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MEAT QUALITY OF POULARDS OBTAINED FROM THREE CONSERVED BREEDS OF HENS*

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Abstract

The aim of the study was to determine the effect of genotype (breed/line) and spaying of pullets on body weight, estradiol level, carcass and meat quality. Subjects were Rhode Island Red (R-11), Yellowleg Partridge (Ż-33) and Sussex hens (S-66), 100 birds per line, which were divided into 2 groups, each having 50 pullets and 50 poulards. Spaying was performed at 10 wk of age, under local anesthesia by a veterinarian. The present study showed that blood estradiol levels in poulards were much lower than in pullets regardless of genotype. Poulards showed higher body weight and their carcasses higher lightness and yellowness. In the sensory evaluation, poulard breast meat was more tasty and leg meat also more juicy and tender compared to pullet meat. Among the three conserved breeds, Rhode Island Red (R-11) and Yellowleg Partridge (Ż-33) hens are the best starting material for poulard production. Their carcasses showed good muscling and intense yellowness desirable to the consumers. R-11 birds achieved highest body weight. Spaying of pullets had no significant effect on the profile of fatty acids, but greater and statistically significant differences in this regard were found between hen lines. Compared to S-66 birds, breast muscles of R-11 and Ż-33 birds contained more polyunsaturated fatty acids (PUFA). The breast and leg muscles of these birds had a lower content of saturated fatty acids (SFA).

Key words: poulards, hens, native breeds, meat quality

Poulards and capons were used in the 17th and 18th centuries to make many dishes popular in old Polish cuisine. There are many different definitions of poulards.

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The French "poularde" means a young hen, fattened and slaughtered before sexual maturity (www.naszkurczak.pl). Potemkowska (1964) described poulards as sexually immature hens, fed during the growth period similarly to broilers.

Chemical castration is allowed in some countries of the world (Mahmud et al., 2013), but this method is not used in Europe. Although poulard farming was known for many years, the current relevant literature is scarce. The first modern studies in this area appeared in China, and the foundation material was provided by local Chinese breeds (Guo et al., 2016; Cui et al., 2016 a; Cui et al., 2016 b). These studies show that poulard meat differs significantly from the meat of pullets slaughtered at the same age with regard to most of the analysed traits.

Poland has 11 breeds/lines of laying hens under conserved breeding, and each of these lines forms a separate genotype, which determines the occurrence of unique qualitative and quantitative traits, not found in the breeds selected for high productivity. Studies conducted at the National Research Institute of Animal Production show that cockerels and capons of some conserved breeds of laying hens and their hybrids with meat-type cockerels provide meat with valuable taste and dietetic qualities (Połtowicz, 2007; Połtowicz and Doktor, 2012; Puchała et al., 2014; Calik et al., 2015; Calik et al., 2017). Special consideration is given to the native lines of laying hens, namely Greenleg Partridge (Z-11), Yellowleg Partridge (Ż-33) and heavier Sussex (S-66) and Rhode Island Red (R-11).

The aim of the study was to determine the effect of genotype (breed/line) and spaying of pullets on body weight, estradiol level, carcass and meat quality. The results will determine the possibility of using native breeds of hens for production of traditional foods. Recent scientific literature provides no results from similar studies using native Polish breeds.

Material and methods

The experiment used Rhode Island Red (R-11), Yellowleg Partridge (Ż-33) and Sussex (S-66) hens, 100 birds per line. After weighing and individual tagging, each line was divided into 2 groups with 50 birds per group; one of each group was spayed at 10 wk of age to obtain poulards (group P). The control group consisted of unspayed pullets (group K). Spaying was performed under local anesthesia by a veterinarian. The experimental procedures were in line with the requirements set by the Ethics Committee no. 954 of 10 July 2012.

Throughout rearing until 23 wk of age, pullets and poulards from both groups were fed *ad libitum* complete starter, grower and finisher diets supplemented with 2% whey powder. The ingredient composition as well as the results of chemical analysis of the feed mixtures, performed according to AOAC methods (1997), are given in Table 1.

Birds were kept on litter in confinement housing (7 birds/m^2) until 10 wk of age. From 11 to 23 wk, birds were allowed unlimited access to the outdoor areas all through the day.

Table 1. Ingredient composition and nutritive value of the diets (kg/100 kg)

Ingredient	Diet I 1–7 wks	Diet II 8–15 wks	Diet III 16–23 wks
Ground maize	15.00	18.00	30.00
Ground wheat	47.40	25.60	20.65
Ground triticale	10.00	25.00	18.00
Ground barley	-	10.00	10.00
Soybean meal	24.00	18.00	16.00
Whey powder	-	-	2.00
Ground limestone	1.25	1.25	1.25
Dicalcium phosphate	1.50	1.30	1.25
NaCl	0.30	0.30	0.30
DL-methionine	0.05	0.05	0.05
Vitamin-mineral premix DKA-S (broiler starter) (0.5%)	0.50	-	-
Vitamin-mineral premix DKA-G (broiler grower) (0.5%)	-	0.50	-
Vitamin-mineral premix DKA-F (broiler finisher) (0.5%)	-	-	0.50
Content in 1 kg			
Crude protein (g)	192	170	160
Metabolizable energy (MJ)	11.8	11.9	12.0
(kcal)	2820	2840	2870
Lys (g)	9.20	7.80	7.20
Met (g)	3.30	3.05	3.00
Ca (g)	8.70	8.10	8.05
P available (g)	4.10	3.65	3.60

