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THE EFFECT OF SLAUGHTER AGE AND THE DIET IN THE FINAL GROWTH PHASE OF POULARDS ON PRODUCTIVITY AND MEAT QUALITY*

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Abstract

The aim of the studies was to evaluate the effect of the diet in the final growth phase and slaughter age of poulards on productivity, dressing percentage, carcass colour and physicochemical properties of meat. The studies were conducted on 78 hybrids obtained by crossing Ross 308 broiler roosters with Rhode Island Red (R-11) dual-purpose laying hens (♂Ross 308 × ♀R-11). Birds were assigned to 3 groups: control group (K) fed starter, grower and finisher diets without addition of dairy products, experimental group S offered a finisher diet supplemented with 4% whey, and experimental group M receiving 4% milk powder supplement in the final growth phase. Spaying procedure was carried out at 8 weeks of age. Poulards were slaughtered at 18 and 20 weeks of age. The studies showed that by using hybrids of dual-purpose hens with broiler roosters for production of poulards, rearing period could be shortened to 18 weeks, and the obtained meat had comparable or even better quality traits compared with poulards slaughtered at 20 weeks of age. Supplementation of poulard diet with 4% whey or milk powder in the final growth phase had a beneficial effect mostly on improvement of sensory properties of meat. There were not many significant differences in meat quality between poulards fed the diet supplemented with milk and whey but instead there were differences between these groups and the control group fed the diet without these additives.

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

Poulards are obtained by spaying procedure, i.e. removal of ovaries in young pullets which prevents their maturation and provides tender and tasty meat which, due to unique quality traits, is featured as a delicacy and niche product in many countries. Poulards are produced in several European countries (Italy, France, Spain)

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with the use of local chicken breeds but the first contemporary studies on production technology and meat quality of poulards have been carried out in China (Guo et al., 2017; Cui et al., 2016 a, b). In Poland, research on feasibility of using native hen breeds for production of poulards was initiated at the National Research Institute for Animal Production using 3 breeds/lines of dual-purpose hens included in the protection programme, which are distinguished by a greater body weight and meat quality traits meeting consumer expectations (Puchała et al., 2014; Obrzut et al., 2018; Krawczyk et al., 2018). Those studies indicate that meat quality of poulards significantly differs from meat of pullets slaughtered at the same age with respect to a majority of tested traits. Since production of poulards derived from pure lines of the above-mentioned hens was not cost-effective due to their slow growth rate and long rearing period (23 weeks) (Obrzut et al., 2018), in the next studies an attempt was made to use hybrids obtained by crossing these hens with Ross 308 broiler roosters for poulard production which is in line with global trends. Currently, production of high quality meat in extensive farming systems is based mostly on poultry of native breeds or their crosses with fast-growing lines (Yin et al., 2013; Sokołowicz et al., 2016).

Numerous studies on meat-type poultry indicate a significant effect of slaughter age on meat quality (Mikulski et al., 2011; Połtowicz and Doktor, 2012; Díaz et al., 2012). An important problem addressed by many research teams relates to appropriate balancing of feed mixtures for meat-type native breeds which have to be reared much longer than broiler chickens (Koenig et al., 2012; Guan et al., 2013; Baeza et al., 2013). In traditional feeding of poulards, ordinary farm feeds included milk and whey which influenced principally colour, tenderness and sensory scores of meat. Majewska et al. (2009), Alloui and Szczurek (2017) and Szczurek et al. (2013, 2018) indicated that whey could be used in feeding of meat-type poultry, however, Chinese have not used dairy products in poulard feeding (Cui et al., 2016 a).

The aim of the present studies was to evaluate the effect of feeding, i.e. the addition of dried whey or milk powder to experimental feed mixtures and slaughter age of poulards on productivity, dressing percentage, carcass colour and physicochemical properties of meat.

Material and methods

Bird management and diets

The experiment was performed in the period from May to September 2015. Spaying procedure of pullets was carried out at 8 weeks of age. Poulards were slaughtered at 18 and 20 weeks of age. The experimental procedures were compliant with requirements set by the Bioethics Committee No. 954 of 10th July 2012.

The studies were conducted on 78 hybrids obtained by crossing Ross 308 broiler roosters with dual-purpose Rhode Island Red (R-11) hens included in Poland in the genetic pool protection program (♂Ross 308 × ♀R-11). Eight-week-old pullets after spaying were allocated to the following groups:

Group (symbol)	Group K Control group	Group S Experimental group	Group M Experimental group
Number of poulards	26	26	26
Feeding	starter, grower, finisher*	starter, grower, finisher with 4% whey*	starter, grower, finisher with 4% milk powder*

* Finisher feed mixture in the form of granulate was offered to poulards for 3 weeks before slaughter.

