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Carcass- and meat quality of pasture vs concentrate fed German Simmental and German Holstein bulls

Abstract

Many factors affect ruminant carcass and meat quality, and among the genetic and environmental factors, feeding plays an important role in the determination of quality. In a large study, sixty-four German Holstein and German Simmental bulls were randomly allocated to either an indoor concentrate feeding system or periods of pasture feeding following by a finishing period. During this period the animals got a concentrate containing linseed to improve the meat quality for the consumer and enhance the contents of beneficial fatty acids in beef. German Simmental bulls grew faster in both feeding groups (concentrate and grass-based) compared to German Holstein bulls. Because of that significantly more days of fattening were necessary to reach the slaughter weight of 620 kg. The feeding system did not affect the carcass weights of both breeds. The results of cutting according to the regulations of the Deutsche Landwirtschaftsgesellschaft (DLG-Schnittführung für die Zerlegung der Schlachtkörper von Rind, Kalb, Schwein und Schaf) showed diet effects for different cuts. Pasture feeding significantly decreased the weights of flank, flat ribs and brisket of both breeds.

The intramuscular fat content of *longissimus* muscle was affected by the diet in the case of German Simmental bulls, only. The intramuscular fat content of *longissimus* muscle of pasture-fed German Simmental bulls was decreased to 1.5 % compared with concentrate-fed bulls (2.6 %). No diet effect was found in the intramuscular fat content of *longissimus* muscle of German Holstein bulls. The colour investigations of both muscles (*longissimus* and *semitendinosus*) showed that the beef produced by pasture feeding is darker. The Warner-Bratzler shear force values (WBSF) of pasture fed bulls were significantly higher compared to the concentrate fed bulls. Pasture feeding resulted in a significant increase in the concentration of *n*-3 fatty acids up to a factor of 2.8 in *longissimus* muscle of bulls compared with the concentrate feeding system.

Key Words: German Holstein bulls, German Simmental bulls, pasture, carcass quality, meat quality, fatty acids

Zusammenfassung

Titel der Arbeit: Schlachtkörper- und Fleischqualität von Bullen der Rassen Deutsches Fleckvieh und Deutsche Holstein bei verschiedenen Fütterungssystemen

Viele Faktoren beeinflussen die Schlachtkörper- und Fleischqualität beim Rind. In der Reihe der exogenen Faktoren spielt das Fütterungssystem eine wichtige Rolle zur Ausprägung der Fleischqualität. In einer großen Studie wurden 64 Bullen der Rassen Deutsche Holstein und Deutsches Fleckvieh nach dem Zufallsprinzip in vier Gruppen mit je 16 Tieren zusammengestellt. Je eine Gruppe der beiden Rassen wurde ausschließlich im Stall gefüttert und zwei weitere Gruppen (eine Gruppe je Rasse) wurden von April bis September auf der Weide gehalten und anschließend im Stall nachgemästet. Während der Nachmast wurde ein mit Leinsaat angereichertes Konzentratfutter gefüttert, das eine vorteilhafte Fettsäurezusammensetzung aufweist. Die Studie wurde durchgeführt, um eine Erhöhung der Gehalte von ernährungsphysiologisch wertvollen Fettsäuren im Rindfleisch zu erreichen und die Fleischqualität für den Verbraucher zu verbessern. Die Bullen der Rasse Deutsches Fleckvieh wuchsen in beiden Fütterungssystemen schneller im Vergleich zu den Deutschen Holstein Bullen. Aus diesem Grund war eine längere Fütterungsperiode für die Deutschen Holstein erforderlich, um das fixierte Schlachtgewicht von 620 kg zu erreichen. Das Fütterungssystem hatte bei beiden Rassen keinen Einfluss auf die Gewichte der Schlachtkörperhälften. Die Ergebnisse der Schlachtkörperzerlegung nach den Regeln der DLG-Schnittführung für die Zerlegung der Schlachtkörper von Rind, Kalb, Schwein und Schaf, zeigten fütterungsbedingte Effekte auf die Gewichte der Teilstücke. Die Weidehaltung führt zu einer Abnahme der Gewichte für Brust, Spannrippe, Knochen- und Fleischdünnung. Der intramuskuläre Fettgehalt des *Musculus longissimus dorsi* wurde nur bei den Deutschen Fleckvieh Bullen durch die Weidehaltung beeinflusst. Der

intramuskuläre Fettgehalt des *Musculus longissimus dorsi* verringerte sich bei den Weide-Bullen auf 1.5 % im Vergleich zum Fettgehalt der ausschließlich im Stall gehaltenen Bullen (2.6 %). Die Untersuchungen zur Fleischfarbe bei beiden Muskeln (*Musculus longissimus dorsi*, *Musculus semitendinosus*) zeigten, dass das Fleisch der Weide-Bullen dunkler ist. Bei den Ergebnissen zu den Scherwerten (WBSF) stellte sich heraus, dass das Fleisch der im Stall gehaltenen Bullen beider Rassen zarter ist im Vergleich zum Fleisch der Weidetiere. Weidehaltung führt zu einer signifikanten Erhöhung der *n*-3 Fettsäurekonzentrationen im Vergleich zur Stallhaltung.

