

Comparison of Physicochemical and Sensory Properties of Breast Muscles of Capons from Different Breeds

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In Poland, after World War II, rearing capons has been reduced significantly as a result of the ban on the castration of birds. Currently, the castration of roosters is carried mainly in China, in the USA, in Taiwan as well as in France, Spain and Italy. In such countries as Spain, France or Hungary the production of capons contributes to the preservation of genetic poultry resources (Calik et al., 2015). In accordance with the Commission Regulation (EC) No. 543/2008 of 16 June 2008 the surgical castration is permitted, which has contributed to the increase in the number of breeders of specific breeds used for capons (Zawacka, 2014). According to the regulation quoted hereinabove, capons have to be fattened for minimum 77 days after castration and slaughtered at a minimum age of 140 days. At the same time the maximum permitted time limit for the birds rearing has not been specified. Notwithstanding, many authors have carried research concerning the quality of the capon meat of different breeds raised up to 24 weeks (Calik, 2015; Calik et al., 2017) and the comparison of the physicochemical characteristics of the breast and thigh muscles in roosters and capons of different ages, i.e. 16, 18 and 20 weeks of age (Adamski et al., 2016). The results obtained by Calik (2015) confirmed that the breast muscles of Yellow-legged Partridge capons and especially leg muscles were characterised by improved water keeping capacity and crispness, lower natural and thermal leakage and higher point notes of analysed sensory features. Furthermore, Calik et al. (2017) indicated a positive impact of the castration of Rhode Island Red (R-11) roosters on the slaughtering yield and muscular system of the carcasses and an increase in the share of general protein, higher water absorption, improved crispiness and sensory quality of breast and leg muscles as compared to the samples obtained from non-castrated roosters. In spite of a higher crude fat content in muscles, its quality is characterised by a more favourable profile of fatty acids, i.e. lower share of SFA and higher share of PUFA, mainly *n-6* and *n-3*. In the research by Adamski et al. (2016), it was noted that the meat of capons was characterised by a good nutritional value as determined by the basic chemical composition and physicochemical properties. In addition, the quoted authors stated that due to a high amount of inter fibre fat the meat is softer and, therefore, may be preferred by the consumers as compared to the meat of roosters. In turn, Diaz et al. (2010), at the same time, were interested in the determination of the impact of the breed and age (20, 24, 28 and 32 weeks) of capons on chemical composition and physicochemical properties of the breast and drumstick muscles. The quoted authors have demonstrated that the meat of Mos capons was characterised by a lower lipid content in the shank, lower water retaining capacity, higher natural leakage and it was brighter and less red than the meat of capons of Sasso T-44 and X-44 breeds. At the same time, the chemical composition, pH, water absorption, colour and texture of meat are significantly affected by the age of the capons, i.e. the breast and shank muscles of the youngest capons were characterised by a higher content of ash, higher value of pH, lower water absorption, higher natural loss and brightness and lower cutting force than the older birds. Tor et al. (2002) state that the capons with a longer period of breeding (i.e. 28 weeks) are heavier than non-castrated roosters. Lin and Hsu (2003) also observed the improvement in the quality of the meat (colour and cutting force) with the age of the capons. The birds after castration reach larger body weight in a shorter time and the obtained meat is

characterised by fine fibres and defatted. It is necessary to apply an appropriate diet, which causes layered and gradual depositing of fat in the muscles (Gogolewski and Czerwiński, 2012).

In accordance with the valid Regulation, the feeding of capons should be based, mainly, on livestock feed free from impurities and non-GM, with significant share of roughage. At the same time, approximately 70% of the feed ratio should include cereals (e.g. maize, wheat, oats and barley). It is also recommended to use several periods of rearing (2 or 3) which differ in the composition of feed ratio (Commission Regulation (EC) No. 534/2008). Research carried out by Tor et al. (2005), Chen et al. (2006), Sirri et al. (2009), Sinanoglou et al. (2011) and Volk et al. (2011) reveal that the ratio of fatty tissue is much higher and the accumulation of subcutaneous fat and intramuscular fat is more intense at the capons than at the roosters. Therefore, the muscle tissue is characterised by better sensory characteristics, i.e. juiciness, delicacy, crispness and taste, which makes the meat more attractive. According to research by Díaz et al. (2010), the chemical composition of the meat of capons does not depend on the breed and only certain parameters are changing to varying extent along with age. Considering the above information research has been carried in order to compare physicochemical parameters and sensory quality determinants of breast muscles at capons of Rhode Island Red, Leghorn and Green-legged Partridge breeds.

