57th Annual Meeting of the European Association for Animal Production (EAAP)

Turkey, Antalya, 17 - 20 September 2006
Commission: Cattle Production
Session: C 33.15
Abstract: 548

Fatty acid profile of different muscles from Charolais and Simmental bulls supplemented with whole sunflower seed

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Abstract
We have examined the effects of cattle breed, dietary fat, and muscle location on the fatty acid (FA) profile of intramuscular fat. Forty-six Charolais (CH) and Simmental (SI) bulls (357±60 kg) were given two isonitrogenous and isocaloric diets supplemented with either whole sunflower seed high in C18:2n6 (SUN) or Megalac high in C16:0 (CON) as different sources of dietary fat. After slaughter, samples of *m. longissimus thoracis* and *m. infraspinatus* were collected and the concentrations of different fatty acids in total lipids were determined. The concentrations of C14:0 and C16:0 were higher in CH bulls (P<0.001) while C18:1n9 was higher in SI (P<0.001). As a result, muscles of SI contained a higher ratio monounsaturated/saturated FA (P<0.001). SUN diet increased C18:0, C18:2n6 (P<0.001), *c9,t11*CLA (P<0.01), and the ratio PUFA n6/n3 (P<0.001). *M. infraspinatus* generally contained less saturated and more polyunsaturated FA than *m. longissimus thoracis*, probably reflecting differences in the content of phospholipids in different metabolic fibre type muscles.

Introduction
Fatty acid composition of beef muscle is influenced by a number of factors including diet, intramuscular fat content, age, sex, breed, muscle location etc. (see e.g. reviews of Nürnberg et al., 1998, and De Smet et al., 2004). Most of these factors have currently received considerable attention due to the well-evidenced relationship between the composition of consumed meat and human health (Jiménez-Colmenero et al., 2001). The objective of the present study was to determine the effects of cattle breed, dietary fat, and muscle location on the fatty acid profile of intramuscular fat.

Material and methods
Forty-six Charolais (CH) and Simmental (SI) bulls were used in the experiment. Throughout the whole experimental period (mean ± s.d. 211 ± 38 days), the animals were offered two diets with similar contents of energy and protein containing either whole sunflower (SUN) or

Megalac (CON) as different sources of dietary fat (5 % on a DM basis). After slaughter (mean ± s.d. 640 ± 38 kg live weight) and a 24 h cooling period, samples of *m. longissimus thoracis* (MLT) at the 9th rib and *m. infraspinatus* (MIS) were collected for fatty acid profile analyses.
Fatty acid (FA) composition (g/100 g total FA) was determined after extraction of total lipids according to the method of Folch et al. (1957). Alkaline trans-methylation of FA was performed in accordance with ISO 5509 (2001). Gas chromatography of methyl esters was performed using an HP 6890 gas chromatograph (Agilent Technologies, Inc.) with a programmed 60 m DB-23 capillary column (150 to 230°C).
Only the major fatty acids are reported as well as fatty acid ratios related to human health. The statistic analysis was performed using the GLM procedure of SAS (SAS Institute Inc., 2001). The model included fixed effects of diet, breed, muscle and all their interactions.

Results and discussion
Intramuscular fat content, FA composition and some nutritionally important ratios are given in Table 1. The MIS contained a higher level of intramuscular fat than the MLT while no effects of breed and diet on this trait were found.
The CH bulls deposited higher concentrations of C14:0, C16:0, SFA ($P<0.001$) and lower proportions of C18:1n-9 and MUFA ($P<0.001$) than the SI animals. As a result, the CH animals exhibited a lower ratio MUFA/SFA ($P<0.001$) and a lower index of Δ9-desaturase (18) activity ($P<0.001$). The tendency towards higher SFA and lower MUFA in intramuscular fat of the CH breed are in agreement with our previous studies focused on breed comparisons (Bartoň et al., 2005; Bureš et al., 2006). The differences in FA composition might be explained by the different activity of the enzyme responsible for conversion mainly stearate into oleate as suggested e.g. by Laborde et al. (2001).
Whole sunflower supplementation as a rich source of linoleic acid increased its proportion in both analysed muscles ($P<0.001$). The SUN diet also enhanced the intramuscular fat concentrations of C18:0 ($P<0.001$), *c9t11*CLA ($P<0.001$) and the ratios PUFA/SFA ($P<0.01$) and PUFAn-6/PUFAn-3 ($P<0.001$), while the proportion of C16:0 ($P<0.001$) and C18:3n-3 ($P<0.05$) were reduced. These results are largely in agreement with the study of Gibb et al. (2004). The animals on the SUN diet also had a lower index of Δ9-desaturase (18) activity ($P<0.05$).
When comparing the fatty acid profile of the two examined muscles, the MIS showed a lower proportion of C16:0 ($P<0.001$), while the proportions of all individual PUFA n-6 were significantly higher. It logically resulted in a considerably higher ratios PUFA/SFA ($P<0.001$) and PUFA n-6/PUFA n-3 ($P<0.01$) in this muscle. Based on the prevalent fibre type, the MIS is classified as red while the MLT as white muscle (Kirchofer et al., 2002). As with our results, red muscles were shown to contain more phospholipids and thus higher proportion of PUFA than white muscles (Lengyel et al., 2003).
The results of this study indicate that all the three examined effects of breed, diet and anatomical location of muscle affect the profile of muscle fatty acids. Muscle from SI contained higher proportions of MUFA and less SFA than muscle from CH. The sunflower supplemented diet increased the proportions of linoleic acid, *c9t11*CLA and the ratio PUFA/SFA. The MIS with more red fibres contained higher proportions of PUFA than the MLT.

