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Enrichment diets of pigs with oil blends and its effects on performance, carcass characteristics and fatty acid profile

[*Dietas enriquecidas com* blends *de óleos para suínos em terminação e seus efeitos sobre o desempenho, as características de carcaça e o perfil de ácidos graxos*]

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ABSTRACT

The addition of different oil blends in the feed of finishing pigs was evaluated. Twenty-four castrated male finishing pigs were used in a randomized block design containing four treatments and six replicates. The treatments consisted of: Reference ration (RR) – 100% soybean oil feed; and the combination of the different oils: Blend1 – 50.0% soybean oil (SO), 25.0% flaxseed oil (FO), 12.5% olive oil (OO) and 12.5% canola oil (CO); Blend2 – 25.0% SO, 50.0% FO, 12.5% OO and 12.5% CO; and Blend3 – 25.0% SO, 12.5% FO, 12.5% OO and 50.0% CO. The performance, quantitative and qualitative carcass parameters, fatty acids profile and economic feasibility of the diets were evaluated. The use of blends in the diets did not influence the performance or carcass quality, but increased marbling and carcass yield. The fatty acid profile of the loin presented greater amounts of stearic acid in Blend3 and higher percentage of unsaturated fatty acids in animals fed with Blend1. The fatty tissue presented greater amounts of myristic acid in Blend1 and oleic acid in Blend3. The reference ration was the most economic. The Blends did not affect performance or carcass characteristics and improved the fatty acid profile.

Keywords: enriched foods, linoleic acid, meat quality, monounsaturated

RESUMO

Foi avaliada a utilização de diferentes blends *de óleo em dietas de suínos em terminação. Foram utilizados 24 suínos, machos, castrados, distribuídos em delineamento de blocos ao acaso, com quatro tratamentos e seis repetições. Os tratamentos consistiram de: ração referência (RR) – 100% de ração com utilização de óleo de soja; e a combinação de diferentes óleos: Blend1 – 50,0% de óleo de soja (OS), 25,0% de óleo de linhaça (OL), 12,5% de óleo de oliva (OO) e 12,5% de óleo de canola (OC); Blend2 – 25,0% OS; 50,0% OL; 12,5% OO e 12,5% OC; e Blend3 – 25,0% OS; 12,5% OL; 12,5% OO e 50,0% OC. Foram avaliados os parâmetros de desempenho, a qualidade de carcaça, o perfil de ácidos graxos e a viabilidade econômica. O uso de* blends *nas dietas não influenciou o desempenho ou a qualidade da carcaça, mas aumentou o marmoreio e o rendimento de carcaça. O perfil de ácidos graxos do lombo apresentou maiores quantidades de ácido esteárico com a utilização do Blend3 e maior porcentagem de ácidos graxos insaturados nos animais alimentados com o Blend1. O tecido adiposo apresentou maiores quantidades de ácido mirístico quando se forneceu o Blend1 e de ácido oleico com o Blend3. A ração testemunha foi a mais econômica. As misturas não afetaram o desempenho e as características de carcaça e melhoraram o perfil de ácidos graxos da carne.*

Palavras-chave: alimentos enriquecidos, ácido linoleico, qualidade da carne, monoinsaturados

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INTRODUCTION

Pig meat has desirable nutritional characteristics such as high protein content and low caloric value, with close to 7% of total fat (Bragagnolo e Rodriguez-Amaya, 2002). In this sense, there has been an increase of approximately 14% in the consumption of pig meat in the last decade, which stimulates researchers to invest in the nutritional enriching of this food (Relatório…, 2016).

One of the most used forms to promote change in the lipid profile of meat is the use of oils rich in poly-unsaturated fatty acids (Teye *et al*., 2006; Realini *et al*., 2010; Sobol *et al*., 2016). Palm, fish, sunflower, flaxseed and canola oils are examples tested in pig diets with effects over performance, carcass characteristics and fatty acid composition in the meat. However, they must be added in adequate dietetic proportions for added benefits to the final product.

