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EFFECT OF AGE AND GENOTYPE OF NATIVE BREED COCKERELS ON CARCASS AND MEAT QUALITY*

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Abstract

The aim of the study was to determine meat quality in cockerels of two multipurpose breeds reared to different ages. The study involved 30 cockerels each of two native breeds: Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11). The results showed that cockerels of the native breeds Rhode Island Red (R-11) and Yellowleg Partridge (Ż-33) represent a good starting material for niche production of poultry meat. R-11 cockerels exhibited a better rate of weight gain and their carcasses had higher yellowness and redness values compared to Ż-33 birds. The carcasses of both cockerel breeds had lower breast and higher leg muscle percentage, and their meat contained more collagen and protein and less fat. As birds aged, body weight and abdominal fat percentage increased, and giblets percentage decreased in the cockerels of both breeds, whereas in the R-11 breed dressing percentage increased, leg bone percentage decreased, yellowness (a*) increased and redness (b*) decreased. Neither genotype nor slaughter age had a significant effect on chemical composition of the breast and leg muscles. In both breeds, the breast and leg muscle quality traits were more affected by age than genotype.

Key words: slaughter cockerels, meat quality, native breeds

Commercial poultry meat production in Poland is based on intensive production of broiler chickens, namely commercial hybrids intended solely for meat production, which reach over 2500 g of body weight at around 35 days of age. Due to a continuous shortening of the rearing period, the meat obtained from chickens for slaughter is less mature and has poorer sensory and technological properties compared to the meat of slow-growing chickens, in particular chickens of native breeds (Połtowicz and Doktor, 2012; Tougan et al., 2013).

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The development of single-purpose production of chickens has marginalized dual-purpose production, thus supplanting native chicken breeds. Research has shown that native breeds of hens and slow-growing chickens provide good quality meat, which is in increasing demand (Smith et al., 2012; Walley et al., 2015). In South Korea, meat from locally bred chickens is considered as therapeutic food (Choo and Chung, 2014). Some of the important factors affecting the quality of meat from native chickens include age at slaughter, genotype and sex. In experiments with slow-growing capons and chickens, Díaz et al. (2012) and Połtowicz and Doktor (2012) found that as the birds aged, their body weight increased significantly, carcass muscling improved, but meat tenderness deteriorated. Tougan et al. (2013) observed significant changes in chemical composition of meat in local breeds of cockerels and chickens as they aged. In turn, in a study on fattening of layer cockerels of two genotypes, Koenig et al. (2012) noted better weight gains and muscling in medium heavy compared to light genotypes. Youssao et al. (2012) and Riedel et al. (2013) confirmed the commonly observed higher weight gains in cockerels than in pullets, while indicating that the body weight of native breed chickens can be increased by crossing with meat-type cockerels. Faraji-Arough et al. (2019), fitting in the trend of the latest research on the use of native breeds for meat production, attempted to construct growth curve models for use in early selection of birds. Poland has no native breeds of meat hens; instead, several multipurpose breeds/lines are available, among which 90% of cockerels are largely liquidated after hatching as redundant breeding stock, which raises ethical concerns. The use of cockerels of the native breeds of multipurpose hens as chickens for slaughter, restores the traditional fattening in Poland in the first half of the 19th century, where all cockerels obtained from spring hatchings served as a handy pantry in peasant farms during the summer period (Potemkowska, 1964). Cockerels were reared in outside runs for around 90 days, because later on they converted the feed less efficiently. Cockerels had to be slaughtered before sexual maturation because increased secretion of reproductive organs has an adverse effect on meat quality. This information as well as the increased consumer interest in meats alternative to broiler meat have inspired us to conduct the present study.

