*Animal Science Papers and Reports* vol. 34 (2016) no. 4, 387-397
Institute of Genetics and Animal Breeding, Jastrzębiec, Poland

# Chemical composition, fatty acid profile, including health indices of intramuscular fat, and technological suitability of the meat of young bulls of three breeds included in a genetic resources conservation programme fattened within a low-input system*

**Zygmunt Litwińczuk[1], Piotr Domaradzki[2]**, Mariusz Florek[2], Paweł Żółkiewski[1]**

[1] Department of Breeding and Conservation of Genetic Resources of Cattle, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland

[2] Department of Commodity Science and Animal Raw Materials Processing, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland

*(Accepted August 16, 2016)*

**Proximate composition and the proportions of 38 fatty acids (FA) were determined in the meat (*m. longisimus lumborum and m. semitendinosus*) of young bulls of 3 native Polish breeds (Polish Red – PR, White-Backed – WB and Polish Black-and-White – PBW) raised in a low-input system on a diet based on fodder from permanent grassland and slaughtered at the age of 18-20 months. The reference groups consisted of young bulls of the Polish Holstein-Friesian (PHF) and Simmental (SIM) breeds fattened in the same conditions. Breed was found to have a significant effect on the chemical composition, total collagen content and its proportion in total protein, protein hydration and net energy, as well as the FA profile, proportions and indices in the meat analysed. The technological properties of the native young bulls' meat showed intermediate values between the SIM (the most favourable) and the PHF (the least favourable) breeds. The beef obtained from the native breeds had more beneficial FA profiles (lower SFA and higher MUFA proportions), ratios (n6/n3 and h/H), and indices (AI and TI) than those from**

*Research was realized within the project "BIOFOOD – innovative, functional products of animal origin" no. POIG.01.01.02-014-090/09 co-financed by the European Union from the European Regional Development Fund within the Innovative Economy Operational Programme 2007-2013.
** Corresponding author: piotr.domaradzki@up.lublin.pl

**the PHF bulls. The meat of the two oldest Polish breeds i.e. PR and WB had significantly (P<0.01) highest levels of α-linolenic acid and PUFA/SFA with h/H ratios, and lowest (the most favourable) indices characterizing the health promoting quality of the fat – AI and TI. This should probably be associated with the pool of genes that remain conserved in these breeds.**

**KEY WORDS: beef / cattle / chemical composition / fatty acids / native breeds**

Consumer awareness of the association between the type of food consumed and health has grown in the recent years. Increasing attention is paid to systems of food production, particularly with regard to health safety. Consumer familiarity with these connections leads to increased interest in products (raw material) of high nutritional value having functional and bioactive components that play vital role in maintaining health and preventing disease [Scollan *et al.* 2006]. This type of food unquestionably includes raw material (milk, meat and eggs) obtained from local breeds kept on low-input farms, where animals are raised extensively and pastured in the summer. It is also worth noting that regional products obtained from local breeds have been highly popular in Europe for many years and are widely regarded as healthy, safe, and having distinctive organoleptic qualities. These cattle breeds are well adapted to local, often very difficult environmental conditions (such as mountainous or wet terrain), in which the use of transboundary breeds in intensive commercial production (e.g. Holstein-Friesians) is not successful [Litwińczuk *et al.* 2012]. According to Litwińczuk *et al.* [2006] and Orellana *et al.* [2009], one of the most important factors in beef production determining the quality characteristics of the carcass and the meat obtained from it is the breed of cattle and its production purpose.

Many authors believe that consumers are willing to pay more for meat obtained in this manner due to its health-related and organoleptic qualities, and because they perceive this system of meat production to be less harmful to the environment and more humane to animals. Thus the promotion of meat obtained from native breeds raised on low-input farms not only has the environmental importance, but generally has economic significance as well [Sepúlveda *et al.* 2008, Monteiro *et al.* 2012]. However, the actual nutritional value of these products (obtained from native breeds), including their health-promoting qualities, must be described.

In Poland, there are four native breeds of cattle that have been included in the genetic resources protection programme: Polish Red, PR (since 1999), White-Backed, WB (since 2003), Polish Red-and-White, PRW (since 2006), and Polish Black-and-White, PBW (since 2007).

The aim of the study was to evaluate the nutritional value and technological suitability of the meat of three native Polish breeds (Polish Red, White-Backed and Polish Black-and-White) fattened in a low-input system, taking into account health indices of intramuscular fat. The reference groups consisted of the meat samples from young bulls of the Simmental the and Polish Holstein-Friesian breeds, fattened in the same conditions as the native breeds.

## Material and methods

The material for the study consisted of samples of two skeletal muscles, the *longissimus lumborum* (LL, n=40) and the *semitendinosus* (ST, n=40), collected from the carcasses of young bulls of 5 breeds (8 from each breed). The fattening was carried out in a low-input system. The experiment included young bulls born on the farms or purchased at the age of 1-3 months, with the first summer season treated as the rearing period. After a period of milk and milk substitutes feeding the calves were fed on grass forage and hay supplemented with concentrates. After the rearing period (6 months of life) the control fattening was begun. It lasted about 12 months and included the winter feeding season and the second summer season. During the fattening, feeding was based mainly on haylage and hay in the winter which made up over 50% DM of the feed ration, and grass forage (over 50% DM of the feed ration) in the summer. The diet was supplemented in both seasons with maize silage and grain meal. The animals were slaughtered at the age of 18-20 months. The results concerning daily weight gain and carcass value, were presented in the paper by Litwińczuk *et al.* [2014]. Slaughter and post-slaughter processing were carried out in accordance with the meat industry regulations and under veterinary inspection. Muscle samples were collected during dissection of the right half of the carcasses (following 24 h refrigeration at 2°C at relative humidity 85%), vacuum-packed in PA/PE vacuum bags and stored at 2-4°C until the analysis, i.e. 48 h after slaughter.

