ACTA SCIENTIARUM POLONORUM
ISSN 1644-0714
ISSN 2300-6145 (online)
www.asp.zut.edu.pl
Acta Sci. Pol. Zootechnica 14(1) 2015, 109–126

FATTY ACIDS PROFILE AND HEALTH LIPID INDICES IN THE *LONGISSIMUS LUMBORUM* MUSCLE OF DIFFERENT BEEF CATTLE BREEDS REARED UNDER INTENSIVE PRODUCTION SYSTEMS

Renata Pilarczyk, Jerzy Wójcik

West Pomeranian University of Technology, Szczecin, Poland

Abstract. The aim of this study was the comparison of the fatty acids profile and health lipid indices of the *longissimus lumborum* muscle from 86 bulls of the Charolais (CH), Limousin (LM), Simmental (SM), Salers (SL), Hereford (HE) and Red Angus (RA) breeds reared under intensive production systems. As compared with the meat from bulls of other investigated breeds, the meat from SM bulls contained significantly more ($P \leq 0.05$) polyunsaturated fatty acids such as C18:2*n*-6 cis (LA), C18:3*n*-3 (LNA), C20:3*n*-6 and C22:6*n*-3 (DHA), a lower percentage of SFA, a higher percentage of PUFA, *n*-6 PUFA and UFA, as well as significantly more C20:5*n*-3 (EPA) and *n*-3 PUFA compared with CH, RA and LM bulls. The meat from CH and RA bulls was characterized by a significantly lower total content of PUFA and *n*-6 PUFA also in comparison with the meat from LM, HE and SL bulls, however higher content of CLA compared with the LM and SL breeds. The most advantageous PUFA/SFA, UFA/SFA and h/H ratios, as well as AI and TI were characteristic of the meat from SM bulls.

Key words: beef, SFA, PUFA, CLA, atherogenic index, thrombogenic index

INTRODUCTION

For many years, fatty acid (FA) composition in meat-producing animals has received considerable interest in view of its implications for human health and

Corresponding author: Renata Pilarczyk, Department of Ruminant Science, West Pomeranian University of Technology, Doktora Judyma 10, 71-466 Szczecin, Poland, e-mail: renata.pilarczyk@zut.edu.pl

for meat quality characteristics [De Smet et al. 2004]. Dietary fat has had a bad image for many years, due to its association with obesity, raised serum cholesterol and illness. As a result, there is a general attitude that foods containing animal fats are simply to be avoided. Today, it is known that not only the amount, but also the structure of the fatty acids plays a major role in maintaining health. Increasing public awareness of the health benefits attributable to *n*-3 polyunsaturated fatty acids (PUFA) has stimulated interest in sources of these FA for human consumption. PUFA perform many vital functions in biological membranes and as precursors of a variety of lipid regulators of cellular metabolism. Certain PUFA are essential because they cannot be synthesised by mammals [Nuernberg et al. 2002]. Foods rich in *n*-3 FA, especially long-chain *n*-3 PUFA, have been shown to reduce the risk of many diseases, such as arteriosclerosis, coronary heart disease, inflammatory diseases and possibly behavioural disorders [Fredriksson Eriksson and Pickova 2007].

The ratios of PUFA/SFA, *n*-6/*n*-3 PUFA, hypocholesterolaemic/hypercholesterolaemic (h/H), atherogenic and thrombogenic indexes are widely used to evaluate the nutritional value of fat. Over the last decades, research has focused on the effects of individual FA upon lipid metabolism and prevention of coronary heart diseases. It is well documented that excessive intake of saturated fatty acids (SFA) in the human diet is related to the increase in plasma LDL–cholesterol and development of coronary heart disease, atherosclerosis, and cancer [Mensink and Katan 1992]. In contrast, monounsaturated fatty acids (MUFA) and PUFA have a number of associated health benefits [Williams 2000]. Ruminant meats are high in SFAs and low in unsaturated fatty acids (UFA), which raises consumers' concerns about the healthiness of beef meat.

Beef fat quality can be influenced by many factors, including breed or genotype, age or live weight, anatomical location, gender and nutrition [Monteiro et al. 2006, Zapletal et al. 2009]. The FA composition of the meat is largely influenced by the management system, such as finishing at grass, the proportion of roughages and the nature of the concentrates. Extensive research data from the last decade show that beef from animals finished on green fodder and silages (except for maize silage) has a lower content of intramuscular fat, but a higher proportion of nutritionally favourable *n*-3 PUFA and the *n*-6/*n*-3 PUFA ratio, than meat from animals fed on grain-based rations [Turner et al. 2015]. However, the most common strategy to produce meat animals, particularly beef cattle, is based on the intake of high levels of concentrate diets rich in cereals, at least in the finishing period [Pestana et al. 2012].

Only few studies evaluating the nutritional quality of meat of different breeds fattened in the same intensive conditions have been reported [Bureš et al. 2006, Cuvelier et al. 2006, Bartoň et al. 2008, Zapletal et al. 2009, Ugarković et al.

2013]. However, in these studies, the body weight of slaughtered animals did not exceed 650 kg and their age was not more than 24 months. Moreover, contradictory results have often been obtained. Most of the beef consumed in Europe comes from animals fattened intensively indoors, mainly from heavy body weight bulls and the research on such beef is more significant for consumers. An analysis of fatty acid profiles in the meat from animals slaughtered at over 650–700 kg body weight and an age of more than 25 months, that is, reared under typical intensive production system, is therefore fully justified, since such meat is often consumed by consumers. A consumer does not consume beef from experimental animals, cattle breeds slaughtered at exactly the same age, of the same body weight and, first of all, of the same fatness level. The consumer consumes the meat of animals from the typical production systems (for example, from intensive fattening to the high final body weight). In the present study, all bulls were of similar body weight (above 650–700 kg) and age (above 24–25 months), fed the same diet and exposed to the same environmental elements. This study allowed for the evaluation of breed effect on FA composition of beef from a typical intensive production system. Therefore, the aim of this study was the comparison of the health-related fatty acids profile and health lipid indices of the *longissimus lumborum* muscle of various beef breeds reared under intensive production systems and slaughtered at over 650–700 kg body weight.

MATERIAL AND METHODS

The research material comprised the meat samples from 14 Charolais (CH), 14 Limousin (LM), 14 Simmental (SM), 15 Salers (SL), 15 Hereford (HE) and 14 Red Angus (RA) bulls. The animals were kept on a commercial farm located in north-western Poland. On the farm, more than 1500 pure-bred nurse cows of the investigated breeds were kept, from which more than 700 bull calves (above 100 within each breed) were obtained from November to May. Meat from fourteen to fifteen bull calves of each breed, being the offspring of different sires, were randomly selected for the study. Bulls born from February to April 2010 remained with their dams until October, being fed entirely on maternal milk and grazing during this period. After weaning, the bulls were kept together indoors and fattened intensively to approx. 650–700 kg body weight at approx. 24–25 months of age. Mean age and body weight at slaughter of the Charolais, Limousin, Simmental, Salers, Hereford, and Red Angus bulls were 24.9 months and 727.2 kg, 24.8 months and 705.9 kg, 24.5 months and 654.2 kg, 24.9 months and 652 kg, 24.7 months and 651.5 kg as well as 24.6 months and 657.6 kg, respectively.

The bulls were fattened and remained together in the free-stall barn with an outside run, which was located along the long wall of the building. There was a

trough for mechanical feeding situated along the outer edge of the run, along its entire length. All bulls were fed identically. The fattening bulls were fed concentrate, crushed barley, maize silage and hay ad libitum.

Samples of the *longissimus lumborum* muscle were collected from the same site between the 12th and 13th rib of the right side of each carcass 24 h post-slaughter, packaged and stored at –20°C in polypropylene containers filled to a maximum capacity with the research material in order to minimize the amount of air coming into contact with the sample. Before analysis, the containers with their content were thawed, the upper layer of meat (approx. 1 cm) was removed and the material was taken from deeper layers, better protected against potentially possible process of unsaturated fatty acids oxidation.

