Possibilities to improve the lipid structure of the pig meat during the finishing period

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Abstract

The purpose of the experiment was to improve pig meat quality by increasing its content of polyunsaturated fatty acids, mostly omega-3. The experiment carry on 30 finishing Large White pigs (30 days) assigned to 3 groups (C, E_1 and E_2). The group C (n=10) received conventional feedstuffs, E_1 (n=10) received ecological feedstuffs and 3% *camelina* oil (12.84% acid α-linolenic) as energy source; group E_2 (n=10) received the same diet as group E_1, supplemented with an antioxidant produced from plants. The *camelina* oil diet increased significantly (P=0.0045) the fatty acids C18:3n-3 in *longissimus dorsi (LD)* in groups E_1 (2.40 times) and E_2 (2.90 times), compared to group C. The content of α-linolenic acid increased highly significantly (P<0.0001) in the *semitendinosus (ST)* muscle both in group E_1 (3.83 times) and in group E_2 (3.90 times), compared to group C. The content of α-linolenic acid of the subcutaneous fat increased distinctly (P<0.0001) in both experimental groups (3.22 and 3.76 times, respectively) compared to group C. The n-6/n-3 ratio in *LD* muscle decreased significantly (P=0.0002) in groups E_1 (2.29 times) and E_2 (3.04 times), compared to group C. The n-6/n-3 ratio in *LD* muscle decreased highly significantly (P<0.0001) in both experimental groups (2.97 and 3.68 times, respectively) compared to group C. The n-6/n-3 ratio in the subcutaneous fat decreased significantly in both experimental groups (3.41 and 4.21 times, respectively) compared to group C. These results suggest that the administration of 3% camelina oil in the diets for finishing pigs changed significantly the omega-3 fatty acids (FA) content, as well as the n-6/n-3 ratio.

Keywords: ecologic ingredients, omega-3, camelina oil, finishing pigs.

INTRODUCTION

The food which can influence favourable human health are demanded more and more within the context in which the modern technologies for animal and crops production are constantly distancing from the natural conditions. Meat production under organic conditions is superior to the conventional meat production in terms of quality, safety and production methods. The availability and price of the organic meat were the key elements for the reluctance of the consumers to buy it. The recent scientific research is trying to find essential arguments for the development of this sector (Hebean et al., 2008; Hăbeanu et al., 2010). Of the meat nutrients, lipids are important for the nutritional and organoleptic quality of the meat.

Generally, the feed ingredients for pig diets (cereals, protein feeds) have high levels of linoleic fatty acid (18:2n-6) whose integration in the adipose or muscle tissue is much higher than that of the linolenic fatty acid (18:3n-3) (Wood et. al., 2007). By supplementing the diet with sources rich in n-3 fatty acids, one may alter the n-6 to n-3 ratio in the pig meat, with beneficial effects on the human consumer (Reddy and Katan 2003; Stoll., 2005; Roos de Baucjesi et., 2009).

The purpose of the study was to reveal the beneficial effect of the camelina oil obtained by ecological technologies (cold pressing) on the lipid structure of the pig meat.

2. MATERIAL AND METHOD

2.1 Animals and diets

The experiment took 30 days and used 30 finishing Large White pigs with an average initial body weight of 67 kg. The animals were assigned to three groups (10 pigs per group):

- the control group (C), fed on a compound feed made of conventional ingredients (barley, wheat, soybean meal, sunflower meal), with sunflower oil (63.97% linolenic fatty acid) as fat source;

- the experimental group E_1, fed on a compound feed made of certified ecological ingredients (barley, wheat, peas, full-fat soybean, sunflower meal), with 3% camelina oil (12.84% alpha-linolenic fatty acid) as energy source (produced by cold pressing);

- the experimental group E_2, fed on a compound feed similar to that of group E_1, supplemented, however, with a vegetal antioxidant rich in polyphenols.

The three types of compound feeds had similar levels of energy and protein and they met the feeding requirements for the category of pigs used in the experiment (NRC, 1998). The animals had free access to the feed and water.

2.2. Chemical analyses

The detailed fatty acids analysis of the dietary ingredients, of the compound feeds and of the muscle and adipose tissues was done by gas chromatography. We used a Perkin Elmer-Clarus 500 gas chromatograph fitted with a system of injection into the capillary column (1:100 splitting ratio), with programmed heating of the chromatograph column oven, with flame ionization detector and capillary separation column with high polarity stationary phase (TR-Fame, 60m 0.25mm ID × 0.25µm film), or with high polarity cyanopril phase which give a similar resolution for different geometrical isomers - THERMO TR-Fame 120m × 0.25mm ID x 0.25µm film. Hydrogen was use as carrier gas.

