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EFFECT OF FEEDING INTENSITY AND TYPE OF ROUGHAGE FED TO LIMOUSIN BULLS IN THE FINISHING PERIOD ON SLAUGHTER TRAITS AND FATTY ACID PROFILE OF MEAT

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Abstract

The objective of the study was to determine the degree to which the intensity of feeding rations differing in the type of roughage affects fattening and slaughter traits, chemical composition, and fatty acid profile of intramuscular fat in m. *longissimus dorsi* (MLD) of bulls. A total of 36 Limousin bulls were assigned according to feeding level (I – intensive or SI – semi-intensive) to 3 analogous groups (with 6 animals per group) differing in the type of roughage fed (maize silage – MS or wilted meadow grass silage – MGS or pasture grass – PG). These feeds were supplemented with meadow hay (1 kg/day) and different amounts of concentrate (1.0 or 0.6 kg/100 kg of body weight). The feeding level had a significant (P < 0.05) effect on differences in the final body weight, daily weight gains, carcass weight after slaughter, bone content in 5 half-carcass cuts, and crude protein content in MLD. The meat of bulls fed meadow grass silage was characterized by considerably lower (P = 0.0001) total cholesterol content in MLD compared to the meat of bulls receiving maize silage or pasture grass. A high interaction (P = 0.0001) was also found for total cholesterol between feeding level and the type of roughage fed. When semi-intensive feeding was used, MLD was characterized by a tendency towards increased proportion of C 14:0, C 18:0, C 18:3 *n-3* and sum of CLA isomers and decreased proportion of C 18:2 *n-6* compared to intensive feeding. The MLD of bulls from the MGS and PG groups was characterized by a lower content of C 18:3 *n-6*, a higher content of C 18:3 *n-3*, EPA, DHA and sum of CLA isomers, and a narrower *n-6* PUFA to *n-3* PUFA ratio compared to the MLD of bulls from the MS group (P = 0.005–0.0001). Compared to the bulls from the MS and MGS groups, the bulls from the PG group had a lower (P<0.01) C 18:2 *n-6* content of MLD. In addition, high interactions (P = 0.009–0.0003) between the type of roughage and the feeding level were found for the C 14:0, MUFA and EPA content of MLD and the *n-6* PUFA to *n-3* PUFA ratio (P = 0.009–0.0003) as well as a significant interaction (P = 0.024) for the proportion of C 18:2 *n-6*.

Key words: Limousin bulls, roughage, feeding intensity, slaughter value, chemical composition of MLD, fatty acid profile

Modern feeding systems of young slaughter cattle are aimed at modifying not only the fat to meat ratio (Yang et al., 2002), but also the proportions of essential unsaturated fatty acids (EUFA), including conjugated linoleic acid (CLA) in cattle carcasses (Scolan and Wood, 2006). An important factor affecting the content of EUFA (including CLA) in milk and meat of ruminants is the type of diet as well as the content and type of dietary fat (Pisulewski et al., 2001). The possibility of modifying the EUFA content of beef through nutrition has not been studied as thoroughly as for milk (Jakobsen, 1993). In feeding young beef cattle, however, it is enough to use the supplement that modifies carcass fat composition in the finishing period only (Skjervold, 1993). Previous studies on the possibility of increasing the concentration of desirable fatty acids in the meat of fattened cattle through nutrition used feeds rich in unsaturated fatty acids, such as oilseeds (Stasiniewicz et al., 2000; Noci et al., 2005) or oil protected from ruminal biohydrogenation (Mir et al., 2004). One of the natural and economically viable ways of increasing the proportion of EUFA in beef is to reduce feeding intensity in the finishing period (Raes et al., 2004) and to increase the dietary proportion of roughages rich in the precursors of *n-3* polyunsaturated fatty acids (Marino et al., 2006). Diets formulated in this way have a more beneficial profile of fatty acids compared to diets with a large proportion of concentrates (Dannerberger et al., 2004). A special role in this regard has been attributed to the feed obtained from permanent grasslands, especially grasses and legumes found in meadow and pasture sward (Scolan and Wood, 2006). Compared to concentrates, pasture grass or grass silage have a higher content of *n-3* PUFA, which are desirable in the human diet, and are characterized by a more favourable *n-6* PUFA/*n-3* PUFA ratio (Dannenberger et al., 2004). As reported by Duckett et al. (1993) and Scollan and Wood (2006), the use of fresh or ensiled sward in the feeding of fattened cattle has a favourable effect on PUFA concentration in muscle fat. Whole-crop maize silage is a valuable roughage. It is commonly used by tradition in the intensive fattening of young beef cattle as it meets the requirements of younger animals for energy concentration and feed intake (Strzetelski and Osięgłowski, 2004). Nevertheless, efforts have recently been made to find nutritional methods for improving the dietetic properties of beef with regard to modern nutritional recommendations (Moloney et al., 2001; Mir et al., 2004). The excessive reduction of cattle feeding intensity during the finishing period, in which the amount of concentrate is limited, may be detrimental to fattening efficiency, slaughter traits and quality traits of meat (Berthiaume et al., 2006; Dannerberger et al., 2006).

