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RESEARCH ARTICLE

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Changes in the content of edible and non-edible components and distribution of tissue components in cockerels and capons

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Abstract

The aim of this study was to determine the effects of castration and age on the content of edible and non-edible components, and the distribution of tissue components in the carcasses of cockerels and capons. The study was conducted on 200 birds (Green-legged Partridge), divided into two sex categories (with 5 replications per group and 20 birds per replication), raised to 28 wk of age. At 8 wk of age, 100 birds were surgically castrated and afterwards at 12 wk of age and at four-wk intervals, 10 intact cockerels and 10 capons were selected randomly and slaughtered. Cockerels, compared with capons, were characterized by a higher proportion of edible components at 24 and 28 wk of age, and a more desirable carcass tissue composition due to a higher content of lean meat in total body weight (BW). Capons had higher abdominal fat content than cockerels, which resulted in a higher percentage of non-edible components in their BW at 24 and 28 wk of age. Differences in the distribution of lean meat in the carcass were noted from 20 wk of age in both castrated and intact birds. The content of breast muscles increased in capons, and the content of leg muscles (thigh and drumstick) increased in cockerels. The results of this study indicate that in view of the optimal lean meat content of the carcass and the optimal distribution of major tissue components, Green-legged Partridge capons should be fattened for a maximum period of 24 wk.

Additional key words: caponization; age; poultry production; tissue composition.

Abbreviations used: BW (body weight).

Authors' contributions: MZ and DMu designed the study, drafted the manuscript, performed the experiments, and analyzed and interpreted the results; MG provided help and assistance with laboratory analyses; DMi supervised the research.

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Introduction

In Europe, the meat of capons (surgically castrated male chickens) is appreciated by consumers for its tenderness and flavor, and it is more expensive than meat from broiler chickens and organic chickens (Muriel Durán, 2004; Franco *et al.*, 2016). Caponization has been found to improve the overall quality of meat, in particular its sensory properties (Adamski *et al.*, 2016; Amorim *et al.*, 2016; Franco *et al.*, 2016; Gesek *et al.*, 2017), which has stirred interest in capon production. Caponization is performed by surgically removing the bird's testes. According to Chen *et al.* (2007), testosterone stimulates muscle protein synthesis in mammals, but it may also exert inhibitory effects in prepubertal birds. The cited authors demonstrated that chickens castrated at an early age (3 wk) had higher body weight (BW) and a higher percentage of breast muscles in the carcass than intact males, whereas such a correlation was not observed in birds caponized at a later age (12 wk). The results of some studies show that caponization affects the length and diameter of long bones in birds (Mahmud *et al.*, 2013; Chen *et al.*, 2014; Muszyński *et al.*, 2016; Tomaszewska *et al.*, 2017). Research has also revealed that castration contributes to increased fat deposition in capons (Díaz *et al.*, 2010; Symeon *et al.*, 2010). A higher proportion of adipose tissue in the form of abdominal and peri-intestinal fat contributes to a higher content of non-edible components in the total BW of birds. The total weight of edible components (lean meat, skin and fat, giblets) and non-edible components (slaughter offal and bones) in poultry carcasses is of key importance for both producers and consumers (Murawska *et al.*, 2011; Murawska, 2013a,b). The distribution of tissue components in the carcass is also important to consumers. The most valuable cuts, *i.e.* the breast and legs, should have the highest lean meat content, whereas less lean meat should be located in less valuable cuts such as the neck, wings and the back portion. The above proportions are much more desirable in broiler chickens than in layer-type chickens (Murawska *et al.*, 2005; Murawska & Bochno, 2007).

There is a general scarcity of published studies investigating changes in the content of edible and non-edible components, and the distribution of tissue components in the carcasses of castrated and intact birds of native breeds. In addition to expanding the existing knowledge base, such findings could also be used for estimating the optimal slaughter age in capons. Increased capon production could contribute to rational management of male chicks of layer-type and dual-purpose breeds which are considered “waste products” in the hatchery industry.

