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MEAT TEXTURE PROFILE AND CUTTING STRENGTH ANALYSES OF PORK DEPENDING ON BREED AND AGE*

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Abstract

The chemical composition and culinary meat tenderness belong to the most important characteristics determining meat quality and value. The aim of this work was to compare texture profiles and shear force of pork loin (*m. longissimus dorsi*) and of pork ham (*m. semimembranosus*) from fatteners of Polish Landrace (PL), Polish Large White (PLW), Duroc, Pietrain and Puławska pig breeds slaughtered at 60, 90, 120, 150, 180 and 210 d of breeding. Meat was roasted at 180°C to inner temperature of 78°C. The intramuscular fat (IMF) content in loin was growing with fattener age (from 1.17% at 60 d to 1.84% at 180 d of life). Between breeds IMF ranged from 0.82% in PLW to 2.29% in Puławska breed. The shear force for loin muscle ranged from 3.42 kG/cm^2 at 60 d to 6.54 kG/cm^2 at 210 d of life while for and ham muscle 4.4 kG/cm^2 at 60 d to 6.78 kG/cm^2 at 210 d of life. The hardness (TPA) ranged from 72.29 N at 90 d of life to 109.46 N at 210 d of life. The shear force of loin and ham meat was increasing with age of fatteners and some texture parameters – hardness and chewiness. Nevertheless it seems that the age of 150 days is the time when meat of fatteners is characterized by the highest technological properties. However, the final decision regarding slaughter age should be made taking into account the technological destination of the carcasses. No significant interactions between the animal breed and their age were found for the parameters analysed.

Key words: pigs, meat parameters, texture profile, shear force

One of the meat quality distinguishing parameters is texture which describes the crosswise meat structure. Texture depends on muscle fibres diameter, the amount of

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muscle fibres in bundle, the surface of meat fibres bundle and the amount and thickness of connective tissue band (Bailey and Light, 1989). The texture can be tight or loose, fine or coarse grained and at the same time it is deciding the tenderness and meat shear force. The amount and diameter of muscle fibres depends on the breed, age and body weight of the animal, breeding system, animal physical activity, the kind of muscle and even the place of sampling (centre or edge of the muscle). Especially the muscle fibre diameter changes directly after birth, increases with age and body mass growth, and so the meat texture depends on the age and weight of the animal at slaughter, and is at the same time one of the most important quality characteristics of meat and meat products (Orzechowska et al., 2008). The texture is made up of composed characteristics determined by the body and structure of the muscles and their chemical composition (Lachowicz et al., 2003).

The main features of meat texture are: tenderness defined as the feeling perceived during biting and chewing of the product, and its measure is the resistance during chewing and juiciness which is a perception of humidity felt during product consumption (Prost, 2006). The aforementioned parameters decide about the meat properties prepared for thermal treatment. Changes in meat components are ongoing with the most important meat protein fraction changes after thermal treatment (cooking, roasting, frying) of meat (Dolik and Kubiak, 2013). Also having an influence on meat texture properties, beside the above-mentioned, is the way of post-slaughter carcass treatment and rigor mortis development, technological conditions, i.e. electric stimulation (Aalhus et al., 1992) and thermal treatment conditions (Panea et al., 2003).

The aim of research was to describe the differences between texture parameters and IMF loin (*m. longissimus*) and ham (*m. semimembranosus*) of fatteners of Polish Landrace, Polish Large White, Duroc, Pietrain and Puławska pig breeds slaughtered at 60, 90, 120, 150, 180 and 210 d of breeding.

Material and methods

Research was conducted on purebred animals of Polish Landrace (PL) (n=36), Polish Large White (PLW) (n=36), Duroc (n=36), Pietrain (n=36) and Puławska (n=36) breeds. Animals used in the experiment in each breed were full or half siblings (the result of crossbreeding of six pairs of sisters of each breed with one boar). All procedures of fattening and slaughter were according to the Polish Pig Testing Station (SKURTCh) (Różycki and Tyra, 2010). The animals were kept in individual pens and fed *ad libitum* (12.5 MJ energy and 174 g protein). Six gilts of each breed were slaughtered at the age of 60, 90, 120, 150, 180 and 210 d. The day before slaughter, the animals were fasted. Prior to slaughter pigs were stunned using electrode forceps. After slaughter and chilling at 4°C for 24 h, the right half-carcass was dissected. Samples were taken from the *m. longissimus dorsi* (after last rib) and *m. semimembranosus* were collected from the right side of the carcass. The 5 cm-thick samples were frozen at –18°C for 14 days till further analysis.