Saturated fat (C12:0, C14:0 and C16:0) consumption is related to the increase in levels of blood cholesterol for reducing the activity of the LDL-cholesterol receptor thereby decreasing the levels of LDL in the bloodstream. Therefore, the substitution of saturated fatty acids in the diet for mono and polyunsaturated fatty acids by means of the inclusion of oils can be considered an indirect strategy for improving the control of cardiovascular diseases (Grundy and Denke, 1990).

In this context, the objective of this work was to evaluate the addition of different blends of vegetable oils in the feed of finishing pigs over the performance, quantitative and qualitative carcass parameters, fatty acid profile and economic feasibility.

MATERIALS AND METHODS

All experimental protocols and procedures were approved by the Ethics Committee in Animal Experimentation (Portuguese acronym: CEUA) (protocol number 019/2015-CEUA/UFRN). The animals were allocated into an experimental shed with concrete flooring, containing simple feeding troughs and pacifier type water fountains. Minimum and maximum thermometers were placed in the interior of the shed for daily registration of temperatures throughout the experimental period. The average minimum and maximum temperatures of the period were 22.3 and 32.4ºC, respectively, and the average relative humidity was of 87.8%.

Twenty-four castrated hybrid male pigs with initial weight of 72.00±3.4kg/LW were distributed in a randomized block design with four treatments and six replicates. The experimental diets were formulated based on corn, soybean bran, wheat bran and commercial core, supplied with different types of vegetable oils to meet the nutritional demands established by the Brazilian poultry and pork tables (Rostagno *et al*., 2011) (Table 1). The treatments were constituted by the supplementation of 2% of the total ingredients in diets and by different types of oils, with T1 – 100% of soybean oil; T2 – Blend 1: 50% of soybean oil, 25% flaxseed oil, 12.5% olive oil and 12.5% canola oil; T3 – Blend 2: 25% soybean oil, 50% flaxseed oil, 12.5% olive oil and 12.5% canola oil; T4 – Blend 3: 25% soybean oil, 12.5% flaxseed oil, 12.5% olive oil and 50% canola oil.

During the experimental period, animals received feed and water *ad libitum*, and the feeds were periodically weighed. The leftovers were weighed to determine the daily feed consumption. The animals were weighed at the beginning and end of the experiment to calculate weight gain and food conversion. When reaching the average weight of 100.00±6.28kg/LW, the animals were led to slaughter. The pigs remained in fasting of solid food for 12 hours and were slaughtered after electric stunning, posteriorly bled, scalded, depilated and eviscerated.

At the end of the slaughter line, the carcasses were identified and weighed for obtaining the warm carcass weight and calculating carcass yield. The initial pH of the *Longissimus dorsi* muscle was measured using a digital pachymeter with insertion electrode. The carcasses were separated in two by a longitudinal cut at the lumbar spine and placed in cold chamber at the temperature of 4ºC for 24 hours.

Table 1. Food and nutritional composition of the experimental feeds

Ingredients (%)	Treatments			
	Soybean oil	*Blend 1*	*Blend 2*	*Blend 3*
Corn	73.152	73.152	73.152	73.152
Soybean meal	15.130	15.130	15.130	15.130
Wheat bran	6.455	6.455	6.455	6.455
Commercial supplement (evimix)[1]	3.000	3.000	3.000	3.000
Soybean oil	2.000	1.000	0.500	0.500
Flaxseed oil	-	0.500	1.000	0.250
Olive oil	-	0.250	0.250	0.250
Canola oil	-	0.250	0.250	1.000
HCL-Lysine	0.219	0.219	0.219	0.219
L-Threonine	0.043	0.043	0.043	0.043
Total	100	100	100	100
Calculated composition				
Metabolizable energy (kcal kg^{-1})	3.241	3.241	3.241	3.241
Crude protein (%)	13.532	13.532	13.532	13.532
Available phosphorus (%)	0.106	0.106	0.106	0.106
Digestible methionine (%)	0.232	0.232	0.232	0.232
Digestible lysine (%)	0.718	0.718	0.718	0.718
Digestible threonine (%)	0.481	0.481	0.481	0.481
Sodium (%)	0.154	0.154	0.154	0.154
Chlorine (%)	0.042	0.042	0.042	0.042

