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Effects of sex on carcass composition and physicochemical, textural and rheological properties of meat from grey partridge

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Abstract

The study aimed to determine the effects of sex on bodyweight (BW) and dimensions, carcass weight, dressing percentage, percentage of carcass components, chemical composition, mineral content, acidity and electrical conductivity of the breast and leg muscles of grey partridges (*Perdix perdix* L.). The experiment also determined the colour attributes, textural and rheological characteristics, and mineral content in the liver of the grey partridge. Fifteen males and 15 females were examined. Carcasses were weighed on electronic scales, then dissected. The chemical compounds in the breast and leg muscles were determined with a near-infrared spectrophotometer. To ascertain the contents of minerals, the meat samples were analysed by spectrometry. The textural and rheological properties were established with the TPA double compression test, Warner-Bratzler (WB) test, and the relaxation test. At 36 weeks, males had significantly longer keels and shanks than females. Males and females did not differ significantly in the weight of the eviscerated carcass, dressing percentage, and percentage of carcass components. There were no significant differences between males and females in the chemical composition of meat from breasts and legs, and in the mineral contents of the breast and leg muscles and the liver. Bird sex had no significant effect on acidity and electrical conductivity of the breast and leg muscles or on the lightness (L*), redness (a*), and yellowness (b*) of the *Pectoralis major* muscle. No significant differences were established between 36-week-old males and females in textural and rheological characteristics. Thus, there was scant evidence for sexual dimorphism in this species.

Keywords: carcass composition, colour coordinates, mineral content, sexual dimorphism
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Introduction

The grey partridge (*Perdix perdix* L.) is a wild bird belonging to the Phasianidae family (Galliformes order). It is also known as the English partridge, Hungarian partridge and the hun (Kokoszyński *et al.*, 2013). The measurements of a grey partridge include average length 30 cm, wingspan 50 cm, tail length 7 - 8 cm, beak length about 1 cm, and the shank length 4 cm. In the natural habitat, the BW of an adult bird ranges from 290 g to 475 g and it exhibits a seasonal pattern. The birds are heaviest in winter and lightest in summer (Krupka, 1989; Meriggi *et al.*, 2007). Grey partridges originally inhabited steppes in the Eastern Mediterranean area. Today they are found all over Europe, in northern Asia Minor and in southern Siberia. They have been also introduced to North America, Great Britain, and New Zealand (Behnke, 1995). Since the early 1990s, the population of wild grey partridges in Poland has declined significantly (Kujiper *et al*., 2009). The number of partridges decreased from about 960,000 in 1990 to about 280,000 in 2015 (Bombik *et al.,* 2019). The number of partridges in Poland in 2019 was only 273,000 (Statistical yearbook of agriculture, 2020). Until 1995, the wild grey partridge was extinct as a breeding species. The main reasons for the decline of the bird population in Europe are change in land use and agricultural development (Buckley *et al.*, 2021).

Partridge carcasses exhibit good muscle content. In the eviscerated carcass, the breast muscle content ranges from 28.3 to 36.0%, and the leg muscle from 20.7 to 20.8% (Adamski & Kuźniacka, 2007;

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Večerek *et al.*, 2008; Kokoszyński *et al.*, 2017). Partridge muscles contain chemical components that make them highly nutritive (proteins, fats, pigments, glycogen, and many others) (Uscebrka *et al.*, 2006). Partridge meat is high in protein (240 g/kg) (Yamak *et al.*, 2016) and low in fat (Hoffman & Wiklund, 2006), which contributes to the quality of meat and therefore it is regarded as delicate and tasty (Choi & Kim, 2009). The breast muscle lipids contain 39% of saturated fatty acids and the leg muscles contain 48%. The breast and leg muscles of partridges are low in monounsaturated fatty acids (20% and 28%) and high in polyunsaturated fatty acids (41% and 20%) (Kuźnicka & Adamski, 2010). The energy value of breast muscles is 133 kcal/100 g (Vitula *et al.*, 2011). This value can be altered by changing the water, protein, and fat content.

