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COMPARISON OF THE PHYSICOCHEMICAL AND SENSORY CHARACTERISTICS OF RHODE ISLAND RED (R-11) CAPONS AND COCKERELS*

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Abstract

The aim of the study was the comparison of the physicochemical and sensory characteristics of capons and cockerels. The experiment involved 80 Rhode Island Red (R-11) cockerels, which were randomly assigned to two groups with 40 birds per group. Group I (control) consisted of uncastrated cockerels, and group II was comprised of birds subjected to castration at 9 weeks of age. The castration was performed under local anaesthesia by a veterinary surgeon. The birds received the same diets *ad libitum* and were kept on litter under optimal environmental conditions, at a stocking density of 7 birds/m^2. At the end of fattening, 8 birds whose body weights were similar to the group average were selected for slaughter from each group. After slaughter, the birds were checked for castration success (removal of the testes), analysed for dressing percentage and technological parameters of the meat and subjected to chemical and sensory evaluation of the breast and leg muscles. In summary, the castration of Rhode Island Red cockerels (R-11) had a favourable effect on body weight, feed conversion ratio, dressing percentage and carcass muscling. The breast and leg muscles of the capons were characterised by better water holding capacity, tenderness and sensory score compared to the uncastrated cockerels. In addition, the castration had a positive effect on the content of crude protein in both the breast and leg muscles which, with a higher crude fat content, were characterised by a more favourable profile of fatty acids, i.e. lower SFA and higher *n-6* and *n-3* PUFA content.

Key words: capon, meat quality, fatty acid, sensorial evaluation, SPME-GC-MS, chemometrics

According to the Codex Alimentarius FAO/WHO, meat quality is defined as a combination of attributes that meet specific demands and make meat desirable for food. Over the last several years there has been an increasing number of consum-

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ers, both in Poland and abroad, who are looking for niche products that are rich in nutrients and exhibit specific sensory characteristics (Augustyńska-Prejsnar and Sokołowicz, 2014). Also, more and more attention is being paid to products obtained from native breed chickens managed under semi-intensive or extensive conditions (Sokołowicz et al., 2016). A notable success in this regard has been achieved by the French Label Rouge system developed in the 1960s, which uses regional slow-growing breeds of chickens and combines traditional farming with caring for bird welfare and quality of the final product (Fanatico et al., 2006).

With the currently growing demand for poultry products from the extensive system, there is a chance to increase the importance of raising native breed hens and using them for capon production, among others (Calik, 2014 a). The caponisation of cockerels is a very old practice that has been carried out since antiquity; first it was connected with religious rites, later it was used to obtain greater body weight, and much later to improve meat quality (Jacob and Mather, 2000). In Poland, the tradition of capon production dates back to the 16th and 17th centuries, when capons were served on the tables of aristocrats and noblemen. Currently the caponisation procedure is common in many countries in Asia, Europe and America (Symeon et al., 2010), and capons are marketed as high-quality special products because their meat is more delicate, tender and juicy (Mast et al., 1981; Tor et al., 2002; Hsu and Lin, 2003; Tor et al., 2005; Shao et al., 2009; Diaz et al., 2010, 2012; Mahmud et al., 2013; Calik et al., 2015).

Capon production is most often based on native or locally adapted breeds. Poland has a large and valuable collection of hens (11 lines) included in the World Watch List (2000); among these, special interest is given to Rhode Island Red (line R-11) hens. This line is predisposed for extensive backyard farming and due to higher body weight it has been used for both egg (Calik, 2014 b) and meat production (Puchała et al., 2014). In Poland, by virtue of Commission Regulation No 543/2008, the surgical caponisation procedure was reinstated in 2008 as a permitted and standard zootechnical practice; since then, there has been a renewed interest in the fattening of capons. This provides an opportunity to use surplus, one-day-old cockerels which most often constitute 50% of hatched chicks.

The aim of the study was to compare physicochemical and sensory characteristics of Rhode Island Red (R-11) capons and cockerels, and to check the possibility of differentiating the groups using volatile organic compounds (VOCs) analysis by the solid phase microextraction-gas chromatography-mass spectrometry (SPME-GC-MS) method and chemometrics.