Samples were defrosting for 24 h at 4°C. The meat was roasted in oven at 180°C, to an inner temperature of 78°C, then cooled to room temperature and samples were cut out. The texture profile (TPA) of the meat was analysed according to PN-ISO Norm 11036:1999, with the TA-XT2 texture analyzer (Stable Micro Systems). Shear force was measured from cylindrical samples (14 mm diameter, 15 mm height) using a Warner-Bratzler attachment (shearing blade thickness of 1.016 mm, V-shaped cutting blade with a 60 degree angle, corner of the V rounded to a quarter-round of a 2.363 mm diameter circle, spacers providing the gab for the cutting blade to slide of 1.245 mm thickness) and a triangular notch in the blade. Blade speed during the test was 1.5 mm/s. The results are presented as force per area (kG/cm^2).

The meat samples were chemically analysed according to Polish Standards – fat content (%), using the Soxhlet method in accordance with PN-ISO-1444.

The meat was roasted to 180°C, to an inner temperature of 78°C, then cooled to room temperature and samples were cut out, parallel to the muscle fibres, as cylinders with a diameter of 16 mm and 15 mm height. The speed of sampling knife movement during the test was 1.5 mm/s. The results are presented as force working on the surface of the cut (kG/cm^2). The analysis of texture profile was performed with the above device with a cylindrical sampling probe with a diameter of 50 mm. The test of double pressing of meat samples was done up to 70% deformation of their height. The speed of cylinder movements was 2 mm/s, the break between two pressings was 3 s, whereas the threshold of sample detection was 10 g. TPA parameters were calculated by the Texture Exponent software version 5.1.15.0 (Stable Micro Systems).

Texture (hardness, springiness, cohesiveness, chewiness) was analysed using the attached cylinder of 50 mm in diameter. The samples were subjected to a double pressing test, applying a force of 10 g to 70% of their height. The cylinder speed was 2 mm/s, and the interval between presses was 3 s.

Analysis of the above parameters was performed separately (independently) in both muscles included in the tests (*m. longissimus dorsi* and *m. semimembranosus*).

Statistical analyses were performed with GLM (General Linear Model) procedure using SAS software (SAS Institute, Cary, NC, USA, v.8.02, 2001).

$$Y_{ijk} = \mu + breed_i + age_j + \beta_{SW} + e_{ijk}$$

where:

Y_{ijk} – traits,

μ – overall mean,

$breed_i$ – fixed effect of breed,

age_j – fixed effect of slaughter age,

β_{SW} – linear regression for carcass weight,

e_{ijk} – general error.

No significant interactions between the animal breed and their age were found for the parameters analysed, so that this interaction was not included in the statistical model.

Statistical differences were analysed using Tukey-Kramer test. Correlation analyses between the analysed traits were performed using COR procedure of SAS software

Table 1. Texture parameters and shear force value (±SE) of fatteners' loin (*m. longissimus*) slaughtered at different age

Type of muscle	Breed of animals						Age of animals (d)						
	PL	PLW	Pietrain	Duroc	Puławska	P-value	60	90	120	150	180	210	P-value
n	36	36	36	36	36		30	30	30	30	30	30	
Shear force (kG/cm^2)	4.72 ±0.30	5.27 ±0.31	5.65 ±0.36	5.01 ±0.32	5.48 ±0.30	0.2595	3.42 A ±0.22	4.02 A ±0.22	5.35 Ba ±0.31	5.80 BC ±0.37	6.23 BCb ±0.33	6.54 C ±0.25	<0.0001
Hardness (N)	88.94 ±6.11	87.93 ±4.56	87.95 ±5.24	75.28 ±3.57	86.92 ±4.88	0.2614	57.41 A ±2.67	57.46 A ±3.18	91.63 B ±3.97	97.30 BC ±4.16	100.47 BC ±4.42	108.02 C ±5.17	<0.0001
Springiness	0.56 ±0.01	0.58 ±0.02	0.6 ±0.03	0.59 ±0.02	0.59 ±0.02	0.6154	0.52 A ±0.02	0.55 A ±0.02	0.56 A ±0.01	0.57 A ±0.02	0.64B ±0.02	0.65 B ±0.02	<0.0001
Cohesiveness	0.51 A ±0.01	0.48 a ±0.01	0.5 Aa ±0.01	0.47 b ±0.01	0.44 B ±0.01	0.0009	0.5 ±0.02	0.5 ±0.01	0.48 ±0.01	0.46 ±0.01	0.45 ±0.01	0.48 ±0.01	0.1134
Chewiness (N)	26.52 ±2.54	25.25 ±1.57	28.54 ±2.85	20.10 ±1.29	24.14 ±2.00	0.0734	15.84 A ±1.07	15.17 A ±0.98	25.24 B ±1.67	25.90 B ±1.93	30.67 BCa ±2.43	36.62 Cb ±2.96	<0.0001
Resilience	0.23 ±0.01	0.22 ±0.01	0.23 ±0.01	0.21 ±0.01	0.21 ±0.01	0.3167	0.25 Aa ±0.01	0.23 a ±0.01	0.21 B ±0.01	0.2 Bc ±0.01	0.21 B ±0.01	0.22 b ±0.01	0.0004
IMF	1.12 A ±0.06	0.82 A ±0.11	1.85 BCa ±0.14	1.78 B ±0.15	2.29 Cb ±0.09	<0.0001	1.17 a ±0.13	1.48 ±0.17	1.53 ±0.14	1.65 ±0.15	1.84b ±0.15	1.62 ±0.17	0.0875