These data suggest that the possibility of improving the dietetic properties of meat by feeding bulls on diets differing in both the type of roughage and the amount of concentrate in the finishing period has not been fully explained.

The objective of the study was therefore to determine the degree to which different intensity of feeding finishing Limousin bulls with diets containing either maize silage, meadow grass silage or pasture grass as the basal feed will affect fattening and slaughter traits, chemical composition of meat, and the profile of some fatty acids in the intramuscular fat of *m. longissimus dorsi* (MLD).

Material and methods

Experimental design, feeding and management of animals

A total of 36 Limousin bulls were investigated over a 70-day finishing period. During calfhood, bulls chosen for the experiment were reared with mothers for 6–7 months on a grass-clover pasture with sward height of 12–25 cm, using rotational grazing. At the end of the pasture season, the bulls reached 230–250 kg of body weight at weaning. From weaning to the beginning of the trial period, bulls received farm-produced feeds (silage, hay and concentrate) to obtain weight gains of approx. 1000 g/day.

The trial period was preceded by a 2-week preliminary period, in which animals were adjusted to a new dietary ration. Three groups with analogous body weights (6 animals per group) and differing in the type of roughage fed, were each subjected to two feeding levels: intensive (I) and semi-intensive (SI). During this period, the basic roughage was *ad libitum* maize silage (MS group), wilted meadow grass silage (MGS) or pasture grass (PG), cut from the early heading stage to the early flowering stage and transported daily to the trough. These feeds were supplemented with meadow hay (1 kg/day) and different amounts of concentrate. Depending on the feeding intensity, the amount of concentrate fed per animal per day was (in terms of 100 kg body weight): 1.0 kg in intensively fed groups (I) or 0.6 kg in semi-intensively fed groups (SI). Concentrate contained: ground barley (42%), ground wheat (20%), ground triticale (17%), rapeseed meal (15%), soybean meal (2%) and mineral-vitamin mixture (4%). During the trial, bulls were fed individually and the concentrate ration was changed every two weeks after the animals were weighed. During these periods, daily feed intake was recorded for 2–3 consecutive days. The energy and protein value of feeds (INRA units) and the percentage composition of concentrate were determined according to the IZ-INRA feeding system (2001), using WINWAR 1.6 (2000) and INRAtion 2.63 software (1999). Intensive rations were formulated to achieve bull weight gains of 1400 g/day and semi-intensive rations were formulated to achieve weight gains of 1000 g/day. Silage, pasture grass and concentrate were given twice daily, and meadow hay was given once daily after evening feeding. Throughout the trial, animals were kept in tie stalls equipped with automatic drinkers and partitions installed in troughs, with separate containers for concentrate.

Measurements, chemical analyses and statistical calculations

During the experiment, initial and final body weight of animals, body weight after a change of concentrate ration, and chemical composition and fatty acid profile of the feeds were determined. The chemical composition, total cholesterol and fatty acid profile of meat samples from MLD were determined after slaughter.