2.3 Measurements and statistical calculations

Samples of LD and ST muscles and of subcutaneous fat were collected in the end of the experiment and assayed for fatty acids composition.

The experimental data is given as average value ± SD. StatView (ANOVA – the general linear model) was used for the variance analysis; the averages were compared with the Student test. The effects were considered significant for $P \leq 0.05$. At 10%, we consider that the results may have been influenced by the treatment.

3. RESULTS AND DISCUSSION

Table 1 shows the detailed fatty acid composition of the sunflower oil, of the camelina oil and of the compound feeds. The supplement of n-3 rich ingredients (camelina oil) is reflected in the compound feed: the content of alpha-linolenic fatty acid was 4.38% in the CF for group E_1 and 4.32% in the CF for group E_2, compared to 0.26% in the CF for group C. Furthermore, the camelina oil also supplied 3.32% docosahexaenoic fatty acid which was also found in the compound feeds for E_1 and E_2 (1.19% and 1.17% respectively), which in beneficial to human health.

The high content of linoleic acid in the sunflower oil (63.97%) contributed with a significant proportion (58.67%) of this type of fatty acid to the compound feed C, compared to the experimental groups (45.52% in E_1 and 44.28% in E_2).

Table 1. Fatty acids composition for oil and diets (%)

Fatty acids	Sunflower oil	Camelina oil	DIETS		
			C	E_1	E2
C14:0 (myristic)	0.09	0.11	0. 20	0.12	0.12
C16:0 (palmitic)	7.34	6.27	12.68	9.95	10.03
C16:1 (palmitoleic)	0.11	-	0.06	0.10	0.27

C18:0 (stearic)	2.40	2.09	2.68	2.66	2.70
C18:1cis-9 (oleic)	23.63	17.93	23.16	19.48	19.77
C18:2n-6 (linoleic)	63.97	22.10	58.67	45.52	44.29
C18:3n-6 (γ linolenic)	0.17	31.61	14.86	15.60	0.17
C18:2 (conjugated linoleic)	0.18	-	0.17	0.68	0.68
C18:3n-3 (α linolenic)	0.13	12.84	0.26	4.38	4.32
C22:1n-9 (erucic)	0.00	-	0.00	0.48	0.47
C20:4n-6 (arachidonic)	0.36	0.90	0.26	0.51	0.50
C22:6n-3 (docosahexaenoic)	0.00	3.32	0.00	1.19	1.17
Alti acizi grasi	1.61	-	0.16	0.06	0.06

Table 2 shows the profile of the polyunsaturated fatty acids in LD muscle. The Camelina oil diet caused a highly significant (P=0.0045) increase of the content of C18:3n-3 FA in *LD* muscle in groups E_1 (1.03%) and E_2 (1.25%), compared to group C (0.43%).

Table 2 Fatty acids composition in *Longissimus dorsi* muscle

Fatty acids	*Longissimus dorsi*			
	C	E_1	E_2	*P*
C14:0 (myristic)	1.63 ± 0.20	1.78 ± 0.69	1.56 ± 0.16	0.6379
C16:0 (palmitic)	25.75 ± 1.98	26.15 ± 3.70	24.41 ± 1.25	0.4431
C18:0 (stearic)	11.48 ± 1.03	10.53 ± 0.73	10.53 ± 0.40	0.0708^{T}
C14: 1(miristoleic)	0.40 ± 0.24	0.44 ± 0.26	0.39 ± 0.13	0.9071
C16:1 (palmitoleic)	2.94 ± 0.51	2.91 ± 0.49	2.97 ± 0.55	0.9816
C18:1cis-9 (oleic)	36.34 ± 2.27	33.95 ± 3.14	34.80 ± 1.69	0.2854
C18:2n-6 (linoleic)	17.54 ± 2.27	17.89 ± 1.97	17.63 ± 2.05	0.9565
C8:3n-6 (γ linolenic)	0.34^{a} ± 0.15	2.65^{b} ± 0.43	2.77^{b} ± 0.40	<0.0001
C18:3n-3 (α linolenic)	0.43^{a} ± 0.11	1.03^{b} ± 0.48	1.25^{b} ± 0.35	0.0045
C20:4n-6 (arachidonic)	2.03 ± 0.87	1.56 ± 0.55	1.96 ± 0.53	0.4214
C22:6n-3 (docosahexaenoic)	0.00 ± 0.00	0.17 ± 0.09	0.22 ± 0.22	0.0713^{T}
Sum SFA	38.86 ± 1.59	38.45 ± 3.85	36.50 ± 1.38	0.2392
Sum MUFA	39.68 ± 2.14	37.30 ± 2.97	38.16 ± 1.86	0.2750
Sum PUFA	20.33^{a} ± 2.91	23.29 ± 2.66	24.84^{b} ± 2.76	0.1110
Sum n-6	19.91 ± 2.93	22.10 ± 2.58	22.36 ± 2.59	0.2812
Sum n-3	0.43^{a} ± 0.11	1.21^{b} ± 0.57	1.47^{b} ± 0.45	0.0031
Linoleic/α linolenic	43.68^{a} ± 12.89	20.50^{b} ± 8.93	14.83^{b} ± 3.31	0.0001
n-6/n-3	49.73^{a} ± 15.45	21.68^{b} ± 10.46	16.38^{b} ± 5.12	0.0002
PUFA/ SFA ratio	0.53^{a} ± 0.9	0.61 ± 0.11	0.65^{b} ± 0.10	0.1158