Grey partridges are characterized by rapid growth. They are considered adult at 12 weeks old and become independent in their natural habitat at the end of 13 weeks. In Poland, partridges are introduced to the wild between 8 and 9 months old, which increases the percentage of partridges that survive there (Kokoszyński *et al.*, 2013). Kobriger (1980) analysed anthropometric measurements of grey partridges over 17 weeks and found that BW gain was highest (9.6 g/day) in the fourth week and lowest (0.1 g/day) in the 16th week. The BW of partridges determines their potential to survive (resistance to the temperature changes), therefore it is regarded as one of the most important traits (Nowaczewski *et al.*, 2014). Wild grey partridges were observed to have lower BW, shorter small intestines, and shorter caecums, resulting in smaller heart, liver and gizzard weights and percentage compared with farmed partridges (Putaala & Hissa, 1995).

The sex of partridge had a significant effect on the content of amino acids in the breast muscles, which ranged in dry matter from 28.52 g/kg (proline) to 109.13 g/kg (glutamine) in males, and from 29.93 g/kg (proline) to 136.46 g/kg (glutamine) in females (Brudnicki *et al.*, 2013).

The study aimed to determine the effect of sex on BW and dimensions, carcass weight, dressing percentage, percentage of carcass components, proximate analysis, acidity (pH_{24}), and electrical conductivity (EC_{24}). There are only a few studies about the mineral content in the liver or leg and breast muscles. Hence the current study addresses that knowledge gap. Also, acidity and electrical conductivity of the breast and leg muscles, colour attributes, and textural and rheological characteristics of the pectoralis major muscle of the 36-week-old grey partridges were all ascertained.

Materials and methods

This study, using 15 male and 15 female 36-week-old grey partridges (*Perdix perdix* L.), was approved by the Ethics Committee for Experiments on Animals, Resolution no. 17/2010 of 23 June 2010. Before slaughter, birds were weighed individually with an electronic scale (PS 1000/X, Radwag, Radom, Poland) with an accuracy of 0.1 g. These parameters were measured with a dressmaker's tape to the nearest 1 mm, namely body length (between the first cervical vertebra and the posterior edge of the ischium), trunk length (between the tuberosity of the shoulder joint and the posterior edge of the ischium), chest circumference (behind the wings, through the anterior edge of the keel and the middle segment of the thoracic vertebrae), keel length (from the anterior to the posterior edge of the sternum), drumstick length (between the knee joint and the tarsal joint), and shank length (between the tarsal joint and the posterior surface of the outer toe at its base).

Eviscerated carcasses and necks were chilled in a refrigerated cabinet (Hendi, Gądki, Poland) at 4 °C for 18 hours, and then weighed with an electronic scale (PS 1000/X, Radwag, Radom, Poland) with an accuracy of 0.1 g. After weighing, the carcasses were dissected according to the method developed by Ziołecki and Doruchowski (1989). Each carcass was dissected into the breast muscles (*Pectoralis major* plus *Pectoralis minor* on both sides of the breast part), leg muscles (all muscles from both thigh and drumstick), skin with subcutaneous fat (without wing fat), abdominal fat, neck without skin, wings with skin, and the remainder of the carcass. The dissected components were weighed with the same electronic scale.

Water, protein, fat and collagen contents of the breast and leg muscles were established with the FoodScan near-infrared (NIR) spectrophotometer (FoodScan Laboratory, Foss, Warrington, UK). The meat samples were freeze-dried and wet mineralized in an Ethos Plus microwave digester (Milestone, Sorisole, Italy) to determine the amount of certain minerals (sodium, potassium, magnesium, phosphorus, zinc, iron, copper) in breast and leg muscles, and liver. The samples were analysed by atomic absorption spectrometry in the iCE 3000 series atomic absorption spectrophotometer (Thermo Scientific, Cambridge, UK). Phosphorus content was determined colorimetrically using the Marcel Media Eko spectrometer (Marcel, Warszawa, Poland). The entire procedure was performed according to Polish Standards.