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The study was supported by the project MZE0002701403.

Table 1: Intramuscular fat, fatty acid profile of intramuscular fat and some nutritionally important ratios

		Charolais				Simmental				Significance						
		SUN (n=12)		CON (n=10)		SUN (n=12)		CON (n=12)								
		LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	B	D	M	BxD	BxM	DxM	BxDxM
Intramusc. fat	MIS	25,1	*1,69*	22,3	*1,85*	22,1	*1,69*	25,2	*1,69*	NS	NS	***	NS	NS	NS	NS
content (g/kg)	MLT	14,2	*1,69*	15,4	*1,85*	14,2	*1,69*	15,4	*1,69*							
C14:0	MIS	2,81	*0,116*	2,84	*0,127*	2,39	*0,116*	2,28	*0,116*	***	NS	NS	NS	NS	NS	NS
	MLT	2,66	*0,116*	2,61	*0,127*	2,23	*0,116*	2,36	*0,116*							
C16:0	MIS	24,23	*0,444*	27,64	*0,486*	22,70	*0,444*	25,71	*0,444*	***	***	***	NS	NS	NS	NS
	MLT	25,78	*0,444*	29,00	*0,486*	23,69	*0,444*	27,35	*0,444*							
C18:0	MIS	22,82	*0,605*	20,70	*0,662*	22,24	*0,605*	20,58	*0,605*	NS	***	NS	NS	NS	NS	NS
	MLT	23,70	*0,605*	21,78	*0,662*	23,35	*0,605*	20,73	*0,605*							
C14:1n-5	MIS	0,33	*0,023*	0,36	*0,025*	0,34	*0,023*	0,34	*0,023*	NS	NS	**	NS	NS	NS	NS
	MLT	0,27	*0,023*	0,30	*0,025*	0,28	*0,023*	0,30	*0,023*							
C16:1n-7	MIS	2,10	*0,095*	2,24	*0,104*	2,08	*0,095*	2,28	*0,095*	NS	**	*	NS	NS	NS	NS
	MLT	1,93	*0,095*	2,00	*0,104*	1,86	*0,095*	2,21	*0,095*							
C18:1n-7	MIS	1,19	*0,040*	1,24	*0,044*	1,24	*0,040*	1,33	*0,040*	NS	NS	NS	NS	NS	NS	NS
	MLT	1,19	*0,040*	1,19	*0,044*	1,22	*0,040*	1,24	*0,040*							
C18:1n-9	MIS	33,30	*0,559*	31,73	*0,612*	34,92	*0,559*	35,25	*0,559*	***	NS	NS	NS	NS	NS	NS
	MLT	32,47	*0,559*	31,97	*0,612*	34,61	*0,559*	34,87	*0,559*							
C18:1n-9 *t*	MIS	0,50	*0,034*	0,44	*0,038*	0,53	*0,034*	0,43	*0,034*	NS	**	NS	NS	NS	NS	NS
	MLT	0,45	*0,034*	0,42	*0,038*	0,47	*0,034*	0,41	*0,034*							
C18:2n-6	MIS	7,24	*0,382*	6,66	*0,419*	7,91	*0,382*	6,22	*0,382*	NS	***	**	NS	NS	NS	NS
	MLT	6,49	*0,382*	5,50	*0,419*	6,98	*0,382*	5,47	*0,382*							
C20:3n-6	MIS	0,29	*0,025*	0,35	*0,027*	0,30	*0,025*	0,32	*0,025*	NS	NS	*	NS	NS	NS	NS
	MLT	0,25	*0,025*	0,26	*0,027*	0,28	*0,025*	0,28	*0,025*							
C20:4n-6	MIS	1,22	*0,109*	1,43	*0,119*	1,44	*0,109*	1,23	*0,109*	NS	NS	***	*	NS	NS	NS
	MLT	0,95	*0,109*	0,98	*0,119*	1,25	*0,109*	1,00	*0,109*							
C22:4n-6	MIS	0,15	*0,015*	0,22	*0,016*	0,18	*0,015*	0,17	*0,015*	NS	NS	***	*	NS	*	NS
	MLT	0,12	*0,015*	0,13	*0,016*	0,16	*0,015*	0,13	*0,015*							
C18:3n-3	MIS	0,52	*0,032*	0,63	*0,035*	0,51	*0,032*	0,55	*0,032*	NS	*	NS	NS	NS	NS	NS
	MLT	0,52	*0,032*	0,56	*0,035*	0,50	*0,032*	0,54	*0,032*							
C20:5n-3	MIS	0,13	*0,017*	0,17	*0,019*	0,12	*0,017*	0,13	*0,017*	NS	NS	NS	NS	NS	NS	NS
	MLT	0,16	*0,017*	0,15	*0,019*	0,14	*0,017*	0,13	*0,017*							
C22:5n-3	MIS	0,38	*0,035*	0,46	*0,039*	0,39	*0,035*	0,43	*0,035*	NS	NS	NS	NS	NS	NS	NS
	MLT	0,34	*0,035*	0,39	*0,039*	0,37	*0,035*	0,38	*0,035*							
C22:6n-3	MIS	0,03	*0,004*	0,05	*0,005*	0,03	*0,004*	0,03	*0,004*	NS	NS	**	*	NS	NS	NS
	MLT	0,02	*0,004*	0,02	*0,005*	0,03	*0,004*	0,03	*0,004*							
*c9t11*CLA	MIS	0,36	*0,025*	0,28	*0,027*	0,33	*0,025*	0,27	*0,025*	NS	***	NS	NS	NS	NS	NS
	MLT	0,34	*0,025*	0,25	*0,027*	0,31	*0,025*	0,24	*0,025*							