Materials and methods

The experimental material consisted of 11 Rhode Island Red (R-11, RIR) and Green-legged Partridge (Zk) and 10 Leghorn (Lg) breed roosters. The birds were bred in the Experimental Pavilion of the Faculty of General Commodity and Experimentation of UWM in Olsztyn to the age of 28 weeks and the mean weight of 2.99, 2.17 and 2.27 kg, respectively. Surgical castration of 32 roosters was carried in the 8th week of the birds' lives. Throughout the period, the capons were kept in a closed room in metal pens, on deep litter and were nourished *ad libitum* with full-ratio mixtures (1 to 8 weeks diet) and (9-28 weeks diet) containing, respectively: 18.77 and 20.88% of general protein, 2.81 and 3.64% of crude fat, 5.22 and 5.47% of crude ash, 2.51 and 2.55% of crude fibre and 11.64 and 11.94 MJ/kg. The composition of diet 1 and 2 included ground wheat grains, maize meal, soybean meal, rape meal, sodium chloride, calcium carbonate, monocalcium phosphate, DL-methionine, L-lysine HCl, L-threonine and mineral-vitamin premixture. Additionally, diet 2 included soybean oil in the amount of 2.60% (Zawacka et al., 2017, 2018). In the course of rearing the birds had identical zoohygenic conditions and unrestricted access to water. At the end of the fattening capons were starved for 24h prior to the slaughter. Afterwards, the slaughter and post-slaughter dressing was carried in accordance with the procedures observed in the poultry breeding industry (Council Regulation (EC) No. 1099/2009). During the 15 minutes and 24h *post mortem* in the left breast muscle (*m. pectoralis*) of the carcasses pH was measured with a pH meter 340i with temperature sensor TFK 150/E WTW. After the post-slaughter processing the carcasses were chilled in a refrigeration rack made by FROST at the temperature of 4±1°C and the relative air humidity of c. 85% for 24 h. Next, the carcasses were separated technology in order to collect the individual dissectional elements.

The research material amounted to total 32 left breast muscles (*m. pectoralis*) obtained from 32 capons, of good quality, namely, pH₁₅ value ranged from 5.90 to 6.20 (elimination of muscles with PSE and DFD defects). The external adipose tissue and membranes were removed from the surface of the muscles in order to ensure the proper preparation of individual samples for laboratory analyses. Next, the quantitative and qualitative analyse were performed in the Laboratory of the Meat Quality Evaluation by the Faculty of Commodity Science and Animal Material Processing which included, as follows:

- the measurement of muscle tissue reaction (ground sample) made in the meat aqueous homogenate (pH_u), assuming a quantitative ratio of meat to redistilled water in the ratio of 1:1 (PN-ISO2917:2001/Ap1:2002). To perform this, a pH meter 340i with temperature sensor TFK 150/E, made by WTW, fitted with combined glass electrode (Double Pore) by Hamilton was used. Before the measurements the device was calibrated according to buffers with known pH;

