Effects of partial replacement of corn and soybean meal with sunflower cake in pig diets on ham fatty acid composition

Efeitos da substituição parcial de milho e farelo de soja por torta de girassol na dieta de suínos sobre a composição em ácidos graxos do pernil

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Abstract

Forty-eight pigs (24 barrows and 24 gilts), Landrace X Large White with initial liveweight of 22.69 kg were subjected to four treatments: diets with 0, 5, 10, and 15% of sunflower cake (SFC). No significant (P>0.05) effect of dietary treatment was observed on crude protein (19.6%), total fat (15.3%), ash (0.89%), and moisture (63.9%) contents of ham. Fatty acids in all ham (*Biceps femoris*, *Semimembranosus and Semitendinosus*) were significantly influenced by diets. Palmitic, oleic, and linoleic acids were the most abundant fatty acids in both diets and pork meat. Linoleic acid (18:2n-6) was the most abundant fatty acid under SFC-based diets. Its levels were also higher in ham of pigs fed SFC diets (T2, T3, and T4 with 15.79, 18.66, and 22.85%, respectively) than in that of pig fed the control diet (13.73%). Incorporation of 5, 10, and 15% SFC in pig diet markedly decreased the proportion of monounsaturated and saturated fatty acids and increased polyunsaturated fatty acids in ham (P<0.05).
Key words: Pork ham, legs, meat composition, polyunsaturated fatty acids

Resumo

Quarenta e oito suínos (24 fêmeas e 24 machos), Landrace x Large White com peso vivo inicial de 22.69 kg foram submetidos a quatro tratamentos: dietas com 0 , 5, 10 e 15% de torta de girassol (SFC). Não foram observados efeitos significativos (P>0.05) nas dietas para os teores de proteína total (19,6%), gordura total (15,3%), cinzas (0,89%) e umidade (63,9%) nos pernis. Os ácidos graxos foram significativamente influenciados pelas dietas. Os ácidos palmítico, oléico e linoléico foram os ácidos graxos mais abundantes tanto nas dietas como no pernil como um todo (*Biceps femoris*, *Semimembranosus and Semitendinosus*). Ácido linoléico (18:2n-6) foi o ácido graxo mais abundante nas dietas SFC. Seus níveis também foram maiores em pernis de suínos alimentados com dietas com SFC (T2, T3 e T4 com 15,8, 18,7 e 22,9%, respectivamente) em relação aos suínos que se alimentaram com a dieta controle (13,7%). Incorporação de 5, 10, 15% de SFC em dietas de suínos, diminuem a proporção de ácidos graxos saturados e monoinsaturados e aumentam a de poliinsaturados na carne de pernil (P<0,05)
Palavras-chave: Pernil suíno, composição da carne, ácidos graxos polinsaturados

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Recebido para publicação 28/09/06 Aprovado em 20/06/07

Introduction

There has been an increased interest in recent years in ways to manipulate meat fatty acid composition. Meat is seen as a major source of dietary fat, especially saturated fatty acids implicated in diseases associated with modern life (WOOD et al., 2003). Many studies have shown that fat composition in human diet has an important effect on health. Saturated fatty acids are the main cause of elevated plasma level of LDL-cholesterol in humans, which correlates with increased risk of coronary heart disease (CHD) (KRIS-ETHERTON; YU, 1997). The increase in polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA) decreases plasma LDL-cholesterol, and it has been shown to have an inverse relationship with CHD (CAGGIULA; MUSTAD, 1997).