Weighed amounts of approx. 500 mg were placed in 7.5 ml screwed vials made from orange glass and equipped with a Teflon seal. Five ml of chloroform was added to each vial, next nitrogen 5.0 was added and in the continuous stream of this gas, the vials were closed and subjected to intensive shaking for 3 hours. To separate chloroform phase from non-lipid residues, the vials were centrifuged for 20 min (2000 RPM). The extraction stage was repeated in an identical way twice and the obtained extracts were combined. The chloroform phase in an amount corresponding to approx. 5 mg of extracted lipids was collected to 4 ml orange glass vials. Next, they were closed using the Mininert® Valves (SUPELCO) enabling the performance of all operations (including the dosage of derivatizing agents) in the atmosphere of neutral gas, without the need for opening the vials. The chloroform was evaporated from the extracts in a nitrogen stream. Next, 400 µl of 0.5 M KOH solution in methanol was added to the solid residue and incubated for 20 min in a heat block at 80°C. After cooling, 500 µl of 14% boron trifluoride (BF_3) solution in methanol was added to the vials and incubated at 80°C for 35 min. To extract fatty acids methyl esters (FAME), 1 ml of a saturated NaCl solution and 2 ml of isooctane (as an extractant) were added to the cooled vials, which were shaken intensively for an hour and left for half an hour until the phase separation. The upper isooctane layers were collected to the separate vials containing approx. 0.5 g anhydrous sodium sulfate (Na_2SO_4) and, after filling the vials with nitrogen, they were left for 2 hours. The dried FAME extracts were transferred to gas chromatograph autosampler vials.

Determination of fatty acids methyl esters content in beef lipids was performed by gas chromatography – mass spectrometry using the CLARUS 600 apparatus (Perkin Elmer) and COL–ELITE–5MS–60 m–0.25 mm–0.25 µm column. The mixture of 37 fatty acids (SUPELCO: FAME mix C4–C24) served as a standard. The GC parameters were as follows: carrier gas: helium (He) 6.0; gas flow rate: 1ml/min; injection: 1 µl; split ratio: 50:1; sample injector temperature: 200°C; programmed temperature: 110°C for 5 min, gradient of 5°C $\cdot$ min^{-1} to 180°C,

180°C for 15 min, gradient of 5°C · min^{-1} to 290°C, 290°C for 5 min; transfer line temperature: 290°C. MS parameters: Selected Ion Recording mode at selected m/z abundances; ionizing energy: 70 eV; ion source temperature: 200ºC.

Statistical analysis of the data was performed using Statistica software (StatSoft Inc., version 10.0). First, the data were investigated to determine their distribution using the Shapiro–Wilk W test. The fatty acid content and health lipid indices were then log-transformed to attain or approach a normal distribution. The significance of differences was tested using one-way ANOVA and Tukey's multiple range test.

RESULTS AND DISCUSSION

An analysis of percentage content of individual FA in the sum of fatty acids (Table 1) showed that the meat from CH and RA bulls was characterized by a significantly ($P \leq 0.05$) higher mean content of most SFA (C8:0, C10:0, C11:0, C12:0, C13:0, C15:0, C:17:0, C20:0, C21:0 and C22:0) and some MUFA (C18:1*n*-9 trans, C20:1, C22:1*n*-9) as well as PUFA (C20:2*n*-6 and C20:3*n*-3) compared with the meat from LM, SM, SL and HE bulls, whereas the content of most PUFA (C18:2*n*-6 cis – LA, C18:3*n*-3 – LNA, C20:3*n*-6, C20:4*n*-6, C20:5*n*-3 – EPA and C22:6*n*-3 – DHA) and long-chain SFA (C23:0 and C24:0) was significantly ($P \leq 0.05$) lower. Moreover, in the meat from RA and CH bulls, a significantly ($P \leq 0.05$) higher mean content of C14:0 and C14:1 acids was found in comparison with LM, SM and HE bulls and also in comparison with SL bulls in the case of RA breed. The content of C15:1 was significantly ($P \leq 0.05$) lower in the CH, RA and LM meat compared with the SM meat and in the RA meat also compared with the SL and HE meat.

The most advantageous FA profile was characteristic of the meat from SM bulls, which contained significantly ($P \leq 0.05$) more PUFA such as C18:2*n*-6 cis (LA), C18:3*n*-3 (LNA), C20:3*n*-6 and C22:6*n*-3 (DHA) and significantly ($P \leq 0.05$) less SFA such as C12:0, C13:0 and C20:0 in comparison with the meat from bulls of other investigated breeds, as well as significantly ($P \leq 0.05$) more C20:5*n*-3 (EPA) – compared with the CH, RA and LM breeds. The total content of SFA in the meat from SM bulls was significantly ($P \leq 0.05$) lower and that of total PUFA, *n*-6 PUFA and UFA was significantly ($P \leq 0.05$) higher in comparison with the meat from bulls of the remaining five investigated breeds. The meat from SM bulls was also characterized by a significantly ($P \leq 0.05$) higher total content of *n*-3 PUFA compared with the CH, RA and LM breeds, whereas the meat from CH and RA bulls was characterized by a significantly ($P \leq 0.05$) lower total content of PUFA and *n*-6 PUFA also in comparison with the meat from LM, HE and SL bulls.

Table 1. Fatty acid profile (% of total fatty acids) in *longissimus lumborum* muscle of investigated breeds

Tabela 1. Profil kwasów tłuszczowych (% w całkowitej zawartości kwasów tłuszczowych) w mięśniu *longissimus lumborum* badanych ras