The basic chemical composition of the meat samples was determined: moisture content by drying (103°C) [PN-ISO 1442, 2000], mineral compounds in the form of ash by combustion [PN-ISO 936, 2000], total protein by the Kjeldahl method [PN-A-04018:1975/Az3, 2002], using a Büchi B-324 apparatus, and free fat by the Soxhlet method [PN-ISO 1444, 2000], using a Büchi B-811 apparatus. Collagen was determined based on the content of hydroxyproline [PN-ISO 3496, 2000] (conversion factor 7.52), using a Varian Cary 300 Bio spectrophotometer. The net energy of 100 g of meat was calculated based on total protein and intramuscular fat content. Atwater energy equivalents were used for the calculations – for protein 4.0 kcal=16.76 kJ, and for fat 9.0 kcal=37.66 kJ.

Fatty acid methyl esters (FAMEs) levels were analysed following fat extraction according to Folch *et al.* [1957]. Further steps were carried out according to PN-EN ISO 5509 [2001] and PN-EN ISO 5508 [1996]. FAMEs were separated in a Varian CG 3900 (Walnut Creek, USA) gas chromatograph with a flame ionization detector (FID). A CP 7420 capillary column was used (Agilent Technologies, USA), 100 m in length, inner diameter 0.25 mm, film thickness 0.25 μm. The analysis was carried out in increasing temperature conditions. The initial temperature of the oven was 50°C, and the final temperature was 260°C. The temperature of the injector and the detector was 270°C, the carrier gas (hydrogen) flow rate 2 ml/min, the size of the injected samples 1 μl, and the split ratio 1:50. Identification of FAMEs was based on retention times corresponding to reference mixtures (Supelco Inc., Bellefonte, PA, USA). Fatty acids

were expressed as percentage of the sum of total fatty acids identified using Star GC Workstation Version 5.5. software (Varian Inc., Walnut Creek, USA).

Statistical calculations were carried out with STATISTICA (ver. 9, StatSoft Inc., USA), using two-way analysis of variance with interaction determining the effect of breed and the type of muscle. Significance of differences between mean values was determined by the Tukey test.

The discussion of the results also took into account research by other authors [Sawicka-Zugaj and Litwińczuk 2012] on genetic variation in the breeds analysed, based on the number of alleles in 24 *loci*, which is commonly used in such research (BM1818, ETH225, BM1824, BM2113, SPS115, HEL1, INRA005, INRA063, ILSTS005, ILSTS006, TGLA53, ETH10, HEL5, HEL9, HEL13, INRA023, INRA035, INRA037, CSRM60, CSSM66, TGLA122, TGLA227, INRA032 and TGLA126).

## Results and discussion

The chemical composition of meat is an important factor determining both its nutritional value and its suitability for culinary purposes and for processing. The data in Table 1 show that breed had a significant ($P<0.01$ and $P<0.05$) effect on all of the meat parameters analysed. The lowest fat content (0.88% in LL and 0.56% in ST) and highest ash content (1.15% and 1.11%, respectively) were found in the muscles of the PR bulls. The meat of young bulls of the other native breeds, WB and PBW, had similar fat content to that of the PHF bulls (1.49% in LL and 1.28% in ST), but higher fat content than the Simmentals (1.27% and 0.70%, respectively). Ash content was similar to that obtained in both reference groups. The highest protein content was observed in the muscles of young WB bulls (23.05% in LL and 22.80% in ST), and the differences between PHF and PR were significant ($P<0.05$).

Collagen content is one of the most important indicators of the technological suitability of meat. Significantly ($P<0.05$) lowest total collagen content was recorded in the meat of the SIM bulls (0.55% in the LL and 0.80% in the ST). It is worth emphasizing that the proportion of collagen in total protein (C/P) in the LL muscle of the Simmentals was nearly 2 times lower than in the other breeds. The least favourable C/P ratio ($P<0.05$) was found in both muscles of the PHF bulls (4.43% in the LL and 7.82% in the ST). Christensen *et al.* [2011] evaluated the quality of the *longissimus thoracis* muscle in young bulls representing 15 European breeds, and demonstrated higher total and insoluble collagen content in the dairy breeds, i.e. Jersey, Holstein and Danish Red (on average 0.39% and 0.30%, respectively) than in young bulls of local breeds: Asturiana de los Valles, Avileña-Negra Ibérica and Pirenaica (on average 0.32% and 0.24%), while the lowest was noted in the beef breeds: Piemontese and Limousin (on average 0.28% and 0.21%). This tendency was confirmed in the present study.

Considering the overall results presented in Table 1, we can conclude that the energy value of the beef from native breeds was comparable to the beef of the SIM (with pronounced musculature) and the PHF bulls (a dairy breed) fattened in the

**Table 1**. Chemical composition (%), collagen content (%) and its share in total protein (C/P), and energy value (kJ/100 g) of the muscles of young bulls of the studied breeds[1]