Pork fat and meat are thought to possess relatively high-saturated fatty acid (SFA) content and are therefore considered rather unhealthy. In pigs, dietary fatty acids are absorbed unchanged by the intestine and incorporated into tissue lipids. Linoleic and á-linolenic polyunsaturated fatty acids cannot be synthesized *in situ*, thus tissue fatty acids concentrations respond rapidly to dietary changes (ROSENVOLD; ANDERSEN, 2003). In contrast, SFA and MUFA are synthesized; hence, their concentrations are less readily influenced by diet (WOOD, 1984). The PUFA fraction of pork fat can be easily influenced by dietary PUFA (KOCH et al., 1968). However, few results have been reported concerning the incorporation of PUFA into intramuscular fat, especially into its lipid subfraction (WARNANTS; VAN OECKEL; BOUCQUÉ, 1996). There is a great interest in modifying animal fat SFA, MUFA, and PUFA composition through feeding for it to meet dietary recommendations for humans, i.e. optimal fatty acid ratio over a long period, (JAKOBSEN, 1999).

The purpose of this study was to test if the inclusion of different percentages of SFC in pig diet can increase PUFA/SFA ratio in ham.

Materials and Methods

Animals

The experiment was carried out in the swine farming sector of the Farm School of Universidade Estadual de Londrina. It was studied 48 mixed-breed animals (Landrace X Large White), being 24 barrows and 24 gilts with average initial liveweight of 22.69 ± 2.11 kg and average age of 73 days. Every two same sex animals were placed in 3 square meter masonry pigsties with compacted floor. The animals received water and food *ad libitum* during all the experiment and were assigned to four treatment groups, T1 (control diet with 0% SFC), T2 (diet with 5% SFC), T3 (diet with 10% SFC), and T4 (diet with 15% SFC) with 12 repetitions (6 barrows and 6 gilts). Diets were formulated according to National Research Council (1998) requirements by dividing nutritional needs in three phases: growing phase I (between 20 and 50 kg liveweight), growing phase II (between 50 and 80 kg liveweight) and finishing (between 80 and 100 kg liveweight). The SFC supplied by EMBRAPA (Centro Nacional de Pesquisa de Soja), Londrina, Pr was obtained by mechanical pressing at 200 kg/cm^2 at an average temperature of 60 °C. Experimental diets were isoenergetic, isoproteic, isolisinic, and had similar calcium and iron levels. Lysine and methionine levels in SFC were estimated from values present in sunflower cake (NATIONAL RESEARCH COUNCIL, 1998) and corrected at oil extraction. Dry matter values were 0.63 and 0.51%, respectively. Table 1 gives the chemical and energetic compositions of the experimental diets. At the end of the experiment, animals were slaughtered in an abattoir (Frigorífico Frimesa, Medianeira/PR) with average finishing weight of 80 to 100 kg liveweight.

Table 1. Chemical and energy composition (%) of the experimental diets[1]

Ingredient	Treatments[1]											
	Growing phase I				Growing phase II				Finishing phase			
	Control	SFC5	SFC10	SFC15	Control	SFC5	SFC10	SFC15	Control	SFC5	SFC10	SFC15
Corn	69.56	66.56	63.56	60.54	76.61	73.75	70.89	67.93	83.17	80.19	77.22	74.24
Soybean meal	26.35	24.44	22.54	20.63	19.46	17.39	15.31	13.26	13.29	11.24	9.19	7.13
Sunflower cake	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00	0.00	5.00	10.00	15.00
Dicalcium phosphate	1.02	0.92	0.83	0.74	0.86	0.77	0.68	0.59	0.69	0.60	0.51	0.42
Limestone	0.60	0.64	0.67	0.71	0.50	0.54	0.57	0.61	0.54	0.57	0.61	0.64
L-Lysine-HCl	0.03	0.04	0.06	0.07	0.06	0.15	0.23	0.32	0.01	0.10	0.18	0.27
DL-Methionine	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
soybean oil	1.64	1.59	1.53	1.50	1.70	1.61	1.51	1.50	1.50	1.50	1.50	1.50
Vitamin supplement[2,3]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mineral supplement[4]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated values[5]												
Crude protein (%)	18.00	18.00	18.00	18.00	15.50	15.50	15.50	15.50	13.20	13.20	13.20	13.20
Metabolizable energy (kcal/kg)	3265	3265	3265	3265	3265	3265	3265	3265	3310	3310	3310	3310
Dry matter	87.96	88.19	88.41	88.64	87.84	88.07	88.29	88.53	87.70	87.94	88.18	88.42
Crude fiber (%)	3.07	4.05	5.03	6.01	2.76	3.73	4.71	5.68	2.49	3.46	4.43	5.40
Methionine (%)	0.29	0.27	0.25	0.25	0.26	0.24	0.22	0.20	0.40	0.21	0.19	0.17
Lysine (%)	0.95	0.95	0.95	0.95	0.80	0.80	0.80	0.80	0.60	0.60	0.60	0.60
Calcium (%)	0.60	0.60	0.60	0.60	0.50	0.50	0.50	0.50	0.45	0.45	0.45	0.45
Total phosphorus (%)	0.50	0.50	0.50	0.50	0.45	0.45	0.45	0.45	0.40	0.40	0.40	0.40

