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Original study

The effects of breed, grazing system and concentrate supplementation on the fatty acid profile of the *musculus longissimus dorsi* and the kidney fat of steers

Matthias Schmutz, Peter Weindl, Salome Carrasco, Gerhard Bellof and Eggert Schmidt

Fakultät Land- und Ernährungswirtschaft, Hochschule Weihenstephan-Triesdorf, Freising, Germany

Abstract

The study is aimed at determining the effect of breed (German Simmental *vs.* German Holstein), grazing system (continuous grazing system [CGS] *vs.* rotational grazing system [RGS]) and concentrate supplementation (level and type of concentrate) on the fatty acid profile of *longissimus* muscle and kidney fat of steers.

The trial involved four phases: in P1 all animals remained indoors; in P2 and P4 they were allocated on CGS or RGS; during P3 one group remained outdoors, the other indoors. In P1 and P3 the steers were offered grass silage and concentrate. In P3 the indoors group received a supplement with a medium or low-concentrate level. For the last 28 days of P4 the steers were offered a concentrate type with 4.9 % linseed oil or with 1.0 % rapeseed oil.

CGS-pasture resulted in higher fatty acid values than RGS-pasture; linseed-oil concentrate resulted in higher ALA, ∑n-3 and lower LA, ∑n-6 than rapeseed-oil concentrate.

German Simmental breed had lower IMF-content and higher ∑n-3, ∑n-6, n-6/n-3 ratio and PUFA/SFA ratio in *longissimus dorsi* and kidney fat than German Holstein breed. The proportion of CLA was higher in German Holstein breed than in German Simmental breed (0.56 *vs.* 0.50 g/100 g FAME). RGS group showed lower ALA and higher n-6/n-3 in *longissimus dorsi* and kidney fat than CGS-group. Neither the level nor the type of concentrate affected the LD and kidney fat fatty acids. Healthy fatty acids levels were higher in the German Holstein breed meat. The CGS-group meat had higher contents of ALA and EPA.

However, the legal requirements for human nutrition and other health related claims could not be met.

Keywords: grazing system, fatty acid profile, kidney fat, *longissimus* muscle, steers

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Corresponding author:
Gerhard Bellof, email: gerhard.bellof@hswt.de
Fakultät Land- und Ernährungswirtschaft, Hochschule Weihenstephan-Triesdorf, Am Hofgarten 1, 85350 Freising, Germany

Abbreviations: AA: arachidonic acid, ALA: α-linolenic acid, CGS: continuous grazing system, CLA: conjugated linoleic acid, DHA: docosapentaenoic acid, DPA: docosapentaenoic acid, EPA: eicosapentaenoic acid, FA: fatty acid; FAME: fatty acid methyl ester, GH: German Holstein, GS: German Simmental, IMF: intramuscular fat, LD: *longissimus dorsi*, LA: linoleic acid, MUFA: monounsaturated fatty acid, PUFA: polyunsaturated fatty acid, RGS: rotational grazing system, SEM: standard error of the mean, SFA: saturated fatty acid, t-BME: tertiary butyl-methylether, TMSH: trimethylsulfonium-hydroxide

Introduction

The increasing demands of consumers for meat with a healthy fatty acid profile and low fat content offering additional health benefits are promoting the extensification of the beef production system.

The consumption of ruminant's meat and milk rich in saturated fatty acids (SFA) has been linked with coronary heart disease, hypertension, inflammation, mammary cancer and high cholesterol concentration in blood (de Deckere *et al*. 1998, Tapiero *et al*. 2002). Nevertheless ruminant meat and milk are also good sources of n-3 PUFA in the human diet (Scollan *et al*. 2001).

However, it is known that fatty acids of adiposities in ruminants derive from *de novo* synthesis or from certain diets, suggesting that enzymes involved in lipogenesis are sensitive to dietary energy levels and possibly to the energy source itself. Studies on breed type and cattle feed strategies have demonstrated that it is possible to manipulate the profile of fatty acids including conjugated linoleic acid (CLA) isomers (Dannenberger *et al*. 2009). Some studies have indicated the presence of a breed related pattern of fat deposition and fatty acid synthesis. However, there are conflicting results, as either certain authors referred to a higher content of n-3 fatty acids in meat breeds than in dairy breeds (Nuernberg *et al*. 2005) or observed the opposite effect (Choi *et al*. 2000, Moreno *et al*. 2008). Pasture-finished cattle resulted in meat with a lower proportion of SFA, greater n-3 and less n-6 PUFA and higher CLA compared to high-grain-finished cattle (French *et al*. 2003, Nuernberg *et al*. 2002, Realini *et al*. 2004, Noci *et al*. 2007, Fincham *et al*. 2009). Additionally, the inclusion of PUFA-rich plant-oil or seeds in ruminant rations (soya oil, linseed oil) increased the concentration of n-3 PUFA, especially ALA and CLA , despite the extensive biohydrogenation of dietary lipids within the rumen. Also restricted grazing plus plant-oil-enriched rations improved the content of some healthy fatty acids in the meat of heifers (Noci *et al*. 2007). However, the aim to achieve the values of n-3 fatty acids required to use the label »source of n-3 fatty acids« was not achieved. According to the legal claims on nutritional value and health benefits of food (Regulation [EC] 1924/2006 and 432/2012) only food with at least 0.3 g/100 g of ALA or 40 mg/100 g asthe sum of EPA and DHA at a maximum energy content of 100 kcal are allowed to be considered »source of n-3 fatty acids«. Is it possible to achieve these levels with grazing animals supplemented with a concentrate rich of n-3 fatty acids? Therefore, the purpose of the present study was to test the effect of two grazing systems supplemented with two plant oil-enriched rations during the last 28 days of the final grazing period on the fatty acid profiles of meat and kidney fat of the two most important breeds in Germany.

Material and methods

Experimental design and animal management

The study was carried out in the research station »Zurnhause« at the University of Applied Sciences Weihenstephan-Triesdorf, Germany.

A group of 96 steers (German Simmental [GS] and German Holstein [GH]) were fattened from January 2011 to October 2012. The initial weight of the animals: GS=171 kg; GH=157 kg. Details of the fattening process and feeding regimen used are extensively described in Schmutz *et al*. (2013).

As is observed in Table 1, the experiment was divided in four phases (from P1 to P4): During P1 all animals remained indoors, subsequently in P2 they were moved to two different grazing systems (continuous grazing system [CGS] or rotational grazing system [RGS]). In P3 a group of 24 animals stayed outdoors and the rest of the group was kept indoors. During P4 the animals were raised as in P2. Animals were fed according to Table 1. In P4, 28 days prior to slaughter, two kinds of concentrate were offered to the steers (a concentrate mixture with 4.9 % linseed oil or a concentrate mixture with 1.0 % rapeseed oil). After reaching the final weight, 94 steers were slaughtered during the period running from the end of August until mid-October 2012.

Slaughter procedure, sampling and analyses

Steers were slaughtered at two-week intervals when they reached a live weight of 625 kg (average). They were transported to the experimental abattoir belonging to the Bavarian State Research Center for Agriculture (LfL) in Poing-Grub, which is located 48 km away from the farm. The transport was carried out according to the EU regulations on animal welfare rules. After a fasting period of 24 h, the steers were slaughtered according to EU laws. Procedures were conducted according to the guidelines of the Council Directive 2010/63/EU on the protection of animals used for experimental and other scientific purposes.

