Suitability of layer-type male chicks for capon production

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ABSTRACT The aim of this study was to determine the effect of age and caponization on the growth performance and carcass quality characteristics of Leghorn cockerels. The experiment was conducted on 224 Leghorn cockerels. At 8 wk of age, 112 birds were surgically castrated by a qualified veterinarian in accordance with Commission Regulation (EC) No. 543/2008. The birds were divided into 2 sex categories (with 8 replications per group and 14 birds per replication). The birds were raised to 28 wk of age, and were fed commercial diets ad libitum. From 12 wk of age, at 4-wk intervals, 8 intact cockerels and 8 capons (1 bird per replication) were selected randomly and slaughtered. Caponization had a beneficial influence on the feed conversion ratio (FCR). FCR (kg/kg) based on body weight (BW) gain, carcass weight gain, and edible weight gain was lower in capons from 24 wk of age ($P < 0.05$), and FCR based on lean weight gain was lower in capons from 21 wk of age ($P < 0.05$). The content of edible components expressed as a percentage of the total BW of cockerels and capons was similar in the corresponding age groups. Caponization had no effect on the total lean meat content of the carcass ($P = 0.744$), but differences were found between the weights of breast muscles and leg muscles. In week 24 and 28, the weight of breast muscles was higher in capons than in cockerels ($P < 0.05$). Cockerels had higher leg muscle weight than capons, and significant differences were noted in week 16 and in 28 ($P < 0.05$).

Key words: caponization, layer-type cockerels, age, growth performance, tissue components

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INTRODUCTION

The elimination of day-old cockerels of layer breeds poses a problem for the poultry industry (Leenstra et al., 2011; Soisontes, 2015; Brümmer et al., 2017). Several solutions have been proposed, including the development of reliable and rapid methods for sexing chick embryos (Krautwald-Junghanns et al., 2018), and effective and humanitarian euthanasia of layer-type male chicks (Gurung et al., 2018). However, social concerns and expectations should also be taken into account. Raising unwanted cockerels for meat is the approach that has met with the highest degree of social acceptance (Bruijnis et al., 2015; Brümmer et al., 2017; Mueller et al., 2018). Due to genetically determined lower body weight (**BW**) gain and higher feed intake per unit of gain, the process of raising layer-type cockerels for meat takes longer and is less profitable compared with broiler chickens (Koenig et al., 2012; Choo et al., 2014). Leenstra et al. (2011) and Brümmer et al. (2017) investigated potential alternatives to the killing of day-old male chicks of layer breeds and found that some consumers declared their willingness to pay a premium for eggs and chicken meat to prevent the above practice. In Asia and Africa, the carcasses of male chicks of layer breeds and traditional native breeds are popular among consumers (Jatarusitha et al., 2008, Khobondo et al., 2015). According to Leenstra et al. (2011), layer cockerels need around 18 wk to attain 2.0 kg BW. Soisontes (2015) reported that in Thailand, layer-type male chicks used for meat production were raised for approximately 60 D to achieve slaughter weight of 0.8 to 1.2 kg. According to other authors, however, extensively raised native chickens achieve BW of 1.0 to 1.5 kg at 4 to 5 mo of age (Leotharakul et al., 2002). An increase in blood testosterone levels, observed in growing cockerels, is an important consideration since it may be associated with antagonistic and/or aggressive behaviors (Queiroz and Cromberg, 2006; Essien et al., 2012). Undesirable behavioral changes

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can be eliminated by surgical or chemical castration (Quaresma et al., 2017). Caponization is carried out to produce meat with exceptional flavor (Díaz et al., 2010; Calik et al., 2015; Adamski et al., 2016; Amorim et al., 2016). Previous research revealed increased deposition of fat in caponized birds, in particular abdominal fat and mesenteric fat, which can decrease carcass dressing percentage (Zawacka et al., 2017). On the other hand, the accumulation of lipids in the muscle tissue of capons improves the palatability of meat (Amorim et al., 2016; Gesek et al., 2017). Lin and Hsu (2002) and Gesek et al. (2017, 2019a) demonstrated that low androgen levels affected the diameter of muscle fibers, which was smaller in the breast muscles of capons compared with intact males. In Europe, the meat of capons of selected traditional breeds is appreciated by some consumer groups for its tenderness and flavor, but it is more expensive than meat from broiler chickens and organic chickens (Muriel Duran, 2004; Franco et al., 2016).