[1]Growing phase I (nutritional requirements between 20 and 50 kg liveweight), Growing phase II (nutritional requirements between 50 and 80 kg liveweight) and Finishing phase (nutritional requirements between 80 and 100 kg liveweight), been Control: diet with 0% SFC; SFC5: diet with 5% of SFC; SFC10: diet with 10% SFD; SFC15: diet with 15% SFC;.[2]Composition of vitamin supplement (growth per product kg)*:* vit. A: 1,000,000 UI; vit. D3: 250,000 UI; vit. E: 2,750 UI; vit. K3: 625 mg; vit. B1: 300 mg; vit. B: 1,050 mg; vit. B6: 275 mg; vit. B12: 3,750 mcg; folic acid: 150 mg; pantothenic acid: 3,500 mg; niacin: 5,750 mg; coline: 25,000 mg; Se: 75 mg; growth promoter: 7.5 g; antioxidant: 2.5 g. [3]Vitamin supplement (finish per product)*:* vit. A: 550,000 UI; vit. D3: 150,000 UI; vit. E: 2,500 UI; vit. K3: 550 mg; vit. B1: 175 mg; vit. B2: 900 mg; vit. B12: 3,000 mcg; folic acid*:* 150 mg; pantothenic acid: 3,000 mg; niacin: 4,750 mg; Se: 75 mg; growth promoter: 6.25 g; antioxidant: 2.5 g. [4] Mineral supplement (per product kg): Fe: 90,000 mg; Cu: 16,000 mg; Mg: 30,000 mg; Zn: 140,000 mg; Co: 200 mg; I: 850 mg; Se: 120 mg. [4]Values calculated according to Empresa Brasileira de Pesquisa Agropecuária (1991) table.

Sampling

Samples of the ham portion including *Biceps femoris, Semimembranosus and Semitendinosus* muscles were stored in a freezer at -18 ºC in polyethylene bags for later analysis.

Proximate chemical composition

Moisture and ash contents were determined according to AOAC (CUNNIF, 1998). Crude protein content was obtained through Kjeldahl method (CUNNIF, 1998). Total lipids of forage and beef were extracted by the Bligh e Dyer (1959) with a chloroform/methanol mixture.

Fatty acid profile

Fatty acid methyl esters (FAME) were prepared by methylation of triacylglycerols according to International Organization for Standardization (1978). Aliquots of lipid extracts were transferred to screw-cap tubes and added with n-heptane and KOH in methanol (2 mol/L). After layer separation, the top layer (containing FAME) was transferred to 5-mL flasks. FAMEs were analyzed in a Shimadzu 14A (Japan) gas chromatograph equipped with flame ionization detector (FID) and fused silica capillary column (50 m, 0.25 mm ID and 0.20 ìm) from Carbowax 20M (Quadrex, USA). Column temperature was programmed at 2 ºC /min from 150 to 240 ºC. The injection port and detector were maintained at 220 and 245 ºC, respectively. The carrier gas was hydrogen (1.2 mL/min) and the make–up gas was nitrogen (30 mL/min). Sample injection split mode 1/100 was used. Identification of fatty acids was made by comparing the relative retention times of FAME peaks of samples with standards from Sigma (USA). The areas of the peaks were determined by CG-300 computing integrator (CG Instruments, Brazil). Total fatty acid data were calculated as normalized area percentages.