Samples of kidney fat were taken from the left side of the carcasses. These were subsequently vacuum-sealed in plastic bags and deep frozen at –20 °C. After chilling the carcasses at –4 °C for 24 h, a muscle sample was taken from the *musculus longissimus dorsi* (LD) at the 9th rib of the left side. Each sample was cleared of adipose tissue, cut into small cubes and mashed in a knife mill to form a homogenous paste. Then they were vacuum-sealed in plastic bags and kept frozen at –20 °C until they were analyzed. Intramuscular fat (IMF) of LD was determined with the near-infrared spectroscopy (NIRS) method (Schmutz *et al*. 2013).

The fatty acid profile of pasture (P4), concentrate (P4), LD and kidney fat were determined according to Firl *et al*. (2014) in the Bioanalytik laboratory Weihenstephan of the Technical University Munich (TUM).

The fat extraction of the samples was carried out according to Bligh & Dyer (1959) modified by Hallermayer (1976). One gram of homogenate sample was mixed with chloroform/methanol (1:1, v/v) and the internal Standard Trinonanoate (Sigma, Taufkirchen, Germany) for 90 s (Ultra Turrax, 8 000 rpm). Next the samples were centrifuged for 5 min at 4 °C (4 000 rpm). The overlap was decanted into a separating funnel and the pellet was extracted twice more and the overlaps combined in the separating funnel. After adding 21 ml of physiological solution of

Table 1
Experimental design according phases

Husbandry	Diet	P1		P2		P3				P4			
		Jan. - April 2011		May - Sept. 2011		October 2011 - March 2012				April - October 2012			
		GS	GH	GS	GH	GS		GH		GS	GH	GS	GH
		n=48	n=48	-	-	n=18	n=18	n=18	n=18	-	-	-	-
Indoor (P1, P3)	Grass silage	*ad libitum*		-		*ad libitum*				-			
	Concentrate	1 kg	1 kg	-		M	L	M	L	-	-	-	-
	Grazing system												
	RGS	-	-	n=24	n=24	n=6		n=6		n=12	n=12	n=12	n=12
Outdoor (P2, P3, P4)	CGS	-	-	n=24	n=24	n=6		n=6		n=12	n=12	n=12	n=12
	Concentrate	-		-		*M*		*M*		-	-	-	-
		------- Concentrate supplementation during the last 28 days of P4 -------								M LS-oil	M RS-oil	L LS-oil	L RS-oil

Level of offered concentrate: medium (M)=1.5 kg/animal/d, low (L)=0.75 kg/animal/d, LS-oil: linseed-oil concentrate, RS-oil: rapeseed-oil concentrate, total consumption of concentrate in the whole trial: M=275 kg/animal, L=191 kg/animal

sodium chloride the mixture was then shaken for one minute. After the phase separation (1 h) the chloroform was evaporated to dryness under vacuum conditions at 37 °C by use of a rotary evaporator (Rotavapor R 210, Büchl Labortechnik GmbH, Essen, Germany). The residue was dried with nitrogen for 15 min and then dissolved in one milliliter tertiary butyl-methylether (t-BME). Of this solution 100 µl together with 50 µl trimethylsulfonium-hydroxide (TMSH) were pipetted into a microvial, shaken and injected on the gas chromatograph. The fatty acid methyl ester (FAME) was broken down with a Hewlett Packard 6890 GC, equipped with an Agilent 7683 Autosampler (Agilent Technologies, Böblingen, Germany). A CP 7420 separation column was used (coating select FAME 100 % bonded cyano-propyl-phase, 100 m × 0.25 mm, Chrompack, Varian, USA) with a 0.25 µm film thickness and flame ionisation detector. The split/splitless injector was used with split 50. The samples were injected at 60 °C. The oven temperature was then raised by 6 °C/min to 120 °C, held for 9 min, subsequently increased by 3 °C/min to 242 °C, held for 90 min, then increased to the final temperature of 250 °C and held for 100 min. The injector was set at 270 °C and the detector at 280 °C. Hydrogen (Westfalen, Münster, Germany) was used as the carrier gas. Peaks were identified by comparison of retention times with known FAME standards. The fatty acids and the fatty acid distribution were analysed according to the DGF standard methods, C-VI 10a (DGF 2000) following the internal standard method. For this purpose the software Chromeleon (version 6.80) was used (Chromeleon, Dionex, Sunnyvale, USA). A FAME-Mix 37 Supelco reference standard (Sigma-Aldrich, Deisenhofen, Germany) was used. More fatty acid methyl ester was purchased from Sigma-Aldrich und conjugated linoleic acid (CLA) from Biotrend (Köln, Germany).

The fatty acid contents in meat were estimated using the IMF content of LD.

Statistical analysis

The statistical analysis was carried out with SPSS v. 20.0 (SPSS Inc., Chicago, IL, USA). All parameters were subjected to a four-factorial ANOVA according to the general linear model (GLM). Breed (A_i), grazing system (B_j), concentrate level (C_k) and type of concentrate (D_l) were used in the model as fixed elements.

$$Y_{ijkl}=\mu+A_i+B_j+C_k+D_l+e_{ijkl} \quad (1)$$

where Y_{ijkl} is the observed value of *ijkl* animal, μ is the population mean, e_{ijkl} is the residual error. Differences were tested by means of the F-Test. After robust F-Test results the means were compared using the Tukey-Test.

Results and discussion

According to the data presented in the companion paper (Schmutz *et al*. 2013), the GS-breed proved to be significantly superior to the GH-breed in all essential parameters of the fattening and the carcass performance (final weight: 631 kg *vs*. 608 kg). Conversely, the GH-breed showed better meat quality parameters (IMF, tenderness, meat colour) (*e. g*. IMF: GH 3.89 % *vs*. GS 2.47 %). The grazing system had a significant impact on only a few parameters (*e. g*. carcass weight, dressing percentage, fat colour). The higher quality of the CGS pasture means a higher grazing yield and a better feedstuff quality. This led to a slightly improved carcass weight. The level of concentrate had no significant effect on the compiled parameters.

During the supplementation period in P4 (28 d before slaughter) some animals consumed little or no concentrate and so animals with a total concentrate intake of less than 5 kg (level low) and 7 kg (level medium) were not considered in the statistical analysis. As a effect, our results showed a slight increase in the IMF-content in comparison to the results for meat quality stated by Schmutz *et al*. (2013).

No statistical significance was found in the first, second and third order interactions for the parameters under consideration in this study.

Fatty acids profile of pasture samples and concentrates

According to Table 2, the most abundant fatty acids are LA, ALA and palmitic acid. This is in accordance with Clapham *et al*. (2005) and Dewhurst *et al*. (2001) who found the same tendency in the species under investigation. The same authors also stated that harvest date and interval have a significant impact on PUFA levels and that the concentrations of fatty acids decline as plants develop and mature. This was the case for the RGS-pasture and explains the presence of the higher amounts of PUFA and n-3 fatty acids (especially ALA) in the CGS-pasture than in the RGS-pasture. These high contents implied high values of MUFA and n-6 fatty acids in RGS-pasture. Consequently, the n-6/n-3 ratio was twice as large in the RGS as in the CGS (0.47 *vs*. 0.20).

The botanical composition of the forage samples was not investigated further, but nearly all of the CGS was covered with perennial ryegrass and white clover. It should be noted that different botanical composition of both grazing systems could also explain the differences in their fatty acid composition.