| Item[2] | | *m. longissimus lumborum* | | | | | *m. semitendinosus* | | | | | Influencing factor | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | native breed | | | reference group | | native breed | | | reference group | | breed (B) | muscle (M) | interaction BxM |
| | | PR | WB | PBW | PHF | SIM | PR | WB | PBW | PHF | SIM | | | |
| Moisture | mean | $76.14^{c}$ | $73.80^{a}$ | $74.42^{ab}$ | $74.78^{ab}$ | $74.91^{b}$ | $76.22^{B}$ | $74.70^{A}$ | $75.35^{AB}$ | $75.64^{AB}$ | $75.23^{AB}$ | ** | * | ns |
| | SD | 1.31 | 1.75 | 0.59 | 0.45 | 0.68 | 0.54 | 1.68 | 1.10 | 0.85 | 0.68 | | | |
| Protein | mean | $21.56^{a}$ | $23.05^{b}$ | $22.96^{b}$ | $22.44^{b}$ | $22.57^{b}$ | $21.89^{a}$ | $22.80^{b}$ | $22.38^{ab}$ | $21.79^{a}$ | $22.79^{b}$ | ** | ns | ns |
| | SD | 1.19 | 1.10 | 0.33 | 0.48 | 0.57 | 0.49 | 1.01 | 1.06 | 0.89 | 0.58 | | | |
| Fat | mean | $0.88^{a}$ | $1.97^{c}$ | $1.40^{ab}$ | $1.49^{bc}$ | $1.27^{ab}$ | $0.56^{a}$ | $1.43^{b}$ | $0.99^{ab}$ | $1.28^{b}$ | $0.70^{a}$ | ** | ** | ns |
| | SD | 0.16 | 1.02 | 0.40 | 0.43 | 0.56 | 0.16 | 0.76 | 0.28 | 0.89 | 0.26 | | | |
| Ash | mean | $1.15^{b}$ | $0.95^{a}$ | $0.98^{a}$ | $1.07^{ab}$ | $1.04^{ab}$ | $1.11^{b}$ | $0.85^{a}$ | $0.98^{ab}$ | $0.96^{ab}$ | $1.04^{ab}$ | * | ns | ns |
| | SD | 0.05 | 0.24 | 0.20 | 0.18 | 0.10 | 0.07 | 0.20 | 0.13 | 0.38 | 0.14 | | | |
| Collagen | mean | $0.87^{b}$ | $0.98^{b}$ | $0.97^{bc}$ | $1.16^{bc}$ | $0.55^{a}$ | $1.10^{b}$ | $1.40^{c}$ | $1.46^{c}$ | $1.69^{d}$ | $0.80^{a}$ | ** | ** | ns |
| | SD | 0.26 | 0.13 | 0.31 | 0.25 | 0.17 | 0.14 | 0.24 | 0.14 | 0.22 | 0.07 | | | |
| W/P | mean | $3.55^{b}$ | $3.21^{a}$ | $3.24^{a}$ | $3.38^{ab}$ | $3.33^{ab}$ | $3.48^{b}$ | $3.30^{a}$ | $3.38^{ab}$ | $3.42^{ab}$ | $3.29^{a}$ | ** | ns | ns |
| | SD | 0.28 | 0.22 | 0.07 | 0.15 | 0.12 | 0.10 | 0.11 | 0.21 | 0.13 | 0.22 | | | |
| C/P | mean | $4.05^{ab}$ | $4.11^{ab}$ | $4.24^{ab}$ | $4.43^{b}$ | $2.40^{a}$ | $5.07^{B}$ | $5.98^{BC}$ | $6.44^{C}$ | $7.82^{D}$ | $3.52^{A}$ | ** | ** | ns |
| | SD | 1.08 | 0.61 | 1.34 | 2.21 | 0.77 | 0.64 | 1.13 | 0.30 | 0.87 | 0.33 | | | |
| Net energy | mean | $394.30^{A}$ | $460.40^{C}$ | $437.58^{BC}$ | $436.37^{BC}$ | $426.02^{B}$ | $388.08^{a}$ | $435.82^{c}$ | $412.43^{cb}$ | $410.72^{b}$ | $408.72^{ab}$ | ** | ** | ns |
| | SD | 24.63 | 45.69 | 18.13 | 12.96 | 21.56 | 11.79 | 39.28 | 20.95 | 29.04 | 14.76 | | | |

[1]PR – Polish Red; WB - White-Backed; PBW – Polish Black-White; PHF – Polish Holstein-Friesian; SIM – Simmental.
[2]W/P, water-to-protein ratio (protein hydration); C/P, share of collagen in total protein (%).
[aA...]Means bearing different superscripts within row and muscle differ significantly at: small letters – $P<0.05$; capitals – $P<0.01$.
*$P<0.05$; **$P<0.01$; ns − not significant.

same conditions and constituting the reference groups. In terms of the technological suitability of the raw product (based on collagen content and its proportion in total protein), the meat of the SIM bulls was the most suitable and PHF the least. The indicators obtained for the meat of the three native breeds were intermediate but generally closer to the values for PHF.

The nutritional value of fat is determined by the quantity and type of fatty acids. The results in Table 2 show that the fatty acids occurring in the highest proportions in the skeletal muscles of the bulls were oleic (C18:1c9), palmitic (C16:0) and stearic