[1]Guaranteed levels per kg of product: calcium (min) 235g/kg; calcium (max) 240g/kg; phosphorus (min) 34.67g/kg; sodium (min) 585g/kg; iron (min) 3.389mg/kg; copper (min) 4.000mg/kg; manganese (min) 1.333mg/kg; zinc (min) 3.333mg/kg; iodine (min) 33.33mg/kg; cobalt (min) 6.86mg/kg; selenium (min) 10mg/kg; vitamin A (min) 116.800ui/kg; vitamin D3 (min) 25.000ui/kg; vitamin E (min) 833.33ui/kg; vitamin K3 (min) 40mg/kg; vitamin B1 (min) 16.7mg/kg; vitamin B2 (min) 66.7mg/kg; niacin (min) 500mg/kg; pantothenic acid (min) 267mg/kg; vitamin B6 (min) 16.7mg/kg; folic acid (min) 5mg/kg; biotin (min) 3.33mg/kg; vitamin B12 (min) 333mcg/kg; phytase 16.66ftu/g; bht 133mg/kg; bacitracin (min) 1.883mg/kg; choline (min) 3.338mg/kg and fluor (max) 332mg/kg.

Subsequently, the carcasses were weighed for obtaining the cold carcass weight and determining the water loss during refrigeration, performing the reading of the final pH, and measuring the carcass length from the cranial edge of the pubic symphysis until the cranio-ventral edge of the atlas with a measuring tape, according to the Brazilian Carcass Classification Method (Bridi and Silva, 2009).

The remaining evaluations were conducted on the left half of the carcass, where a cut was made on point P2 (correspondent to the perpendicular projection of the last rib 4cm from the spine) to expose the *Longissimus dorsi* muscle and the fat layer in order to measure its thickness at this point (at 6.5cm from the dorsal line), the *Longissimus dorsi* muscle depth, using a pachymeter, and of the rib eye and fat area, designed in tracing paper by planimeter and expressed in millimeters. The meat:fat relation was calculated according to technique designed by Bridi and Silva (2009). The back thickness was measured in three points of the carcass: at the height of the first rib, at the last rib and between the last and the second-to-last lumbar by using a pachymeter.

With data of loin depth (LD), backfat thickness (P2), warm carcass weight (WCW), and cold carcass weight (CCW), it was possible to calculate the amount of cooled meat ([7.38-(0.48 x P2) + 0.059 x LW) + 0.525 x WCW)]), meat yield ([60-(P2 x 0.58) + (LW x 0.10)]), meat yield in cold carcass (65.92-{0.685 x P2) + (0.094 x LW) – (0.026 x CCW)]) and the amount of meat in the carcass (CCW x meat yield), according to methodology described by Bridi and Silva (2009). For qualitative parameter analyzes, in addition to pH parameters, the coloration and marbling of the muscle were evaluated, according to the Brazilian Method of Carcass Classification (Método…, 1973; Bridi and Silva, 2009).

The muscle pigmentation was determined using a panel of colors in a scale from one to six of the National Pork Producers Council (Pork…, 1998), where 1 represents meats with low pigmentation, and value 6 represents high pigmentation. Marbling was evaluated by using the marbling scale which ranges from 1 to 7. Meats with value 1 present only traces of marbling, while meat with value 7 presents excessive marbling (Meat…, 2001). Samples of loin and fat were collected, identified and forwarded to the Animal Nutrition Laboratory for evaluating the fatty acid profile of these samples.

The analysis of the fatty acid profile of the fat tissue and loin (*Longissimus dorsi*) was performed according to methodology proposed by Bligh and Dyer (1959). A mixture containing 5g of moist and shredded fat sample, 12.5mL of chloroform and 12.5mL of methanol was homogenized in a shaker table for 20 minutes and subsequently left to repose in freezer for 16 hours at -19ºC. Then, the mixture was filtered with filter paper and transferred to a separation funnel of 250mL, later were added 12.5mL of chloroform and 12.5mL of 2% sodium sulphate solution. The mixture was vigorously agitated and left in repose for two hours.