Because native breed hens can adapt to more demanding housing conditions, they are recommended for backyard farming. This is consistent with the widespread opinion that practical use of hens is one of the better ways of protecting them against extinction. Among the native breeds of multipurpose hens in Poland, Yellowleg Partridge and Rhode Island Red cockerels have specific characteristics that make them especially suited to be used as birds for fattening, which motivated us to choose these breeds for the present study. The populations of these breeds and their unique traits have been registered by FAO as protected genetic resources (World Watch List, FAO, 2000). Detailed characteristics of the breeds as well as the method of conservation breeding, in which birds are not selected for improved performance traits, are included in conservation programmes available at www.izoo.krakow.pl. The birds of these breeds have the genetically determined yellow carcasses and better weight gains compared to other populations conserved in Poland. It follows from both historical records and our research that the meat of 56-week-old hens of some native breeds is characterized by very good nutritive value (Puchała et al., 2014). In the breast muscles from these birds, crude protein exceeds 24% and is higher than in young chickens for slaughter (Wattanachant et al., 2004). The meat of intensively reared broiler chickens is not good for making broths due to the low solubility of collagen fibres. Puchała et al. (2014) demonstrated that the meat of one-year--old multipurpose hens is suitable for making broth which received high sensory scores.

The Yellowleg Partridge breed (Ż-33) was obtained in the 1960s by crossing light hens of the oldest native breed Greenleg Partridge and heavy New Hampshire cocks with yellow skin. This resulted in chickens with valuable meat characteristics, and the average body weight of the cockerels at 20 weeks of age ranges from 1.85 to 2.3 kg depending on the diet. Rhode Island Red (R-11) birds (popularly known as karmazyny in Poland), which constituted more than 60% of the hen population used for production of eggs and poultry meat before the Second World War, are highly popular with small farmers because in addition to good laying performance they are characterized by yellow carcasses, good muscling and very good meat quality. This breed was developed in the second half of the 19th century in the State of Rhode Island (USA), and the R-11 line was brought into Poland from Great Britain before the Second World War. These birds are not fearful and have reddish-brown feathers. The average body weight of the cockerels at 20 weeks of age ranges from 2.00 to 2.50 kg depending on the diet.

In Germany, over 40 million of 1-day-old cockerels that are hatchery waste, are slaughtered annually. Few studies in the literature investigated the use of these cockerels as slaughter chickens with good quality meat, which is economically less profitable compared to raising typical meat breeds (Lichovniková et al., 2009; Koenig et al., 2012; Siekmann et al., 2018). The demand for meat from slow-growing chickens, such as laying-type cockerels, is limited by high price, which is mainly due to feeding costs during the long rearing period (Youssao et al., 2012). Therefore, in the present study we shortened the rearing period to 16 weeks, when cockerels of the studied breeds enter sexual maturation and their body weight is around 2 kg, which is similar to that of broiler chickens. A preliminary hypothesis was formulated that the meat from 16-week-old cockerels will be tasty and of good quality, and the feed costs will considerably decrease. It was also assumed that a comparison with the meat from other slow-growing chickens (including native breeds) will show differences that may be important for consumers. One innovation of the present study is the objective assessment (using modern tools) of meat quality in cockerels before maturation (week 16) compared to mature 20-week-old cockerels. Our study fits in the current trend to develop extensive production of poultry meat under sustainable farming conditions. The use of native breeds of birds will also result in region promoting products.

The aim of the study was to determine meat quality in cockerels of two multipurpose breeds reared to different ages. The results of the study provide valuable information about the possibility of using surplus cockerels chickens of the two native multipurpose breeds for meat with specific quality parameters, which may provide an alternative to broiler chicken meat.

Material and methods

Birds, maintenance and diets

The study involved 30 cockerels each of two native breeds: Yellowleg Partridge (Ż-33) and Rhode Island Red (R-11). Cockerels were kept on litter in a confinement house, at a stocking density of 7 birds/m^2. From 10 weeks of age, a room temperature of 15 to 25°C and a relative humidity of 60 to 70% were maintained. Cockerels received diets formulated specifically for this study. Birds were fed *ad libitum* with a complete starter diet (20.4% CP and 11.92 MJ) from 0 to 7 weeks, a grower diet (18.4% CP and 12.09 MJ) from 8 to 13 weeks, and a finisher diet (16.5% CP and 12.18 MJ) from 14 weeks. Over the course of the experiment, data on mortality and feed consumption were recorded but not statistically analysed. All birds were marked with wing tags and individually weighed once a week. The experimental procedures were compliant with requirements set by the Bioethics Committee No. 1122 of 27 November 2014.

