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Effect of breed and aging time on physicochemical and organoleptic quality of beef and its oxidative stability

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Abstract. In this experiment we used the meat of 16 Polish Red-and-White and Simmental bulls slaughtered at the age of 24 months. Physicochemical and organoleptic analyses were carried out on meat aged for 2, 7, 14 and 21 days and subjected to heat treatment. In addition, the effect of aging on oxidative stability and fatty acid profile of meat lipids was examined after 21 days of aging.

The meat aging process determined all the physicochemical characteristics except for heating loss, as well as most of the sensory properties of meat. During aging, lightening of muscle colour, increased redness and chroma, and improved tenderness were observed. High scores were given for aroma intensity and taste desirability. The highest scores were awarded to meat aged for 7 and 14 days. The evaluation showed that meat tenderness and delicate texture steadily improved until day 14, after which they remained at a similar level or slightly deteriorated after 21 days of aging. Meat from the conserved breed generally had better scores, which could be influenced by better component scores for delicate texture and juiciness, as well as taste intensity. This study revealed no significant effect of breed on the degree of lipid peroxidation expressed as thiobarbituric acid-reactive substances (TBARS). The amount of malondidehyde was higher in meat aged for 21 days than in fresh meat. Aging did have an effect on the fatty acid profile of longissimus dorsi muscle (MLD) intramuscular fat. Wet aging of meat for 21 days was found to alter the content of capric (C10 : 0), palmitoleic (C16 : 1) and stearic acids (C18 : 0).

1 Introduction

Polish Red-and-White cattle was brought to south-western Poland from Westphalia, Rheinland and East Friesland over a century ago. The Polish Red-and-White conservation programme has been running since 2007. According to herdbooks, the Polish Red-and-White population has almost 5500 animals, of which around 3000 cows are included in the genetic resource conservation programme. Dual-purpose Polish Red-and-White cattle have preserved the characteristics of autochthonous populations: excellent adaptation to harsh environmental conditions, good resistance and health, longevity, and undemanding feeding habits. The herds are located mainly in southern Poland, where high-quality feeds are hard to obtain due to the lie of the land and harsher climate. The breed yields an average of 4500–5000 kg of milk with average dressing percentage of 54 %. In 2013, "beef from Polish Red-and-White cow" was included in the Ministry of Agriculture and Rural Development's national list of traditional products. Yet, there are hardly any recent studies concerning the quality of products from this breed, accounting for the last 10 years of breeding work performed as part of the conservation programme. Meat can be aged by wet or dry methods (Smith et al., 2008). In the wet aging method, meat is stored in vacuum-packed bags and obviously requires no strict moisture and air flow control, which makes this method more popular than dry aging. It is accepted that beef should be aged for up to 6 weeks, whereas other types of meat are aged for 2–12 days (pork; Juárez et al., 2011) or up to 12 h (poultry meat; Nowak, 2005). Changes in protein, fat and pigments, pH and water loss observed during aging of meat determine the major organoleptic quality characteristics, namely colour, tenderness, juiciness, taste and aroma of culinary meat. The rate and direction of meat lipid peroxidation depend on many factors such as chemical composition (amount and type of lipids, water content), the presence of natural pro-oxidants and antioxidants in meat, and the technological processes and storage conditions (Belitz et al., 2004; Shah et al., 2014). During fat oxidation, unsaturated fatty acids are degraded to volatile short-chain oxidation products, which determine not only taste and aroma but also physicochemical characteristics, including colour and texture (Santos-Fandila et al., 2014; Resconi et al., 2013). The end products of peroxidation, such as malondialdehyde (MDA), may have mutagenic and carcinogenic effects (Ayala et al., 2014).

Between-breed differences may play a considerable role in determining the quality characteristics of aged beef. The differences in chemical composition, including the fatty acids of intramuscular fat, may have an effect on the other physicochemical and organoleptic characteristics of beef as well as on changes in its health-promoting value during storage or heat treatment.