A biphasic system was formed and its inferior phase with purified lipids was diluted in chloroform and filtered with filter paper containing anhydrous sodium sulphate. Samples were stored in amber flask and frozen at -20ºC until the moment of esterification. After extraction, the material was saponified and underwent methylation according to the methodology proposed by Hartman and Lago (1973).

The obtained material underwent gas chromatography (Thermo Scientific – GC/FID-FOCUS) with a flame ionization detector (FID) and Supelco SPTM SP™-2560 capillary column (100m x 0.25mm x 0.2µm). The temperatures of the detector and injector were 270ºC and 230ºC, respectively. The programming of the column heating was initiated with 40ºC for three minutes, followed by 180ºC for five minutes at a rate of 10ºC/minute, 180ºC to 220ºC for three minutes at a rate of 10°C/minute, 220ºC to 240°C for 25 minutes at a rate of 20°C/minute. The injection volume was of 1µL with Split ratio of 1:10. Nitrogen was used as carrier gas. The identification and quantification of spikes was done by comparing the retention time and the area of spikes of samples with those of fatty acid metallic ester patterns (Supelco 37 components FAME Mix, ref. 47885-U).

The economic feasibility of the use of oil blends in the feed of finishing pigs was determined according to Bellaver *et al*. (1985), where:

$$\text{Feed Cost (kg)} = \frac{\text{Feed consumption x Price per Kg of feed}}{\text{Weight gain}}$$

The calculations of Economic Efficiency Index (EEI) and average cost index (CI) were performed according to Barbosa *et al*. (1992), using the following equations:

$$\text{EEI} = \frac{\text{MCe}}{\text{CTei}} \text{ x } 100 \qquad \text{CI} = \frac{\text{CTei}}{\text{MCe}} \text{ x100}$$

In which: MC*e* = lowest average cost in feed per kilogram of gained live weight observed between treatments; CT*ei* = average cost of treatment *i*. The prices of ingredients (expressed in R$/kilogram) used in the calculation of feed costs were collected in the region of Natal, Rio Grande do Norte, Brazil. A randomized block design was used to control initial differences in weight, which consisted of four treatments and six replications, constituting 24 plots.

The following model was used for this design: Yijk = µ+ Ti + Bj +eijk, where Yijk is an observation of the dependent variable ij; µ is the population mean for the variable; Ti is the treatment effect, as a fixed effect, Bj is a block effect with in situ animals, as a random effect, and eijk is the random error associated with the observation ij. Analysis of variance was performance using the GLM procedure of the SAS software (Statistical analysis system, version 9.0) by considering the 5% (F test) ($P<0.05$) as significant. Data considered as statistically significant were compared by the Duncan at 5% probability level.

RESULTS

The performance of pigs fed with the different blends of vegetable oils presented no effect ($P>0.05$) between treatments (Table 2).

Table 2. Daily feed consumption, daily weight gain and food conversion of pigs fed diets containing vegetable oil Blends

Variables	Treatments				CV (%)
	Soybean oil	*Blend 1*	*Blend 2*	*Blend 3*	
Initial weight (kg)	72.33	72.33	72.16	72.00	4.85
Final weight (kg)	109.16	105.16	105.00	106.00	5.29
Weight gain (kg dia^{-1})	0.94	0.84	0.84	0.87	12.77
Feed consumption (kg dia^{-1})	2.75	2.70	2.46	2.68	9.70
Food conversion (kg kg^{-1})	2.92	3.21	2.93	3.08	9.87

The parameters of meat quality, pH, muscle coloration, carcass yield, quantity of cold meat and quantity of meat on the carcass were not influenced (P>0.05) by the blends, as presented in Table 3, except for marbling, which was higher for animals receiving diets containing the blends. This fact suggests that the combinations of oils rich in polyunsaturated fatty acids influenced the deposition of intramuscular fat. The blend did not influence (P>0.05) carcass parameters such as cold and warm carcass weights, carcass length, backfat thickness, loin depth, shank weight, rib eye area, fat and meat:fat relation.

