biotin 1.80 mg, vitamin B12 550 mcg, choline5.000 mg, and lincomycin 733.33 mg.

Diets and water were provided *ad libitum*. Coconut and safflower oils were administered orally in the form of capsules at a dose of three capsules in the morning (8:00 h) and three capsules in the afternoon (16:00 h), totaling six capsules per day per animal. Vegetable oil dosages followed the recommended values for human consumption. Capsules were delivered directly into the mouth of the animal to ensure successful feeding. The composition of each capsules is shown in table 2.

The animals were weighed at the beginning, middle, and end of the experiment (days 1, 14, and 28, respectively). Leftover feed was collected daily and weighed. These data were used for calculation of performance parameters (daily weight gain, daily feed intake, and feed conversion ratio).

At the end of the experimental period, pigs were fasted for 8 h and transported to a meat processing unit. At the processing unit, the animals were rested for 4 h pre-slaughter, totaling 12 h of fasting, stunned by electronarcosis, and exsanguinated by puncture of the jugular vein.

After dehairing and evisceration, carcasses were analyzed to obtain the initial pH and temperature, which were measured in the muscle *longissimus dorsi* (loin) by using a portable pH meter equipped with an insertion electrode (H1 99613 Meat pH Meter, Hanna Instruments). Then, the carcasses were cut into two and weighed to obtain the hot carcass weight, according to the method described by the Brazilian Association of Pig Breeders (ABCS, 1973). The weights of the liver, heart, lung, kidneys, intestines, and stomach were also determined.

At 24 h post-slaughter, carcasses were evaluated for quantitative and qualitative parameters, according to the Brazilian Method of Carcass Classification (ABCS, 1973) and Bridi and Silva (2009). The quantitative variables analyzed were fat area, loin area and depth, backfat thickness, and meat/fat ratio. Qualitative parameters included muscle color, marbling score, temperature, and pH (ABCS, 2014). After 24 h, final pH and temperature were measured after transformation of muscle into meat. Then, the carcasses were weighed to determine the cold carcass weight. The carcass yield was calculated from the hot carcass weight and live weight at slaughter (Eq. 2).

Table 2. Composition capsules

Composição	Safflower Oil	Coconut oil
Energy (kcal)	9	9
Total fat (g)	1	1
Saturated fat (g)	0.1	-
Linoleic acid (mg)	750	-
Oleic acid (mg)	150	250
Lauric acid (mg)	-	500
Myristic acid (mg)		250
Vitamin E (mg)	2.5	-

1 capsule of oil 1000 mg.

Carcass yield = hot carcass weight/live weight at slaughter x 100 (2)

Measurements of the loin eye area were performed at the height of the last rib, in the region between the last thoracic vertebra and the first lumbar vertebra. Loin and backfat areas were traced onto tracing paper, and traced areas were measured using a planimeter. The same procedure was used on loin samples to determine fat and muscle areas. The meat/fat ratio was calculated as the muscle area divided by the fat area.

Backfat thickness was determined according to ABCS (1973), at three different points. The first point was at the height of the first rib; the second, at the height of the last rib; and the third, at the height of the last lumbar vertebra. Measurements were made perpendicular to the dorsolumbar axis using a caliper.

Loin depth was measured by positioning the caliper perpendicular to the extreme opposite end of *longissimus dorsi* (ABCS, 1973).

Carcass meat weight was determined using Eq. (3), proposed by Irgang (1998):

Carcass meat weight = cool carcass weight × meat yield ÷ 100 (3)

Meat color and marbling score were determined by using the meat quality standards of the National Pork Producers Council (2000). The parameters were assessed on *longissimus dorsi* samples at 24 h after slaughter.

Ham samples were taken by making a straight cut to the axis between the last and second-last lumbar vertebrae and weighed. Ham samples included fat, meat, tail, and feet without hooves.

For assessment of the economic viability of treatments, the cost of diet per kilogram live weight gain was determined using the method of Bellaver et al. (1985) (Eq. 4):

$$Y_i = P_i \times D_i / G_i \quad (4)$$

where Y_i is the cost of diet per kilogram of body weight gained in the *i*-th treatment, P_i is the price per kilogram of diet used in the *i*-th treatment, D_i is the amount of diet consumed in the *i*-th treatment, and G_i is the weight gain of pigs in the *i*-th treatment.