Parameter Parametr	CH Mean ±SEM Średnia ±SEM	LM Mean ±SEM Średnia ±SEM	SM Mean ±SEM Średnia ±SEM	SL Mean ±SEM Średnia ±SEM	HE Mean ±SEM Średnia ±SEM	RA Mean ±SEM Średnia ±SEM	P value Wartość P
∑FA (mg/100g)	3674.7 ±99.9	3729.0 ±147.1	3830.7 ±220.3	3779.6 ±100.3	3811.2 ±76.7	3868.4 ±129.8	0.904
C8:0	0.022^{a} ±0.001	0.018^{b} ±0.001	0.017^{b} ±0.001	0.019^{b} ±0.001	0.018^{b} ±0.001	0.024^{a} ±0.001	<0.001***
C10:0	0.101^{a} ±0.004	0.083^{b} ±0.004	0.077^{b} ±0.001	0.091^{b} ±0.004	0.087^{b} ±0.005	0.102^{a} ±0.003	<0.001***
C11:0	0.0010^{a} ±0.000	0.0009^{b} ±0.000	0.0008^{b} ±0.000	0.0009^{b} ±0.000	0.0009^{b} ±0.000	0.0011^{a} ±0.000	<0.001***
C12:0	0.097^{a} ±0.010	0.044^{b} ±0.014	0.008^{c} ±0.001	0.041^{b} ±0.012	0.042^{b} ±0.013	0.110^{a} ±0.003	<0.001***
C13:0	0.016^{a} ±0.001	0.012^{b} ±0.001	0.009^{c} ±0.001	0.013^{b} ±0.001	0.012^{b} ±0.001	0.017^{a} ±0.001	<0.001***
C14:0	4.25^{ac} ±0.131	3.69^{b} ±0.106	3.66^{b} ±0.104	3.99^{bc} ±0.103	3.72^{b} ±0.120	4.51^{a} ±0.099	<0.001***
C14:1	0.74^{ac} ±0.024	0.65^{b} ±0.029	0.62^{b} ±0.031	0.68^{bc} ±0.029	0.65^{b} ±0.018	0.77^{a} ±0.013	<0.001***
C15:0	0.68^{a} ±0.042	0.49^{b} ±0.036	0.42^{b} ±0.010	0.52^{b} ±0.041	0.51^{b} ±0.035	0.73^{a} ±0.015	<0.001***
C15:1	0.035^{bd} ±0.002	0.038^{cd} ±0.002	0.046^{a} ±0.002	0.042^{ac} ±0.002	0.040^{bc} ±0.002	0.033^{d} ±0.001	<0.001***
C16:0	38.31 ±0.571	39.67 ±0.395	37.87 ±0.437	38.14 ±0.636	37.95 ±0.533	38.02 ±0.591	0.192
C16:1	3.78 ±0.082	3.64 ±0.079	3.74 ±0.121	3.62 ±0.115	3.67 ±0.094	3.77 ±0.064	0.727
C17:0	1.27^{a} ±0.047	1.01^{b} ±0.046	1.00^{b} ±0.027	1.09^{b} ±0.060	1.02^{b} ±0.040	1.29^{a} ±0.028	<0.001***
C17:1	0.56 ±0.015	0.52 ±0.018	0.53 ±0.016	0.56 ±0.013	0.53±0.013	0.57 ±0.018	0.147
C18:0	24.79 ±0.411	24.42 ±0.281	24.42 ±0.307	24.93 ±0.595	25.46 ±0.454	24.43 ±0.385	0.468
C18:1*n*-9*t*	2.65^{a} ±0.118	2.10^{b} ±0.132	1.89^{b}±0.047	2.22^{b} ±0.129	2.24^{b} ±0.125	2.85^{a} ±0.083	<0.001***
C18:1*n*-9*c*	18.60 ±0.240	18.90 ±0.328	19.86 ±0.348	18.88 ±0.428	18.96 ±0.403	18.83 ±0.477	0.421
CLA	0.21^{ac} ±0.025	0.04^{b} ±0.012	0.12^{bcd} ±0.024	0.09^{b} ±0.017	0.19^{ad} ±0.024	0.26^{a} ±0.036	<0.001***
C18:2*n*-6*c*	2.75^{a} ±0.158	3.61^{b} ±0.230	4.59^{c} ±0.072	3.89^{b} ±0.277	3.76^{b} ±0.306	2.52^{a} ±0.051	<0.001***
C18:3*n*-3	0.052^{a} ±0.004	0.068^{b} ±0.005	0.087^{c} ±0.002	0.073^{b} ±0.005	0.070^{b} ±0.006	0.046^{a} ±0.001	<0.001***
C20:0	0.20^{a} ±0.021	0.09^{b} ±0.028	0.02^{c} ±0.001	0.10^{b} ±0.031	0.08^{b} ±0.024	0.24^{a} ±0.005	<0.001***
C20:1	0.038^{a} ±0.002	0.028^{bc} ±0.002	0.024^{c} ±0.001	0.031^{b} ±0.002	0.028^{bc} ±0.002	0.039^{a} ±0.001	<0.001***
C20:2*n*-6	0.036^{a} ±0.002	0.028^{b} ±0.002	0.023^{c} ±0.001	0.029^{b} ±0.002	0.028^{b} ±0.002	0.038^{a} ±0.001	<0.001***
C20:3*n*-3	0.089^{a} ±0.009	0.043^{b} ±0.011	0.015^{c} ±0.001	0.044^{b} ±0.011	0.041^{b} ±0.010	0.102^{a} ±0.002	<0.001***
C20:3*n*-6	0.012^{a} ±0.001	0.015^{b} ±0.001	0.019^{c} ±0.001	0.016^{b} ±0.001	0.016^{b} ±0.001	0.010^{a} ±0.001	<0.001***
C20:4*n*-6	0.41^{ad} ±0.024	0.46^{ac} ±0.027	0.57^{b} ±0.016	0.54^{b} ±0.030	0.52^{bc} ±0.033	0.36^{d} ±0.008	<0.001***
C20:5*n*-3	0.18^{a} ±0.006	0.20^{b} ±0.008	0.23^{c} ±0.011	0.21^{bc} ±0.007	0.21^{bc} ±0.009	0.18^{a} ±0.003	<0.001***
C21:0	0.010^{a} ±0.001	0.009^{b} ±0.001	0.009^{b} ±0.001	0.009^{b} ±0.001	0.009^{b} ±0.001	0.010^{a} ±0.001	0.002**
C22:0	0.019^{a} ±0.001	0.016^{b} ±0.001	0.015^{b} ±0.001	0.017^{bc} ±0.001	0.016^{b} ±0.001	0.018^{ac} ±0.001	<0.001***
C22:1*n*-9	0.011^{a} ±0.001	0.008^{b} ±0.001	0.006^{b} ±0.000	0.008^{b} ±0.001	0.008^{b} ±0.001	0.012^{a} ±0.001	<0.001***
C22:2*n*-6	0.003 ±0.000	0.003 ±0.000	0.003 ±0.000	0.003 ±0.000	0.003 ±0.000	0.003 ±0.000	0.055
C22:6*n*-3	0.041^{a} ±0.002	0.048^{d} ±0.002	0.061^{c} ±0.001	0.054^{b} ±0.002	0.050^{bd} ±0.002	0.040^{a} ±0.001	<0.001***
C23:0	0.008^{a} ±0.001	0.009^{b} ±0.001	0.010^{b} ±0.001	0.009^{b} ±0.001	0.009^{b} ±0.001	0.007^{a} ±0.001	<0.001***
C24:0	0.008^{a} ±0.001	0.010^{b} ±0.001	0.012^{c} ±0.001	0.010^{b} ±0.001	0.010^{b} ±0.001	0.008^{a} ±0.001	<0.001***
C24:1	0.0046^{bc} ±0.001	0.0047^{bc} ±0.001	0.0059^{a} ±0.001	0.0051^{b} ±0.001	0.0049^{b} ±0.001	0.0042^{c} ±0.001	<0.001***
SFA	69.84^{b} ±0.249	69.59^{b} ±0.375	67.55^{a} ±0.416	68.98^{b} ±0.464	68.89^{b} ±0.540	69.26^{b} ±0.495	0.025*
MUFA	26.49 ±0.221	25.89 ±0.361	26.73 ±0.368	26.06 ±0.492	26.06 ±0.393	27.15±0.480	0.467
PUFA	3.67^{a} ±0.138	4.52^{b} ±0.255	5.72^{c} ±0.084	4.96^{b} ±0.301	5.05^{b} ±0.328	3.58^{a} ±0.075	<0.001***
n-6 PUFA	3.10^{a} ±0.177	4.12^{b} ±0.253	5.21^{c} ±0.077	4.49^{b} ±0.301	4.48^{b}±0.336	2.96^{a} ±0.051	<0.001***
n-3 PUFA	0.36^{a} ±0.005	0.36^{a} ±0.006	0.39^{b} ±0.010	0.38^{ab} ±0.007	0.38^{ab} ±0.008	0.36^{a} ±0.005	0.005**
UFA	30.16^{b} ±0.262	30.41^{b} ±0.375	32.45^{a} ±0.416	31.02^{b} ±0.464	31.11^{b} ±0.575	30.74^{b} ±0.542	0.032*
DI (18)	46.19 ±0.480	46.21 ±0.512	47.10 ±0.605	45.89 ±0.876	45.44 ±0.735	46.99 ±0.683	0.525
DI (16)	9.01 ±0.241	8.41 ±0.173	9.00 ±0.318	8.71 ±0.305	8.82 ±0.223	9.06 ±0.194	0.419

a, b – means within a row with different superscripts differ significantly ($P \leq 0.05$); ∑FA: Sum of fatty acids; SFA: Total saturated fatty acids; MUFA: Total monounsaturated fatty acids; PUFA: Total polyunsaturated fatty acids; UFA: Total unsaturated fatty acid (MUFA + PUFA); *n*-6 PUFA: Total *n*-6 PUFA fatty acids; *n*-3 PUFA: Total *n*-3 PUFA fatty acids; DI (18): Δ^9–desaturase (18) index = 100(18:1*n*-9/(18:1*n*-9 + 18:0)); DI (16): Δ^9––desaturase (16) index = 100(16:1*n*-9/(16:1 + 16:0)).

a, b – średnie w wierszu oznaczone różnymi literami w indeksie górnym różnią się istotnie ($P \leq 0.05$); ∑FA: Suma kwasów tłuszczowych; SFA: Całkowita zawartość nasyconych kwasów tłuszczowych; MUFA: Całkowita zawartość jednonienasyconych kwasów tłuszczowych; PUFA: Całkowita zawartość wielonienasyconych kwasów tłuszczowych; UFA: Całkowita zawartość nienasyconych kwasów tłuszczowych (MUFA + PUFA); *n*-6 PUFA: Całkowita zawartość kwasów tłuszczowych *n*-6 PUFA; *n*-3 PUFA: Całkowita zawartość kwasów tłuszczowych *n*-3 PUFA; DI (18): indeks Δ^9–desaturazy (18) = 100(18:1*n*-9/(18:1*n*-9 + 18:0)); DI (16): indeks Δ^9–desaturazy (16) = 100(16:1*n*-9/(16:1 + 16:0)).