**Table 2**. Fatty acids composition (% of total fatty acids) in the muscles of young bulls of the studied breeds[1]

| Item | *m. longissimus lumborum* | | | | | | *m. semitendinosus* | | | | | | Influencing factor | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | native breed | | | reference group | | | native breed | | | reference group | | | breed | muscle | interaction |
| | PR | WB | PBW | PHF | SIM | | PR | WB | PBW | PHF | SIM | | | | |
| C10:0 | 0.03 | 0.03 | 0.05 | 0.04 | 0.05 | | 0.04 | 0.05 | 0.05 | 0.05 | 0.03 | | ns | ns | ns |
| C12:0 | $0.05^{a}$ | $0.05^{a}$ | $0.06^{a}$ | $0.09^{b}$ | $0.08^{ab}$ | | $0.05^{A}$ | $0.05^{A}$ | $0.06^{A}$ | $0.22^{B}$ | $0.07^{A}$ | | ** | ** | ** |
| C13:0 | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 | | 0.02 | 0.03 | 0.03 | 0.03 | 0.03 | | ns | ns | ns |
| C14:0 | $2.20^{a}$ | $2.27^{a}$ | $2.43^{ab}$ | $2.86^{bc}$ | $2.97^{c}$ | | 2.21 | 2.25 | 3.08 | 3.69 | 2.75 | | ** | ns | ns |
| C14:1c9 | $0.58^{B}$ | $0.60^{B}$ | $0.56^{B}$ | $0.27^{A}$ | $0.92^{C}$ | | 0.61 | 0.60 | 0.85 | 0.18 | 0.69 | | ** | ns | ** |
| C15:0anteiso | $0.26^{ab}$ | $0.26^{ab}$ | $0.31^{b}$ | $0.25^{ab}$ | $0.19^{a}$ | | 0.22 | 0.24 | 0.22 | 0.26 | 0.20 | | ns | ns | ns |
| C15:0iso | 0.23 | 0.23 | 0.16 | 0.15 | 0.14 | | $0.20^{b}$ | $0.22^{b}$ | $0.15^{ab}$ | $0.20^{b}$ | $0.10^{a}$ | | * | ns | ns |
| C15:0 | $0.55^{ab}$ | $0.62^{b}$ | $0.43^{a}$ | $0.64^{c}$ | $0.48^{ab}$ | | 0.51 | 0.48 | 0.47 | 0.48 | 0.52 | | ns | ns | ns |
| C15:1c10 | 0.20 | 0.20 | 0.15 | 0.15 | 0.18 | | 0.19 | 0.18 | 0.20 | 0.18 | 0.20 | | ns | ns | ns |
| C16:0 | $26.00^{a}$ | $26.68^{ab}$ | $29.06^{c}$ | $28.08^{bc}$ | $29.30^{c}$ | | $26.22^{a}$ | $27.33^{ab}$ | $28.04^{b}$ | $29.10^{bc}$ | $29.71^{c}$ | | ** | ns | ns |
| C16:1c7 | 0.23 | 0.22 | 0.28 | 0.20 | 0.16 | | $0.25^{ab}$ | $0.24^{ab}$ | $0.14^{a}$ | $0.29^{b}$ | $0.25^{b}$ | | ns | ns | ns |
| C16:1c9 | 2.73 | 2.77 | 3.17 | 2.80 | 3.60 | | $3.44^{ab}$ | $2.89^{a}$ | $4.12^{b}$ | $3.40^{ab}$ | $3.06^{a}$ | | ns | ns | ns |
| C17:0anteiso | $0.34^{b}$ | $0.31^{ab}$ | $0.33^{ab}$ | $0.29^{ab}$ | $0.25^{a}$ | | 0.32 | 0.28 | 0.29 | 0.31 | 0.30 | | ns | ns | ns |
| C17:0iso | 0.65 | 0.65 | 0.67 | 0.66 | 0.50 | | $0.61^{ab}$ | $0.67^{b}$ | $0.50^{a}$ | $0.62^{ab}$ | $0.54^{ab}$ | | ns | ns | ns |
| C17:0 | $1.14^{ab}$ | $1.19^{b}$ | $1.02^{ab}$ | $1.03^{ab}$ | $0.93^{a}$ | | 1.05 | 1.09 | 0.94 | 0.85 | 1.02 | | ns | ns | ns |
| C17:1c9 | 0.63 | 0.64 | 0.71 | 0.63 | 0.61 | | $0.71^{b}$ | $0.70^{ab}$ | $0.67^{ab}$ | $0.63^{ab}$ | $0.54^{a}$ | | ns | ns | ns |
| C18:0 | $18.99^{BC}$ | $19.87^{BC}$ | $17.10^{AB}$ | $20.37^{C}$ | $15.05^{A}$ | | $16.50^{ab}$ | $16.60^{ab}$ | $15.54^{ab}$ | $17.75^{b}$ | $15.01^{a}$ | | ** | ** | ns |
| C18:1t6 to t11 | 1.83 | 1.86 | 2.19 | 1.57 | 1.52 | | 1.78 | 1.85 | 1.78 | 1.76 | 1.99 | | ns | ns | ns |
| C18:1c9 | $36.30^{ab}$ | $34.72^{ab}$ | $35.69^{ab}$ | $34.00^{a}$ | $38.04^{b}$ | | 37.93[b] | $38.19^{b}$ | $38.15^{b}$ | $34.88^{a}$ | $37.97^{b}$ | | ** | ** | ns |
| C18:1c11 | $1.36^{abc}$ | $1.26^{ab}$ | $1.58^{c}$ | $1.48^{bc}$ | $1.21^{a}$ | | 1.53 | 1.42 | 1.47 | 1.60 | 1.44 | | ns | ns | ns |
| C18:2t9t12 | $0.22^{ab}$ | $0.22^{ab}$ | $0.26^{b}$ | $0.22^{ab}$ | $0.20^{a}$ | | 0.22 | 0.21 | 0.22 | 0.21 | 0.24 | | ns | ns | ns |
| C18:2c9t12 | 0.21 | 0.20 | 0.20 | 0.17 | 0.19 | | 0.23 | 0.22 | 0.17 | 0.20 | 0.21 | | ns | ns | ns |
| C18:2c9c12n6 | $2.31^{B}$ | $1.99^{B}$ | $1.14^{A}$ | $2.10^{B}$ | $1.42^{A}$ | | $2.25^{B}$ | $1.64^{AB}$ | $1.14^{A}$ | $1.26^{A}$ | $1.36^{A}$ | | ** | ** | ns |
| C18:3c6c9c12n6 | $0.03^{ab}$ | $0.03^{ab}$ | $0.03^{a}$ | $0.04^{ab}$ | $0.05^{b}$ | | 0.07 | 0.07 | 0.04 | 0.05 | 0.03 | | ns | * | ns |
| C18:3c9c12c15n3 | $0.86^{B}$ | $0.80^{B}$ | $0.40^{A}$ | $0.39^{A}$ | $0.54^{A}$ | | $0.82^{B}$ | $0.67^{B}$ | $0.40^{A}$ | $0.42^{A}$ | $0.45^{A}$ | | ** | ns | ns |
| CLA (C18:2c9t11/t10c12) | 0.39 | 0.40 | 0.43 | 0.29 | 0.43 | | $0.34^{b}$ | $0.35^{b}$ | $0.32^{b}$ | $0.20^{a}$ | $0.36^{b}$ | | * | ** | ns |
| C20:0 | $0.06^{a}$ | $0.39^{b}$ | $0.10^{ab}$ | $0.18^{ab}$ | $0.09^{ab}$ | | $0.05^{a}$ | $0.06^{a}$ | $1.03^{b}$ | $0.05^{a}$ | $0.07^{a}$ | | ns | ** | ns |
| C20:1c9 | $0.06^{ab}$ | $0.09^{c}$ | $0.06^{b}$ | $0.08^{bc}$ | $0.04^{a}$ | | $0.09^{bc}$ | $0.12^{c}$ | $0.03^{a}$ | $0.07^{abc}$ | $0.06^{ab}$ | | ** | ns | ns |
| C20:1c11 | 0.09 | 0.09 | 0.13 | 0.27 | 0.12 | | 0.11 | 0.08 | 0.09 | 0.08 | 0.11 | | ns | ns | ns |
| C20:2c11c14n6 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | | $0.06^{c}$ | $0.05^{bc}$ | $0.03^{ab}$ | $0.04^{abc}$ | $0.03^{a}$ | | ns | ns | ns |
| C20:3c8c11c14n6 | 0.09 | 0.09 | 0.27 | 0.07 | 0.06 | | 0.07 | 0.06 | 0.06 | 0.06 | 0.07 | | ns | ns | ns |
| C20:4n6 | $0.49^{b}$ | $0.43^{b}$ | $0.45^{b}$ | $0.21^{a}$ | $0.21^{a}$ | | $0.41^{b}$ | $0.30^{ab}$ | $0.20^{a}$ | $0.31^{ab}$ | $0.23^{ab}$ | | * | ns | ns |
| C20:3c11c14c17n3 | $0.04^{a}$ | $0.03^{a}$ | $0.18^{b}$ | $0.03^{a}$ | $0.02^{a}$ | | 0.03 | 0.03 | 0.02 | 0.09 | 0.16 | | ns | ns | ns |
| C22:0 | $0.02^{a}$ | $0.03^{ab}$ | $0.03^{ab}$ | $0.03^{ab}$ | $0.04^{b}$ | | $0.03^{ab}$ | $0.02^{a}$ | $0.05^{b}$ | $0.03^{ab}$ | $0.03^{ab}$ | | ns | ns | ns |
| C20:5n3 | 0.13 | 0.14 | 0.12 | 0.10 | 0.07 | | 0.10 | 0.10 | 0.05 | 0.10 | 0.09 | | ns | ns | ns |
| C24:1c15 | 0.05 | 0.05 | 0.03 | 0.04 | 0.05 | | $0.07^{b}$ | $0.06^{ab}$ | $0.05^{ab}$ | $0.04^{ab}$ | $0.03^{a}$ | | ns | ns | ns |
| C22:5n3 | $0.57^{b}$ | $0.53^{b}$ | $0.25^{a}$ | $0.22^{a}$ | $0.34^{ab}$ | | $0.74^{b}$ | $0.67^{b}$ | $0.34^{a}$ | $0.21^{a}$ | $0.19^{a}$ | | ** | ns | ns |
| C22:6n3 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | | 0.04 | 0.03 | 0.4 | 0.02 | 0.03 | | ns | ns | ns |