Schlüsselwörter: Deutsche Holstein Bullen, Deutsche Fleckvieh Bullen, Weide, Schlachtkörperqualität, Fleischqualität, Fettsäuren

Introduction

Many factors affect ruminant carcass and meat quality and all of them can be divided into two categories: endogenous factors directly linked with the animal (breed, age, sex, etc.) and exogenous factors (diet, weather, slaughtering procedures etc.) indicated by the generic expression 'environmental'. Among the environmental factors, feeding plays an important role in the determination of quality.

Beef meat has gained the reputation of being less healthy and has often wrongly been identified as having a high fat and saturated fatty acids concentration. In fact lean beef meat is very low in fat (2-3 %). Fat, especially animal fat has been the subject of much interest and debate because of their implications for maintenance of human health and association with risks for some diseases when consumed in excess (ENDER et al., 1997). Fat is not only a concentrated source of energy for the body; the fat in meat provides flavour, aroma and texture. Fat is a carrier of the soluble vitamins A, D, E and K and the essential fatty acids, important in growth and in the maintenance of many body functions (BIESALSKI, 2005; VALSTA et al., 2005). Dietary fats are capable of acting on the composition, organisation and functions of membranes. Today it is known that not only the amount, but also the structure of the fatty acids plays a major role in maintaining health. In Germany it is recommended that human beings should increase their intake of *n*-3 fatty acids and decrease the *n*-6/*n*-3 ratio in the diet to levels $\leq 5:1$ (DGE, 2000). Animal experiments and clinical intervention studies indicate that a lower ratio of *n*-6/*n*-3 fatty acids in dietary fat is desirable in reducing the risk of many of the chronic diseases (PFEUFFER, 2001; SIMOPOULUS, 2002). Consumer's interest in the nutritional aspects of health is increased in the last years. Animal production practices, particularly the nutrient composition of the diet, can change the carcass- and meat quality, and fatty acid profile of meat (KREUTZER et al., 1995; LEIBETSEDER, 1996; FRENCH et al., 2001; REICHARDT et al., 2002; SCOLLAN et al., 2003; RAES et al., 2003; STOCKDALE et al., 2003; DEWHURST et al., 2003; DANNENBERGER et al., 2004; HOLLO et al., 2005; NUERNBERG et al., 2005).

Grass feeding has been reported to affect several meat quality characteristics of beef, in particular colour, flavour and fatty acid composition compared to concentrate diet systems (MOLONEY et al., 2001; PRIOLO et al., 2001; REICHARDT et al., 2002; STEEN et al., 2003; WOOD et al., 2003; VARELA et al., 2004; REALINI et al., 2004; KNOWLES et al., 2004; HOLLO et al., 2004; NUERNBERG et al., 2005). A pasture-based feeding system, including fresh and conserved forages and also occasional dietary supplements, leads to improved nutritional quality of meat from cattle to the consumers (KNOWLES et al., 2004). Pasture feeding and diets containing proportionally high level of linolenic acid in the fat, such as fresh grass and grass

silage resulted in increased deposition of *n-3* fatty acids in the muscles (FRENCH et al., 2001; SCOLLAN et al., 2003; STEEN et al., 2003; DANNENBERGER et al., 2004; NUERNBERG et al., 2005).

The objective of this study was to investigate the effect of different cattle breeds and different keeping systems to improve the meat quality for the consumer and enhance the contents of beneficial fatty acids in beef. The experiment included sixty-four beef cattle of two different breeds (German Holstein bulls and German Simmental bulls). One group of each breed was kept on pasture with finishing and the other group was maintained on concentrate indoor to investigate the influence of feeding on meat quality and fatty acid composition in muscle. This paper reports the effects of pasture vs. concentrate diet on carcass and meat quality of German Holstein and German Simmental bulls. The results of the experiment on aspects of fatty acid composition were recently published (NUERNBERG et al., 2005 and DANNENBERGER et al., 2003, 2004, 2005).

Materials and methods

Materials

Sixty-four bulls of two breeds (5-6 months old), German Simmental (n=31) and German Holstein (n=33) were randomly assigned to two dietary treatments, concentrate or pasture. German Simmental (n=16) and German Holstein bulls (n=17) fed on concentrate were kept in a stable and fed using single fodder workstations. The concentrate ration consisted of winter barley, molasses particles, soybean extraction particles, calcium carbonate, sodium chloride and a mixture of minerals and vitamins (Vollkraft-Mischfutterwerk, Güstrow, Germany). Forage component of the diet consisted of maize silage (13.8 kg/day), concentrated feed (3.2 kg/day), soybean extraction particles (0.15 kg/day), hay (0.1 kg/day) and straw (0.09 kg/day). German Simmental (15) and German Holstein (16) were kept on pasture during two summer periods (approximately 160 days) followed by indoor periods (approximately 190 days) when animals received semi *ad libitum* a high-energy diet. The latter consisted of wilted silage (15 kg/day), hay (0.7 kg/day), a mixture of minerals and a mixture of vitamins and a special concentrate diet containing 12 % barley, 10 % coarsely cracked linseed, and a mixture minerals and vitamins. The chemical composition including the fatty acid composition of the diets has been reported by NUERNBERG et al. (2005). All bulls were slaughtered as they reached 620 kg live weight by captive bolt stunning followed by exsanguinations in the abattoir of the Research Institute for the Biology of Farm Animals Dummerstorf (Germany). The carcasses were chilled for 24 h before sampling. The slaughter and dressing procedures were in accordance with EU specifications. *Longissimus* muscle samples for meat quality and fatty acid analysis were taken at the 6th-13th rib of the left carcass side 24 h after slaughter.

