Chemical composition, sensory characteristics, and fatty acid profile of muscle from Aberdeen Angus, Charolais, Simmental, and Hereford bulls

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ABSTRACT: Aberdeen Angus (AA), Charolais (CH), Simmental (SI), and Hereford (HE) bulls were used in two fattening experiments with the objective of determining breed differences in chemical composition, sensory characteristics, and fatty acid profile of *m. longissimus thoracis et lumborum*. The target slaughter live weights were set at 550 kg for earlier maturing breeds AA and HE and 630 kg for later maturing breeds CH and SI. Intramuscular lipid contents were higher in AA and HE ($P < 0.05$) than in CH and SI, but cholesterol contents were similar among the breed groups. The highest content of dry matter was found in HE ($P < 0.05$), while AA had the lowest protein content ($P < 0.001$). Meat from AA generally received the highest scores for different sensory characteristics (odour, flavour, texture, and juiciness). Concentrations of stearic acid (C18:0) in total muscle lipids were lower in SI than in CH ($P < 0.05$), while total saturated fatty acids were lower in SI compared to CH ($P < 0.001$) and AA ($P < 0.05$). CH had less oleic acid (C18:1-n9c) and total monounsaturated fatty acids than AA ($P < 0.05$), SI and HE ($P < 0.01$). Concentrations of linolenic acid (C18:3-n3) were highest in AA ($P < 0.01$).

Keywords: beef cattle; bulls; breeds; meat quality; sensory characteristics; fatty acid composition

In the last 15 years, major changes have taken place in beef consumption in the Czech Republic. While in 1990 the per capita consumption of beef was 30 kg, it was less than 10 kg in 2004 (Kvapilík, 2004). A similar, although less pronounced, decline can also be observed in other EU countries and in the USA. The changes in consumer demand for meat are affected by health concerns, changes in demographic characteristics, need for convenience, and changes in distribution and price (Resurreccion, 2004). Consumers consistently demand tender, flavourful meat with low fat content (Homer et al., 1997).

Compositional and sensory characteristics of beef are influenced by a number of factors (e.g. breed, slaughter weight, age of animal, diet, aging of meat). Differences in palatability traits and in the chemical composition of muscle between individual sire breeds were investigated by Wheeler et al. (1996, 2005). Meat quality of different beef breeds fattened to the same intramuscular fat content was examined by Chambaz et al. (2001, 2003).

The fatty acid composition of human diet fat has recently received increased attention due to its impact on health. Besides environmental effects, meat fatty acid composition is also influenced by genetic factors (De Smet et al., 2004). Laborde et al. (2001) suggested that a genetic basis for differences in fatty acid composition between Simmental and Red Angus breeds might exist. Selective breeding could be used to improve the fatty acid composition of intramuscular fat. Breed differences in fatty acid proportions were also reported in the subcutaneous and intramuscular fat of Aberdeen Angus and Wagyu steers (May et al., 1993), muscle phospholipids of Jersey and Limousin cattle (Malau-Aduli et al., 1998), intramuscular triacyglycerol and polar lipids of Aberdeen Angus and Simmental steers (Itoh et al., 1999), and intramuscular fat from crosses of Czech Fleckvieh and different beef breeds (Šubrt et al., 2001).

The objective of this study was to determine breed differences in chemical composition, fatty

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acid profile, and sensory characteristics of *musculus longissimus lumborum et thoracis* samples from bulls of the four currently most numerous beef breeds kept in the Czech Republic – Aberdeen Angus, Charolais, Simmental, and Hereford.