[1]PR – Polish Red; WB – White-Backed; PBW – Polish Black-White; PHF – Polish Holstein-Friesian; SIM – Simmental.
[a,A]Means bearing different superscripts within row and muscle differ significantly at: small letters – P<0.05; capitals – P<0.01.
*P<0.05; **P<0.01; ns – not significant.

(C18:0) acid. According to Alfaia *et al.* [2006], Scollan *et al.* [2006] and Nogi *et al.* [2011] these are the most important acids present in beef. The breed of cattle had a significant effect on the level of 12 of the 38 fatty acids determined and the type of muscle significantly affected 7 of them, while the interaction between the two factors was significant only in the case of 2 fatty acids. Among saturated fatty acids (SFA), the significantly lowest percentage of C12:0 was recorded in the meat of the native breeds (0.05-0.06%), compared to 0.07-0.08% in the meat of the SIM bulls and 0.09-0.22% in PHF ($P<0.05$ and $P<0.01$). Oleic acid (C18:1c9) was dominant among monounsaturated fatty acids (MUFA), accounting for over one-third of all of the acids determined in the intramuscular fat of the young bulls (irrespective of breed). Significantly ($P<0.05$) lowest proportion of oleic acid was noted in the muscles of the PHF bulls (34.00% in LL and 34.88% in ST), while in the muscles (particularly ST) of the bulls of native breeds the percentage was similar to that found for SIM, ranging from 37.93% to 38.19%.

Among 38 fatty acids, it is worth noting the level of biologically active acids. Higher percentages of CLA were found in the meat of the bulls of the three local breeds (0.32-0.43%) and SIM (0.36-0.43%) than in the PHF meat (0.20-0.29%). In the case of the ST muscle the differences were statistically significant ($P<0.05$). The muscles of the young bulls of the PR and WB breeds had significantly highest level of α-linolenic acid (C18:3n3, $P<0.01$) and docosapentaenoic acid (C22:5n3, $P<0.05$). Fraser *et al.* [2009] found that the LL muscle of Welsh Black steers had significantly lower proportion of C16:0 (by 1.2%) and significantly higher proportion of C18:3n3 (by 0.3%), C18:2n6 (by 0.7%) and CLA (by 0.15%) compared with Charolais crossbreds. Similarly, Choi *et al.* [2000], in a comparison of fatty acid composition in the *longissimus thoracis* of the Welsh Black and Holstein-Friesian cattle, observed a higher percentage of the acids C18:3n3, C20:5n3 and C22:5n3, which are beneficial from the health-promoting point of view, in the Welsh Black cattle, resulting in a lower n6/n3 ratio. Also Aldai *et al.* [2012] demonstrated the effect of breed on the fatty acid profile of veal. Comparison of fatty acid content in muscle tissue lipids in crossbreeds of the local Spanish breed Tudanca with Charolais and purebred Limousin, raised in mountainous terrain, revealed a more beneficial fatty acid profile for the local breed, i.e. a higher percentage of PUFA (including CLA) and a lower n6/n3 ratio.

The results presented in Table 3 show that breed had a significant effect on fatty acid profile, proportions and indices. The type of muscle significantly affected the percentages of SFA, MUFA and PUFA, as well as the saturation index (S/P). No significant interaction of the two variables was found for any of the traits evaluated.

The most beneficial fatty acid profile was noted for the meat of the young bulls of the PR and WB breeds, with the highest percentages of polyunsaturated fatty acids (PUFA) of all the breeds: 4.56% and 4.11% in the LL ($P<0.01$) and 4.51% ($P<0.05$) and 3.53% in the ST respectively. The meat from the PR and WB bulls also had significantly the most beneficial health-promoting properties. It had the highest PUFA/SFA ratio ($P<0.01$ in the LL and $P<0.05$ in the ST) and the most beneficial