PL – Polish Landrace, PLW – Polish Large White.
A,B,C,D – values with the different letters differ significantly ($P \leq 0.01$) (separately for breed and age of animals).
a, b, c, d – values with the different letters differ significantly ($P \leq 0.05$) (separately for breed and age of animals).

Table 2. Texture parameters and shear force value of fatteners' ham (*m. semimembranosus*) slaughtered at different age

Type of muscle	Breed of animals						Age of animals (d)						
	PL	PLW	Pietrain	Duroc	Puławska	P-value	60	90	120	150	180	210	P-value
n	36	36	36	36	36		30	30	30	30	30	30	
Shear force (kG/cm^2)	4.94 a ±0.24	5.29 ±0.34	5.75 ±0.32	5.24 ±0.28	6.00 b ±0.39	0.1579	4.4 A ±0.25	5.01 Aca ±0.30	5.22 Aca ±0.27	4.96 Aca ±0.34	6.23 BCb ±0.43	6.78 B ±0.32	<0.0001
Hardness (N)	102.41 ±4.95	99.96 ±4.85	104.52 ±4.99	100.53 ±3.61	100.68 ±4.05	0.9536	89.58 A ±5.28	87.08 A ±3.85	111.57 B ±4.09	110.48 B ±5.66	100.13 ±4.21	110.9 B ±4.25	<0.0001
Springiness	0.55 A ±0.01	0.58 A ±0.02	0.6 a ±0.02	0.57 A ±0.02	0.67 Bb ±0.02	0.0002	0.53 Aa ±0.02	0.58 a ±0.02	0.56 AB ±0.02	0.63 BC ±0.02	0.61 b ±0.02	0.66 Cb ±0.02	0.0009
Cohesiveness	0.53 a ±0.01	0.52 ±0.01	0.52 ±0.01	0.51 ±0.01	0.49 b ±0.01	0.1408	0.51 ±0.01	0.52 a ±0.01	0.53 a ±0.01	0.52 ±0.01	0.53 a ±0.01	0.48 b ±0.01	0.0940
Chewiness (N)	29.25 ±1.82	31.06 ±2.25	33.99 ±2.41	29.72 ±1.66	34.57 ±2.21	0.2491	23.73 A ±1.81	26.49 Aba ±1.83	34.48 BCb ±2.12	36.91 C ±2.64	33.19 BCb ±2.24	35.5 C ±2.14	<0.0001
Resilience	0.23 ±0.01	0.24 ±0.01	0.24 ±0.01	0.24 ±0.01	0.23 ±0.01	0.5971	0.24 ±0.01	0.24 ±0.01	0.24 ±0.01	0.22 ±0.01	0.23 ±0.01	0.23 ±0.01	0,4405

PL – Polish Landrace, PLW – Polish Large White A,B,C,D – values with the different letters differ significantly (P≤0.01) (separately for breed and age of animals).
a, b, c, d – values with the different letters differ significantly (P≤0.05) (separately for breed and age of animals).

Table 3. Correlations (P-value) of texture and shear force of loin muscle (*m. longissimus*) of fatteners slaughtered at different age (all breeds together)