A few studies have investigated the suitability of layer-type male chicks for capon production. Chen et al. (2010) found that caponization increased final BW and decreased the feed conversion ratio (**FCR**) in Single Comb White Leghorn chickens. Symeon et al. (2012, Lohman Silver, Lohman Tierzucht) reported that caponization had no significant effect on the growth performance of male chicks of a layer line and suggested that they could be used for the production of capon meat, appreciated by consumers as a niche product. However, consumers' interest in niche food products and their prices are difficult to estimate. Consumers' preferences change over time in response to both increasing awareness of animal welfare and socio-cultural factors affecting their food choices (Soisontes, 2015; Long and Blok, 2017; Bosona and Gebresenbet, 2018). In view of the above, the suitability of layer-type male chicks for meat production should be analyzed, and their optimal slaughter age should be established.

The aim of this study was to determine the effect of age and surgical caponization on the growth performance and carcass quality characteristics of Leghorn cockerels.

MATERIALS AND METHODS

The experiment was conducted on 224 Leghorn cockerels (supplied by the National Research Institute of Animal Production in Chorzelów, Poland). One-day-old birds were weighed and marked with wing tags. The birds were raised in the experimental center of the Department of Commodity Science and Animal Improvement of the University of Warmia and Mazury in Olsztyn (Poland), to 28 wk of age, and were fed commercial diets ad libitum (Table 1). At 8 wk of age, 112 birds were surgically castrated by a qualified veterinarian in accordance with Commission Regulation (EC) No. 543/2008. The procedure was approved by the Local Ethics Committee in Olsztyn, Poland. The birds were divided into 2 sex categories (with 8 replications per group and 14 birds per replication). From 12 wk of age, at 4-wk intervals, 8 intact cockerels and 8 capons (1 bird per replication) were selected randomly and slaughtered (electrical stunning followed by cutting the jugular vein). Carcasses were eviscerated after the removal of heads (between the occipital condyle and the atlas) and feet (at the carpal joint). The digestive tract, liver, heart, and abdominal fat were removed. Live BW was determined before slaughter, and carcass weight was determined after bleeding and plucking. The weights of the head, feet, hot carcass, heart, liver, gizzard, gastrointestinal tract (including the contents and peri-intestinal fat, excluding the gizzard), kidneys, trachea, lungs, and abdominal fat were also determined. Carcasses were chilled at 4°C for around 18 h and were divided into primal cuts (neck, wings, legs, back, and breast) which were subjected to detailed dissection (Ziołecki and Doruchowski, 1989).

Table 1. Composition and calculated nutrients density of diets.

Item	Diet 1 (weeks 1 to 8)	Diet 2 (weeks 9 to 28)
Ingrediens (%)		
Wheat	74.22	64.46
Soybean meal	19.00	25.00
Rapeseed meal	3.00	4.00
Soybean oil	-	2.60
Sodium chloride	0.42	0.31
Limestone	1.27	1.48
Monocalcium phosphate	0.86	0.86
DL-Methionine (99%)	0.07	0.06
L-Lysine HCL (78%)	0.16	0.15
L-Treonine (99%)	0.64	0.08
*Vitamin – mineral premix	1.0	1.0
Nutrient density (g/kg)		
Crude protein	187.7	208.8
Arginine	11.1	12.6
Lysine methionine (%)	9.40	10.8
Methionine + Cysteine	7.20	7.60
Threonine	6.40	8.00
Tryptophan	2.40	2.60
Calcium	7.70	8.70
Total phosphorus	5.80	5.90
Sodium	1.80	1.40
Apparent metabolizable energy (MJ/kg)	11.64	11.94
Crude protein (%)		