**Table 3**. Partial sums of fatty acids (%), proportions and indices in the muscles of young bulls of the studied breeds[1]

| Item[2] | *m. longissimus lumborum* | | | | | *m. semitendinosus* | | | | | Influencing factor | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | native breed | | | reference group | | native breed | | | reference group | | breed (B) | muscle (M) | interaction BxM |
| | PR | WB | PBW | PHF | SIM | PR | WB | PBW | PHF | SIM | | | |
| SFA | 49.06$^{a}$ | 51.14$^{ab}$ | 50.27$^{ab}$ | 53.34$^{b}$ | 48.95$^{a}$ | 46.65$^{a}$ | 47.93$^{ab}$ | 48.32$^{ab}$ | 52.23$^{b}$ | 49.22$^{ab}$ | ** | * | ns |
| | 3.24 | 2.22 | 3.37 | 1.74 | 1.03 | 3.55 | 2.92 | 1.71 | 1.22 | 1.99 | | | |
| BCFA | 1.47$^{b}$ | 1.45$^{b}$ | 1.43$^{b}$ | 1.34$^{ab}$ | 1.07$^{a}$ | 1.36$^{abc}$ | 1.41$^{c}$ | 1.16$^{ab}$ | 1.38$^{bc}$ | 1.11$^{a}$ | ** | ns | ns |
| | 0.19 | 0.21 | 0.33 | 0.20 | 0.11 | 0.26 | 0.16 | 0.09 | 0.15 | 0.17 | | | |
| MUFA | 42.21$^{ab}$ | 40.63$^{a}$ | 42.35$^{ab}$ | 39.92$^{a}$ | 44.92$^{b}$ | 44.91$^{b}$ | 44.49$^{ab}$ | 45.74$^{b}$ | 41.36$^{a}$ | 44.34$^{b}$ | * | * | ns |
| | 4.52 | 2.60 | 3.81 | 1.29 | 1.10 | 3.12 | 3.43 | 1.20 | 1.27 | 1.65 | | | |
| TFA | 2.66 | 2.68 | 3.09 | 2.26 | 2.33 | 2.57 | 2.64 | 2.50 | 2.36 | 2.81 | ns | ns | ns |
| | 0.60 | 0.76 | 1.21 | 0.38 | 0.37 | 0.65 | 0.91 | 0.36 | 0.26 | 0.54 | | | |
| PUFA | 4.56$^{B}$ | 4.11$^{B}$ | 2.88$^{A}$ | 3.19$^{A}$ | 2.73$^{A}$ | 4.51$^{c}$ | 3.53$^{bc}$ | 2.29$^{a}$ | 2.55$^{ab}$ | 2.57$^{ab}$ | ** | * | ns |
| | 1.14 | 0.34 | 0.49 | 0.31 | 0.74 | 0.80 | 1.29 | 0.70 | 0.26 | 0.77 | | | |
| PUFA/SFA | 0.09$^{B}$ | 0.08$^{B}$ | 0.06$^{A}$ | 0.06$^{A}$ | 0.06$^{A}$ | 0.10$^{c}$ | 0.07$^{bc}$ | 0.05$^{a}$ | 0.05$^{a}$ | 0.05$^{ab}$ | ** | ns | ns |
| | 0.02 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.03 | 0.02 | 0.01 | 0.02 | | | |
| n6/n3 | 1.81$^{A}$ | 1.71$^{A}$ | 2.14$^{A}$ | 3.48$^{B}$ | 1.86$^{A}$ | 1.68 | 1.44 | 2.05 | 2.09 | 1.99 | ** | ns | ns |
| | 0.18 | 0.29 | 0.73 | 1.22 | 0.34 | 0.29 | 0.53 | 0.87 | 0.54 | 0.23 | | | |
| h/H | 1.45$^{b}$ | 1.34$^{ab}$ | 1.23$^{a}$ | 1.20$^{a}$ | 1.26$^{a}$ | 1.49$^{c}$ | 1.43$^{c}$ | 1.30$^{b}$ | 1.13$^{a}$ | 1.25$^{ab}$ | ** | ns | ns |
| | 0.14 | 0.12 | 0.16 | 0.08 | 0.09 | 0.16 | 0.12 | 0.11 | 0.05 | 0.08 | | | |
| S/P | 1.02$^{ab}$ | 1.10$^{ab}$ | 1.09$^{ab}$ | 1.19$^{b}$ | 0.99$^{a}$ | 0.92$^{A}$ | 0.97$^{A}$ | 0.97$^{A}$ | 1.15$^{B}$ | 1.02$^{AB}$ | ** | * | ns |
| | 0.14 | 0.11 | 0.17 | 0.09 | 0.05 | 0.14 | 0.11 | 0.06 | 0.06 | 0.09 | | | |
| AI | 0.75$^{A}$ | 0.79$^{A}$ | 0.87$^{AB}$ | 0.92$^{B}$ | 0.87$^{AB}$ | 0.71$^{a}$ | 0.76$^{ab}$ | 0.84$^{b}$ | 1.00$^{c}$ | 0.87$^{b}$ | ** | ns | ns |
| | 0.09 | 0.06 | 0.11 | 0.06 | 0.06 | 0.08 | 0.10 | 0.10 | 0.04 | 0.07 | | | |
| TI | 1.69$^{a}$ | 1.83$^{a}$ | 1.93$^{a}$ | 2.17$^{b}$ | 1.77$^{a}$ | 1.54$^{a}$ | 1.64$^{ab}$ | 1.76$^{ab}$ | 2.06$^{c}$ | 1.83$^{bc}$ | ** | ns | ns |
| | 0.18 | 0.16 | 0.31 | 0.14 | 0.11 | 0.25 | 0.20 | 0.17 | 0.13 | 0.18 | | | |

[1]PR – Polish Red; WB - White-Backed; PBW – Polish Black-White; PHF – Polish Holstein-Friesian; SIM – Simmental.