	Age of animals (d)	Hardness (N)	Springiness	Cohesiveness	Chewiness (N)	Resilience	IMF
Shear force (kG/cm^2)	60	–0.015 (0.9370)	0.061 (0.7492)	0.038 (0.8410)	–0.007 (0.9694)	0.075 (0.6923)	–0.098 (0.5866)
	90	–0.009 (0.9613)	0.069 (0.7171)	–0.158 (0.4056)	–0.072 (0.7056)	0.006 (0.3406)	–0.176 (0.3445)
	120	0.228 (0.2254)	0.114 (0.5482)	0.251 (0.1817)	0.165 (0.3846)	0.300 (0.1070)	–0.049 (0.7858)
	150	**0.388** (0.0340)	0.104 (0.5859)	–0.089 (0.6397)	0.280 (0.1340)	–0.077 (0.6866)	–0.197 (0.2869)
	180	0.173 (0.3607)	**0.472** (0.0085)	0.036 (0.8487)	**0.394** (0.0310)	0.142 (0.4537)	–0.026 (0.8878)
	210	0.091 (0.6329)	0.082 (0.6650)	0.110 (0.5612)	0.066 (0.7279)	0.036 (0.8519)	–0.233 (0.1721)
Hardness (N)		60	0.143 (0.4517)	–**0.488** (0.0062)	**0.734** (<0.0001)	–**0.492** (0.0057)	–0.149 (0.4064)
		90	0.054 (0.7768)	–**0.398** (0.0294)	**0.843** (<0.0001)	–0.180 (.3406)	–0.223 (0.2282)
		120	0.266 (0.1552)	**0.445** (0.0137)	**0.857** (<0.0001)	0.218 (0.5065)	–0.221 (0.2156)
		150	0.303 (0.1034)	–0.211 (0.2641)	**0.771** (<0.0001)	–0.185 (0.3278)	–0.301 (0.1002)
		180	0.177 (0.3483)	**0.534** (0.0024)	**0.736** (<0.0001)	0.186 (0.8977)	–0.168 (0.3767)
		210	0.044 (0.8159)	0.292 (0.1177)	**0.528** (0.0027)	0.345 (0.0622)	–0.233 (0.1714)
Springiness			60	–0.036 (0.8515)	0.352 (0.0566)	0.048 (0.08028)	0.081 (0.6544)
			90	–0.138 (0.4667)	0.291 (0.1181)	0.074 (0.6978)	0.031 (0.8683)
			120	0.015 (0.9367)	**0.539** (0.0021)	0.126 (0.5065)	–0.104 (0.5640)
			150	–0.206 (0.2757)	**0.715** (<0.0001)	–0.165 (0.3846)	–0.092 (0.6220)
			180	0.042 (0.8248)	**0.699** (<0.0001)	–0.025 (0.8977)	0.0255 (0.1582)
			210	–0.208 (0.2709)	0.109 (0.5682)	–0.067 (0.7240)	0.198 (0.2481)
Cohesiveness				60	–0.215 (0.2538)	**0.899** (<0.0001)	–0.190 (0.2892)
				90	–0.050 (0.7923)	**0.663** (<0.0001)	–**0.483** (0.0060)
				120	**0.556** (0.0014)	**0.571** (0.0010)	–0.249 (0.1618)
				150	0.101 (0.5964)	**0.684** (<0.0001)	–0.123 (0.5103)
				180	**0.555** (0.0014)	**0.606** (0.0004)	–0.108 (0.5546)
				210	**0.590** (0.0006)	**0.792** (<0.0001)	–**0.340** (0.0426)

Chewiness (N)	60	–0.229 (0.2232)	–0.193 (0.2812)
	90	0.071 (0.7099)	–0.082 (0.6618)
	120	**0.431** (0.0173)	–0.214 (0.2319)
	150	0.053 (0.7800)	–0.168 (0.3656)
	180	0.289 (0.1208)	–0.092 (0.6166)
	210	**0.516** (0.0035)	–0.325 (0.0532)
Resilience		60	–0.113 (0.5304)
		90	–0.285 (0.1200)
		120	–0.180 (0.3150)
		150	–0.297 (0.1051)
		180	–0.250 (0.1668)
		210	–0.097 (0.5738)

Table 4. Correlations (P-value) of texture and shear force of ham muscle (*m. semimembranosus*) of fatteners slaughtered at different age (all breeds together)