The objective of the study was to determine the effect of aging on organoleptic and physicochemical characteristics of meat from two breeds of dual-purpose cattle.

2 Materials and methods

The study was conducted at the Odrzechowa Ltd. Experimental Station of the National Research Institute of Animal Production. Bulls were housed, fed and treated according to Ordinance of Minister of Agriculture and Rural Development (2010). The test material used was meat from eight Polish Red-and-White (ZR) and eight Simmental (SM) bulls. Due to the conditions of the conservation programme, in terms of genotype the ZR bulls were in fact crossbreeds with a low percentage of Holstein-Friesian inheritance (from 9 to 25 %). Bulls were fed maize silage and hay, or haylage supplemented with concentrate, about 2.0 kg per day (88.5 % DM, 0.96 UFV, 120 g PDIN, 108 g PDIE).[1] The concentrates fed to the bulls contained soybean meal, rapeseed cake, barley, wheat, triticale, ground limestone, and dicalcium phosphate. Rations were formulated to meet IZ-INRA (2009) requirements for weight gains of approx. 1000 g day^{-1}. Animals were kept in breed groups in a free-stall building on straw, and had constant access to water from automatic drinkers. The experiment terminated at 24 months of age when the bulls were slaughtered following 24 h withdrawal of feed. Animals were slaughtered in a commercial EU-licensed abattoir, stunned using a captive-bolt pistol. The samples of longissimus dorsi muscle (MLD) were collected from the right side of the carcass, cut into consistently sized pieces, weighed, vacuum-packed in plastic bags (polyamide / polyethylene: 50 / 40) and stored at 4 °C until further analyses.

Physicochemical analysis of the meat was performed at 2, 7, 14 and 21 days of aging. pH of meat was measured with a penetrating electrode (Hanna Instruments FC232D) connected to a pH meter (Hanna Instruments HI 99163) after calibration with two buffers (pH = 4.01 and pH = 7.01). The pH meter automatically corrected pH values, taking into account muscle temperature. Meat colour was determined using the model CR-310 Minolta chroma meter fitted with a 50 mm orifice according to CIE-L*a*b* system. Heating loss was determined when preparing the meat for sensory assessment according to Boccard et al. (1981). The maximum shear force (F_{max} expressed in N) was measured with a Warner–Bratzler V blade on a texture analyzer (model TA-XT2 plus, Stable Micro Systems, Godalming, Surrey, England). Meat samples were cut (1.5 mm s^{-1} crosshead speed) into 10 mm^2 cubes (minimum of five per sample) parallel to muscle fibre orientation. Results of shear force measurements were analysed using testXpert II software. Organoleptic analysis of the samples (i.e. colour, aroma, flavour, texture, juiciness and delicacy) was performed following heat treatment (oven roasting at 165 °C to an internal temperature of 70 °C). The sensory properties were evaluated by a panel of nine judges on a five-point scale (1 point – worst score; 5 points – best score) according to the procedures described by Baryłko-Pikielna and Matuszewska (2014).

To determine oxidative stability of the meat in response to aging, the fatty acid profile was compared in samples of fresh meat and in meat aged for 21 days, and the degree of fat peroxidation in meat was determined as thiobarbituric acid-reactive substances (TBARS) (milligrams of malonaldehyde per kilogram of meat). The composition of fatty acids was determined as described by Folch et al. (1957) as methyl esters in hexane by gas chromatography with a Shimadzu GC-2010 with a Rtx 2330 capillary column (105 m length × 0.32 mm × 0.2 µm), with an injection volume of 1.0 µL, a temperature programme of 60–240 °C, an injector temperature of 250 °C, a detector temperature of 250 °C, helium as the carrier gas, according to ISO 12966-2:2011, with slight modifications. The atherogenic index (AI) was calculated according to Ulbricht and Southgate (1991) based on the following equation:

$$\mathrm{AI} = (\mathrm{C12:0} + 4 \times \mathrm{C14:0} + C16:0) / (\mathrm{MUFA} + \mathrm{PUFA}).$$