Material and methods

The experiment used 80 Rhode Island Red cockerels (line R-11), which were randomly assigned to two groups with 40 birds per group. The cockerels from group II (experimental) were castrated, and those from group I (control) were uncastrated. At 9 wks of age, the birds were castrated under local anaesthesia by a veterinary

surgeon. The experimental procedures complied with the requirements established by the Ethics Commission No 953 of 10 July 2012. The birds were kept under good environmental conditions (temperature of 18–20°C, relative humidity of 60–75%) on litter, at a stocking density of 7 birds/m^2. Throughout the rearing and fattening period, i.e. until 24 wks of age, the birds were provided with free access to water and feed. A three-phase feeding programme with cereal-soybean meal diets was applied. Table 1 presents the composition and nutrient content of the diets.

Table 1. Composition and nutrient content of the diets used in the experiment (kg/100 kg)

Component	Phase I day 1 to week 7	Phase II weeks 8 to 16	Phase III weeks 17 to 24
Ground maize	41.35	40.45	35.70
Ground wheat	25.00	22.00	29.00
Ground triticale	-	5.00	7.00
Ground barley	-	5.00	7.00
Soybean meal	30.00	24.00	18.00
Ground limestone	1.25	1.30	1.20
Dicalcium phosphate	1.60	1.45	1.30
NaCl	0.30	0.30	0.30
Vitamin-mineral premix DKA-F (finisher) (0.5%) (kg)	0.50	0.50	0.50
Crude protein (g)	204	184	165
Metabolisable energy (MJ)	11.92	12.05	12.18
(kcal)	2850	2880	2910
Lys (g)	10.3	8.90	7.50
Met (g)	3.10	2.85	2.60
Ca (g)	8.95	8.60	7.90
P available (g)	4.10	3.80	3.50

At 24 wks of age, 8 birds whose body weights were similar to the group mean were selected for slaughter from each group. The cockerels and capons received no feed for about 12 h prior to slaughter but had continuous access to water. After slaughter, the castration success (i.e. removal of the testes) was checked, which was followed by standard post-slaughter processing (scalding, defeathering, evisceration). The chilled carcasses (24 h at 4°C) were subjected to simple slaughter analysis according to the method of Ziołecki and Doruchowski (1989). Next, samples of breast and leg muscles were collected from every carcass to determine:

– acidity – determined 15 minutes (pH_{15}) and 24 hours (pH_{24}) postmortem using a CyberScan 110 pH meter equipped with a glass electrode for meat analysis;

– colour – determined 24 h postmortem with the L*a*b* system (CIE, 2007), using a Minolta CR 310 reflectance colorimeter, where L* is lightness, a* indicates redness, and b* indicates yellowness. Colour measures are the mean of 5 point carcass measurements and 2 point measurements of breast and leg muscles performed on the inner surface, immediately after deboning;

– water-holding capacity – based on the volume of juices squeezed from a sample, using the Grau and Hamm method (1953);

– drip loss – determined after 24-hour storage of the samples at +4°C;

– thermal loss – based on weight loss during cooking. Samples of 80 g were placed in plastic bags and the muscles were cooked – at 80°C for 14 min (breast muscles) and 16 min (leg muscles);

– meat tenderness, using a Stable Micro Systems texture analyser fitted with a Warner-Bratzler shear blade (2 mm s^{-1}). To this end, a cylindrical piece (10 mm in diameter and 30 mm long) was cut from the cooked muscles. The sample was cut at three points perpendicular to the orientation of the muscle fibres and the mean value was given as the final measurement result.

The breast and leg muscles (roasted muscles – 1 h at 180°C) were subjected to sensory assessment according to the methodology developed by Baryłko-Pikielna and Matuszewska (2009). The assessment was made by a panel of 10 adult individuals based on a scale of 1 to 5, with the best score being 5 and the worst score being 1. For each parameter, the scores were accurate to 0.5 point. Aroma, juiciness, tenderness and flavour were included in the assessment.

In addition, samples of breast and leg muscles were collected from 5 cockerels and 5 capons subjected to slaughter analysis in order to determine the chemical composition of water (dry matter) by the drying method (PN-ISO1442: 2000); crude protein according to Kjeldahl and using the nitrogen to protein conversion factor of 6.25 (PN-75/A-04018/Az3:2002); crude fat using the Soxhlet method (Buchi 810) according to PN-ISO 1444:2000; crude ash (PN-ISO 936:2000); and cholesterol using the colorimetric method (PO26 ver. 1: 2001). Fatty acid content was determined by gas chromatography (VARIAN 3400 CX) using helium as a carrier gas and column Rtx 2330 (105 m). Injector temperature was 200°C and detector temperature 240°C. The samples were prepared by the method of Folch el al. (1957) using BF3/methanol methylation.