	Age of animals (d)	Hardness (N)	Springiness	Cohesiveness	Chewiness (N)	Resilience
Shear force (kG/cm^2)	60	–0.139 (0.4625)	–0.209 (0.2672)	0.137 (0.4695)	–0.263 (0.1611)	0.050 (0.7927)
	90	0.165 (0.3831)	0.052 (0.7848)	0.222 (0.2374)	0.213 (0.2588)	–0.128 (0.5016)
	120	–0.118 (0.5357)	**0.457** (0.0110)	–0.050 (0.7939)	0.046 (0.8097)	–0.019 (0.9189)
	150	0.154 (0.4160)	**0.468** (0.0092)	**0.425** (0.0192)	**0.429** (0.0179)	0.124 (0.5135)
	180	0.213 (0.2607)	**0.638** (0.0001)	–0.256 (0.1715)	**0.428** (0.0183)	0.166 (0.3799)
	210	–0.062 (0.7449)	0.316 (0.0889)	0.158 (0.4053)	0.270 (0.1493)	0.045 (0.8135)
Hardness (N)		60	–0.103 (0.5887)	0.252 (0.1789)	**0.784** (<0.0001)	–0.229 (0.2253)
		90	0.037 (0.8444)	–0.009 (0.9643)	**0.728** (<0.0001)	–0.203 (0.2825)
		120	0.271 (0.1474)	0.271 (0.1469)	**0.814** (<0.0001)	0.110 (0.5631)
		150	0.206 (0.2745)	0.293 (0.1160)	**0.804** (<0.0001)	0.239 (0.2031)
		180	0.291 (0.1183)	0.151 (0.4262)	**0.816** (<0.0001)	0.236 (0.2098)
		210	0.070 (0.7139)	0.186 (0.3256)	**0.621** (0.0002)	–0.117 (0.5396)
Springiness			60	0.002 (0.9911)	0.356 (0.0536)	–0.270 (0.1492)
			90	0.050 (0.7950)	**0.513** (0.0038)	**0.399** (0.0289)
			120	0.006 (0.9756)	**0.571** (0.0010)	–0.108 (0.5695)
			150	0.019 (0.9225)	**0.616** (0.0003)	0.062 (0.7466)
			180	–0.276 (0.1398)	**0.632** (0.0002)	0.105 (0.5819)
			210	–0.080 (0.6734)	**0.662** (<0.0001)	–0.059 (0.7565)
Cohesiveness				60	**0.385** (0.0355)	0.202 (0.2846)
				90	0.283 (0.1301)	**0.546** (0.0018)
				120	**0.485** (0.0066)	**0.643** (<0.0001)
				150	**0.517** (0.0034)	**0.753** (<0.0001)
				180	0.239 (0.2033)	**0.418** (0.0214)
				210	0.251 (0.1815)	**0.638** (0.0002)
Chewiness (N)					60	–0.020 (0.9182)
					90	0.261 (0.1636)
					120	0.203 (0.2811)
					150	**0.443** (0.0141)
					180	**0.408** (0.0254)
					210	–0.028 (0.8832)

Table 5. Correlations (P-value) of texture and shear force of loin muscle (*m. longissimus*) of fatteners slaughtered at different age (all slaughter ages together)

	Breed	Hardness (N)	Springiness	Cohesiveness	Chewiness (N)	Resilience	IMF
Shear force (kG/cm^2)	PL	**0.520** (0.0012)	0.118 (0.4913)	0.051 (0.7667)	**0.481** (0.0029)	–0.119 (0.4894)	0.056 (0.7216)
	PLW	**0.376** (0.0239)	0.321 (0.056)	0.085 (0.6232)	**0.330** (0.0492)	0.091 (0.5987)	**–0.373** (0.0209)
	Pietrain	**0.438** (0.0075)	**0.414** (0.0122)	–0.089 (0.6057)	**0.456** (0.0052)	–0.101 (0.5588)	–0.257 (0.1094)
	Duroc	**0.654** (<0.0001)	**0.346** (0.0390)	–0.218 (0.2011)	**0.617** (<0.0001)	–0.307 (0.0687)	–0.218 (0.1943)
	Puławska	**0.653** (<0.0001)	**0.364** (0.0289)	–0.122 (0.4796)	**0.500** (0.0019)	–0.102 (0.5523)	0.005 (0.9743)
Hardness (N)		PL	0.289 (0.0870)	–0.234 (0.1703)	**0.830** (<0.0001)	–0.371 (0.0259)	0.053 (0.7351)
		PLW	0.188 (0.2721)	0.025 (0.8845)	**0.823** (<0.0001)	–0.097 (0.5729)	–0.146 (0.3819)
		Pietrain	**0.409** (0.0133)	–0.037 (0.8313)	**0.686** (<0.0001)	–0.247 (0.9407)	0.033 (0.8391)
		Duroc	**0.419** (0.0110)	**–0.465** (0.0042)	**0.837** (<0.0001)	**–0.382** (0.0215)	–0.224 (0.1819)
		Puławska	**0.531** (0.0009)	0.148 (0.3904)	**0.877** (<0.0001)	0.059 (0.7330)	0.072 (0.6663)
Springiness			PL	–0.021 (0.9050)	0.318 (0.0589)	–0.016 (0.9267)	0.146 (0.3501)
			PLW	–0.130 (0.4516)	**0.451** (0.0058)	–0.050 (0.7733)	0.261 (0.1142)
			Pietrain	–0.097 (0.5729)	**0.711** (<0.0001)	–0.013 (0.9407)	0.118 (0.1142)
			Duroc	**–0.347** (0.0383)	**0.576** (0.0002)	–0.250 (0.1407)	0.179 (0.2903)
			Puławska	0.016 (0.9257)	**0.703** (<0.0001)	–0.034 (0.8424)	0.092 (0.5321)
Cohesiveness				PL	0.092 (0.5938)	**0.728** (<0.0001)	–0.125 (0.4260)
				PLW	0.240 (0.1588)	**0.800** (<0.0001)	–0.068 (0.6871)
				Pietrain	0.090 (0.6036)	**0.675** (<0.0001)	**–0.363** (0.0213)
				Duroc	–0.166 (0.3332)	**0.782** (<0.0001)	–0.252 (0.1323)
				Puławska	**0.398** (0.0162)	**0.728** (<0.0001)	–0.001 (0.9929)
Chewiness (N)					PL	–0.029 (0.8679)	0.098 (0.5326)
					PLW	0.167 (0.3289)	0.038 (0.8189)
					Pietrain	–0.118 (0.4945)	–0.071 (0.6639)
					Duroc	–0.148 (0.3900)	0.180 (0.2854)
					Puławska	0.262 (0.1221)	0.073 (0.6652)
Resilience						PL	0.012 (0.9374)
						PLW	0.034 (0.8385)
						Pietrain	–0.197 (0.2230)
						Duroc	–0.212 (0.2069)
						Puławska	–0.006 (0.9713)