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

Ingredient	Starter	Grower
Ground maize	15.00	18.00
Ground wheat	47.45	25.65
Ground triticale	10.00	25.00
Ground barley	–	10.00
Soybean meal	24.00	18.00
Ground limestone	1.25	1.25
Dicalcium phosphate	1.50	1.30
NaCl	0.30	0.30
Vitamin-mineral premix DKA-S (broiler starter) (0.5%)[1]	0.50	–
Vitamin-mineral premix DKA-G (broiler grower) (0.5%)[2]	–	0.50
Content in 1 kg:		
Crude protein (g)	192	170
Metabolizable energy (MJ)	11.8	11.9
(kcal)	2820	2840
Lys (g)	9.20	7.80
Met (g)	2.90	2.60
Ca (g)	8.70	8.10
P available (g)	4.10	3.65

[1]Provided the following per kilogram of starter diet: vitamin A (retinol) – 4.05 mg; vitamin D_3 (cholecalciferol) – 0.0875 mg; vitamin E (alpha-tocopherol) – 45 mg; vitamin K_3 (menadione) – 3 mg; vitamin B_1 (thiamine) – 3.25 mg; vitamin B_2 (riboflavin) – 7.5 mg; vitamin B_6 (pyridoxine) – 5 mg; vitamin B_{12} (cyanocobalamin) – 0.0325 mg; biotin – 0.15 mg; Ca-pantothenate – 15 mg; niacin – 45 mg; folic acid – 1.5 mg; choline chloride – 600 mg; Mn ($MnSO_4$) – 100 mg; Zn (ZnO) – 75 mg; Fe ($FeSO_4$) – 67.5 mg; Cu ($CuSO_4$) – 17.5 mg; I (KI) – 1 mg; and Se (Na_2SeO_3) – 0.275 mg.

[2]Provided the following per kilogram of diet: vitamin A (retinol) – 3.6 mg; vitamin D_3 (cholecalciferol) – 0.8125 mg; vitamin E (alpha-tocopherol) – 40 mg; vitamin K_3 (menadione) – 2.25 mg; vitamin B_1 (thiamine) – 2 mg; vitamin B_2 (riboflavin) – 7.25 mg; vitamin B_6 (pyridoxine) – 4.25 mg; vitamin B_{12} (cyanocobalamin) – 0.03 mg; biotin – 0.1 mg; Ca-pantothenate – 12 mg; niacin – 40 mg; folic acid – 1.0 mg; choline chloride – 450 mg; Mn ($MnSO_4$) – 100 mg; Zn (ZnO) – 65 mg; Fe ($FeSO_4$) – 65 mg; Cu ($CuSO_4$) – 15 mg; I (KI) – 0.8 mg; and Se (Na_2SeO_3) – 0.25 mg.

Stocking density was 5 birds/m^2 of floor area, average house temperature ranged from 15 to 26°C, with relative humidity of 60–70%.

Depending on the age of slaughter till the 15th or 18th week of age, all pullets and poulards were fed *ad libitum* on the same complete starter and grower diets with the same nutrient content as used in our previous study (Obrzut et al., 2018), the composition of which is presented in Table 1. Three weeks before slaughter, poulards were offered a complete finisher feed mixture supplemented with 4% whey (group S) or milk powder (group M). Its composition is presented in Table 2. The control group (K) was fed a finisher feed without the addition of dairy products.

Table 2. Ingredient composition and nutritive value of the diets (kg/100 kg) – finisher

Ingredient	Group K (control)	Group S (whey powder)	Group M (milk powder)
Ground maize	25.00	39.00	27.00
Ground wheat	25.20	18.35	24.90
Ground triticale	21.00	10.00	18.00
Ground barley	10.00	9.00	10.00
Soybean meal	15.50	16.50	13.00
Whey powder (12.2% protein, 1.0% fat)	–	4.00	–
Milk powder (32.7% protein, 3.0% fat)	–	–	4.00
Ground limestone	1.25	1.20	1.20
Dicalcium phosphate	1.25	1.15	1.10
NaCl	0.30	0.30	0.30
Vitamin-mineral premix DKA-F (broiler finisher) (0.5%)[1]	0.50	0.50	0.50
Content in 1 kg:			
Crude protein (g)		160	
Metabolizable energy (MJ)		12.1	
(kcal)		2880	
Lys (g)		7.20	
Met (g)		2.60	
Ca (g)		7.90	
P available (g)		3.50	

K – control group, S – experimental group fed a finisher feed mixture supplemented with 4% whey powder for 3 weeks before slaughter, M – experimental group fed a finisher feed mixture supplemented with 4% milk powder for 3 weeks before slaughter.

[1]Provided the following per kilogram of diet: vitamin A (retinol) – 3.6 mg; vitamin D_3 (cholecalciferol) – 0.8125 mg; vitamin E (alpha-tocopherol) – 40 mg; vitamin K_3 (menadione) – 2.25 mg; vitamin B_1 (thiamine) – 2 mg; vitamin B_2 (riboflavin) – 7.25 mg; vitamin B_6 (pyridoxine) – 4.25 mg; vitamin B_{12} (cyanocobalamin) – 0.03 mg; biotin – 0.1 mg; Ca-pantothenate – 12 mg; niacin – 40 mg; folic acid – 1.0 mg; choline chloride – 450 mg; Mn ($MnSO_4$) – 100 mg; Zn (ZnO) – 65 mg; Fe ($FeSO_4$) – 65 mg; Cu ($CuSO_4$) – 15 mg; I (KI) – 0.8 mg; and Se (Na_2SeO_3) – 0.25 mg.