Collection of samples

At the end of the rearing period (16 and 20 weeks), 8 birds were selected out of each group, with body weight similar to the mean of the group. Prior to slaughter, the cockerels were subjected to 12-hour feed withdrawal but had continuous access to water during this period. The birds were weighed before the slaughter, slaughtered, and their pH was measured 15 minutes postmortem (breast – *pectoralis major* muscle and thigh – *biceps femoris* muscle). All carcasses of birds were weighed after gutting and then chilled at 4°C. After 24 hours of cooling, the whole carcasses were subjected to simplified slaughter analysis according to Ziołecki and Doruchowski (1989) after specifying their colour (whole carcass with skin) and pH_{24}. Whole breast and leg muscles were dissected, from which samples were taken for the tests and analyses described below. Next, samples of the breast muscle and leg (thigh) muscles were collected from each whole carcass to determine their colour, water holding capacity, drip loss, cooking loss, and tenderness. The chemical analysis of these muscles was also performed and cholesterol, collagen, crude fat and crude protein were determined.

Analytical methods

pH measurement

The pH measurement of the breast muscles and leg (thigh) muscles was performed using the CyberScan 110 pH meter (Eutech Instruments Pte Ltd/Oakton Instruments) with a Hamilton glass electrode calibrated at pH 4.0 and 7.0.

Colour measurement

The colour of the cockerel carcasses and muscles was determined according to L*a*b* scale (CIE, 2007) using a Minolta CR 310 (Konica Minolta Holdings, Inc., Japan; light source D65, observer 2°) reflectance spectrophotometer, where L* means lightness, positive a* value is redness, and positive b* value is yellowness. The colour result is the mean of five whole carcass 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 (*pectoralis major*) muscle and 2 femoral (*biceps femoris*) muscle measurements taken on the inner surface immediately after bone separation.

Water holding capacity (WHC) measurement

WHC of breast muscles and leg (thigh) muscles was determined using the Grau and Hamm method (1953), based on the amount of juice mechanically pressed from the sample into a filter paper (Whatman Grade No. 1, Cat No 1001 917, UK Limited), and the expressible juice area was estimated using a planimeter (Haff Digital Polar Planimeter No. 301, Germany).

Drip and cooking loss determination

The meat juice loss was determined after storing the samples of breast and thigh muscles for 24 hours at +4°C. In order to do so, 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 drip loss was calculated according to the formula:

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

Cooking 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 cooking loss was calculated according to the formula:

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

Shear value determination

The measurement of muscle tenderness was performed using texture analyser TA.XT.plus (Stable Micro Systems Ltd, Godalming, Surrey, UK). In order to do so, a sample 10 mm in diameter and 30 mm in height, was cut out from the cooked breast and thigh muscles (85°C). The collected sample was cut with a Warner-Bratzler knife (2 mms^{-1}) in three places, perpendicular to the direction of muscle fibers, while providing the final measurement result as a mean value.

Chemical analyses

Samples of breast and thigh muscles were collected from birds of each group in order to determine the chemical composition, i.e. the contents of total dry matter, crude protein (Kjeldahl method), crude fat (Soxhlet method) and collagen 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 National Research Institute of Animal Production in Aleksandrowice (Poland).

Statistical analysis

Feed conversion and mortality were analysed collectively. Statistical differences between cockerel genotypes in body weight at 2-week intervals were calculated using one-way analysis of variance, and the other data were analysed by two-way analysis of variance (genotype × slaughter age). Significant differences between the means were estimated with Duncan's test (Statistica 6.0). The statistical analysis involved the determination of arithmetic means (x) and standard deviation (SD) for the traits analysed in the study.