The results were statistically analysed by analysis of variance (ANOVA). The calculations were made using Statgraphics®.

To investigate the possibility of determining the differences between the groups of the birds, VOCs were analysed in 5 cockerels' and 5 capons' breast muscle, by use of SPME-GC-MS (Shimadzu, QP 2010 Plus, fibre DVB/CAR/PDMS, column ZB-WAX plus 30m x 0.25mm, 0.25um, helium, 1 ml/min). The samples were treated in such a way as to avoid repeated thawing. A meat sample (–80°C±5°C) was blended in liquid nitrogen, placed into a SPME vial (20 ml) and tightly capped using a crimp cap with PTFE/silicone septum. To lower analytical trends due to aging of the chromatographic system, a vial rack was cooled and in addition, the samples in the rack were placed in a staggered manner. Spectral data of all peaks from the chromatogram were logarithmically transformed and the preselection of most differentiating variables (m/z ions) was done in Excel® using Fisher's ratio (Pierce et al., 2006). Next, principal component analysis (PCA) was used. After a reduction in the number of variables to three main components, a discriminant analysis was executed. Finally, cross validation was used to calculate classification accuracy. The chemometric analysis was performed using Statgraphics® Centurion XVI software equipped with a multivariate statistics package.

Results

The rearing of cockerels and capons proceeded correctly (Table 2). In group II, 5.0% mortality was noted at 9 wks of age, on the day when the birds were castrated. Feed conversion (kg feed/kg gain) averaged 4.43 kg for cockerels and 3.95 kg for capons.

Table 2. Mortality and health cullings and feed conversion per kg weight gain

Item	Mortality and health cullings					Feed conversion ratio (kg/kg)
	number of birds				%	
	0 – 8 weeks	9 – 12 weeks	13 – 24 weeks	Total		
Cockerels	-	-	-	0	0.00	4.43
Capons	-	2	-	2	5.00	3.95

Table 3. Body weight and results of slaughter analysis

Item	Cockerels	Capons
Live body weight (g)	2477±152.13 a	2697±163.72 b
Carcass weight loss during chilling (%)	1.97±0.15 a	1.55±0.48 b
Dressing percentage with giblets (%)	72.53±1.03 a	73.83±0.81 b
Dressing percentage without giblets (%)	66.91±1.24 a	68.22±0.89 b
Content in carcass:		
breast muscles (%)	18.27±1.62 a	20.74±1.43 b
leg muscles (%)	23.90±1.29 a	26.28±1.70 b
Giblets (%)	4.54±0.26 A	5.30±0.29 B
Liver (%)	1.95±0.23	1.92±0.05
Gizzard (%)	2.08±0.08 A	2.90±0.30 B
Heart (%)	0.51±0.04	0.48±0.04
Leg bones (%)	7.05±0.56	6.72±0.44
Abdominal fat (%)	0.70±0.14 A	2.84±0.36 B
Carcass colour:		
– L*	70.12±0.76 A	72.13±0.60 B
– a*	4.28±0.21 a	3.35±0.58 b
– b*	11.38±0.96 A	15.23±1.14 B

Values in rows with different letters a, b differ at $P \leq 0.05$.
Values in rows with different letters A, B differ at $P \leq 0.01$.

Table 3 presents data for the body weight of cockerels and capons and the slaughter results. At 24 wks of age, the body weight of cockerels and capons averaged 2477 and 2697 g, respectively, being significantly ($P \leq 0.05$) higher in the group of castrated birds. Also in group II, there was significantly ($P \leq 0.05$) lower carcass weight loss during chilling (by 0.42 percentage points) and higher dressing percentage with and without giblets (by an average of 1.30 p.p.). Compared to the cockerels, the capons were also characterised by significantly ($P \leq 0.05$) higher content of breast muscle (18.27% vs 20.74%) and leg muscle in the carcass (23.90% vs 26.28%) and a significantly ($P \leq 0.01$) greater proportion of the gizzard (by 0.82 p.p.). No signifi-

cant differences were found in leg bone percentage and the cockerels and capons exhibited significant (P≤0.01) differences in abdominal fat content (0.70% vs 2.84% of carcass weight). Large differences (P≤0.05 or P≤0.01) were observed between the groups in carcass colour. The carcasses from the capons were lighter (L*=72.13) and yellower (b*=15.23), but less red (a*=3.35) compared to those from the uncastrated cockerels, in which L*a*b* values were 70.12%, 4.28% and 11.38%, respectively.