Methods

The cutting of the carcasses was carried out according to the regulations of the Deutsche Landwirtschaftsgesellschaft (DLG-Schnittführung für die Zerlegung der Schlachtkörper von Rind, Kalb, Schwein und Schaf) into 10 cuts. The pH value of the *longissimus* muscle was measured at 24 h post mortem by stabbing a pH-Star CPU (Matthäus, Klaus, Germany) into the left carcass side at the 7th/9th rib. The colour of the *longissimus* muscle was measured at 24 h with a Minolta CR 200 (Minolta GmbH,

Ahnsbeck, Germany) with triplicate measurements on a freshly cut surface using the parameter L^* (brightness). One section of *longissimus* muscle (2.54 cm) was conditioned at 2°C for 12 days under vacuum, and then cooked at 160°C in an oven for 75 minutes in an aluminium container. After cooling for 90 minutes at room temperature, 3-4 cores were cut from the steaks parallel to the muscle fibre orientation. The Warner-Bratzler shear force (WBSF) was measured with the Texture Analyser Winopal (Winopal, Ahnsbeck, Germany) with a Warner-Bratzler blade (2.8 mm wide).

Extraction of muscle lipids

The intramuscular fat of 2 g muscle was extracted with chloroform/methanol (2:1, v/v) according to FOLCH et al. (1956) by homogenization at room temperature. The details of muscle lipid extraction were described previously (DANNENBERGER et al., 2004; NUERNBERG et al., 2005).

Gas chromatography analysis

The fatty acid composition of muscle lipids, were determined by capillary gas chromatography using a CP SIL 88 CB column (100m x 0.25 mm, Chrompack-Varian, USA) installed in a Perkin Elmer gas chromatograph Autosys XL with a flame ionisation detector and split injection (Perkin Elmer Instruments, Shelton, USA). Initial oven temperature was 150 °C, held for 5 min, subsequently increased to 175 °C at a rate of 2 °C min⁻¹, held for 15 min, then to 200 °C at 7 °C min⁻¹, held for 20 min, then to 220 °C at 5°C min⁻¹ and held for 25 minutes. Hydrogen was used as the carrier gas at a flow rate of 1 ml min⁻¹. The split ratio was 20:1, the injector was set at 260 °C and the detector at 280 °C. The amounts were calculated using the internal standard method of Turbochrom workstation software (NUERNBERG et al., 2005).

A reference standard 'Sigma-FAME mixture' was obtained from Sigma-Aldrich (Deisenhofen, Germany). All solvents used were HPLC grade from Lab-Scan (Dublin, Ireland).

Statistical analysis

All data were analysed by the least-squares method using the GLM procedures with fixed factors feeding and breed (SAS)[®]. All tables contain the least squares means (LSM) and the standard error (SEM) of the LSM. All statistical tests of LSM were performed for a significance level $\alpha = 0.05$.

Results

Carcass composition and meat quality

The parameters of carcass composition are presented in Tables 1 and 2. The daily gain of grass-based bulls was significantly lower than that of the concentrate group; hence, they were significantly older at the slaughter weight of 620 kg. German Simmental bulls grew faster in both feeding groups (concentrate and grass-based) compared to German Holstein bulls. Because of that significantly more days of fattening were necessary for German Holstein bulls to reach the slaughter weight of 620 kg (Table 1). The live weight at slaughter ranged between 619 and 624 kg. The feeding system did not affect the carcass weights warm and cold, but the carcass weights of German Simmental bulls of both feeding systems were significantly higher compared with the

German Holstein bulls (Table 1). There were significant differences in the weights of organs. The weights of liver, kidney, and heart were significantly higher in bulls fed pasture compared with concentrate-fed bulls. The results of cutting according to the regulations of the Deutsche Landwirtschaftsgesellschaft (DLG-Schnittführung für die Zerlegung der Schlachtkörper von Rind, Kalb, Schwein und Schaf) showed diet effects for different cuts. Pasture feeding significantly decreased the weights of flank, flat ribs and brisket of both breeds. In the case of round of beef, sirloin and neck higher weights for both feeding systems were measured for German Simmental bulls (Table 2).

Table 1
Results of finishing and slaughter traits (Ergebnisse der Mast- und Schlachtleistung)