Statistical analysis was performed with Statistica ver. 12 software (2013). Single-factor analysis of variance with repeated measures was used. Scheffe's test was applied to determine differences between the means and also to identify homogeneous groups, which were later analysed using planned comparisons (contrast analysis). Two-factor analysis of variance was used to determine the effect of breed and aging time (2 and 21 days of aging) on the fatty acid profile of meat, and differences between the means were determined

[1] DM: dry matter; UFV: unit for meat production; PDIN: protein truly digested in the small intestine when rumen available nitrogen is limiting microbial growth; PDIE: protein truly digested in the small intestine when rumen available energy is limiting microbial growth.

with Duncan's test. The results were considered significant at $P \leq 0.05$ and highly significant at $P \leq 0.01$.

3 Results and discussion

3.1 Changes in the physicochemical properties of aged meat

Parameters such as yellowness (b^*) or chroma (C^*), as well as instrumental tenderness measured as shear force, were affected during the aging process by the breed of the bulls. The meat from the Polish Red-and-White breed was characterized by more yellow colour (5.96 vs. 4.79) and distinctly higher chroma (21.93 vs. 21.06) compared to Simmental meat. The meat from the ZR breed was more tender than SM meat (69.28 vs. 93.61 N). The results obtained for colour lightness are lower than those reported for Italian Maremmana bulls slaughtered at 18 and 24 months of age (Sargentini et al., 2010; an average of 33.79 vs. 38.4 and 41.1, respectively). Unlike our study, Marino et al. (2014) noted no effect of breed on yellowness (b^*). Simmental meat was characterized by higher shear force compared to meat from the Polish Red-and-White breed ($P \leq 0.05$). It is in line with the study of Litwińczuk et al. (2014), who observed higher shear force value for Simmental meat (97.7 N) than for meat of the native breed: Polish Red (92.2 N) and Polish Black-and-White (89.0 N). Similar high shear force values (for the initial value SM 110.98 N) of Simmental meat were observed by Sochor et al. (2005).

The weight loss, meat colour lightness and redness of meat increased during the aging process, while pH and shear force decreased (Table 1). The loss in the meat sample weight increased linearly such that after 21 days of aging it exceeded 5 % regardless of the breed. The heating loss observed in our study was relatively high (35–41 %) and remained independent of aging time or breed of the bulls (Table 1). Niedźwiedź et al. (2012) noted lower values for heating loss (about 33 %) and, like in our study, found that meat aging time had no effect on this parameter. Kołczak et al. (2007) report that the capillary space becomes more permeable to water as a result of these changes and the changes in interactions between ions and proteins. Meat colour lightness (L^*) increased during aging of the meat regardless of the breed. Similar relationships during the aging of meat from Podolian and Friesian cattle and their crossbreeds were reported by Marino et al. (2014). In addition, they obtained similar results for redness (a^*), which increased with aging time, although they observed greater variation in this parameter in the analysed breeds. As regards meat colour parameters, an interaction between breed and aging time was observed. With time, the meat of the ZR breed increased in yellowness, whereas SM meat decreased in yellowness. Chroma was relatively more stable for SM meat but increased with time in the meat of the ZR breed. Changes within proteins that occur during aging of meat also contribute to improved tenderness. The ongoing process of meat aging changes muscle structure as a result of degradation of myofibrils, cytoskeletal proteins (Kołczak et al., 2003a, b) and intramuscular collagen (Purslow, 2005). Monsón et al. (2004), who analysed changes in tenderness of Holstein, Brown Swiss, Limousin and Blonde d'Aquitaine beef aged for up to 35 days, observed differences between the breeds only during the initial period (up to day 14 of aging). During the aging of meat, shear force was observed to decrease considerably between 1 and 7 days of aging, regardless of the breed. At later dates the observed differences between the breeds were smaller. Similar relationships were observed in our study, where the greatest differences occurred between the conserved and Simmental breeds up to 14 days of aging, after which the analysed parameter became gradually uniform.