The technological parameters of the breast and leg muscles are presented in Table 4. Breast muscle pH values of the cockerels and capons ranged from 6.22 to 6.25 when measured 15 min postmortem and decreased to 5.70–5.75 after 24-h chilling of the carcasses. The breast muscle of the capons showed lower water loss (0.38%) and lower losses during heat treatment (22.05%), but the differences were not significant. The assessment of colour showed the breast muscles of the capons to be lighter (L*=62.61) and more yellow (b*=9.73), and those of the cockerels more red (a*=11.25), with a significant difference for L* (P≤0.05) and a non-significant difference for a* and b*. Castration of the birds had a positive effect on breast muscle tenderness (13.27%) and improved the water-holding capacity (14.93%); the differences between the groups were statistically significant (P≤0.05).

Table 4. Technological parameters of breast and leg muscles

Item	Breast muscles		Leg muscles	
	cockerels	capons	cockerels	capons
pH_{15}	6.22±0.12	6.25±0.07	6.48±0.13	6.59±0.06
pH_{24}	5.70±0.09	5.75±0.08	5.96±0.15	6.07±0.06
Drip loss after 24 h (%)	0.57±0.10	0.38±0.13	0.38±0.09	0.31±0.07
Thermal loss (%)	22.57±2.49	22.05±0.87	35.83±1.31	34.68±1.17
Colour:				
– L*	60.50±1.22 a	62.61±0.99 b	45.11±3.45 a	48.87±0.92 b
– a*	11.25±0.87	10.22±1.57	18.26±0.59	17.41±1.02
– b*	9.10±1.03	9.73±0.28	6.61±0.83 A	8.21±0.48 B
Water holding capacity (%)	17.47±1.10 a	14.93±2.80 b	19.37±0.81 a	16.27±1.53 b
Tenderness (N)	17.39±1.57 a	13.27±1.86 b	23.46±1.64 A	19.14±0.44 B

For notes see Table 3.

In the leg muscles of the cockerels and capons, muscle pH values 15 min postmortem ranged from 6.48 to 6.59, while after 24 h the decrease of pH in the groups was similar and averaged 0.52. In the group of capons, non-significantly lower water loss from the muscles after 24-h storage (0.31%) and cooking loss (34.68%) were established. Similarly in the case of breast muscles, the leg muscles of the capons were lighter (P≤0.05) and more yellow (P≤0.01), whereas those of the cockerels showed a tendency for higher redness, with no statistically significant differences. The leg muscles of the capons were also characterised by significantly (P≤0.05) higher water binding capacity (16.27%) and highly significantly (P≤0.01) better tenderness (19.14 N) compared to the same muscles in the cockerels, for which the corresponding values were 19.37% and 23.46 N.

In the sensory analysis (Table 5), the meat of the capons received better scores than the meat of the cockerels in all the categories. Statistically significant differences ($P \leq 0.05$) were noted for juiciness and flavour (breast meat) and for aroma, juiciness, tenderness and flavour (leg meat).

The present study also revealed significant differences in the content of the main chemical components in the muscles of the cockerels and capons (Table 6). Analysis of the data demonstrated significantly higher ($P<0.05$) contents of dry matter (by 1.12 p.p.), crude protein (by 0.67 p.p.) and crude fat (by 1.06 p.p.; $P \leq 0.01$) in the breast muscles of the capons. Also, the leg muscles of the castrated birds contained 2.17 p.p. more dry matter ($P<0.01$), 0.56 p.p. more crude protein ($P<0.05$) and 3.27 p.p. more crude fat ($P<0.01$). In both the breast and leg muscles, no significant differences were observed between the analysed groups in crude ash and cholesterol content, except that slightly higher values were found in the castrated birds.