The content of MUFA and the predominant C16:0, C18:0 and C18:1*n*-9 cis acids did not differ significantly between investigated breeds, in contrast to the studies by many other authors [Bureš et al. 2006, Cuvelier et al. 2006, Bartoň et al. 2008, Ugarković et al. 2013].

Fatty acids content in meat of different cattle breeds has been investigated in many studies; however, the obtained results were often contradictory. Bureš et al. [2006] showed a significantly higher content of C18:0 in the musculus *longissimus lumborum et thoracis* of Charolais bulls compared with Simmental bulls, and a lower content of C18:1*n*-9 cis and MUFA compared with the Simmental, Hereford and Aberdeen Angus breeds. The content of C18:3*n*-3 and *n*-3 PUFA in the Charolais, Simmental and Hereford meat did not differ significantly; however, it was significantly lower than that in the Aberdeen Angus meat. Similarly as in the present study, the total SFA content was significantly lower in the Simmental meat compared with the Charolais and Aberdeen Angus meat; however, it was not lower in comparison with the Hereford meat. Bartoň et al. [2008] found a significantly higher content of C14:0, C16:0 and SFA, and a lower content of C18:1*n*-9 cis and MUFA in the musculus *longissimus lumborum* of Charolais bulls compared with Simmental bulls. The differences in PUFA content were not found.

Different results were obtained in the study by Ugarković et al. [2013], in which the content of FA in the tissue of *m. longissimus dorsi* of Simmental, Hereford and Charolais steers was compared. The content of C14:0, C16:0 and C17:0 acids was significantly higher in the Hereford meat compared with Simmental meat and the C15:0 content was also higher in comparison with the Charolais breed, whereas the content of C20:3*n*-6, C20:5*n*-3 and PUFA was significantly lower compared with the Simmental and Charolais breeds. The Charolais meat was characterized by a significantly lower content of C18:1*n*-9 cis, C20:1 and MUFA and a higher content of C20:4*n*-6 in comparison with the Simmental and Charolais breeds and a higher content of C22:5*n*-3 and *n*-3 PUFA compared with the Hereford breed. Similarly as in the present study, the total SFA content was significantly lower in the Simmental meat in comparison with the Charolais and Hereford meat. Contrary to the present study, Rule et al. [1997] reported that the Hereford sire steers had a higher content of C16:0, C18:0 and total SFA in the lipid of the *longissimus* muscle than the cattle sired by the Charolais. Meanwhile, Siebert et al. [1996] found no differences in the percentage of SFA as well as individual and total MUFA and PUFA of the *longissimus* muscle lipids between Simmental and Hereford steers.

Laborde et al. [2001] compared the FA composition of total lipids from the *longissimus* muscle of Angus- and Simmental-sired steers. Similarly as in the present study, there were no breed differences for C18:1*n*-9, C16:0 and C18:0 acids, the main fatty acids in beef. Overall relative content of *n*-3 PUFA was, however,

lower in Simmental than in Red Angus steers, but total SFA, MUFA and PUFA did not differ between breeds. Cuvelier et al. [2006] compared the FA content in the *longissimus thoracis* from young Belgian Blue, Limousin and Aberdeen Angus bulls. The Aberdeen Angus bulls had a significantly higher content of C20:2*n*-6 and SFA and lower C20:4*n*-6 and C20:5*n*-3 contents; however, in contrast to the present study, they had also a higher content of MUFA, *n*-3 PUFA and C18:3*n*-3 than the Belgian Blue and Limousin bulls and that of total PUFA compared to the Limousin bulls. Moreover, the Limousin bulls had significantly higher contents of SFA, MUFA, *n*-3 PUFA, C18:3*n*-3, C20:2*n*-6 and C20:4*n*-6 than the Belgian Blue bulls.

According to some authors, a plausible explanation of the differences in the FA composition may be the different activities of enzymes involved in the FA synthesis and modification [Zapletal et al. 2009]. The enzyme responsible for the conversion of SFA into MUFA is Δ^9–desaturase. In the case of ruminants, FA in feed are chemically reduced by microorganisms in the rumen and absorbed as SFA. The composition of FA stored in the fat depots reflects the previous action of Δ^9–desaturase on substrates such as C18:0 or C16:0 [Yang et al. 1999]. Given its determinant role in FA oxidation, Δ^9–desaturase is a candidate for genetic variation in FA composition [Taniguchi et al. 2004b]. Taniguchi et al. [2004a] found an association between SCD mRNA expression and MUFA content in bovine subcutaneous adipose tissue, which was confirmed in subsequent works [Dance et al. 2009, Duckett et al. 2009, Costa et al. 2013]. However, the same association has not been reported for muscle [Dance et al. 2009, Bartoň et al. 2011]. Nonetheless, the SCD gene expression in the muscle tissues is influenced by diet composition, particularly *n*-3 PUFA contents [Costa et al. 2013], as shown in the works by Archibeque et al. [2005] and Deiuliis et al. [2010].

The differences in Δ^9–desaturase activity were associated with the genetic basis for breed differences in C16:1 and C18:1. Bureš et al. [2006] detected a higher Δ^9–desaturase activity in the Simmental compared to Charolais muscle resulting from the higher values of both Δ^9–desaturase (16) and (18) indexes. In the experiment by Zapletal et al. [2009], a higher value of Δ^9–desaturase (16) index was found in Czech Fleckvieh bulls compared to Montbeliarde bulls, while the Δ^9–desaturase (18) index values were similar. Laborde et al. [2001] found the higher values of Δ^9–desaturase (16) index in Simmental cattle compared to Red Angus cattle. Ugarković et al. [2013] found the higher values of Δ^9–desaturase (16) and (18) indexes in the tissue of the *m. longissimus dorsi* in Hereford steers compared to Charolais steers. In the present study, the values of both Δ^9–desaturase (16) and (18) indexes did not differ significantly, similarly as the content of C16:0, C16:1, C18:0 and C18:1cis acids.

The PUFA/SFA and *n*-6/*n*-3 PUFA ratios, atherogenity index (AI) and thrombogenity index (TI) are commonly used to assess the nutritional value and consumer health of intramuscular fat. In general, a ratio of PUFA to SFA above about 0.45 and a ratio of *n*-6/*n*-3 below 4.0 are required in the diet to combat various "lifestyle diseases" such as coronary heart disease and cancers [Simopoulos 2002]. The PUFA/SFA and *n*-6/*n*-3 ratios in this study were considerably lower than the recommended values (Table 2). The P/S ratio ranged from 0.05 in the CH and RA breeds to 0.08 in the Simmental breed and was highly unfavourable. If the fat from ruminant meat is highly saturated, it is considered to have detrimental effects on human health [Monteiro et al. 2006].

