Ann. Anim. Sci., Vol. 16, No. 4 (2016) 1227–1239 DOI: 10.1515/aoas-2016-0049

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THE EFFECTS OF STRAIN AND CAPONISATION ON CARCASS AND MEAT TRAITS OF COCKERELS AGED TWENTY WEEKS*

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Abstract

The analysis of slaughter yield and meat quality was performed on a total number of 96 birds from four medium-heavy weight pedigree strains. Based on their strain, cockerels were divided into the following groups: group I – strain N88 (originating from New Hampshire), group II – strain R55 (Rhode Island Red), group III – strain S11 (Sussex) and group IV – strain P55 (Plymouth Rock). Each group consisted of 24 birds. At 12 weeks of age, half of the cockerels from each group was caponised. In total, 48 birds were caponised (12 birds in each strain). Based on the strain, capons were then divided into groups V (N88), VI (R55), VII (S11) and VIII (P55). It was noted that the strain and caponisation had influence on differences in such traits as the weight of eviscerated carcass with neck and slaughter yield. On the other hand, it was observed that caponisation did not affect significantly the total weight, percentage share of breast and drumstick muscles in carcasses of birds from analysed strains. No significant differences were observed between groups in terms of physicochemical properties of meat. The highest content of water in breast and drumstick muscles was observed among cockerels and capons from strain N88 (groups I and V). Protein content in cockerels' breast muscles differed depending on their strain whilst among capons (groups V–VIII) it was similar. It was also noted that capons originating from strains S11 (VII) and P55 (VIII) stood out significantly with higher fat content in breast muscles compared to cockerels from the same strain (groups III and IV). The effect of caponisation on higher fat content in drumstick muscles was confirmed in all observed groups. Capons from all strains had more fat in drumstick muscles compared to cockerels of the same origin.

Key words: cockerel, capon, caponisation, slaughter yield, meat quality

Recently in Poland, the production of bird livestock has been developing dynamically. In 2013 Poland produced 1,849 thousand tonnes of chicken meat. The majority is meat from broilers, which is over 72% of the total production (Wencek

*This study was funded from statutory activity.

et al., 2014). At the same time, considering such a high production and the unlimited access to fresh chicken meat, consumer market is looking for niche products. They are considered exclusive and are distinguished by very high quality. Capon meat may be considered such a product due to its delicate meat, overgrown with adipose tissue. It is also of very high taste quality (Calik 2014 a, b; Kasperek et al., 2014; Zawacka et al., 2014; Adamski et al., 2016). In Poland it is a product which, despite entrenched culinary traditions, is not very popular and rather forgotten, and is also hard to find for the average consumer. The main reasons are a small number of producers engaged in capon production and the relatively high price which is a result of the production specification (Zawacka and Murawska, 2013).

In the process of obtaining laying hens in hatching 50% of the chicks are cockerels. They are not used for further breeding; instead they become fodder for carnivorous animals or they are utilised. It causes difficulties for hatcheries (Klein et al., 2003; Nandi et al., 2003). This is the main motivation for utilising these cockerels in capon production.

For this kind of production medium-heavy weight cockerels originating from such strains as New Hampshire, Rhode Island Red, Sussex or Plymouth Rock are particularly suitable. Selected lines or crossbreds from these strains are one of the most popular in the country considering the number of utilised birds.