	German Holstein		German Simmental		Significance (P < 0.05)
	Concentrate	Pasture with finishing	Concentrate	Pasture with finishing	
	LSM _{SEM} (n=17)	LSM _{SEM} (n=16)	LSM _{SEM} (n=16)	LSM _{SEM} (n=15)	
Live weight (kg)	619.8 _{2.68}	624.0 _{2.76}	623.4 _{2.77}	620.2 _{2.86}	
Age of slaughter (d)	594.3 _{8.06}	732.1 _{8.31}	495.8 _{8.31}	680.2 _{8.58}	D, B, D*B
Days of fattening (d)	412.3 _{8.06}	550.1 _{8.31}	313.8 _{8.31}	498.2 _{8.58}	D, B, D*B
Gain in weight (kg)	474.4 _{4.46}	478.7 _{4.60}	435.3 _{4.60}	447.3 _{4.75}	B
Daily gain (kg/d)	1.15 _{0.02}	0.87 _{0.02}	1.40 _{0.02}	0.90 _{0.02}	D, B, D*B
Carcass weight (kg) (warm)	344.5 _{2.72}	347.5 _{2.81}	361.2 _{2.81}	352.3 _{2.90}	B, D*B
Carcass weight (kg) (cold)	339.2 _{2.68}	341.3 _{2.76}	355.3 _{2.76}	346.3 _{2.85}	B, D*B
Liver (kg)	7.45 _{0.14}	8.39 _{0.14}	6.47 _{0.14}	7.64 _{0.15}	D, B
Kidney (left) (kg)	0.64 _{0.02}	0.82 _{0.02}	0.52 _{0.02}	0.66 _{0.02}	D, B
Kidney (right) (kg)	0.66 _{0.02}	0.82 _{0.02}	0.50 _{0.02}	0.65 _{0.02}	D, B
Lungs (kg)	6.36 _{0.16}	6.94 _{0.16}	5.71 _{0.16}	5.45 _{0.18}	B, D*B
Heart (kg)	2.69 _{0.06}	2.79 _{0.06}	2.43 _{0.06}	2.67 _{0.07}	D, B

D – significant influence of diet, B – significant influence of breed, D*B – significant interaction of D*B

Table 2
Results of cutting following rules of DLG* (Ergebnisse der Schlachtkörperzerlegung nach DLG-Schnittführung)

	German Holstein		German Simmental		Significance (P < 0.05)
	Concentrate	Pasture with finishing	Concentrate	Pasture with finishing	
	LSM _{SEM} (n=17)	LSM _{SEM} (n=16)	LSM _{SEM} (n=16)	LSM _{SEM} (n=15)	
Hind shank (kg)	7.88 _{0.12}	8.05 _{0.13}	8.10 _{0.13}	8.14 _{0.13}	
Round of beef (kg)	43.7 _{0.46}	45.3 _{0.48}	47.1 _{0.48}	46.9 _{0.49}	B
Sirloin (kg)	12.3 _{0.19}	12.9 _{0.19}	14.8 _{0.19}	14.0 _{0.20}	B, D*B
Flank (kg)	21.0 _{0.43}	18.6 _{0.48}	21.0 _{0.48}	18.6 _{0.49}	D
Fore rib chuck (kg)	17.1 _{0.24}	16.9 _{0.25}	17.2 _{0.25}	17.5 _{0.26}	
Neck (kg)	18.4 _{0.44}	19.1 _{0.45}	20.6 _{0.45}	21.1 _{0.46}	B
Flat ribs (kg)	9.54 _{0.21}	8.86 _{0.21}	8.88 _{0.21}	8.21 _{0.22}	D, B
Brisket (kg)	12.2 _{0.24}	11.9 _{0.24}	12.4 _{0.24}	11.4 _{0.25}	D
Shoulder (kg)	21.2 _{0.29}	22.5 _{0.30}	21.8 _{0.30}	21.0 _{0.31}	D*B
Shin (kg)	5.47 _{0.10}	6.00 _{0.10}	5.68 _{0.10}	6.00 _{0.11}	D
Sum of cuts (kg)	168.8 _{1.27}	170.1 _{1.31}	177.7 _{1.31}	172.8 _{1.35}	B, D*B

DLG* - Schnittführung für die Zerlegung der Schlachtkörper von Rind, Kalb, Schwein und Schaf (see references)

For footnotes see Table 1

However, no feeding effect occurred in the weights of hind shank, fore rib chuck and shoulder as a result of cutting of all animals. Overall, the sum weights of all cuts showed a significant effect of breed, with higher weights (sum of cuts) in the case of German Simmental bulls compared with the values of German Holstein bulls (Table 2). The diet effect on sum weights (sum of cuts) resulted in a significant interaction of diet and breed, whereby the sum weight of pasture-fed German Holstein bulls tended to higher values, and the sum weights of pasture-fed German Simmental bulls were significantly lower compared with the values of concentrate-fed bulls (Table 2).

The results of meat quality investigations are shown in Table 3. The intramuscular fat content of *longissimus* muscle was affected by the diet in the case of German Simmental bulls, only. The intramuscular fat content of *longissimus* muscle of pasture-fed bulls was decreased to 1.5 % compared with concentrate-fed bulls (2.6 %). No diet effect was found in the intramuscular fat content of *longissimus* muscle of German Holstein bulls. The values ranged between 2.3 and 2.7 % for the pasture and concentrate group, respectively (Table 3).