Collection of samples

Data concerning body weight gains and feed intake were collected over the course of the experiment. After completion of experiment (18th or 20th week), 6 birds were selected out of each group, with body weight similar to the mean of the group. An additional poulard selection criterion included having a comb much smaller than in hens. Before slaughter, the chickens were subjected to 12-hour starvation, though provided with continuous water access in this period. The birds were weighed before the slaughter, slaughtered, and then pH was measured 15 minutes after the slaughter (breast – *pectoralis major* muscle and thigh – *biceps femoris* muscle). The whole bird was weighed again after gutting, and then cooled at a temperature of 4°C. After 24 hours of cooling, the whole birds were subjected to a simplified slaughter analysis according to Ziołecki and Doruchowski (1989) methods, after specifying their colour first (whole bird with skin) and pH_{24}. Next, samples of the breast muscle (*pectoralis major)* and the leg muscles – thigh (*biceps femoris*) were collected from each whole bird to determine their colour, water absorption, meat juice leakage, thermal losses and tenderness. A chemical and sensory analysis of these muscles was also performed.

Analytical methods

pH measurement

The measurement of the pH of the breast muscles (*pectoralis major*) and the leg muscles – thigh (*biceps femoris*) was performed using the Cyber Scan 110 pH meter (Eutech Instruments Pte Ltd/Oakton Instruments with Hamilton glass electrode, calibration at pH 4.0 and 7.0).

Colour measurement

The colour of the whole bird was specified according to the L*a*b* scale (CIE, 2007) using a Minolta CR 310 (Konica Minolta Holdings, Inc., Japan; light source D65, observer 2^{o}), reflective spectrophotometer, where L* means brightness, a positive a* value means colour saturation towards red, and a positive b* value means colour saturation towards yellow. Carcass colour is the mean of five whole bird measurements (1 measurement from the dorsal part, 2 measurements from the thoracic part, 2 measurements from the thigh part of the legs), while the muscle colour is the mean of 2 measurements of the breast muscle (*pectoralis major* muscle) and 2 femoral muscle measurements (*biceps femoris* muscle) taken on the inner surface immediately after bone separation.

Water holding capacity (WHC) measurement

WHC of breast muscles (*pectoralis major*) and leg muscles – thigh (*biceps femoris*) were determined using the Grau and Hamm's method (1953), based on the amount of juice mechanically pressed from the sample onto a filter paper (Whatman, 1 Qualitative, Cat No 1001 917, UK Limited), and the leakage area was estimated using a planimeter (Haff Digital Polar Planimeter No. 301, Germany).

Drip and cook loss determination

The meat juice leakage was determined after storing the samples of breast muscles (*pectoralis major)* and thigh muscles (*biceps femoris*) for 24 hours at +4°C. In order to do this, 80 g meat samples were collected from the thigh and the pectoral muscle which were then placed in tightly sealed containers and stored in a refrigerator. Next, the samples were weighed and the leak was calculated according to the formula:

$$\textit{drip loss (\%)} = \frac{\textit{sample weight before refrigeration (g) – sample weight after refrigeration (g)}}{\textit{sample weight before refrigeration (g)}} \times 100$$

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. The samples were weighed and the thermal losses were calculated according to the formula:

$$\textit{cooking loss (\%)} = \frac{\textit{sample weight before cooking (g) – sample weight after cooking (g)}}{\textit{sample weight before cooking (g)}} \times 100$$

Shear value determination

The measurement of muscle tenderness was performed using the TA.XT.plus texture analyser (Stable Micro Systems Ltd, Godalming, Surrey, GU71YU, UK). In order to do this, 10 mm in diameter and 30 mm in height samples were cut out from the cooked breast (*pectoralis major* muscle) and thigh muscle (*biceps femoris* muscle) (85°C). The collected sample was cut with a Warner-Bratzler knife (velocity 2 mms^{-1}) in three places, perpendicularly to the course of muscle fibres, while the final measurement result was provided as a mean value.

Chemical analyses

Samples of breast (*pectoralis major* muscle*)* and thigh (*biceps femoris* muscle) were collected from birds of each group in order to determine the chemical composition, i.e. the contents of total dry matter, total protein (Kjeldahl method) and crude fat (Soxhlet method) using the AOAC method (2000). Cholesterol content was determined using gas chromatography (Shimadzu GC-2010 Plus). Chemical analyses were performed at the Central Laboratory of the Institute.

Sensory evaluation

The study also included sensory evaluation of breast muscles (*pectoralis major*) and thigh muscles (*biceps femoris*), according to the methodical assumptions of Baryłko-Pikielna and Matuszewska (2009). The sensory evaluation test was carried out on meat samples cooked without salt or spices to an internal temperature of 80°C. After cooking, the muscle samples were cut into 1 × 2 cm pieces, protected with aluminium foil, and marked with an identification number. Next, the samples were served for tasting to a sensory panel consisting of 10 people. The team of people included experienced and specially trained employees of the Institute. The following parameters were taken into account in the evaluation: smell, juiciness, tenderness and taste. A 5-point scale from 1 to 5 points (with an accuracy of 0.5 points) was used, with a rating of 5 being the best, and 1 being the worst. Panelists were also asked to provide comments or notes on the evaluated samples.

Statistical analysis

The obtained results were verified statistically, and the significance of differences was specified using single- or two-factorial analysis of variance (feed × age) and Duncan's test (Statistica 12.0). The statistical analysis involved the determination of arithmetic means (x), the coefficient of variation (v%) and standard deviation (SD) or standard error of the mean (SEM) for the traits analysed in the study.

Results

Feed mixtures used for feeding poulards were balanced, and the levels of all components were appropriate for birds' age (Tables 1 and 2).

