Effect of Linseed Supplementation on Carcass, Meat Quality and Fatty Acid Composition in Pigs

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Summary

The effect of linseed supplementation on carcass, meat quality and fatty acid profile of fat tissue was studied. No differences in carcass and meat quality traits were observed, the exception being drip loss that was lower in pigs supplemented with linseed. As regards fatty acids, linseed supplementation led to the increased content of unsaturated, polyunsaturated and *n-3* fatty acids and decreased content of saturated fatty acids and *n-6*/*n-3* ratio in the subcutaneous and intramuscular fat of pigs.

Key words

pig, linseed, carcass quality, meat quality, fatty acids

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Aim

Meat is generally considered as the rich source of saturated fatty acids (SFA) that are often associated with some critical diseases. From the nutritional point of view favourable balance between polyunsaturated (PUFA) and saturated fatty acids (SFA) and between *n-6* and *n-3* fatty acids is important. In pigs, which are monogastric, the fatty acid composition can be manipulated through feeding. The aim was to evaluate linseed supplementation effect on fatty acid composition of fat tissues and carcass or meat quality.

Material and methods

The experiment was carried out on a family farm in Ljutomer in a period from December 2009 (housing of pre-fattening pigs) to April 2010 (slaughter). The study comprised two groups of 24 pigs (commercial crossbreeds composed of female line Landrace-11 × large White and male line Landrace-55 × Pietrain). In both groups females and castrates were equality represented. Both groups (control and experimental) were fed conventional feeding mixtures Bek 25, Bek 60 and Bek 90 (Panvita). In the experimental group, the pigs were fed a diet supplemented with 1.5% linseed. Pigs were slaughtered at app. six months of age, weighing app. 110 kg. Slaughter of animals was carried out according to the routine abattoir procedure *i.e.* CO_2 stunning, vertical exsanguination, vapour scalding, dehairing and evisceration followed by the veterinary inspection and the SEUROP carcass classification.

Carcass quality traits. At the end of the slaughter line, pigs were classified according to SEUROP by the approved classification body (Bureau Veritas), using a method for lean meat percentage approved for Slovenia (Commission Decision, 2008) which consists of taking two measurements at the carcass split line: DM fat (minimal fat thickness over the *m. gluteus medius*) and DM muscle (shortest distance between the cranial end of *m. gluteus medius* and dorsal edge of the vertebral canal). One day after the slaughter, additional carcass traits were measured. The hind leg (without shank) was cut off the carcass between 6th and 7th *lumbar vertebra* and the percentage of ham meat was calculated. It was weighed prior to and after the removal of subcutaneous fat, and the ratio between the weights was calculated. A digital image of the carcass cross section (last rib) was taken with a digital photo camera (Canon PowerShot G3, Canon Inc., Tokyo, Japan). The loin eye area (area of muscle *longissimus dorsi* - LD), corresponding fat area (fat over LD) and their ratio (LD meat : fat ratio) were determined from the images with LUCIA.NET 1.16.5 software (Laboratory Imaging s.r.o, Prague, Czech Republic). Belly leanness was assessed using a 1–4–7 scale (1 represents only fat, 4 half meat and half fat, and 7 only meat).

Meat quality traits. The measurements of pH were taken in duplicate using a MP120 Mettler Toledo pH meter fitted with a combined glass electrode InLab427 (Mettler-Toledo, GmbH; 8603 Schwarzenbach, Switzerland) one day (24 hours) after slaughter (pH_U) in the LD muscle at the level of the last rib. Measurements of colour (Minolta CIE L*a*b*) were taken one day after slaughter from a freshly cut surface of LD (at the level of the last rib) using a Minolta Chroma Meter CR-300 (Minolta Co. Ltd, Osaka, Japan) with an 11 mm diameter aperture and D65 illuminant, calibrated against a white tile. At the same time, the colour intensity of LD was also assessed using a 1-6 Japanese colour scale (1 and 2 represent pale, 3 and 4 normal, and 5 and 6 dark meat colour). A 2.5 cm slice of LD was taken from the loin at the level of the last rib for determination of drip loss (EZ drip loss) according to the method described in Christensen (2003). Drip loss was determined in duplicate, after 24 and 48 hours of storage at 4°C, and expressed as a percentage of the initial sample weight. Samples of LD and *semispinalis capitis* (SC) muscles were taken to the laboratory where intramuscular fat (IMF) content was determined using calibration models developed on NIR spectra (spectrometer NIR Systems model 6500, Silver Springs, MD, USA) according to Prevolnik *et al.* (2005).