*Provided per kg of diet: mg; Cu – 8.0, Fe – 116.0, Mn – 80.0, Zn – 100.0, I – 0.80, Se – 0.20 vitamin E – 68.0, vitamin K3 – 4.80, vitamin B1 – 2.2, vitamin B2 – 7.2, vitamin B6 – 5.0, niacin – 44.0, Ca-D-pantothenate – 18.0, mcg; vitamin B12 - 44, vitamin H (biotin) – 136, IU; vitamin A (E 672) 13,200, vitamin D3 (E671) 3,120, g; Choline 1.6.

Edible components comprised lean meat (muscle tissue including intermuscular fat), skin with subcutaneous fat, giblets (gizzard, liver, heart), kidneys, and lungs. Non-edible components comprised bones and slaughter offal (blood, feathers, head, feet, gastrointestinal tract, abdominal fat, trachea).

To determine the percentage of edible components and non-edible components in total BW, the weights of all components were added up. The total weight of edible components and non-edible components is not equal to the BW of birds before slaughter. The difference results from loss during post-slaughter

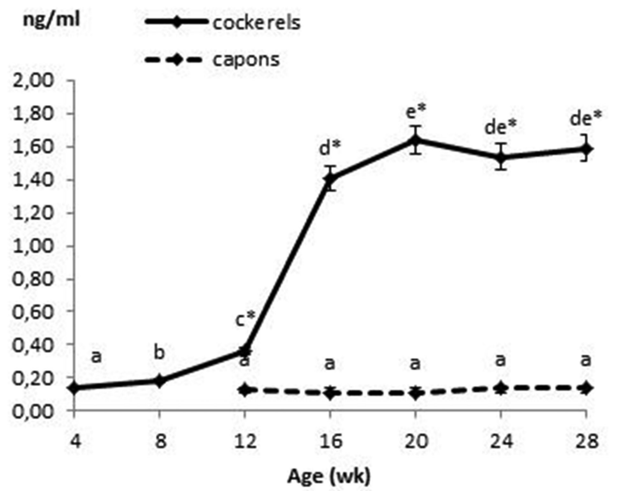

Figure 1. Blood testosterone levels in cockerels and capons (ng/mL; mean ± SD). Values followed by different letters (age) or * ("sex") differ significantly: $\alpha = 0.05$

processing and dissection: drip loss, evaporation, and drying. The total amount of loss was comparable across the age groups of cockerels and capons.

At 4 and 8 wk of age, blood samples were collected from 8 randomly selected birds to determine testosterone levels. In successive weeks (from 12 to 28 wk), at 4-wk intervals, blood samples were collected from 8 cockerels and 8 capons (one bird per pen) into test tubes containing heparin. Freshly collected blood was centrifuged twice (MPW-350R centrifuge, MPW MED INSTRUMENTS; 5 min, 10 000 rpm), and each time the supernatant was transferred to 1.5 mL Eppendorf Safe-Lock micro test tubes with an Eppendorf automatic electronic pipette. Plasma samples were frozen at −72°C in 1.5 mL Eppendorf Safe-Lock micro test tubes in the Kaltis 390 ultralow temperature laboratory freezer. Testosterone levels were analyzed by radioimmunoassay (**RIA**) with the use of commercial kits supplied by DIAsource TESTO–RIA–CT (DIAsource ImmunoAssays S.A., Belgium).

The statistical analysis involved the determination of arithmetic means ($\bar{X}$) and standard deviations (SD). The data were analyzed by 1-way ANOVA (age or caponization) and 2-way ANOVA (age x caponization). The significance of differences in mean values between age groups was determined by Duncan's test. All calculations were performed using Statistica 2010 software. Significance was set at $P \leq 0.05$.