** different superscripts = significant differences (P≤ 0.05).*

A higher content of α-linolenic FA in LD muscle was reported by Nurenberg et al., 2004 (8.5% in castrated males and 9.1% in females) using 10% linen oil (with an estimated content of 67.1% α-linolenic FA). A better incorporation of the alpha-linolenic FA in muscle tissue (2-3%) was reported by Kouba, 2003 who used 6% linen seeds in the diet. The increase of n-3 FA decreased the level of arachidonic acid. The α-linolenic acid is precursor for the synthesis of eicosapentaenoic (EPA; C20:5n-3) and docosahexaenoic FA (DHA; C22:6n-3), playing an important role in the reduction of the cardiovascular diseases (Reddy and Katan, 2003; Stoll, 2005; Roos de Baukjesi et al., 2009). Although we didn't identify EPA in our experiment, DHA was identified in both groups (0.17% in E_1 and 0.22% in E_2) due to the dietary Camelina oil. The ratio n-6/n-3 was decreased significantly (P=0.0002) in LD muscle, 2.29 times in group E_1 and 3.04 times in group E_2 compared to the control group C, due to the decrease of C20:4n-6 content, concomitantly with the increase of n-3 content (Eggert et al., 2001, Nurenberg et. al. 2004).

Similar trends of influence on FA composition due to the applied treatments (use of n-3 rich Camelina oil) were noticed in the ST muscle (Table 3).

Table 3 Fatty acids composition in *Semitendinosus* muscle

Fatty acids	*Semitendinosus* muscle			
	C	E_1	E_2	*P*
C14:0 (myristic)	1.71 ± 0.14	1.69 ± 0.26	1.78 ± 0.15	0.6545
C16:0 (palmitic)	26.89 ± 1.95	25.82 ± 1.46	26.60 ± 1.03	0.4570
C18:0 (stearic)	13.09 ± 0.57	12.31 ± 0.71	12.48 ± 0.84	0.2149
C14: 1(miristoleic)	0.21 ± 0.17	0.35 ± 0.19	0.22 ± 0.13	0.2572
C16:1 (palmitoleic)	2.42 ± 0.28	2.13 ± 0.49	2.33 ± 0.32	0.4228
C18:1cis-9 (oleic)	36.56^a ± 1.83	33.22^b ± 2.17	34.12^b ± 1.55	0.0262
C18:2n-6 (linoleic)	16.38 ± 1.81	17.38 ± 1.77	15.46 ± 1.88	0.1994
C8:3n-6 (γ linolenic)	0.28^a ± 0.04	3.14^b ± 0.58	2.83^b ± 0.27	<0.0001
C18:3n-3 (α linolenic)	0.40^a ± 0.91	1.53^b ± 0.42	1.56^b ± 0.28	<0.0001
C20:4n-6 (arachidonic)	1.05 ± 0.74	0.92 ± 0.45	0.75 ± 0.12	0.5595
C22:6n-3 (docosahexaenoic)	0.00^a ± 0.00	0.21^b ± 0.09	0.22^b ± 0.10	0.0006
Sum SFA	41.70 ± 2.48	39.81 ± 1.50	40.86 ± 1.47	0.2520
Sum MUFA	39.19^a ± 1.81	35.70^b ± 2.43	36.67^b ± 1.74	0.0333
Sum PUFA	18.14^a ± 2.35	23.21^b ± 2.44	20.82 ± 2.33	0.0108
Sum n-6	17.72^a ± 2.31	21.45^b ± 2.32	19.04 ± 2.13	0.0412
Sum n-3	0.42^a ± 0.13	1.77^b ± 0.40	1.78^b ± 0.28	<0.0001
Linoleic/α linolenic	42.81^a ± 10.55	12.45^b ± 5.02	10.04^b ± 0.96	<0.0001
n-6/n-3	46.45^a ± 12.67	15.61^b ± 6.35	12.61^b ± 1.28	<0.0001
PUFA/ SFA ratio	0.44^a ± 0.08	0.59^b ± 0.08	0.51 ± 0.07	0.0166