Recent years have witnessed a growing interest in native chicken breeds which are well adapted to extensive egg and meat production systems (Padhi, 2016). The Green-legged Partridge, a medium-heavy breed, enjoys particular popularity in Poland. At the end of the 1960s, Green-legged Partridge hens accounted for nearly 30% of the total chicken population in Poland. Green-legged Partridge hens are characterized by high disease resistance, and the yolk of their eggs has lower cholesterol content compared with other breeds. Today, the Green-legged Partridge is the most common chicken breed for organic farming (Krawczyk & Calik, 2006; Calik, 2008).

The objective of this study was to determine the effects of castration and age on the content of edible and non-edible components, and the distribution of tissue components in the carcasses of Green-legged Partridge cockerels and capons.

Table 1. Composition and calculated nutrients density of diets.

Item	Diet 1 (weeks 1-8)	Diet 2 (weeks 9-28)
Ingredients (%)		
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]	1.0	1.0
Nutrient density (g/kg)		
Crude protein	187.7	208.8
Arginine	11.1	12.6
Lysine	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

[1]Provided per kg of diet: Cu, 8.0 mg; Fe, 116.0 mg; Mn, 80.0 mg; Zn, 100.0 mg; I, 0.80 mg; Se, 0.20 mg; vitamin E, 68.0 mg; vitamin K3, 4.80 mg; vitamin B1, 2.2 mg; vitamin B2, 7.2 mg; vitamin B6, 5.0 mg; niacin, 44.0 mg; Ca-D-pantothenate, 18.0 mg; vitamin B12, 44 mcg; vitamin H (biotin), 136 IU; vitamin A (E 672), 13200 IU; vitamin D3 (E671), 3120 IU; choline, 1.6 g.

Material and methods

The experiment was conducted on 200 Green-legged Partridge cockerels. One-day-old birds were weighed, marked with wing tags and randomly distributed to 10 pens in the experimental center of the Department of Commodity Science and Animal Improvement of the University of Warmia and Mazury in Olsztyn, Poland. The birds were raised to 28 wk of age, and were fed commercial diets ad libitum (Table 1). At 8 wk of age, 100 birds were surgically castrated by a qualified veterinarian in accordance with Commission Regulation No. 543/2008 (EC, 2008). The procedure was approved by the Local Ethics Committee in Olsztyn, Poland. The birds were divided into two sex categories (with 5 replications per group and 20 birds per replication).

From 12 wk of age, at four-wk intervals, 10 intact cockerels and 10 capons (2 birds 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 & Doruchowski, 1989).

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 was not equal to the body weight of birds before slaughter because of losses during post-slaughter processing and dissection: drip loss, evaporation and drying. The total amount of loss was comparable across the age groups of cockerels and capons.

The statistical analysis involved the determination of arithmetic means ($\overline{x}$) and standard deviations (SD). The data were analyzed by two-way ANOVA (age × sex category; A × B: 5 × 2) or one-way ANOVA (age or sex category). 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

The weights of edible and non-edible components in Green-legged Partridge were affected by castration and the birds' age (Fig. 1). In both cockerels and capons, a significant increase in edible and non-edible weights was observed until 24 wk of age ($p \leq 0.05$). At 24 and 28 wk of age, the weight of edible components was higher in cockerels than in capons ($p \leq 0.05$), which was reflected in the content of edible and non-edible components expressed as a percentage of total BW (Table 2). Anincrease in the percentage of edible components in the total BW of cockerels and capons was noted until 24 wk of age ($p \leq 0.05$), whereas the percentage of non-edible components first tended to decrease, and then remained at a stable level from 20 wk of age (the differences were not statistically significant, Table 2).

In cockerels, the content of lean meat and skin with subcutaneous fat in total BW increased by 5.9% (from 37.9% to 43.8%, $p \leq 0.05$) and 3.4% (from 7.6% to 11.0%, $p \leq 0.05$, Table 2), respectively. In capons, the content of lean meat and skin with subcutaneous fat in BW increased by 4.3% (from 36.6% to 40.9%, $p \leq 0.05$) and 2.8% (from 8.9% to 11.7%, $p \leq 0.05$), respectively Cockerels were characterized by a higher percentage of lean meat in BW (from 20 wk of age, $p \leq 0.05$) and a lower percentage of skin with subcutaneous fat (from 16 wk of age, $p \leq 0.05$), compared with capons (Table 2).