MATERIAL AND METHODS

Two separate fattening experiments were conducted in two years (EXP1 and EXP2). Each experiment initially involved 48 bulls of Aberdeen Angus (AA), Charolais (CH), Simmental (SI), and Hereford (HE) breeds. They were the progeny of a total of 28 sires used in natural service or in the system of artificial insemination. After weaning at approximately 8 months of age, the animals were loose-housed in 4 pens and given a mixed diet available *ad libitum* based on maize and lucerne silage and concentrates. The diet contained approximately 42% dry matter (DM), 0.145 kg crude protein/kg DM, 0.085 kg protein digestible in the small intestine (PDI-N)/kg DM, and 7.01 MJ net energy for growth (NEV)/kg DM. The bulls were weighed once a month to determine daily live weight gain. Eight bulls had to be removed from the experiment during the fattening period due to health problems (two CH and two HE in EXP1; one CH and three SI in EXP2). The target slaughter live weights were set at 550 kg for earlier maturing breeds AA and HE and 630 kg for later maturing breeds CH and SI. After reaching the target slaughter weights, the animals were transported to an abattoir and slaughtered following standard handling procedures.

After slaughter and a chill period of approximately 24 hours, samples of *m. longissimus lumborum et thoracis* (MLLT) were collected from between the 9th and 11th rib. Totally 87 samples (23 AA, 21 CH, 21 SI, and 22 HE) for the analysis of chemical composition were homogenized, and the content of crude protein was determined (Kjeltec AUTO 1030 Analyser). Dry matter content was determined by oven drying at 105°C to a constant weight. Dried samples were analysed for total lipids (petrol ether extract, Soxtec 1047) and ash (total ash; 6 h, 550°C). The cholesterol content of the homogenized MLLT samples was determined after extraction of total lipids according to the method of Folch et al. (1957). The lipids were saponified by a solution of potassium hydroxide in ethanol, and cholesterol was isolated by repeated extraction to diethylether. The isolated sterol fraction was analysed by gas chromatography with 5-alpha cholestane as the internal standard under isothermic conditions (carrier gas – nitrogen, 2 ml/min; temperature of inlet 285°C; split 1:50; temperature of oven 285°C; detector FID 295°C; GC HP5890 II; column SAC-5, 5% diphenyl, 85% dimethylpolysiloxane – 30 m × 0.25 mm × 0.25 μm).

The fatty acid (FA) composition (g/100 g total FA) of MLLT samples was determined only in EXP2 (samples from 11 AA, 11 CH, 9 SI, and 12 HE bulls). Total lipids were extracted as described by Folch et al. (1957), saponified by methanolic-potassium hydroxide, and the fatty acid methyl esters were separated to heptane. The isolated methylesters were quantified by gas chromatography (carrier gas – nitrogen, 1 ml/min; temperature of inlet 185°C; split 1:40; temperature programme of oven 150 to 230°C; FID detector 240°C; GC HP5890 II; column DB 23, cyanoprophyl-methylpolysiloxane – 60 m × 0.25 mm × 0.15 μm).

A total of 84 samples (22 AA, 21 CH, 19 MS, and 22 HE) for sensory evaluation were vacuum-packaged, aged for 4 days at approx. 4°C and then frozen at –18°C. After thawing, the samples were boiled in water in a closed container for 150 min. Sensory characteristics were assessed by 10 trained panellists. The panellists scored odour, flavour, texture, and juiciness using a 7-point scale (1 – worst, 7 – best). The averages of panellists' scores for each sample were used for statistical analyses. In addition, differences between early and late maturing breeds were evaluated using triangular tests. Each assessor received a set of three samples; two were alike (from the bull of one breed), and one was different (from the bull of another breed). The assessors had to report which of the three samples was different and, in addition, whether the overall liking of the different sample was higher or lower or there was no difference. The objective of these tests was to determine whether there are any differences in the overall liking between the breed combinations AA × CH, AA × SI, HE × CH, and HE × SI.

Statistical analyses were performed using the GLM procedure of SAS (SAS Institute Inc., 2001). Fixed effects of breed and year and interaction of breed × year were included in the model for the analyses of slaughter traits, chemical composition, and sensory evaluation. The model for fatty acid composition involved breed as a fixed effect and intramuscular fat content as a covariate. Differences between breed means were tested by Tukey's method.

The tables contain least-squares means (LSM), standard errors of the mean (SEM), and the significance level of the effect of breed.