Comparing slaughter yield and meat quality of cockerels and capons depending on the origin, age, breeding system and feeding was a subject of many studies (Chen et al., 2000; Tor et al., 2002; Sirri et al., 2009; Symeon et al., 2010; Rikimaru et al., 2011; Sinanoglou et al., 2011; Volk et al., 2011; Symeon et al., 2012; Calik 2014 a, b; Kasperek et al., 2014; Zawacka et al., 2014; Kwiecień et al., 2015; Adamski et al., 2016). The outcome of these studies proves that caponising significantly increases the content of fat in muscles which results in their tenderness. Considering the influence of caponisation on body weight, better musculature or physicochemical characteristics, observations of quoted authors are ambiguous. A crucial factor according to Shao et al. (2009) is the age in which castration is performed, as caponisation in the early weeks of breeding is more beneficial due to the highest survivability, better growth and quality of carcasses. So far no studies were conducted in domestic conditions on strains of different origins and the possibility of castrating them at different age. It was only demonstrated that suggestions on the age of terminating the breeding of cockerels and capons depending on their strain differ. For example, Diaz et al. (2010) suggested breeding capons until the age of twenty or thirty-two weeks, Chen et al. (2007 a) until the age of sixteen or twenty-six weeks, Calik (2014 a) until week twenty-four for Rhode Island Red capons, Kasperek et al. (2014) until weeks twenty-two to twenty-three for Greenleg Partridge, and Symeon et al. (2012) for capons from laying-type breeds suggested week thirty-four. Due to different strains and, as a result, a very different growth rate of cockerels originating from Polish reproductive laying-type breeds, in this study a rather late date of castration (week twelve) was chosen as well as a shorter period of breeding.

The main aim of this study was to compare slaughter yield and meat quality of cockerels and capons originating from four reproductive strains bred until week twenty.

Material and methods

Experimental birds

Experimental material was a total of 96 cockerels and capons from 4 pedigree strains coming from the State Pedigree Breeding Farm in Rszew, Poland. Cockerels were divided into identical groups based on their strain with 24 birds in each: I – strain N88 (New Hampshire), II – strain R55 (Rhode Island Red), III – strain S11 (Sussex) and IV – strain P55 (Plymouth Rock). At the 12th week of breeding a certified veterinarian caponised half of the cockerels. In total, 48 birds were caponised (12 from each strain). The very procedure as well as the performance were conducted in accordance with the Commission Regulation (EC) No 543/2008 (2008). Capons originating from strain N88 were assigned to group V, R55 to group VI, S11 to group VII and P55 to group VIII.

The breeding was conducted until the 20th week of age in regulated environment conditions on deep litter without access to a poultry yard. All environmental parameters were in accordance with recommendations (Technical Guidelines for Rosa Hens, 2010). At the beginning of breeding, birds were kept under a 24-hour lighting programme. On the 4th day of breeding, hours of darkness were gradually introduced, and then, at the 10th week of age, an 8-hour light day was gradually prolonged to 16 hours. Until the 7th week of breeding, birds were fed with a pelleted all-mash consisting of 19.0% of crude protein MJ ME in 1 kg of fodder. From week 9 to week 16 they were fed with a mash containing 15.0% of crude protein and 11.5 MJ ME per kg, and from week 16 with fodder containing 15.5% of crude protein and 11.3 MJ ME per kg. Throughout the breeding period, the birds were fed *ad libitum*, and had unlimited access to water. The birds were fed in accordance with recommendations (Nutrient Requirements of Poultry, 2005).

Carcass dissection and meat analysis

At the 20th week of breeding a dissection analysis of the entire carcass of cockerels and capons from each group was conducted according to the method of Ziołecki and Doruchowski (1989). Right after the slaughter, from a left breast superficial muscle of each bird, a sample was taken along the line of muscle fibres to indicate intramuscular fat. Every sample was individually frozen in liquid nitrogen in the temperature of –195.8°C. Afterwards, carcasses were plucked and 15 minutes after the slaughter, the pH_{15} indicator of breast muscles was measured. Before the dissection, and after 18 hours of cooling the carcasses (+4°C), the pH_{24} indicator of the breast muscles was measured once more. After that, the carcasses were gutted and the following elements were separated: giblets (heart, gizzard and liver) and inedible parts as well as the neck without skin, breast and drumstick muscles, skin with subcutaneous fat from the entire carcass, abdominal fat, wings and the remains of the carcass. Separated elements of carcass were weighed and the percentage share in the eviscerated carcass with neck was calculated.