Then, the cost per kilogram of carcass was calculated, and, with this, the economic efficiency (Eq. 5) and cost indices (Eq. 6), as proposed by Fialho et al. (1992):

$$\text{Economic efficiency index} = (LC/C_i) \times 100 \quad (5)$$

$$\text{Cost index} = (C_i/LC) \times 100 \quad (6)$$

where LC is the lowest cost of diet per kilogram of weight gain among all diets and C_i is the cost of treatment *i*.

Data were evaluated by analysis of variance (ANOVA). When significant, the means were compared by Duncan's test, adopting $\alpha = 0.05$. The analyses were performed using SAS software version 8.0 (2003).

RESULTS

Dietary intake of ractopamine or thermogenic oils did not affect ($p > 0.05$) daily weight gain, daily feed intake, or feed conversion (Table 3).

The liver of the animals fed coconut oil were different from the other treatments but the organ weights were not influenced by ractopamine and safflower oil supplementation ($p > 0.05$) (Table 4).

Ractopamine and vegetable oil supplementation did not affect meat color or marbling score, but ractopamine treatment influenced initial pH, final pH, and initial and final temperature of meat ($p < 0.05$) (Table 5).

Dietary supplements did not influence ($p > 0.05$) carcass weight and yield, ham relative weight, fat area, loin eye area, or loin depth. Coconut oil treatment influenced meat/fat ratio, significantly increasing ($p < 0.05$) the parameter compared with the control and ractopamine supplementation (Table 6).

Cold carcass yield was enhanced by the use of coconut oil supplements ($p < 0.05$) as compared with ractopamine. Safflower oil supplementation increased carcass meat yield ($p < 0.05$) compared with ractopamine supplementation.

Control feed had the lowest price ($p < 0.05$); however, when taking into account the cost of diet per kilogram weight gain, it was observed that control and ractopamine diets were the most economically viable ($p < 0.05$). Control and ractopamine diets had better economic efficiency and cost indices, providing the lowest costs ($p < 0.05$) (Table 7).

Table 3. Performance of pigs supplemented with ractopamine or vegetable oils. (n=6/ treatment)

Parameter	Control	Ractopamine	Safflower oil	Coconut oil	*P*-value	SEM
IW (kg)	99.500	97.333	100.333	97.667	0.635	4.445
W14 (kg)	111.667	109.167	112.500	108.667	0.594	4.827
FW (kg)	121.833	113.600	121.667	119.167	0.176	5.466
DWG (kg)	0.798	0.731	0.762	0.768	0.932	0.001
DFI (kg)	2.952	2.556	2.875	2.872	0.284	0.003
FCR	3.865	3.469	3.928	3.788	0.557	0.005

IW, Initial Weight; W14, Weight at 14 days; FW, Final Weight; DWG, daily weight gain; DFI, daily feed intake; FCR, feed conversion ratio; SEM, standard error of the mean.

Table 4. Relative organ weights (%) of pigs supplemented with ractopamine or vegetable oils. (n=6/ treatment)

Organ (%)	Control	Ractopamine	Safflower oil	Coconut oil	*P*-value	SEM
Heart	0.307	0.295	0.294	0.301	0.950	0.016
Liver	1.328^{B}	1.356^{B}	1.268^{B}	1.566^{A}	0.038	0.087
Spleen	0.129	0.125	0.132	0.138	0.744	0.007
Lung	0.523	0.475	0.490	0.559	0.805	0.057
Kidneys	0.233	0.245	0.253	0.277	0.594	0.024
Intestines	2.888	3.051	3.034	3.152	0.581	0.136
Stomach	0.434	0.427	0.434	0.427	0.977	0.022

SEM, standard error of the mean.