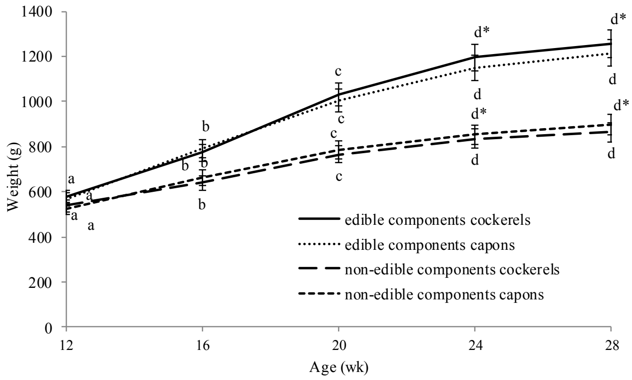

Figure 1. Weight (g) of edible and non-edible components in Green-legged Partridge cockerels and capons (mean ±SD). [a-d] Mean values (age) with different letters are significantly different at α = 0.05. *Mean values in the age groups of intact cockerels and capons are significantly different at α = 0.05.

Unlike other edible components, the percentage of giblets in BW decreased with age (Table 2). Between 12 and 28 wk of age, the decrease reached 1.6% in cockerels (from 4.4% to 2.8%, $p \leq 0.05$) and 1.8% in capons (from 4.7% to 2.9%, $p \leq 0.05$). No significant differences in the total content of giblets (gizzard+heart+liver) expressed as a percentage of BW (Table 2) were found between cockerels and capons across age groups. However, differences were noted in the percentages of individual organs. The percentage of gizzard in BW was lower in cockerels than in capons in all age groups ($p \leq 0.05$), but it decreased at a faster rate in capons than in cockerels. The percentage of liver in BW was lower in cockerels older than 20 wk ($p \leq 0.05$). In cockerels, the percentage of heart in BW remained at a stable level throughout the experiment (0.5%, Table 2), whereas in capons it decreased from 24 wk of age (sex × age interaction, Table 2).

Non-edible components comprise slaughter offal and bones. Between 12 and 28 wk of age, the percentage of bones in BW (Table 2) decreased from 13.6% to 10.5% in cockerels ($p \leq 0.05$), and from 13.0% to 10.8% in capons ($p \leq 0.05$). Bone content was similar in cockerels and capons of different age groups, except in wk 16 when the percentage of bones in BW was higher in capons ($p \leq 0.05$) which points to a sex x age interaction ($p \leq 0.05$, Table 2). Between 12 and 28 wk of age, the content of slaughter offal (excluding abdominal fat) decreased (Table 2, $p \leq 0.05$) by 4.8% in cockerels and by 3.7% in capons ($p \leq 0.05$). Over this period, the percentage of abdominal fat increased from 0.6% to 2.1% in cockerels, and from 1.4% to 3.8% in capons ($p \leq 0.05$). In all age groups, the percentage

Table 2. Edible components and non-edible components[†] and percentage content of individual tissue components in the body weight of Green-legged Partridge cockerels and capons (%; mean±SD)