RESULTS AND DISCUSSION

A summary of slaughter traits including slaughter weight, age at slaughter, and hot carcass weight is given in Table 1. Generally in agreement with the experiment design, later maturing (CH, SI) bulls were slaughtered at higher slaughter weights and had higher hot carcass weights than earlier maturing (AA, HE) animals. AA bulls reached their target slaughter weight at a lower average age due to exceptionally high live weight gains recorded in the period before weaning.

The results of the chemical analysis are shown in Table 2. The MLLT samples from AA and HE bulls had higher ($P < 0.05$) lipid contents than the samples from the other breeds. The highest content of dry matter was found in HE ($P < 0.05$), while AA bulls had the lowest protein content ($P < 0.001$). These results indicate that the increase in lipid concentrations was associated with the increased dry matter content and the decreased protein content, which is in accordance with the findings of Van Koevering et al. (1995). Similarly to our results, greater intramuscular fat deposition and less moisture in MLLT of AA and HE compared with SI and CH steers were reported by Gregory et al. (1994a). Higher percentages of lipids and lower percentages of moisture in MLLT were also found in Angus- and Red Angus-sired steers in compari-

Table 1. Slaughter traits

Trait	Breed								Pr > F
	AA (n = 23)		CH (n = 21)		SI (n = 21)		HE (n = 22)		
	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	
Slaughter weight (kg)	562.9^{a}	5.60	620.9^{b}	5.86	632.8^{b}	5.92	539.3^{c}	5.75	< 0.0001
Age at slaughter (day)	444.0^{a}	6.47	509.7^{b}	6.77	508.0^{b}	6.84	495.8^{b}	6.64	< 0.0001
Hot carcass weight (kg)	326.8^{a}	3.52	361.8^{b}	3.68	364.0^{b}	3.72	302.3^{c}	3.61	< 0.0001

Values with different superscripts (a,b,c) differ significantly ($P < 0.05$)

Table 2. Chemical analysis traits

Trait	Breed								Pr > F
	AA (n = 23)		CH (n = 21)		SI (n = 21)		HE (n = 22)		
	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	
Dry matter (g/kg)	258.4^{ab}	2.19	250.2^{a}	2.30	253.2^{a}	2.32	262.6^{b}	2.25	0.0012
Protein (g/kg)	206.0^{a}	0.81	212.0^{b}	0.84	212.9^{b}	0.85	210.6^{b}	0.83	< 0.0001
Lipid (g/kg)	34.3^{a}	2.45	24.2^{b}	2.57	24.1^{b}	2.59	33.9^{a}	2.51	0.0027
Ash (g/kg)	9.76	0.055	9.91	0.058	9.82	0.058	9.915	0.056	0.2014
Cholesterol (g/kg)	0.68	0.032	0.63	0.034	0.59	0.034	0.65	0.033	0.3005

Values with different superscripts (a,b) differ significantly ($P < 0.05$)

Table 3. Sensory analysis traits

Trait	Breed								Pr > F
	AA (n = 23)		CH (n = 21)		SI (n = 21)		HE (n = 22)		
	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	
Odour	5.83^{a}	0.063	5.58^{b}	0.064	5.47^{b}	0.068	5.58^{b}	0.063	0.0017
Flavour	5.75^{a}	0.062	5.41^{b}	0.064	5.28^{b}	0.067	5.46^{b}	0.062	< 0.0001
Texture	5.50^{a}	0.121	4.81^{b}	0.123	4.51^{b}	0.129	4.66^{b}	0.121	< 0.0001
Juiciness	5.20^{a}	0.090	4.79^{b}	0.092	4.68^{b}	0.096	5.00^{ab}	0.090	0.0009

Values with different superscripts (a,b) differ significantly ($P < 0.05$)

Table 4. Fatty acid composition (g/100 g FA)