In the concentrate mixtures in P4 (Table 2), higher levels of n-3 fatty acids (11.29 *vs*. 3.73) and lower levels of n-6 fatty acids (25.01 *vs*. 34.17) were detected in the linseed-oil concentrate than in the rapeseed-oil concentrate. Thus, the n-6/n-3 ratio was 2.2 in the linseed-oil concentrate and 9.2 in the rapeseed-oil concentrate. This is in accordance with the fatty acid composition of these oils. Thus, linseed oil presents a higher content of C 18:3 and lower content of C 18:2 than rapeseed oil (Noci *et al*. 2007, Pospišil *et al*. 2007). Additionally, the amount of oil present in the concentrate was higher for the linseed-oil concentrate than for the rapeseed-oil concentrate (4.9 % *vs*. 1.0 %).

Fatty acid intake

Using the reported values for the dry matter intake by animals according to Schmutz *et al*. (2013): during the P4 (grazing period) the CGS-group consumed twice as much linoleic acid from the pasture as the RGS-group (Figure 1-Graphic A). The same trend was observed for PUFA and n-3 fatty acids which were 1.5 and 2 times higher respectively. This is in line with the high n-3 fatty acid values detected in the CGS-pasture (Table 2). The ALA contribution of linseed-oil concentrate in the CGS-group was 2.6 % and in the RGS-group 4.8 %; rapeseed-oil concentrate contributed with 0.5 % and 1.0 % in CGS and RGS-group respectively (Figure 1-Graphic B and C). Most of the consumed n-3 PUFAs derived from the pasture. Therefore, only small differences were found in the fatty acid profiles due to the different types of concentrate.

Table 2
Fatty acid profiles (g/100 g FAME) during the last grazing period (P4) of pasture from the rotational and continuous grazing system also of concentrate with linseed and rapeseed oil

Fatty acid	Pasture type				Concentrate type	
	RGS Juli/August	RGS Sept/October	CGS Juli/August	CGS Sept/October	Linseed oil	Rapeseed oil
8:0	0.06	0.06	0.05	0.05	-	-
12:0	0.12	0.10	0.11	0.10	-	-
14:0	0.35	0.38	0.33	0.34	0.12	0.08
iso-15:0	0.14	0.10	0.14	0.39	-	-
anteiso-15:0	0.16	0.11	0.14	0.40	-	-
15:0	0.18	0.16	0.14	0.15	0.11	0.13
iso-16:0	0.08	0.05	0.07	0.19	-	-
16:0	13.80	15.39	13.93	14.08	20.24	17.86
16:1, 9*t*	-	0.14	0.06	0.12	-	-
16:1, 6*c*	1.29	1.53	2.78	2.73	-	-
16:1, 9*c*	0.64	0.46	0.31	0.31	0.24	0.23
iso-17:0	0.07	0.06	0.06	0.16	-	-
anteiso-17:0	0.08	0.06	0.07	0.12	-	-
17:0	0.19	0.21	0.16	0.13	0.23	0.18
17:1,9*c*	0.06	0.05	0.05	-	0.06	0.05
18:0	2.45	2.04	1.44	1.51	7.60	3.23
18:1, 9*t*	0.12	0.08	-	-	-	-
18:1, 9*c*	15.26	9.76	2.74	2.25	29.42	34.15
18:1, *c*11	1.47	1.03	0.34	0.28	1.54	1.98
18:2 n6 (LA)	20.85	20.07	13.74	11.98	25.01	34.17
18:3 n6	0.10	-	-	-	-	-
18:3 n3 (ALA)	37.66	43.33	59.60	60.95	10.99	3.45
20:0	0.42	0.39	0.16	0.17	0.50	0.42
20:1, 11*c*	0.33	0.22	0.05	-	0.32	0.66
21:0	0.06	0.05	0.06	-	-	-
20:2 n6	0.18	0.13	0.04	-	-	-
20:3 n3	-	-	-	-	0.31	0.29
20:3 n6	0.05	0.07	0.07	0.07	-	-
22:0	0.65	0.59	0.43	0.52	0.56	0.51
22:1	-	-	-	-	0.08	0.10
22:2 n6	0.16	0.26	0.15	0.17	-	-
23:0	0.11	0.05	-	-	-	-
24:0	0.65	0.56	0.39	0.54	0.47	0.46
24:1, 15*c*	0.18	0.42	0.31	0.23	0.19	0.06
22:5 n3 (DPA)	0.11	0.09	0.07	0.07	-	-
∑SFA	19.56	20.36	17.68	18.84	29.83	22.87
∑MUFA	19.22	13.48	6.59	5.80	31.86	37.24
∑PUFA	59.10	63.94	73.68	73.23	36.30	37.90
∑trans-FA	0.12	0.22	0.06	0.12	<0.05	<0.05
∑n-3	37.77	43.42	59.68	61.08	11.29	3.73
∑n-6	21.33	20.53	14.00	12.15	25.01	34.17

The sum of n-3 FAs=C 18:3n-3+C 18:4n-3+C 20:5n-3+C 22:5n-3+C 22:6n-3, the sum of n-6 FAs=C 18:2n-6+C 18:3n-6+C 20:3n-6+C 20:4n-6+C 22:4n-6, the sum of MUFAs=C 14:1+C 16:1+C 17:1+C 18:1 9c+C 18:1 11c+C 18:1 12c+C 20:1, the sum of trans-FAs=C 16:1 9t+C 18:1 9t+C 18:1 11t