Item	Sex category	Age (wk)					Analysis of variance (significance)		
		12	16	20	24	28	Age	Sex category	A×S
Edible components	Cockerels	51.9^{a} ±0.58	55.4^{b}±0.57	55.9^{b}±0.68	*57.9^{c}±0.64	*58c.5^{c}±0.59	0.008	0.025	0.166
	Capons	52.6^{a}±0.93	54.6^{b}±0.52	55.4^{b}±0.83	56.2^{c}±0.58	56.5^{c}±0.74			
Non-edible components	Cockerels	44.9^{a}±0.69	42.4^{b}±0.53	40.4^{c}±0.62	38.8^{c}±0.66	38.6^{c}±0.81	0.005	0.016	0.239
	Capons	44.1^{a}±0.64	42.6^{ab}±0.62	40.8^{bc}±048	*40.3^{c}±0.59	*40.6^{c}±0.72			
Lean meat	Cockerels	37.9^{a} ±1.08	40.4^{b} ±1.18	*42.5^{c} ±1.45	*43.5^{d} ±1.66	*43.8^{d} ±1.51	0.000	0.000	0.235
	Capons	36.6^{a} ±1.34	39.8^{b} ±1.26	40.1^{b} ±1.69	41.7^{c} ±1.53	40.9^{b} ±1.10			
Skin with subcutaneous fat	Cockerels	7.6^{a} ±0.70	6.9^{a} ±1.40	8.8^{b} ±0.54	8.5^{b} ±0.84	11.0^{c} ±0.96	0.000	0.002	0.498
	Capons	8.9^{a} ±1.29	*8.8^{a} ±0.56	*10.0^{b} ±0.44	*10.5^{b} ±0.58	11.7^{c}±1.11			
Giblets	Cockerels	4.4^{a}±0.35	3.7^{b} ±0.31	3.3^{b} ±0.33	2.9^{bc} ±0.21	2.8^{c} ±0.23	0.000	0.185	0.276
	Capons	4.7^{a} ±0.40	4.0^{a} ±0.51	3.4^{b} ±0.48	3.3^{b} ±0.39	2.9^{b} ±0.38			
Gizzard	Cockerels	2.1^{a}±0.33	1.7^{b}±0.29	1.7^{b}±0.28	1.3^{c}±0.15	1.3^{c}±0.20	0.012	0.013	0.043
	Capons	*2.3^{a}±0.32	*1.9^{ab}±0.39	*1.9^{b}±0.39	*1.6^{b}±0.28	*1.4^{bc}±0.31			
Heart	Cockerels	0.5^{a}±0.04	0.5^{a}±0.05	0.5^{a}±0.06	*0.5^{a}±0.07	*0.5^{a}±0.06	0.036	0.043	0.032
	Capons	0.5^{a}±0.03	0.5^{a}±0.04	0.5^{a}±0.04	0.4^{b}±0.06	0.4^{b}±0.03			
Liver	Cockerels	1.9^{a}±0.18	1.5^{b}±0.15	1.1^{c}±0.11	1.1^{c}±0.10	0.9^{c}±0.11	0.000	0.026	0.045
	Capons	1.9^{a}±0.19	1.6^{b}±0.18	*1.3^{c}±0.18	*1.3^{c}±0.18	*1.1^{c}±0.18			
Bones	Cockerels	13.6^{a} ±0.46	12.7^{a} ±0.75	11.8^{b} ±0.58	11.5^{b} ±0.70	10.5^{c} ±0.83	0.019	0.925	0.018
	Capons	13.0^{a} ±0.66	*13.5^{a} ±0.87	11.5^{b} ±0.92	11.1^{b} ±0.44	10.8^{b} ±0.67			
Abdominal fat	Cockerels	0.6^{a} ±0.41	0.8^{ab} ±0.38	1.0^{b} ±0.54	0.9^{b} ±0.61	2.1^{c} ±0.58	0.000	0.000	0.149
	Capons	*1.4^{a} ±0.35	*1.3^{b} ±0.31	*2.6^{c} ±0.33	*2.9^{c} ±0.21	*3.8^{d} ±0.23			
Slaughter offal	Cockerels	30.7^{a} ±1.09	28.9^{a} ±1.65	27.6^{b} ±1.45	26.4^{b} ±1.29	25.9^{c} ±0.75	0.014	0.285	0.170
	Capons	29.7^{a} ±1.07	27.8^{b} ±1.85	26.7^{b} ±1.61	26.3^{c} ±1.10	26.0^{d} ±1.38			

[†]Edible components and non-edible components expressed as a percentage of total body weight, excluding the loss resulting from post-slaughter processing and dissection: drip loss, evaporation and drying. [a-d] Mean values (age) followed by different letters are significantly different at α = 0.05. *Mean values in the age groups of intact cockerels and capons are significantly different at α = 0.05

of abdominal fat in total BW was higher in capons ($p \leq 0.05$).