Table 5. Meat quality parameters of pigs supplemented with ractopamine or vegetable oils. (n=6/ treatment)

Parameter	Control	Ractopamine	Safflower oil	Coconut oil	*P*-value	SEM
Initial pH	6.802^{A}	6.463^{B}	6.828^{A}	6.753^{A}	0.010	0.002
Initial temp. (°C)	29.250^{AB}	28.431^{B}	29.907^{A}	29.483^{AB}	0.049	0.108
Final pH	5.520^{B}	5.630^{A}	5.503^{B}	5.477^{B}	0.037	0.001
Final temp. (°C)	9.183^{B}	9.813^{A}	9.250^{B}	9.200^{B}	0.043	0.003
Color	2.667	3.000	2.667	2.833	0.622	0.005
Marbling score	1.500	2.164	2.000	2.000	0.292	0.006

Means within rows followed by different letters are significantly different by Duncan's test ($p < 0.05$). SEM, standard error of the mean.

Table 6. Carcass parameters of pigs supplemented with ractopamine or vegetable oils. (n=6/ treatment)

Parameter	Control	Ractopamine	Safflower oil	Coconut oil	*P*-value	SEM
CW (kg)	96.217	89.388	97.350	95.087	0.157	4.049
CY (%)	79.904	79.372	79.182	79.320	0.591	0.009
MBT (mm)	35.37^{AB}	34.09^{B}	36.65^{A}	35.61^{AB}	0.023	0.003
HW (%)	15.398	15.262	15.883	15.601	0.244	0.215
LEA (cm^2)	47.590	44.222	48.678	45.610	0.183	0.863
LD (mm)	66.333	63.367	65.300	66.999	0.665	0.007
FA (cm^2)	27.401	26.378	24.371	24.093	0.321	0.513
MFR	1.737^{B}	1.676^{B}	1.997^{AB}	2.683^{A}	0.048	0.006
CCMY (%)	66.267^{AB}	66.134^{B}	66.267^{AB}	66.589^{A}	0.039	0.002
CMW (kg)	57.610^{AB}	52.569^{B}	58.489^{A}	56.844^{AB}	0.045	0.393

Means within rows followed by different letters are significantly different by Duncan's test ($p < 0.05$). CY, carcass yield; BT, backfat thickness (measured at three different points); MBT, mean backfat thickness; HW, ham weight; LEA, loin eye area; FA, fat area; MFR, meat/fat ratio; CCMY, cold carcass meat yield; CMW, carcass meat weight; LD, loin depth; SEM, standard error of the mean.

Table 7. Economic viability of supplementing late-finishing pigs with ractopamine or vegetable oils. (n=6/ treatment)

Parameter	Control	Ractopamine	Safflower oil	Coconut oil	*P*-value	SEM
FC (R$)	1.039^{D}	1.137^{C}	1.368^{A}	1.319^{B}	<0.001	0
FC/LW (R$/LW)	4.016^{B}	3.945^{B}	5.346^{A}	4.997^{A}	0.047	0.716
EEI	100.185^{A}	101.532^{A}	75.744^{B}	80.315^{B}	0.048	14.112
CI	101.801^{B}	100^{B}	135.519^{A}	126.67^{A}	0.047	18.164

Means within rows followed by different letters are significantly different by Duncan's test ($p < 0.05$). FC, feed cost; FC/LW, feed cost per kilogram of live weight gain; EEI, economic efficiency index; CI, cost index; SEM, standard error of the mean.

DISCUSSION

In this study, animal performance might have been affected by environmental conditions. During the experimental period, the relative humidity and minimum and maximum temperatures were 54%, 23 °C, and 37 °C, respectively. Nevertheless, weather effects were the same for all treatment groups, not influencing the objectives of the study.

Animal performance was not influenced by any treatment, in contrast to a previous study by Leal et al. (2015). The authors supplemented finishing pigs with different concentrations of ractopamine (0, 3, 6, 9, 12, and 15 ppm) for 28 days and found an increase in daily weight gain and a reduction in feed conversion with increasing supplementation level. Research has shown that the use of ractopamine reduces feed intake and enhances lean meat production in pigs (BRIDI et al., 2008, FERREIRA et al., 2011 and GARBOSSA et al., 2013).