Throughout the experiment, data on body weight gains, feed intake and mortality were recorded. During rearing, 8 birds from each group were subjected to blood collection before spaying, 2 weeks after spaying, and 4 days before slaughter to determine estradiol 17β concentrations using the RIA DIAsource kit. At the end of the rearing period (wk 23), 8 birds whose body weight was similar to group average, were selected from each group for slaughter. An additional criterion for choosing poulards was the much smaller comb than in hens. Prior to slaughter, birds were subjected to 12 h of feed withdrawal but not water withdrawal. After weighing birds were slaughtered, measured for pH 15 min postmortem, their carcasses were eviscerated, weighed and chilled at 4°C. After 24-h chilling, pH_{24} of breast and thigh muscles was measured, and carcasses were subjected to simplified slaughter analysis according to the method of Ziołecki and Doruchowski (1989). This was preceded by the determination of carcass and muscle colour, which was measured with the L*a*b* scale (CIE, 2007) using a Minolta CR 310 reflectance spectrophotometer, where L* is lightness, positive a* corresponds to redness, and positive b* is yel-

lowness. The colour value is the mean of five carcass measurements and two breast and leg muscle measurements, performed on the inner surface immediately after deboning.

Water holding capacity (WHC) of breast and leg muscles was determined by the Grau and Hamm method (1953), based on the amount of juice mechanically pressed from a sample. Juice loss was determined after 24-h storage of the breast and thigh muscle samples at +4°C. To this end, 80 g samples of meat were taken from the right thigh and breast muscle, placed in airtight containers, and stored in a refrigerator.

Thermal loss was determined as the loss in weight of breast and thigh muscles during cooking. 80 g samples were placed in plastic bags and cooked at 100°C for 14 min (breast muscles) and 16 min (thigh muscles) to an internal temperature of 76–78°C. After cooking, the samples were chilled at room temperature for 30 min and then in a refrigerator at 4°C for 45 min. Meat tenderness was measured with a Stable Micro Systems texture analyser. To this end a cylinder, 10 mm in diameter and 30 mm in height, was cut out from the cooked breast and thigh muscle (85°C). The collected sample was sheared with a Warner-Bratzler device in three locations, perpendicular to muscle fibre direction, and the final result was given as the mean value of measurements. Samples of breast and leg muscles were collected from four birds per group to determine the chemical composition, namely the content of crude protein (by Kjeldahl), fat (by Soxhlet), and cholesterol (by gas chromatography). The profile of fatty acids was determined with a Varian 3400 CX gas chromatograph, using helium as a carrier gas and a 105-m Rtx 2330 column, injector temperature 200°C, detector temperature 240°C; the samples were prepared by methylation with BF3/methanol using the Folch et al. (1957) method. Breast and leg muscles were subjected to sensory evaluation according to the method described by Baryłko-Pikielna and Matuszewska (2009). The aroma, appearance and taste of meat were scored on a 5-point scale where 5 = very desirable and 1 = undesirable. The evaluated meat was portioned into 15 g pieces, which were put on identical plates coded with group numbers.

The results were statistically analysed and significant differences were determined by one- or two-way analysis of variance (genotype × experimental factor) and Duncan's test (Statgraphic 5.0). A statistical analysis involved the determination of arithmetic means and standard deviation (SD) or standard error of the mean (SEM) for the traits analysed in the study.

Results

Spaying was found to have a significant effect on blood estradiol levels of birds (Table 2). Prior to spaying, the level of this hormone remained at a similar level in all the groups. However, 2 weeks after spaying and immediately before slaughter, blood estradiol levels were considerably lower in poulards than in pullets ($P \leq 0.01$), regardless of genotype.

Table 2. Blood estradiol levels in birds (pg/ml) of different ages

Line of hens	Before spaying			2 weeks after spaying			4 days before slaughter		
	hens (K) (Means; SD)	birds intended for poulards (P) (Means; SD)	significance	hens (K) (Means; SD)	poulards (P) (Means; SD)	significance	hens (K) (Means; SD)	poulards (P) (Means; SD)	significance
R-11	63.53±17.98	75.56±21.74	NS	85.18±26.27	44.55±32.48 a	**	248.38±93.76 a	50.21±35.28 a	**
S-66	67.64±15.41	71.81±14.81	NS	86.30±24.20	27.89±20.25 ab	**	173.91±64.75 b	21.81 ± 12.87 b	**
Ż-33	59.19±19.85	67.44±20.86	NS	144.24±93.14	19.48±7.55 b	**	171.38±27.99 b	31.50± 14.89 ab	**

Notes: Ż-33 – Yellowleg Partridge; R-11 – Rhode Island Red; S-66 – Sussex; K – hens; P – poulards.
Significance of differences between poulards and hens: NS – not significant, * – significant (P≤0.05), **– highly significant (P≤0.01).
Differences between hen breeds: same letters – not significant, different small letters – significant (P≤0.05), different capital letters – highly significant (P≤0.01).

Table 3. Mean body weight (g) from 8 to 23 weeks of age

Week	Line of hens (A)			Type of birds (B)		A × B						SEM	Effect		
	R-11	S-66	Ż-33	K	P	R-11K	R-11 P	S-66K	S-66P	Ż-33K	Ż-33P		A	B	A×B
8	508 A	515 A	405 B	474	483	511	504	519	512	388	426	6.67	**	NS	NS
11	782 A	785A	712 B	723	800	748	817	752	818	668	761	8.99	**	**	NS
14	1118 A	999 A	965 B	997	1054	1087	1149	948	1056	956	973	11.9	**	**	NS
18	1413 A	1320 B	1317 B	1344	1351	1391	1434	1337	1300	1300	1334	12.5	**	NS	NS
23	1793 A	1697 B	1670 B	1682	1753	1740	1845	1678	1726	1618	1717	11.4	**	**	NS

For explanations, see Table 2.