Table 3 presents the distribution of lean meat, fat with skin and bones in different carcass cuts in Green-legged Partridge cockerels and capons. The weight of each tissue component (lean meat, skin with subcutaneous fat, bones) separated during detailed dissection was assumed to be 100%, and the percentage of respective components in different carcass cuts was calculated. In both cockerels and capons, the breast and legs had the highest lean meat content (Table 3). At 12 wk of age, lean meat located in the breast and legs accounted for 69.8% and 68.7% of total lean weight in cockerels and capons, respectively. Until 28 wk of age, the lean meat content of breast and legs increased by 0.9% and 1.6% in cockerels and capons, respectively. In cockerels, lean meat content decreased in the breast (from 34.2% to 31.9%, $p \leq 0.05$) and increased in the legs (from 35.6% to 38.8%, $p \leq 0.05$) with age. In capons, lean meat content increased in the breast (from 33.3% to 36.0%, $p \leq 0.05$) and remained stable in the legs (around 35.5%, Table 3). Differences in the percentages of leg and breast muscles between cockerels and capons were noted from 16 and 20 wk of age, respectively ($p \leq 0.05$, Table 3).

Lean meat located in the back and neck had a higher share of total lean weight in cockerels, from 24 wk of age and in wk 28, respectively (both $p \leq 0.05$). Lean meat located in the wings had a higher share of total lean weight in capons from 24 wk of age ($p \leq 0.05$).

In growing cockerels, the content of skin with subcutaneous fat increased in the neck, back and legs ($p \leq 0.05$), decreased in the wings ($p \leq 0.05$), and remained stable in the breast. In growing capons, the content of skin with subcutaneous fat increased in the back and breast ($p \leq 0.05$), and decreased in the neck and wings ($p \leq 0.05$, Table 3).

Table 3. Percentages of lean meat, skin with subcutaneous fat and bones from different cuts in the total weight of a given tissue component in Green-legged Partridge cockerels and capons (%).