Prior to dissection, 24 hours post mortem, the pH of the breast muscles (*Pectoralis major*) and the leg (drumstick) muscles (pH_{24}) were measured with the Star CPU pH meter (Ingenieurbüro R. Matthäus, Nobitz, Germany), equipped with a combination glass electrode for meat pH measurement. Before measurement, the pH meter was calibrated with pH buffers 7.0 and 5.5. The results were determined with an accuracy of

0.01. Electrical conductivity (mS/cm) of breast muscles and leg muscles (at 4 °C) 24 hours post mortem (EC_{24}) was also measured with a LF-Star CPU device (Ingenieurbüro R. Matthäus, Nobitz, Germany). The device's steel electrodes were inserted into breast muscles or leg muscles (drumstick) at an angle of 90° along the muscle fibres. The measurement had an accuracy of 0.1 mS/cm.

The cooking loss of meat was determined according to the method described by Walczak (1959). The meat samples (20 g) were formed into balls, wrapped in absorbent gauze, and placed in a 85 °C water bath for 10 min. After removal from the water bath, they were cooled for 30 min. at 4 °C and weighed again with the precision balance (Pioneer, Ohaus, USA). The meat weight loss (%) was calculated as the difference in meat weight before and after heat treatment. The meat colour was determined on the inner surface of raw breast muscles *(Pectoralis major)* and leg muscles (thigh and drumstick muscles, without patella and tendons) obtained after dissection. The colour lightness (L*), redness (a*), and yellowness (b*) were measured with a CR-410 chroma meter (Konica Minolta, Osaka, Japan) with a 20-mm measurement area and D_{65} illuminant. Before the measurements, the chroma meter was calibrated against a white reference tile (Y=94.40, x=0.3159, y=0.3325).

The textural properties (hardness, cohesiveness, springiness, chewiness, gumminess, WB *shear force*) and the rheological properties (the sum of elastic moduli and the sum of viscous moduli) of the 30 *Pectoralis major* muscle samples were determined with an Instron 1140 apparatus (Instron Corp. USA), using the TPA double compression test, WB test, and the relaxation test. Each test was performed in four replications for each sample (120 determinations in total). The tests were performed with the samples treated thermally in water heated to 70.2 °C in the geometric centre of the sample, which was cooled to 18 °C. Muscle-thick blocks were cut perpendicular to the muscle fibre orientation from each sample with a Siemens MS 6000 electric slicer (Hausgeräte GmbH, Köln, Germany). Next, the plunger -- 0.62 cm in diameter -- was driven twice into the sample parallel with the muscle fibre orientation, with an 80% deformation and a crosshead speed of 50 mm/min (TPA test). These parameters were determined from the curve representing strength-deformation dependence, namely hardness, cohesiveness, springiness, chewiness, and gumminess (Bourne, 1982).

The WB test involved cutting the *Pectoralis major* muscle samples across the muscle fibres using a special triangular blade. The working speed of the crosshead was 50 mm/min. The maximum shear force was determined in the test (Bourne, 1982). In the relaxation test the plunger -- 1.26 cm in diameter -- was driven into the muscle samples. Changes in stress were recorded for 90 seconds. The elasticity and viscosity moduli were calculated with the generalized Maxwell model, made up of three elements connected in parallel, namely the Hooke body and two viscous-elastic Maxwell bodies. The equation model was:

$$\delta = \epsilon * \left[E_0 + E_1 * \exp\left(\frac{-E_1 * t}{\mu_1}\right) + E_2 * \exp\left(\frac{-E_2}{\mu_2}\right)\right]$$

where: δ *denotes* tension (kPa);
ϵ denotes deformation;
E_0 denotes elasticity module for the Hooke body (kPa);
E_1 and E_2 denote elasticity moduli for Hooke body 1 and 2 (kPa);
μ_1 and μ_2 were viscosity moduli for Maxwell body 1 and 2 (kPa × s); and
t denotes time.

To make the interpretation of the results easier for each sample, the sum of the elasticity moduli (E_0+E_1+E_2) and the sum of the viscosity moduli (μ_1+μ_2) was calculated.

The statistical analysis was performed using SAS (SAS Institute, Inc., Cary, North Carolina USA). Differences in means between males and females were assessed (at $P < 0.05$) with Tukey's test.