Pullets and poulards showed satisfactory growth performance, and no birds died after spaying procedure. Pullets obtained by crossing dual purpose laying hens of R-11 line with Ross 308 broiler roosters attained high body weight already at 18 weeks of age (Table 3). Poulards from the control group (K) reached a lower body weight compared with experimental groups (M and S) at both 18 weeks and 20 weeks of age ($P \leq 0.01$). Body weight gain of poulards from 18 to 20 weeks of age was high in all groups ($P \leq 0.01$) and amounted to 437 g in group S, 213 g in group M and 326 g in control group (K). A relatively high coefficient of variation was noted in all groups.

Table 3. Feed conversion (x) and body weight (x±SD) of poulards

Group	Feed conversion (kg/1 kg b.w. gain)		Body weight (g)		Significance of differences in body weight between 18 and 20 weeks old poulards
	0–18 weeks	0–20 weeks	18th week (x±SD)	20th week (x±SD)	
K – control	3.70	3.91	3045±301 A	3371±331 A	**
S – whey powder	3.26	3.31	3425±313 B	3862±350 B	**
M – milk powder	3.28	3.49	3483±272 B	3696±493 B	*

**– highly significant differences ($P \leq 0.01$).
*– significant differences ($P \leq 0.05$) between poulard age groups K, S, M.
A, B in columns denote highly significant differences ($P \leq 0.01$) between groups K, S, M.

The highest feed conversion was seen in the control group (K) at both 18 and 20 weeks of age (Table 3). The lowest feed conversion per kg of body weight gain was noted in poulards fed on the diet with whey supplement (group S).

No statistically significant differences were observed in carcass colour lightness (L*) and redness (a*) between all three groups (K, M, S) (Table 4). On the other hand, among poulards slaughtered at 20 weeks of age, yellowness (b*) was lower in group M ($P \leq 0.05$).

Differences in such traits as: carcass weight loss during chilling, dressing percentage, and pectotral and thigh muscle percentage were slight and statistically non-significant, both between groups K, S and M, and between poulards slaughtered at 18 and 20 weeks of age (Table 4). Only giblet percentage was significantly lower in carcasses of older poulards ($P \leq 0.05$) (Table 4) while group S showed a greater leg bone percentage ($P \leq 0.05$) compared to groups K and M. Abdominal fat was at a similar level both among groups K, S and M and between 18- and 20-week-old poulards, and the statistical calculations revealed that this trait was significantly affected by both factors at the same time.

Table 4. Carcass colour, weight loss during chilling and dressing percentage of poulards

Item	Group symbol (A)			Slaughter age (week) (B)		A × B						SEM	Effect		
	K	S	M	18	20	K18	K20	S18	S20	M18	M20		A	B	A × B
Carcass colour:															
a*	72.5	73.1	72.7	71.5	74.0	71.5	73.6	71.5	74.7	71.6	73.8	0.353	NS	**	NS
b*	2.54	2.31	2.90	2.82	2.35	3.09	1.98	2.53	2.10	2.83	2.97	0.144	NS	NS	NS
L*	12.7 b	11.2 ab	10.5 a	12.4	10.6	12.68	12.66	13.41	9.07	11.03	10.04	0.437	*	*	*
Carcass weight loss during chilling (%)	1.54	1.93	1.67	1.74	1.68	1.66	1.37	1.87	2.02	1.68	1.66	0.073	NS	NS	NS
Dressing percentage without giblets (%)	77.5	75.3	77.5	77.10	76.41	78.31	76.72	75.50	75.10	77.52	77.43	34.8	NS	NS	NS
Proportion of:															
breast muscles (%)	22.9	21.5	23.9	23.6	21.9	23.37	22.46	23.27	19.84	24.26	23.54	0.866	NS	NS	NS
leg muscles (%)	18.9	19.7	20.0	19.5	19.6	18.74	19.17	19.66	19.76	19.97	19.99	0.257	NS	NS	NS
giblets (%)	3.30	3.45	3.19	3.51	3.10	3.10	3.50	3.80	3.09	3.64	2.73	0.113	NS	*	*
leg bones (%)	3.82 ab	3.95 b	3.46 a	3.66	3.82	3.50	4.14	3.97	3.93	3.51	3.40	0.092	*	NS	NS
abdominal fat (%)	3.13	3.30	3.38	3.36	3.19	3.61	2.66	3.42	3.18	3.05	3.72	0.131	NS	NS	*

K – control group, S – experimental group fed a finisher feed mixture supplemented with 4% whey powder for 3 weeks before slaughter, M – experimental group fed a finisher feed mixture supplemented with 4% milk powder for 3 weeks before slaughter; K18 – control group in 18 week, K20 – control group at 20 weeks, S18 – experimental group fed whey powder at 18 weeks, S20 – experimental group fed whey powder at 20 weeks, M18 – experimental group fed with milk powder at 18 weeks, M20 – experimental group fed with milk powder at 20 weeks.

**– highly significant differences ($P \leq 0.01$).

*– significant differences ($P \leq 0.05$).

NS – not significant in tested traits.

Lower case letters in rows – significant differences ($P \leq 0.05$) between groups K, S, M.