Table 1: Intramuscular fat, fatty acid profile of intramuscular fat and some nutritionally important ratios (continued)

		Charolais				Simmental				Significance[a]						
		SUN		CON		SUN		CON								
		LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	B	D	M	BxD	BxM	DxM	BxDxM
SFA[b]	MIS	49,86	*0,673*	51,17	*0,737*	47,33	*0,673*	48,57	*0,673*	***	*	***	NS	NS	NS	NS
	MLT	52,15	*0,673*	53,40	*0,737*	49,28	*0,673*	50,45	*0,673*							
MUFA[c]	MIS	37,41	*0,620*	36,01	*0,679*	39,11	*0,620*	39,63	*0,620*	***	NS	NS	NS	NS	NS	NS
	MLT	36,31	*0,620*	35,88	*0,679*	38,45	*0,620*	39,04	*0,620*							
PUFA[d]	MIS	10,24	*0,580*	10,29	*0,635*	11,19	*0,580*	9,40	*0,580*	NS	*	**	NS	NS	NS	NS
	MLT	9,12	*0,580*	8,29	*0,635*	9,99	*0,580*	8,25	*0,580*							
PUFA n-6[e]	MIS	8,89	*0,510*	8,67	*0,559*	9,82	*0,510*	7,95	*0,510*	NS	**	***	NS	NS	NS	NS
	MLT	7,81	*0,510*	6,86	*0,559*	8,67	*0,510*	6,88	*0,510*							
PUFA n-3[f]	MIS	1,05	*0,078*	1,30	*0,085*	1,05	*0,078*	1,14	*0,078*	NS	*	NS	NS	NS	NS	NS
	MLT	1,03	*0,078*	1,12	*0,085*	1,03	*0,078*	1,08	*0,078*							
PUFA/SFA	MIS	0,21	*0,013*	0,20	*0,015*	0,24	*0,013*	0,19	*0,013*	NS	**	***	NS	NS	NS	NS
	MLT	0,18	*0,013*	0,16	*0,015*	0,20	*0,013*	0,16	*0,013*							
MUFA/SFA	MIS	0,75	*0,021*	0,71	*0,022*	0,83	*0,021*	0,82	*0,021*	***	NS	**	NS	NS	NS	NS
	MLT	0,70	*0,021*	0,67	*0,022*	0,78	*0,021*	0,78	*0,021*							
PUFAn-6/PUFAn-3	MIS	8,55	*0,360*	6,74	*0,394*	9,66	*0,360*	7,08	*0,360*	*	***	**	NS	NS	NS	NS
	MLT	7,67	*0,360*	6,20	*0,394*	8,62	*0,360*	6,45	*0,360*							
C18DESA[g]	MIS	59,37	*0,945*	60,52	*1,036*	61,10	*0,945*	63,17	*0,945*	***	**	NS	NS	NS	NS	NS
	MLT	57,88	*0,945*	59,45	*1,036*	59,70	*0,945*	62,75	*0,945*							

*P<0.05 **P<0.01 ***P<0.001 NS – P>0.05

[a]B – breed; D – diet; M – muscle, interactions BxD, BxM, DxM, BxDxM

[b]SFA = C14:0 + C16:0 + C18:0

[c]MUFA = C14:1n-5 + C16:1n-7 + C18:1n-9 *t* + C18:1n-9 + C18:1n-7

[d]PUFA = PUFA n-3 + PUFA n-6

[e]PUFA n-6 = C18:2n-6 + C20:3n-6 + C20:4n-6 + C22:4n-6

[f]PUFA n-3 = C18:3n-3 + C20:5n-3 + C22:5n-3 + C22:6n-3

[g]Δ^9-desaturase (18) index = C18:1n-9/(C18:0+C18:1n-9)