Table 2. Health lipid indices in *longissimus lumborum muscle* of investigated breeds

Tabela 2. Lipidowe wskaźniki zdrowia w mięśniu *longissimus lumborum* badanych ras

Parameter Parametr	CH Mean ±SEM Średnia ±SEM	LM Mean ±SEM Średnia ±SEM	SM Mean ±SEM Średnia ±SEM	SL Mean ±SEM Średnia ±SEM	HE Mean ±SEM Średnia ±SEM	RA Mean ±SEM Średnia ±SEM	P value Wartość P
PUFA/SFA	0.05^{a} ±0.002	0.06^{b} ±0.004	0.08^{c} ±0.002	0.07^{b} ±0.004	0.07^{b} ±0.005	0.05^{a} ±0.001	<0.001***
MUFA/SFA	0.38 ±0.004	0.37 ±0.007	0.40 ±0.008	0.38 ±0.009	0.38 ±0.008	0.39 ±0.010	0.467
UFA/SFA	0.43^{b} ±0.005	0.44^{b} ±0.008	0.48^{a} ±0.009	0.45^{b} ±0.010	0.45^{b} ±0.011	0.44^{b} ±0.011	0.028*
N-6/*n*-3 PUFA	8.79^{a} ±0.444	11.53^{b} ±0.608	13.33^{b} ±0.308	11.77^{b} ±0.872	11.46^{b} ±0.813	8.04^{a} ±0.103	<0.001***
AI	1.85^{b} ±0.030	1.78^{b} ±0.039	1.62^{a} ±0.032	1.75^{b} ±0.042	1.71^{ab} ±0.054	1.82^{b} ±0.053	0.010**
TI	3.95^{b} ±0.045	3.98^{b} ±0.066	3.63^{a} ±0.073	3.84^{ab} ±0.085	3.88^{b} ±0.088	3.90^{b} ±0.089	0.050*
DFA	54.74^{b} ±0.51	54.84^{b} ±0.40	56.87^{a} ±0.41	55.95^{ab} ±0.64	56.46^{ab} ±0.65	55.28^{b} ±0.63	0.049*
h/H	0.52^{b} ±0.011	0.54^{b} ±0.013	0.62^{a} ±0.014	0.57^{ab} ±0.018	0.57^{ab} ±0.020	0.54^{b} ±0.019	0.007**

a, b – means within a row with different superscripts differ significantly ($P \leq 0.05$); AI: index of atherogenity = (12:0 + 4 × 14:0 + 16:0)/(MUFA + PUFA) calculated according to Ulbricht and Southgate [1991]; TI: index of thrombogenity = (12:0 + 16:0 + 18:0)/[(0.5 × MUFA) + (0.5 × *n*-6 PUFA) + (3 × *n*-3 PUFA) + (*n*-3 PUFA/*n*-6 PUFA)] calculated according to Ulbricht and Southgate [1991]; DFA: desirable fatty acids = UFA + C18:0; h/H: hypocholesterolemic/hypercholesterolemic ratio = (C18:1 + PUFA)/(C14:0 + C16:0).

a, b – średnie w wierszu oznaczone różnymi literami w indeksie górnym różnią się istotnie ($P \leq 0,05$); AI: Wskaźnik aterogenności = (12:0 + 4 × 14:0 + 16:0)/(MUFA + PUFA) obliczony według Ulbricht i Southgate [1991]; TI: Wskaźnik trombogenności = (12:0 + 16:0 + 18:0)/[(0.5 × MUFA) + (0.5 × *n*-6 PUFA) + (3 × *n*-3 PUFA) + (*n*-3 PUFA/*n*-6 PUFA)] obliczony według Ulbricht i Southgate [1991]; DFA: wskazane kwasy tłuszczowe = UFA + C18:0; h/H: stosunek kwasów hipocholesterolemicznych/hipercholesterolemicznych = (C18:1 + PUFA)/(C14:0 + C16:0).

A low PUFA/SFA ratio in this study resulted from a high content of some SFA in the meat of investigated breeds, especially that of palmitic (C16:0) and stearic (C18:0) ones, whose consequence was a very high total content of SFA, amounting to 67.6–69.8% depending on breed. The content of palmitic acid ranged from 38% to almost 40% of the total sum of FA, whereas that of stearic acid was approx. 25%, which already accounted for 63–65%. After adding to this sum approx. 4% of miristic acid content (C14:0), the total content of these three main SFA accounted for as much as 67–69% of the total sum of FA. It is a very high value, which is much higher than that reported in most studies [Laborde et al. 2001, Bureš et al. 2006, Warren et al. 2008, Zapletal et al. 2009, Ugarković et al. 2013], in which it ranged from 35 to 53% for animals fattened under intensive production conditions. At the same time, the PUFA content was similar to or lo-

wer than that in the previous studies. It should also be emphasized that in these studies, oleic acid had the highest contribution to the sum of fatty acids (31–43%); however, it only ranked third in the present study (18.6–19.9%), after palmitic and stearic acids. A very high proportion of SFA was most probably caused by a long, lasting for more than 18 months, intensive fattening mainly based on maize silage and crushed barley with a concentrate. The concentrate supplement promotes the synthesis of SFA. The bulls were slaughtered at more than 25 months of age and body weight above 650–700 kg. Thus, they were older than those in most earlier studies, in which the animals were slaughtered at approx. 400 to 630 kg body weight [Laborde et al. 2001, Nuernberg et al. 2005, Bureš et al. 2006] or at approx. 14 to 24 months of age [Warren et al. 2008, Ugarković et al. 2013]. Therefore, they were also more fattened. According to De Smet et al. [2004] the content of SFA and MUFA increases faster with increasing fatness than does the content of PUFA, leading to a decrease in the relative proportion of PUFA and consequently in the PUFA/SFA ratio. Hence, the PUFA/SFA ratio of beef can drop to a value of 0.05 in fat breeds and can rise to >0.5 in very lean breeds.

Raes et al. [2003] suggested that these ratios are mainly influenced by genetic factors, because fat deposition differs between breeds. In most previous studies, the PUFA/SFA ratio in the meat of intensively fattened breeds was higher, ranged from 0.13 to 0.8 [Laborde et al. 2001, Cuvelier et al. 2006, Bureš et al. 2006, Bartoň et al. 2008]. In these studies, the PUFA/SFA ratios in the meat of investigated breeds did not differ significantly. In the present study, the PUFA/SFA and UFA/SFA ratios were significantly ($P \leq 0.05$) higher in the meat from SM bulls compared with other five investigated breeds (Table 2). The meat from CH and RA bulls was also characterized by a significantly ($P \leq 0.05$) lower PUFA/SFA ratio in comparison with the LM, SL and HE meat. In the study by Ugarković et al. [2013], the PUFA/SFA ratio in the meat from Hereford steers was similar to that in the present study (0.07), however, it was significantly lower than that for the Simmental and Charolais breeds (0.20 and 0.24, respectively). The PUFA/SFA ratios similar to those in the present study (0.06–0.07) were also reported by Zapletal et al. [2009] in the *longissimus dorsi* muscle of Montbeliarde and Czech Fleckvieh bulls, fattened to over 700 kg live weight. A low PUFA/SFA ratio in the meat from Aberdeen Angus and Holstein-Friesian steers (0.04 and 0.07, respectively) fattened intensively with silage until 24 months of age was also indicated by Warren et al. [2008].

However, some authors consider that an index such as PUFA/SFA may not be an adequate way to evaluate the nutritional value of fat because some SFA do not increase plasma cholesterol and ignore the effects of MUFA [Orellana et al. 2009]. More recent lipid research would suggest that C12:0 and C14:0, have a greater total cholesterol raising effect than C16:0, whereas C18:0 has a neutral effect

on the concentration of total serum cholesterol, including no apparent impact on either LDL or HDL [Mensink and Katan 1992, Daley et al. 2010]. Hence, it has been shown that the C12:0, C14:0, and C16:0 FA are associated with an increase in plasmatic cholesterol concentrations when they are present in human diets. This association is stronger for C14:0, which has a potential to increase cholesterol concentrations 4 to 6 times greater than C16:0 [Mensink and Katan 1992, Bressan et al. 2011].