Table 5. Results of sensory analysis of breast and leg muscles

Item	Breast muscles		Leg muscles	
	cockerels	capons	cockerels	capons
Aroma (pts.)	4.30±0.63	4.65±0.34	4.00±0.78 a	4.45±0.59 b
Juiciness (pts.)	3.50±0.66 a	4.35±0.74 b	3.65±0.88 a	4.40±0.53 b
Tenderness (pts.)	3.75±0.89	4.30±0.48	4.10±0.51 a	4.60±0.52 b
Flavour (pts.)	4.00±0.67 a	4.60±0.39 b	4.20±0.63 a	4.65±0.58 b

For notes see Table 3.

Table 6. Results of effect of caponization on chemical analysis of the breast and leg muscles

Item	Breast muscles		Leg muscles	
	cockerels	capons	cockerels	capons
Dry matter (%)	25.41±0.61 a	26.53±0.39 b	24.71±0.23 A	26.88±0.51B
Crude ash (%)	1.12±0.01	1.13±0.02	1.02±0.01	1.03±0.01
Crude protein (%)	24.12±0.63 a	24.79±0.27 b	20.15±0.23 a	20.71±0.16 b
Crude fat (%)	1.11±0.18 A	2.17±0.46 B	3.37±0.71 A	6.64±1.29 B
Cholesterol (mg/100 g)	54.38±4.16	56.67±3.42	94.17±2.88	96.15±5.74

For notes see Table 3.

The breast muscles of the capons (Table 7) contained significantly ($P \leq 0.05$) less saturated fatty acids (SFA), in particular myristic acid (C14:0) and stearic acid (C18:0). The evaluated groups differed non-significantly in the content of unsaturated fatty acids (UFA). In general, the castrated birds tended to show a higher content of monounsaturated fatty acids (MUFA) and *n-6* and *n-3* polyunsaturated fatty acids (PUFA). In breast muscles the *n-6/n-3* PUFA ratio, which is considered important from the viewpoint of human nutrition, varied from 8.73 in the capons to 9.05 in the cockerels.

The profile of fatty acids in the leg muscles was similar to that in the breast muscles. Here again, the group of castrated birds tended to show a lower content of saturated fatty acids (C14:0; C16:0; C18:0). At the same time, the capons had a sig-

nificantly higher (P≤0.05) content of *n-3* PUFA, in particular α-linolenic (C18:3n-3) and docosahexaenoic acids (C22:*6n-3*), and of n-6 PUFA, in particular linoleic acid (C18:2*n-6*). The *n-6/n-3* PUFA ratio ranged from 16.52 in the capons to 18.49 in the cockerels.

Table 7. Results of the fatty acid profile of breast and leg muscles (g/100 g)

Fatty acids	Breast muscles		Leg muscles	
	cockerels	capons	cockerels	capons
C 14:0	0.76±0.15 a	0.56±0.11 b	0.90±0.12	0.71±0.20
C 16:0	19.95±0.72	18.54±2.01	25.86±2.18	23.19±3.65
C 18:0	11.03±1.17 a	7.65±0.94 b	9.94±1.44	8.13±0.98
C 16:1	2.35±0.68	3.24±0.78	4.50±0.86	4.67±0.66
C 18:1	31.57±1.89	34.22±2.39	36.09±1.43	37.58±1.99
C 18:2*n-6*	14.39±1.38	15.82±1.17	15.30±1.27 a	17.76±1.28 b
C 18:3*n-6*	0.11±0.007	0.10±0.02	0.14±0.06	0.15±0.04
C 18:3*n-3*	0.35±0.10	0.45±0.09	0.52±0.08 a	0.65±0.05 b
C 20:4*n-6*	14.91±2.34	15.78±1.20	4.81±0.69	5.39±0.42
C 22:*6n-3*(DHA)	2.91±0.31	3.19±0.41	0.59±0.16 a	0.76±0.15 b
∑ SFA	31.99±1.06 a	26.75±3.05 b	36.77±1.32	32.58±2.30
∑ UFA	67.64±0.99	72.89±4.82	62.07±1.36	67.19±5.05
∑ MUFA	34.97±2.52	37.64±2.54	40.62±2.16	42.41±3.01
∑ PUFA	32.69±1.40	35.34±0.99	21.43±1.10	24.71±1.63
∑ PUFA*n-6*	29.43±1.49	31.72±1.46	20.27±1.01 a	23.30±1.50 b
∑ PUFA*n-3*	3.25±0.25	3.64±0.54	1.10±0.17 a	1.41±0.16 b
PUFA*n-6/n-3*	9.05±0.74	8.73±1.96	18.49±2.10	16.52±2.30

For notes see Table 3.