RESULTS

Average plasma testosterone levels in cockerels reached 0.14 ng/mL at 4 wk of age and 0.18 ng/mL at 8 wk of age (castration). Testosterone concentration increased to 1.55 ng/mL in control group (intact) cockerels at 28 wk of age. The highest increase in testosterone levels (by 1.05 ng/mL, Figure 1, $P < 0.05$) was observed between week 12 and 16. In caponized birds, average testosterone concentration between week 12 and 28 was 0.13 ng/mL, and it was significantly lower than in cockerels (Figure 1, $P < 0.05$).

Daily feed intake (**DFI**, g/bird) increased with age ($P = 0.038$, Table 2). In cockerels, DFI values continued to increase until the end of the experiment (from 61 g in week 12 to 127 g in week 28, $P < 0.01$). In capons, DFI values continued to increase until week 24 (from 57 g in week 12 to 100 g in week 24). In general, caponization had no effect on the DFI ($P = 0.184$), but in week 28, DFI was significantly higher in cockerels than in capons (age x caponization interaction, $P = 0.021$).

FCR (kg/kg) based on BW gain, carcass weight gain, edible weight gain, and lean weight gain increased with age in both cockerels and capons ($P < 0.01$, Table 2). Caponization had no effect on the FCR, but at 28 wk of age, FCR based on edible weight gain was higher in cockerels than in capons (age x caponization interaction, $P = 0.036$) by 0.34 kg (9.11 kg/kg in cockerels vs. 8.77 kg/kg in capons, $P < 0.05$). FCR based on lean weight gain was higher in cockerels than in capons (age x caponization interaction, $P = 0.032$), by 0.35 kg in week 24 (12.08 kg/kg in cockerels vs. 11.72 kg/kg in capons, $P < 0.05$) and by 0.66 kg in week 28 (12.23 kg/kg in cockerels vs. 11.57 kg/kg in capons, $P < 0.05$).

At 8 wk of age (before castration), the average BW of birds was 595 g. Caponization had no significant effect on BW, carcass weight, or the weights of tissue components (lean meat, skin with subcutaneous fat, bones), which were affected by age (except in week 16, Table 3, $P < 0.05$).

Caponization had no effect on the total lean meat content of the carcass ($P = 0.744$, Table 3), but differences were found between the weights of breast muscles (Figure 2a) and leg muscles (Figure 2b). In week 24 and 28, the weight of breast muscles was higher in capons than in cockerels by 35.5 g (300.6 and 265.1 g, Figure 2a, $P < 0.05$) and 24.2 g (316.9 and 292.7 g, Figure 2a, $P < 0.05$), respectively. Cockerels had higher leg muscle weight than capons, and significant differences were noted in week 16 (257.1 g in cockerels vs. 215.6 g in capons, Figure 2b, $P < 0.05$) and in week 28 (406.6 g in cockerels vs. 356.3 g in capons, Figure 2b, $P < 0.05$).

Abdominal fat weight was affected by caponization ($P = 0.031$) and age ($P = 0.000$, Table 3). In week 12 and 28, abdominal fat weight was higher in capons than in cockerels (by 2.1 and 27.8 g, respectively, Table 2, $P < 0.05$).

Caponization had no influence on the total weight of giblets (heart + gizzard + liver, $P = 0.132$), which was affected by age ($P < 0.000$), but had a significant effect on heart weight and gizzard weight (Table 3). Heart weight was lower in capons than in cockerels ($P = 0.000$), whereas gizzard weight was higher in capons than in cockerels ($P = 0.006$). Between week 12 and 28, heart weight increased from 5.8 to 12.5 g in cockerels ($P < 0.05$), and from 5.3 to 9.2 g in capons ($P < 0.05$).

Table 2. Daily feed intake (DFI, g/bird) and feed conversion ratio (FCR, kg/kg) in Leghorn cockerels and capons.