Table 5. Physical features of poulardes breast muscles (*m. pectoralis major*)

Item	Group symbol (A)			Slaughter age (week) (B)		A × B						SEM	Effect		
	K	S	M	18	20	K18	K20	S18	S20	M18	M20		A	B	A × B
pH_{15min}	6.41	6.43	6.56	6.55	6.38	6.50	6.31	6.55	6.32	6.59	6.52	0.035	NS	*	NS
pH_{24h}	5.91	5.88	5.89	6.10	5.68	6.13	5.68	6.07	5.69	6.11	5.68	0.040	NS	**	NS
Drip loss after 24 h (%)	0.94	1.04	0.97	0.66	1.31	0.72	1.15	0.74	1.33	0.51	1.45	0.092	NS	**	NS
Thermal loss (%)	24.1	21.8	24.4	22.2	24.6	23.2	24.9	19.4	24.1	24.1	24.8	0.749	NS	NS	NS
WHC (%)	18.2	18.4	18.4	20.5	16.2	20.8	15.6	19.7	17.1	21.0	15.8	0.440	NS	**	NS
Shear force (N)	16.6 ab	19.0 b	15.4 a	17.7	16.3	17.3	15.9	20.1	17.8	15.6	15.1	0.662	*	NS	NS
Colour:															
L*	60.0	62.4	58.1	60.6	59.8	58.8	61.2	62.9	61.9	60.1	56.2	1.026	NS	NS	NS
a*	11.6	9.6	10.3	10.6	10.4	11.9	11.1	8.92	10.4	10.8	9.83	0.416	NS	NS	NS
b*	8.93 ab	10.1 b	8.80 a	9.87	8.71	8.4	9.47	11.5	8.74	9.70	7.91	0.321	*	*	*

K – control group, S – experimental group fed a finisher feed mixture supplemented with 4% whey powder for 3 weeks before slaughter, M – experimental group fed a finisher fed mixture supplemented with 4% milk powder for 3 weeks before slaughter; K18 – control group at 18 weeks, K20 – control group at 20 weeks, S18 – experimental group fed whey powder at 18 weeks, S20 – experimental group fed whey powder at 20 weeks, M18 – experimental group fed with milk powder at 18 weeks, M20 – experimental group fed with milk powder at 20 weeks.

**– highly significant differences (P≤0.01).

*– significant differences (P≤0.05).

NS – not significant in tested traits.

Lower case letters in rows – significant differences (P≤0.05) between groups K, S, M.

Table 6. Physical features of poulards thigh (*m. biceps femoris*)

Item	Group symbol (A)			Slaughter age (weeks) (B)		A × B						SEM	Effect		
	K	S	M	18	20	K18	K20	S18	S20	M18	M20		A	B	A × B
pH_{15min}	6.61	6.50	6.53	6.66	6.44	6.69	6.52	6.66	6.35	6.62	6.44	0.033	NS	**	NS
pH_{24h}	6.35	6.24	6.28	6.46	6.12	6.58	6.12	6.39	6.08	6.39	6.16	0.044	NS	**	NS
Drip loss after 24 h (%)	0.57	0.64	0.51	0.49	0.65	0.43	0.71	0.60	0.67	0.45	0.58	0.040	NS	*	NS
Thermal loss (%)	35.4	37.2	36.4	36.6	36.0	35.8	34.9	37.1	37.4	37.0	35.8	0.426	NS	NS	NS
WHC (%)	18.6 b	17.9 a	18.8 b	20.7	16.3	20.8	16.4	20.4	15.5	20.7	16.9	0.429	*	**	NS
Shear force (N)	25.8 a	30.3 b	28.7 ab	26.1	30.3	23.7	27.9	28.0	32.6	26.7	30.6	0.904	*	*	NS
Colour:															
L*	48.0	48.2	47.4	48.2	47.6	48.5	47.6	51.1	45.3	44.9	49.9	0.924	NS	NS	NS
a*	16.4	16.3	16.5	16.4	16.5	16.5	16.3	15.7	17.0	17.1	16.0	0.490	NS	NS	NS
b*	7.57	8.26	7.56	7.92	7.67	7.38	7.76	9.15	7.37	7.22	7.89	0.202	NS	NS	*

K – control group, S – experimental group fed a finisher feed mixture supplemented with 4% whey powder for 3 weeks before slaughter, M – experimental group fed a finisher feed mixture supplemented with 4% milk powder for 3 weeks before slaughter; K18 – control group at 18 weeks, K20 – control group at 20 weeks, S18 – experimental group fed whey powder at 18 weeks, S20 – experimental group fed whey powder at 20 weeks, M18 – experimental group fed with milk powder at 18 weeks, M20 – experimental group fed with milk powder at 20 weeks.

**– highly significant differences ($P \leq 0.01$).

*– significant differences ($P \leq 0.05$).

NS – not significant in tested traits.

Lower case letters in rows – significant differences ($P \leq 0.05$) between groups K, S, M.