In the present study, the predominant FA were C16:0, C18:0 and C18:1*n*-9 cis. The high levels of C16:0 in the current study are not desirable, although this is partly countered by the contents of MUFA, in particular oleic acid, and PUFA. MUFA have neutral effects on human cholesterol levels. Oleic acid increases the concentration of HDL-cholesterol and lowers the concentration of LDL. Long-chain PUFA are beneficial to human health due to their antitherogenic, antithrombotic, and anti-inflammatory effects. Meat represents one of their important dietary sources [Givens et al. 2006].

In the PUFA category, 18:2*n*-6 and 20:4*n*-6 predominated in all breeds. Animal breed influences PUFA in the *longissimus* muscle of bovines. The mean content of PUFA ranged from 3.58% in RA to 5.72% in SM, that of n-6 PUFA ranged between 2.96 and 5.21%, respectively, whereas the content of *n*-3 PUFA was in the range from 0.36% (for LM) to 0.39% (for SM). The values are lower than or similar to those obtained in other studies, in which the contents of PUFA, *n*-6 PUFA and *n*-3 PUFA were 3.0–12%, 1.5–8%, and 0.30–2.8%, respectively, for animals fattened under intensive production conditions [Laborde et al. 2001, Nuernberg et al. 2005, Bureš et al. 2006, Warren et al. 2008, Zapletal et al. 2009, Bartoň et al. 2010, Ugarković et al. 2013]. The low *n*-3 PUFA content in the present study resulted from a much lower content of C18:3 *n*-3 in the meat of investigated breeds compared with the values reported in other studies for animals fattened under intensive production conditions.

The *n*-6/*n*-3 PUFA ratio in the present study ranged from approx. 8 to 13 (Table 2). It was significantly ($P \leq 0.05$) lower in the meat from RA and CH bulls (8–8.8) compared with SM, SL, LM and HE bulls (11.5–13.3). A significantly lower *n*-6/*n*-3 PUFA ratio in the meat from RA and CH bulls resulted from a considerably lower *n*-6 PUFA content in their meat (2.96 and 3.10%, respectively) in comparison with the remaining breeds (from 4.12% for LM to 5.21% for SM), while the *n*-3 PUFA content in the meat of all investigated breeds was less varied (0.36–0.39%). In several other studies, the *n*-6/*n*-3 ratio has ranged between 3.4 to 13.6 for animals fattened under intensive production conditions [Laborde et al. 2001, Raes et al. 2003, Bureš et al. 2006, Cuvelier et al. 2006, Bartoň et al. 2008, Ugarković et al. 2013], even though it can be as large as 20 in animals finished with grain [Warren et al. 2008]. A very high *n*-6/*n*-3 ratio was found by

Brugiapaglia et al. [2014] in the *longissimus thoracis* muscle from Piemontese, Limousin and Friesian young bulls purchased at retail from local butcher shops. It amounted to 22.9, 17.07 and 15.79, respectively.

Other studies have shown that a high concentrate diets negatively affect the *n*-6/*n*-3 ratio of the meat. The higher *n*-6/*n*-3 ratio with the cereal-based diet is likely to be explained by a high concentration of C18:2*n*-6 in maize, that is, about 50–60% of the total of FA [Cuvelier et al. 2006]. Typically, feeding maize silages results in a high *n*-6/*n*-3 ratio in body fat due to its high content in C18:2*n*-6 [O'Sullivan et al. 2002].

Stanley et al. [2007] have proposed that it is more important to evaluate the total amount of dietary PUFA than their respective ratio. According to Wijendran and Hayes [2004], epidemiological and clinical studies have established that the *n*-6 FA, linoleic acid [LA], and the *n*-3 fatty acids, linolenic acid [LNA], eicosapentaenoic acid [EPA], and docosahexaenoic acid [DHA] collectively protect against coronary heart disease. Linoleic acid is the major dietary FA regulating low-density lipoprotein cholesterol metabolism by downregulating low-density lipoprotein cholesterol production and enhancing its clearance. By contrast, *n*-3 FA, especially EPA and DHA, are potent antiarrhythmic agents. EPA and DHA also improve vascular endothelial function and help lower blood pressure, platelet sensitivity, and the serum triglyceride level. The distinct functions of these two families make the balance between dietary *n*-6 and *n*-3 fatty acids an important consideration influencing cardiovascular health. Therefore, Wijendran and Hayes [2004] suggest that an adequate achievable intake for most healthy adults is approximately 6% linoleic acid, 0.75% linolenic acid, and 0.25% eicosapentaenoic acid and docosahexaenoic acid, which corresponds to an *n*-6/*n*-3 ratio of approximately 6:1. However, the absolute mass of essential FA consumed, rather than their *n*-6/*n*-3 ratio, should be the first consideration when contemplating lifelong dietary habits affecting cardiovascular benefit from their intake.

In the present study, the content of LA, LNA, EPA and DHA acids was highest in the meat from SM bulls, and significantly ($P \leq 0.05$) higher in comparison with the remaining five investigated breeds, whereas the content of these acids in the meat from RA and CH bulls was lowest and also significantly lower in comparison with the SL, HE and LM breeds. The combined content of EPA and DHA in the meat of investigated breeds ranged from 0.22 to 0.29%. The content of EPA and DHA in the human diet is important due to the low efficiency of transformation of LA to EPA and DHA by an organism. Whole body conversion of LA to DHA is below 5% in humans, the majority of these long-chain FA are consumed in the diet. More recent research has established that EPA and DHA play a crucial role in the prevention of atherosclerosis, heart attack, depression and cancer [Daley et al. 2010].

It should also be noted that a markedly lower *n*-3 and *n*-6 PUFA content was partially compensated for by a markedly higher CLA content in the meat from RA and CH bulls. The meat from RA, CH and HE bulls was characterized by a significantly ($P \leq 0.05$) higher mean content of CLA compared with the LM and SL breeds. The meat from RA bulls was also characterized by a significantly ($P \leq 0.05$) higher mean content of CLA compared with the SM breed (Table1). The mean CLA content in the meat from RA and CH bulls was more than five times higher compared with the meat from LM bulls and two times higher compared with that from SL bulls. The CLA content in the meat from RA bulls was also two times higher in comparison with that from SM bulls. The CLA content was characterized by the greatest variability among all analyzed FA, not only among investigated breeds, but also within the breed. The mean content of CLA ranged from 0.04% in LM to 0.26% in RA and was lower than or similar to those obtained in other studies, in which the contents of CLA ranged from 0.18 to 0.75% for animals fattened under intensive production conditions [Laborde et al. 2001, Nuernberg et al. 2005, Warren et al. 2008, Bartoň et al. 2010, Ugarković et al. 2013, Brugiapaglia et al. 2014]. Contrary to the present study, Ugarković et al. [2013] reported that the Charolais steers had a lower content of CLA in comparison with the Simmental and Hereford steers, whereas Laborde et al. [2001] found no differences in the CLA content between Simmental and Red Angus steers. There is a great interest in CLA because of its anticarcinogenic and antiatherogenic properties and its ability to reduce body fat while enhancing lean body mass [Garcia et al. 2008]. Both *n*-3 PUFA and CLA are present in much smaller quantities compared with the other fatty acid classes; however, lipids of ruminant origin are among the richest sources of CLA [Sexten et al. 2012].