Table 3

Meat quality parameter (NUERNBERG et. al., 2005) (Merkmale der Fleischqualität)

	German Holstein		German Simmental		Significance (P < 0.05)
	Concentrate	Pasture with finishing	Concentrate	Pasture with finishing	
	LSM _{SEM} (n=17)	LSM _{SEM} (n=16)	LSM _{SEM} (n=16)	LSM _{SEM} (n=15)	
pH ₂₄	5.76 _{0.04}	5.91 _{0.04}	5.85 _{0.04}	5.72 _{0.04}	D*B
Intramuscular fat (%) (<i>longissimus</i> muscle)	2.67 _{0.24}	2.30 _{0.2}	2.61 _{0.25}	1.51 _{0.26}	D
Intramuscular fat (%) (<i>semitendinosus</i> muscle)	1.85 _{0.17}	1.15 _{0.17}	1.34 _{0.18}	1.11 _{0.18}	D
Colour (L*) (<i>longissimus</i> muscle)	33.1 _{0.49}	29.2 _{0.51}	35.8 _{0.51}	35.2 _{0.53}	D, B
Colour (L*) (<i>semitendinosus</i> muscle)	37.8 _{0.52}	34.3 _{0.54}	38.6 _{0.54}	36.4 _{0.56}	D, B
Shear force (kg) (After 12 d conditioning) (<i>longissimus</i> muscle)	11.1 _{0.75}	14.3 _{0.78}	13.2 _{0.78}	15.9 _{0.80}	D, B

For footnotes see Table 1

The intramuscular fat content of *semitendinosus* muscle was lower compared to the contents of *longissimus* muscle in both breeds. However, the diet affected the intramuscular fat content of *semitendinosus* muscle. Pasture feeding significantly decreased the intramuscular fat content of *semitendinosus* muscle from 1.8 to 1.2 % in German Holstein bulls and from 1.3 to 1.1 % in German Simmental bulls compared to concentrate-fed bulls, respectively (Table 3). Muscle pH values showed significant interactions of breed and feed. Both, *longissimus* muscle and *semitendinosus* muscle colour was affected by the diet. The meat color investigations of the two muscles showed that the beef produced by pasture feeding of both breeds is darker compared with the beef produced by concentrate feeding. However, the meat colour of *semitendinosus* muscle was brighter as well as for German Holstein and German Simmental bulls at the two feeding systems compared with the meat colour of

longissimus muscle (Table 3). Furthermore, the shear force values were affected by the diet. Pasture feeding resulted in tougher meat for both breeds compared with the meat of concentrate-fed bulls (Table 3).

Fatty acid composition

The impact of diet on the concentration of fatty acids (mg/ 100g fresh muscle) of the *longissimus* muscle is presented in Table 4. The results of the experiment on aspects of fatty acid composition in different lipid fractions (total lipids, triglycerides and phospholipids), distribution of conjugated linoleic acids (CLA) and C18:1*trans* fatty acid isomers, eating quality and flavour have been reported by NUERNBERG et al. (2005) and DANNENBERGER et al. (2003, 2004, 2005, 2005a) recently.

Table 4

Fatty acid concentration (mg/100g fresh muscle) of intramuscular fat in *longissimus* muscle of German Holstein and German Simmental bulls (DANNENBERGER et al., 2005a) (Konzentrationen ausgewählter Fettsäuren (mg/ 100g frischer Muskel) im intramuskulären Fett des M. *longissimus* von Bullen der Rassen Deutsche Holstein und Deutsches Fleckvieh)

	German Holstein		German Simmental		Signif. (P ≤ 0.05)
	Concentrate LSM _{SEM} (n=17)	Pasture LSM _{SEM} (n=16)	Concentrate LSM _{SEM} (n=16)	Pasture LSM _{SEM} (n=15)	
C14:0	84.5 _{8.8}	51.9 _{9.1}	50.6 _{9.1}	30.3 _{9.4}	D, B
C16:0	870.6 ₇₄	531.9 ₇₆	616.3 ₇₇	350.1 ₇₉	D, B
C18:0	498.9 ₄₅	421.9 ₄₇	423.0 ₄₇	276.8 ₄₈	D, B
C18:1 <i>cis</i> -9	1361.0 ₁₁₂	786.7 ₁₁₅	976.8 ₁₁₅	496.1 ₁₁₉	D, B
C18:2 <i>n</i> -6	124.7 _{5.4}	87.2 _{5.6}	114.1 _{5.6}	77.3 _{5.8}	D
C18:3 <i>n</i> -3	11.0 _{1.6}	35.3 _{1.7}	10.9 _{1.7}	27.8 _{1.7}	D, B, D*B
C20:4 <i>n</i> -6	39.8 _{1.8}	27.2 _{1.8}	36.9 _{1.8}	28.2 _{1.9}	D
C20:5 <i>n</i> -3	3.6 _{0.4}	10.7 _{0.4}	1.7 _{0.4}	10.8 _{0.4}	D, B, D*B
C22:4 <i>n</i> -6	5.4 _{0.3}	2.0 _{0.3}	5.9 _{0.3}	2.1 _{0.3}	D
C22:5 <i>n</i> -3	9.7 _{0.5}	15.1 _{0.6}	6.2 _{0.5}	15.6 _{0.6}	D, B, D*B
C22:6 <i>n</i> -3	2.2 _{0.2}	2.7 _{0.2}	1.0 _{0.2}	2.0 _{0.2}	D, B
CLA <i>cis</i> -9, <i>trans</i> -11 ^a	17.1 _{1.7}	17.3 _{1.8}	13.3 _{1.7}	11.5 _{1.8}	B
Sum C18 :1 <i>trans</i> ^b	93.9 ₁₁	102.0 ₁₂	80.8 ₁₂	71.0 ₁₂	
Sum SFA ^c	1506.0 ₁₃₀	1047.0 ₁₃₃	1126.4 ₁₃₄	685.8 ₁₃₈	D, B
Sum PUFA ^d	223.3 ₁₀	196.4 ₁₀	199.8 ₁₀	177.1 ₁₁	D, B
Sum <i>n</i> -3 FA ^e	28.1 _{2.1}	65.1 _{2.2}	20.5 _{2.2}	57.3 _{2.3}	D, B
Sum <i>n</i> -6 FA ^f	181.7 _{7.2}	124.7 _{7.5}	167.7 _{7.5}	115.1 _{7.7}	D
<i>n</i> -6/ <i>n</i> -3 ratio	6.5 _{0.1}	1.9 _{0.2}	8.4 _{0.2}	2.0 _{0.2}	D, B, D*B