Fatty acid profile. Fatty acids were determined in the samples of LD, SC and adipose tissue using gas chromatography with *in situ* transesterification without previous lipid extraction (Park and Goins, 1994). Gas chromatograph Agilent Technologies 6890 N equipped with flame ionization detector and capillary column Supelco OMEGAWAX 320 was used, respecting conditions for the determination and detection of methyl esters of fatty acids according to Joseph and Ackman (1992). Gas flow: helium (1.8 ml/min, carrier gas), hydrogen (30 ml/min), synthetic air (400 ml/min) as detector gas, nitrogen (25 ml/min, "make up" gas). Chromatography duration was 65 minutes. Saturated (SFA), unsaturated (UFA), mono (MUFA), polyunsaturated (PUFA), total *n-6* and total *n-3* fatty acids were determined. The ratios UFA/SFA, PUFA/SFA and total *n-6*/total *n-3* were calculated.

Statistical analysis. Analysis of variance (GLM procedure of SAS 9.1) was performed in order to evaluate the effect of linseed supplementation on carcass, meat quality traits and fatty acid profile. The model comprised fixed effects of feeding regime, sex and their interaction. In the case of fatty acid profile of fat tissues, the interaction between the treatment and sex was often significant; in such case the differences between control and experimental group are presented also separately for each sex. Least squares means (*LS* means) were compared using the PDIFF option in SAS.

Results and discussion

Carcass and meat quality

Supplementing pigs' diet with linseed had no major effect on carcass or meat quality traits, except for drip loss and visually assessed colour. It is worth noting that group of pigs fed linseed had higher meat water holding capacity (1.4 and 1.6 percent point lower drip loss after 24 and 48 hours, respectively) than the control group that is of practical importance. As regards the effect of sex, generally known differences between females and castrated males were confirmed (data not shown) *i.e.* higher fatness and higher intramuscular fat content was observed in castrates as compared to the females, whereas no differences were found for other meat quality traits.

Fatty acid composition

LD muscle

Pigs supplemented with the linseed had lower SFA, higher UFA and *n-3* fatty acid content, resulting in higher UFA : SFA and *n-6/n-3* ratio as compared to the pigs of the control group (Table 2). In the case of significant interactions between the treatment and sex, we looked at the effect of linseed supplementa-

Table 1. Effect of linseed supplementation on carcass and meat quality traits

	Treatment group - T (*lsmeans ± se*)		*Sig.*	
	Control (n=24)	Linseed (n=24)	T	(T × Sex)
Carcass quality				
Carcass weight, kg	87.4 ± 1.2	87.5 ± 1.2	ns	ns
DM muscle, mm	73.5 ± 1.1	72.0 ± 1.1	ns	ns
DM fat, mm	12.7 ± 0.7	14.0 ± 0.7	ns	ns
DM meat, %	60.5 ± 0.5	59.3 ± 0.5	ns	ns
LD area, cm^2	51.5 ± 1.0	50.2 ± 1.0	ns	**
Females	54.9 ± 1.4	49.4 ± 1.4	**	
Castrates	48.1 ± 1.4	51.1 ± 1.4	ns	
Fat over LD, cm^2	14.1 ± 0.7	14.1 ± 0.7	ns	ns
LD meat : fat ratio	3.90 ± 0.20	3.80 ± 0.20	ns	ns
Belly (1-7)	4.7 ± 0.2	4.8 ± 0.2	ns	ns
Ham, kg	11.3 ± 0.2	11.1 ± 0.2	ns	ns
Ham (muscle+bone), kg	9.4 ± 0.2	9.2 ± 0.2	ns	ns
Ham meat, %	83.5 ± 0.8	82.9 ± 0.8	ns	ns
Meat quality				
LD pH_U	5.43 ± 0.01	5.44 ± 0.01	ns	ns
LD colour (1-6)	3.0 ± 0.1	3.3 ± 0.1	*	ns
LD Minolta L*	52.0 ± 0.5	52.5 ± 0.5	ns	ns
LD Minolta a*	7.6 ± 0.2	8.0 ± 0.2	ns	ns
LD Minolta b*	2.9 ± 0.2	3.2 ± 0.2	ns	ns
LD drip loss 24h, %	4.1 ± 0.3	2.7 ± 0.3	**	ns
LD drip loss 48h, %	6.4 ± 0.4	4.8 ± 0.4	**	ns
LD IMF fat, %	1.4 ± 0.1	1.5 ± 0.1	ns	ns
SC IMF fat, %	7.1 ± 0.4	6.9 ± 0.4	ns	ns