Table 7. Chemical composition of breast (*m. pectoralis major*) and thigh (*m. biceps femoris*) muscles of poulards

Item	Groups (A)			Slaughter age (weeks) (B)		A × B						SEM	Significance		
	K	S	M	18	20	K18	K20	S18	S20	M18	M20		A	B	A × B
Breast muscle (*m. pectoralis major*)															
Dry matter (%)	26.1	26.4	26.3	26.1	26.4	25.9	26.2	26.4	26.4	26.1	26.6	0.089	NS	NS	NS
Crude protein (%)	24.7	24.8	24.8	24.8	24.8	24.7	24.6	24.8	24.3	24.8	24.9	0.066	NS	NS	NS
Crude fat (%)	1.52	1.56	1.69	1.51	1.67	1.47	1.56	1.62	1.48	1.43	1.95	0.058	NS	NS	*
Cholesterol (g/kg)	0.55	0.54	0.54	0.58	0.51	0.59	0.51	0.62	0.48	0.55	0.53	0.010	NS	**	*
Thigh muscle (*m. biceps femoris*)															
Dry matter (%)	27.2	26.6	26.9	26.8	26.9	27.3	27.1	27.0	26.1	26.2	27.5	0.220	NS	NS	NS
Crude protein (%)	20.5	20.9	20.7	20.8	20.6	20.5	20.6	21.2	20.6	20.6	20.8	0.090	NS	NS	NS
Crude fat (%)	6.69	5.70	6.21	6.11	6.29	6.63	6.76	6.47	4.93	5.27	7.18	0.257	NS	NS	*
Cholesterol (g/kg)	0.88 Bb	0.81 Aa	0.85 b	0.92	0.77	0.94	0.81	0.90	0.72	0.92	0.78	0.017	**	**	NS

K – control group, S – experimental group fed a finisher feed mixture supplemented with 4% whey powder for 3 weeks before slaughter, M – experimental group fed a finisher feed mixture supplemented with 4% milk powder for 3 weeks before slaughter; K18 – control group at 18 weeks, K20 – control group at 20 weeks, S18 – experimental group fed whey powder at 18 weeks, S20 – experimental group fed whey powder at 20 weeks, M18 – experimental group fed with milk powder at 18 weeks, M20 – experimental group fed with milk powder at 20 weeks.

**– highly significant differences ($P \leq 0.01$).

*– significant differences ($P \leq 0.05$).

NS – not significant in tested traits.

Lower case letters in rows – significant differences ($P \leq 0.05$) between groups K, S, M.

Uppercase letters in rows – highly significant differences ($P \leq 0.01$) between groups K, S, M.

In experimental groups (K, S and M), acidity of pectoral and thigh muscles measured both 15 minutes after slaughter and after 24-hour chilling remained at similar level but poulard age had a significant effect on this trait (Tables 5 and 6). The $pH_{15\,min}$ and pH_{24h} values were lower in muscles of 20-week-old poulards compared with 18-week-old birds (P≤0.05 or P≤0.01). Such a relationship occurred in all three groups.

Table 8. The effect of poulard age and diet on sensory scores of meat

Group	Slaughter age (weeks)	Flavour			Juiciness			Tenderness			Taste		
		x	SD	V%	X	SD	V%	x	SD	V%	x	SD	V%
							Breast muscle (*m. pectoralis major*)						
K	18	4.02 A	0.36	8.97	4.06	0.42	10.20	4.16 a	0.54	13.06	4.07 a	0.52	12.70
	20	3.93 A	0.35	9.03	3.68 aA	0.39	10.72	3.95 A	0.51	12.89	3.70 aA	0.49	12.90
	Effect of age		NS			**			NS			*	
S	18	4.43 B	0.44	10.00	4.22	0.66	15.80	4.39 ab	0.60	13.59	4.32 ab	0.55	12.60
	20	4.59 B	0.37	7.97	4.20 bB	0.48	11.40	4.32 B	0.42	9.81	4.34 bB	0.39	8.98
	Effect of age		NS			NS			NS			NS	
M	18	4.50 B	0.49	10.80	4.32	0.55	12.6	4.57 b	0.52	11.35	4.39 b	0.48	11.10
	20	4.66 B	0.32	6.93	4.48 cB	0.36	8.06	4.73 C	0.33	7.09	4.61 cB	0.34	7.43
	Effect of age		NS			NS			NS			NS	
							Thigh muscle (*m. biceps femoris*)						
K	18	4.29	0.53	12.30	4.25 a	0.53	12.40	4.02 A	0.29	7.15	3.93 A	0.49	12.60
	20	4.09 A	0.37	8.95	3.93 A	0.23	5.94	4.14 a	0.47	11.30	4.20 a	0.45	10.80
	Effect of age		NS			*			NS			NS	
S	18	4.50	0.53	11.90	4.57 b	0.44	9.72	4.50 B	0.41	9.07	4.56 B	0.41	9.12
	20	4.50 B	0.44	9.70	4.36 B	0.49	11.28	4.23 ab	0.46	10.80	4.43 ab	0.42	9.40
	Effect of age		NS			NS			*			NS	
M	18	4.57	0.47	10.30	4.41 ab	0.57	12.90	4.64 B	0.41	8.92	4.63 B	0.44	9.51
	20	4.45 B	0.46	10.30	4.45 B	0.37	8.42	4.50 b	0.44	9.70	4.61 b	0.43	9.41
	Effect of age		NS			NS			NS			NS	

Sensory properties were scored according to 5-point scale in which 1 – the worst score, 5 – the best score. Significance of differences between groups K, M, S was marked with capital or lower case letters, separately for leg and breast meat and separately for poulards slaughtered at 18 weeks of age and 20 weeks of age.

**– highly significant differences (P≤0.01).

*– significant differences (P≤0.05).

NS – not significant in tested traits.

Lower case letters in rows – significant differences (P≤0.05) between groups K, S, M.