[2]SFA – saturated fatty acids, sum of C10:0, C12:0, C13:0, C14:0, C15:0, C16:0, C17:0, C18:0, C20:0 and C22:0; BCFA – branched-chain fatty acids, sum of C15:0anteiso, C15:0iso, 17:0anteiso and C17:0iso; MUFA– monounsaturated fatty acids, sum of C14:1c9, C15:1c10, C16:1c7, C16:1c9, C17:1c9, C18:1c9, C18:1c11, C20:1c9, C20:1c11 and C24:1c15; TFA, *trans* isomers of fatty acids, sum of C18:1t6 to t11, C18:2t9t12, C18:2c9t12 and CLA (C18:2c9t11 and C18:2t10c12); PUFA – polyunsaturated fatty acids, sum of n6 and n3, n6 = sum of C18:2c9c12n6, C18:3c6c9c12n6, C20:2c11c14n6, C20:4n6 and C20:3c8c11c14n6, n3 = sum of C18:3c9, 12, 15n3, C20:3c11c14c17n3, C20:5n3, C22:5n3 and C22:6n3; PUFA/SFA – polyunsaturated/saturated ratio; n6/n3 - n6/n3 ratio; h/H – hypocholesterolemic/hypercholesterolemic ratio, sum of [(C18:1c9, C18:2c9c12n6, C18:3c6c9c12n6, C18:3c9c12c15n3, C20:2c11c14n6, C20:4n6, C20:3c8c11c14n6, C20:3c11c14c17n3, C20:5n3, C22:5n3 and C22:6n3)/(sum of C12:0, C14:0 and C16:0)]; S/P – saturation index [(sum of C14:0, C16:0 and C18:0)/(sum of MUFA and PUFA)]; AI – atherogenic index [(sum of C12:0, 4 x C14:0 and C16:0)/(sum of MUFA, n6 and n3)]; TI – thrombogenic index [(sum of C14:0, C16:0 and C18:0)/(sum of 0.5 x MUFA, 0.5 x n6, 3 x n3 and n3/n6)]; S/P, AI, TI indices were calculated according to Ulbricht and Southgate [1991].

$^{aA}$...Means bearing different superscripts within row and muscle differ significantly at: small letters – P<0.05; capitals – P<0.01.

*P<0.05; **P<0.01; ns – not significant.

n6/n3 ratio: 1.81 and 1.71 in the LL and 1.68 and 1.44 in the ST. In the LL muscle the differences between means for these bulls and the PHF breed were significant (P<0.01). The muscles of the PR and WB bulls also had the most beneficial (i.e. the highest) h/H (hypocholesterolaemic/hypercholesterolaemic acids) ratio, 1.34-1.45 in the LL and 1.41-1.49 in the ST, which in the other breeds was 1.20-1.26 and 1.13-1.30. The differences were significant in both muscles for the PR breed, but only in the ST in the case of WB (P<0.05). The atherogenic (AI) and thrombogenic (TI) indices,

calculated using the formulas proposed by Ulbricht and Southgate [1991] also had lower (more beneficial) values in these breeds (PR and WB), and the differences were significant ($P<0.01$ and $P<0.05$ respectively) in relation to PHF.

The proportions of selected groups of fatty acids obtained in the present study are consistent with the results reported by other authors [Orellanna *et al.* 2009, Morales *et al.* 2012]. According to Scollan *et al.* [2006], the PUFA/SFA ratio in beef is relatively low, ranging on average from 0.05 to 0.11. A low PUFA/SFA ratio in beef with respect to the recommended value (over 0.4) is a natural phenomenon associated with hydrogenation of unsaturated fatty acids originating in fodder in the rumen. According to Orellana *et al.* [2009] the PUFA/SFA, n6/n3 and h/H indices are the most important indicators of the nutritional quality of fat, whereas the AI and TI indicate the degree to which the fatty acids present in food contribute to increased frequency of coronary disease. According to nutritional recommendations, the optimum n6/n3 ratio is between 1 and 2, and should not exceed 4.0 [Alfaia et al. 2006]. In the present study a highly favourable n6/n3 ratio, falling within the recommended range, was obtained in the young bulls of local breeds, namely from 1.71 to 2.14 in the LL and from 1.44 to 2.05 in the ST. The least favourable n6/n3 ratio was obtained in the LL of the PHF bulls (3.48; $P<0.01$). According to many authors, meat obtained from cattle raised in traditional (low-input) production systems, in which feeding is based mainly on grass forage and haylage, has a higher percentage of polyunsaturated fatty acids and a lower n6/n3 ratio than in intensively fed animals [Oprządek and Oprządek 2003, Alfaia *et al.* 2006, Wood *et al.* 2008, Morales *et al.* 2012].

Considering the overall results presented in Tables 2 and 3, we can conclude that the meat obtained from the young bulls of native breeds (especially PR and WB) had more beneficial fatty acid profiles in terms of health-promoting value, reflected in lower proportions of saturated fatty acids (C12:0, C14:0 and C16:0) and higher proportions of polyunsaturated fatty acids (C18:3n3, C18:2n6 and C22:5n3). This, of course, meant significantly more beneficial values in these breeds of indices used to characterize the health-promoting properties of intramuscular fat.

The Polish Red and White-Backed breeds are the oldest native breeds of cattle in Poland. They exhibit the highest genetic variation, which is confirmed by the markedly higher number of alleles at the 24 selected loci: 181 for PR and 171 in WB, 158 in PBW but only 146 in PHF [Sawicka-Zugaj and Litwińczuk 2012]. Among the alleles there were considerably more 'specific alleles' (occurring in only one breed) in these two native breeds, i.e. 10 in PR and WB and only 4 in PBW and PHF. Certain genes still present in the native breeds but lost (during selection for high productivity) in high-production breeds are probably also those responsible for better nutritional quality of the products, including the content of biologically active compounds determining their health-promoting properties. A study by the authors of this paper [Litwińczuk *et al.* 2012] showed that the milk of cows of the three native breeds (particularly PR), exploited on small farms in a low-input system, had significantly better chemical composition (including content of biologically active compounds)

and indicators of suitability that are important for cheese production (better curd quality) in comparison with the milk of other breeds used in Poland (particularly in intensive technologies). For this reason the milk of the PR cows was placed on the list of traditional products.

To sum up, the meat of the native cattle breeds had the most beneficial fatty acid profile, with the highest percentage of PUFA, on average 4.54% in the case of PR and 3.82% for WB, in comparison with the other evaluated breeds (2.58-2.87%). It also had more beneficial n6/n3 and h/H ratios and fatty acid indices (AI and TI) than the meat of the PHF bulls. The intramuscular fat of the two oldest Polish cattle breeds, Polish Red and White-Backed, had significantly better health-promoting properties. Therefore beef obtained in a low-input system from the native breeds of cattle should be treated as a product not only of high nutritional value but also having valuable health-promoting properties. This should probably be associated with the pool of genes (responsible for the quality of products) that remain conserved in these breeds but have been lost in high-production breeds during the intensive selection process, e.g. selection for milk yield in the Holstein-Friesian breed. Milk and meat obtained from the native breeds of cattle in a low-input system only account for a small proportion of global production in the developed countries, but can be a valuable raw material source for regional and traditional products which, following an adequate promotion, could be an important source of farming income.