After terminating the dissection, the colour of breast and drumstick muscles was evaluated. The colour measurement of both types of muscles in reflecting light was performed using CR 400 MINOLTA colorimeter in colour space L*, a*, b* (L* –

lightness, a* – redness, b* – yellowness). The water holding capacity of breast and drumstick muscles was also evaluated using a modified Grau and Hamm (1952) method. Chemical composition and collagen percentage share were measured in breast and drumstick muscles using a near-infrared transmission spectroscopy method. The device used for the measurement was FoodScan™ – an analyser for physicochemical properties of meat. The content of intramuscular fat was marked on a microscopic section stained with Oil Red. The number of intramuscular fat cells was defined using Zeiss Scope A1 AXIO microscope at magnification 0.5 × 20. The percentage share of intramuscular fat was defined using System for Image Processing and Analysis ZEN/2012 (2012).

Statistical analysis of the data

Using STATISTICA PL 10.0 (2011) software mean values ($\bar{x}$) and standard deviations (SD) of measured traits were calculated by subjecting them to one-way analysis of variance and significant difference evaluation using the Scheffe test.

Results

The body weight of cockerels (Table 1) was between 1650 g (N88) and 1900 g (S11); for capons it was between 1560 g (R55) and 2000 g (P55). Cockerels compared at the 20th week of breeding were characterised by similar weight of eviscerated carcass with neck (from 1045.6 g – N 88 to 1249.9 g – S 11). In the same evaluation period capons originating from strain P55 (group VIII) could be distinguished by the highest carcass weight (1321.8 g), which was significantly higher than the weight of carcasses of capons from strain R55 (group VI) and similar to the weight of carcasses of capons from strain N88 (group V) and S11 (group VII). Despite similar mean weight of eviscerated carcass with neck among observed cockerels, significant differences were observed between groups IV (P55) and II (R55) in terms of slaughter yield. Similar differences were noted between the capons from groups V (N88) and VI (R55).

The weight of wings and the remains of carcass (Table 1) between cockerels (groups I and IV) was similar (no statistically significant differences). However, capons from strain N88 (group V) could be distinguished by statistically significantly higher weight of wings and remains of carcass compared to capons R55 (group VI). Higher weight of remains of carcass was also observed among capons P55 (group VIII), which could be a result of a high mean weight of eviscerated carcass with neck among birds from this group. No significant differences were observed between groups of cockerels and capons considering these traits, which proves the lack of influence between caponisation and the weight of wings and remains of carcass. The weight and the percentage share of neck, as well as the weight of giblets did not differ statistically significantly between compared groups.

Table 1. Mean values ($\bar{x}$) and standard deviation (SD) of the body weight and slaughter traits in the 20th week of rearing in cockerels and capons