Table 6. Correlations (P-value) of texture and shear force of ham muscle (*m. semimembranosus*) of fatteners slaughtered at different age (all slaughter ages together)

		Hardness (N)	Springiness	Cohesiveness	Chewiness (N)	Resilience
Shear force (kG/cm^2)	PL	0.213 (0.2125)	**0.342** (0.0410)	0.035 (0.8381)	0.245 (0.1495)	–0.077 (0.6559)
	PLW	–0.044 (0.8005)	**0.507** (0.0016)	0.035 (0.8394)	0.197 (0.2507)	0.059 (0.7317)
	Pietrain	**0.350** (0.0361)	**0.510** (0.0015)	–0.187 (0.2756)	**0.459** (0.0049)	–0.080 (0.6470)
	Duroc	0.124 (0.4703)	**0.347** (0.0383)	0.119 (0.4908)	**0.349** (0.0371)	0.151 (0.3792)
	Puławska	0.007 (0.9660)	0.132 (0.4425)	0.288 (0.0890)	0.153 (0.3743)	–0.113 (0.5116)
Hardness (N)		PL	0.221 (0.1946)	0.249 (0.1425)	**0.882** (<0.0001)	–0.010 (0.9559)
		PLW	0.132 (0.4446)	0.289 (0.0868)	**0.882** (<0.0001)	0.195 (0.2547)
		Pietrain	0.211 (0.2166)	0.142 (0.4076)	**0.792** (<0.0001)	–0.040 (0.8188)
		Duroc	0.088 (0.6096)	–0.137 (0.4261)	**0.647** (<0.0001)	–0.159 (0.3545)
		Puławska	**0.333** (0.0471)	0.180 (0.2940)	**0.741** (<0.0001)	–0.282 (0.0959)
Springiness			PL	–0.155 (0.3681)	**0.447** (0.0063)	–0.061 (0.7239)
			PLW	–0.249 (0.1434)	**0.395** (0.0170)	–0.020 (0.9070)
			Pietrain	–0.083 (0.6287)	**0.585** (0.0002)	–0.234 (0.1690)
			Duroc	–0.154 (0.3690)	**0.687** (<0.0001)	–0.084 (0.6244)
			Puławska	**0.369** (0.0270)	**0.755** (<0.0001)	0.203 (0.2342)
Cohesiveness				PL	**0.334** (0.0465)	**0.554** (0.0005)
				PLW	**0.344** (0.0401)	**0.744** (<0.0001)
				Pietrain	0.302 (0.0730)	0.301 (0.0741)
				Duroc	0.120 (0.4856)	**0.749** (<0.0001)
				Puławska	**0.576** (0.0002)	**0.438** (0.0076)
Chewiness (N)					PL	0.106 (0.5366)
					PLW	0.253 (0.1362)
					Pietrain	–0.093 (0.5890)
					Duroc	0.130 (0.4492)
					Puławska	0.211 (0.2159)

Results

Table 1 presents the results for texture parameters and shear force of loin (*m. longissimus*), and Table 2 the results for ham (*m. semimembranosus*) of fatteners slaughtered at different age. The correlation coefficients are presented in Tables 3–6. The shear force and hardness of loin and ham were increasing with fattener's age. The loin shear force ranged from 4.72 kG/cm^2 (PL) to 5.65 kG/cm^2 (Pietrain) and from 4.94 kG/cm^2 (PL) to 6.00 kG/cm^2 (Puławska) for ham. The hardness (TPA) was from 75.28 (Duroc) to 88.94 N (PL) for loin and from 99.96 N (PLW) to 102.41 (PL). The shear force of loin and ham was increasing with fattener's age and some texture parameters decreasing – the increase of hardness and chewiness. The analysis of correlations between meat texture for both assessed muscles showed, in most cases, the low values (Tables 3 and 4). The exception was correlations between hardness and chewiness of both muscles at the assessed age ranges, where the correlation values ranged from rp = 0.528 to 0.857, and were statistically highly significant.