Item	Sex category	Age (wk)					Analysis of variance (significance)		
		12	16	20	24	28	Age	Sex category	A×S
Lean meat									
Breast	Cockerels	34.2^{a} ±1.15	33.8^{ab} ±1.62	32.7^{b} ±1.83	31.1^{c} ±1.68	31.9^{cb} ±1.53	0.000	0.038	0.000
	Capons	33.3^{a} ±1.21	33.9^{ab} ±1.70	*35.7^{b} ±1.62	*35.9^{c} ±1.59	*36.0^{cb} ±1.61			
Legs	Cockerels	35.6^{a} ±1.25	*36.8^{b} ±1.73	*37.8^{c} ±1.68	*39.2^{d} ±1.91	*38.8^{d} ±1.93	0.042	0.000	0.001
	Capons	35.4^{a} ±1.18	35.3^{a} ±1.62	35.9^{a} ±1.52	35.4^{a} ±1.74	35.3^{a} ±1.69			
Back	Cockerels	15.7^{a} ±1.16	15.3^{a} ±1.08	16.2^{b} ±0.60	*16.9^{b} ±1.22	*16.8^{b} ±1.38	0.046	0.010	0.077
	Capons	15.9^{b} ±0.97	15.5^{ab} ±1.12	15.0^{a} ±0.86	15.7^{ab} ±1.34	15.9^{b} ±1.48			
Wings	Cockerels	10.4^{a} ±1.11	10.1^{a} ±0.72	9.3^{b} ±1.20	8.8^{b} ±1.10	8.6^{b} ±1.36	0.000	0.000	0.251
	Capons	11.0^{a} ±0.95	10.5^{a} ±0.89	9.6^{a} ±0.69	*9.5^{b} ±1.01	*9.4^{b} ±1.23			
Neck	Cockerels	4.1^{a} ±0.37	4.1^{a} ±0.39	4.0^{a} ±0.34	4.1^{a} ±0.40	*3.9^{a} ±0.43	0.077	0.000	0.017
	Capons	4.4^{a} ±0.38	4.2^{a} ±0.32	3.8^{ab} ±0.40	3.6^{b} ±0.31	3.4^{b} ±0.35			
Skin with subcutaneous fat									
Breast	Cockerels	17.4^{a} ±1.17	17.7^{a} ±1.23	16.6^{b} ±1.12	16.6^{b} ±1.31	17.7^{a} ±1.19	0.047	0.017	0.035
	Capons	17.8^{a} ±1.67	18.8^{b}±1.66	18.2^{c} ±1.19	*18.9^{b} ±1.52	*18.7^{bc} ±1.62			
Legs	Cockerels	21.2^{a} ±1.16	22.3^{a} ±1.06	*21.6^{a} ±1.21	*21.3^{a} ±1.22	*23.0^{b} ±1.55	0.032	0.003	0.694
	Capons	20.5^{a} ±1.49	21.3^{a}±1.54	20.7^{a} ±1.36	20.5^{a} ±1.34	21.1^{a} ±1.48			
Back	Cockerels	21.0^{a} ±1.87	20.4^{a} ±1.56	23.6^{b} ±1.69	23.4^{b} ±1.74	23.1^{b} ±1.64	0.003	0.000	0.441
	Capons	*23.2^{a} ±2.01	*23.9^{a} ±1.87	*27.8^{b} ±1.98	*28.3^{b} ±1.83	*28.5^{b} ±1.73			
Wings	Cockerels	20.2^{a} ±1.48	19.2^{a} ±1.36	15.7^{b} ±1.11	15.9^{b} ±1.24	12.4^{c} ±1.18	0.000	0.073	0.174
	Capons	19.4^{a} ±1.49	18.1^{a} ±1.41	15.1^{b} ±1.24	13.8^{b} ±1.16	13.3^{b} ±1.13			
Neck	Cockerels	20.2^{a} ±1.13	*20.4^{ab} ±1.21	*23.6^{b} ±1.38	*23.2^{b} ±1.29	*23.8^{b} ±1.19	0.000	0.001	0.033
	Capons	19.1^{a} ±0.97	18.0^{a} ±1.31	18.1^{a} ±1.21	18.5^{a} ±1.32	18.3^{a} ±1.26			
Bones									
Breast	Cockerels	14.8^{a} ±0.89	15.0^{a} ±1.21	13.3^{b} ±1.35	13.6^{b} ±1.41	13.2^{b} ±1.17	0.001	0.143	0.964
	Capons	15.2^{a} ±1.00	15.2^{a} ±1.14	15.5^{a} ±1.19	14.3^{b} ±1.23	14.0^{b} ±1.26			
Legs	Cockerels	27.3^{a} ±1.61	26.8^{a} ±1.17	26.0^{b} ±1.09	26.2^{b} ±1.38	26.1^{b} ±1.29	0.046	0.164	0.992
	Capons	27.1^{a} ±1.53	26.1^{ab} ±1.25	25.4^{b} ±1.23	25.8^{b} ±1.41	25.7^{b} ±1.25			
Back	Cockerels	30.1^{a} ±2.08	31.0^{a} ±1.75	32.8^{b} ±1.65	33.6^{b} ±1.25	33.2^{b} ±1.62	0.000	0.295	0.827
	Capons	29.5^{a} ±1.89	30.8^{a} ±1.68	31.5^{a} ±1.81	33.0^{b} ±1.38	33.1^{b} ±1.54			
Wings	Cockerels	21.1^{a} ±0.98	20.9^{a} ±1.21	21.4^{a} ±1.28	20.2^{a} ±1.12	20.9^{a} ±1.02	0.158	0.367	0.782
	Capons	21.4^{a} ±0.99	21.9^{a} ±1.39	21.6^{a} ±1.34	20.9^{a} ±1.18	20.6^{a} ±1.11			
Neck	Cockerels	6.6^{a} ±0.60	6.3^{a} ±0.71	6.5^{a} ±0.64	6.4^{a} ±0.36	6.6^{a} ±0.57	0.146	0.394	0.229
	Capons	6.8^{a} ±0.63	6.1^{a} ±0.69	6.1^{a} ±0.67	6.1^{a} ±0.42	6.6^{a} ±0.61			