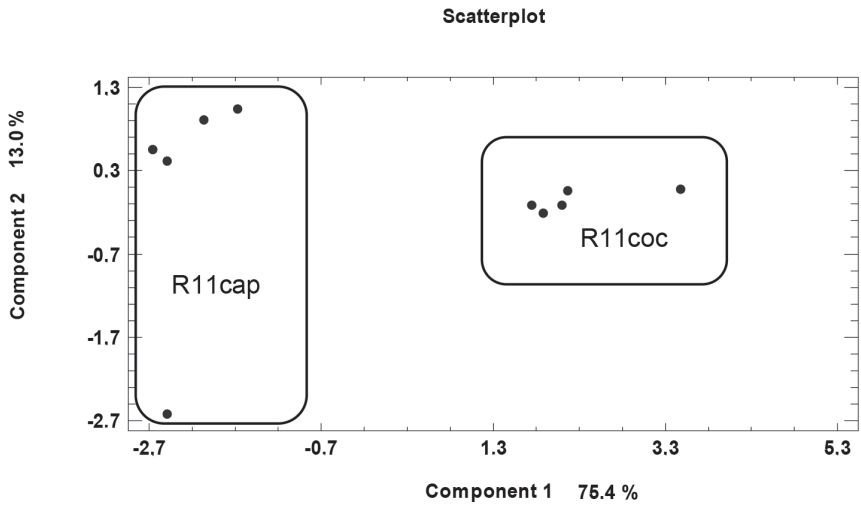

Figure 1. PCA based on mass spectra (SPME-GC-MS, ZB-Wax column) of VOCs in breast muscles of cockerels (coc) and capons (cap)

PCA based on mass spectra of VOCs analysed in the breast muscles shows that two first principal components accounted for 88.4% of the total variance. The differentiation between the cockerels and capons is presented in the scatterplot (Figure 1). The classification accuracy, calculated using cross-validation, was 100%.

Discussion

According to the Commission Regulation No. 543/2008 of 16 June 2008, "a capon is a male fowl castrated surgically before reaching sexual maturity and slaughtered at a minimum age of 140 days: after castration the capons must be fattened for at least 77 days." Surgical removal of the testes can be performed in birds of all ages, but the most appropriate period is between 6 and 14 wks of age, with the timing depending on breed and the achieved body weight, which should be around 500 g. Shao et al. (2009), when comparing birds castrated at 6 and 18 wks, showed that it is more beneficial to castrate cockerels during the first weeks of rearing due to higher survival, better gains and carcass quality characteristics. Many studies also determined the age at completion of rearing capons depending on their origin. Muriel Duran (2004), who analysed the growth of cockerels and capons between 8 and 30 wks of rearing, found that due to significant differences in body weight, the optimal slaughter date is at wk 25 of rearing. Likewise, Chen et al. (2007) and Shao et al. (2009) suggest that rearing should be completed between 22 and 26 wks of age depending on capon origin. In the present experiment, castration was performed at 9 wks of age, when the birds weighed around 650 g, which means that the capons were fattened for 15 wks. Up to wk 24 of age, mortality and health-related culling occurred in 5% of the capons during the first days after the surgery. Rikimaru et al. (2011) estimated the losses due to caponising to range from 5 to 20%. Changes in the appearance and behaviour of birds are observed shortly after castration (Lin et al., 2012). As reported by Sirri et al. (2009), high precision is essential for caponisation because failure to remove single testicular cells will cause the organ to regenerate and resume sex hormone production. This is reflected in the increased activity of the birds and regrowth of the comb and wattles.

In the present study, feed conversion per kg of weight gain was more efficient for the capons than cockerels. Similar results were obtained by Chen et al. (2006), Shao et al. (2009) and Rikimaru et al. (2009). The authors stressed that both origin and castration may significantly influence the production efficiency expressed in feed consumption and feed conversion, which is directly related to the body weight of the birds.