Basic chemical composition of the feeds was determined using the standard procedure (AOAC, 1990), and ADF and NDF fibre fractions in roughages according to Goering and van Soest (1970). Except lactic acid, VFA analyses in silages were performed and the profile of fatty acids in feed samples was determined with gas chromatography (Varian 3400, column CP-WAX 58, 25 m, 0.53 mm, 1.0 micron, FID detection, 260°C, range 11, helium as carrier gas, 6 ml/min, injector temperature

200°C), using an 8200 CX autosampler. Lactic acid was determined by high-performance liquid chromatography (HPLC) after centrifugation of water filtrates with 24% metaphosphoric acid using a Shimadzu chromatograph (column Nucleosil 250/4 – C 18, detector UV-Vis SPP-6 AV and autosampler SIL-10 AX). Analysis time was 17 min for determination of VFA content of silage and 65.4 min when fatty acid profile was determined in the other feeds. In both analyses, sample injection volume was 1.0 µl. pH of silages was determined using an Elwro N 5170 potentiometer. At the end of fattening, bulls were transported to a slaughterhouse, in which they were slaughtered after 24-hour feed withdrawal. Postmortem carcass analysis and dissection of 5 valuable cuts (fore ribs, shoulder, best ribs, rump steak, round) into meat, fat and bones were performed using a method developed at the National Research Institute of Animal Production. Meat was analysed for basic chemical composition using the standard procedure (AOAC, 1990), and total cholesterol using the colourimetric method (Korzeniowski et al., 1992). Fatty acid profile in MLD samples was determined by way of gas chromatography, using the same gas chromatograph and procedures as for the determination of the fatty acid profile in feed samples.

The cost of feeds used per kg weight gain was calculated based on the mean daily intake of feed in particular feeding groups, assuming feed prices from the fourth quarter of 2007 according to the Research Institute's own costs.

The results were analysed by two-way analysis of variance including interaction using the GLM procedure of the SAS package (1999/2001). Significance of differences between the MS, MGS and PG groups was determined using Duncan's test. Tabular values marked with different letters differ significantly ($P<0.05$), and those marked with the same letter or without letters denote non-significant differences ($P>0.05$).

Results

The nutrient content of the silages, pasture grass and meadow hay and their nutritive value (Table 1) corresponded to the values characteristic of medium-quality feeds. The fatty acid profile of the feed samples is presented in Table 2. The data show that meadow grass silage, pasture grass and meadow hay were characterized by lower content of MUFA and *n-6* PUFA compared to maize silage and concentrate. Compared to maize silage and concentrate, pasture grass, meadow grass silage and meadow hay were characterized by much higher concentration of *n-3* PUFA, narrower *n-6* PUFA to *n-3* PUFA ratio, as well as slightly higher SFA content. When the bulls were fed maize silage, daily nutrient intake (Table 3) was similar to the requirement specified by the IZ-INRA feeding standards (2001) for medium-early maturing beef bulls with a daily weight gain of 1400 g or 1000 g. Similar intake of dry matter and energy (UFV) as with maize silage feeding and higher intake of protein (PDI) were found in the groups receiving meadow grass silage or pasture grass. In the groups fed intensively (I), nutrient intake per kg weight gain was lower than for semi-intensive feeding (S-I). Likewise, better nutrient conversion per kg weight gain was observed in animals fed maize silage (MS) compared to animals receiving meadow grass silage

(MGS) or pasture grass (PG). Regardless of the feeding intensity used, the lowest cost of feed per kg weight gain (€1.24 on average) was found for pasture grass (PG) and the highest (€1.46) for maize silage (MS) feeding.

Table 1. Chemical composition (% DM) and nutritive value of the feeds

Components	Maize silage	Meadow grass silage	Pasture grass	Meadow hay	Concentrate
Dry matter	29.20	37.50	21.20	85.20	87.70
Crude ash	4.48	11.00	10.09	9.23	7.91
Crude protein	8.59	12.15	15.33	9.11	17.16
Crude fat	3.97	3.92	2.78	1.78	2.75
Crude fibre	19.83	29.36	24.81	34.19	6.36
N-free extractives	62.77	48.51	46.70	45.73	64.72
ADF	29.90	38.24	24.10	34.62	-
NDF	41.61	53.12	37.78	55.75	-
Lactic acid	7.68	3.25	-	-	-
Acetic acid	1.40	1.47	-	-	-
Butyric acid	0.14	0.16	-	-	-
Silage pH	3.67	4.70	-	-	-
Content in 1 kg DM:			-	-	-
UFV	0.82	0.72	0.80	0.66	1.05
PDIN (g)	52.1	73.3	99.1	56.3	116.3
PDIE (g)	65.4	60.8	89.6	66.9	111.3
P (g)	1.68	4.75	12.7	3.07	5.26
Ca (g)	2.70	9.76	30.7	6.33	0.81