Item	Sex	Age (wk)					*P-value*		
		9 to 12	13 to 16	17 to 20	21 to 24	25 to 28	Sex	Age	S x A
DFI (g/bird)	Cockerels	61.5[a] ±5.0	96.7[b] ±7.0	84.6[c] ±4.8	103.5[d] ±6.2	*127.4[e] ±4.8	0.184	0.038	0.021
	Capons	57.6[a] ±6.1	80.3[b] ±4.0	82.4[b] ±3.4	100.2[c] ±5.4	86.4[b] ±5.1			
FCR (kg/kg)									
Body weight	Cockerels	3.21[a] ±0.05	3.81[a,b] ±0.03	4.28[b,c] ±0.07	4.58[c] ±0.21	*4.91[c] ±0.12	0.666	0.000	0.036
	Capons	3.24[a] ±0.06	3.72[b] ±0.11	4.20[c] ±0.07	4.58[d] ±0.02	4.79[e] ±0.03			
Carcass weight	Cockerels	5.35[a] ±0.18	5.84[a,b] ±0.08	6.62[b,c] ±0.13	6.89[b,c] ±0.43	*7.49[c] ±0.55	0.660	0.000	0.042
	Capons	5.35[a] ±0.22	5.67[a] ±0.21	6.38[b] ±0.10	6.79[b,c] ±0.03	7.31[c] ±0.22			
Edible components	Cockerels	6.10[a] ±0.12	7.45[b] ±0.08	8.30[b,c] ±0.11	8.76[b,c] ±0.43	*9.12[c] ±0.68	0.459	0.000	0.036
	Capons	6.28[a] ±0.04	7.27[b] ±0.23	8.15[c] ±0.18	8.63[c,d] ±0.01	8.77[d] ±0.02			
Lean meat	Cockerels	8.48[a] ±0.20	10.28[a,b] ±0.08	11.46[b,c] ±0.12	*12.08[b,c] ±0.54	*12.23[c] ±0.95	0.355	0.000	0.032
	Capons	*8.74[a] ±0.06	10.05[b] ±0.30	11.29[c] ±0.29	11.72[c] ±0.11	11.57[c] ±0.23			

[a–d]Mean values in a row (age) followed by different letters are significantly different at $\alpha = 0.05$.
*Mean values in the age groups of cockerels and capons are significantly different at $\alpha = 0.05$.

From 12 wk of age, gizzard weight remained stable in cockerels (age x caponization interaction, $P = 0.002$), and it increased from 25.6 to 43.7 g in capons ($P < 0.05$). Liver weight increased from 23.3 g in week 12 to 30.9 g in cockerels ($P < 0.05$), and from 21.2 to 31.8 g in capons ($P < 0.05$). Caponization had no significant effect on liver weight ($P = 0.342$).

The weights of edible and non-edible components increased with age (Table 3, $P < 0.000$), and were comparable in cockerels and capons at corresponding ages. Between week 12 and 28, the weight of edible components increased from 608.5 to 1330.2 g in cockerels ($P < 0.05$), and from 589.3 to 1331.3 g in capons ($P < 0.05$). The weight of non-edible components increased from 523.6 to 846.2 g in cockerels ($P < 0.05$), and from 501.2 to 868.8 g in capons ($P < 0.05$).

Table 4 presents carcass dressing percentage and the percentage content of edible and non-edible components in the total BW of Leghorn cockerels and capons. Dressing percentage was similar in cockerels and capons at corresponding ages, and it increased until week 28 in cockerels (from 62.2% in week 12 to 70.9% in week 28, $P < 0.05$), and until week 20 in capons (from 62.8% in week 12 to 69.70% in week 20, $P < 0.05$).

The percentage of edible and non-edible components in the total BW of cockerels and capons was affected by age ($P < 0.000$), but not by caponization (Table 4).