Results

No mortality occurred during the experiment. Feed conversion (kg feed/kg gain) was 4.43 kg (Ż-33) and 4.41 kg (R-11) up to 16 weeks, and 8.66 kg (Ż-33) and 8.67 kg (R-11) up to 20 weeks.

As is evident from Table 1, R-11 cockerels achieved significantly higher body weight compared to Ż-33 cockerels at both 16 and 20 weeks of age. The rate of weight gain in Ż-33 cockerels was higher than in R-11 birds up to 10 weeks, but later this trend was reversed and R-11 cockerels achieved higher body weights, by 106 g at 16 weeks and by 208 g at 20 weeks.

Table 1. Body weight of cockerels (g) from 0 to 20 weeks

Week of age	n	R-11 (mean±SD)	Ż-33 (mean±SD)	P-value
0	60	40.3±3.19	37.7±2.02	<0.001
2	60	70.5±7.44	70.0±6.92	0,802
4	60	183.1±31.0	194.2±25.7	0,133
6	60	363.1±74.4	400.2±62.4	0,041
8	60	656.3±141.7	709.5±83.1	0,081
10	60	949.7±182.5	977.3±87.2	0,458
12	60	1360.3±181.9	1291.3±136.2	0,102
14	60	1774.8±181.1	1668.3±131.7	0,012
16	60	2040.0±175.9	1826.3±145.5	<0.001
18	16	2277.5±52.8	2102.5±95.2	<0.001
20	16	2490.0±122.3	2282.5±158.0	0,011

Notes: R-11 – Rhode Islands Red cockerels; Ż-33 – Yellowleg Partridge cockerels;

Regardless of bird genotype and age, carcass lightness (L*) was similar, but redness (a*) was higher in R-11 (P≤0.01) compared to Ż-33 birds (Table 2). With the advancing age of cockerels, their carcasses were characterized by higher redness (a*).

Carcass yellowness (b*) was also influenced by slaughter age and genotype. Carcass chilling loss was influenced by both genotype and age at slaughter. Carcass weight loss during chilling was higher in Ż-33 cockerels, and at 20 weeks it was lower than at 16 weeks whatever the genotype. Carcass yield without giblets increased with the age of the birds and was influenced by age, genotype, and by both these factors. Carcass yield without giblets at 16 weeks was at a similar level in both the R-11 and Ż-33 breeds, and at 20 weeks this trait increased significantly in R-11 cockerels. The percentage of breast muscles and leg muscles was similar in the two breeds at both 16 and 20 weeks, with small and non-significant differences. With advancing age, breast muscle percentage decreased slightly regardless of genotype. A similar trend was observed for the leg muscles of R-11 cockerels, while in Ż-33 birds leg muscle percentage increased slightly at 20 weeks, but the differences were not significant. Giblets percentage was similar in both breeds at 16 weeks, but at 20 weeks it was higher in Ż-33 compared to R-11 cockerels. Regardless of genotype, 20-week-old cockerels had lower giblets and leg bones percentage, and higher abdominal fat percentage compared to 16-week-old birds (Table 2).

Table 2. Carcass colour, carcass weight loss during chilling, and dressing percentage of cockerels

Item	Age (weeks)	Breed (mean±SD)		P-value		
		R-11	Ż-33	Age	Breed	Interaction A×B
Carcass colour L*	16	67.3±2.16	68.4±7.26	0.414	0.317	0.524
	20	68.3±2.61	68.5±2.45			
Carcass colour a*	16	5.62±1.31	3.59±1.16	0.003	<0.001	0.414
	20	6.57±1.57	4.13±2.14			
Carcass colour b*	16	16.7±3.65	15.5±4.72	0.158	0.533	<0.001
	20	13.3±3.88	17.1±4.42			
Carcass weight loss during chilling (%)	16	6.61±0.592	7.26±0.447	<0.001	0.004	0.939
	20	5.23±0.368	5.85±0.790			
Carcass yield without giblets (%)	16	68.4±1.37	68.6±1.88	0.001	0.033	0.018
	20	72.2±1.39	69.2±2.23			
Breast muscle %	16	15.09±1.35	15.3±1.05	0.488	0.897	0.791
	20	14.8±2.73	14.7±1.06			
Leg muscle %	16	22.8±1.74	21.3±1.11	0.838	0.702	0.136
	20	20.5±6.91	23.0±1.00			
Giblets %	16	4.55±0.488	4.76±0.341	<0.001	0.016	0.280
	20	3.62±0.255	4.14±0.470			
Leg bones %	16	7.22±0.671	6.42±1.17	0.009	0.076	0.373
	20	6.15±0.679	5.88±0.633			
Abdominal fat %	16	0.342±0.25	1.05±0.88	0.005	0.211	0.189
	20	1.53±0.61	1.51±1.06			