Table 4. Carcass quality characteristics

Parameters (%)	Line of hens (A)			Type of birds (B)		A × B						SEM	Effect		
	R-11	S-66	Ż-33	K	P	R-11K	R-11P	S-66K	S-66P	Ż-33K	Ż-33P		A	B	A × B
Carcass weight loss during chilling (%)	2.72	2.19	3.12	3.65	1.86	3.50	1.94	2.95	1.43	4.51	2.33	0.312	NS	**	NS
Dressing percentage without giblets (%)	65.94	67.94	65.52	64.07	68.85	62.3	69.5	66.3	69.6	63.6	67.4	0.725	NS	**	NS
Proportion of breast muscles (%)	17.4 b	15.9 a	17.4 ab	16.7	17.1	16.9	17.9	16.0	15.8	17.2	17.5	0.303	*	NS	NS
Proportion of leg muscles (%)	20.47	19.75	19.54	20.26	19.57	20.8	20.1	19.7	19.8	20.2	18.8	0.331	NS	NS	NS
Proportion of giblets (%)	6.03 b	5.87 a	5.25 a	6.17	5.27	6.83	4.92	5.59	4.91	6.18	5.88	0.182	*	**	NS
Proportion of leg bones (%)	4.78	4.73	4.49	4.70	4.63	4.82	4.74	4.91	4.56	4.37	4.61	0.089	NS	NS	NS
Proportion of abdominal fat (%)	3.14	4.98	3.60	3.55	4.26	2.46	3.81	4.87	5.08	3.17	4.03	0.388	NS	NS	NS
Carcass colour: L*	69.2 A	70.6 B	69.2 A	69.2	70.2	68.9	69.7	70.3	70.9	68.4	70.0	0.216	**	**	NS
a*	4.25 B	3.57 B	2.98 A	3.54	2.98	4.23	4.28	3.35	3.80	3.04	2.94	0.137	**	NS	NS
b*	14.2 B	9.97 A	13.7 B	11.6	13.6	12.2	16.2	9.71	10.2	13.1	14.3	0.540	**	*	NS

For explanations, see Table 2.

As a consequence of the changes in estradiol levels, distinct alterations in secondary sex characters, namely in exterior appearance and behaviour, were noted in poulards. During sexual maturation, a large red comb grew in the pullets while in the poulards it became considerably smaller and faded. Poulards were also much calmer than hens.

From wk 8 to 23, poulards were characterized by higher body weight than pullets (Table 3). The final body weight of 23-wk-old poulards averaged 1753 g and was higher by 71 g than in pullets ($P \leq 0.01$). Among the three lines studied, Yellowleg Partridge showed the lowest, and Rhode Island Red the highest body weight ($P \leq 0.01$).

Higher carcass cooling loss was noted in pullets compared to poulards ($P \leq 0.01$) (Table 4). Dressing percentage without giblets was much higher in poulards than in pullets ($P \leq 0.01$), with no significant differences among all the lines. No significant changes were found in breast muscle percentage and in leg muscle and leg bone percentage between poulards and pullets. Such differences were established for giblets percentage, which was lower in poulards than in pullets ($P \leq 0.01$), and higher in R-11 out of all lines ($P \leq 0.05$). For all the lines, the proportion of abdominal fat was higher in poulards than in pullets, but the differences were not significant. No effect of both factors together (genotype and spaying of pullets) on the percentage yield was observed.

Large differences were found in carcass colour between poulards and pullets, and among all three lines (Table 4). Carcasses from S-66 hens and poulards were lighter (L*) compared to the other groups. Redness (a*) was highest in R-11 and S-66, and lowest in Ż-33 birds ($P \leq 0.01$). The highest yellowness (b*) was observed for R-11 and Ż-33 carcasses ($P \leq 0.01$). Compared to pullet carcasses, poulard carcasses showed higher lightness ($P \leq 0.01$) and yellowness ($P \leq 0.05$), and lower redness.

Breast muscle pH values in 23-wk-old birds, measured 15 min after slaughter and after 24 h of carcass chilling, remained at a similar level, both among different lines and between poulards and pullets (Table 5). Differences in breast muscle colour, drip loss after 24 h and water holding capacity between the lines and between poulards and pullets were also small and not significant. Breast muscles were more tender for poulards than for pullets ($P \leq 0.05$).

Leg muscle pH at 15 min postmortem was at a similar level in all the groups, whereas both experimental factors (genotype and spaying) had an effect ($P \leq 0.01$) on the pH of these muscles 24 h after carcass chilling (Table 6). Differences between poulards and pullets, as well as between bird genotypes in drip loss of leg muscles 24 h postmortem and in water holding capacity were small and non-significant. Greater differences were observed for thermal loss, which proved smaller for leg muscles of poulards compared to pullets, and also in group S-66 compared to group R-11 ($P \leq 0.05$). The highest lightness (L*) and yellowness (b*) in leg muscles was observed in the group of S-66 hens. The lowest lightness (L*) ($P \leq 0.01$) and yellowness (b*) ($P \leq 0.05$) was found for leg muscles of Ż-33 birds. No statistically significant differences were noted between poulards and pullets in leg muscle tenderness and colour.