- the thermal leak marking (Honikel, 1998) by pasteurizing of a weighed meat sample (c. 50 g) in string plastic bags (PE), immersed in a water bath at the temperature of 80°C for 50 minutes. The sample was then chilled (30 minutes) in a stream of cold water, dried and weighed to the nearest 0.01 g on the electronic scales. The value of the thermal leak (%) was determined by calculating the difference between the mass of the meat sample before and after the heat treatment;
- water absorption marking by Grau and Hamm's method (Van Oeckel et al., 1999) by placing the ground sample (c. 300 mg) on a blotting paper Whatman no. 1. The blotting paper along with the sample were placed between two glass plates and pressed with the load of 5 kg for 5 minutes. After the expiration of the assumed pressing time, the boundaries of the area occupied by the meat sample and the leakage of the meat juice were marked on the blotting paper, which was then planimeterised. The measure of the size of the forced leakage of meat juice was the difference in both areas, which was multiplied by 0.3 g and converted into the weight - it was the result that allowed the interpretation of water absorption (cm²) (the higher value - the less water absorption of meat);
- the muscle colour characteristics based on the values of L*, a* and b* parameters in the CIE LAB system (CIE, 1978) by reflection method using the HunterLab MiniScan XE Plus apparatus through a direct 3-fold measurement of their surface at the same 3 measurement points. A light source D₆₅ and standard colorimetric observer of the field of view of 10° was used. The measurements were carried after half an hour retention of the muscles at the temperature of 4°C. Before each measurement session the apparatus was calibrated according to the white and black pattern;
- the assessment of sensory characteristics referred to on the samples treated in 0.62% NaCl solution (weight ratio of the solution to the sample of meat 2:1) at the temperature of 96°C until the inside of the sample temperature 80°C is obtained (according to the method of Baryłko-Pikielna and Matuszewska, 2009). In the assessment of meat carried by a 5-person team with proven sensory sensitivity, a 5-point rating scale extended with half-marks was applied (PN-ISO 4121: 1998), considering the following qualitative characteristics: aroma, juiciness, crispness and palatability. For individual characteristics, each grade level was assigned to the appropriate quality definition (1-poor, 2-insufficient, 3-sufficient, 4-good, 5-very good).

The obtained results were subjected to statistical analysis, enumerating basic measures (\bar{x} , s). The significance of differences between the results of the examined features in individual experimental groups was determined by means of one-way analysis of variance and Tukey's test for various N, using the licensed computer program, Statistica, version 13.1 (StatSoft Inc., 2011).

The results and their discussion

An important factor that determines the direction of biophysicochemical transformations is the reaction of meat, which is also an indicator of the diversity of the quality and technological suitability of the raw material, as well as a factor that inhibits the growth of bacterial microflora. The genetic and environmental factors as well as *ante-mortem* treatment of animals have a big influence on the changes of the acidity of the muscle tissue, however, the colour, water absorption, crispiness and taste of the meat depend on this parameter. The processing quality is determined by the physicochemical properties of meat, such as free, thermal and forced leakage. According to Choi et al. (2016), Ormian et al. (2015) and Skomoruchy and Sosnowka-Czajka (2015) thermal losses are undesirable due to the loss of soluble ingredients and the reduction of meat juiciness. The amount of losses during the meat heating depends on the temperature and processing time but also on the input water and fat content in the meat. Barbanti and Pasquini (2005) proved that a short heat treatment time and lower temperature result in lower loss during this process. In own research (tab. 1) it was confirmed that the ultimate acidity (pH_u) of breast muscles depends on the breed of capons. It has been proven that the breast muscles of the Leghorn and Green-legged Partridge breeds have a significant ($P \leq 0.01$) higher pH_u value, i.e., respectively: 6.14 and 6.04 and thermal leakage - 27.49% on average. It was noted that significantly

($P \leq 0.01$) the highest water absorption (0.42 cm^2) and, therefore, the best ability to keep own and added water, was characterised by the muscles of Green-legged Partridge capons as compared to other meat samples.

The colour is an important parameter determining the technological usefulness of meat as a raw material (Marcinkowska-Lesiak et al., 2013, Ormian et al., 2015). The content of haem dyes depends on the genotype of birds, age, sex, nutrition, muscle type and activity, and the colour depends mainly on the content of myoglobin and intramuscular fat (Augustyńska-Prejsnar and Sokołowicz, 2014). These factors also have a direct impact on the acidity of the meat, which, in turn, is closely related to the ability to retain water (Fleather, 2002). On the basis of the obtained data, a significant ($P \leq 0.01$) influence of the capon breed on the brightness of their muscles was found. The lightest breast muscle samples were obtained from the RIR capons ($L^* = 59.20$), and the darkest from the Green-legged Partridge, as evidenced by the average value of $L^* = 54.82$. The highest share of red colour at the level of $a^* = 7.11$, which corresponded to a low L^* value, was recorded in the case of muscles obtained from Zk capons while the lowest value of the trichromatic yellow in the capillary muscles of Leghorn breed capons $b^* = 16.74$.