$^{a\text{-}d}$ Mean values (age) followed by different letters are significantly different at $\alpha = 0.05$. *Mean values in the age groups of intact cockerels and capons are significantly different at $\alpha = 0.05$

The distribution of bones in the analyzed cuts was similar in cockerels and capons (Table 3). In both cockerels and capons, the proportion of bones increased in the back and decreased in the legs and breast (until 20 wk of age in cockerels, $p \leq 0.05$ and until 24 wk of age in capons, $p \leq 0.05$).

Discussion

One-day-old chicks are characterized by poorly developed muscle and adipose tissues, which is reflected in a low content of edible components in their BW.

In one-day-old broiler chickens, edible components account for approximately 47% of total BW, and their share increases to approximately 63% at slaughter (Murawska *et al.*, 2011). In the present study, edible components accounted for approximately 52% of total BW in Green-legged Partridge cockerels and capons at 12 wk of age. At 28 wk of age, edible components had a higher share of BW in cockerels compared with capons (58.5% *vs.* 56.5%, Table 2). Capon production is typically based upon native chicken breeds (Terčič *et al.*, 2007; Miguel *et al.*, 2008; Rikimaru *et al*, 2009; Díaz *et al.*, 2010; Calik *et al.*, 2015). Many indigenous chicken breeds are classified as dual-purpose. Dual-purpose chickens have lower nutrient requirements than broilers, but they are also characterized by a slower growth rate and lower carcass quality than broilers (Terčič *et al.*, 2007; Sokołowicz *et al.*, 2016).

In the current study, the percentages of gizzard and liver in total BW were higher, and the percentage of heart was lower in capons (24 and 28 wk of age) than in cockerels (Table 2). In studies by Rahman *et al.* (2004) and Miguel *et al.* (2008), capons were characterized by higher liver weight and lower heart weight than cockerels (Miguel *et al.*, 2008), whereas no differences were found in gizzard weight between the two groups. Among edible components, a greater increase in the percentage of lean meat in total BW was noted in cockerels (by 1.6%), and a greater increase in the percentage of skin with subcutaneous fat was observed in capons (by 0.6%, Table 2). Increased fat deposition in caponized birds, including both abdominal and subcutaneous fat, has also been reported by other authors (Tor *et al.*, 2002; Díaz *et al.*, 2010; Symeon *et al.*, 2010; Kwiecień *et al.*, 2015; Adamski *et al.*, 2016). Capons have also been found to have a significantly higher content of total intramuscular fat compared with intact males (Sinanoglou *et al.*, 2011; Calik *et al.*, 2015; Gesek *et al.*, 2017; Zawacka *et al.*, 2017).

As already mentioned, cockerels of different breeds raised for various purposes are used for capon production. The type of chickens has a significant influence on muscle development. For instance, in growing broiler chickens, the percentage of muscle tissue increases in the breast and decreases insignificantly in the legs, relative to the total lean content of the carcass (Murawska *et al.*, 2011; Michalczuk *et al.*, 2016). In layer-type cockerels, the percentage of lean meat increases in the legs and decreases in the breast with age (Murawska *et al.*, 2005). Such a tendency was also observed in Green-legged Partridge cockerels, whereas in capons, an increase was noted in the content of breast muscles (Table 3). Similar changes in the distribution of muscle tissue in Extremeña Azul cockerels and capons were also reported by Muriel Durán (2004). In the cited study, the percentage of breast muscles in the carcass was higher by approximately 2% in capons than in cockerels, whereas the percentage of leg muscles (thighs + drumsticks) was approximately 1.2% lower in the former. Breast muscles, similarly to leg muscles, belong to the most valuable components of the carcass, therefore an increase in the percentage of breast muscles in the total lean weight of Green-legged Partridge capons is highly desirable.