In an attempt to take into account the different effects of the various FA, Ulbricht and Southgate [1991] proposed two indices which might better characterize the atherogenic and thrombogenic potential of the diet than simple approaches such as PUFA/SFA ratio. Atherogenic index (AI) and thrombogenic index (TI) take into account the different effects that single FA might have on human health and in particular on the probability of increasing the incidence of pathogenic phenomena, such as atheroma and/or thrombus formation. AI and TI are highest for most atherogenic and thrombogenic dietary components. In the present study, AI was unfavourable and ranged from 1.62 to 1.85. It is assumed that AI below 1 is beneficial for human health. Also TI was very unfavourable, since its value ranged between 3.63 and 3.98. Such high indices were caused by a high content of SFA, especially palmitic and stearic ones, and a low content of *n*-3 PUFA. The most advantageous AI and TI were characteristic of the meat from SM bulls (Table 2). AI was significantly ($P \leq 0.05$) lower in the meat from SM bulls in comparison with RA, CH, LM and SL bulls, whereas TI was significantly ($P \leq 0.05$) lower

compared with RA, CH, LM and HE animals. The h/H ratio and DFA were also most advantageous in the meat from SM bulls and were significantly ($P \leq 0.05$) higher in the meat from SM bulls compared with the RA, CH and LM breeds.

CONCLUSIONS

Due to the high content of saturated fatty acids and a low content of polyunsaturated ones, especially *n*-3 PUFA, the meat of all investigated breeds was characterized by unfavourable fatty acid profile and health lipid indices. In comparison with the meat from bulls of the remaining investigated breeds, the meat from SM bulls contained significantly more polyunsaturated fatty acids such as C18:2*n*-6 cis, C18:3*n*-3, C20:3*n*-6 and C22:6*n*-3 (DHA), a lower total percentage of SFA, a higher total percentage of PUFA, *n*-6 PUFA and UFA, as well as significantly more C20:5*n*-3 (EPA) and *n*-3 PUFA compared with the CH, RA and LM breeds. On the other hand, the meat from CH and RA bulls was characterized by a significantly lower total content of PUFA and *n*-6 PUFA also in comparison with the meat from LM, HE and SL bulls. However, the meat from RA, CH and HE bulls was characterized by a significantly higher mean content of CLA compared with the LM and SL breeds. The meat from RA bulls was also characterized by a significantly higher mean content of CLA compared with the SM breed. It shows a different potential of each of the breeds to synthesize fatty acids in the same production conditions. The PUFA/SFA and UFA/SFA ratios in the meat from SM bulls were significantly higher, while atherogenic and thrombogenic indices were mostly significantly lower compared with the remaining five investigated breeds. The most advantageous PUFA/SFA, UFA/SFA and h/H ratios, as well as AI and TI were characteristic of the meat from SM bulls. One should also pay attention to fatty acid profile and health lipid indices of HE and RA breeds. Both these breeds, due to their fatness and intramuscular fat content have been considered very similar so far; however, in the present study their fatty acid profile is clearly different, mostly due to the significantly higher PUFA content and a lower content of some saturated fatty acids in the meat of HE breed. Summarizing, it should be emphasized that under the conditions of long (lasting for more than 18 months) intensive fattening, mainly based on maize silage and crushed barley with a concentrate, the SFA content in beef may be increased, which is of great importance to consumers.

REFERENCES

Archibeque, S.L., Lunt, D.K., Gilbert, C.D., Tume, R.K., Smith, S.B. (2005). Fatty acid indices of stearoyl-CoA desaturase do not reflect actual stearoyl-CoA desaturase enzyme activities in adipose tissues of beef steers finished with corn-, flaxseed-, or sorghum-based diets. J. Anim. Sci., 85, 1153–1166.

Bartoň, L., Bureš, D., Kudrna, V. (2010). Meat quality and fatty acid profile of the musculus *longissimus lumborum* in Czech Fleckvieh, Charolais and Charolais × Czech Fleckvieh bulls fed different types of silages. Czech J. Anim. Sci., 55, 479–487.

Bartoň, L., Bureš, D., Kott, T., Řehák, D. (2011). Effect of sex and age on bovine muscle and adipose fatty acid composition and stearoyl-CoA desaturase mRNA expression. Meat. Sci., 89, 444–450.

Bartoň, L., Marounek, M., Kudrna, V., Bureš, D., Zahrádková, R. (2008). Growth, carcass traits, chemical composition, and fatty acid profile in beef from Charolais and Simmental bulls fed different types of dietary lipids. J. Sci. Food Agric., 88, 2622––2630.

Bressan, M.C., Rossato, L.V., Rodrigues, E.C., Alves, S.P., Bessa, R.J., Ramos, E.M., Gama, L.T. (2011). Genotype x environment interactions for fatty acid profiles in Bos indicus and Bos taurus finished on pasture or grain. J. Anim. Sci., 89, 221–232.

Brugiapaglia, A., Lussiana, C., Destefanis, G. (2014). Fatty acid profile and cholesterol content of beef at retail of Piemontese, Limousin and Friesian breeds. Meat Sci., 96, 568–573.

Bureš, D., Bartoň, L., Zahrádková, R., Teslík, V., Krejčová, M. (2006). Chemical composition, sensory characteristics, and fatty acid profile of muscle from Aberdeen Angus, Charolais, Simmental, and Hereford bulls. Czech J. Anim. Sci., 51, 279–284.

Costa, A.S., Silva, M.P., Alfaia, C.P., Pires, V.M., Fontes, C.M., Bessa, R.J., Prates, J.A. (2013). Genetic background and diet impact beef fatty acid composition and stearoyl-CoA desaturase mRNA expression. Lipids, 48, 369–381.

Cuvelier, C., Clinquart, A., Hocquette, J.F., Cabaraux, J.F., Dufrasne, I., Istasse, L., Hornick, J.L. (2006). Comparison of composition and quality traits of meat from young finishing bulls from Belgian Blue, Limousin and Aberdeen Angus breeds. Meat Sci., 74, 522–531.

Daley, C.A., Abbott, A., Doyle, P.S., Nader, G.A., Larson, S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutrition J., 9, 10.

Dance, L.J.E., Matthews, K.R., Doran, O. (2009). Effect of breed on fatty acid composition and stearoyl-CoA desaturase protein expression in the Semimembranosus muscle and subcutaneous adipose tissue of cattle. Livest. Sci., 125, 291–297.

De Smet, S., Raes, K., Demeyer, D. (2004). Meat fatty acid composition as affected by fatness and genetic factors, a review. Anim. Res., 53, 81–98.

Deiuliis, J., Shin, J., Murphy, E., Kronberg, S.L., Eastridge, M.L., Suh, Y., Yoon, J.T., Lee, K. (2010). Bovine adipose triglyceride lipase is not altered and adipocyte fatty acid-binding protein is increased by dietary flaxseed. Lipids, 45, 963–973.

Duckett, S.K., Pratt, S.L., Pavan, E. (2009). Corn oil or corn grain supplementation to steers grazing endophyte-free tall fescue. II. Effects on subcutaneous fatty acid content and lipogenic gene expression. J. Anim. Sci., 87, 1120–1128.

Fredriksson Eriksson, S., Pickova, J. (2007). Fatty acids and tocopherol levels in *M. Longissimus dorsi* of beef cattle in Sweden – A comparison between seasonal diets. Meat Sci., 76, 746–754.

Garcia, P.T., Pensel, N.A., Sancho, A.M., Kloster, N.J.L., Amigone, M.A., Casal, J.J. 2008. Beef lipids in relation to animal breed and nutrition in Argentina. Meat Sci., 79, 500–508.

Givens, D.I., Kliem, K.E, Gibbs, R.A. (2009). The role of meat as a source of *n*-3 polyunsaturated fatty acids in the human diet. Meat Sci., 74, 209–218.

Laborde, F.L., Mandell, I.B., Tosh, J.J., Wilton, J.W., Buchanan-Smith, J.G. (2001). Breed effects on growth performance, carcass characteristics, fatty acid composition, and palatability attributes in finishing steers. J. Anim. Sci., 79, 355–365.

Mensin, R.P., Kata, M.B. (1992). Effect of dietary fatty acids on serum lipids and lipoproteins. A meta-analysis of 27 trials. Arterioscler. Thromb., 12, 911–919.

Monteiro, A.C.G., Santos-Silva, J., Bessa, R.J.B., Navas, D.R., Lemos, J.P.C. (2006). Fatty acid composition of intramuscular fat of bulls and steers. Livest. Sci., 99, 13–19.