Niedźwiedź et al. (2012) found no changes in pH in response to aging for 14 days, while Marino et al. (2014) observed no changes when aging the meat for up to 21 days. The changes that we observed in pH during aging of the meat may indicate that postmortem glycolysis took an abnormal course. The pH value has an effect on the other physicochemical properties of meat, including its colour. Marino et al. (2014) observed the colour of longissimus dorsi muscle to lighten as the pH value decreased during 21-day aging of meat from Podolian cattle.

3.2 Changes in sensory properties of aged meat

Breed had no discernible effect on sensory properties of the beef, although according to the sensory panel the meat from the Polish Red-and-White breed was characterized by slightly greater taste intensity, juiciness and delicate texture, receiving better overall score (3.82 vs. 3.47; $P = 0.09$) (Table 2). The differences observed between the breeds could result from intramuscular fat content, for the meat of ZR bulls was characterized by higher fat content compared to the meat of SM bulls (1.99 % vs. 1.5 %), although the differences were not significant. Fat, particularly intramuscular fat, largely determines meat taste, making beef juicy and delicate while also improving its aroma (Litwińczuk and Litwińczuk, 1998). The olfactory–gustatory sensations could also be influenced by the higher content of polyunsaturated fatty acids in the Simmental breed, which are more susceptible to lipid peroxidation (Table 3). As a result of changes, unsaturated fatty acids can yield several products such as ketones, aldehydes, alcohols and acids, which may improve the taste and aroma of meat; however, intense fatty acid metabolism generates secondary lipid peroxidation products and leads to unfavourable changes in taste and aroma (i.e. development of rancidity) (Campo et al., 2006; Scollan et al., 2014).

The visual assessment of meat colour involved analysis of its lightness. The sensory scores for colour were confirmed by instrumental measurements, where lightness parameter L also increased with aging time. The greatest differences were observed between 2 and 21 days of aging ($P \leq 0.01$). Like-

Table 1. Effect of breed on physicochemical characteristics of meat during aging.

Item	Meat aging time (days)				Breed	*P*			Aging time – contrast					
	2	7	14	21		Aging time	Breed	Aging time × breed	2 vs. 7, 14, 21	2, 7 vs. 14, 21	2 vs. 21	7 vs. 14	7 vs. 21	14 vs. 21
Weight loss during aging, %														
$\bar{x}$	–	2.36	3.22	5.52					–	–	–	ns	≤ 0.01	≤ 0.01
ZR	–	2.08	3.41	5.16	3.55	≤ 0.01	0.55	0.54						
SM	–	2.63	3.02	5.87	3.84									
Heating loss, %														
$\bar{x}$	36.6	38.85	38.75	39.75					ns	ns	ns	ns	ns	ns
ZR	35.1	39.6	38.4	38.0	37.78	0.3	0.19	0.18						
SM	38.1	38.1	39.1	41.5	39.2									
pH														
$\bar{x}$	5.99	5.82	5.77	5.72					≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	0.04
ZR	5.99	5.84	5.74	5.74	5.83	≤ 0.01	0.65	0.46						
SM	5.98	5.8	5.79	5.69	5.82									
Colour L^*														
$\bar{x}$	33.75	33.65	35.2	35.65					0.02	≤ 0.01	≤ 0.01	0.02	0.02	ns
ZR	33.4	33.1	35.4	36.2	34.53	≤ 0.02	0.92	0.24						
SM	34.1	34.2	35.0	35.1	34.6									
a^*														
$\bar{x}$	19.85	20.9	21.3	21.1					≤ 0.01	≤ 0.01	≤ 0.01	ns	ns	ns
ZR	19.7	20.9	22.1	21.7	21.1	≤ 0.01	0.14	0.02						
SM	20.0	20.9	20.5	20.5	20.48									
b^*														
$\bar{x}$	5.32	4.87	5.66	5.66					ns	ns	ns	ns	ns	ns
ZR	5.40	5.08	6.85	6.5	5.96^{A}	0.1	≤ 0.01	≤ 0.01						
SM	5.24	4.66	4.46	4.81	4.79^{B}									
C^*														
$\bar{x}$	20.58	21.43	22.11	21.87					≤ 0.01	≤ 0.01	≤ 0.01	ns	ns	ns
ZR	20.44	21.46	23.18	22.64	21.93^{A}	0.07	≤ 0.01	≤ 0.01						
SM	20.71	21.39	21.03	21.09	21.06^{B}									
Shear force, *N*														
$\bar{x}$	111.2	77.87	74.95	61.75					≤ 0.01	≤ 0.01	≤ 0.01	ns	0.05	0.07
ZR	99.3	63.0	62.0	52.8	69.28^{a}	≤ 0.01	0.02	0.81						
SM	123.1	92.74	87.9	70.7	93.61^{b}									