Table 2. Fatty acid profile (% of total acids) in feeds

Fatty acids	Feeds				
	maize silage	grass silage	pasture grass	meadow hay	concentrate
SFA (sum)	12.46	19.74	23.04	27.70	11.39
C 14:0	0.17	0.31	0.54	0.69	0.21
C 16:0	8.39	16.20	18.70	19.87	9.89
C 18:0	1.56	1.42	1.349	2.68	1.12
UFA (sum)	87.54	80.26	76.90	72.29	88.61
MUFA (sum)	16.41	3.70	4.55	5.80	17.60
PUFA (sum)	71.14	76.56	72.35	66.49	71.00
C 18:2 *n-6*	66.83	30.38	24.60	31.49	65.12
C 18:3 *n-6*	0.035	0.084	0.075	0.121	0.014
C 18:3 *n-3*	3.89	45.88	44.77	34.68	4.68
PUFA *n-6*	66.86	30.47	24.68	31.61	75.46
PUFA *n-3*	3.89	45.88	44.77	34.68	4.68
PUFA *n-6/n-3*	17.19	0.66	0.55	0.91	16.12

The feeding level of the bulls had a significant effect ($P < 0.05$) on differences in the final body weight, daily weight gains, carcass weight after slaughter, bone content in 5 half-carcass cuts and crude protein content in MLD (Table 4). Higher values for these traits (except bone content) were found in the groups of bulls fed intensively compared to semi-intensive feeding ($P=0.036–0.0001$). No significant differences ($P > 0.05$) were found for the analysed parameters and chemical composition of MLD meat between the groups fed the different type of roughage. The intramuscular fat of MLD in the bulls fed meadow grass silage had a considerably lower (P = 0.0001) content of total cholesterol compared to maize silage or pasture grass feeding. A high interaction (P = 0.0001) was found for the cholesterol content of MLD between feeding level and the type of roughage fed.

Table 3. Mean daily feed and nutrient intake by the bulls and feed consumption and cost per kg weight gain

Item	Feeding level		Type of roughage[1]		
	I	S-I	MS	MGS	PG
Feed intake:					
wet roughages	17.3	21.2	16.0	15.2	26.6
meadow hay	1.0	1.0	1.0	1.0	1.0
concentrate	4.89	2.84	3.91	3.87	3.81
Nutrient intake:					
dry matter (kg)	9.92	9.35	9.18	9.91	9.81
crude protein (g)	1394.5	1204.8	1069.8	1357.3	1471.8
PDIN (g)	908.9	770.0	693.9	855.1	969.3
PDIE (g)	880.8	745.9	746.2	781.4	912.4
UFV	8.81	7.61	7.98	8.20	8.44
Conversion per kg weight gain:					
dry matter (kg)	7.44	9.58	8.10	9.01	8.42
crude protein (g)	1067.6	1233.7	930.7	1260.8	1261.1
PDIN (g)	695.2	787.8	601.9	792.8	829.9
PDIE (g)	672.4	763.9	650.2	723.5	780.7
UFV	6.73	7.81	6.98	7.61	7.21
Roughage to concentrate ratio (% DM)	57/43	72/28	63/37	65/35	65/35
Energy value of 1 kg DM (UFV/kg DM)	0.90	0.81	0.86	0.85	0.86
Cost of feeds per kg weight gain (€)	1.35	1.39	1.46	1.42	1.24

[1] MS – maize silage; MGS – meadow grass silage; PG – pasture grass.