D – significant influence of diet, B – significant influence of breed, D*B – significant interaction of D*B

^a - coelution (CLA*trans*-7,*cis*-9 and CLA*trans*-8,*cis*-10)

^b - Sum of the isomers C18:1*trans*6-*trans*11

^c - Sum of C10:0+C11:0+C12:0+C13:0+C14:0+C15:0+C16:0+C17:0+C18:0+C20:0+C21:0+C22:0+C23:0+C24:0

^d - Sum of C14:1+ C15:1+ C16:1+ C17:1+ C18:1*trans*+ C18:1*cis*9+ C18:1*cis*11+ C18:2*trans*+ C18:2 *n*-6+ C18:3 *n*-3+C18:4 *n*-3+ C20:3 *n*-6+C20:4 *n*-6+ C20:5 *n*-3+ C22:1+ C22:4 *n*-6+ C22:5 *n*-3+ C22:6 *n*-3+ *cis*9,*tr*11CLA+ C18:3 *n*-6+ C20:2 *n*-6+ C20:3 *n*-3+ C22:2 *n*-6+ C24:1

^e - Sum of C20:3*n*-3+ C22:6*n*-3+ C22:5*n*-3+ C20:5*n*-3+ C18:4*n*-3+ C18:3*n*-3

^f - Sum of C22:2*n*-6+ C20:2*n*-6+ C18:3*n*-6+ C22:4*n*-6+ C20:3*n*-6+ C18:2*n*-6+ C20:4*n*-6

Pasture feeding resulted in a significant increase in the concentration of *n*-3 fatty acids compared with the concentrate feeding system. Linolenic acid (C18:3*n*-3) and eicosapentaenoic acid (C20:5*n*-3, EPA) showed a up to 3.2 and 6.3-fold increase, respectively, in the intramuscular fat of *longissimus* muscle of both breeds (Table 4). The concentrations of the longer chain *n*-3 fatty acids C22:5*n*-3 (DPA) and C22:6*n*-3 (DHA) were increased by pasture feeding compared with concentrate, however to a lower extent up to a factor of 2.5 (Table 4). In contrast, pasture feeding resulted in a

significant decrease in the concentration of *n*-6 fatty acids. The sum *n*-6 fatty acid concentration were decreased from 182 to 125 mg/100g fresh muscle and from 168 to 115 mg/100g fresh muscle in the intramuscular fat of *longissimus* muscle of German Holstein and German Simmental bulls, respectively (Table 4). Consequently, one important nutritional value, the *n*-6/*n*-3 ratio was beneficially low in pasture-fed bulls. The *n*-6/*n*-3 ratio in intramuscular fat of *longissimus* muscle was 6.5:1 and 1.9:1, 8.4:1 and 2.0:1 for concentrate and pasture fed bulls of both breeds, respectively (Table 4). In addition, the diet affected the concentration of saturated fatty acids (SFA) in the muscle. Pasture feeding resulted in a significant decrease of all investigated saturated fatty acids compared concentrate. Pasture feeding decreased the SFA concentration (sum) compared with the concentrate feeding system from 1506 to 1047 mg/100g fresh muscle (German Holstein) and from 1126 to 685 mg/100g fresh muscle (German Simmental). No diet effect was detected for the concentration of C18:1*trans* fatty acids, the values ranged between 71 and 102 mg/ 100g fresh muscle (Table 4). Also, the diet did not affect the concentration of CLA *cis*-9,*trans*-11 in the muscle. However, there was a significant influence of breed. The overall CLA *cis*-9,*trans*-11 level was higher in the *longissimus* muscle of German Holstein bulls (17.1 – 17.3 mg/ 100g fresh muscle) compared with the German Simmental bulls (11.5 - 13.3. mg/ 100g fresh muscle, Table 4).

Discussion

The specific effects of the dietary constituents on carcass and meat quality are not easy to evaluate (PRIOLO et al., 2001). The feeding system can have an influence on animal growth rate and its difficult to establish if the meat characteristics are due to the dietary components for their intrinsic properties or if the diet has influenced the growth rate and the body composition in animals (MUIR et al., 1998). There are differences in the diet effects on carcass and meat quality if the animals are slaughtered at different ages (same weight, but different growth rates) or at different weights (same age, and different growth rates), (PRIOLO et al., 2001).