ZR – Polish Red-and-White breed; SM – Simmental breed; L^* – colour lightness, a^* – redness, b^* – yellowness; C^* – chroma. Values in rows with different letters are significantly different: $^{a,\,b}$ $p \leq 0.05$ and $^{A,\,B}$ $p \leq 0.01$; ns: non-significant.

wise, in the study of Vitale et al. (2014), visual assessment revealed a negative effect of longer storage periods (14 and 21 days) on meat colour stability.

Sensory analysis revealed that most of the characteristics improved up to 14 days of aging regardless of the breed, whereas some of the parameters such as taste intensity and desirability deteriorated after 21 days of the aging process.

3.3 Oxidative stability of fat in aged meat

Our study found no significant effect of breed on the degree of lipid peroxidation expressed as TBARS (Table 3). The amount of malondialdehyde was higher in meat aged for 21 days compared to fresh meat ($P \leq 0.01$). The increased rate of meat lipid peroxidation after 14–15 days of wet aging was observed in the Podolian breed by Cifuni et al. (2004) and in Limousin crossbreeds by Popova et al. (2009). Similar results were obtained by Wen (2013) for the Brown Swiss meat after a 21-day aging period. Insauti et al. (1999) reported that meat with higher pigment content is more susceptible to oxidative processes, while McKenna et al. (2005) associate meat lipid peroxidation directly with the oxidation of muscle pigments. Ongoing lipid peroxidation made the colour of meat more red and yellow during the aging pro-

Table 2. Effect of breed on organoleptic characteristics of meat during aging.

	Meat aging time (days)				Breed	*P*			Aging time – contrast				
	2	7	14	21		Aging time	Breed	Aging time × breed	2 vs. 7, 14, 21	2, 7 vs. 14, 21	2 vs. 21	7 vs. 14	14 vs. 21
Colour													
$\bar{x}$	4.41	4.11	3.94	3.9					≤ 0.01	0.02	≤ 0.01	ns	ns
ZR	4.67	4.19	4.05	3.83	4.19	≤ 0.01	0.28	0.12					
SM	4.14	4.02	3.83	3.97	3.99								
Aroma intensity													
$\bar{x}$	3.63	3.82	3.93	3.71					ns	ns	ns	ns	ns
ZR	3.56	3.88	4.1	3.86	3.85	0.2	0.5	0.35					
SM	3.69	3.76	3.76	3.55	3.69								
Aroma desirability													
$\bar{x}$	4.13	3.8	4.1	4.11					ns	ns	ns	ns	ns
ZR	4.29	3.96	4.22	4.29	4.19	0.9	0.22	0.47					
SM	3.96	4.06	3.97	3.92	3.98								
Taste intensity													
$\bar{x}$	3.65	3.76	3.86	3.44					ns	ns	ns	ns	ns
ZR	3.77	3.89	4.05	3.9	3.9	0.37	0.11	0.48					
SM	3.52	3.63	3.67	2.98	3.45								
Taste desirability													
$\bar{x}$	3.66	3.91	4.05	3.41					ns	ns	ns	ns	ns
ZR	3.79	4.23	4.01	3.89	3.98	0.12	0.22	0.26					
SM	3.52	3.59	4.08	2.92	3.53								
Texture – tenderness													
$\bar{x}$	2.6	2.99	3.56	3.43					≤ 0.01	0.03	0.02	ns	ns
ZR	2.55	3.11	3.74	3.76	3.29	0.01	0.19	0.4					
SM	2.65	2.86	3.38	3.09	3.0								
Juiciness													
$\bar{x}$	3.43	3.09	3.6	3.45					ns	ns	ns	ns	ns
ZR	3.76	3.18	3.86	3.72	3.63	0.31	0.05	0.81					
SM	3.1	3.0	3.33	3.18	3.15								
Delicacy													
$\bar{x}$	2.82	3.0	3.51	3.52					0.03	0.07	0.09	0.06	ns
ZR	2.9	3.23	3.64	4.0	3.44	0.03	0.11	0.42					
SM	2.73	2.76	3.37	3.03	2.97								
Overall score													
$\bar{x}$	3.53	3.59	3.82	3.63					ns	ns	ns	ns	ns
ZR	3.65	3.72	3.96	3.93	3.82	0.42	0.09	0.69					
SM	3.41	3.46	3.67	3.33	3.47								