Group		Weight (g)			Trait weight and percentage share in carcass						Offal (g)			
		body before slaughter	eviscerated carcass with neck	slaughter yield (%)	wings		neck without skin		carcass remains		stomach	liver	heart	total
					(g)	(%)	(g)	(%)	(g)	(%)				
Cockerels														
I	x	1650.0 bc	1045.6 bc	63.2 ab	150.2 ab	14.5	63.3	6.0	344.0 ab	33.1	45.1	30.4	7.1	82.6
	SD	±201.4	±164.7	±4.2	±19.8	±1.2	±13.8	±0.6	±52.5	±3.1	±6.7	±4.8	±1.7	±10.5
II	x	1810.0 abc	1107.6 abc	61.1 b	152.1 ab	13.7	58.4	5.3	341.1 ab	30.8	49.9	38.5	8.6	96.9
	SD	±233.1	±163.9	±3.4	±22.1	±0.6	±8.8	±0.7	±65.9	±3.7	±7.7	±7.1	±1.5	±12.9
III	x	1900.0 ab	1249.9 ab	65.7 ab	164.2 ab	13.2	61.4	4.9	387.4 ab	31.1	52.6	34.9	8.6	96.1
	SD	± 81.6	±82.9	±2.1	±12.3	±0.8	±9.6	±0.8	±21.1	±1.9	±6.1	±3.6	±1.3	±6.8
IV	x	1720.0 abc	1155.8 abc	67.1 a	154.8 ab	13.4	64.7	5.6	364.8 ab	31.8	47.9	31.2	9.1	88.2
	SD	±131.7	±106.1	±1.3	±10.9	±0.9	±11.8	±0.8	±28.5	±3.8	±8.4	±5.3	±2.3	±12.2
Capons														
V	x	1930.0 ab	1295.9 ab	66.9 a	176.7 a	13.7	68.0	5.2	416.1 a	32.3	42.9	36.7	8.3	87.9
	SD	±182.9	±188.0	±3.8	±21.2	±0.9	±10.8	±0.7	±46.4	±2.6	±6.9	±4.2	±1.3	±10.1
VI	x	1560.0 c	969.4 c	62.0 b	138.4 b	14.3	51.3	5.4	314.7 b	32.6	44.5	31.3	7.7	83.5
	SD	±211.9	±152.9	±1.9	±22.6	±0.6	±6.5	±0.9	±45.7	±3.0	±6.9	±4.9	±2.1	±9.7
VII	x	1810.0 abc	1150.7 abc	63.6 ab	156.8 ab	13.6	60.8	5.3	367.5 ab	31.9	51.1	33.8	7.1	91.6
	SD	±119.7	±71.5	±1.5	±12.5	±0.9	±13.2	±1.2	±35.4	±2.8	±10.2	±3.6	±0.9	±11.8
VIII	x	2000.0 a	1321.8 a	65.9 ab	172.9 a	13.1	66.6	5.1	403.5 a	30.6	56.4	35.1	8.7	100.1
	SD	±235.7	±183.3	±2.6	±24.5	±0.8	±10.1	±1.1	±51.7	±1.1	±12.7	±4.9	±1.3	±15.3

a, b, c – mean values marked with different letters in columns differ significantly ($P \leq 0.05$).

Table 2. Mean values ($\bar{x}$) and standard deviation (SD) of the weight and share of muscles and skin with subcutaneous fat and abdominal fat in the 20th week of rearing in cockerels and capons

Group		Breast		Muscle legs		Trait weight and percentage share in eviscerated carcass with neck skin with subcutaneous						Skin with subcutaneous fat and abdominal fat	
						total		fat		abdominal fat			
		(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)
Cockerels													
I	x	135.1 c	12.8 b	256.3 ab	24.5	391.4 bc	37.3	91.5 b	8.6	5.3	0.5	96.8 b	9.1
	SD	±33.1	±1.8	±46.6	±2.2	±76.7	±3.4	±25.8	±1.2	±4.4	±0.4	±29.5	±1.4
II	x	175.4 abc	15.8 ab	271.4 ab	24.5	446.8 abc	40.2	103.3 ab	9.4	5.9	0.5	109.2 ab	9.9
	SD	±36.2	±1.7	±47.8	±1.9	±82.3	±3.4	±10.9	±0.9	±4.8	±0.4	±14.6	±0.9
III	x	193.4 ab	15.4 ab	315.4 a	25.2	508.8 ab	40.6	122.3 ab	9.8	5.9	0.5	128.2 ab	10.3
	SD	±32.7	±1.8	±31.4	±1.0	±60.4	±2.5	±19.7	±1.3	±4.3	±0.4	±20.6	±1.5
IV	x	168.2 abc	14.5 ab	281.6 ab	24.2	449.8 abc	38.7	111.1 ab	9.5	10.7	0.9	121.8 ab	10.4
	SD	±33.8	±2.1	±44.3	±2.1	±74.2	±3.8	±24.3	±1.6	±5.4	±0.4	±28.8	±1.9
Capons													
V	x	183.7 abc	14.1 ab	313.1 a	24.1	496.8 ab	38.1	125.5 ab	9.6	12.9	0.9	138.4 ab	10.6
	SD	±38.9	±1.6	±55.9	±1.7	±92.7	±2.9	±25.3	±0.8	±9.1	±0.6	±33.2	±1.2
VI	x	144.7 bc	14.9 ab	221.2 b	22.6	365.8 c	37.5	94.2 b	9.7	4.9	0.5	99.2 b	10.3
	SD	±29.7	±1.3	±53.4	±2.4	±79.7	±2.8	±14.3	±0.6	±4.2	±0.4	±14.3	±0.5
VII	x	176.7 abc	15.3 ab	270.1 ab	23.5	446.8 abc	38.8	107.4 ab	9.6	8.4	0.7	118.9 ab	10.3
	SD	±26.3	±1.9	±29.8	±2.1	±47.6	±3.1	±19.2	±1.3	±3.4	±0.3	±18.6	±1.3
VIII	x	213.4 a	16.2 a	313.4 a	23.7	526.8 a	39.9	135.8 a	10.2	16.3	1.2	152.0 a	11.3
	SD	±33.8	±1.5	±49.6	±1.3	±77.0	±1.6	±31.4	±1.2	±13.5	±0.9	±43.6	±1.9