LD – *longissimus dorsi*; SC – *semispinalis capitis*; T – treatment group; pH_U – ultimate pH measured 24 hours after slaughter; IMF – intramuscular fat; Sig. – statistical significance; ns – non significant; * p<0.05; ** p<0,01.

tion separately for both sexes. In females the situation was the same as on the whole, whereas in castrates, a significant increase was found only in the case of *n-3* fatty acids and ratio *n-6/n-3*. Overall, the linseed group had nearly twofold higher content of *n-3* fatty acids compared to the control group, resulting in more favourable ratio *n-6/n-3*.

SC muscle

Overall, pigs supplemented with the linseed had higher UFA, lower SFA content and higher content of *n-3* fatty acids resulting in higher ratio UFA : SFA and *n-6/n-3* (Table 2). Here again, the effect of linseed supplementation on SFA, UFA content and ratio UFA : SFA was more important in female pigs, in castrates only SFA and UFA content were affected. Supplementing pigs' diet with linseed resulted in twofold higher content of *n-3* fatty acids compared to the control group, resulting in more favourable ratio *n-6/n-3*.

Subcutaneous fat

The only significant effect of linseed supplementation observed for the subcutaneous adipose tissue was related to the higher content of *n-3* fatty acids resulting in lower *n-6/n-3* ratio (for both sexes). Thus, linseed fed pigs had nutritionally more favourable ratio *n-6/n-3*.

Discussion

In the present study, we confirmed the reported results (Enser et al., 2000; Guillevic et al., 2009; Hoz et al., 2003; Huang et al., 2008; Kouba et al., 2003) on the beneficial effect of linseed sup-

Table 2. Effect of linseed supplementation on fatty acid composition of fat tissues