ZR – Polish Red-and-White breed; SM – Simmental breed; evaluation scale: 1 point – worst score, 5 points – best score; $n = 8$ per each aging time. ns: non-significant.

cess. The increases in TBARS and a^* and b^* parameters of meat were also observed by Domaradzki (2014).

The fat of SM bulls was characterized by a lower content of saturated fatty acids (SFAs), a higher content of polyunsaturated fatty acids (PUFAs), and a lower, more favourable atherogenic index (AI). In the Simmental breed, Laborde et al. (2001) observed higher activity of Δ-9 desaturase catalysing the transformation of *trans*-vaccenic acid (C18 : 1,

Table 3. Effect of breed and meat aging time on fatty acid profile of longissimus dorsi muscle fat and TBARS.

Item	Breed		Aging time					
	ZR	SM	2 days	21 days	SEM	Breed	Aging time	Breed × aging time
TBARS, mg MDA kg^{-1}	0.4	0.43	0.36	0.47	0.02	0.55	≤ 0.01	0.11
C10 : 0	0.17^{a}	0.04^{b}	0.04^{a}	0.17^{b}	0.03	0.04	0.03	0.02
C12 : 0	0.27	0.18	0.17	0.28	0.04	0.19	0.13	0.13
C14 : 0	2.0^{A}	1.09^{B}	1.6	1.49	0.15	≤ 0.01	0.66	0.51
C16 : 0	26.3^{A}	16.18^{B}	21.31	21.18	1.54	≤ 0.01	0.96	0.26
C16 : 1	2.67	2.12	2.02^{a}	2.76^{b}	0.18	0.11	0.04	0.92
C18 : 0	18.51^{a}	21.14^{b}	21.56^{A}	18.09^{B}	0.75	0.05	≤ 0.01	0.22
C18 : 1	32.99	30.25	32.0	31.25	1.23	0.3	0.77	0.88
C18 : 2*n*-6	10.00	14.22	10.98	13.24	1.18	0.08	0.34	0.98
C18 : 3*n*-3	1.71	2.2	1.92	1.98	0.13	0.06	0.83	0.35
C20 : 0	0.1^{A}	0.2^{B}	0.16	0.14	0.01	≤ 0.01	0.35	0.95
C20 : 4*n*-6	4.21^{A}	10.59^{B}	6.85	7.94	1.31	0.01	0.65	0.52
C22 : 0	0.28	0.46	0.35	0.38	0.05	0.11	0.78	0.52
C22 : 1	0.08	0.01	0.01	0.08	0.03	0.34	0.37	0.3
C20 : 5*n*-3	0.43^{a}	1.03^{b}	0.7	0.76	0.13	0.02	0.82	0.57
C22 : 6*n*-3	0.03^{a}	0.00^{b}	0.01	0.02	0.00	0.02	0.7	0.7
CLA *c*-9, *t*-11	0.19	0.27	0.24	0.22	0.02	0.13	0.6	0.81
CLA *c*-9, *c*-11	0.03	0.00	0.02	0.006	0.00	0.08	0.28	0.27
CLA *t*-9, *t*-11	0.02	0.03	0.03^{a}	0.02^{b}	0.00	0.08	0.04	0.77
CLA	0.24	0.3	0.3	0.24	0.02	0.28	0.28	0.96
SFA	47.65^{A}	39.29^{B}	45.2	41.74	1.65	≤ 0.01	0.25	0.65
UFA	52.35^{A}	60.71^{B}	54.8	58.26	1.65	≤ 0.01	0.25	0.65
MUFA	35.73	32.39	34.04	34.08	1.37	0.25	0.99	0.86
PUFA	16.62^{a}	28.32^{b}	20.76	24.18	2.51	0.02	0.47	0.67
n-6	14.21^{a}	24.8^{b}	17.83	21.18	2.31	0.02	0.44	0.71
n-3	2.16^{a}	3.22^{b}	2.64	2.75	0.23	0.02	0.78	0.39
n-6 / *n*-3	6.68	7.32	6.6	7.4	0.32	0.33	0.22	0.73
AI[1]	0.68^{A}	0.36^{B}	0.54	0.5	0.05	≤ 0.01	0.59	0.43