For explanation see Table 1.

The pH of breast muscles, measured 15 min postmortem, was similar in both groups at 16 weeks, and lower at 20 weeks (Table 3). The acidity of breast muscles pH_{24h} postmortem was higher in group Ż-33 than R-11 for both young and older cockerels. With advancing age, both groups of birds showed a decrease in this parameter. Drip loss of breast muscle after 24 h of chilling was similar in both groups, but this measurement decreased significantly in older compared to younger cockerels. No significant differences were noted in water holding capacity (WHC), cooking loss and muscle tenderness measured by shear force, both between cockerels of different genotypes and between their slaughter age. Lightness of breast meat (L*) was influenced by age, genotype, and by both these factors, while redness (a*) was affected by age and both factors, and yellowness (b*) by genotype only (Table 3). As cockerels aged, lightness (L*) decreased and redness (a*) increased in group R-11. In group Ż-33, redness (a*) decreased significantly with the age of the cockerels.

Table 3. Physical traits of cockerel breast muscle (*m. pectoralis major*)

Item	Age (weeks)	Breed (mean±SD)		P-value		
		R-11	Ż-33	Age	Breed	Interaction A×B
pH_{15min}	16 20	6.37±0.147 5.94± 0.524	6.19±0.188 6.07±0.266	0.230	0.804	0.173
pH_{24h}	16 20	5.62±0.092 5.56±0.081	5.82±0.075 5.68±0.141	0.008	0.001	0.318
Drip loss after 24 h (%)	16 20	0.780±0.209 0.426±0.174	0.679±0.257 0.435±0.176	<0.001	0.536	0.458
WHC (%)	16 20	16.93±1.97 15.32±2.27	14.84±3.35 14.88±3.16	0.441	0.743	0.923
Cooking loss (%)	16 20	22.69±1.82 23.42±1.94	24.38±2.03 23.74±2.78	0.957	0.201	0.380
Shear force (N)	16 20	18.05±5.23 18.10±3.84	17.99±5.95 19.62±9.14	0.188	0.844	0.178
Muscle colour L*	16 20	60.7±3.48 53.5±2.95	55.5±3.93 54.6±4.09	<0.001	0.033	0.001
Muscle colour a*	16 20	11.3±1.73 14.7±2.63	14.4±5.78 13.9±2.24	0.007	0.179	0.012
Muscle colour b*	16 20	11.2±2.37 9.92±2.09	9.35±5.58 11.4±1.24	0.084	0.041	0.422

For explanation see Table 1

As is clear from Table 4, most physical traits of cockerel thigh muscle (*m. biceps femoris*) was influenced by the age at slaughter, while the effect of genotype was small and statistically not significant. There were no significant differences in water holding capacity of thigh muscles and in cooking loss between cockerels of different genotypes and between their slaughter ages. With the advancing age of cockerels, both breeds showed a decrease in thigh muscle tenderness (P≤0.01). The differences in thigh muscle colour between R-11 and Ż-33 birds were small and not significant. With the age of the birds, thigh muscles showed decreases in lightness (L*) in group R-11 and in yellowness in both groups.