No significant differences were found in the content of total SFA, UFA, MUFA and PUFA or in the content of some types of fatty acids, especially unsaturated acids in MLD, according to the feeding level applied (Table 5). However, compared to intensively (I) fed bulls, semi-intensively (SI) fed bulls showed a tendency towards higher content of C 14:0, C 18:0, C 18:3 *n-3* and total CLA isomers (P = 0.035–0.006), and lower content of C 18:2 *n-6* in meat. Greater differences were found in the composition of MLD fatty acids according to the type of roughage fed. Compared to animals fed maize silage, the meat of bulls receiving meadow grass silage or pasture grass had a greater content of *n-3* PUFA (including C 18:3 *n-3*, EPA and DHA), a lower proportion of C 14:0 and C 18:2 *n-6*, and a narrower *n-6* PUFA to *n-3* PUFA ratio (P = 0.005–0.0001). In the bulls receiving pasture grass, the content of total CLA isomers was much higher (P = 0.0001) compared to the other groups. In addition, high interactions (P = 0.009–0.0003) were found between the type of roughage and the feeding level for the C 14:0, MUFA and EPA content and for the *n-6* PUFA to *n-3* PUFA ratio.

Table 4. Production parameters of fattened bulls

Item	Feeding level		P	Type of roughage			P	SE	Interaction P
	I	S-I		MS	MGS	PG			
Initial body weight (kg)	438.7	437.6	0.853	440.3	436.3	437.8	0.858	17.81	0.983
Final body weight (kg)	532.2 a	507.2 b	0.029	521.7	516.5	520.7	0.8405	23.09	0.911
Days of feeding	70	70		70	70	70			
Daily weight gain (g)	1323.7 A	994.2 B	0.0001	1162.6	1128.4	1185.7	0.4906	117.00	0.1666
Carcass weight after slaughter (kg)	332.9 A	312.0 B	0.0001	328.7	319.2	319.4	0.0911	11.64	0.6878
Dressing percentage	62.55	61.55	0.083	62.98	61.80	61.39	0.069	1.67	0.776
Content in 5 half-carcass cuts (%):									
meat	77.63	76.82	0.203	77.64	76.69	77.34	0.443	1.85	0.695
fat	6.85	6.943	0.136	6.69	6.77	6.45	0.619	0.835	0.475
bones	15.52 b	16.75 a	0.010	15.66	16.53	16.20	0.293	1.349	0.182
Chemical composition of MLD (%):									
dry matter	24.07	23.93	0.522	23.97	24.23	23.80	0.317	0.683	0.276
crude ash	1.10	1.09	0.443	1.10	1.09	1.09	0.627	0.034	0.486
crude protein	22.33 a	21.85 b	0.036	22.10	22.17	22.01	0.831	0.657	0.525
crude fat	1.53	1.43	0.354	1.49	1.38	1.58	0.341	0.311	0.014
Total cholesterol in MLD (mg/100 g)	44.29	44.26	0.966	46.81 A	40.67 B	45.35 A	0.0001	2.152	0.0001

a, b – 0.01 < P < 0.05 A, B, C.

Table 5. Fatty acid profile (% of total acids) of the *m. longissimus dorsi* (MLD) of fattened bulls

Fatty acids	Feeding level		P	Type of roughage			P	SE	Interaction P
	I	S-I		MS	MGS	PG			
SFA (sum)	40.23	41.24	0.346	41.30	39.95	40.97	0.553	3.162	0.662
C 14:0	1.05 b	1.32 a	0.038	1.49 A	1.02 B	1.05 B	0.005	0.367	0.004
C 16:0	20.12	20.38	0.741	20.56	20.36	19.84	0.378	2.338	0.223
C 18:0	16.98 b	18.65 a	0.010	18.41	17.62	17.42	0.385	1.820	0.097
UFA (sum)	56.41	55.52	0.476	56.64	56.55	54.72	0.370	3.715	0.295
MUFA (sum)	34.76	35.14	0.779	33.05 b	34.35 ab	37.46 a	0.029	3.932	0.009
PUFA (sum)	21.60	20.58	0.520	23.84 A	22.20 A	17.23 B	0.005	4.704	0.216
C 18:2 *n-6*	16.48	13.66	0.082	17.88 A	16.87 A	10.47 B	0.001	4.697	0.024
C 18:3 *n-3*	2.027 B	2.487 A	0.006	1.515 B	2.46 A	2.71 A	0.0001	0.467	0.869
C 18:3 *n-6*	0.136	0.133	0.665	0.149 A	0.133 B	0.123 B	0.005	0.018	0.061
EPA (C 20:5 *n-3*)	0.576	0.647	0.276	0.383 C	0.632 B	0.818 A	0.0001	0.187	0.007
DHA (C20:6 *n-3*)	0.173	0.203	0.093	0.100 C	0.192 B	0.271 A	0.0001	0.055	0.043
PUFA *n-6*	18.40	16.97	0.354	20.99 A	18.79 A	13.31 B	0.0008	4.550	0.176
PUFA *n-3*	3.20	3.47	0.182	2.63 B	3.45 A	3.93 A	0.0001	0.588	0.029
PUFA *n-6/n-3*	5.86	5.54	0.395	8.10 A	5.57 B	3.43 C	0.0001	1.111	0.0003
CLA (1)	0.68 b	0.77 a	0.035	0.59 B	0.671 B	0.911 A	0.0001	0.122	0.085