a, b, c – mean values marked with different letters in columns differ significantly ($P \leq 0.05$).

Table 3. Mean values ($\bar{x}$) and standard deviations (SD) of physicochemical traits of the muscles in the 20th week of rearing in cockerels and capons

Group		Trait – muscles									
		pH		Breast				Leg			
				colour			water holding capacity	colour			water holding capacity
		15	24	L*	a*	b*	(%)	L*	a*	b*	(%)
Cockerels											
I	x	5.95	5.87	55.09	0.68	11.07	73.24	43.79	9.25	13.09	73.75
	SD	±0.18	±0.11	±6.67	±1.55	±2.02	±3.71	±4.42	±3.99	±2.97	±7.23
II	x	5.84	5.84	54.41	0.27	10.89	77.99	43.87	9.51	14.53	72.81
	SD	±0.27	±0.13	±3.43	±1.10	±1.04	±3.72	±6.59	±3.59	±1.32	±4.67
III	x	5.82	5.81	52.54	0.64	11.59	73.78	40.38	10.06	14.77	69.89
	SD	±0.13	±0.10	±3.43	±1.21	±1.61	±4.97	±2.27	±1.52	±2.03	±2.86
IV	x	5.91	5.88	53.69	0.45	11.16	77.51	39.52	10.23	14.08	71.92
	SD	±0.17	±0.14	±5.06	±1.29	±2.17	±3.35	±4.02	±1.88	±2.80	±2.23
Capons											
V	x	5.93	5.91	52.38	–0.23	10.62	77.28	40.27	8.93	14.09	70.82
	SD	±0.14	±0.18	±3.69	±0.72	±0.97	±3.35	±3.74	±2.28	±1.65	±2.05
VI	x	5.87	5.87	50.06	1.29	9.79	72.75	40.59	9.64	14.93	70.56
	SD	±0.10	±0.14	±5.02	±3.74	±1.90	±3.18	±2.31	±1.92	±1.96	±3.80
VII	x	5.97	5.77	52.54	0.62	10.84	77.03	41.25	9.45	14.67	73.76
	SD	±0.20	±0.14	±3.35	±1.28	±1.95	±4.19	±4.22	±3.17	±1.35	±4.18
VIII	x	5.85	5.83	51.93	- 0.60	9.01	77.61	40.10	9.27	12.88	69.45
	SD	±0.08	±0.12	±2.70	±1.17	±1.69	±4.29	±2.73	±3.62	±1.58	±2.54

* – no significant differences were found ($P \leq 0.05$).

Table 4. Mean values ($\bar{x}$) and standard deviations (SD) of the chemical composition of the muscles in the 20th week of rearing in cockerels and capons