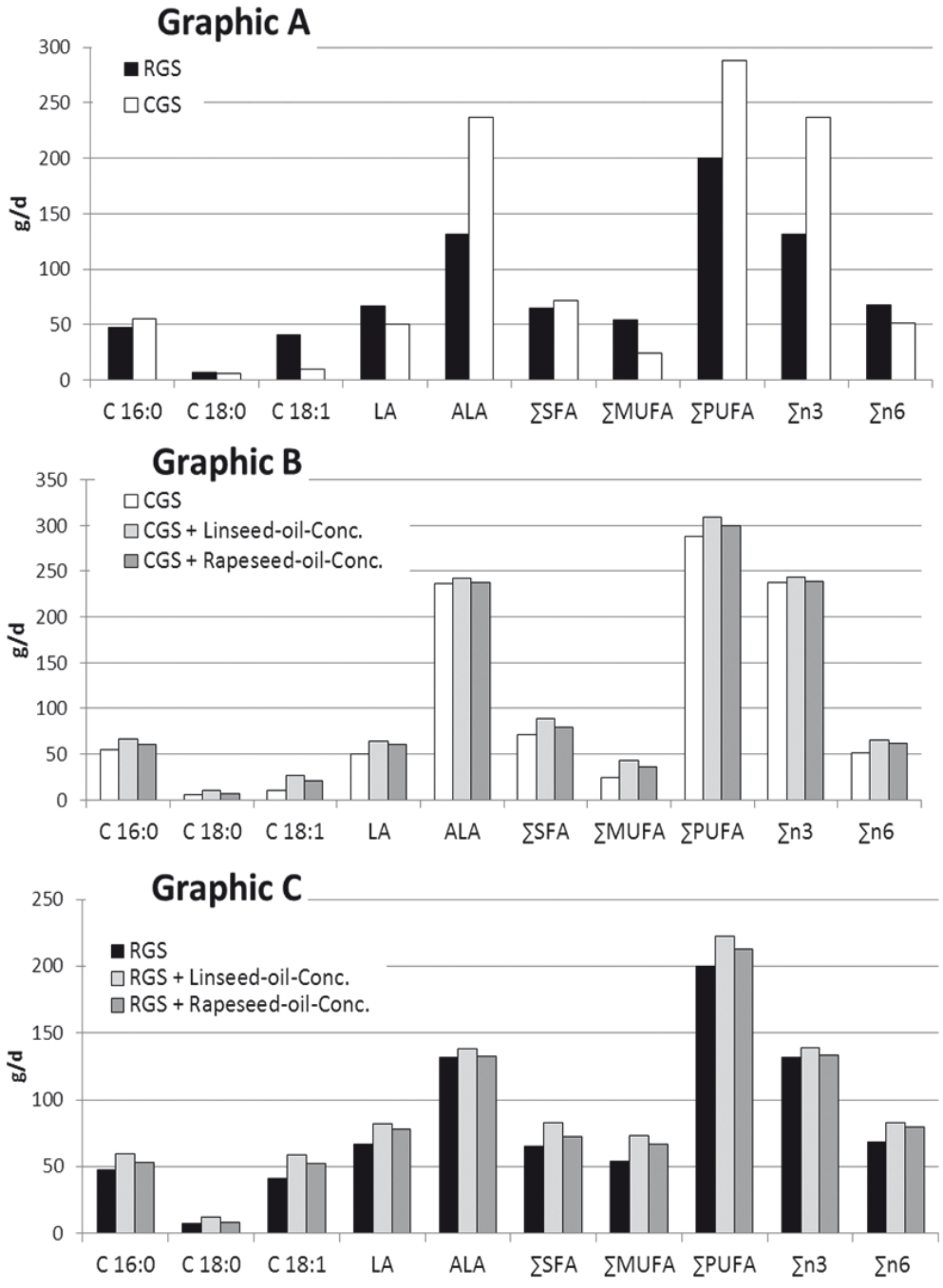

Figure 1
Calculated selected fatty acids intake (g/d/animal) according to the registered dry matter intake as forage and as concentrate (level medium) in Schmutz *et al.* (2013).
A: from RGS or CGS, B: with or without oil supplemented concentrate under CGS, C: with or without oil supplemented concentrate under RGS

Fatty acid profile in LD

The type of breed had a significant effect on most of the fatty acids of the LD. While the GH-breed showed high proportions of CLA, SFA and trans-FA, the GS-breed had significantly higher proportions of PUFA, n-3 (ALA, EPA, DPA, DHA) and n-6 (LA, C 18:3) fatty acids. Nevertheless, the GH-breed had a significantly lower n-6/n-3 ratio. This is in line with earlier research, which has shown that, in addition to nutritional factors, genetic factors are considered to contribute to differences in fatty acid composition (Scollan *et al*. 2006). Such differences between breeds occur due to a different gene expression or enzyme activity involved in fatty acid synthesis (De Smet *et al*. 2004). Differences between both breeds were also found in a study by Nuernberg *et al*. (2005) where German Simmental bulls showed higher proportions of n-6 and n-3 fatty acids and a higher n-6/n-3 ratio than German Holstein bulls. Choi *et al*. (2000) and Moreno *et al*. (2008) describe a significantly higher n-6/n-3 ratio in dairy breeds than in meat breeds.
Conjugated linoleic acid deposition is also influenced by breed (Costa *et al*. 2012, Shen *et al*. 2007) and is related to vaccenic acid variations (Shen *et al*. 2007). Small proportions of CLA pass through the rumen and the main proportion of CLA in the fat tissue derives from local biosynthesis by vaccenic acid and by the effect of the Δ9-desaturase enzyme (Costa *et al*. 2012, Baumann *et al*. 1999). So this explains the significantly low values of linoleic acid in the GH-breed which exhibit significantly high values of trans-vaccenic acid and CLA.

Grazing systems had a significant impact on few fatty acids. The CGS-group showed a significantly higher proportion of ALA and a significantly lower n-6/n-3 ratio in comparison with the RGS-group. As most of fatty acids stem from the microbiological synthesis in the rumen, the significant effects of grazing systems might possibly be explained by the differing rumen environments of the animals caused by different levels of raw fiber supply in pasture grass (raw fiber supply RGS>CGS, Schmutz *et al*. 2013). Razminowicz *et al*. (2006) found no evidence of the feeding practice having an influence on C 17:1, 18:1 12t and 22:1. The significant impact of grazing systems on the higher content of ALA and trans-vaccenic acid in the CGS-group is in line with the high content of ALA in the CGS-pasture. This heightened intake of ALA (Figure 1-Graphic A) might cause a higher proportion of ALA to be metabolized into trans-vaccenic acid and to then be accumulated in the intramuscular fat tissue; which leads to a significant lower n-6/n-3 ratio. In the case of C 22:1, its content in both grazing systems was probably different (which was not reported; Table 2) and caused the significant effect of grazing system on C 22:1 since this fatty acid is probably not subjected to the biological hydrogenation (Borgatti & Trigari 1979).

Neither the concentrate level nor the type of concentrate had a significant impact on the fatty acids of LD, with the exception of C 20:1, which was affected by type of concentrate ($P<0.05$). The group fed with rapeseed-oil concentrate showed higher C 20:1 values than the group fed with linseed-oil concentrate. This effect is in line with the high content of this fatty acid in the rapeseed-oil concentrate, which would give rise to only low-grade metabolism for this fatty acid in the rapeseed-oil concentrate group.

Table 3
Fatty acid profile (g/100 g FAME) of selected fatty acids of *musculus longissimus dorsi* of steers of the breeds GH and GS in relation to grazing system, concentrate level and type of concentrate (LS-Means [SEM])