Results and Discussion

At 36 weeks old, the male grey partridges had significantly greater keel and shank lengths than females and the lengths of their trunks and drumsticks tended (P <0.10) to be greater (Table 1). Thus, some sexual dimorphism was observed in skeletal size. However, the greater skeletal size of males was not reflected in their having greater BW in these data.

Table 1 Bodyweight and dimensions in 36-week-old grey partridges

Trait	Male	Female	Pooled SE	*P*-value
Bodyweight, g	433.7	415.9	8.68	0.165
Body length, cm	20.4	20.3	0.21	0.932
Trunk length, cm	13.1	12.8	0.15	0.094
Chest circumference, cm	20.7	20.3	0.13	0.319
Keel length, cm	7.5	6.8	0.18	0.004
Drumstick length, cm	8.5	8.1	0.15	0.078
Shank length, cm	5.4	5.2	0.04	0.023

The male grey partridges tended (P <0.10) to have greater carcass weights and neck percentages than females, with the carcass remainders tending to be greater in females (Table 2).

Table 2 Carcass weight, dressing percentage and proportion of carcass components in 36-week-old grey partridges

Trait	Male	Female	Pooled SE	*P*-value
Carcass weight, g	331.6	312.5	7.23	0.071
Dressing percentage, %	76.5	75.1	0.83	0.274
Breast meat, %	29.8	29.0	1.31	0.573
Leg meat, %	18.2	17.6	0.46	0.388
Skin with subcutaneous fat, %	10.8	10.4	0.63	0.698
Abdominal fat, %	1.2	1.0	0.15	0.351
Neck, %	2.7	2.4	0.19	0.073
Wings, %	9.6	9.5	0.26	0.562
Carcass remainders, %	27.7	30.1	0.82	0.086

No significant differences were detected ($P > 0.05$) between the male and female birds in the chemical composition of breast and leg muscles (Table 3). However, female grey partridges tended (P <0.10) to have a greater percentage of water in the leg at the expense of fat relative to males.

Table 3 Chemical composition of breast and leg muscles in 36-week-old grey partridges

Trait	Muscle	Male	Female	Pooled SE	*P*-value
Water, %	Breast	72.4	72.1	0.08	0.178
	Leg	71.2	72.0	0.19	0.062
Protein, %	Breast	24.5	24.4	0.13	0.299
	Leg	20.9	20.9	0.10	0.901
Fat, %	Breast	1.4	2.1	0.14	0.062
	Leg	5.5	5.0	0.19	0.051
Collagen, %	Breast	1.6	1.7	0.04	0.156
	Leg	1.7	1.8	0.06	0.339

The results showed that the sex of the partridge had no detectable effect (P >0.10) on the mineral contents of breast and leg muscles (Table 4).

Table 4 Mineral content of breast and leg meat in 36-week-old grey partridges

Mineral	Muscle	Male	Female	Pooled SE	*P*-value
Sodium, mg/100g	Breast	47.8	49.0	4.88	0.922
	Leg	84.0	73.6	5.09	0.456
Potassium, mg/100g	Breast	314.9	329.5	8.87	0.495
	Leg	326.9	360.8	11.94	0.289
Phosphorus, mg/100g	Breast	47.7	47.7	0.47	0.998
	Leg	50.2	48.8	1.75	0.769
Magnesium, mg/100g	Breast	31.3	28.7	0.90	0.219
	Leg	29.2	27.1	1.33	0.563
Zinc, mg/100g	Breast	0.7	0.9	0.11	0.303
	Leg	1.9	1.3	0.25	0.443
Iron, mg/100g	Breast	1.8	2.0	0.18	0.579
	Leg	3.2	2.7	0.50	0.601
Copper, mg/100g	Breast	0.1	0.1	0.01	0.608
	Leg	0.2	0.1	0.01	0.143

Similar to the results for the breast and leg muscles, the sex of the partridge had no detectable effect (P >0.10) on the mineral content of the liver (Table 5).