DISCUSSION

The results of this study are difficult to compare with the findings of other authors due to considerable differences in capon production systems, age at caponization, length of the rearing period, breed, and diet. Chen et al. (2010) analyzed Single Comb White Leghorn chickens that were caponized at 12 wk of age and reported higher feed intake and lower FCR in capons between week 16 and 26. Calik et al. (2017) compared Rhode Island Red (R-11) cockerels and capons and reported lower FCR in the latter. In the present study, a tendency toward lower DFI was observed in capons, particularly at the end of rearing (week 24 to 28), compared with intact males. Unfortunately, there are no published data regarding FCR values calculated based on carcass weight gain, edible weight gain, or lean weight gain in caponized birds. In our study, FCR based on BW gain, carcass weight gain, and edible weight gain was lower in capons between week 24 and 28, and FCR based on lean weight gain was lower between week 21 and 24 and 24 to 28 (Table 2). Higher feed intake in intact males may be associated with their higher maintenance energy requirements due to increased activity and behavioral changes (ruffling feathers, chasing and pushing other birds around, antagonistic behaviors; Queiroz and Cromberg, 2006) induced by an increase in testosterone levels from 12 wk of age (Figure 1). Removal of the gonads in males also entails other consequences that are reflected in the bird's habits (Gryzińska et al., 2011). FCR values are lower in capons than in cockerels but considerably higher than in broiler chickens (Murawska and Bochno, 2007; Koenig et al., 2012). The temperament of individual birds also changes—they become more sleepy and quiet. In a study by Soma (2006), capons did not crow, did not try to mate with females, and did not fight aggressively with other males. Caponized birds are more gentle and docile, which was also observed in our study, and this could contribute to improving the efficiency of feed utilization.

Table 3. Body weight, carcass weight, weights of tissue components and organs in Leghorn cockerels and capons (g; mean ± SD).

Item	Sex	Age (wk) 12	16	20	24	28	P-*value* Sex	Age	S x A
Body weight	Cockerels	1170.00[a] ±21.76	*1597.00[b] ±20.90	1753.88[b] ±63.19	2034.00[c] ±85.97	2308.38[d] ±60.16	0.331	0.000	0.594
	Capons	1124.29[a] ±43.09	1437.42[b] ±53.70	1762.71[c] ±66.68	2035.80[d] ±78.04	2315.86[e] ±63.91			
Carcass weight	Cockerels	702.22[a] ±18.17	*1033.29[b] ±22.69	1133.69[b] ±40.40	1348.06[c] ±55.43	1519.18[d] ±39.73	0.512	0.000	0.616
	Capons	684.54[a] ±28.07	930.90[b] ±35.64	1155.57[c] ±47.14	1362.78[d] ±47.73	1513.51[e] ±61.05			
Lean meat	Cockerels	439.65[a] ±10.56	*680.21[a] ±17.83	777.88[b] ±26.40	935.37[c] ±37.01	1049.89[d] ±30.10	0.744	0.000	0.586
	Capons	433.63[a] ±20.83	599.22[b] ±19.37	787.80[c] ±32.75	938.54[d] ±32.05	1012.69[d] ±39.07			
Bones	Cockerels	160.52[a] ±5.98	208.87[b,a] ±2.72	227.88[b] ±8.82	236.54[b,c] ±9.55	264.25[c] ±6.94	0.689	0.000	0.441
	Capons	153.39[a] ±5.56	197.82[b,a] ±8.66	234.40[b,c] ±12.37	257.90[c] ±9.79	265.81[c] ±12.10			
Skin with subcutaneous fat	Cockerels	89.40[a] ±4.98	124.76[a] ±4.33	108.83[b] ±7.85	157.07[c] ±14.82	181.03[c] ±9.10	0.688	0.000	0.417
	Capons	83.41[a] 4.72	114.80[b] 8.64	115.29[b] 7.79	155.0[c] 11.73	205.13[d] 15.64			
Abdominal fat	Cockerels	6.92[a] 2.44	5.20[a] 2.90	15.45[b] 7.85	17.46[b] 4.57	14.24[b] 3.40	0.031	0.001	0.048
	Capons	9.00[a] 1.64	11.28[a] 1.86	15.86[a] 1.98	*23.10[b] 8.00	*42.06[c] 7.09			
Giblets	Cockerels	57.98[a] ±1.63	67.94[b,c] ±3.56	61.01[a,b] ±3.39	63.24[a,b] ±3.17	72.66[c] ±1.43	0.132	0.000	0.034
	Capons	52.06[a] ±2.96	64.90[a,b] ±3.35	62.71[a,b] ±5.13	75.58[b] ±5.86	84.69[c] ±3.66			
Heart	Cockerels	5.83[a] ±0.32	8.67[b] ±0.62	9.76[c] ±0.57	*12.23[c] ±0.87	*12.45[c] ±0.38	0.000	0.000	0.051
	Capons	5.29[A] ±0.29	7.07[B,a] ±0.36	8.43[B,C,b] ±0.66	8.98[C] ±0.26	9.24[C] ±0.36			
Liver	Cockerels	23.32[a] ±0.85	24.16 [a] ±1.05	22.63 [a] ±1.39	23.47[a] ±1.38	30.93 [b] ±0.97	0.342	0.000	0.097
	Capons	21.19[a] ±0.91	22.63[a,b] ±1.47	25.91[b,c] ±1.37	26.82[b,c] ±1.11	31.76[c,d] ±1.56			
Gizzard	Cockerels	28.83[a] 1.27	35.11 [b] 2.94	28.63 [a] 1.95	27.54 [a] 1.62	29.29 [a] 0.81	0.006	0.001	0.002
	Capons	25.59[a] ±2.25	35.20[b] ±2.34	28.37[b,a] ±3.72	*39.78[b,c] ±5.16	*43.69[c] ±2.65			
Edible components	Cockerels	608.90[a] ±13.60	896.10[b,c] ±17.24	971.66[c] ±36.13	1176.21[d] ±52.61	1330.16[e] ±33.79	0.467	0.000	0.589
	Capons	589.34[a] ±25.33	800.87[b] ±27.08	988.71[c] ±42.60	1184.94[d] ±43.80	1331.30[e] ±54.18			
Non-edible components	Cockerels	523.63[a] ±10.93	656.73[b] ±11.73	693.28[b,c] ±27.00	796.57[c,d] ±37.37	846.18[d] ±58.74	0.399	0.000	0.815
	Capons	501.21[a] ±18.00	599.51[b] ±27.19	684.94[c] ±22.12	772.10[d] ±40.40	868.80[e] ±31.25			