Trait	Breed								Pr > F
	AA (*n* = 11)		CH (*n* = 11)		SI (*n* = 9)		HE (*n* = 12)		
	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	LSM	*SEM*	
C12:0	0.08	0.005	0.08	0.005	0.06	0.006	0.07	0.005	0.2207
C14:0	2.95	0.149	2.85	0.155	2.56	0.165	2.66	0.148	0.2741
C16:0	28.92	0.480	29.36	0.500	27.74	0.531	28.23	0.475	0.1310
C18:0	19.56^{ab}	0.537	21.10^{a}	0.559	18.57^{b}	0.593	19.80^{ab}	0.531	0.0282
C14:1-n9	0.44	0.038	0.34	0.039	0.38	0.042	0.42	0.037	0.2554
C16:1-n9	2.19	0.126	2.12	0.131	2.41	0.139	2.37	0.125	0.3742
C18:1-n9c	35.89^{a}	0.762	32.83^{b}	0.794	36.88^{a}	0.842	36.78^{a}	0.754	0.0030
C18:2-n6c	4.60	0.392	5.58	0.408	5.96	0.433	4.67	0.387	0.0715
C18:3-n6	0.03	0.017	0.07	0.018	0.03	0.019	0.04	0.017	0.3828
C20:3-n6	0.26	0.031	0.35	0.033	0.35	0.035	0.29	0.031	0.1429
C20:4-n6	1.10	0.106	1.32	0.111	1.30	0.117	1.09	0.105	0.3448
C18:3-n3	1.01^{a}	0.042	0.70^{b}	0.044	0.76^{b}	0.047	0.77^{b}	0.042	0.0001
C20:3-n3	0.04	0.004	0.03	0.004	0.04	0.004	0.04	0.004	0.2695
C20:5-n3	0.30	0.028	0.22	0.029	0.24	0.031	0.29	0.028	0.2095
C22:6-n3	0.05	0.004	0.05	0.004	0.05	0.005	0.05	0.004	0.7942
SFA[1]	51.43^{ac}	0.621	53.30^{a}	0.646	48.87^{b}	0.686	50.68^{bc}	0.614	0.0004
MUFA[2]	38.53^{a}	0.774	35.29^{b}	0.806	39.67^{a}	0.855	39.56^{a}	0.766	0.0015
PUFA[3]	7.39	0.590	8.31	0.615	8.73	0.652	7.23	0.584	0.2992
PUFA-n6[4]	5.99	0.529	7.32	0.551	7.65	0.584	6.09	0.523	0.1060
PUFA-n3[5]	1.40^{a}	0.070	0.99^{b}	0.073	1.08^{b}	0.078	1.14^{ab}	0.069	0.0019
PUFA/SFA	0.15	0.013	0.16	0.013	0.18	0.014	0.14	0.012	0.1889
PUFA-n6/n3	4.23^{a}	0.184	7.05^{b}	0.191	6.97^{b}	0.203	5.21^{c}	0.182	0.0001
Δ9-desaturase (16) index[6]	7.02^{ab}	0.299	6.67^{a}	0.311	7.96^{b}	0.330	7.65^{ab}	0.296	0.0240
Δ9-desaturase (18) index[7]	64.75^{ab}	0.890	60.87^{a}	0.927	66.47^{b}	0.983	64.97^{ab}	0.881	0.0012

Values with different superscripts (a,b,c) differ significantly ($P < 0.05$)

[1]SFA (saturated fatty acids) = C14:0 + C16:0 + C18:0

[2]MUFA (monounsaturated fatty acids) = C14:1-n9 + C16:1-n9 + C18:1-n9c

[3]PUFA (polyunsaturated fatty acids) = PUFA-n3 + PUFA-n6

[4]PUFA-n6 = C18:2-n6c + C18:3-n6 + C20:3-n6 + C20:4-n6

[5]PUFA-n3 = C18:3-n3 + C20:3-n3 + C20:5-n3 + C22:6-n3

[6]Δ9-desaturase (16) index = C16:1-n9/(C16:0 + C16:1-n9)

[7]Δ9-desaturase (18) index = C18:1-n9/(C18:0 + C18:1-n9)

son with the other breed sires including HE, SI, and CH (Wheeler et al., 2005).