Table 1. Physicochemical properties of breast muscles of capons depending on the breed (mean \pm SD)

Item	Capons			P-value
	Rhode Island Red (n=11)	Leghorn (n=10)	Greenleg Partridge (n=11)	
$pH_{ultimate}$	5,87 B \pm 0,06	6,14 A \pm 0,11	6,04 A \pm 0,09	$\leq 0,001$
Thermal loss (%)	25,47 B \pm 0,35	27,20 Ab \pm 0,35	27,79 Aa \pm 0,33	$\leq 0,001$
Water holding capacity (cm^2)	1,05 A \pm 0,13	1,02 A \pm 0,04	0,42 B \pm 0,32	$\leq 0,001$
Colour parameters:				
L^* – lightness	59,20 A \pm 0,21	55,83 B \pm 0,35	54,82 C \pm 0,23	$\leq 0,001$
a^* – redness	6,58 B \pm 0,17	6,33 B \pm 0,22	7,11 A \pm 0,17	$\leq 0,001$
b^* – yellowness	17,98 A \pm 0,26	16,74 B \pm 0,24	17,39 A \pm 0,35	$\leq 0,001$

Means values in rows denoted by different letters differ statistically significantly: A, B, C – at $P \leq 0.01$; a, b – at $P \leq 0.05$.

According to studies by Volk et al. (2011), the procedure of caponisation on day 52 did not affect the changes in acidity, brightness and yellow colour share measured at the cross-section of breast muscles of Prelux-G roosters and capons, bred for 185 days in the ecological farming system. The quoted authors proved that the pH of the capon muscles was 5.88 while the values of the colour parameters were at the level of: $L^* = 46.2$, $a^* = 17.8$ and $b^* = 9.3$. Amorim et al. (2016) revealed significant differences in the red colour of meat of 20-week old capons ($a^* = 12.9$) and roosters ($a^* = 9.32$). Sirri et al. (2009), however, obtained lower pH_u (5.71) and thermal leakage (20.50%) values of breast muscles of Hubbard x Golden Comet cross-breeds than in own study. According to the above authors, the muscles were also characterised by lower values of the colour parameters, namely: $L^* = 53.58$, $a^* = 1.70$ and $b^* = 12.34$. In research carried out by Miquel et al. (2008) breast muscles of 29 weeks old Castellana Negra Capons were characterised by lower water absorption (6.19 cm^2) and pH_{24} value at the level of 5.90. In studies carried out by Adamski et al. (2016) it was proved that the values of brightness and red colour of breast muscles at 20 weeks old Sussex (S-11) capons and roosters were similar and were, on average, 52.54 and 0.63. In the case of yellow colour, this value was lower at capons by 0.75 in relation to the muscles of roosters ($b^* = 11.59$) analysed by the author. According to Calik et al. (2017), breast muscles of 24 weeks old RIR (R-11) capons were characterised by lower thermal leakage than in their own research (22.05%) and higher brightness value ($L^* = 62.61$) and red colour ($a^* = 10.22$) as well as lower share of yellow colour ($b^* = 9.73$) measured on the inside surface of the samples. Calik et al. (2015) proved, on the other hand, that the breast muscles of 24 weeks old Zk capons were characterised by lower thermal leakage than in their own research (22.05%) and higher brightness value ($L^* = 62.61$) and red colour ($a^* = 10.22$) as well as lower share of yellow colour ($b^* = 9.73$) measured on the inside surface of the samples.