[a–d]Mean values in a row (age) followed by different letters are significantly different at $\alpha = 0.05$.
* Mean values in the age groups of cockerels and capons are significantly different at $\alpha = 0.05$.

Caponization did not cause an increase in the BW of birds or the weights of major tissue components except abdominal fat (Table 3). No differences in final BW between cockerels and capons were observed by Symeon et al. (2012, males of a layer line) and Miguel et al. (2008, Castellana Negra - native Spanish chickens).

The percentage share of edible components was comparable in Leghorn capons and capons of a native dual-purpose breed known as the Green-legged Partridge. Zawacka et al. (2018) demonstrated that in Green-legged Partridge capons (caponization at 8 wk of age), edible components accounted for approximately 50% of total BW in week 12 and 55.5% in week 28. In the current study, edible components accounted for 52.4% of the total BW of Leghorn capons in week 12 and 57.4% in week 28. In Leghorn capons, the above values resulted from a relatively low percentage of abdominal fat in total BW. Previous research shows that abdominal fat usually has a high share of total BW in capons, ranging from 3.7 to 4.5% (Terčič et al., 2007) to nearly 5% (Calik et al., 2015) depending on breed and slaughter age.

In layer-type male chicks, the content of leg muscles increases and the content of breast muscles decreases with age (Murawska et al., 2005). Such a trend was

Table 4. Carcass dressing percentage, and the percentage content of edible and non-edible components in the total body weight of Leghorn cockerels and capons (%; mean ± SD).