Table 5. Physical traits of breast muscles from 23-wk-old birds

Item	Line of hens (A)			Type of birds (B)		A × B						SEM	Effect		
	R-11	S-66	Ż-33	K	P	R-11K	R-11P	S-66K	S-66P	Ż-33K	Ż-33P		A	B	A × B
pH_{15min}	6.33	6.24	6.28	6.29	6.28	6.36	6.31	6.20	6.27	6.30	6.25	0.026	NS	NS	NS
pH_{24h}	5.56	5.59	5.46	5.54	5.54	5.61	5.51	5.78	5.96	5.42	5.50	0.023	NS	NS	NS
Drip loss after 24 h (%)	0.46	0.47	0.58	0.52	0.48	0.46	0.46	0.42	0.50	0.59	0.58	0.032	NS	NS	NS
Thermal loss (%)	25.59	24.08	24.84	24.33	25.35	24.86	26.31	24.01	24.14	25.90	23.78	0.541	NS	NS	NS
WHC (%)	15.44	14.92	15.46	15.07	15.48	15.82	15.06	14.66	15.18	14.75	16.36	0.266	NS	NS	NS
Shear force (N)	12.3	12.3	12.8	13.0	11.9	12.2	12.3	12.4	12.1	14.3	11.4	0.285	NS	*	NS
Colour: L*	61.7	60.7	59.7	60.8	60.6	62.9	60.5	59.3	62.1	60.3	59.1	0.464	NS	NS	NS
a*	9.34	9.21	8.79	8.71	9.52	9.61	9.06	9.05	9.36	8.24	9.34	0.283	NS	NS	NS
b*	7.44	7.55	8.28	7.67	7.84	6.94	7.93	7.63	7.47	7.95	8.62	0.262	NS	NS	NS

For explanations, see Table 2.

Table 6. Physical traits of leg muscles from 23-wk-old birds

Item	Line of hens (A)			Type of birds (B)		A × B						SEM	Effect		
	R-11	S-66	Ż-33	K	P	R-11K	R-11P	S-66K	S-66P	Ż-33K	Ż-33P		A	B	A × B
pH15min	6.56	6.59	6.70	6.59	6.64	6.52	6.61	6.51	6.66	6.96	6.71	0.028	NS	NS	NS
pH24h	6.08	6.09	6.11	6.06	6.13	6.16	6.00	6.07	6.11	5.98	6.26	0.037	NS	NS	**
Drip loss after 24 h (%)	0.29	0.33	0.27	0.28	0.31	0.25	0.33	0.39	0.26	0.23	0.30	0.022	NS	NS	NS
Thermal loss (%)	38.50 b	34.84 a	35.93 ab	37.85	34.98	37.50	39.4	37.5	32.2	38.5	33.3	0.747	*	*	*
WHC (%)	15.50	13.97	14.65	15.36	14.02	15.78	15.22	14.22	13.72	16.08	12.87	0.392	NS	NS	NS
Shear force (N)	25.7	25.2	26.7	27.8	23.9	25.9	25.4	28.1	22.3	29.5	23.9	1.00	NS	NS	NS
Colour: L*	46.30 a	49.0 Bb	44.10 A	45.9	46.99	46.2	46.4	48.2	49.7	43.4	44.8	0.563	**	NS	NS
a*	17.07	16.89	16.94	17.12	16.81	17.0	17.1	17.1	16.7	17.7	16.1	0.208	NS	NS	NS
b*	7.08 ab	7.30 b	6.05 a	6.70	6.91	6.68	7.47	7.39	7.20	6.04	6.07	0.216	*	NS	NS

For explanations, see Table 2.

Table 7. Chemical composition of breast and leg muscles

Item	Lien of hens (A)			Type of birds (B)		A × B					SEM	Effect		
	R-11	S-66	Ż-33	K	P	R-11K	R-11P	S-66K	S-66P	Ż-33K	Ż-33P		A	B	A × B
Breast muscles															
Dry matter (%)	26.85	27.24	27.15	26.75	27.44	26.5	27.8	26.9	27.5	26.8	26.9	0.162	NS	*	NS
Crude protein (%)	24.96	25.28	25.14	24.96	25.31	24.9	25.4	25.3	25.3	24.7	25.2	0.099	NS	NS	NS
Crude fat (%)	1.34 B	0.72 A	0.84 A	0.92	1.01	1.32	1.36	0.58	0.87	0.87	0.81	0.063	**	NS	NS
Cholesterol (g/kg)	0.52	0.52	0.53	0.53	0.52	0.56	0.50	0.53	0.51	0.49	0.57	0.010	NS	NS	*
Leg muscles															
Dry matter (%)	27.74 a	29.34 b	28.20 ab	27.63	29.25	27.6	28.8	27.9	30.7	27.3	28.2	0.324	*	**	NS
Crude protein (%)	20.69	20.67	20.52	20.71	20.54	20.5	20.6	20.7	20.6	20.9	20.4	0.101	NS	NS	NS
Crude fat (%)	5.94 B	4.09 A	4.43 A	4.35	5.28	5.60	6.29	3.89	4.30	3.58	5.28	0.236	**	**	NS
Cholesterol (g/kg)	0.84	0.81	0.84	0.85	0.81	0.90	0.79	0.88	0.75	0.78	0.92	0.022	NS	NS	*

For explanations, see Table 2.

Table 8. Content of fatty acids in breast muscles (g/100 g)