The study showed a positive effect of caponising Rhode Island Red cockerels (R-11) on the final body weight. At the end of fattening at 24 wks of the experiment, body weight differed significantly and was higher by 220 g in the capons. A similar difference to the advantage of caponised birds was reported for the native breed of Z-11 Greenleg Partridge hens (Calik et al., 2015). The positive effect of sterilization on body weight was reported by Mast et al. (1981), Tor et al. (2002), Muriel Duran

(2004), Chen et al. (2006) and Mahmud et al. (2013). These authors observed that the decrease in male sex hormones is paralleled by lower physical activity of the castrated birds which contributes to better feed conversion and higher weight gains with deposition of intramuscular fat which, in turn, improves the quality of the meat. In contrast, in a study with broilers, Symeon et al. (2010) observed no advantage in body weight of castrated over intact cockerels, which may be dependent on the genetic origin of the birds, the age of their castration and slaughter date.

The castration of cockerels also had a beneficial effect on lower carcass weight loss during chilling and higher dressing percentage with and without giblets, with statistically significant differences between the analysed groups. The capons were also characterised by significantly higher content of breast muscles and leg muscles. Improvements in dressing percentage and body muscling of capons were reported by Tor et al. (2005) and Chen et al. (2007). The analysed groups of birds differed significantly in the proportion of the gizzard, which was significantly greater in the sterilised birds. The increase in gizzard – but also liver weight – as a result of castration was also observed by Rachman et al. (2004), Chen et al. (2006) and Mahmud et al. (2013). In the present study, we observed no significant differences in bone percentage and there was only a tendency for higher values in the uncastrated cockerels, which was also noted by Tor et al. (2002). Adamski et al. (2016a) when comparing the physical characteristics of bones in Sussex S-11 cockerels and capons, found bone strength to significantly increase with age in capons, which may be indicative of a positive effect of castration on this trait. Muszyński et al. (2017) showed a negative effect of castration on the mechanical strength of the long bones.

It is worth noting that the content of abdominal fat was significantly higher in the caponised birds, which is consistent with the findings of Hsu and Lin (2003), Chen et al. (2006), Sirri et al. (2009), Sinanoglou et al. (2011), Volk et al. (2011) and Adamski et al. (2016 b). As reported by Chen et al. (2005), the caponisation of cockerels reduces testosterone concentration and increases the capacity for lipogenesis and the accumulation of lipids in the bird's body. The higher fat content considerably improves the technological parameters of the meat, in particular its tenderness and juiciness, has a positive effect on the sensory attributes of the meat, and may give rise to differences in carcass colour, which was also observed in the present study. The carcasses of the capons were characterised by a significantly lighter and yellower colour and lower redness, which was also confirmed by Lin and Hsu (2002) and Symeon et al. (2010). Similar tendencies occurred for muscle colour, with significant differences for L* in the breast and leg muscles, and only for b* in the leg muscles. As reported by Cason et al. (1987), muscle colour, dependent mainly on the breed, sex, age and physical activity of birds, is mainly determined by the content of myoglobin and intramuscular fat.

These factors also have a direct effect on meat acidity, which is, in turn, strictly related to water-holding capacity (Fletcher, 2002). The results obtained indicate that caponisation had no effect on the acidity of breast and leg muscles after slaughter and chilling. The pH_{15} values in the groups were higher than the pH_{24} values, which is indicative of normal glycolytic changes in the muscles and proper maturation of the muscle tissue. This is supported by Volk et al. (2011) and Symeon et al. (2010), who

found no differences in the water-holding capacity of the muscles. The present study showed, in turn, that breast muscles of capons were characterised by more favourable water-holding capacity, with a tendency for lower water loss and lower losses during heat treatment. In the leg muscles the differences between the analysed groups were smaller and significant only for water-holding capacity. A very important parameter in evaluating the physical quality of meat is tenderness (Zdanowska-Sąsiadek et al., 2013), which is the outcome of the morphological structure of muscle tissue (in particular, muscle fibre size), the amount of connective tissue and the proportion of its different forms. The study showed that caponisation had a significant effect on meat toughness. Instrumentally-measured breast and leg muscles of the capons were tenderer than those from uncastrated cockerels, which was confirmed statistically. The higher tenderness of capon meat compared to cockerel meat was indicated by the findings of Lin and Hsu (2002), Rikimaru et al. (2009), Sirri et al. (2009) and Lin and Hsu (2013), who stressed that the increase in intramuscular fat is associated with greater meat tenderness and contributes to improving the sensory parameters. Such meat is tastier, juicier and tenderer (Zdanowska-Sąsiadek et al., 2013). The authors showed that the fat found in the muscles reduces the drying of muscle tissue during heat treatment and improves the perception of juiciness. Furthermore, Augustyńska-Prejsnar and Sokołowicz (2014) showed that the concentration of taste precursors increases as the birds grow, reaching a peak after the attainment of sexual maturity, which is why the meat of older birds has a more intensive, more characteristic flavour and aroma. Also, the meat from slow-growing birds, including that from native or locally-adapted breeds, is characterised by a more intensive aroma and better flavour (Puchała et al., 2014). In the sensory assessment, the breast and leg muscles of the capons achieved higher scores for all the analysed traits. Significant differences were confirmed for the juiciness and flavour of the breast muscles. At the same time, the tasters gave significantly higher scores for aroma, juiciness, tenderness and flavour to the more fatty leg muscles. According to Castellini et al. (2008), different muscles of the same bird differ in taste. The authors indicate that in general, leg muscles that are more active *in vivo* exhibit a stronger aroma than the less active breast muscles.