(1)Sum of isomers CLA:c9t11, t10c12, c9c11, t9t11.

Discussion

The traits characterizing fattening and slaughter value of intensively fed bulls were similar to those obtained by Oprządek et al. (2002) for bulls of different meat breeds fed TMR diets. For semi-intensive fattening of bulls, the values of these traits were lower than those reported by the above authors. For Simmental bulls fattened intensively with maize silage diets, Dannenberger et al. (2006) and Sami et al. (2006) obtained similar fattening and slaughter traits and crude fat content of MLD to those obtained in our study for intensively fed Limousin bulls. The tendency towards higher fattening and slaughter traits and higher crude fat and crude protein content of meat from intensively fed bulls, found in the present study, is in agreement with the study of Berthiaume et al. (2006). These two studies showed that excessive reduction in the energy and protein concentration of the diet fed in the finishing period can negatively affect fattening and slaughter traits of beef cattle while reducing fattening efficiency. Much higher fat content of MLD dry matter (12.1–26.3%) compared to that obtained in our study was reported by Mir et al. (2004) for fattened cattle of different meat breeds (Wagyu, Wagyu × Limousin, Limousin) receiving farm-produced feeds. The total cholesterol content of MLD in bulls fed meadow grass silage, which was lower compared to that in animals receiving pasture grass or maize silage, was probably correlated with the lower crude fat content of the meat samples in these animals. Total cholesterol content of food products is strictly correlated with fat content (Rule et al., 2002), but meat fat content is a less important factor of atherogenicity compared to fatty acid profile, in particular the proportion of saturated fatty acids (Moloney et al., 2001). In our study, the introduction of meadow grass silage as the basal roughage produced a lower proportion of saturated fatty acids (C 14:0) in MLD compared to maize silage feeding.

Our results on the fatty acid profile of MLD samples have confirmed that the type of roughage fed changes PUFA content in the meat of beef cattle. Similar total SFA and UFA to those obtained in our study for pasture grass or meadow grass silage feeding, and a similar tendency towards increased *n-3* PUFA content of MLD and decreased *n-6* PUFA/*n-3* PUFA ratio were also reported by Dannenberger et al. (2004) for the groups fed pasture grass compared to concentrate. It was shown that feed with a high proportion of long-chain *n-3* PUFA fatty acids, such as fresh or ensiled meadow grass is rich in C 18:3 *n-3* despite the low fat content (Dannenberger et al., 2004). This is evidenced in the present study by the more beneficial *n-6* PUFA to *n-3* PUFA ratios and higher content of *n-3* PUFA (including EPA and DHA) and sum of selected CLA isomers in the groups fed meadow grass or wilted grass silage compared to those fed maize silage. Pasture grass and grass silage are rich sources of linoleic acid (*n-6*), especially α-linolenic acid (*n-3*), i.e. substrates used for TVA and CLA production that also affect the activity of Δ^9-desaturase, which takes part in endogenous synthesis of CLA from trans 11 C 18:1 acid (Mir et al., 2004; Moloney et al., 2001). Likewise, O'Sullivan et al. (2002) showed that feeding beef bulls with grass silage or pasture grass compared to maize silage, increases the proportion of *n-3* PUFA and α-tocopherol antioxidants in intramuscular fat. These authors also reported that feeding cattle with grass silage had a favourable effect on meat colour stability and reduction of lipid oxidation in meat. Similar results as in our study for the feeding of beef cattle on fresh grass or grass silage were also obtained by Scollan and Wood (2006). They showed that compared to concentrates, grass forage increases not only the content of C 18:3 *n-3*, but also the content of EPA, DPA and DHA in muscle fat. This suggests that the type of ration affects rumen metabolism (including biohydrogenation) and the type of fatty acids synthesized by rumen microorganisms during lipolysis and hydrogenation of "dietary PUFA" to saturated fatty acids and acids with a small number of double bonds, despite the fact that part of dietary PUFA bypasses rumen and can be absorbed in unchanged form and deposited in muscle fat (Moloney et al., 2001; Dannenberger et al., 2005).