Changes in the tissue composition of different carcass parts in cockerels and capons do not occur evenly. In the current study, the content of skin with subcutaneous fat increased in the legs, back and neck in Green-legged Partridge cockerels, and in the back and breast in capons (Table 3). It appears that such differences in the distribution of skin with subcutaneous fat between cockerels and capons result from increased deposition of fat (including subcutaneous fat) in the abdominal and dorsal area (Zawacka *et al.*, 2014). Symeon *et al.* (2010) also observed a higher proportion of skin with fat in the breast of capons. In layer-type chickens raised to 18 wk of age, the content of skin with subcutaneous fat increased only in the legs (Murawska *et al.*, 2005). The results of our study and the findings of Tor *et al.* (2002) indicate that the deposition of subcutaneous fat in the carcasses of capons could be affected not only by testosterone levels but also by the type of cockerels.

It should be noted that in Green-legged Partridge cockerels and capons, a considerable increase in the content of muscle tissue and skin with a fat layer is accompanied by a decrease in the content of giblets (Table 2). Similar trends were also observed in broiler chickens (Murawska *et al.*, 2011) and turkeys (Murawska, 2013a). The available literature provides no information about age-related changes in the percentage of giblets in the total BW of caponized cockerels. Studies which analyzed the percentage of giblets in the total BW of birds have not revealed significant differences between cockerels and capons (Miguel *et al.*, 2008; Calik *et al.*, 2015).

Bones had a somewhat lower share of total BW in Green-legged Partridge cockerels and capons (12.7% and 13.5% at 16 wk of age, respectively, Table 2) than in layer-type cockerels (14.5% at around 15 wk of age, Murawska, 2005). The age x sex category interaction for the percentage of bone tissue in total BW (Table 2) could result from a rapid increase in testosterone concentrations observed in Green-legged Partridge cockerels from 12 wk of age (Zawacka *et al.*, 2017). The growth of bone tissue is completed earlier than the growth of muscle and adipose tissues, which contributed to eliminating the difference between cockerels and capons at 16 wk of age.

Between 12 and 24 wk of age, changes in the distribution pattern of bones were minor and similar in cockerels and capons (Table 3). In a study of Green-legged Partridge fowl conducted by Tomaszewska *et al.* (2017), caponization had no effect on the weight or length of bones, but it reduced the mineral density of femoral bones.

In gallinaceous birds, non-edible components comprise not only bones but also slaughter offal including abdominal fat. The total percentage of slaughter offal in BW decreases with age, despite an increase in abdominal fat content (Murawska *et al.*, 2011; Murawska, 2013a; Eleroğlu *et al.*, 2017). In our study, the proportion of offal components in total BW decreased with age in both cockerels and capons. The observed changes tended to be greater in cockerels than in capons (3.3 % *vs*. 1.3%, Table 2) due to increased abdominal fat deposition in the latter (abdominal fat content increased by 2.4% in capons and by 1.6% in cockerels, Table 2). According to Miguel *et al.* (2008), castration had no influence on the weight of viscera, but contributed to an increase in the weight of abdominal fat in capons. Other authors also demonstrated that abdominal fat has a high share of total BW in capons, ranging from 3.7% - 4.5% (Terčič *et al.*, 2007) to nearly 5% (Calik *et al.*, 2015) depending on breed and slaughter age.

The current study demonstrated that Green-legged Partridge cockerels are suitable for capon production. Capon carcasses are characterized by a desirable composition and desirable proportions of major components, including a higher percentage of breast muscles in total lean weight relative to cockerels.

In conclusion, at 24 and 28 wk of age, cockerels compared with capons, are characterized by a higher proportion of edible components and a more desirable carcass tissue composition due to a higher content of lean meat in total BW. In capons, a higher percentage of non-edible components in total BW results from the deposition of abdominal fat, which increases from 20 wk of age. Differences in the distribution of lean meat in the carcass are noted from 20 wk of age in both castrated and intact birds. The content of breast muscles increases in capons, and the content of leg muscles increases in cockerels. The results of this study indicate that in view of the optimal lean meat content of the carcass and the optimal distribution of major tissue components, Green-legged Partridge capons should be fattened for a maximum period of 24 wk.

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