Group		Trait content in muscles (%)							
		Breast				Leg			
		water	protein	fat	collagen	water	protein	fat	collagen
Cockerels									
I	x	76.5 a	21.9 e	1.6 b	1.0 a	75.3 a	19.8 e	4.5 d	1.6 ab
	SD	±0.2	±0.2	±0.1	±0.1	±0.3	±0.1	±0.1	±0.1
II	x	75.2 cd	23.3 b	1.4 cd	0.9 ab	73.8 c	19.8 e	5.1 c	1.7 a
	SD	±0.1	±0.1	±0.1	±0.1	±0.1	±0.2	±0.2	±0.1
III	x	75.4 bc	22.9 c	1.6 bc	0.9 ab	73.7 c	20.3 cd	5.2 bc	1.6 ab
	SD	±0.1	±0.1	±0.1	±0.1	±0.2	±0.1	±0.1	±0.1
IV	x	74.9 de	23.7 a	1.6 bc	0.8 b	74.3 b	21.0 a	3.9 e	1.5 b
	SD	±0.3	±0.1	±0.1	±0.1	±0.3	±0.2	±0.4	±0.1
Capons									
V	x	75.8 b	22.6 d	1.7 b	0.9 ab	73.4 c	20.3 d	5.8 a	1.5 bc
	SD	±0.4	±0.3	±0.1	±0.1	±0.2	±0.2	±0.4	±0.1
VI	x	75.3 cd	23.4 b	1.3 d	0.8 b	74.3 b	20.7 ab	4.4 de	1.5 bc
	SD	±0.1	±0.1	±0.1	±0.1	±0.1	±0.2	±0.1	±0.1
VII	x	74.8 ef	23.3 b	2.2 a	1.0 ab	73.7 c	20.2 d	5.6 ab	1.7 a
	SD	±0.2	±0.1	±0.1	±0.1	±0.3	±0.2	±0.5	±0.1
VIII	x	74.5 f	23.0 b	2.3 a	0.9 ab	73.5 c	20.6 bc	5.4 abc	1.4 c
	SD	±0.2	±0.1	±0.1	±0.1	±0.2	±0.2	±0.4	±0.1

a, b, c – mean values marked with different letters in columns differ significantly ($P \leq 0.05$).