Table 4. Physical traits of cockerel thigh muscle (*m. biceps femoris*)

Item	Age (weeks)	Breed (mean±SD)		P-value		
		R-11	Ż-33	Age	Breed	Interaction A×B
pH_{15min}	16	6.57±0.237	6.55±0.147	0.001	0.223	0.168
	20	6.13±0.322	6.36±0.234			
pH_{24h}	16	6.08±0.239	6.16±0.095	0.204	0.852	0.157
	20	6.09±0.236	5.98±0.134			
Drip loss after 24 h (%)	16	0.65±0.47	0.47±0.16	0.021	0.741	0.131
	20	0.28±0.10	0.39±0.09			
WHC (%)	16	13.7±2.48	15.20±3.35	0.666	0.314	0.735
	20	14.22±2.26	15.50±2.21			
Cooking loss (%)	16	31.68±2.15	32.74±0.85	0.723	0.238	0.996
	20	31.35±3.33	32.43±2.96			
Shear force (N)	16	18.58±5.01	17.73±5.64	0.003	0.461	0.966
	20	21.91±5.31	21.15±3.94			
Muscle colour L*	16	49.4±5.52	47.5±4.74	0.001	0.487	0.379
	20	43.9±4.23	44.2±4.86			
Muscle colour a*	16	17.3±3.12	17.4±2.34	0.722	0.400	0.354
	20	18.1±1.46	17.1±1.88			
Muscle colour b*	16	9.24±1.96	8.57±1.94	<0,001	0.367	0.601
	20	7.18±1.71	7.00±1.86			

For explanation see Table 1.

Table 5. Chemical composition of cockerel breast muscle (*m. pectoralis major*) and thigh muscle (*m. biceps femoris*)

Item	Age (weeks)	Breed (mean±SD)		P-value		
		R-11	Ż-33	Age	Breed	Interaction A×B
breast (*m. pectoralis major*)						
Cholesterol (%)	16	0.662±0.071	0.590±0.100	0.023	0.114	0.167
	20	0.570±0.007	0.564±0.018			
Collagen (g/100 g meat)	16	0.877±0.168	0.929±0.126	0.783	0.293	0.573
	20	0.827±0.145	0.845±0.099			
Crude fat (%)	16	1.280±0.212	1.468±0.299	0.755	0.551	0.733
	20	1.462±0.747	1.410±0.313			
Crude protein (%)	16	24.74±0.45	24.44±0.49	0.008	0.748	0.278
	20	25.30±0.36	25.14±0.54			
thigh (*m. biceps femoris*)						
Cholesterol (%)	16	1.115±0.295	1.151±0.249	0.138	0.945	0.764
	20	0.994±0.137	0.972±0.126			
Collagen	16	1.744±0.403	1.464±0.206	0.265	0.053	0.900
	20	1.874±0.284	1.626±0.185			
Crude fat (%)	16	4.732±1.127	4.082±0.750	0.253	0.610	0.432
	20	3.756±1.424	3.895±0.970			
Crude protein (%)	16	20.05±0.482	20.60±0.793	0.033	0.204	0.489
	20	20.87±0.354	21.04±0.682			

For explanation see Table 1.

The differences in chemical composition of the breast and thigh muscles between R-11 and Ż-33 cockerels and between 16 and 20 weeks of age were small and not significant except for crude protein content, which was significantly higher in the muscles sampled from 20-week-old R-11 cockerels compared to the muscles of 16-week-old birds (Table 5). As the birds aged, the level of cholesterol in breast muscle decreased.