** different superscripts = significant differences (P≤ 0.05).*

The α-linolenic FA concentration was very high both in E_1 (1.53%) and in E_2 (1.56%) compared to group C (0.40%), the differences being significant (P<0.0001). In the *ST* muscle, the decrease of n-6/n-3 ratio was very significant (P<0.0001), for groups E_1 and E_2 (2.97 and 3.68 times, respectively), compared to group C. Similar results were reported by Habeanu et al., 2010. Significant differences (P=0.026) have been noticed between C and the two experimental groups E_1 and E_2 for the oleic acid, precursor of the stearic acid and a major component of the neutral lipids (Wood et al., 2007).

The FA composition of the subcutaneous fat is shown in Tale 4. Both the α and γ-linolenic FA and the n-3 FA were significantly different (P<0.0001) from the control group, due to the use of the dietary Camelina. The ratio n-6/n-3 was decreased from 70.79 in group C to 20.75 in group E_1 and 16.80% in group E_2.

Table 4 Fatty acids composition in subcutanous fat

Fatty acids	Subcutaneous fat			
	C	E_1	E_2	*P*
C14:0 (myristic)	1.49 ± 0.06	1.48 ± 0.20	1.43 ± 0.10	0.7465
C16:0 (palmitic)	21.81 ± 1.73	20.53 ± 1.75	20.41 ± 1.28	0.3121
C18:0 (stearic)	10.70 ± 0.82	9.61 ± 1.53	9.98 ± 1.12	0.3457
C16:1 (palmitoleic)	2.01 ± 0.22	1.97 ± 0.19	1.86 ± 0.31	0.5535
C18:1cis-9 (oleic)	37.61^a ± 2.24	34.10^b ± 2.19	35.52 ± 2.78	0.0755
C18:2n-6 (linoleic)	24.03 ± 2.32	23.10 ± 2.64	21.97 ± 2.60	0.4240
C8:3n-6 (γ linolenic)	0.55^a ± 0.11	6.13^b ± 0.75	5.60^b ± 0.70	<0.0001
C18:3n-3 (α linolenic)	0.46^a ± 0.19	1.48^b ± 0.31	1.73^b ± 0.33	<0.0001
C20:4n-6 (arachidonic)	0.24^a ± 0.08	0.66^b ± 0.20	0.57^b ± 0.11	0.0007
C22:6n-3 (docosahexaenoic)	0.00 ± 0.00	0.02 ± 0.06	0.00 ± 0.00	0.4831
Sum SFA	34.00 ± 2.48	31.62 ± 3.34	31.83 ± 2.21	0.3193

Sum MUFA	$39.62^{a} \pm 2.12$	$36.07^{b} \pm 2.19$	37.38 ± 3.05	0.0823
Sum PUFA	$25.31^{a} \pm 2.45$	$31.39^{b} \pm 3.41$	$29.87^{b} \pm 3.24$	0.0140
Sum n-6	$24.82^{a} \pm 2.48$	$29.89^{b} \pm 3.34$	28.14 ± 3.19	0.0413
Sum n-3	$0.49^{a} \pm 0.22$	$1.50^{b} \pm 0.34$	$1.73^{b} \pm 0.33$	<0.0001
Linoleic/α linolenic	$69.92^{a} \pm 55.52$	$16.15^{b} \pm 3.75$	$13.12^{b} \pm 3.03$	0.0086
n-6/n-3	$70.79^{a} \pm 58.79$	$20.75^{b} \pm 5.2$	$16.80^{b} \pm 3.85$	0.0192
PUFA/ SFA ratio	$0.75^{a} \pm 0.13$	$1.01^{b} \pm 0.21$	0.94 ± 0.14	0.0526

** different superscripts = significant differences (P≤ 0.05).*

CONCLUSIONS

The Camelina oil, due to its high content of n-3 FA and particularly of α-linolenic FA, has beneficial effects on the quality of the pig meat.

The dietary use of Camelina oil improved the structure of the lipids in n-3 fatty acids, particularly in α-linolenic acid, and decreased significantly the n-6/n-3 ratio in the muscle tissue (LD and ST) and in the adipose tissue of the finishing pigs.

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