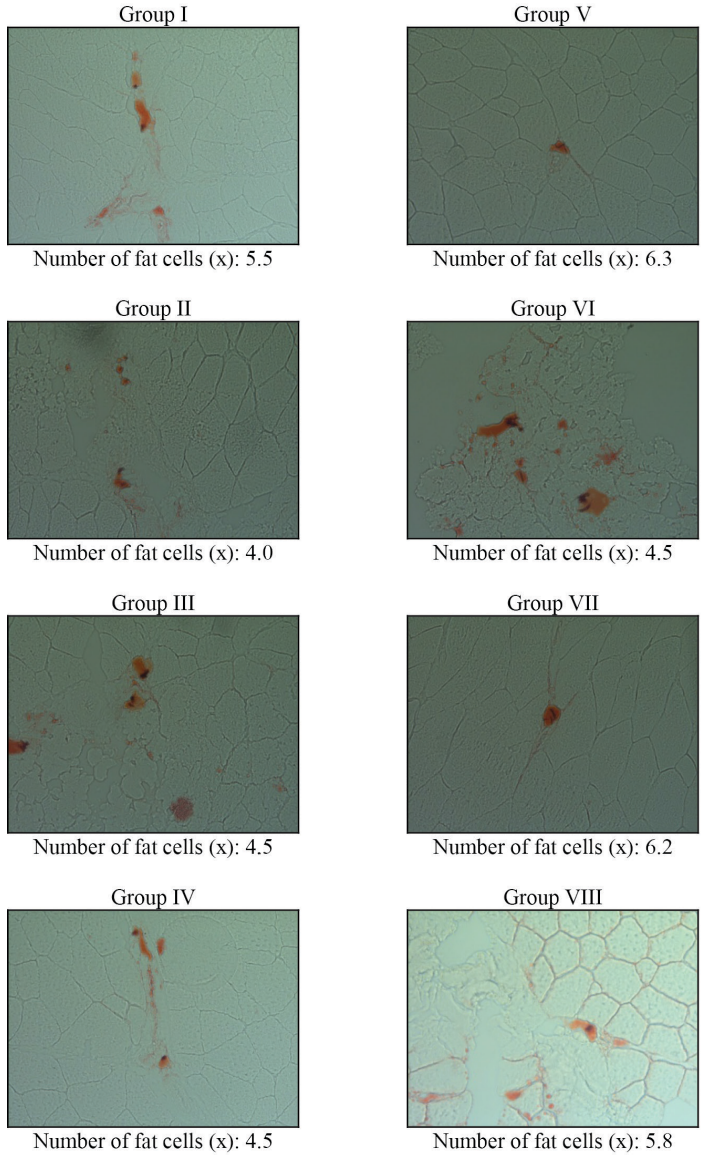

Figure 1. Mean number of fat cells* per 1 mm^2 of the cross-section of the breast muscle in the 20th week of rearing in cockerels and capons. * No significant differences found (P≤0.05)

The lack of a significant influence of caponisation on the weight and the percentage share of breast muscles among birds from evaluated strains was also presented (Table 2). Significantly higher weight of breast muscles (by 58.3 g) was found only among cockerels from strain S11 (group III) compared to strain N88 (group I). Among capons breast muscles of birds from strain P11 (group VIII) weighed 68.7 g

more than from strain R55 (group VI). The weight and the percentage share of drumstick muscles among all evaluated groups were similar. However, the influence of caponisation on the total weight of muscles depending on the origin was observed. Capons from strain R55 (group VI) were characterised by the lowest weight of muscles in carcass ($P \leq 0.05$) compared to capons from strain P55 (group VIII) and N88 (group V). Similarly, fatness of capons from strain N88 (group V) was significantly lower compared to strain P55 (group VIII) which had the highest fatness. Percentage share of skin with subcutaneous fat, as well as the weight in all evaluated groups were similar and did not differ statistically significantly ($P \leq 0.05$).

Among 20-week-old birds from all groups no significant differences were observed in terms of physicochemical characteristics of meat (Table 3). It may prove the lack of influence of the birds' origin as well as caponisation on the quality of meat. The highest ($P \leq 0.05$) water content in breast and drumstick muscles (Table 4) was shown among cockerels from strain N88 (group I). Similarly, significantly highest water content in breast muscles was noted among capons from the same strain (group V). Among capons the highest water content was observed in strain R55, in other groups of capons the content of water was similar.

Protein content in breast muscles was different depending on the cockerels' origin (Table 4), whilst among capons (groups VI–VIII) it was similar and differed statistically significantly only from capons from strain N88 (group V). It was also noted that capons originating from strains S11 (group VII) and P55 (group VIII) differed significantly in terms of fat content in breast muscles compared to cockerels from the same strain (groups III and IV). The influence of caponisation on higher fat content in drumstick muscles was confirmed in all evaluated groups. Capons from all strains had more fat in drumstick muscles compared to cockerels from the same strains. Likewise, caponisation influenced the diversity of protein content in drumstick muscles among all strains (except for S11 – groups III and VII). It also influenced the collagen content among all strains (except for P55 – groups IV and VIII).

The analysis of the mean number of fat cells (Figure 1) showed that at the 20th week of breeding their number was slightly higher in breast muscles of capons (by 4.5 in strain R55 and by 6.3 in strains N88) than in breast muscles of cockerels (from 4.0 in strain R55 to 5.5 in strain N88, respectively). These differences were not statistically significant.

Discussion

In our study capons were not significantly heavier than cockerels. Similar conclusions were drawn by Shao et al. (2009), but among cockerels castrated at the 6th or 18th weeks of age and slaughtered slightly later, at the 24th week. At the same time quoted authors noted lower weight of body in the end of breeding than in our study among both cockerels (from 1471 g to 1505 g) and capons (1431 g). It might be a result of different strains of evaluated birds. Capons evaluated by Volk et al. (2011) were bred in an extensive system until the 26th week, they also reached similar body weight compared to cockerels of the same strain. However, capons had higher

fatness and less musculature compared to cockerels (differences confirmed statistically). Our study does not confirm it as no distinctive influence of caponisation on the weight and percentage share of breast and drumstick muscles as well as fatness (shown in percentage) and the percentage share of skin with subcutaneous fat and abdominal fat was noted.