Uppercase letters in rows – highly significant differences (P≤0.01) between groups K, S, M.

In each group of poulards, drip loss after 24 hours from pectoral and thigh muscles of 20-week-old poulards was higher than that of 18-week-old birds ($P \leq 0.01$ or $P \leq 0.05$) (Tables 5 and 6).

Slaughter age of poulards did not affect heat loss of pectoral and thigh muscles (Tables 5 and 6). Water holding capacity (WHC) of pectoral and thigh muscles from 20-week-old poulards was lower compared with 18-week-old birds ($P \leq 0.01$). WHC of thigh muscles was reduced in group S vs. groups K and M ($P \leq 0.05$).

The most tender pectoral muscles were observed in group M while thigh muscles in group K ($P \leq 0.05$). There were no significant differences in tenderness of pectoral muscles between 18- and 20-week-old poulards (Table 5) but thigh muscles were significantly less tender at 20 than 18 weeks of age (Table 6).

No significant differences were noted in thigh and pectoral muscle colour both between young and old poulards and between groups K, M and S, except for yellowness (b^*) of pectoral muscles which was the highest in group S compared with group M and in poulards slaughtered at 18 than 20 weeks of age ($P \leq 0.05$).

Chemical composition of pectoral and leg muscles of poulards did not statistically significantly differ between groups, except for cholesterol level which was lower in pectoral and leg muscles of older compared with younger birds and in thigh muscles in group S ($P \leq 0.01$) (Table 7). Pectoral muscles of all poulards contained higher crude protein content and reduced crude fat content compared with their leg muscles.

Sensory analysis showed that breast and leg meat of birds fed on milk (M) or whey (S) supplemented feed, irrespective of age, was superior with respect to all quality scores compared with the control group (K) ($P \leq 0.01$ or $P \leq 0.05$), except for juiciness of breast meat and flavour of leg meat in 18-week-old poulards where differences were not confirmed by statistical analysis (Table 8). Breast meat of control poulards slaughtered at 20 weeks of age was given lower juiciness ($P \leq 0.01$) and taste ($P \leq 0.05$) scores compared with the meat of 18-week-old poulards. As for leg meat, in group S tenderness scores were higher for the meat of 18- than 20-week-old poulards. A similar relationship was observed in terms of juiciness in group K. No statistically significant impact of poulard age on the remaining sensory traits of breast and leg meat was seen.

Discussion

Satisfactory production performance observed for hybrids obtained by crossing dual purpose hens with broiler roosters (Krawczyk et al., 2018) and reduction of the rate of body weight gain after 18th week of age (Symeon et al., 2012; Obrzut et al., 2018) inspired us to carry out the studies presented in this article. The use of finisher feed mixture supplemented with whey or milk entails making use of a traditional Polish method of rearing poulards in which liquid whey and other dairy products were offered to birds at the final stage of rearing period in order to improve meat tenderness, colour and flavour. Protein from whey products is a source of amino acids indispensable for young birds and can have a beneficial effect on cellular oxidative processes, which protects the body against oxidative stress (Szczurek et al., 2013). Since liquid whey contains many valuable nutrients, it is also used for feeding calves and pigs. The use of whey products in poultry feeding as a source of lactose, albeit to a limited extent, is gaining interest due to a positive effect of whey on digestive processes in birds (Majewska et al., 2009; Szczurek et al., 2013). Alloui and Szczurek (2017) reported positive, prebiotic effect of dried whey, added to the diet at a 3% level as lactose source, on performance indices of broiler chickens. In their subsequent experiment such effect on growth performance was not confirmed, however in chickens fed diet supplemented with dried whey beneficial changes in some physiological indices of alimentary tract were observed (Szczurek et al., 2018).

The problem of correct balancing of feed mixtures for chickens of meat-type native breeds, reared much longer that broiler chickens, has been investigated by many research teams (Koenig et al., 2012; Guan et al., 2013; Baeza et al., 2013). The main aim of those studies is to develop feed mixtures which provide for optimal feed conversion and satisfactory body weight gain of birds with concomitant reduction of excessive fat content and supplying the meat with desired sensory values, which will also meet expectations of producers of poulards.

In the present studies, feed mixtures with a 4% whey or milk supplement were distinguished by a better caloric value than those offered to birds in our first experiments with poulards (Obrzut et al., 2018; Krawczyk et al., 2018) which could contribute to improvement of feeding efficiency. Moreover, body weight gain in poulards fed milk- or whey-supplemented mixtures (group M and S) was much higher and carcasses had a greater muscle percentage than in the control group. Also studies of Chen et al. (2007) on Chinese native chicken breeds demonstrated better body weight gains and muscle content in birds fed the mixtures characterized by a higher caloric value. On the other hand, Zhu et al. (2012) obtained the best body weight gains in Chinese native breeds of chickens reared for 65 days, in the group fed the diet having the highest protein content but a lower caloric value. Slightly different results were obtained by Koenig et al (2012) in the studies on production performance of laying-type cockerels reared only for 49 days. In that experiment, cockerels receiving a finisher diet containing less protein showed lower body weight gains and greater feed consumption per bird.