	Breed		*P*	Grazing system		*P*	Concentrate level		*P*	Type of concentrate		*P*
Fatty acid	GH	GS		CGS	RGS		medium	low		linseed oil	rapeseed oil	
14:0	2.30 (0.06)	2.12 (0.05)	0.017	2.20 (0.10)	2.21 (0.12)	0.916	2.26 (0.05)	2.16 (0.07)	0.235	2.20 (0.06)	2.22 (0.06)	0.743
16:0	25.4 (0.2)	25.0 (0.2)	0.137	25.2 (0.2)	25.2 (0.2)	0.851	25.3 (0.2)	25.1 (0.2)	0.487	25.1 (0.2)	25.3 (0.2)	0.350
17:0	1.15 (0.02)	1.07 (0.02)	0.001	1.10 (0.02)	1.12 (0.02)	0.226	1.10 (0.01)	1.13 (0.02)	0.198	1.12 (0.02)	1.10 (0.02)	0.547
18:0	20.0 (0.3)	19.5 (0.3)	0.268	19.9 (0.3)	19.7 (0.3)	0.728	19.5 (0.3)	20.0 (0.4)	0.287	19.9 (0.3)	19.7 (0.3)	0.665
20:0	0.09 (0.002)	0.09 (0.002)	0.015	0.09 (0.002)	0.09 (0.002)	0.414	0.09 (0.002)	0.09 (0.003)	0.944	0.09 (0.002)	0.09 (0.002)	0.785
17:1	0.52 (0.008)	0.52 (0.008)	0.517	0.51 (0.008)	0.54 (0.008)	0.009	0.53 (0.007)	0.52 (0.010)	0.401	0.52 (0.008)	0.52 (0.008)	0.572
18:1 11*t*	3.14 (0.10)	2.69 (0.09)	0.001	3.05 (0.09)	2.78 (0.09)	0.048	2.88 (0.08)	2.95 (0.11)	0.652	3.02 (0.10)	2.81 (0.10)	0.113
18:1 9*c*	33.2 (0.4)	33.1 (0.4)	0.851	32.9 (0.4)	33.4 (0.4)	0.313	33.4 (0.3)	33.0 (0.5)	0.419	33.1 (0.4)	33.3 (0.4)	0.674
18:1 11*c*	1.12 (0.02)	1.20 (0.02)	0.004	1.15 (0.02)	1.17 (0.02)	0.369	1.17 (0.02)	1.16 (0.02)	0.742	1.14 (0.02)	1.19 (0.02)	0.062
18:1 12*c*	0.12 (0.004)	0.12 (0.003)	0.220	0.13 (0.003)	0.11 (0.003)	0.005	0.12 (0.003)	0.12 (0.004)	0.571	0.12 (0.003)	0.12 (0.003)	0.754
20:1	0.11 (0.112)	0.11 (0.112)	0.995	0.10 (0.006)	0.12 (0.006)	0.063	0.11 (0.005)	0.11 (0.007)	0.783	0.10 (0.006)	0.12 (0.006)	0.017
22:1	0.19 (0.009)	0.23 (0.008)	0.001	0.23 (0.009)	0.19 (0.008)	0.002	0.21 (0.007)	0.22 (0.010)	0.326	0.21 (0.008)	0.22 (0.008)	0.523
18:2 n-6 (LA)	2.39 (0.15)	3.26 (0.14)	0.000	2.84 (0.15)	2.80 (0.14)	0.829	2.74 (0.12)	2.90 (0.18)	0.446	2.81 (0.15)	2.83 (0.15)	0.941
18:3 n-6	0.04 (0.002)	0.06 (0.002)	0.000	0.05 (0.002)	0.05 (0.002)	0.812	0.05 (0.002)	0.05 (0.003)	0.777	0.05 (0.002)	0.05 (0.002)	0.469
18:3 n-3 (ALA)	1.45 (0.07)	1.78 (0.06)	0.001	1.72 (0.07)	1.50 (0.06)	0.015	1.56 (0.05)	1.67 (0.08)	0.274	1.61 (0.07)	1.62 (0.07)	0.899
18:2 9c11t (CLA)	0.56 (0.018)	0.50 (0.017)	0.006	0.54 (0.018)	0.51 (0.017)	0.213	0.54 (0.014)	0.52 (0.021)	0.552	0.55 (0.017)	0.51 (0.017)	0.109
20:3 n-6	0.21 (0.013)	0.29 (0.012)	0.000	0.25 (0.013)	0.25 (0.012)	0.626	0.25 (0.010)	0.25 (0.015)	0.621	0.25 (0.013)	0.25 (0.012)	0.795
20:4 n-6 (AA)	0.60 (0.047)	0.85 (0.046)	0.000	0.73 (0.047)	0.72 (0.045)	0.951	0.72 (0.038)	0.73 (0.055)	0.923	0.73 (0.046)	0.72 (0.046)	0.798
20:5 n-3 (EPA)	0.39 (0.029)	0.52 (0.027)	0.001	0.49 (0.029)	0.43 (0.028)	0.160	0.44 (0.023)	0.48 (0.034)	0.354	0.46 (0.028)	0.45 (0.028)	0.795
22:4 n-6	0.06 (0.004)	0.08 (0.003)	0.000	0.07 (0.004)	0.07 (0.004)	0.197	0.07 (0.003)	0.07 (0.004)	0.407	0.07 (0.004)	0.07 (0.004)	0.444
22:5 n-3 (DPA)	0.70 (0.041)	0.96 (0.038)	0.000	0.84 (0.040)	0.82 (0.039)	0.693	0.82 (0.033)	0.84 (0.048)	0.744	0.85 (0.040)	0.81 (0.039)	0.394
22:6 n-3 (DHA)	0.06 (0.005)	0.09 (0.005)	0.000	0.08 (0.005)	0.08 (0.005)	0.615	0.08 (0.004)	0.08 (0.006)	0.857	0.08 (0.005)	0.08 (0.005)	0.904
∑SFA	51.6 (0.4)	50.3 (0.3)	0.009	50.9 (0.4)	50.9 (0.4)	0.977	50.8 (0.3)	51.0 (0.4)	0.658	50.9 (0.4)	51.0 (0.4)	0.944
∑MUFA	38.2 (0.5)	38.0 (0.4)	0.808	37.8 (0.4)	38.4 (0.4)	0.293	38.4 (0.4)	37.8 (0.5)	0.333	38.0 (0.4)	38.2 (0.4)	0.633
∑PUFA	6.65 (0.34)	8.54 (0.32)	0.000	7.78 (0.34)	7.41 (0.32)	0.414	7.43 (0.27)	7.76 (0.40)	0.492	7.64 (0.33)	7.55 (0.33)	0.844
∑trans-FA	3.60 (0.11)	3.16 (0.10)	0.003	3.52 (0.11)	3.25 (0.10)	0.062	3.35 (0.09)	3.41 (0.13)	0.712	3.50 (0.11)	3.27 (0.10)	0.109
∑n-3	2.79 (0.14)	3.52 (0.13)	0.000	3.30 (0.13)	3.01 (0.13)	0.108	3.07 (0.11)	3.24 (0.16)	0.398	3.18 (0.13)	3.13 (0.13)	0.799
∑n-6	3.30 (0.21)	4.53 (0.20)	0.000	3.94 (0.21)	3.89 (0.20)	0.859	3.82 (0.17)	4.01 (0.25)	0.539	3.92 (0.21)	3.91 (0.20)	0.988
n-6/n-3 ratio	1.17 (0.02)	1.28 (0.02)	0.000	1.17 (0.02)	1.27 (0.02)	0.000	1.23 (0.01)	1.21 (0.02)	0.403	1.21 (0.02)	1.23 (0.02)	0.420
PUFA/SFA ratio	0.13 (0.007)	0.17 (0.007)	0.000	0.15 (0.007)	0.15 (0.007)	0.417	0.15 (0.006)	0.15 (0.008)	0.547	0.15 (0.007)	0.15 (0.007)	0.797

The sum of n-3 FAs=C 18:3n-3+C 18:4n-3+C 20:5n-3+C 22:5n-3+C 22:6n-3, the sum of n-6 FAs=C 18:2n-6+C 18:3n-6+C 20:3n-6+C 20:4n-6+C 22:4n-6, the sum of MUFAs=C 14:1+C 16:1+C 17:1+C 18:1 9c+C 18:1 11c+C 18:1 12c+C 20:1, the sum of trans-FAs=C 16:1 9t+C 18:1 9t+C 18:1 11t

Table 4
Fatty acid profile (g/100 g FAME) of selected fatty acids of kidney fat from steers of the breeds GH and GS in relation to grazing system, concentrate level and type of concentrate (LS-Means [SEM])