Table 5 Mineral content in mg/100 g of liver in 36-week-old grey partridges

Mineral	Male	Female	Pooled SE	*P*-value
Sodium, mg/100g	84.4	95.3	8.51	0.598
Potassium, mg/100g	265.4	239.3	21.20	0.611
Phosphorus, mg/100g	58.6	58.2	0.74	0.843
Magnesium, mg/100g	20.2	20.5	0.61	0.837
Zinc, mg/100g	6.5	5.7	0.99	0.462
Iron, mg/100g	32.3	31.8	2.77	0.947
Copper, mg/100g	0.7	0.6	0.08	0.396

An analysis of the physicochemical properties of breast and leg muscles showed generally similar characterizations of the male and female birds (Table 6). However, cooking loss from the legs of female birds tended (P <0.10) to be greater than that from their male counterparts -- as might have been expected from the corresponding greater water contents. The breast muscle of the female birds also tended (P <0.10) to have a slightly lighter colour that that of the male birds.

Table 6 Physicochemical properties of breast and leg muscles in 36-week-old grey partridges

Trait	Muscle	Male	Female	Pooled SE	*P*-value
pH_{24}	Breast	6.00	6.00	0.04	0.974
	Leg	6.78	6.71	0.07	0.539
EC_{24}, mS/cm	Breast	9.3	9.5	0.21	0.504
	Leg	5.4	5.4	0.33	0.932
Cooking loss, %	Breast	21.4	22.1	0.43	0.272
	Leg	28.0	30.4	0.86	0.069
L*: lightness	Breast	39.6	41.2	0.56	0.053
a*: redness	Breast	17.3	17.5	0.28	0.640
b*: yellowness	Breast	2.7	2.7	0.25	0.940

No conclusive evidence was revealed in this study for sexual dimorphism in the textural and rheological properties of the *Pectoralis major* muscle (Table 7).

Table 7 Textural and rheological traits of *Pectoralis major* muscle in 36-week-old grey partridges

Trait	Male	Female	Pooled SE	P-value
Hardness, N	29.7	26.5	1.35	0.114
Cohesiveness	0.3	0.3	0.01	0.331
Springiness, cm	1.0	1.0	0.01	0.826
Chewiness, N x cm	7.8	6.9	0.67	0.393
Gumminess, N	7.9	7.0	0.53	0.228
Warner-Bratzler shear force, N	64.1	61.5	2.78	0.546
Sum of elastic moduli, KPa	340	318	19	0.466
Sum of viscous moduli, KPa x s	15891	15706	1070	0.908

Kokoszyński *et al.* (2017) evaluated biometric traits of the body and digestive tract in 36-week-old grey partridges and observed lower BW in the males (302 g) and the females (258.60 g) compared with the present results, because of the reduced amount of dietary protein after 16 weeks old. Kokoszyński *et al.* (2017) also found smaller trunk length, chest circumference and keel length and longer shanks in the 36-week-old partridges compared with the birds tested in the current study. The BW of partridges is correlated with age (Nowaczewski *et al.*, 2014). At 15 weeks, female grey partridges had greater BW (341.2 g) than males (340.9 g). In turn, Hašcik *et al.* (2008) reported greater BW in the adult females (405 g) than in the males (371.2 g), which was not supported by the findings of the current study.

Kokoszyński *et al.* (2013) investigated 32-week-old grey partridges and observed lower average carcass weight of males (218.2 g) and females (216.0 g) compared with the current study. Kokoszyński *et al.* (2013) also reported lower dressing percentage, wings percentage, leg muscles and skin with subcutaneous fat, but higher percentages of neck and breast muscles than in the current study. In Večerek *et al.* (2008), carcass weight of 5-month-old grey partridges was 265.2 g, abdominal fat was 0.81% and the breast muscles were 18.65% of BW which is less than that of the current study. In turn, Adamski and Kuźniacka (2007) reported that eviscerated carcasses with neck from 12-week-old male grey partridges contained 36% breast muscles and 20.8% leg muscles, whereas female muscles contained 32.7% breast muscles and 20.7% leg muscles, which is more than in the 36-week-old partridges of the current study. In the same study Adamski and Kuźniacka (2007) found that a higher content of wings with skin (males 10.7%, females 11.2%), neck without skin (males 3.4%, females 3.8%), a lower content of skin with subcutaneous fat (males 4.8, females 4.8%) and lower carcass remainders (males 24.4%, females 26.8%) compared with the 36-