Discussion

In the present study, feed conversion was considerably poorer than in broiler chickens, mainly as a result of the lower rate of weight gain in R-11 and Ż-33 cockerels. These findings are consistent with the study by Koenig et al. (2012) with laying-type cockerels. Body weight should be one of the important criteria to be considered when selecting breeds for use as chickens for slaughter, because the good rate of growth has a direct effect on improving production profitability. Laying-type cockerels are characterized by significantly lower rate of growth and, according to Lichovniková et al. (2009), at 95 days of growth their body weight is 3-fold lower than in Ross 308 broiler chickens. In an interesting study conducted in Germany, dual-purpose Lohmann Dual cockerels were used to produce poultry meat and their body weight at 10 weeks of age was slightly higher than that of cockerels from our study (Siekmann et al., 2018). Van Marle-Köster and Webb (2000) reported that the body weight of 77-week-old South African native chicken lines was 50 to 67% that of Cobb broilers. In our study, the rate of weight gain was similar for both breeds up to 14 weeks, but later, until the end of the growth period, R-11 cockerels had higher body weight than the Ż-33. The literature shows that differences in the body weight of native chickens of different breeds are considerably greater than those of commercial broiler chicken hybrids, but the quality of their meat is completely different, which may be of considerable importance on the market (Franco et al., 2012 a, b; Siekmann et al., 2018; Faraji-Arough et al., 2019). In the study by Youssao et al. (2012), the body weight of 16-week-old native African chicken breeds was 2.5- and 4-fold lower than that of French Label Rouge chickens, despite the fact that in this experiment the African climate was very unfavourable for the latter. Faraji-Arough et al. (2019) undertook an interesting study to develop an optimal growth model for native breeds of chickens, suggesting that these birds should be selected for increased body weight, because their resistance is of great economic importance under specific African conditions. In the study of Murawska and Bochno (2007), laying-type cockerels aged 10 weeks achieved only 60% of the body weight of 6-week-old broiler chickens. Due to such low weight gains and unfavourable feed conversion, the production costs of chickens for fattening using laying-type or native breed cockerels are high, and the price of their meat is a significant constraint that limits the demand. These economically adverse aspects of raising laying-type cockerels are supported by Koenig et al. (2012), who also stated the need for conducting research in this area so as to make producers interested in using laying-type cockerels, the liquidation of which in hatcheries represents an ethical concern.

Colour is an important part of the consumer's evaluation of carcass quality (Zdanowska-Sąsiadek et al., 2013). Ż-33 and R-11 cockerels have genetically determined yellow carcasses, which is desirable from the consumer point of view. The different colours of poultry carcasses and meat are another characteristic feature of the native/local breeds, because all the carcasses of various broiler lines are bright and no effect of genotype on this trait is generally observed (Wattanachant et al., 2004).

After 24 h of chilling, carcass weight loss was slightly higher in Ż-33 compared to R-11 cockerels, and in both breeds this parameter showed higher values compared to the carcasses of 23-week-old cockerels and capons investigated by Calik et al. (2017).

The carcass yield of the cockerels of both breeds, which ranged from 68.4 to 72.2%, was comparable to that of 84-day-old slow-growing chickens (Połtowicz and Doktor, 2012) and 23-week-old cockerels and capons (Calik et al., 2017), but higher by 10% on average compared to 10-week-old layer cockerels (Murawska and Bochno, 2007). Despite the significant differences in the final body weight of the cockerels, the breast and leg muscle percentages were similar and comparable to those of laying-type cockerels aged 90 days, but much lower than those of broiler chickens of the same age (Lichovniková et al., 2009). In our study, the carcasses of both cockerel breeds had a lower breast muscle and a higher leg muscle percentage, which is in line with the observations of other authors who studied muscling in layer cockerels (Gerken et al., 2003; Lichovniková et al., 2009; Calik et al., 2017; Siekmann et al., 2018). In broiler chickens these relationships are reversed as a result of selection for increased weight of breast muscles, which are valuable for consumers. The giblets, leg bone and abdominal fat percentages in the carcasses of the cockerels of both breeds were at a similar level as in the study conducted by Calik et al. (2017) with R-11 capons and cockerels.