rised by low thermal leakage (16.11%), higher brightness (55.44) and red colour share (9.46) and lower yellow component value (9.13) measured on the internal surface as compared to own results. Research carried by Calik et al. (2015, 2017) confirmed that the breast muscles of Zk and RIR capons were characterised by a more favourable water absorption, with a tendency for less water loss and lower losses during heat treatment. Diaz et al. (2010) found that the breast muscles of 28 weeks old Mos, T-44 and X-44 capons were characterised by low thermal leakage, on average at the level of 18.7% while the measurement performed on the cross-section of the muscles confirmed their darker colour ($L^*=44.9$) with a low share of red ($a^*=0.53$) and yellow ($b^*=5.87$) components. A comparison of own research with the results obtained by the authors quoted above showed that the thermal leakage was much higher and the water absorption was better in all the analysed muscles obtained from capons (RIR, Lg and Zk). The samples were characterised by a bright colour with a high share of red and yellow components as evidenced by the obtained average values, amounting to 56.62, 6.67 and 17.37, respectively. Similar results to own were characteristic for ground breast muscles of 26 weeks old Hinai-jidori capons analysed by Rikimaru et al. (2009), with L^* value of 56.5, and the trichromatic a^* and b^* shaped at the level of 5.5 and 14.8, respectively. A similar trend in the brightness values ($L^*=52.23$) and red ($a^*=6.31$) and yellow ($b^*=13.23$) components measured on the outer surface of breast muscles of 26-, 30- and 34-week old Lohmann Silver capons, with a low mean intramuscular fat content (1.19%), were obtained in their research by Symeon et al. (2012). It has been noted that the muscles of RIR, Lg and Zk capons are characterised by a much lighter and more yellow colour, and this correlation is also confirmed in their studies by Symeon et al. (2010), Miguel et al. (2008), Sirri et al. (2009) and Adamski et al. (2016). The observed differences between physicochemical parameters (water absorption, thermal leakage and colour) of breast muscles of capons of the three analysed breeds as compared to the results of research by other authors (Díaz et al., 2010, Volk et al., 2011, Calik et al., 2015, 2017) may result from the method of preparation of the samples for marking, the conditions and the place of measurement in the case of colour and use of other breeds, feeding methods, castration dates and the length of rearing. On the other hand, the high value of the trichromatic yellow colour could have resulted from the significant under and intramuscular fat of capons as well as the measurement made on the outer surface of the breast muscles after removing the skin.

According to Augustyńska-Prejsnar and Sokołowicz (2018), the sensory characteristics of meat depend mainly on the age of slaughtered birds, environmental factors and methods of thermal processing, which is an essential determinant affecting the formation of a specific meat flavour-aroma profile. The concentration of flavour precursors increases with the age of birds, reaching the peak after the sexual maturity, which is why the meat of older birds has a more intense, and more characteristic aroma and taste. In the carried experiment, there were no statistically significant differences between the analysed capon muscles with respect to sensory characteristics (Tab. 2). Nevertheless, in the evaluation of the sensory panel, the intensity and desirability of the aroma and the tastiness of the Zk capon muscles obtained the highest notes: 4.00 and 4.05 and 3.88 points, respectively. The sensory quality level obtained at our own research - regardless of the breed of capons - could be influenced by the conditions for meat preparation for the determinations, namely: time, temperature inside the samples and temperature of the heating medium, low intramuscular fat content and hydration status of the muscle tissue. In the available literature, the method of heat treatment of capon breast muscles or legs presented by the authors varies and consists in boiling, baking or frying at the temperature range from 80 to 180°C for 50 minutes to 1 hour, which may translate into significant variability in the quality assessment by the sensory panel. Additionally, many authors undertake research on the impact of caponing and the comparison of sensory quality of breast muscles with leg muscles between capons and roosters within one breed or the influence of the age of slaughtering capons on physicochemical changes and meat texture measured instrumentally. Therefore, different conditions of assumed experiments (bird breed, diet, age of caponisation and slaughter, muscle type, cooling or freezing of samples and measurement methods) have a significant impact on the obtained results and make it impossible to compare the same characteristics even for the same breed.

Table 2. Sensory quality of breast muscles of capons depending on the breed (points)(mean \pm SD)

Item	Capons			P-value
	Rhode Island Red (n=11)	Leghorn (n=10)	Greenleg Partridge (n=11)	
Aroma – intensity	3,89 \pm 0,59	3,88 \pm 0,46	4,00 \pm 0,55	0,900
Aroma – desirability	3,93 \pm 0,66	3,88 \pm 0,46	4,04 \pm 0,51	0,852
Juiciness	3,29 \pm 0,77	3,13 \pm 0,63	3,13 \pm 0,59	0,874
Tenderness	3,39 \pm 0,56	3,28 \pm 0,53	3,46 \pm 0,58	0,831
Palatability – intensity	3,43 \pm 0,79	3,25 \pm 0,78	3,88 \pm 0,49	0,284
Palatability – desirability	3,25 \pm 0,78	3,25 \pm 0,78	3,88 \pm 0,49	0,218

No statistically significant differences.