Similar correlations were obtained for meat springiness and chewiness for ham (from rp = 0.513 to 0.662). There was also observed highly statistically significant correlation for cohesiveness and resilience for almost all age ranges of the examined animals. The analogical correlations are presented for the breeds in Tables 5 and 6. Highly significant correlations between chewiness and hardness of loin and ham meat were also observed for all the breeds, and also between cohesiveness and resilience, except for Pietrain *m. semimebranosus* (Table 6). Furthermore, for *m. longissimus*, high correlations were observed between shear force and hardness, except for Polish Large White, and cohesiveness and springiness, except for Polish Landrace (Table 5). For *m. semimembranosus* of ham, the correlations were confirmed only for shear force and springiness and shear force and chewiness for the Duroc and Pietrain breeds (Table 6).

Discussion

According to Kołczak (2007), the hardness values of 4–5 kG/cm² are typical for very tender meat, whereas values above 15 kG/cm² for very hard meat, therefore the meat of the analysed fatteners should be described as tender and semi-tender meat. Among the analysed breeds, the Duroc breed has the more advantageous meat characteristics compared to the meat of the Pietrain breed. Similar results were obtained by Florowski et al. (2006); when comparing the processing suitability of meats of Duroc, Pietrain, Polish Landrace, Polish Large White and of line 990 they proved that the meat of Duroc pigs is characterised by what influences on its small shear and pressing forces, and at the same time very good culinary suitability, whereas the meat of the Pietrain breed is characterised by both low culinary and technological suitability. The shear force of loin and ham was increasing with age.

The authors of the present study found that some parameters were increasing, such as hardness and chewiness, but they decrease the meat quality. This could be caused by the growth of muscle fibres' diameters and growth of collagen content. The structure of collagen changes with age – it is more cohesive and its solubility decreases. During curing and preparation of meat for consumption, the most popular method is heating during which the thermal denaturation of proteins takes place, which leads to some changes in muscle fibre's microstructure, connective tissue and meat water holding capacity (Kołczak et al., 1992). According to Čandek-Potokar et al. (1999), in parallel with fattener's body weight growth – from 100 to 130 kg – the muscle fibre's diameter (especially of red and white fibres) increased, which had a positive influence on fresh, raw meat water holding capacity and on the juiciness of that meat after thermal treatment.

Based on results of our earlier research (Migdał et al., 2006), it can be stated that fatteners with higher daily body mass growth i.e. faster growing, are characterised by soft meat with better chewiness. Barton-Gade (1987), Jeremiah et al. (1999) and Wood et al. (1989) showed the influence of sex on meat quality traits. The meat of castrated fatteners was tenderer and obtained lower values of shear force in comparison to boar and gilt meat. It can also be caused by differences in proportions and diameters of individual muscle fibres, allowing for detection of differences in meat sensory quality traits. The observation made by Karlsson et al. (1999) revealed that fibres of type I and II A contain much more intracellular fat than fibres of type II B. It can evolve from metabolic specificity of fibres, because fibres of type I and partly of II A type have an oxidative metabolism, whereas type II B fibres – glycolytic. Cameron et al. (1990), Jeremiah et al. (1999), Trombetta et al. (1997) and Warriss et al. (1990) pointed to the significant influence of breed (genotype) on chemical composition and quality traits of pork meat.

With age, an increase of shear force and meat texture parameters (hardness and chewiness) were observed, which was also confirmed by high correlations estimated for these parameters. Despite the adverse growth of some parameters for animals slaughtered at 210 d of life, the dependences between hardness and chewiness were lowered in comparison to analogical connections observed for animals slaughtered at a younger age. Such a dependence was observed for both loin and ham muscles. Besides the unfavourable influence of age on texture parameters, the advantageous effect of growing amounts of intramuscular fat tend, to a certain extent, to compensate for the adverse effects of age on texture parameters. A high correlation between shear force and chewiness was observed for all the breeds, but only in loin (*m. longissimus dorsi*). For the *m. semimembranosus* of ham such dependences were confirmed only for the Pietrain breed.

The fatteners of the Duroc and Hampshire breeds are characterised by more tender meat in comparison to Landrace and Yorkshire fatteners. Guzek et al. (2016) showed that Duroc breed crossing with Polish Landrace maternal line contributes to changes in the basic chemical composition of the obtained meat, although there is no change either in sarcomere length or the quality features recognised by consumers (texture, colour). In addition, Florowski et al. (2006) reported that the breed of pigs was the significant diversifying factor for many quality traits of meat. Gil et al. (2008), when analysing profile of muscle fibres of Large White, Landrace, Duroc, Pietrain and Meishan pigs slaughtered at the same body weight of 110 kg, found statistically significant differences for percentage amounts of individual types of muscle fibres for *m. longissimus thoracis*. Also in Migdał et al. (2005), the obtained results allowed for the conclusion that the histochemical profile of fatteners' muscles depends on breed, sex, body weight, feeding intensity and the type of muscle.