Fatty acids	Line of hens (A)			Type of birds (B)		A × B						SEM	Effect		
	R-11	S-66	Ż-33	K	P	Ż-33 K	Ż-33 P	R-11K	R-11P	S-66 K	S-66 P		A	B	A × B
C14:0	0.55 Aa	0.93 B	0.69 Ab	0.69	0.76	0.59	0.80	0.51	0.59	0.96	0.90	0.034	**	NS	NS
C16:0	24.53 A	27.20 B	24.42 A	25.08	25.78	23.91	25.07	24.11	24.96	27.22	27.17	0.325	**	NS	NS
C16:1	4.06 A	5.35 B	4.07 A	4.34	4.68	4.16	3.95	3.49	4.64	5.37	5.32	0.186	**	NS	NS
C18:0	8.31	8.16	8.22	8.38	8.07	8.07	8.41	8.92	7.70	8.16	8.16	0.133	NS	NS	*
C18:1	37.45	35.49	35.41	36.31	35.96	36.62	33.90	36.71	38.19	35.60	35.39	0.440	NS	NS	NS
C18:2*n-6*	12.72	11.66	12.36	12.49	11.98	12.57	12.11	13.04	12.39	11.87	11.46	0.312	NS	NS	NS
Gamma 18:3	0.08 ab	0.10 b	0.07 a	0.09	0.08	0.09	0.04	0.08	0.09	0.10	0.10	0.005	*	NS	NS
C18:3*n-3*	0.47	0.49	0.42	0.45	0.47	0.42	0.41	0.42	0.52	0.51	0.47	0.015	NS	NS	NS
C22:0	0.08 b	0.05 a	0.08 b	0.07	0.07	0.05	0.11	0.09	0.06	0.06	0.04	0.006	*	NS	**
C20:4*n-6*	10.26 a	8.94 A	12.55 Bb	10.49	10.54	11.84	13.45	11.13	9.40	8.51	9.37	0.458	**	NS	NS
C22:1	0.03 A	0.03 a	0.04 Bb	0.03	0.03	0.03	0.05	0.04	0.02	0.03	0.03	0.002	**	NS	**
C 22:6*n-3*(DHA)	1.16	1.15	1.38	1.24	1.20	1.41	1.34	1.22	1.09	1.10	1.20	0.060	NS	NS	NS
SFA	33.64 A	36.67 B	33.59 A	34.44	34.92	32.77	34.63	33.75	33.54	36.81	36.53	0.373	**	NS	NS
UFA	66.36 B	63.33 A	66.41 B	65.56	65.08	67.23	65.37	66.25	66.46	63.19	63.47	0.373	**	NS	NS
MUFA	41.54	40.87	39.52	40.68	40.68	40.82	37.89	40.23	42.85	41.00	40.74	0.486	NS	NS	NS
PUFA	24.81 AB	22.46 A	26.89 B	24.87	24.40	26.42	27.48	26.02	23.61	22.18	22.73	0.605	**	NS	NS
PUFA*n-6*	23.07 AB	20.70 A	24.99 B	23.07	22.60	24.49	25.60	24.25	21.88	20.48	20.92	0.578	**	NS	NS
PUFA*n-3*	1.69	1.72	1.88	1.76	1.76	1.90	1.87	1.70	1.68	1.67	1.77	0.058	NS	NS	NS
PUFA*n-6/n-3*	14.14	12.23	13.40	13.52	12.97	13.15	13.73	15.07	13.22	12.35	12.11	0.457	NS	NS	NS

For explanations, see Table 2.

Table 9. Content of fatty acids in leg muscles (g/100 g)

Fatty acids	Line of hens (A)			Type of birds (B)		A × B						SEM	Effect		
	R-11	S-66	Ż-33	K	P	Ż-33 K	Ż-33 P	R-11K	R-11P	S-66 K	S-66 P		A	B	A × B
C14:0	0.63 Aa	0.82 B	0.70 Ab	0.72	0.71	0.67	0.73	0.65	0.61	0.84	0.79	0.019	**	NS	NS
C16:0	24.95 A	27.58 B	24.89 A	25.41	26.30	24.18	25.77	24.60	25.31	27.44	27.72	0.349	**	NS	NS
C16:1	5.83 a	7.47 b	6.47 ab	6.26	6.96	6.42	6.52	5.27	6.39	7.08	7.87	0.277	*	NS	NS
C18:0	6.98	6.89	6.73	7.10	6.63	6.65	6.85	7.44	6.52	7.21	6.57	0.154	NS	NS	NS
C18:1	42.55 b	39.94 a	41.92 b	41.13	41.81	42.04	41.78	42.27	42.83	39.08	40.81	0.397	*	NS	NS
C18:2*n-6*	14.13	13.02	14.00	14.14	13.25	14.47	13.42	14.58	13.68	13.37	12.67	0.396	NS	NS	NS
Gamma 18:3	0.10	0.11	0.09	0.11	0.09	0.11	0.07	0.11	0.09	0.11	0.11	0.005	NS	NS	NS
C18:3*n-3*	0.60	0.63	0.60	0.59	0.63	0.57	0.63	0.56	0.65	0.64	0.62	0.016	NS	NS	NS
C22:0	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.002	NS	NS	NS
C20:4*n-6*	3.64	2.89	3.92	3.86	3.04	4.16	3.61	3.92	3.36	3.50	2.27	0.191	NS	*	NS
C22:1	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.001	NS	NS	NS
C22:6*n-3*(DHA)	0.32	0.36	0.38	0.40	0.30	0.44	0.30	0.32	0.31	0.43	0.29	0.023	NS	*	NS
SFA	32.70 A	35.46 B	32.51 A	33.41	33.79	31.69	33.54	32.85	32.56	35.69	35.24	0.388	**	NS	NS
UFA	67.30 B	64.54 A	67.49 B	66.59	66.21	68.31	66.46	67.15	67.44	64.31	64.76	0.388	**	NS	NS
MUFA	48.39	47.44	48.41	47.40	48.78	48.48	48.33	47.56	49.23	46.17	48.70	0.486	NS	NS	NS
PUFA	18.90	17.10	19.07	19.19	17.42	19.83	18.13	19.60	18.21	18.14	16.06	0.556	NS	NS	NS
PUFA*n-6*	17.87	16.02	18.01	18.11	16.38	18.73	17.11	18.60	17.13	16.99	15.06	0.541	NS	NS	NS
PUFA*n-3*	0.96	1.02	1.01	1.02	0.97	1.04	0.96	0.90	1.01	1.10	0.95	0.030	NS	NS	NS
PUFA*n-6/n-3*	19.10 b	15.65 a	17.85 ab	18.09	16.91	17.97	17.69	20.84	17.36	15.46	15.84	0.550	*	NS	NS

For explanations, see Table 2.