In the present study, there was a slight tendency towards higher cholesterol levels in groups with higher intramuscular fat contents, but the differences in cholesterol between breeds were not significant ($P = 0.3005$). Similarly, the breed type was not significant for muscle cholesterol content in the studies of Eichhorn et al. (1986), Baker and Lunt (1990), and Gariépy et al. (1999). In contrast, Van Koevering et al. (1995) reported a positive relationship between intramuscular fat and cholesterol content of MLLT.

There were significant but generally small differences in sensory traits between breeds (Table 3). The meat from AA bulls received the highest scores

for odour ($P < 0.05$), flavour ($P < 0.01$), and texture ($P < 0.001$). Juiciness was scored higher in AA compared to CH and SI ($P < 0.05$), while HE were intermediate. Favourable sensory panel tenderness and juiciness scores for AA breed in comparison with HE, CH, and SI animals were reported by Gregory et al. (1994b), who also found high correlations between these scores and the percentage of intramuscular fat. Higher scores of juiciness are sometimes associated with higher levels of carcass fatness (Homer et al., 1997), which may also have been the case in our study. Similarly, poorer sensory ratings were achieved by large, late maturing CH steers than by small, early maturing, and fatter AA steers (Sinclair et al., 2001).

The results of triangular tests revealed that the assessors were able to recognize the different samples in 79, 83, 78 and 74% of comparisons when testing the pairs of breeds AA × CH, AA × SI, HE × CH and HE × SI, respectively. The comparisons of the overall liking (whether different samples are better, worse, or similar) corresponded to the results of the sensory evaluation given in Table 3. AA was better in 77%, CH in 13%, and no difference was found in 10% when the combination AA × CH was compared, while AA was better in 76%, SI in 14%, and no difference was found in 10% in the case of the combination AA × SI. When the breed combinations HE × CH and HE × MS were tested, the differences were less evident (HE better in 39%, CH better in 40%, no difference in 21%, and HE better in 45%, SI better in 29%, no difference in 26%, respectively).

The fatty acid composition of MLLT total lipids is presented in Table 4. Only the major fatty acids and fatty acid ratios are reported. Stearic acid (C18:0) was lower in SI compared to CH ($P < 0.05$), while AA and HE were intermediate. Total SFA calculated as the sum of myristic (C14:0), palmitic (C16:0), and stearic (C18:0) acid was lower in SI than in CH ($P < 0.001$) and AA ($P < 0.05$). Samples from CH had less oleic acid (C18:1-n9c) and total MUFA than AA ($P < 0.05$), SI ($P < 0.01$), and HE ($P < 0.01$). Both Δ^9-desaturase (16) and Δ^9-desaturase (18) indexes expressing the activity of Δ^9-desaturase enzyme were higher in SI than CH. Similarly to our results, SI steers tended to deposit less stearic acid and total SFA and more total MUFA in comparison with Red Angus steers in the study of Laborde et al. (2001). The authors suggested that the breed differences in fatty acid composition of total lipids might be due to the different activity of Δ^9-desaturase.

No significant differences were detected for individual polyunsaturated fatty acids except for linolenic acid (C18:3-n3), which was higher in AA than in CH ($P < 0.001$), SI ($P < 0.01$), and HE ($P < 0.001$). Similarly, AA had a higher sum of PUFA-n3 than CH ($P < 0.01$), SI ($P < 0.05$), and HE ($P = 0.0557$). These differences were reflected in a lower ratio of PUFA-n6/n3 in AA in comparison with the other breeds ($P < 0.001$). In agreement with our results, more C18:3-n3 in intramuscular triacylglycerides of Aberdeen Angus steers when compared to Simmental steers was reported by Itoh et al. (1999).

Generally, it can be concluded that there exist differences in the chemical composition and sensory characteristics of meat from bulls of different beef breeds. Early maturing breeds AA and HE produced MLLT with a higher content of intramuscular fat and received higher scores for sensory characteristics (particularly AA). Differences in fatty acid composition between breeds occurred mainly in concentrations of total SFA, MUFA, and PUFA-n3. The relative oleic acid muscle content and total MUFA were lower in CH than in the other breeds, while AA had higher concentrations of linolenic acid.

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