Statistical analysis

The results are expressed as mean values standard deviation (SD) of six repetitions in triplicate. The results were compared using variance analysis (ANOVA) at 5% significance level with Statistica 5.0 software (STATSOFT, 1996). Mean values were compared by Tukey's test.

Results and Discussion

No significant effect of dietary treatment on crude protein (19.0% ± 0.07), total fat (24.5% ± 0.05), ash (0.85% ± 0.01), and moisture (55.6% ± 0.47) contents was observed for any ham or in muscle composition and fatty acid profile of either barrows or females.

The percentages of fatty acids in the diets are presented in Table 2. The control diet had a higher level of palmitic acid (16:0) when compared to other diets. The fatty acid composition of diets based on the replacement of corn and soybean with sunflower cake (SFC) reflected the high fatty acid composition of sunflower oil, while the fatty acid composition of high SFC diets has high levels of oleic (18:1n-9) and linoleic (18:2n-6) acids.

Several researchers have noted that the level of saturated fat in pork could be altered by inclusion of unsaturated fat in pig diet (MORAN JÚNIOR., 1996; WARNANTS; VAN OECKEL; BOUCQUÉ, 1996). The effect of experimental diets on ham fatty acid composition is shown in Table 3. Fatty acids are ordered according to chromatographic retention times. The values are given as weight percentages of the total acid methyl esters. The main fatty acids found in ham of control fed pigs were saturated C16:0 (23.8%) and C18:0 (15.0%); monounsaturated C18:1n-9 (39.5%) and polyunsaturated C18:2n-6 (13.7%). These values are close to those found by Zara et al. (2005).

The percentage of total saturated fatty acids (C14:0, C16:0, C17:0, C18:0, and C22:0) in ham fat of pigs fed diets SFC5, SFC10, and SFC15 were 4.1, 6.5, and 12.8% lower than that of ham of control diet-fed animals, respectively. Fat from groups fed SFC5, SFC10, and SFC15 had 1.3, 5.8, and 9.7% less total percent monounsaturated fatty acids (C16:1n-9, C16:1n-7, C17:1n-9 and C18:1n-9), respectively, when compared to the control group. Consequently, the ratio of monounsaturated fatty acids to saturated fatty acids (MUFA/SFA) increased from 1.11 in the control group to 1.15 in SFC15 group (3.6% increase). The percentage of total polyunsaturated fatty acids (C18:2n-6, C18:3n-6, C18;3n-3, C20:2n-6, C20:4n-6, and C22:4n-6) were 14.4, 33.5, and 61.3% higher when compared to results of animals fed control and SFC5, SFC10, and SFC15 diets, respectively. Consequently, the ratio of polyunsaturated fatty acids to saturated fatty acids (PUFA/SFA) increased from 0.39 in the control group

to 0.73 in the SFC15 group (87% increase). In terms of percentage of fatty acids which potentially affect blood cholesterol levels (fatty acids other than stearic, monounsaturated, and polyunsaturated fatty acids), 25.0% of fatty acids in ham from the control diet were cholesterol-raising fatty acids, while the corresponding values of SFC5, SFC10, and SFC15 groups were 23.8, 22.9, and 21.1%, a reduction of 4.8, 8.4, and 15.6%, respectively. The reduction in saturated fatty acid content in animal products is considered most advantageous. Dietary PUFA are known to act as a substitute of de novo synthesized saturated and monounsaturated long-chain fatty acids. The gastrointestinal system transfers fat from diet to the animal body and its potential products (MORAN JÚNIOR, 1996).