It follows from the chemical analysis of breast and thigh muscles (Table 7) that compared to pullets, the meat from breast and legs of poulards contained more dry matter (P≤0.05 and P≤0.01), and the meat from legs had more fat (P≤0.01). In addition, the breast and leg muscles contained more crude fat in R-11 compared to S-66 and Ż-33 birds (P≤0.01).

Both experimental factors together (genotype and type of birds) had a significant effect on the level of cholesterol in the analysed muscle samples (P≤0.05). In the breast muscles of poulards and pullets, no significant differences were established in the profile of fatty acids (Table 8). Higher and statistically significant differences in this regard were found between the lines. Most saturated fatty acids (SFA), in particular myristic (C14:0) and palmitic acids (C16:0) were found in breast muscles from S-66 hens. The R-11 and Ż-33 lines had much more unsaturated fatty acids (UFA), including *n-6* PUFA, compared to line S-66.

Table 10. Results of sensory evaluation of hen and poulard meat

Item	Line of hens (A)			Type of birds (B)		SEM	Effect		
	R-11	S-66	Ż-33	K	P		A	B	A × B
Breast meat									
Aroma	4.55	4.62	4.71	4.58	4.66	0.059	NS	NS	NS
Juiciness	4.30	4.19	4.33	4.21	4.34	0.076	NS	NS	NS
Tenderness	4.37 a	4.35 a	4.70 b	4.36	4.58	0.064	*	NS	NS
Taste	4.32 a	4.30 a	4.59 b	4.23	4.57	0.052	*	**	NS
Leg meat									
Aroma	4.75	4.76	4.73	4.64	4.58	0.044	NS	NS	NS
Juiciness	4.48	4.42	4.41	4.30	4.64	0.066	NS	*	NS
Tenderness	4.36	4.31	4.38	4.05	4.65	0.061	NS	**	NS
Taste	4.53	4.46	4.44	4.29	4.67	0.047	NS	**	NS

Notes: sensory scores on a 5-point scale: 1 – undesirable trait (worst score), 5 – very desirable trait (best score).

For other explanations, see Table 2.

Fatty acid profile of leg muscles was similar to that in breast muscles (Tables 8 and 9). Here again, much more SFA was noted in line S-66, and more UFA in lines R-11 and Ż-33 compared to S-66 (P≤0.01). In line S-66, the *n-6/n-3* PUFA ratio was lower compared to R-11 and Ż-33 for both breast and leg muscles (Tables 8 and 9). Furthermore, the leg muscles of poulards contained less polyunsaturated fatty acids: docosahexaenoic (DHA) (C22:6*n-3*) and arachidonic (C20:4*n-6*) (P≤0.05).

In the sensory evaluation, poulard meat received higher scores than pullet meat in all categories (Table 10). Significant differences were confirmed for taste (P≤0.01) of breast meat, and for juiceness (P≤0.05), tenderness and taste of leg meat (P≤0.01).

Discussion

Our study showed that bird genotype has a large effect on body weight, as did Adamski et al. (2016) in a study with pedigree strain cockerels. The body weight of both pullets and poulards, despite a long rearing period of 23 wks, was not high (<1870 g), but exceeded the values reported by Guo et al. (2016) for the native Chinese Huainai breed, where the body weight of 23-wk-old birds was 1582 g for poulards and 1448 g for pullets. The findings of Cui et al. (2016 b) obtained for Beijing-you breed at 22 wk were 1555 g for poulards and 1469 g for pullets. In addition, it follows from the study of Guo et al. (2016) that ovariectomy of Huainai hens did not increase the weight of breast and leg muscles. In Spain, native hens aged 10 months reach a body weight of around 4-5 kg and their dressing percentage exceeds 80% (Franco et al., 2012 b). At 5 months, the body weight of capons obtained from these breeds ranges from 2.60 to 4.04 kg (Diaz et al., 2012).

Spanish consumers prefer capons weighing 4–5 kg and poulards weighing 2.5–3.0 kg. The body weight of 16-wk-old heavy-type poulards (Cornish) is around 3 kg; medium-type poulards (Euskal Oiloa) reach a similar body weight at over 18 wks, and light-type poulards (Penedesenca and del Prat) after 25 wks. It follows from the study of Rikimaru et al. (2009 a) with local Asian breeds of chicken that in birds older than 22 wks, the growth rate considerably decreases and cockerels reach a higher body weight compared not only to pullets, but also to capons. The proportion of carcass breast muscles in all the studied groups was comparable to 77-d-old native breeds of African chickens (Marle-Köster and Webb, 2000). In China, some native breeds of hens already reach the body weight of 2.5–3.2 kg, and dressing percentage of around 80% at 13 wk of age (Zhao et al., 2012).

Colour is an important component of the consumer assessment of carcasses and one of the major quality characteristics of meat, which determines its processing suitability (Batorska et al., 2016; Zdanowska-Sąsiadek et al., 2013). In the traditional old Polish cuisine, the carcasses for making dishes, in particular broths, were expected to be yellow. In Ż-33 and R-11 hens, yellow carcass colour is genetically determined, which was confirmed by our study. The yellow colour of carcasses, desirable from a consumer perspective, was more intense in poulards than in pullets. Differences in the colour of poultry carcasses and meat are another trait characteristic of the native/local breeds, whereas in broiler chickens of different varieties, all the carcasses are light in colour and generally this trait is not affected by genotype (Wattanachant et al., 2004; Mikulski et al., 2011).

The weight of breast and leg muscles in poulards was higher than in pullets, but much lower than in 6-wk-old broiler chickens (Murawska and Bochno, 2007). Whereas the significantly higher weight of leg compared to breast muscles, observed in our study, is characteristic of laying and general purpose hens (Murawska and Bochno, 2007), slow-growing hens raised under extensive conditions (Grashorn and Clostermann, 2002), and local breeds (Choo et al., 2014; Calik, 2015; Calik et al., 2017). An almost twice higher weight of leg muscles compared to breast muscles was found in capons and cockerels produced based on pedigree strains (Adamski et al., 2016) and native Asian breeds (Rikimaru et al., 2009 a).