Table 3. Qualitative and quantitative parameters of pigs fed diets containing vegetable oil blends

Variables	Treatments				CV(%)
	Soybean oil	*Blend 1*	*Blend 2*	*Blend 3*	
Qualitative parameters					
pH_{45}	6.36	6.59	6.33	6.42	3.19
pH_{24}	5.41	5.45	5.45	5.43	0.88
Coloration	2.83	3.33	3.17	3.17	19.31
Marbling	1.00^{B}	2.00^{A}	2.00^{A}	1.83^{A}	35.85
Quantitative parameters					
Warm carcass weight (kg)	85.28	81.60	83.20	83.11	5.22
Cold carcass weight (kg)	84.31	80.90	81.51	82.28	5.54
Quantity of cold carcass (kg)	51.76	49.66	50.58	50.59	4.46
Shank weight (kg)	13.13	12.61	12.90	12.88	5.44
Carcass yield (%)	78.08^{AB}	77.56^{B}	79.25^{A}	78.38^{AB}	1.35
Meat yield (%)	60.57	60.49	60.52	60.54	0.11
Meat yield in the cold carcass (%)	66.37	66.15	66.24	66.32	0.51
Weight loss in cooling (%)	0.96	0.70	1.68	0.83	1.25
Carcass length (cm)	101.91	99.83	101.33	100.83	2.46
Backfat thickness (mm)	28.18	26.60	28.50	27.88	12.98
Backfat thickness P2 (mm)	16.30	19.00	17.72	16.87	28.62
Muscle depth (cm)	6.66	6.07	6.28	6.35	7.57
Rib eye area (cm^2)	47.92	42.31	42.89	45.13	10.71
Fat area (cm)	21.33	22.09	21.98	20.83	26.15
Carcass:fat relation (cm^2)	2.30	2.30	2.00	2.30	33.62

Means followed by different letters in the same line statistically differ by the Duncan test at the level of 5% of significance. CV = coefficient of variation.

A difference (P<0.05) was verified in carcass yield, for which the animals fed Blend 2, Blend 3 and the reference diet presented higher yield. The analysis of fatty acids of the loin (*Longissimus dorsi*) (Table 4) demonstrated that the combination of oil blends did not change the profiles of lauric, myristic, palmitic and palmitoleic acids, but was capable of changing (P<0.05) the profile of stearic acid, insofar as the contents of flaxseed and canola oil in the diet increased, and Blend 3 had the highest content in the meat.

The amount of unsaturated fatty acids was also different (P<0.05) between the studied treatments, with better results found for animals fed Blend 2, followed by those fed the reference diet, Blend 3 and Blend 1, respectively. Despite the profile of unsaturated fatty acids having been influenced by the diet, they were uncapable of changing (P<0.05) the SFA/UFA (saturated/unsaturated fatty acid) relation.

The use of the vegetable oil blends did not alter (P>0.05) the concentration of fatty acids in the fat, apart from myristic acid (C14:0) and oleic acid (C18:1 n9C), which demonstrated greater deposition in animals fed diets with Blend 1, Blend 3, Blend 2 and reference diet; and Blend 3, Blend 2, Blend 1 and reference diet, respectively. The analysis of the economic feasibility demonstrated difference (P<0.05) between all analyzed variables of the treatments (Table 5).

Table 4. Fatty acid profile (%) and saturated/unsaturated fatty acid relation in the loin (*Longissimus dorsi*) and fat tissue of pigs fed with vegetable oil blends