In the present study, significant differences in the nutritive value of the capon and cockerel muscles were observed. The breast muscles of the castrated birds were characterised by a significantly higher protein content, which corresponds with the findings of Amorin et al. (2016), Franco et al. (2016) and Kwiecień et al. (2015). Compared to the cockerels, the capons also had a considerably higher content of dry matter and crude fat, especially in the leg muscles. The higher lipid and cholesterol concentration in capon muscles was reported by Sirri et al. (2009), Sinanoglou et al. (2011), Lin and Hsu (2013) and Franco et al. (2016). Furthermore, the breast muscles of the caponised birds contained significantly less myristic (C14:0) and stearic acids (C18:0), which had an effect on the total SFA content. At the same time, the capons tended to have a higher UFA content. These differences were particularly evident in the leg muscles, where a significantly higher content of *n-6* and *n-3* PUFA was observed. These results are consistent with the findings of Tor et al. (2005), Franco et al. (2016) and Kwiecień (2015), but disagree with Sinanoglou et al. (2011), who showed different relationships for the above groups of fatty acids. The authors indi-

cated that the fatty acid profile of cockerel and capon muscles is influenced by bird genotype, diet, and age, whereas a reduced level of SFA and an increased content of MUFA and PUFA in poultry has beneficial effects on human health. In the present study, we obtained a much lower *n-6/n-3* PUFA ratio (beneficial from the standpoint of human nutrition) compared to MOS and SASSO X-44 chickens (Franco et al., 2016). Likewise, in the muscles of 25-wk-old capons and cockerels, the hybrids of broiler and laying hens, Sirri et al. (2009) showed a more favourable ratio of *n-6/n-3* acids in breast muscles (9.60 and 9.49, respectively) and leg muscles (11.79 and 11.76, respectively).

The SPME-GC-MS method can be used for VOCs analysis in meat coming from different species of animals (Gąsior and Wojtycza, 2016). The composition of these compounds depends on many factors, among them: breed, fodder type, maintenance method and gender. Moreover, the meat of local animal breeds is worthy of scientific investigation, because of its specific aromatic properties that are influenced by volatile compounds. In addition the latest research papers increasingly include the question of food products (e.g. cheese) authentication using VOCs analysis by GC-MS methods. In the present study the percentage value of correct classification for both meat groups was 100%, similar to the results presented by Majcher et al. (2015) for Oscypek cheese – a smoked cheese made of salted sheep milk exclusively in the Tatra Mouintains region of Poland (100%), and an Oscypek-like cheese produced from cow's milk (2 methods of classification accuracy: 93.1%, 96.6%).

Conclusion

In summary, the castration of Rhode Island Red cockerels (R-11) had a favourable effect on body weight, feed conversion per kg weight gain, dressing percentage and carcass muscling. The breast and leg muscles of the capons were characterised by better water-holding capacity, tenderness and sensory score compared to the uncastrated cockerels. In addition, the castration had a positive effect on the content of crude protein in both breast and leg muscles which, with a higher crude fat content were characterised by a more favourable profile of fatty acids, i.e. lower SFA and higher *n-6* and *n-3* PUFA content. It is also possible to differentiate the cockerels and capons using VOCs analysis by SPME-GC-MS method coupled with chemometrics.

Therefore, capon meat could be an attractive raw material in traditional Polish cuisine, and could supplement poultry meat production with a niche product for consumers who are looking for products of a special quality. In addition, the castration procedure may help to use surplus cockerels, which has an additional economic aspect.

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