After 24 h of chilling, carcass weight losses for all the three breeds were small and lower than for young broiler chickens (Połtowicz and Doktor, 2011). Carcass weight losses during chilling, comparable to those in broiler chickens, were higher in pullets than in poulards.

Dressing percentage in all the breeds was small (62.3–66.3%) and much lower than in broiler chickens, but similar to those in poulards (Guo et al., 2016), local breeds of hens (Chen et al., 2006; Choo et al., 2014; Puchała et al., 2014) and male layers (Murawska and Bochno, 2007). Dressing percentage in poulards was 4.78% higher than in pullets, but around 4% lower than in 7-wk-old broiler chickens (Gornowicz, 2008). Poulards had higher dressing percentage without giblets, but the differences in the yield of breast and leg muscles were small and non-significant. The sexual dimorphism in laying and general purpose hens causes that the muscles of both pullets and poulards are much smaller compared to cocks and capons (Chen et al., 2006; Rikimaru et al., 2009 a; Rikimaru et al., 2009 b). The proportion of giblets in carcass weight remained at a level similar to that in slow-growing native chickens (Połtowicz and Doktor, 2012). Thigh muscle percentage was higher than breast muscle percentage in the carcass, which is consistent with the results reported for Chinese poulards (Cui et al., 2016 b).

The content of abdominal fat in all the three breeds was lower than in 22-wk-old poulards and capons of the Beijing-you breed (Cui et al., 2016 b) and in 23-wk-old Huainan birds (Guo et al., 2016). This value was much higher than in 20-wk-old cockerels and capons (Adamski et al., 2016) and in 42-wk-old broiler chickens (Gornowicz, 2008), but comparable to that of chickens reared for 63 days (Berri et al., 2005; Zhu et al., 2012) and 26-wk-old heavy hens of Asian breeds (Rikimaru et al., 2009 a), where this indicator was below 4%. Poulards are characterized by higher fatness than pullets, which increases with the age of the birds, as confirmed by our study and the findings of Cui et al. (2016 b). Also capons compared to cockerels have a higher content of abdominal fat, which additionally shows a constant upward trend with the age of the birds (Rikimaru et al., 2009 a).

Muscle pH is considered an important indicator of meat quality as it reflects the intensity of glycolytic changes in muscles. pH value measured 15 min postmortem should range between 5.9 and 6.2 for normal meat (Jakubowska et al., 2004). This measurement allows distinguishing normal meat from PSE (pale, soft, exudative) meat when pH≤5.7 or DFD (dark, firm, dry) meat when pH≥6.3. pH of the breast muscles from all three hen breeds as well as pullets and poulards, fell within the upper standard range and the results were consistent with the findings of Połtowicz and Doktor (2012) for slow-growing chickens. In the leg muscles from all the groups, pH_{15min} was much higher and despite a greater rate of decline than in the study of Połtowicz and Doktor (2012), after 24 h it still exceeded 5.98. Similar results were obtained by Berri et al. (2005), who also noted lower pH values of breast and leg muscles in 12-wk-old compared to 6-wk-old chickens. No significant differences were found in pH values between poulards and pullets, similar to the study of Sirri et al. (2009) with capons. The pH of breast muscles after 24 h in 17-wk-old Beijing-you poulards (Cui et al., 2016 a) and in 23-wk-old ovariectomized pullets (Guo et al., 2016) was higher than in the muscles of the studied birds.

The lower drip loss after 24 h of chilling shows that leg muscles were characterized by higher juiciness (Berri et al., 2005). The drip loss of breast muscles in all the analysed breeds as well as in poulards and pullets was much lower than in broiler chickens (Połtowicz and Doktor, 2011), but comparable to the results obtained by Puchała et al. (2014) for the meat of 56-wk-old hens.

The results concerning thermal loss in the meat of different birds vary greatly depending mainly on genotype and slaughter age. Thermal loss in the muscles of the analysed birds was considerably higher than in five different local Asian breeds (Wattanachant, 2008). Berri et al. (2005) demonstrated that meat from fast-growing chickens is characterized by lower loss than the meat of slow-growing chickens. A reverse relationship was noted in the study by Pietrzak et al. (2013). In our study, in all the groups of hens, thermal loss was higher for leg muscles than for breast muscles, and the results are in agreement with the results reported for broiler chickens (Gornowicz, 2008), capons (Lin and Hsu, 2002), slow-growing chickens (Wattanachant et al., 2004; Połtowicz, 2007) and 56-wk-old hens (Puchała et al., 2014).

Water holding or binding capacity is an important characteristic of meat attesting to its technological suitability. Meat with high water holding capacity is more juicy than meat with low water holding capacity. The water holding capacity of the breast and leg muscles of all the analysed breeds of hens and poulards was almost twice as low as for the muscles of 42-d-old broiler chickens (Gornowicz, 2008), but the level of this trait was similar to the results obtained by 20-wk-old cockerels and capons (Calik, 2015) and 56-wk-old hens (Puchała et al., 2014; Puchała et al., 2015). Thus, the performed research showed that the meat of the studied pullets and poulards has a higher water binding capacity compared to the meat of young broiler chickens.