Nuernberg, K., Dannenberger, D., Nuernberg, G., Ender, K., Voigt, J., Scollan, N.D., Wood, J.D., Nute, G.R., Richardson, R.I. (2005). Effect of a grass-based and a concentrate feeding system on meat quality characteristics and fatty acid composition of *longissimus* muscle in different cattle breeds. Livest. Prod. Sci., 94, 137–147.

Nuernberg, K., Nuernberg, G., Ender, K., Lorenz, S., Winkler, K., Rickert, R., Steinhart, H. (2002). *N*-3 fatty acids and conjugated linoleic acids of *longissimus* muscle in beef cattle. Eur. J. Lipid Sci. Technol., 104, 463–471.

O'Sullivan, A., O'Sullivan, K., Galvin, K., Moloney, A.P., Troy, D.J., Kerry, J.P. (2002). Grass silage versus maize silage effects on retail packaged beef quality. J. Anim. Sci., 80, 1556–1563.

Orellana, C., Peña, F., García, A., Perea, J., Martos, J., Domenech, V., Acero, R. (2009). Carcass characteristics, fatty acid composition, and meat quality of Criollo Argentino and Braford steers raised on forage in a semi-tropical region of Argentina. Meat Sci., 81, 57–64.

Pestana, J.M., Costa, A.S., Martins, S.V., Alfaia, C.M., Alves, S.P., Lope, P.A., Bessa, R.J.B., Prates, J.A.M. (2012). Effect of slaughter season and muscle type on the fatty acid composition, including conjugated linoleic acid isomers, and nutritional value of intramuscular fat in organic beef. J. Sci. Food Agric., 92, 2428–2435.

Raes, K., Balcaen, A., Dirinck, P., De Winne, A., Claeys, E., Demeyer, D., De Smet, S. (2003). Meat quality, fatty acid composition and flavour analysis in Belgian retail beef. Meat Sci., 65, 1237–1246.

Rule, D.C., M.D. MacNeil, Short, R.E. (1997). Influence of sire growth potential, time on feed, and growing–finishing strategy on cholesterol and fatty acids of the ground carcass and *longissimus* muscle of beef steers. J. Anim. Sci., 75, 1525–1533.

Sexten, A.K., Krehbiel, C.R., Dillwith, J.W., Madden, R.D., McMurphy, C.P., Lalman, D.L., Mateescu, R.G. (2012). Effect of muscle type, sire breed, and time of weaning on fatty acid composition of finishing steers. J. Anim. Sci., 90, 616–625.

Siebert, B.D., Deland, M.P., Pitchford, W.S. (1996). Breed differences in the fatty acid composition of subcutaneous and intramuscular lipid of early and late maturing, grain-finished cattle. Aust. J. Agr. Res., 47, 943–952.

Simopoulos, A.P. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed. Pharmacother. 56, 353–379.

Stanley, J.C., Elsom, R.L., Calder, P.C., Griffin, B.A., Harris, W.S., Jebb, S.A., Lovegrove, J.A., Moore, C.S., Riemersma, R.A., Sanders, T.A. (2007). UK Food Standards Agency Workshop Report, the effects of the dietary *n*-6, *n*-3 fatty acid ratio on cardiovascular health. Br. J. Nutr., 98, 1305–1310.

Taniguchi, M., Mannen, H., Oyama, K., Shimakura, Y., Oka, A., Watanabe, H., Kojima, T., Komatsu, M., Harper, G.S., Tsuji, S. (2004a). Differences in stearoyl-CoA desaturase mRNA levels between Japanese Black and Holstein cattle. Livest. Prod. Sci., 87, 215–220.

Taniguchi, M., Utsugi, T., Oyama, K., Mannen, H., Kobayashi, M., Tanabe, Y., Ogino, A., Tsuji, S. (2004b). Genotype of stearoyl-CoA desaturase is associated with fatty acid composition in Japanese Black cattle. Mamm. Genome, 15, 142–148.

Turner, T.D., Jensen, J., Pilfold, J.L., Prema, D., Donkor, K.K., Cinel, B., Thompson, D.J., Dugan, M.E.R., Church, J.S. (2015). Comparison of fatty acids in beef tissues from conventional, organic and natural feeding systems in western Canada. Can. J. Anim. Sci., 95, 49–58.

Ugarković, N.K., Ivanković, A., Konjačić, M. (2013). Effect of breed and age on beef carcass quality, fatness and fatty acid composition. Arch. Tierzucht, 56, 97.

Ulbritch, T.L.V., Southgate, D.A.T. (1991). Coronary Heart Disease, Seven Dietary Factors. Lancet, 338, 985–92.

Warren, H.E., Scollan, N.D., Enser, M., Hughes, S.I., Richardson, R.I., Wood, J.D. (2008). Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. I, Animal performance, carcass quality and muscle fatty acid composition. Meat Sci., 78, 256–269.

Wijendran, V., Hayes, K.C. (2004). Dietary *n*-6 and *n*-3 fatty acid balance and cardiovascular health. Annu. Rev. Nutr. 24, 597–615.

Williams, C.M. (2000). Dietary fatty acids in human health. Ann. Zootech., 49, 165–180.

Yang, A., Larsen, T.W., Smith, S.B., Tume, R.K. 1999. D9 desaturase activity in bovine subcutaneous adipose tissue of different fatty acid composition. Lipids, 34, 971–978.

Zapletal, D., Chládek, G., Šubrt, J. (2009). Breed variation in the chemical and fatty acid compositions of the *Longissimus dorsi* muscle in Czech Fleckvieh and Montbeliarde cattle. Livest. Sci., 123, 28–33.

PROFIL KWASÓW TŁUSZCZOWYCH ORAZ LIPIDOWE WSKAŹNIKI ZDROWIA W MIĘŚNIU *LONGISSIMUS LUMBORUM* RÓŻNYCH RAS BYDŁA MIĘSNEGO UTRZYMYWANYCH W INTENSYWNYM SYSTEMIE PRODUKCJI

Streszczenie. Celem badań było porównanie profilu kwasów tłuszczowych oraz lipidowych wskaźników zdrowia w mięśniu *longissimus lumborum* różnych ras bydła mięsnego utrzymywanych w intensywnym systemie produkcji. Materiał do badań stanowiły próby mięśnia *longissimus lumborum* pochodzące łącznie od 86 buhajów ras: Charolais (CH), Limousin (LM), Simmental (SM), Salers (SL), Hereford (HE) i Red Angus (RA). Mięso buhajów rasy SM, w porównaniu do mięsa buhajów pozostałych badanych ras, zawierało istotnie więcej ($P \leq 0.05$) wielonienasyconych kwasów tłuszczowych, takich jak: C18:2*n*-6 cis, C18:3*n*-3, C20:3*n*-6 i C22:6*n*-3 (DHA), mniejszą procentową zawartość SFA, większą PUFA, *n*-6 PUFA oraz UFA, a także w porównaniu do CH, RA i LM istotnie większą zawartość C20:5*n*-3 (EPA) i *n*-3 PUFA. Mięso buhajów CH i RA charakteryzowało się istotnie mniejszą całkowitą zawartością PUFA oraz *n*-6 PUFA również w porównaniu do mięsa buhajów LM, HE i SL, natomiast istotnie większą zawartością CLA w porównaniu LM i SL. Najkorzystniejszymi wskaźnikami PUFA/SFA, UFA/SFA i h/H, a także AI i TI charakteryzowało się mięso pochodzące od buhajów rasy SM.

Słowa kluczowe: wołowina, SFA, PUFA, CLA, wskaźnik aterogenności, wskaźnik trombogenności

Accepted for print: 21.04.2015

For citation: Pilarczyk, R., Wójcik, J. (2015). Fatty acids profile and health lipid indices in the *longissimus lumborum* muscle of different beef cattle breeds reared under intensive production systems. Acta Sci. Pol. Zootechnica, 14(1), 109–126.