	Breed		*P*	Grazing system		*P*	Concentrate level		*P*	Type of concentrate		*P*
Fatty acid	GH	GS		CGS	RGS		medium	low		linseed oil	rapeseed oil	
14:0	2.78 (0.06)	2.81 (0.06)	0.651	2.81 (0.06)	2.78 (0.06)	0.706	2.83 (0.05)	2.76 (0.07)	0.443	2.77 (0.06)	2.81 (0.06)	0.609
16:0	24.5 (0.2)	24.9(0.2)	0.144	25.0 (0.2)	24.4 (0.2)	0.075	24.6 (0.2)	24.7 (0.3)	0.768	24.5 (0.2)	24.9 (0.2)	0.269
17:0 *iso*	0.50 (0.009)	0.49 (0.009)	0.580	0.48 (0.009)	0.52 (0.009)	0.002	0.50 (0.007)	0.49 (0.011)	0.307	0.50 (0.009)	0.50 (0.009)	0.997
17:0 *anteiso*	0.72 (0.012)	0.70 (0.011)	0.226	0.69 (0.012)	0.72 (0.011)	0.064	0.71 (0.010)	0.70 (0.014)	0.691	0.71 (0.012)	0.70 (0.012)	0.601
17:0	1.63 (0.02)	1.58 (0.02)	0.059	1.58 (0.02)	1.63 (0.02)	0.075	1.61 (0.02)	1.60 (0.02)	0.661	1.61 (0.02)	1.59 (0.02)	0.467
18:0 *iso*	0.17 (0.004)	0.16 (0.004)	0.097	0.16 (0.004)	0.17 (0.004)	0.016	0.17 (0.003)	0.16 (0.004)	0.714	0.16 (0.004)	0.17 (0.004)	0.375
18:0	33.6 (0.5)	33.5 (0.4)	0.900	34.0 (0.5)	33.1 (0.4)	0.147	33.5 (0.4)	33.6 (0.5)	0.958	33.8 (0.5)	33.3 (0.4)	0.473
20:0	0.25 (0.009)	0.25 (0.009)	0.875	0.24 (0.009)	0.26 (0.009)	0.033	0.25 (0.007)	0.25 (0.011)	0.597	0.25 (0.009)	0.25 (0.009)	0.796
16:1, 9*t*	0.10 (0.004)	0.09 (0.004)	0.276	0.10 (0.004)	0.09 (0.004)	0.004	0.09 (0.003)	0.09 (0.005)	0.919	0.10 (0.004)	0.09 (0.004)	0.460
17:1	0.32 (0.008)	0.31 (0.008)	0.408	0.29 (0.008)	0.33 (0.008)	0.002	0.32 (0.007)	0.31 (0.010)	0.483	0.31 (0.008)	0.32 (0.008)	0.498
18:1 9*c*	4.39 (0.13)	4.01 (0.12)	0.030	4.40 (0.13)	4.00 (0.12)	0.024	4.18 (0.11)	4.22 (0.15)	0.842	4.31 (0.13)	4.09 (0.13)	0.196
18:1 11*t*	22.9 (0.5)	22.8 (0.4)	0.854	22.0 (0.5)	23.8 (0.4)	0.004	22.9 (0.4)	22.8 (0.5)	0.938	22.8 (0.5)	22.9 (0.4)	0.784
18:1, *c*11	0.59 (0.017)	0.62 (0.016)	0.172	0.60 (0.016)	0.61 (0.016)	0.508	0.60 (0.013)	0.61 (0.019)	0.689	0.59 (0.016)	0.63 (0.016)	0.080
18:1, *c*12	0.13 (0.003)	0.14 (0.003)	0.203	0.14 (0.003)	0.13 (0.003)	0.009	0.14 (0.003)	0.13 (0.004)	0.111	0.13 (0.003)	0.13 (0.003)	0.822
20:1	0.06 (0.003)	0.07 (0.003)	0.520	0.06 (0.003)	0.07 (0.003)	0.023	0.07 (0.002)	0.06 (0.003)	0.219	0.06 (0.003)	0.07 (0.003)	0.309
18:2 9*t*12*c*	0.89 (0.021)	0.90 (0.020)	0.684	0.87 (0.021)	0.91 (0.020)	0.115	0.88 (0.017)	0.90 (0.025)	0.425	0.90 (0.021)	0.89 (0.020)	0.851
18:2 n-6 (LA)	0.92 (0.023)	0.99 (0.021)	0.041	0.98 (0.022)	0.93 (0.022)	0.080	0.97 (0.018)	0.94 (0.027)	0.388	0.94 (0.022)	0.97 (0.022)	0.261
18:3 n-3 (ALA)	0.83 (0.026)	0.88 (0.025)	0.171	0.92 (0.026)	0.79 (0.025)	0.000	0.85 (0.021)	0.86 (0.031)	0.818	0.84 (0.026)	0.87 (0.025)	0.479
18:2 9c11t (CLA)	0.39 (0.012)	0.38 (0.011)	0.316	0.38 (0.012)	0.39 (0.011)	0.575	0.39 (0.010)	0.38 (0.014)	0.912	0.39 (0.012)	0.38 (0.011)	0.889
20:3 n-6	0.038 (0.002)	0.044 (0.002)	0.021	0.04 (0.002)	0.04 (0.002)	0.165	0.04 (0.002)	0.04 (0.002)	0.374	0.04 (0.002)	0.04 (0.002)	0.900
22:1	0.05 (0.003)	0.06 (0.003)	0.194	0.06 (0.003)	0.05 (0.003)	0.051	0.06 (0.003)	0.06 (0.004)	0.692	0.06 (0.003)	0.06 (0.003)	0.534
20:5 n-3 (EPA)	0.06 (0.005)	0.07 (0.005)	0.188	0.06 (0.005)	0.06 (0.005)	0.757	0.07 (0.004)	0.06 (0.006)	0.225	0.06 (0.005)	0.07 (0.005)	0.393
∑SFA	66.5 (0.5)	66.9 (0.4)	0.542	67.4 (0.4)	66.0 (0.4)	0.023	66.7 (0.4)	66.7 (0.5)	0.945	66.7 (0.4)	66.7 (0.4)	0.894
∑MUFA	25.4 (0.5)	25.3 (0.5)	0.889	24.3 (0.5)	26.3 (0.5)	0.006	25.3 (0.4)	25.3 (0.6)	0.922	25.2 (0.5)	25.4 (0.5)	0.701
∑PUFA	2.24 (0.05)	2.35 (0.05)	0.111	2.39 (0.05)	2.21 (0.05)	0.007	2.31 (0.04)	2.28 (0.06)	0.648	2.27 (0.05)	2.33 (0.05)	0.343
∑trans-FA	5.89 (0.16)	5.51 (0.15)	0.075	5.88 (0.16)	5.52 (0.15)	0.089	5.67 (0.13)	5.73 (0.19)	0.792	5.82 (0.16)	5.58 (0.15)	0.249
∑n-3	0.89 (0.027)	0.95 (0.026)	0.117	0.98 (0.027)	0.85 (0.026)	0.000	0.92 (0.02)	0.92 (0.03)	0.967	0.90 (0.027)	0.93 (0.026)	0.396
∑n-6	1.04 (0.03)	1.10 (0.02)	0.071	1.10 (0.03)	1.05 (0.02)	0.144	1.08 (0.02)	1.06 (0.03)	0.534	1.06 (0.02)	1.09 (0.02)	0.290
n-6/n-3 ratio	1.19 (0.03)	1.18 (0.03)	0.772	1.13 (0.03)	1.25 (0.03)	0.003	1.20 (0.02)	1.17 (0.03)	0.447	1.20 (0.03)	1.18 (0.03)	0.620
PUFA/SFA ratio	0.03 (0.001)	0.04 (0.001)	0.163	0.04 (0.001)	0.03 (0.001)	0.060	0.04 (0.001)	0.03 (0.001)	0.583	0.03 (0.001)	0.04 (0.001)	0.339

The sum of n-3 FAs=C 18:3n-3+C 18:4n-3+C 20:5n-3+C 22:5n-3+C 22:6n-3, the sum of n-6 FAs=C 18:2n-6+C 18:3n-6+C 20:3n-6+C 20:4n-6+C 22:4n-6, the sum of MUFAs=C 14:1+C 16:1+C 17:1+C 18:1 9c+C 18:1 11c+C 18:1 12c+C 20:1, the sum of trans-FAs=C 16:1 9t+C 18:1 9t+C 18:1 11t

Fatty acid profile of the kidney fat

Similarly, the breed had a significant effect on the fatty acid profile of the kidney fat (Table 4) for C 18:1 9c, LA and C 20:3. The GS-breed had a significantly higher proportion of LA, which did not affect the n-6/n-3 ratio. Effects on LA and C 20:3 were also observed in the LD. The effect of breed on oleic acid might be attributed to the observed significant difference of the LA, as any consumed LA would be transformed into stearic acid in the rumen and finally metabolized into oleic acid by Δ9-desaturase in the fat tissue (Baumann *et al*. 1999).