	Treatment group – T (*lsmeans ± se*)		*Sig.*		Control-Linseed			
	Control (n=24)	Linseed (n=24)	T	T × Sex	Females	*Sig.*	Castrates	*Sig.*
LD muscle								
SFA[a]	35.8 ± 0.3	34.9 ± 0.3	*	**	2.2	**	−0.4	ns
UFA[a]	64.2 ± 0.3	65.1 ± 0.3	*	**	−2.2	**	0.4	ns
MUFA[a]	39.4 ± 1.2	39.7 ± 1.2	ns	ns				
PUFA[a]	24.8 ± 1.3	25.4 ± 1.3	ns	†	−3.9	ns	2.6	ns
UFA:SFA	1.79 ± 0.02	1.87 ± 0.02	*	**	−0.18	***	0.03	ns
PUFA:SFA	0.69 ± 0.04	0.74 ± 0.04	ns	*	−0.16	ns	0.08	ns
n-3[a]	1.7 ± 0.1	3.3 ± 0.1	***	*	−2.0	***	−1.3	***
n-6[a]	23.1 ± 1.2	22.1 ± 1.2	ns	†	−1.9	ns	3.9	ns
n-6:n-3	13.9 ± 0.2	6.7 ± 0.2	***	*	6.5	***	8.0	***
SC muscle								
SFA[a]	38.9 ± 0.5	37.4 ± 0.5	*	*	3.1	**	−0.26	ns
UFA[a]	61.1 ± 0.5	62.6 ± 0.5	*	*	−3.1	**	0.26	ns
MUFA[a]	44.4 ± 0.7	44.7 ± 0.7	ns	ns				
PUFA[a]	16.8 ± 1.0	17.8 ± 1.0	ns	ns				
UFA:SFA	1.58 ± 0.03	1.68 ± 0.03	*	*	−0.22	**	0.02	ns
PUFA:SFA	0.44 ± 0.03	0.48 ± 0.03	ns	ns				
n-3[a]	1.2 ± 0.1	2.7 ± 0.1	***	ns				
n-6[a]	15.5 ± 0.9	15.0 ± 0.9	ns	ns				
n-6:n-3	12.6 ± 0.2	5.5 ± 0.2	***	ns				
Subcutaneous fat								
SFA[a]	37.2 ± 0.7	36.1 ± 0.7	ns	ns				
UFA[a]	62.8 ± 0.7	63.9 ± 0.7	ns	ns				
MUFA[a]	44.1 ± 0.5	44.8 ± 0.5	ns	†				
PUFA[a]	18.7 ± 0.7	19.1 ± 0.7	ns	*	1.9	ns	−2.7	†
UFA:SFA	1.70 ± 0.05	1.78 ± 0.06	ns	ns				
PUFA:SFA	0.51 ± 0.03	0.53 ± 0.03	ns	†				
n-3[a]	1.3 ± 0.1	3.2 ± 0.1	***	*	−1.5	***	−2.0	***
n-6[a]	17.3 ± 0.6	16.0 ± 0.6	ns	*	3.3	*	0.8	ns
n-6:n-3	13.0 ± 0.1	5.3 ± 0.1	***	ns				

[a] % of total fatty acids content; LD – *longissimus dorsi*; SC – *semispinalis capitis*; T – treatment group; Sig. – statistical significance; ns – non significant; † p<0.10; * p<0,05; ** p<0,01; *** p<0,001.

plementation on fatty acid composition of different pig adipose tissue depots (intramuscular and subcutaneous). As in other studies, the effect was particularly notable for *n-3* fatty acid (higher) content resulting in more favourable indicators of nutritional quality, *i.e.* higher UFA/SFA ratio and lower *n-6/n-3* ratio. There is no clear-cut recommendation regarding the optimal levels of *n-3* fatty acids and *n-6/n-3* ratio of pork; WHO (2003) recommends ratio between 2 to 8, whereas values below 4 have also been recommended (Wood et al., 2003). In the present study, despite the considerably improved *n-6/n-3* ratio, it remained above 4.0 in all fat depots in the case of linseed supplemented pigs. This can be ascribed to the fact, that the level of supplementation in the present study was relatively low (1.5%) compared to other studies (Guillevic et al., 2009; Hoz et al., 2003; Huang et al., 2008; Kouba et al., 2003). As for the effect of linseed supplementation on carcass and meat quality, our results mainly agree with the literature reports showing no major effect on carcass traits and physico-chemical properties of meat. An interesting observation of the present study is a beneficial effect (lower drip loss) of linseed supplementation on meat water holding capacity and significant negative correlation (−0.5 to −0.6) between drip loss and *n-3* fatty acid content, indicating that improved fatty acid composition was associated with better water holding capacity of meat. This result is difficult to comment and would need further confirmation/clarification. It may be related to stress susceptibility, since in humans *n-3* status has been associated with stress or different mental disorders (Bourre, 2005).

Conclusions

As expected, linseed supplementation of the diet improved fatty acid composition of pig intramuscular and subcutaneous fat with no detrimental effect on carcass and fresh meat quality. The content of *n-3* fatty acids and consequently the content of UFA and MUFA were increased, resulting in more favourable nutritionally important indicators, *i.e.* higher UFA/SFA ratio and lower total *n-6*/total *n-3* ratio. In addition, a beneficial effect (lower drip loss) of linseed supplementation on meat water holding capacity was observed.

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