ZR – Polish Red-and-White breed; SM – Simmental breed; values in rows with different letters are significantly different: ^{a,b} $p \leq 0.05$, ^{A,B} $p \leq 0.01$;
[1] Atherogenic index (C12 : 0 + 4 × C14 : 0 + C16 : 0) / (MUFA + PUFA).

n-7) to CLA, as well as higher MUFA content. Scollan et al. (2006) reported that the content of SFAs and MUFAs increase faster than the content of PUFAs with increasing fatness and thus the relative proportion of PUFAs and the P : S ratio decrease. The atherogenic index was higher ($P \leq 0.01$) in the meat of the Polish Red-and-White compared to the Simmental breed (0.68 vs. 0.36), which was due to the higher content of saturated fatty acids C12 : 0, C14 : 0, C16 : 0 and the markedly lower PUFA percentage.

Aging time had an effect on the fatty acid profile of MLD intramuscular fat (Table 3). The wet aging of meat for 21 days caused changes in the content of capric (C10 : 0, $P = 0.03$), palmitoleic (C16 : 1, $P = 0.04$) and stearic acids (C18 : 0, $P \leq 0.01$) and CLA*t*9*t*11 ($P = 0.04$). No statistically significant differences in the content of the other fatty acids were noticed, but the observed directions of changes in different groups of acids were consistent with the findings of Wen (2013). The proportion of unsaturated fatty acids (UFAs), in particular *n*-6 and *n*-3 polyenoic fatty acids (PUFAs), increased. During heat treatment, unsaturated fatty acids are transformed to volatile aromatic compounds of the aldehyde and alkane group. Wen (2013) reports (citing Evans et al., 1969) that autooxidation of unsaturated fatty acids such as linoleic acid (C18 : 1) generates hydroperoxide, which in turn increases the alkane (mainly pentane) production efficiency during heat treatment. Our organoleptic analysis of roasted meat demonstrated no differences in aroma desirability and intensity between meat aged for 2 days and meat aged for 21 days (Table 2).

4 Conclusions

Breed and meat aging time were found to have a positive effect on physicochemical properties of the meat, including improved tenderness. The meat from the conserved breed was more tender and, from a sensory assessment, had a more delicate texture and higher juiciness and taste intensity than Simmental meat. Meat tenderness increased up to 14 days of aging regardless of the breed, but for the meat from the conserved breed, 7-day aging was optimal because tenderness had considerably improved while colour stability was maintained. The wet aging of the meat was accompanied by the peroxidation of meat lipids, as indicated by higher TBARS and changes in the fatty acid profile, but there were no differences between the breeds.

Data availability. The original data are available upon request to the corresponding author.

Competing interests. The authors declare that they have no conflict of interest.

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