Measurement of pH 15 minutes after slaughter allows distinguishing normal meat (pH_{15}=5.9–6.2) from defective PSE ($pH_{15}\leq5.7$) or DFD meat ($pH_{15}>6.2$) (Szałkowska and Meller, 1998). According to this classification, breast meat from the studied cockerels was normal except for 16-week-old R-11 birds. Leg muscles showed DFD (dark, firm, dry) characteristics except for the meat of 20-week-old R-11 cockerels. As reported by Szałkowska and Meller (1998), DFD meat is more susceptible to deterioration. Many authors consider the effect of pH level on important muscle traits such as water holding capacity, colour and tenderness, which determine sensory value of the meat (Qiao et al., 2002; Połtowicz and Doktor, 2012). Also in our study we noted that less acidic Ż-33 muscles showed a higher water holding capacity and better tenderness. Regardless of the cockerels' age, like in the study of Siekmann et al. (2018), we found pH_{24h} value to be higher in leg than breast muscles. Lower drip loss after 24 h of chilling is indicative of higher muscle juiciness. The drip loss of breast muscles from the cockerels of the analysed breeds at 16 weeks was considerably higher than at 20 weeks and this trait followed a similar pattern in the study of Połtowicz and Doktor (2012) with slow-growing chickens reared to 84 days. As cockerels aged, the tenderness of their breast and leg meat decreased, and such a relationship has been reported in the literature (Northcutt et al., 2001; Połtowicz and Doktor, 2012).

Meat cooking loss in different birds varies widely, mainly according to genotype and age at slaughter. Cooking losses in the muscles of the analysed birds were considerably higher than in five different local breeds from Asia (Wattanachant, 2008). Siekmann et al. (2018) reported that the meat of fast-growing Ross 308 cockerels is characterized by higher cooking loss than the meat of multipurpose cockerels. Both cockerel groups showed higher cooking loss in the leg than breast muscles, and the results coincide with the results reported for cockerels and capons (Calik et al., 2017), slow-growing chickens (Wattanachant et al., 2004; Połtowicz and Doktor, 2012) and 56-week-old multipurpose hens (Puchała et al., 2014).

In the breast muscles of the analysed cockerel breeds, the level of crude protein ranged from 24.44% to 25.30% and was 5% higher compared to young broiler chickens and a local Chinese breed (Wattanachant et al., 2004) and 20-week-old local African breeds of slaughter chickens (Tougan et al., 2013), but similar to that in the Spanish Mos breed (Franco et al., 2012 a, b). The meat of local Korean chicken breeds contains less fat and more protein compared to the commercial broiler chickens, which makes consumers willing to pay twice or three times as much for them (Choo and Chung, 2014). At the same time the authors pointed to the increasing demand in Asia for the meat of native chicken breeds. In our study, the level of crude protein in the leg muscles remained similar in both breeds, but its content increased with the age of the cockerels to reach a level comparable to 23-week-old cockerels and capons (Kwiecień et al., 2015).

One of the important components of poultry meat that influences the quality of poultry meat preparations is collagen, the glue-producing properties of which affect the quality of broth cooked from such meat. In the analysed muscle samples, with the advancing age of the cockerels of both breeds, the collagen content decreased in breast muscle and increased in thigh muscle, which is supported by the results of other authors (Kijowski and Tomaszewska-Gras, 2009). In the meat of mature poultry, which was studied here, collagen plays a major role in texture development. The collagen percentage in the analysed samples was much higher than in young broiler chickens and a Chinese local breed investigated by Wattanachant et al. (2004), which leads us to conclude (although no such studies were performed) that the meat of the studied cockerels could be a good raw material for preparing broth.

Conclusions

– R-11 cockerels exhibit a better rate of weight gain and their carcasses are characterized by better yellowness and redness values compared to the Ż-33.

– The carcasses of both cockerel breeds contain a lower breast muscle and a higher leg muscle percentage, and the meat of the studied birds contains more collagen and protein, and less fat.

– Leg muscles of the studied cockerels showed DFD (dark, firm, dry) characteristics and thereby are susceptible to rapid decay.

– As birds age, body weight and abdominal fat percentage increases and giblets percentage decreases in the cockerels of both breeds, whereas in the R-11 breed dressing percentage increases, leg bone percentage decreases, yellowness (a*) increases and redness (b*) decreases.

– Neither genotype nor slaughter age had a significant effect on chemical composition of the breast and leg muscles. In both breeds, the breast and leg muscle quality traits were more affected by age than genotype.

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