The higher *n-3* PUFA content, found in the bulls fed grass silage or pasture grass, compared to the animals fed maize silage, was probably due to the higher content of C 18:3 *n-3*, which is the main fatty acid in meadow grass silages and pasture grass while being the precursor of EPA (C 20:5 *n-3*) and DHA (C 22:6 *n-3*) in animal products (Marmer et al., 1984). Dymnicka et al. (2005) showed that the intramuscular fat of beef bulls (Charolais, Limousin and Hereford) fed grass silage with hay and concentrate had a higher content of health-promoting fatty acids compared to animals fed maize silage. Likewise, Sami et al. (2006) reported that the use of feed from permanent grasslands or mixed (roughage-concentrate) diets for fattening cattle increases the content of *n-3* PUFA in muscle tissues and reduces *n-6* PUFA compared to feeding diets with a high proportion of maize silage and concentrate.

The higher content of total CLA isomers in MLD of the bulls fed pasture grass compared to silages was probably due to better protection of PUFA (including C 18:2 *n-6*) against ruminal biohydrogenation. The best natural protection of PUFA against this process is provided by oilseeds or cell organelles (e.g. chloroplasts in grass), by which fat is enclosed and protected against rumen microflora (Oprządek et al., 2002; Scolan and Wood, 2006). Also, it cannot be ruled out that the higher CLA content of meat of the experimental bulls receiving pasture grass resulted from differences in the content of easily soluble sugars and easily digestible fibre in the grass fed, as indicated by Kelly et al. (1998). In the fermentation processes that take place during preservation (ensilage) of roughages, the content of these compounds decreases, which may adversely affect the rate of microbiological fermentation and thus the rate of CLA production (Stasiniewicz et al., 2000). The high concentration of rapidly soluble starch, sugars and easily fermentable fibre, present in fresh pasture grass, could also have a favourable effect on the rumen milieu. This reduces the biohydrogenation of unsaturated fatty acids and increases CLA production and flow to further parts of the digestive tract as well as CLA deposition in muscle tissue (Strzetelski and Stasiniewicz, 1999).

As shown by Lee et al. (2006) and Marino et al. (2006), the regulation of rumen processes using appropriate rations determines the content of and mutual proportions between individual fatty acids in muscle tissue. When analysing the effect of feeding intensity on the fatty acid profile of MLD, the results were not so conclusive as the findings of other authors (Marino et al., 2006). Compared to intensive feeding, the bulls fed semi-intensively were characterized by increased content of *n-3* PUFA (including C 18:3 *n-3*) and sum of CLA isomers in the intramuscular fat of MLD.

This is because the roughage to concentrate ratio in the diet affects the pH level of ruminal fluid and thus the type of rumen microorganisms that take part in the biohydrogenation and isomerization of unsaturated fatty acids (Lee et al., 2006). As a result, this contributes to changes in *de novo* synthesis of fatty acids in muscle tissue. This could also be due to the fact that compared to intensively fed animals, the animals fed semi-intensively had a higher intake of pasture grass and wilted grass silage, which are classified as feeds rich in *n-3* PUFA (C 18:3 *n-3*). Our study and studies by other authors (Dannenberger et al., 2004; O'Sullivan et al., 2002) suggest that these feeds have a higher content of desirable fatty acids than concentrate and maize silage, thus causing favourable differences in the composition of fatty acids in the muscle tissue of fattened animals (Scolan and Wood, 2006).