The grazing systems affected the concentration of some fatty acids: C 17:0 iso, 18:0 iso, 20:0, 16:1 9t, 17:1, 18:1 9c, 18:1 11 t, 18:1 12c, 20:1, ALA, 22:1, as well as the parameters ∑SFA, ∑MUFA, ∑PUFA, ∑n-3 and the n-6/n-3 ratio. The CGS-group had a higher proportion of oleic acid, ∑SFA, ALA, ∑n-3 and ∑PUFA as well as a lower n-6/n-3 ratio. But the RGS-group presented a higher proportion of trans-vaccenic acid (C 18:1 11 t) and ∑MUFA. Concentrate levels and concentrate types had no significant effect on the fatty acids of the kidney fat.

The higher oleic acid level of LD compared to kidney fat could be due to a lower activity of the Δ9-desaturase in the kidney fat (Lee *et al*. 2011). The higher proportion of LA in the RGS-pasture could explain the significant difference in trans-vaccenic acid (CGS-group<RGS-group). The observed higher proportion of oleic acid in the kidney fat of the CGS-group is explained by the high ruminal transformation of LA into trans-vaccenic acid, which is then metabolized into oleic acid in the kidney fat as would be the case in RGS-group. Scollan *et al*. (2001) found that a higher content of ALA in the feedstuff leads to higher contents of ALA in the muscles and the subcutaneous adipose tissue. This could explain the higher proportion of ALA in the CGS-group.

According to Ashes *et al*. (1992) heavier and fattier carcasses have higher proportions of neutral fat, which mainly contains SFAs. So this might explain the significantly higher proportion of ∑SFA in the kidney fat of the CGS-group which had heavier and fattier carcasses (Schmutz *et al*. 2013).

It is remarkable that, with the exception of C 20:1 11c, neither the level of the concentrate nor the type of concentrate had a significant effect on the analysed fatty acids of LD and kidney fat. It is likely that the consumed concentrate was low and neither level M (275 kg/animal) nor level L (191 kg/animal) could influence the fatty acid profile. The considered proportions of plant-oils in concentrates were probably low and as such they were unable to cause differences in the studied fatty acid profiles.

Fatty acid profile of the meat (LD)

The IMF of the GH-breed was significantly higher than that in the GS-breed (4.1 *vs*. 2.4 %). Consequently, the GH-breed presented higher nutritionally relevant fatty acid values (ALA, CLA, EPA, DHA) in meat (Table 5). High IMF leads to a high CLA level in muscle (Moreno *et al*. 2008), which is mainly located in the neutral fats and rises with increasing fatness (Scollan *et al*. 2003, Noci *et al*. 2007).

The GH-breed showed a significantly higher proportion of SFA and trans-fatty acids but nevertheless a lower PUFA/SFA ratio. Both genotypes show a very tight n-6/n-3 ratio.

The CGS-group showed higher PUFA and n-3 values than the RGS-group, which can be attributed to the high values of these fatty acids in the CGS-pasture. Rich provisions of n-3 raise the amount of n-3 in the meat (Warren *et al*. 2008).

Table 5

Concentration of selected fatty acids (mg/100 g meat) in the *musculus longissimus dorsi* of steers of the breeds GH and GS in relation to grazing system, concentrate level and type of concentrate (LS-Means [SEM])