The addition of 4% milk or whey to the finisher diet, applied in the present study, did not cause significant differences in a majority of the tested physicochemical properties of meat. The experiment did not confirm the expectation that whey and milk supplement will improve colour lightness (L*) of carcasses and meat. Slight, and smaller than expected, changes were also noted in meat tenderness. Pectoral muscles from group M poulards proved to be most tender but the most tender thigh muscles were observed in the group offered the mixture without milk or whey. A positive effect of whey or milk addition in the final growth stage of poulards was also expressed by reduced cholesterol level in leg muscles vs. control group. There are no reports in the literature dealing with the impact of the above-described feeding method on physicochemical properties of meat of slow-growing chickens or capons. Studies on the use of whey in bird feeding are limited to broiler chickens and to the effect of different levels of this product in feed mixtures on changes in the digestive tract and body weight gains (Majewska et al., 2009; Szczurek et al., 2013; Alloui and Szczurek, 2017; Szczurek et al., 2018).

Slaughter age is also an important determinant of meat quality which was confirmed as well by the present studies as by other foreign and Polish studies (Mikulski et al., 2011; Połtowicz and Doktor, 2012; Díaz et al., 2012). However, the pattern of age-dependent changes in meat quality of poulards differs from that in young chickens from intensive farming systems. At a slight increase in feed conversion of ca. 0.20 g per kg of body weight gain, body weight of poulards rose by ca. 10% in the period from 18th to 20th week of age, and the obtained results are in agreement with those reported by Díaz et al. (2012). However, there were no significant differences in dressing percentage of carcasses of 18- and 20-week-old poulards while in broiler chickens and slow-growing chickens, dressing percentage markedly increased with age (Northcutt et al., 2001; Lichovníková et al., 2009; Połtowicz and Doktor, 2012). Lichovníková et al. (2009) evaluated changes in carcass and meat quality of Isa Brown laying hens and Ross 308 broiler chickens and noted an increase in pectoral and thigh muscle percentage in older birds but it was much smaller in laying hens than in meat-type birds. Also studies by Murawska et al. (2005) confirmed different contribution of muscles in carcasses of laying hens and broiler chickens. These studies suggest that in laying hens, pectoral muscle percentage in carcass decreases with age but leg muscle percentage slightly rises.

The pH_{15min} and pH_{24h} measurements showed a higher acidity of muscles of 20-week-old poulards vs. 18-week-old birds. Similar effect of age on acidity was demonstrated in studies by Pudyszak et al. (2005) on guinea fowls, while Połtowicz and Doktor (2012) observed this relationship in broiler chickens only when pH measurements were conducted 15 min post-slaughter.

Water holding capacity of pectoral and leg muscles was significantly reduced in older poulards compared with younger ones and the same observation was made by Połtowicz and Doktor (2012) in broiler chickens. Drip loss from meat after 24-hour chilling was greater in older poulards vs. younger birds and these results are congruent with data obtained in laying hens (Lichovníková et al., 2009).

No significant differences were noted in meat colour, except for yellowness (b*) of pectoral muscles; however, it appears that the difference in slaughter age of poulards was too small for such analysis because according to studies by Lichovníková et al. (2009) in hens slaughtered at 49 and 90 days of age, these differences in yellowness were highly statistically significant. Greater differences in meat colour between 14- and 34-day-old poulards were also noted by Guo et al. (2017). Moreover, in Chinese poulards, independently of slaughter age, colour lightness was reduced while yellowness was increased compared with the present studies.

Leg meat of older poulards in our studies was less tender vs. young birds, and such relationship was observed in a majority of studies exploring this subject (Northcutt et al., 2001; Połtowicz and Doktor, 2012).

Tougan et al. (2013) investigated chemical composition of meat of broiler chickens of African native breeds and found that meat of 28-day-old birds contained more crude fat and less crude protein in comparison with 20-week-old birds. In the present studies, poulard age did not significantly affect chemical composition of meat, except for cholesterol, but much higher content of protein than in broiler chicken meat was notable, and comparable with capons (Calik et al., 2017) and guinea fowls (Pudyszak et al., 2005).

Palatability of meat depends on contribution of taste and flavour but carcass appearance is also important before purchase. Poulards are an exclusive product which in Western European large multiples is most often sold with heads, like capons, because the lack of developed comb confirms product authenticity. Literature data indicate that sensory quality of meat significantly depends on physiological maturity, thus, the meat of longer reared chickens is scored higher than meat of young broiler chickens (Touraille et al., 1981; Lichovníková et al., 2009). The authors of those studies on young broiler chicken meat underlined that tenderness and colour of meat deteriorated with age but palatability rose. The results of our studies in 18- and 20-week-old poulards did not confirm this relationship. All sensory scores of breast and leg meat of poulards fed whey- or milk-supplemented feed mixtures were higher compared with the control group. Moreover, coefficients of variation for particular traits were high which suggests wide divergence in scoring between panelists. Based on the obtained results, it can be concluded that apart from commonly known feed additives improving palatability of meat (herbs, tocopherols, etc.), whey and milk also fulfil this role.

Conclusion

The present studies demonstrated that by using hybrids obtained by crossing dual-purpose hens and broiler roosters for production of poulards, rearing period can be shortened to 18 weeks without compromising or even improving meat quality traits compared with poulards slaughtered at 20 weeks of age.

Poulard diet supplementation with 4% whey or milk powder at the final stage of growth, had a beneficial effect on improvement of sensory properties of meat with not many significant differences in meat quality between poulards fed milk- and whey-supplemented feed mixtures, but instead there were differences between these groups and the control group receiving unsupplemented diet.

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