According to Karlsson et al. (1993) and Petersen et al. (1998), the number and type of muscle fibres are determined genetically and imposed at foetus period development of the fattener. Cameron et al. (1998) reported that the growth of white muscle fibres' thickness is positively correlated to tenderness and negatively to meat juiciness, whereas the greater thickness of red muscle fibres correlates positively to juiciness and negatively to tenderness. The growth of muscle fibres' diameter for heavy fatteners (120–130 kg body weight) favourably influences meat processing characteristics (Oksbjerg et al., 2000), because muscles composed of thicker fibres react more easily during processing and curing massage. Orzechowska et al. (2008) showed that shear force was negatively related to type IIA muscle fibre size. Research conducted by Hviid et al. (2002) and Lachowicz et al. (1998, 2003) reported that the chemical composition and texture parameters depend also on genotype stress susceptibility. Wojtysiak and Migdał (2007), on the contrary, proved that genotype of *RYR1* had no effect on muscle fibre percentage, meat hardness and shear force, but influenced the diameter of muscle fibre. With the drop in fatteners' fatness the losses during preparation and preservation of meat for consumption were increasing (Trombetta et al., 1997).

Borzuta (1998) obtained a statistically significant correlation coefficient between slaughter weight and content of meat in carcass: $r = -0.4$. The growth in slaughter weight implies a lowering of carcass meatiness, at an average of 1.3% per 10 kg of body mass growth. Virgili et al. (2003), for slaughter of fatteners at 8 and/or 10 months of life, concluded that the drip loss of loin and ham meat from 10 months old was lower and also the thermal losses were smaller. The amount of intramuscular fat was growing and the marbling of meat was greater for older fatteners, and the hams of those fatteners were more suitable for production of long aged, dry cured Italian style hams. Similar results were obtained in our study – IMF level was growing up to 180 d of life. Beattie et al. (1999), when slaughtering both sows and boars with body weight of 92, 105,118 and 131 kg, observed the statistically not significant decrease in shear force of *m. longissimus dorsi* with the growth of body weight of fatteners; in parallel, these authors observed the growth of drip loss and lowering of weight losses during meat thermal treatment.

Texture and tenderness were indicated by consumers in many experiments as the most important quality traits for meat and meat products. There exist many methods of instrumental measurements of meat tenderness, and the results obtained should correlate to a sensory assessment of this parameter, but they are doubtful because instrumentally measured texture has no connection to the sensory traits of taste and odour. Tenderness is most frequently estimated instrumentally based on shear force obtained for a piece of meat perpendicular to the muscles fibres anatomical location (Kołczak, 2007). The greater the value of shear force, the lower the meat tenderness.

The sensation of tenderness during meat consumption concerns the initial ease of mastication during gnawing, ease of grinding into particles during chewing, and the mouthfeel of residue after mastication – mainly the dimensions and characteristics. The tenderness of meat depends on the muscle tissue composition, especially myofibrillar proteins, and on connective tissue proteins. The sarcoplasma proteins do not really influence meat tenderness, which is caused by their solubility in water solutions. The final effect on tenderness is composed from: the muscle type, muscle chemical composition and structure and method and temperature of thermal treatment. The most pronounced differences for different carcass muscles are presence, composition and distribution of intramuscular connective tissue. Even slight changes in connective tissue characteristics and structure have an influence on final meat quality parameters. Wojtysiak (2013) reported that structural changes in the architecture of the intramuscular connective tissue (an increase in collagen fibre density and an increase in the thickness of both endomysium and perimysium with age) as well as a decrease in the content of soluble collagen in *m. longissimus lumborum* during growth of pigs are both important factors influencing shear force value and thus raw meat tenderness.

Conclusion

To conclude, it should be stressed that with fatteners' age, the shear force of both ham and loin muscles increases and some texture parameters increase, which leads to a decrease of meat quality parameters – growth of hardness and chewiness. The age of 150 d is the point when the fatteners' meat (with the exception of the Puławska breed) is characterised by the most advantageous IMF and technological values. But the final decision of slaughter should be made taking into account the technological destination of the carcass. For ham production, the more favourable are fatteners slaughtered with higher body mass weight, and such demands are imposed by the meat industry on farmers and breeders. The Pietrain breed meat was characterised by the worst texture parameters and by the highest shear force, whereas the Duroc breed meat was characterised by the best texture parameters.

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