Item	Sex	Age (wk)					*P*-value		
		12	16	20	24	28	Sex	Age	S x A
Carcass dressing percentage	Cockerels	62.24[a] ±0.81	66.43[b] ±1.01	68.80[c] ±0.52	68.59[c] ±0.42	70.82[d] ±1.95	0.763	0.000	0.673
	Capons	62.76[a] ±0.97	66.34[b] ±0.68	69.72[c] ±0.64	69.96[c] ±0.90	69.21[c] ±1.51			
Edible components	Cockerels	52.03[a] ±0.43	56.11[b] ±0.72	55.39[b,c] ±0.36	57.79[d] ±0.44	57.64[d] ±0.45	0.689	0.000	0.935
	Capons	52.37[a] ±0.56	55.77[b] ±0.68	56.03[b] ±0.62	58.24[c] ±0.89	57.42[b] ±1.28			
Non-edible components	Cockerels	44.78[a] ±0.75	41.15[b] ±0.77	39.51[b] ±0.39	39.14[b] ±0.46	36.45[c] ±2.05	0.920	0.000	0.809
	Capons	44.64[a] ±0.68	41.66[b] ±0.69	38.93[c] ±0.62	37.87[d] ±0.89	37.59[d] ±1.27			

[a–d]Mean values in a row (age) followed by different letters are significantly different at $\alpha = 0.05$.
*Mean values in the age groups of cockerels and capons are significantly different at $\alpha = 0.05$.

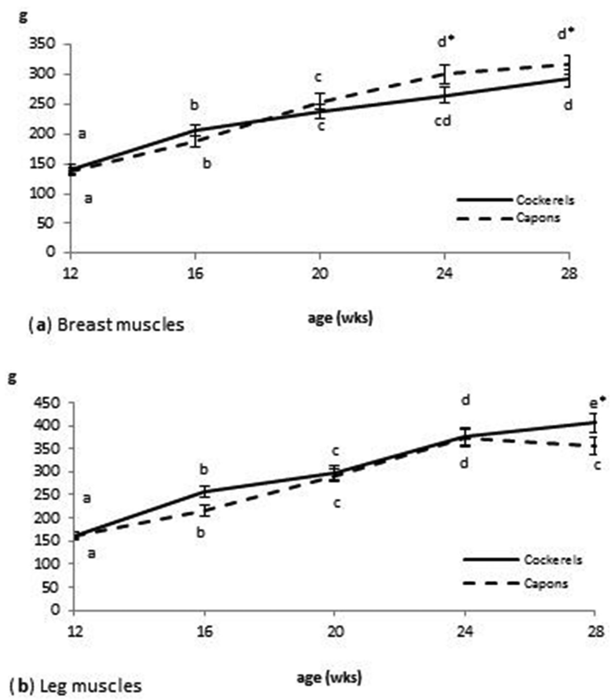

Figure 2. Arithmetic means for the weight of (a) breast muscles and (b) leg muscles (g) in cockerels and capons, subject to the age of birds (g, mean ± SD). Values followed by different letters (age) or * ("sex") differ significantly: $\alpha = 0.05$

also observed in this study in Leghorn cockerels, but not in capons which were characterized by an increase in the content of lean meat located in the breast. This could indicate that testosterone exerts varied effects on different muscle groups in birds (Chen et al., 2007).

According to Mahmud et al. (2013), low levels of sex steroids in capons can increase fat deposition and affect the weight and function of bodily organs. In the current study and in experiments conducted by other authors (Miguel et al., 2008; Symeon et al., 2012), heart weight was lower in capons than in cockerels, and no differences were found in gizzard weight or liver weight. Chen et al. (2006) observed higher gizzard weight and liver weight in capons. A histopathological analysis of selected organs in Leghorn cockerels and capons revealed that surgical castration did not induce any pathological changes except increased lipid accumulation (Gesek et al., 2019b).

In conclusion, caponization had a beneficial influence on feed intake and FCR in layer-type (Leghorn) cockerels, but it did not contribute to an increase in BW or the weights of major tissue components. The content of edible components expressed as a percentage of the total BW of cockerels and capons was similar in the corresponding age groups. From 20 wk of age, the percentage of breast muscles in total BW was higher, and the percentage of leg muscles in total BW was lower in capons than in cockerels. The carcasses of Leghorn capons may arouse interest among consumers, but future demand is difficult to estimate.

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