Grass feeding has reported to affect several carcass and meat quality characteristics, in particular colour and flavour (SCHWARZ et al., 1998; MUIR et al., 1998; PRIOLO et al., 2001; PURCHAS et al., 2002; YANG et al., 2002; LANARI et al., 2002; ARTHUR et al., 2004; HOLLO et al., 2004; SCHNAECKEL et al., 2006). However, FRENCH et al. 2000 showed that when steers had a similar mean rate of carcass growth, pre-slaughter diet (autumn grazed grass, concentrates or grass silage) did not affect the sensory perception of meat quality. Furthermore, FRENCH et al. (2001) found no difference in the meat of steers fed grass or concentrates for colour, Warner-Bratzler shear force (WBSF) and any sensory attribute. The authors concluded that high carcass growth could be achieved on a grass-based diet without a deleterious effect on meat quality. Also, VESTERGAARD et al. (2000) showed, that a concentrate-based finishing period improved the meat and eating quality of animal raised at pasture. Recently, VARELA et al. (2004) confirmed these results of pasture-fed animals in measurements of the *longissimus thoracis* muscle of steers of the Rubia Gallega breed compared with concentrate diet (maize silage). The animals in these experiments were slaughtered at different weights and had the same age. In our experiment, all bulls were slaughtered as they reached 620 kg live weight (Table 1).

Growth performance of German Holstein and German Simmental bulls was lower on the grass-based system compared with concentrates. However, the diet did not affect the carcass weight of both breeds. The higher weights of liver, kidney and heart in pasture-fed bulls should be caused to the higher ages of pasture-fed bulls, approximately 160 days older compared with the concentrate-fed animals. HOLLO et al. (2004) found similar effects of pasture feeding compared to the concentrate feeding system for Hungarian Grey cattle bulls and Holstein Frisian bulls.

The intramuscular fat content of *longissimus* muscle of pasture-fed German Simmental bulls in our experiment was significantly decreased to 1.5 % compared with concentrate-fed bulls (2.6 %, Table 3). Also, YANG et al. (2002) and REALINI et al. (2004) found up to two-fold higher intramuscular fat contents in the *longissimus* muscle of concentrate-fed Hereford steers and Hereford-Frisian bulls, respectively, compared to the pasture-fed animals. The modification of beef production systems to substitute energy-dense concentrate ingredients with grass of lower energy concentration resulted in carcasses with lower intramuscular fat content. It is possible that bulls were unable to deposit sufficient lipid in the muscle to ensure consumer acceptability, with regard to flavour, toughness, and tenderness. However, no diet effect was detected in the intramuscular fat content of *longissimus* muscle of German Holstein bulls (Table 3). Recently, VARELA et al. (2004) also found that pasture feeding did not affect the intramuscular fat content of steers of the Rubia Gallega breed compared with a maize silage concentrate diet. However, these animals were slaughtered at the same age, and not if they reached a certain weight. The investigations made by FRENCH et al. (2000) confirmed these results, as described above. Furthermore, intramuscular fat could be responsible for a part of the differences in meat lightness found between animals raised in different production systems. Fat is lighter in colour than muscle and therefore its presence could contribute to an increased lightness value. Pasture feeding tends to produce darker meat (NUERNBERG et al., 2005; SCHNAECKEL et al., 2006). However, for this difference several factors more than a specific one seem to play a role (PRIOLO et al., 2001). The effect of pasture vs. concentrate feeding systems on beef meat colour (*longissimus* muscle) was investigated in many experiments and reviewed by PRIOLO et al. (2001). The meat from animals finished on pasture is darker than meat from concentrate-fed animals. Causes of this effect are difficult to evaluate because several factors, not a specific one are responsible for this differences. VARNAM and SUTHERLAND (1995) hypothesized that grass-fed animals have more muscle myoglobin, due to the higher physical activity compared to indoor kept concentrate fed bulls. Furthermore, meat colour is influenced by factors such as carcass fatness, pH value, animal age, carcass weight and intramuscular fat (PRIOLO et al., 2001). The colour measurements of *longissimus* and *semitendinosus* muscle in our experiment confirmed the described results of pasture-fed animals. The bulls of both breeds fed on the grass-based system including pasture showed a darker muscle colour than concentrate-fed animals (Table 3). Grass feeding was found to improve the stability of the meat resulting in improvements in colour and shelf life (NUERNBERG et al., 2005). This is related to the naturally high content of α -Tocopherol (vitamin E) in grass. This very important antioxidant helps to stabilise the fats and colour pigment in stored meat. Investigation of vitamin E supplementation of pasture-fed cattle showed, that the concentrations in fresh grass may be a good dietary source of α -Tocopherol

and can theoretically result in muscle saturation with α -Tocopherol. YANG et al. (2002) and SCHWARZ et al. (2003) found no further significant accumulation of muscle and liver α -Tocopherol contents during vitamin E supplementation of pasture-fed cattle. VESTERGAARD et al. (2000) measured a higher proportion of oxidative fibres and a darker meat colour in pasture fed young bulls compared to grain fed animals. Also, RAES et al. (2003) reported a paler colour in Belgian Blue beef (intensive fed) than Irish and Argentine beef (grass based).