Costa et al. (2020) investigated the effects of supplementation of finishing pigs with ractopamine and safflower and coconut oils on feed conversion and weight gain. Ractopamine-supplemented diets resulted in the best feed conversion ratio and highest weight gain, followed by safflower oil and coconut oil diets. However, in this work, when using heavier animals (100-120kg) it was observed that such effects did not occur, and may have occurred due to the age and stage of the animal that consumes and converts nutrients in different amounts.

Oils and ractopamine may not have had any influence on the performance of these animals, as according to Bertol et al. (2001), there is a decrease in the deposition of lean tissue, while there is an increase in the fat content due to the curve of deposition is more pronounced at this stage. Thus, these additives may not have acted efficiently.

Yang et al. (2018) fed 0–28-day-old piglets with coconut and palm oils (as capsules or as feed additives) and observed that addition of coconut oil to feed did not influence feed conversion, weight gain, or feed intake; however, when supplied as capsule, coconut oil increased weight gain and feed conversion compared with the control, although there were no differences between coconut oil added to feed and coconut oil capsule. It is important to point out that in the case of the author's work the animals were growing and that coconut oil is very palatable, so that its consumption resulted in increased feed intake and weight gain of piglets, however for heavy animals such as those used in this experiment it did not influence such parameters, because these animals do not have an adequate feed conversion rate due to fat deposition being greater than lean tissue. Although coconut oil is palatable, it did not influence the consumption of these animals, so its ingestion may have caused satiety effects on these animals, thus reducing their food intake.

Coconut oil in its concentration has more than 50% lauric acid, which, when in excess, activates pro-inflammatory functions of the TLR4 signal in immune cells, and also contributes to increased lipid deposition in the liver, increasing your weight.

Organ weights were not affected by ractopamine, in agreement with the findings of Sanches (2010). The authors observed no differences between ractopamine supplementation levels on heart, lung, spleen, and small intestine weights but found that liver weight decreased with increasing ractopamine concentration. It is important to evaluate the liver and kidneys of pigs, as these organs play an important role in protein and lipid metabolism under ractopamine supplementation. Moreover, their efficiency increases with the use of ractopamine in diets, as the kidneys and liver act more on the catabolism of amino acids to eliminate excess nitrogen, which leads to increased organ weights. However, no such effect was observed.

Several authors in the literature have used safflower oil in rat diets and reported that there were no changes in the weights of the organs (heart, spleen, liver, lung, kidneys, stomach, intestines) that were fed the rations with this oil (TSO et al., 2012; GUO et al., 2013; APPLETON et al., 2015).

In the current study, initial meat pH was influenced ($p < 0.05$) by ractopamine supplementation. However, all values were within the normal pH range of 6.3 to 7.0 for pork, as described by Pearce et al. (2011).

The meat of pigs supplemented with ractopamine showed the lowest initial temperatures as well as the highest final temperatures. These parameters are correlated with pH, in that higher pH values are associated with temperature stability (CARMO et al., 2014). As discussed by Silva et al. (2015), β-adrenergic agonists consume muscle glycogen, resulting in accumulation of lactic acid in carcasses, reducing pH. the presence of beta adrenergic agonists in the carcass of the animals speeds up the process of body glycogen consumption, resulting in an accumulation of lactic acid in the carcass of the animals, thus decreasing the pH.

Rincker et al. (2009) reported similar results to those found here. The authors supplemented finishing pigs with 5 ppm ractopamine for 28 days and observed that ractopamine significantly increased final meat pH but did not influence color or marbling score. In a previous study (COSTA et al., 2020), inclusion of coconut oil, safflower oil, or ractopamine in finishing pig diets did not influence meat color; all treatments resulted in meat with similar color properties, in agreement with our results.

Color is one of the most important attributes of foods. In the case of meat, color is determined by the amount of myoglobin in muscles (RESENDE et al., 2015), in addition, stress, gender, age, breed, management, time and form of cooling, pH drop and final pH of the meat can also affect the final color of the meat. Myoglobin concentrations also indicate the oxidation state of muscles. Muscle oxidation is promoted by the action of oxygen and free radicals, which are produced via lipid oxidation.