In conclusion, incorporation of 5, 10, and 15% SFC to swine diet markedly decreased the proportion of monounsaturated and saturated fatty acids and increased polyunsaturated fatty acids in ham ($P<0.05$). Whether the softer fat and oilier carcass produced by the use of 5 (SFC5), 10 (SFC10), and 15% (SFC15) SFC dietary treatments affect the acceptability of cooked ham and processed ham products needs further investigation.

Table 2. Fatty acid (FA) composition in experimental diets[1].

	Treatments[2]			
FA (%)	Control	SFC5	SFC10	SFC15
C16:0	12.85 ± 0.05 [a]	11.61 ± 0.34 [b]	10.78 ± 0.11 [c]	9.92 ± 0.05 [d]
C18:0	2.97± 0.03 [a]	3.00 ± 0.18 [a]	2.75 ± 0.01 [a]	2.82 ± 0.10 [a]
C18:1 n-9	32.68 ± 0.25 [a]	34.10 ± 0.12 [b]	33.52 ± 0.18 [b]	34.13 ± 0.09 [b]
C18:1 n-7	1.51 ± 0.44 [a]	1.05 ± 0.01 [a]	1.02 ± 0.02 [a]	1.06 ± 0.00 [a]
C18:2 n-6	47.94 ± 0.36 [a]	47.99 ± 0.24 [a]	49.71 ± 0.06 [b]	50.18 ± 0.21 [b]
C18:3 n-6	-	0.40 ± 0.00 [a]	0.31 ± 0.01 [b]	0.34 ± 0.02 [c]
C18:3 n-3	2.05 ± 0.10 [a]	1.84 ± 0.02 [a.b]	1.90 ± 0.05 [b]	1.55 ± 0.04 [c]
PUFA	49.99 ± 0.96 [a]	50.23 ± 0.81 [a]	51.92 ± 0.91 [b]	52.07 ± 0.98 [b]
MUFA	34.19 ± 1.08 [a]	35.15 ± 0.72 [b.c]	34.54 ± 0.80 [a.b]	35.19 ± 0.63 [c]
SFA	15.82 ± 0.62 [a]	14.61 ± 1.00 [b]	13.53 ± 0.75 [c]	12.74 ± 0.83 [d]
n-6	47.94 ± 0.36 [a]	48.39 ± 0.72 [a]	50.02 ± 0.69 [b]	50.52 ± 0.82 [b]
n-3	2.05 ± 0.10 [a]	1.84 ± 0.02 [a]	1.90 ± 0.58 [a]	1.55 ± 0.55 [b]
PUFA/SFA	3.16 ± 0.14 [a]	3.44 ± 0.23 [b]	3.84 ± 0.21 [c]	4.09 ± 0.26 [d]
n-6/n-3	23.44 ± 1.16 [a]	26.30 ± 0.48 [a]	26.32 ± 7.98 [a]	32.59 ± 11.57 [b]

[1]Results expressed as percent fatty acid methyl esters. Values are mean ± standard deviation in triplicate; sunflower cake (SFC). [2] Control: diet with 0% SFC; SFC5: diet with 5% of SFC; SFC10: diet with 10% SFD; SFC15: diet with 15% SFC; PUFA = polyunsaturated fatty acids; MUFA = monounsaturated fatty acids; SFA = saturated fatty acids; n6 = total n6 fatty acid; n3 = total n3 fatty acid. Different letters in the row indicate differences ($P<0.05$) by Tukey's test.

Table 3. Fatty acid (FA) profile in ham of pigs fed diets with different amounts of SFC[1].