The pasture-fed German Holstein and German Simmental bulls had tougher meat (*longissimus* muscle, after 12 d conditioning) compared with concentrate-fed bulls (Table 3). The WBSF values ranged between 11.1 and 13.2 kg for the *longissimus* muscle of concentrate-fed bulls, and between 14.3 and 15.9 kg for the *longissimus* muscle of pasture-fed bulls (Table 3). The values measured were high compared with other studies (FRENCH et al., 2001; RAES et al., 2003; VARELA et al., 2004). This may partly be due to different methodology compared with other published work (e.g. wide of the blade, a higher cooking temperature, a higher internal temperature), but furthermore bulls on the grass-based system were approximately 160 days older than the concentrate-fed animals and the intramuscular fat content of *longissimus* muscle was lower. It is recognised in the literature that age at slaughter influences tenderness. FRENCH et al. (2001) and VARELA et al. (2004) showed that pasture feeding had no effect on WBSF values of muscle compared with concentrate feeding system. However, these animals were slaughtered at the same age, and not if they reached a certain weight. FRENCH et al. (2001) investigated the meat quality from cattle finished on grass alone, on concentrates or on various combinations of both. There were no differences between diets for colour, WBSF values or sensory attributes in muscle. The authors calculated a negative correlation between WBSF values and carcass growth rate ($r=-0.31$). In our study the daily gain of the grass-based bulls was significantly lower than in intensive fed animals (Table 1). However, in contrast to the Irish experiment using steers (FRENCH et al., 2001) we did not find a relationship between daily gain and WBSF values ($r=0.08$), (NUERNBERG et al., 2005). Contrary to that, REALINI et al. (2004) measured only similar initial WBSF values of *longissimus* muscle of Hereford steers in pasture- and concentrate-fed animals despite differences in carcass weight. However, more intensive aging was evident in muscle from pasture-fed steers, which had lower WBSF values at 7 and 14 days of aging, than the muscle from concentrate-fed animals. A reduction in tenderness has been reported as age increased from 8 to 10 months in cattle (PURCHAS et al., 2002). WHEELER et al. (2002) calculated correlation coefficients between tenderness rating and total collagen of -0.12 (raw steak) and -0.45 (cooked steak) in beef *longissimus* muscle. Grass-based bulls in this study were approximately 160 days older than those fed concentrate and hence the differences in tenderness may reflect more collagen (NUERNBERG et al., 2005).

Pasture diet affected the concentration of fatty acids in different tissues of German Holstein and German Simmental bulls compared with the concentrate feeding system (DANNENBERGER et al., 2004; NUERNBERG et al., 2005; DANNENBERGER et al., 2005; DANNENBERGER et al., 2005a). Forages such as grass and wilted silage contain a high proportion of linolenic acid (C18:3n-3), typically 50 - 75 %, in the lipids. Despite the biohydrogenation of C18:3n-3 in the rumen, the linolenic acid was deposited at higher concentrations in muscle of bulls on the grass-based diet

(FRENCH et al., 2001; SCOLLAN et al., 2003; STEEN et al., 2003). Pasture feeding resulted in a significant increase in the concentration of *n*-3 fatty acids up to a factor of 2.8 in *longissimus* muscle of German Holstein and German Simmental bulls compared with the concentrate feeding system (Table 4). The increased concentrations of C20:5*n*-3, C22:5*n*-3 and C22:6*n*-3 in muscle of animals fed on grass suggests that the high availability of 18:3*n*-3 in the diet has resulted in an enhanced synthesis of the long chain *n*-3 polyunsaturated fatty acids. In contrast, pasture feeding resulted in a significant decrease in the concentration of *n*-6 fatty acids. Finally, the important nutritional value, the *n*-6/*n*-3 ratio, was beneficially decreased to lower than <5:1, hence achieving an important target with respect to human health (DANNENBERGER et al., 2004; NUERNBERG et al., 2005). Furthermore, the diet affected the concentration of saturated fatty acids (SFA) in the muscle. Pasture feeding resulted in a significant decrease of all investigated saturated fatty acids (Table 4). Consumption of selected saturated fatty acids has been associated with a rise of serum low-density lipoprotein cholesterol concentration to enhance the risk for coronary heart disease (YU et al., 1995). Palmitic acid (C16:0) is less potent than myristic acid (C14:0) in this regard (WILLIAMSON et al., 2005). Stearic acid (C18:0) has been shown to be neutral in its effect on plasma cholesterol in human (KRIS-ETHERTON et al., 2005). Strategies, which decrease the SFA concentrations in intramuscular fat of beef, would improve the healthiness of beef and contribute to better consumer acceptance of the product.

The results of this study demonstrated, that different diets and particularly longer periods of pasture feeding affect the carcass and meat quality of German Holstein and German Simmental bulls. The meat colour investigations of muscle showed that the beef produced by pasture feeding is darker. Beef produced by pasture feeding present meat with enhanced nutritional quality for the consumer resulted from a high accumulation of beneficial fatty acids (*n*-3 fatty acids) and lower concentration of saturated fatty acids and *n*-6 fatty acids compared with beef meat from a concentrate feeding system. However, pasture feeding led to a lower intramuscular fat content and a tougher meat for both breeds compared with the concentrate-fed bulls. Further research is needed to increase to intramuscular fat content of pasture-fed bulls and consequently improve the meat quality, with regard to toughness and tenderness and to ensure the consumer acceptability.

Acknowledgements

This work was funded by grants from the European Commission (Research project QRLT-2000-31423).

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Received: 2006-03-17

Accepted: 2006-05-19

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