The present study shows that the modification of the fatty acid profile of beef is more effective when rations are differentiated for the type of roughage fed rather than for feeding intensity. The lower intensity of feeding finishing bulls diets containing (maize or grass) silage or pasture grass, meadow hay and concentrate, used in the present study, did not change the profile of desirable fatty acids in MLD as much as the type of roughage fed. Compared to intensive feeding, the bulls fed semi-intensively were characterized not only by the higher content of C 18:3 *n-3* and sum of CLA isomers in the intramuscular fat of MLD, but also by the higher content of saturated fatty acids (especially C 14:0) and poorer fattening and slaughter value. The meat of bulls receiving wilted grass silage was characterized by lower content of total cholesterol compared to the meat of bulls fed maize silage or pasture grass. High interactions were found between the type of roughage fed and the feeding level for the total cholesterol and C 14:0, MUFA and EPA content of MLD and the *n-6* PUFA to *n-3* PUFA ratio.

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Wpływ intensywności żywienia i rodzaju skarmianej paszy objętościowej w końcowym okresie opasania buhajków rasy Limousin na cechy rzeźne i profil kwasów tłuszczowych mięsa

STRESZCZENIE

Celem badań było określenie, w jakim stopniu intensywność żywienia buhajków dawkami zróżnicowanymi pod względem rodzaju paszy objętościowej wpłyną na cechy opasowe i rzeźne, skład chemiczny oraz profil kwasów tłuszczowych w tłuszczu śródmięśniowym m. *longissimus dorsi* (MLD). Doświadczenie przeprowadzono na 36 buhajkach, które w zależności od poziomu żywienia (I – intensywny lub SI – średnio-intensywny) przydzielono do 3 analogicznych grup (po 6 sztuk), różniących się rodzajem skarmianej paszy objętościowej (kiszonka z kukurydzy – MS, kiszonka z przewiędniętych traw – MGS lub zielonka pastwiskowa – PG). Pasze te uzupełniano sianem łąkowym (1 kg/dzień) i zróżnicowaną (1,0 lub 0,6 kg/100 kg masy ciała) ilością mieszanki treściwej.

Stwierdzono, że poziom żywienia wpłynął istotnie ($P < 0,05$) na zróżnicowanie końcowej masy ciała, dziennych przyrostów masy ciała, masy tuszy po uboju, zawartości kości w pięciu wyrębach półtuszy i zawartości białka ogólnego w MLD. U buhajków żywionych kiszonką z trawy łąkowej wykazano znacznie niższą ($P = 0,0001$) zawartość cholesterolu całkowitego w m. *longissimus dorsi* niż przy żywieniu kiszonką z kukurydzy lub zielonką pastwiskową. W odniesieniu do zawartości cholesterolu całkowitego zaobserwowano również wysoką interakcję ($P = 0,0001$) pomiędzy poziomem żywienia, a rodzajem skarmianej paszy objętościowej.

Przy stosowaniu średnio-intensywnego żywienia stwierdzono tendencję do zwiększenia zawartości w MLD C 14:0, C 18:0, C 18:3 *n-3* i sumy izomerów CLA oraz obniżenia udziału C 18:2 *n-6* w porównaniu z żywieniem intensywnym. W MLD buhajków grup: MGS i PG wykazano niższą zawartość C 18:3 *n-6*, a wyższą C 18:3 *n-3*, EPA, DHA, sumy izomerów CLA i zawężenie proporcji PUFA *n-6* do PUFA *n-3* w porównaniu z grupą MS ($P = 0,005–0,0001$). U buhajków grupy PG wykazano istotnie niższą ($P<0,01$) w porównaniu z grupami MS i MGS zawartość w MLD C 18:2 *n-6*. Ponadto, stwierdzono wysokie interakcje ($P = 0,009–0,0003$) pomiędzy rodzajem skarmianej paszy objętościowej a zastosowanym poziomem żywienia w odniesieniu do zawartości w MLD C 14:0, MUFA, EPA i relacji PUFA *n-6*/*n-3* ($P = 0,009–0,0003$) oraz istotną interakcję ($P = 0,024$) do udziału C 18:2 *n-6*.