Variables	Treatments				CV (%)
	Soybean oil	*Blend* 1	*Blend* 2	*Blend* 3	
Loin					
C12:0 Lauric	0.102	0.107	0.098	0.092	24.71
C14:0 Myristic	0.690	0.773	0.797	0.665	32.32
C16:0 Palmitic	20.436	20.855	20.845	21.477	7.30
C16:1 Palmitoleic	1.515	1.391	1.426	1.372	26.30
C18:0 Stearic	10.547^{B}	10.815^{AB}	11.414^{AB}	11.757^{A}	8.17
C18:1 n9C Oleic	25.192	24.354	27.501	25.694	14.80
C18:1 n9T Elaidic	0.145	0.153	0.147	0.187	31.84
C18:2 n6C Linoleic	21.824	20.606	19.986	20.151	16.45
C18:2 n6T Linolelaidic	0.146	0.145	0.40	0.163	21.30
C18:3 n6 γ-Linolenic	0.557	0.572	0.664	0.702	28.06
SFA	30.983	32.103	32.482	33.235	6.68
UFA	48.532^{AB}	46.046^{A}	48.752^{B}	47.112^{AB}	4.28
SFA/UFA	1.553	1.445	1.500	1.413	7.49
Fatty tissue					
C12:0 Lauric	0.104	0.177	0.141	0.137	59.40
C14:0 Myristic	1.076^{A}	1.655^{B}	1.256^{A}	1.379^{AB}	19.49
C16:0 Palmitic	24.003	22.871	22.987	22.828	16.09
C16:1 Palmitoleic	1.245	1.813	1.445	1.447	30.51
C18:0 Stearic	16.016	16.181	15.853	14.867	14.40
C18:1 n9C Oleic	31.727^{B}	34.379^{AB}	35.925^{A}	38.003^{A}	9.24
C18:1 n9T Elaidic	0.194	0.162	0.147	0.143	40.73
C18:2 n6C Linoleic	17.109	17.150	15.269	14.596	18.28
C18:2 n6T Linolelaidic	0.261	0.284	0.234	0.240	21.77
C18:3 n6 γ-Linolenic	0.557	0.572	0.664	0.702	28.17
SFA	40.838	40.707	40.096	39.075	12.04
UFA	50.081	47.827	53.810	54.219	12.63
SFA/UFA	1.270	1.351	1.345	1.415	16.26

Means followed by different letters in the same line statistically differ by the Duncan test at the level of 5% of significance. CV = coefficient of variation.

Table 5. Economic evaluation of the pig feeds containing vegetable oils

Variables	Treatments				CV (%)
	Soybean oil	*Blend* 1	*Blend* 2	*Blend* 3	
Feed cost (R$/Kg)	1.83^{C}	2.86^{AB}	3.18^{A}	2.45^{B}	10.58
Cost index	100.00^{C}	156.02^{AB}	173.46^{A}	133.66^{B}	10.57
Economic efficiency index	101.57^{A}	65.68^{BC}	58.25^{C}	76.03^{B}	8.84

Means followed by different letters in the same line statistically differ by the Duncan test at the level of 5% of significance. CV = coefficient of variation.

DISCUSSION

In the performance evaluation, no significant differences were observed between the studied treatments. This may have been because the diets were isonutritive and met the animals' needs. As the feeds were supplemented with oil blends containing different fatty acid concentrations, effects were expected on animal metabolism. According to Campanella et. al 2014, the composition of safflower oil can affect the satiety center and reduce feed intake, but in the studied context, the oil blends did not have this characteristic.

The results obtained in this experiment are in line with studies by Bertol *et al*. (2013), in which was evaluated the feasibility of using flaxseed and canola oils for the enrichment of pig meat, but no significant differences for performance variables were found. Similarly, Sobol *et al*. (2016) evaluated diets enriched with a mixture of 2% flaxseed oil, 0.5% canola oil and 5% fish oil for finishing pigs and no significant differences were found either. Santos, *et al*., 2008 and Murakami, *et al*., 2014, studied the use of flaxseed oil in pigs feed and observed a reduction in feed intake that was attributed to the possibility of animals' refusal due to the odor and unpleasant taste of the mixture used, but this was not observed in the present study.

In the study of meat quality, an increase in the degree of marbling in the loin of the animals that consumed the oil blends was observed. This can be a result of the enrichment of diets with olive, canola and flaxseed oils, differing from studies developed by Bertol *et al*. (2013), who studied flaxseed and canola oils and Nuernberg *et al*. (2005), who evaluated the supplementation of olive oil and flaxseed oil for pigs and found no difference in marbling. The increase of intramuscular fat is extremely important as it improves the juiciness, tenderness and taste of meat (Bridi and Silva, 2009).

The use of oil blends in diets did not affect the carcass characteristics of pigs, as observed by several authors (Teye *et al*. 2006 and Realini, *et al*. 2010) who studied the effects of different types of oils on diets and did not observe effects either. Oils may enrich meat with beneficial fatty acids to human health, but may not interfere with animal growth, and this same effect is observed when using oil mixtures.