	Breed		*P*	Grazing system		*P*	Concentrate level		*P*	Type of concentrate		*P*
Fatty acid	GH	GS		CGS	RGS		medium	low		linseed oil	rapeseed oil	
IMF (%)	4.12 (0.18)	2.45 (0.17)	0.000	3.30 (0.18)	3.27 (0.18)	0.928	3.25 (0.15)	3.32 (0.22)	0.813	3.31 (0.18)	3.26 (0.18)	0.855
14:0	96.56 (5.8)	53.03 (5.3)	0.000	74.38 (5.6)	75.22 (5.5)	0.904	75.21 (4.4)	74.38 (6.6)	0.911	75.06 (5.7)	74.54 (5.5)	0.941
16:0	1054.35 (55.4)	615.71 (50.5)	0.000	834.07 (53.5)	835.99 (52.5)	0.977	827.38 (41.7)	842.67 (62.3)	0.828	836.69 (54.1)	833,36 (51.9)	0.960
17:0	47.52 (2.6)	26.30 (2.4)	0.000	36.86 (2.5)	36.97 (2.5)	0.972	36.27 (2.0)	37.56 (3.0)	0.695	37.43 (2.6)	36.39 (2.5)	0.734
17:1	21.57 (1.2)	12.72 (1.1)	0.000	16.81 (1.1)	17.48 (1.1)	0.623	17.14 (0.9)	17.15 (1.3)	0.996	17.37 (1.1)	16.92 (1.1)	0.745
18:0	828.67 (45.9)	476.95 (41.8)	0.000	660.29 (44.2)	645.33 (43.5)	0.780	639.93 (34.5)	665.68 (51.1)	0.655	662.65 (44.7)	642.97 (43.0)	0.714
18:1 11*t*	130.66 (8.4)	66.55 (7.7)	0.000	105.07 (8.1)	92.13 (8.0)	0.196	97.75 (6.3)	99.46 (9.5)	0.873	104.18 (8.2)	93.03 (7.9)	0.265
18:1 9*c*	1377.14 (72.0)	817.41 (65.5)	0.000	1092.26 (69.4)	1102.29 (68.2)	0.907	1089.56 (54.1)	1104.99 (80.8)	0.867	1099.41 (70.1)	1095.13 (67.4)	0.960
18:1 11*c*	45.49 (2.1)	28.90 (1.9)	0.000	36.85 (2.0)	37.55 (2.0)	0.779	37.10 (1.6)	37.29 (2.3)	0.945	36.53 (2.0)	37.87 (1.9)	0.591
18:1 12*c*	4.78 (0.26)	3.00 (0.24)	0.000	4.13 (0.25)	3.65 (0.25)	0.126	3.87 (0.20)	3.92 (0.30)	0.885	3.90 (0.26)	3.89 (0.25)	0.981
18:2 n-6 (LA)	89.14 (2.5)	74.27 (2.2)	0.000	81.93 (2.4)	81.48 (2.3)	0.881	80.63 (1.8)	82.78 (2.8)	0.506	81.15 (2.4)	82.25 (2.3)	0.716
18:3 n-6	1.64 (0.07)	1.28 (0.07)	0.000	1.46 (0.07)	1.46 (0.07)	0.990	1.46 (0.06)	1.46 (0.08)	0.967	1.50 (0.07)	1.42 (0.07)	0.395
18:3 n-3 (ALA)	55.77 (2.0)	41.27 (1.9)	0.000	51.84 (2.0)	45.21 (1.9)	0.009	47.57 (1.5)	49.47 (2.3)	0.476	48.44 (2.0)	48.61 (2.0)	0.946
20:0	3.86 (0.23)	2.10 (0.21)	0.000	2.98 (0.22)	2.98 (0.21)	0.993	2.91 (0.17)	3.05 (0.25)	0.627	3.01 (0.22)	2.95 (0.21)	0.817
18:2 9c11t (CLA)	23.38 (1.5)	12.27 (1.4)	0.000	18.65 (1.4)	17.01 (1.4)	0.359	18.03 (1.1)	17.62 (1.7)	0.830	18.76 (1.5)	16.90 (1.4)	0.298
20:1 11*c*	4.62 (0.32)	2.79 (0.29)	0.000	3.50 (0.30)	3.91 (0.30)	0.292	3.69 (0.24)	3.72 (0.35)	0.954	3.36 (0.31)	4.04 (0.30)	0.081
20:3 n-6	8.02 (0.24)	6.56 (0.22)	0.000	7.42 (0.23)	7.16 (0.23)	0.375	7.21 (0.18)	7.38 (0.27)	0.579	7.14 (0.23)	7.44 (0.22)	0.304
20:4 n-6 (AA)	21.61 (0.6)	19.27 (0.6)	0.003	20.45 (0.6)	20.43 (0.6)	0.984	20.70 (0.5)	20.18 (0.7)	0.520	20.48 (0.6)	20.40 (0.6)	0.914
22:1	7.36 (0.25)	5.49 (0.23)	0.000	7.01 (0.24)	5.84 (0.24)	0.000	6.23 (0.19)	6.62 (0.28)	0.232	6.28 (0.24)	6.57 (0.23)	0.342
20:5 n-3 (EPA)	14.39 (0.39)	11.97 (0.35)	0.000	14.04 (0.4)	12.31 (0.4)	0.001	12.74 (0.3)	13.61 (0.4)	0.104	13.27 (0.4)	13.09 (0.4)	0.714
22:4 n-6	2.19 (0.08)	1.81 (0.07)	0.000	1.93 (0.08)	2.07 (0.07)	0.149	1.99 (0.06)	2.01 (0.09)	0.847	2.04 (0.08)	1.96 (0.07)	0.403
22:5 n-3 (DPA)	26.20 (0.7)	22.13 (0.7)	0.000	24.46 (0.7)	23.87 (0.7)	0.523	24.05 (0.5)	24.28 (0.8)	0.819	24.46 (0.7)	23.87 (0.7)	0.516
22:6 n-3 (DHA)	2.32 (0.09)	2.06 (0.08)	0.035	2.15 (0.09)	2.23 (0.09)	0.480	2.23 (0.07)	2.15 (0.10)	0.528	2.17 (0.09)	2.21 (0.09)	0.763
∑SFA	2137.54(113.2)	1234.73(103.1)	0.000	1691.84(109.3)	1680.43(107.3)	0.932	1665.32(85.2)	1706.95(127.3)	0.771	1699.65(110.5)	1672.62(106.1)	0.839
∑MUFA	1580.71 (82.3)	937.56 (74.9)	0.000	1252.20(79.4)	1266.08(80.0)	0.887	1252.04(61.9)	1266.24(92.5)	0.893	1261.10(80.3)	1257.18(77.1)	0.968
∑PUFA	252.22 (7.0)	197.09 (6.4)	0.000	230.16 (6.8)	219.15 (6.7)	0.200	222.44 (5.3)	226.87 (7.9)	0.629	225.37 (6.9)	223.94 (6.6)	0.867
∑trans-FA	149.59 (9.4)	78.01 (8.6)	0.000	120.56 (9.1)	107.04 (8.9)	0.226	112.97 (7.1)	114.63 (10.6)	0.890	119.89 (9.2)	107.71 (8.8)	0.275
∑n-3	106.24 (3.1)	81.62 (2.8)	0.000	98.33 (2.9)	89.53 (3.0)	0.022	92.42 (2.3)	95.44 (3.5)	0.457	94.29 (3.0)	93.57 (2.9)	0.847
∑n-6	122.60 (3.1)	103.20 (2.8)	0.000	113.19 (3.0)	112.61 (2.9)	0.878	111.99 (2.3)	113.81 (3.5)	0.655	112.32 (3.0)	113.48 (2.9)	0.761
n-6/n-3 ratio	1.17 (0.02)	1.28 (0.02)	0.000	1.17 (0.02)	1.27 (0.02)	0.000	0.23 (0.01)	1.21 (0.02)	0.403	1.21 (0.02)	1.23 (0.02)	0.420
PUFA/SFA ratio	0.13 (0.007)	0.17 (0.007)	0.000	0.15 (0.007)	0.15 (0.007)	0.417	0.15 (0.006)	0.15 (0.006)	0.347	0.15 (0.007)	0.15 (0.007)	0.797

The sum of n-3 FAs=C 18:3n-3+C 18:4n-3+C 20:5n-3+C 22:5n-3+C 22:6n-3, the sum of n-6 FAs=C 18:2n-6+C 18:3n-6+C 20:3n-6+C 20:4n-6+C 22:4n-6, the sum of MUFAs=C 14:1+C 16:1+C 17:1+C 18:1 9c+C 18:1 11c+C 18:1 12c+C 20:1, the sum of trans-FAs=C 16:1 9t+C 18:1 9t+C 18:1 11t

As in the fatty acid profile of the LD, neither the concentrate level nor the type of concentrate had any impact on the levels of relevant healthy fatty acids in meat (ALA, EPA, DHA).

Healthy fatty acids in the meat (LD)

A portion of 200 g of meat (LD) from GH-breed provides 47 mg CLA. Moreno *et al*. (2008) obtained 38 mg CLA with a similar calculation. The obtained n-6/n-3 ratios are under the recommended ratio by the German Association for Nutrition (DGE 2008) (<5:1). This value is difficult to reach due to the ruminal biohydrogenation (Warren *et al*. 2008). In order to be allowed to use the label »source of omega-3 fatty acids«, the food has to contain at least 0.3 g/100 g of ALA or 40 mg/100 g as the sum total of EPA and DHA at a maximum energy content of 100 kcal (Regulation [EC] 1924/2006 and 432/2012). In the study only 17 % in the ALA and 40 % in the sum EPA+DHA of these recommendations were achieved (ALA: 56 mg [GH-breed], 41 mg [GS-breed]; sum of EPA+DHA: 17 mg [GH-breed], 14 mg [GS-breed]). So they do not qualify for nutrition and health related claims for beef produced under the conditions of the present study. A maximum of 60 mg ALA and 18 mg EPA+DHA for the GH-breed in the CGS-group was obtained. Warren *et al*. (2008) reported similar levels with 43 mg/100 g ALA and 24 mg EPA+DHA; and Nuernberg *et al*. (2002) reached 71 mg/100 g ALA. After considering the transformation rate of ALA into EPA (8-12 %) in the human body (Goyens *et al*. 2006), the value of EPA+DHA was 24 mg for GH-breed and 19 mg for GS-breed both in CGS-group.

The beef, besides milk and eggs, is the single natural source for long chain n-3 fatty acids for people who do not eat fish or fish products. In agreement to the results of our study, Nuernberg *et al*. (2002) and Razminowicz *et al*. (2006) determined that these products cover the human requirements only to a small extent. Hence it was possible to raise the proportions of nutritionally beneficial fatty acids in the meat of steers through a feeding practice based on small provisions of concentrate and high amounts of grass (grass silage and pasture).

In conclusion, in fattening steers fed with grass and grass products including limited supplementation of concentrate, both genotype as well as grazing system had an effect on the fatty acid profile of the LD and kidney fat. While the genotype primarily affected the fatty acid profile of LD, the grazing system critically influenced the fatty acid profile of the kidney fat. Concentrate level and type of concentrate did not have a decisive influence. In general, the contents of healthy fatty acids in the meat, especially n-3 fatty acids could be raised. However, the legal requirements for a corresponding marketing could not be met.

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