On the other hand, compared to our study, Duran (2004) observed a different pattern in the weight of 20-week-old slaughter chickens bred in free range from the 6th week. These cockerels weighed significantly less (1909.48 g) than capons (2171.37 g). Similar conclusions in terms of body weight were drawn by Calik (2014 a) who compared slaughter yield of Rhode Island Red cockerels and capons older than in our study (24 weeks old). These results showed that castration had positive effect on the body weight and it also improved carcass musculature. Higher body weight of capons compared to cockerels of Greenleg Partridge birds slaughtered at the 23rd week was also observed by Kasperek et al. (2014).

Data presented in Tables 1 and 2 confirm diverse influence of caponisation on slaughter traits (the weight of eviscerated carcass and slaughter yield) depending on the birds' origins since capons from strain P55 (originating from Plymouth Rock) had significantly higher weight of eviscerated carcass compared to strain R55 (Rhode Island Red). This is in accordance with studies conducted earlier by Chen et al. (2000), Jaturasitha et al. (2008 a, b) and Rikimaru et al. (2009) where significant differences in carcass weight and slaughter yield were shown depending on the birds' origin. Opinions of different authors vary as to the effects of caponisation on slaughter yield. Studies conducted by Diaz et al. (2010, 2012) and Calik (2014 a) proved the influence of caponisation on slaughter yield of cockerels and capons slaughtered at different age (20 and 24 weeks of breeding, respectively). However, Kasperek et al. (2014) did not observe the influence of castration on slaughter yield among cockerels aged 22–23 weeks.

Our study did not confirm the influence of birds' strain and caponisation on meat quality (Table 3). This is confirmed by an earlier study of Symeon et al. (2012), who did not show distinctive differences in pH indicators or lightness (L*), redness (a*) and yellowness (b*) in breast muscles of 18-week-old cockerels and capons. Twenty-week-old capons evaluated in another study (Diaz et al., 2010) had similar pH indicators of breast compared to our study. However, water loss expressed by water holding capacity was 18.6% for capons and 23.8% for cockerels, which means they were much smaller than in our study. These differences may result from different cockerel and capon strains in our study. The same may apply to evaluation of muscle colour using L*a*b*. Similar results were reported by Volk et al. (2011) who proved that cockerels' castration has no influence on better musculature and physicochemical characteristics of slaughter chickens bred in an extensive system. Slightly different conclusions were drawn by Calik (2014 a) who stated lighter (L*) breast and drumstick muscles (also higher yellowness (b*)) of 24-week-old Rhode Island Red capons compared to cockerels. At the same time better tenderness especially of breast muscles of cockerels compared to capons was noted.

As it is presented in Table 4 capons from all strains could be distinguished by higher content of fat in drumstick muscles compared to cockerels of the same origin.

The influence of castration on diverse protein content in drumstick muscles except for strain S11 (groups III and VII) and the content of collagen except for strain P55 (groups IV and VIII) were demonstrated. This statement is in accordance with conclusions drawn by other authors (Diaz et al., 2010, 2012) who presented significant ($P \leq 0.05$) differences in protein and fat content in cockerels' and capons' muscles.

Through analysis of mean values of fat cells in breast muscles which, according to many authors (Baeza et al., 1998; Elminowska-Wenda et al., 2001), have direct influence on tenderness and microstructure of meat, our study showed that capons had higher number of fat cells in breast superficial muscle compared to cockerels from evaluated strains (Figure 1), although the differences were not significant. Alongside changes analysed earlier (Table 2) in terms of breast muscles fatness, it may prove better culinary quality of the meat from capons compared to cockerels.

To conclude, it is safe to state that caponisation of cockerels originating from four Polish reproductive strains influences slaughter yield of the birds depending on the strain. Taking into consideration slaughter traits and meat quality it is possible to say that cockerels from reproductive strains N88, S11, R55 and P55 may be castrated at the age of 12 weeks and then bred until the age of twenty weeks.

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Received: 11 III 2015
Accepted: 19 VII 2016