Meat tenderness depends on muscle fibre thickness and the amount of connective tissue, and these traits result from bird genotype, age and welfare levels (Guan et al., 2013). Shear force, which reflects meat tenderness, is a trait correlated directly to the age of birds, which is why the results obtained in our study are much higher than those reported for the meat of young native chickens (Fanatico et al., 2005; Połtowicz and Doktor, 2012; Guan et al., 2013). The effect of genotype on this trait was confirmed by Wattanachant et al. (2004), who observed an almost twice higher shear force of thigh muscles in the native Thai breed of chickens compared to the muscles of broiler chickens. The lower shear force values of breast and leg muscles in poulards compared to pullets are in line with the results obtained for Chinese breed poulards (Cui et al., 2016 a) and capons (Rikimaru et al., 2009 b; Calik et al., 2015) and confirm the superior tenderness of meat from spayed birds. The best effect in this respect was obtained for Ż-33 poulards, but among pullets shear force value of breast and leg muscles was higher in Ż-33 than in the other two breeds.

The colour of poultry meat depends on the concentration and oxidation state of myoglobin. Magdelaine et al. (2008) reported that meat colour is an important attribute by which consumers judge meat dishes, and Zdanowska-Sąsiadek et al. (2013) stated that darker meat, which results from a higher proportion of oxidized myoglobin is less desirable to the consumer. In turn, Touraille et al. (1981) reported that dark meat from slow-growing chickens received better sensory scores, which is supported by our own research. The best sensory scores were obtained for breast

meat of the Ż-33 breed, which was darker than the meat of R-11 and S-66 birds. This trait is genetically determined (Puchała et al., 2014).

In our study we did not find any statistically significant differences in breast muscle colour between poulards and pullets, whereas Guo et al. (2016) showed significantly higher yellowness and lower redness in breast muscles of poulards compared to pullets of local Chinese breeds.

The carcasses of Spanish and Chinese poulards have a lower content of tissue, subcutaneous and abdominal fat, and a higher content of intramuscular fat, which makes the meat delicate, juicy and tasty (http://www.uclm.es/profesorado/produccionanimal/ProduccionAnimalIII/G.; Cui et al., 2016 a).

The results of our study showed that the breast and leg muscles of poulards contained more dry matter ($P \leq 0.05$) and crude fat ($P \leq 0.01$) compared to pullets, and that there were no significant differences in protein and cholesterol levels, similarly as in capons compared to cockerels in the studies of Calik et al. (2015) and Kwiecień et al. (2015). In the breast muscles of all the studied hen breeds, crude protein ranged from 24.70% to 25.30% and was higher by 3–4% compared to young native chickens (Gornowicz, 2008; Połtowicz and Doktor, 2011) and 20-wk-old local breeds of African chickens (Tougan et al., 2013), but similar to the Mos native Spanish hens (Franco et al., 2012 a, b). In turn, Wattanachant et al. (2004) noted a 2% higher protein content, and lower fat content in the breast muscles of a native chicken breed compared to broiler chickens.

The spaying of pullets had no significant effect on the profile of fatty acids in the total SFA, MUFA and PUFA content of breast and thigh muscles, and these results are consistent with those obtained for capon muscles (Rikimaru et al., 2009 a, b; Sirri et al., 2009; Kwiecień et al., 2015). From the study of Cui et al. (2016 a) it follows that the fatty acid profile of poulard and pullet meat shows greater variation, but these changes fail to improve the health quality of the meat. The meat of poulards obtained from local Chinese breeds was found to contain a higher proportion of SFA and MUFA, and much less PUFA (Cui et al., 2016 a). Our study demonstrated that breed of hens has a considerable effect on the fatty acid content of the analysed muscle samples. The content of SFA in the breast muscles of the studied hens was comparable to the results reported for 56-wk-old hens (Puchała et al., 2014), but higher than in broiler chickens (Szymczyk and Frys-Żurek, 2011) and around 20% lower than in guinea fowl (Bernacki et al., 2012) and hybrid hens obtained from the crossing of native breeds with meat-type hens (Wattanachant et al., 2004). The content of PUFA was lower by around 15% compared to broiler chickens (Szymczyk and Frys-Żurek, 2011), but slightly higher than in breast muscles of native Spanish hens (Franco et al., 2012 a; Franco et al., 2012 b). The least saturated and the most unsaturated fatty acids were found in Yellowleg Partridge hens (Ż-33), and these results are similar to those reported by Puchała et al. (2014, 2015) for the meat of Greenleg Partridge hens, from which this breed originates.

Many authors believe that fat accumulation in the muscles is positively correlated to organoleptic evaluation, including taste (Gornowicz, 2008; Puchała et al., 2015; Calik et al., 2015; Calik et al., 2017). Meanwhile, Kopeć and Bobak (2009) point out that the taste of meat is determined by its content of proteins, peptides, amino

acids and nucleotides, whereas aroma is influenced by processing temperature. In our study, the meat of poulards, which was found to contain more fat, received better organoleptic scores – compared to pullets – for most of the categories evaluated. These results are in accordance with the findings of Gornowicz (2008), Puchała et al. (2015) and Franco et al. (2012 b). It follows from the study of Touraille et al. (1981) that dark meat from slow-growing chickens receives better sensory scores, and this tendency was observed for birds from the Ż-33 group.

Conclusion

The present study showed that blood estradiol levels in poulards were much lower than in pullets, regardless of genotype. Poulards showed higher body weight and their carcasses higher lightness and yellowness. In the sensory evaluation, poulard breast meat was more tasty and leg meat also more juicy and tender compared to pullet meat. Among the three conserved breeds, Rhode Island Red (R-11) and Yellowleg Partridge (Ż-33) hens are the best starting material for poulard production. Their carcasses showed good muscling and intense yellowness desirable to the consumers. These birds (R-11) achieved highest body weight. Spaying of pullets had no significant effect on the profile of fatty acids, but greater and statistically significant differences in this regard were found between hen lines. Compared to S-66 birds, breast muscles of R-11 and Ż-33 birds contained more polyunsaturated fatty acids. The breast and leg muscles of these birds had a lower content of saturated fatty acids.

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