Regarding carcass yield, the best results were observed for Blends 2 and 3. Blend 1 had the worst results, because nutrient utilization was less efficient, since animals from this treatment presented lower carcass weight and higher thickness of backfat P2 and fat area than animals of different treatments. This showed the oil mixture used for the composition of Blend 1 provided higher fat deposition in the carcass and probably higher organ weight, resulting in lower carcass yield.

Regarding the results obtained in the evaluation of fatty acids, among the saturated, the manipulation of the ratio of oils used promotes the increase of the stearic fatty acid deposition in the loin of pigs fed with the blends. This is a favorable result, since this fatty acid, although saturated, has a neutral action on the animal organism, and is converted to oleic acid by their metabolism. Although stearic acid has a saturated chain, it does not elevate serum cholesterol levels, because dehydrogenation of this fatty acid is faster than chain elongation, thereby making it more rapidly converted to oleic acid in the liver through the enzyme Δ^9 desaturase (Martin *et al*., 2006; Lottenberg, 2009).

Another benefit associated with eating C18:0-rich foods is related to decreased cholesterol absorption. Unlike hypercholesterolemic saturated fatty acids (lauric, myristic and palmitic), C18:0 does not suppress LDL receptors and therefore, does not contribute to the increase in circulating cholesterol content (Schneider, *et al*., 2000). Jang *et al*. (2017) evaluated the fat content and fatty acid composition in different cuts of pork and observed a higher concentration of palmitic fatty acids (C16:0), stearic acid (C18:0) and oleic acid (C18:1, n -9) in the loin of evaluated pigs.

Regarding adipose tissue, an increase in oleic fatty acid deposition with the use of blends was observed, proving the best ratio of unsaturated fatty acids in these treatments. The increase in the percentage of oleic acid is related to the higher inclusion of canola oil in Blend 3 (50%), a product rich in polyunsaturated fatty acids with about 61% of oleic acid in its composition (Johnson, *et al*.,2007). The incorporation of oleic acid in tissues by feed manipulation was also observed by Teye *et al*. (2006) and Mitchaothai *et al*. (2007), which corroborates the results of the present study. The authors also reported that dietary manipulation should be encouraged in order to establish the limits of oil inclusion, thereby producing healthier meat. Mas *et al*. (2011) reported that diets with higher levels of oleic acid present higher proportions of all monounsaturated fatty acids and C18:1 in intramuscular fat compared with basal diets.

As described by Morel *et al*. (2008), diet composition affects pig meat composition in terms of polyunsaturated fatty acids. Different sources of dietary fat will result in a different fat composition than pork cuts. Continuing the fatty acid profile study, Morel *et al*. (2013), found that the fatty acid profiles of the loin and backfat were similar to the fatty acid profiles of the diets (tallow and soybean oil + flaxseed oil). The authors reported the direct influence of high fatty acid diets on increasing levels of these fatty acids in pig meat.

In a review of the benefits of canola oil-rich nutrition, Lin *et al*. (2013), reported that the use of this oil in the feeding of monogastric animals provides significant decrease in total cholesterol and LDL levels and positive actions to increase tocopherol levels, and improve insulin sensitivity. Regarding the economic viability of the feeds used in this experiment, the average cost was higher when offering feeds containing the blends. Blend 1, Blend 2 and Blend 3 increased food costs by 55%, 73% and 33%, respectively, when compared to the reference diet. Blend 2 presented the highest cost, explained by the higher concentration of flaxseed oil in the diet (50%), since this is the highest value oil.

The best economic results, measured by economic efficiency and cost indices, were obtained with the reference diet, followed by diets containing Blend 3, Blend 1 and Blend 2. The average cost of flaxseed oil feed negatively impacted the economic efficiency index, and the index improved when its inclusion in the blends decreased. However, the feed costs vary according to the prices of ingredients, which fluctuate throughout the year and may become more affordable at certain times.

CONCLUSION

The use of blends is recommended because it promotes greater meat marbling, higher carcass yield and loin and backfat enrichment with stearic acid and omega-9, respectively, even though its use has increased the feed costs.

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