	Treatments[2]			
FA (%)	Control	SFC5	SFC10	SFC15
C14:0	0.86 ± 0.05[a.b]	0.94 ± 0.08[a]	0.86 ± 0.10[a.b]	0.72 ± 0.04[b]
C16:0	23.78 ± 0.50[a]	22.57 ± 0.39[a.b]	21.72 ± 0.62[b]	20.15 ± 0.26[c]
C16:1n-9	0.16 ± 0.01[a]	0.21 ± 0.02[a]	0.15 ± 0.01[a]	0.17 ± 0.01[a]
C16:1n-7	1.19 ± 0.03[a]	1.10 ± 0.16[a]	0.90 ± 0.05[b]	0.73 ± 0.03[b]
C17:0	0.39 ± 0.01[a]	0.32 ± 0.01[a.b]	0.27 ± 0.01[b]	0.27 ± 0.01[b]
C17:1n-9	0.27 ± 0.02[a]	0.23 ± 0.02[a.b]	0.18 ± 0.00[b]	0.16 ± 0.01[b]
C18:0	15.00 ± 0.33[a]	14.52 ± 0.11[a]	14.55 ± 0.50[a]	13.71 ± 0.36[a]
C18:1n-9	39.51 ± 0.51[a]	38.97 ± 0.39[a]	37.56 ± 0.37[b]	36.41 ± 0.29[b]
C18:1n-7	2.62 ± 0.22[a]	2.67 ± 0.11[a]	2.40 ± 0.20[a]	2.05 ± 0.09[b]
C18:2n-6	13.73 ± 0.19[a]	15.79 ± 0.19[a]	18.66 ± 0.46[b]	22.85 ± 0.35[c]
C18:3n-6	0.28 ± 0.06[a]	0.29 ± 0.02[a]	0.29 ± 0.02[a]	0.28 ± 0.02[a]
C18:3n-3	0.51 ± 0.01[a]	0.48 ± 0.01[a]	0.44 ± 0.02[a]	0.47 ± 0.01[a]
C20:1n-9	0.69 ± 0.04[a]	0.68 ± 0.03[a]	0.67 ± 0.15[a]	0.59 ± 0.02[b]
C20:2n-6	0.56 ± 0.02[a]	0.63 ± 0.03[a]	0.79 ± 0.03[b]	0.85 ± 0.03[b]
C22:0	0.10 ± 0.00[a]	0.11 ± 0.01[a.b]	0.13 ± 0.03[b]	0.13 ± 0.01[a.b]
C20:4n-6	0.25 ± 0.04[a]	0.34 ± 0.02[b]	0.30 ± 0.01[a.b]	0.32 ± 0.01[a.b]
C22:4n-6	0.11 ± 0.01[a]	0.13 ± 0.01[a]	0.12 ± 0.02[a]	0.13 ± 0.01[a]
PUFA	15.44 ± 0.19[a]	17.66 ± 0.18[b]	20.62 ± 0.17[c]	24.90 ± 0.18[d]
MUFA	44.44 ± 0.28[a]	43.87 ± 0.19[a]	41.85 ± 0.21[b]	40.12 ± 0.12[c]
SFA	40.12 ± 0.24[a]	38.47 ± 0.12[a.b]	37.53 ± 0.27[b]	34.98 ± 0.25[c]
n-6	14.93 ± 0.19[a]	17.18 ± 0.18[b]	20.17 ± 0.16[c]	24.44 ± 0.18[d]
n-3	0.51 ± 0.01[a]	0.48 ± 0.01[a]	0.44 ± 0.02[a]	0.47 ± 0.01[a]
PUFA/SFA	0.39 ± 0.01[a]	0.46 ± 0.01[a]	0.56 ± 0.01[b]	0.73 ± 0.01[c]
n-6/n-3	29.48 ± 0.56[a]	36.25 ± 0.61[b]	46.22 ± 1.38[c]	54.06 ± 1.88[d]

[1]Results expressed as percent fatty acid methyl esters. Values are mean ± standard deviation of six repetitions in triplicate; sunflower cake (SFC).). [2] Control: diet with 0% SFC; SFC5: diet with 5% of SFC; SFC10: diet with 10% SFD; SFC15: diet with 15% SFC; PUFA = polyunsaturated fatty acids; MUFA = monounsaturated fatty acids; SFA = saturated fatty acids; n6 = total n6 fatty acid; n3 = total n3 fatty acid. Different letters in the row indicate differences (P<0.05) by Tukey's test.

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