According to Ferreira (2011), pork marbling scores vary from 1% to 3%. Scores below 1% indicate lack of juiciness, whereas scores above 3% indicate excess marbling. Treatments did not influence marbling score.

Carcass meat weight was higher in pigs fed safflower oil than in animals fed ractopamine. Such a result can be explained by the vitamin E content of safflower oil, which confers antioxidant properties (SOUZA and SILVA, 2014). Thus, it is possible that carcasses suffered less from chilling temperature effects and consequently had lower losses, resulting in greater meat. The low fat content of pigs supplemented with ractopamine, resulting from lipolysis, might have contributed to cold shortening.

Chilling of carcasses after slaughter might lead to the shortening of sarcomeres, thereby increasing meat hardness (BRIDI and SILVA, 2015). Cold shortening can be minimized by subcutaneous fat deposition, given that fat acts as a thermal insulator. As discussed by Silva et al. (2015), cold shortening might also have been reduced by the antioxidant effect of vitamin E from safflower oil on free radicals, thereby mitigating oxidative damage to meat.

This effect can also be observed with MBT, so that the vitamin E present in its composition guaranteed the adipose tissue a better coating and protection against free radicals that could act on the meat by oxidizing it through the effects of temperature.

Meat/fat ratio and cold carcass meat yield were enhanced by supplementation with coconut oil. Such findings may be associated with the ease of absorption of coconut oil. Medium-chain fatty acids, the major type of fatty acids in coconut oil, are rapidly absorbed into the body because they are transported directly via the portal system, facilitating hepatic metabolism and mitochondrial oxidation and decreasing the amount of fat deposited in tissues (HANN et al., 2014).

The form of absorption of the short and medium chain fatty acids differs from the long chain ones, because the latter are absorbed by the chylomicrons and follow through the lymphatic ducts to the deposition in the tissues, while the short and medium chain fatty acids are more easily absorbed by the body due to their water solubility. In the process of metabolism they are transformed into free fatty acids and monoacylglycer. They do not pass through the re-terification process, so they are already absorbed by the portal way and sent to the liver by albumin (BACH & BABAYAN, 1982). When they arrive, they undergo oxidation for energy production and transforms into other fatty acids (JONES et al., 2006).

The control diet had the lowest feed cost, whereas safflower oil was the most expensive, with an increase of R$ 0.33/kg feed (31%). Coconut oil supplementation increased the cost of feed by R$ 0.28/kg feed (26%), whereas ractopamine increased the cost by only R$ 0.10/kg feed (9%) compared with the control.

The use of vegetable oils also increased the cost of diet per kilogram of weight gain compared with control and ractopamine diets: safflower oil increased feed costs by R$ 1.33 and coconut oil by R$ 0.98. Oil capsules were expensive, thereby increasing diet costs.

The price of oil capsules reflected on the cost index, which was higher for oil-supplemented diets, given that their economic effects were not as expressive as those of ractopamine and control diets. The economic efficiency index confirmed that oil diets were the least economically effective treatments. Diet ingredients and oils may suffer price variations; thus, their use may become more feasible at certain times of the year.

The use of coconut oil in the diet of heavy pigs showed a better MFR on ractopamine. This result is interesting from the perspective of a feed with low fat content compared to meat. It also guarantees a greater amount of CCMY, because this result allows to influence that after the process of cooling the carcasses in the cold room, coconut oil is able to guarantee in the end a carcass with a greater amount of meat. However, its excessive use, due to the lauric acid, can cause inflammatory problems and lead to cases of hepatic steatosis.

The safflower oil in the diet of pigs had the advantage of a higher meat production in the carcass, this result is very advantageous for producers and companies, because it has the chance to reward more for a product, despite having had a slight increase in average thickness of bacon of the animals, It was possible to observe that this fat may be directly related to the protection of meat, not to mention that there was an addition of vitamin E, which ensured a higher quality and protection of the carcass, resulting in a meat with a marbling plus antioxidants and may have delayed the shelf life of products.

CONCLUSION

Supplementation of heavy pigs with thermogenic oils is a viable alternative to stimulate lean meat production and decrease the amount of fat in the carcass, safely and from natural products.

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