**REFERENCES**


1. ALDAI N., LAVÍN P., KRAMER J.K.G., JAROSO R., AND MANTECÓN A.R., 2012 – Breed effect on quality veal production in mountain areas: emphasis on meat fatty acid composition. ***Meat Science*** 92, 687-696.
2. ALFAIA C.M.M., RIBEIRO V.S.S., LOURENC M.R.A., QUARESMA M.A.G., MARTINS S.I.V., PORTUGAL A.P.V., FONTES C.M.G., BESSA R.J.B., CASTRO M.L.F., PRATER J.A.M., 2006 – Fatty acid composition, conjugated linoleic acid isomers and cholesterol in beef from crossbred bullocks intensively produced and from Alentejana purebred bullocks reared according to Carnalentejana-PDO specifications. ***Meat Science*** 72, 425-436.
3. CHOI N.J., ENSER M., WOOD J.D., SCOLLAN N.D., 2000 – Effect of breed on the deposition in beef muscle and adipose tissue of dietary n-3 polyunsaturated fatty acids. ***Animal Science*** 71, 509-519.
4. CHRISTENSEN M., ERTBJERG P., FAILLA S., SAŃUDO C, RICHARDSON R.I., NUTE G.R., OLLETA J.L., PANEA B., ALBERTÍ P., JUÁREZ M., HOCQUETTE J.F., WILLIAMS J.L., 2011 – Relationship between collagen characteristics, lipid content and raw and cooked texture of meat from young bulls of fifteen European breeds. ***Meat Science*** 87, 61-65.
5. FOLCH J.M., LEES M., SLOANE-STANLEY G.H., 1957 – A simple method for the isolation and purification of total lipids from animal tissues. ***Journal of Biological Chemistry*** 226, 497-509.
6. FRASER M.D., DAVIES D.A., VALE J.E., NUTE G.R., HALLETT K.G., RICHARDSON R.I., WRIGHT I.A., 2009 – Performance and meat quality of native and continental cross steers grazing improved upland pasture or semi-natural rough grazing. ***Livestock Science*** 123, 70-82.
7. KARSTEN H.D., PATTERSON P.H., STOUT R., CREWS G., 2010 – Vitamins A, E and fatty acid composition of the eggs of caged hens and pastured hens. ***Renewable Agriculture and Food Systems*** 25, 45-54.

8. LITWIŃCZUK Z., BARŁOWSKA J., CHABUZ W., BRODZIAK A., 2012 – Nutritional value and technological suitability of milk from cows of three polish breeds included in the genetic resources conservation programme. ***Annals of Animal Science*** 3, 423-432.
9. LITWIŃCZUK Z., FLOREK M., PIETRASZAK K., 2006 – Physico-chemical quality of meat from heifers and young bulls of the Black-and White (BW) variety of Polish Holstein-Fresian breed, and commercial BW crossbreds sired by Limousine and Charolaise bulls. ***Animal Science Papers and Reports*** 24 (2 suppl.), 179-186.
10. LITWIŃCZUK Z., ŻÓŁKIEWSKI P., FLOREK M., CHABUZ W., DOMARADZKI P., 2014 – Semi-intensive fattening suitability and slaughter value of young bulls of 3 Polish native breeds in comparison with Polish Holstein-Friesian and Simmental. ***Annals of Animal Science*** 2, 453-460.
11. MONTEIRO A.C.G., FONTES M.A, BESSA R.J.B., PRATES J.A.M., LEMOS J.P.C., 2012 – Intramuscular lipids of Mertolenga-PDO beef, Mertolenga-PDO veal and "Vitela Tradicional do Montado"-PGI veal. ***Food Chemistry*** 132, 1486-1494.
12. MORALES R., FOLCH C., IRAIRA S., TEUBER N., REALINI C.E., 2012 – Nutritional quality of beef produced in Chile from different production systems. ***Chilean Journal of Agricultural Research*** 72, 80-86.
13. NOGI T., HONDA T., MUKAI F., OKAGAKI T., OYAMA K., 2011 – Heritabilities and genetic correlations of fatty acid compositions in longissimus muscle lipid with carcass traits in Japanese Black cattle. ***Journal of Animal Science*** 89, 615-621.
14. OPRZĄDEK J., OPRZĄDEK A., 2003 – Modyfikowanie składu kwasów tłuszczowych w tłuszczu mięsa przeżuwaczy (Modifications of fatty acids composition in ruminants). In Polish, summary in English. ***Medycyna Weterynaryjna*** 59, 492-495.
15. ORELLANNA C., PEŃA F., GARCIA A., PEREA J., MARTOS J., DOMENECH V., ACERO R., 2009 – Carcass characteristics, fatty acids composition, and meat quality of Cirollo Argentino and Bradford steers raised on forage in a semi-tropical region of Argentina. ***Meat Science*** 81, 57-64.
16. SAWICKA-ZUGAJ W., LITWIŃCZUK Z., 2012 – Genetic variation in the population of three Polish cattle breeds included into the programme of genetic resources protection and Holstein-Friesian breed, estimation on the basis of polymorphism of 24 microsatellite DNA sequences. ***African Journal of Biotechnology*** 11, 14116-14122.
17. SCOLLAN N.D., HOCQUETTE J.F., NUERNBERG K., DANNENBERGER D., RICHARDSON I., MOLONEY A., 2006 – Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality. ***Meat Science*** 74, 17-33.
18. SEPÚLVEDA W., MAZA M.T., MANTECÓN A.R., 2008 – Factors that affect and motivate the purchase of quality-labelled beef in Spain. ***Meat Science*** 80, 1282-1289.
19. ULBRICHT T.L., SOUTHGATE D.A.T., 1991 – Coronary heart disease: seven dietary factors. ***The Lancet*** 338, 985-992.
20. WOOD J.D., ENSER M., FISHER A.V., NUTE G.R., SHEARD P.R., RICHARDSON R.I., HUGHES S.I., WHITTINGTON F.M., 2008 – Fat deposition, fatty acid composition and meat quality. A review. ***Meat Science*** 78, 343-358.