According to Calik et al. (2015), breast muscles of the Zk capons were characterised by a good quality in terms of such qualitative factors as aroma, juiciness, crispness and taste, as evidenced by high notes at the level of: 4.45, 4.35 and 4.60 points. In the studies of Calik et al. (2017), it was proved that breast muscles of RIR (R-11) capons had significantly higher point notes in the case of aroma (4.65), juiciness (4.35), crispness (4.30) and taste (4.60) as compared to own results. Miguel et al. (2008) showed that the breast muscles of the 29-week-old Castellana Negra capons were characterised by a significantly better juiciness (5.29 points) and an increased amount of connective tissue (3.46 points) and fibrousness (3.74 points) as well as worse taste intensity (5.89 points) as compared to rooster meat. The results obtained by Rikimaru et al. (2009), Sirri et al. (2009) and Lin and Hsu (2013) confirmed higher crispness of capon meat as compared to rooster meat. At the same time, the authors indicated that the increase in intramuscular fat content contributes to the greater crispness of meat and contributes to the improvement of sensory characteristics, mainly juiciness, crispness and taste. Additionally, the fat in the muscles reduces the drying of muscle tissue during heat treatment and increases the perception of juiciness. According to Castellini et al. (2008), different muscles of the same bird differ in taste, namely the muscles of the legs are characterised by a stronger aroma than the less active breast muscles which also contain less intramuscular fat. According to Augustyńska-Prejsnar and Sołowicz (2018), the collagen content and the thickness of muscle fibres increase with the age of birds, which results in lower crispness.

Summary and Results

1. It has been found that the muscles of the Leghorn and Green-legged Partridge capons are characterised by significantly lower acidity, higher thermal leakage and darker colour as compared to the muscle samples obtained from RIR capons.
2. At the same time, it was noted that significantly lower water absorption and a lower value of the red colour parameter are found in the breast muscles of RIR and Leghorn capons.
3. Despite the lack of statistical differences between the average point notes for individual sensory characteristics, the muscles of the Green-legged Partridge capons were of good quality in terms of intensity and desirable aroma.
4. The obtained results provide valuable information about the shaping of the quality of the breast muscles obtained from capons of different breeds and their use in the poultry industry, storage, distribution and retail sale.

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COMPARISON OF PHYSICOCHEMICAL AND SENSORY PROPERTIES OF BREAST MUSCLES OF CAPONS FROM DIFFERENT BREEDS

Summary

The aim of the study was to evaluate the physicochemical parameters and sensory quality of breast muscles of capons from three breeds. The experimental material consisted of 11 Rhode Island Red (R-11, RIR), 11 Greenleg Partridge (Zk) and 10 Leghorn (Lg) cocks which were reared up to the age of 28 weeks. The surgical castration of 32 cocks was carried out in the 8th week of birds' life. Throughout the study capons were kept in a closed room in a metal cage, on deep litter and fed *ad libitum* with commercial feeding mixtures. During rearing the birds were provided with the same environmental conditions and free access to water. At the end of fattening capons were subjected to a 24-hour preslaughter fasting. The slaughter and post-slaughter processing were carried out at a poultry processing plant in accordance with Council Regulation (EC) No 1099/2009. The carcasses were chilled in a chilling chamber at $4\pm 1^{\circ}\text{C}$ and 85% relative humidity for 24 h. The research material included 32 left breast muscles obtained from 32 capons, which were of normal quality, with pH_{15} values ranging from 5.90 to 6.20. Then, quantitative and qualitative analysis was carried out in the laboratory, which included: determination of ultimate acidity (pH_u), thermal loss, water holding capacity, muscle colour based on L^* , a^* , b^* parameters in the CIELAB system and sensory assessment on a 5-point scale (PN-ISO 4121:1998).

It was found that the breast muscles of the Lg and Zk capons were characterized by significantly lower acidity, higher thermal loss and darker colour compared to the samples obtained from the RIR breed. Simultaneously, it was noted that significantly lower water holding capacity and lower redness was characteristic of the breast muscles from RIR and Lg capons. Despite the lack of statistical differences between the average scores for individual sensory features, the muscles of Greenleg Partridge birds were characterized by good quality in terms of aroma intensity and desirability.

Key words: capons, breed, breast muscles, physicochemical properties, sensory quality