week-old partridges of the current study. In the study of Kirikçi *et al*. (2017), 12-week-old rock partridges were characterised by carcasses weight of 342 g for males and 309.73 g for females, which is far greater than the findings of the current study. Higher percentages of pectoral muscles in males (34.66%) and in females (35.11%) were also observed in the same study (Kirikçi *et al*., 2017). The rock partridges also were characterized by a higher percentage of the wings proportion of carcass (11.78% for males and 11.04% for females) than in the current study. The reason for the differences might have been the greater weight of the male rock partridges (458.54 g) compared with the male grey partridge (433.7 g) or differences in feed and environmental conditions. The study of Kirikçi *et al*. (2017) was conducted in winter. Sevim *et al.* (2020) studied the effect of various amounts of rosemary oil on carcass traits in 32-week-old Chukar partridge. Average carcass weight was 417.16 g for males and 352.79 g for females. These values are similar to those of the current study. The carcass remainders differed (77.02 g for males and 77.07 g for females) from the values obtained in the current study, which was because of differences in slaughter age and breed. In Bolacali *et al.* (2018), 112-day-old males of *Alectoris chukar* had a similar percentage of abdominal fat in a free-range group (1.15 - 1.32%), floor group (1.24 - 2.50%), and a group that was supplemented with dietary yeast autolysate *(Saccharomyces cerevisiae)* (1.19 - 1.41%). Similarly, wing percentage (free-range 10.22 - 10.72%, floor 6.67 - 9.96%, dietary yeast autolysate 9.94 - 10.34%) differed. Additionally, the percentage of breast muscles (free-range 35.82 - 36.72%, floor 37.02 - 37.59%, feed supplementation 36.42 - 37.15%) and leg muscles (free-range 24.77 - 25.31%, floor 24.07 - 24.54%, food supplementation 24.42 - 24.92%) was much larger than those obtained in the current study.

Putaali and Hissa (1995) observed that breast muscles of wild grey partridges contained more water (72.1%) and the same amount of fat (70.7%) compared with farmed partridges. Stęczny and Kokoszyński (2019) noted a slightly higher collagen content in the female breast muscles of 42-day-old broiler chickens than the male, which is consistent with the findings of the current study. In Flis *et al.* (2020) the average amount of water in breast muscles in 38-week-old pheasants was 73.64% for males and 74.06% for females. The research was conducted among wild and farmed pheasants. The protein content was also slightly higher than the values reported by the current study (protein content in the breast muscle was 34.64% for males and 34.34% for females).

Michalczuk and Siennicka (2010) compared the mineral content of poultry meat (100 g of edible parts) and showed the highest sodium content (91 mg) in the chicken thigh without skin, which was higher than that of male and female grey partridges aged 36 weeks in the present research. The highest potassium content (460 mg) was found in turkey fillet without skin. Chicken fillet without skin had the highest phosphorus content (240 mg). Furthermore, turkey fillet without skin had the highest magnesium content (35 mg). Turkey thigh without skin contained the highest amount of zinc (2.64 mg). The highest amounts of iron and copper were observed in goose carcasses (2.4 mg and 0.17 mg, respectively). In addition to the highest content of iron and copper in the leg muscles of male grey partridges (3.2 mg and 0.2 mg), the breast muscles of chickens and turkeys studied by Michalczuk and Siennicka (2010) contained more minerals. Suchý *et al.* (2009) analysed the content of some minerals in grey partridges and found phosphorus content of 0.8 mg/100 g and magnesium content of 0.096 mg/100 g in breast muscles, as well as phosphorus content of 0.79 mg/100 g and magnesium content of 0.087 mg/100 g in leg muscles, which was much less than in the current study. In Flis *et al.* (2020) the average magnesium content in the breast muscle in 38-week-old males of pheasants was 0.12 mg/100 g, while in females was 0.08 mg/100 g. The average zinc content in males and females was 1.7 mg/100 g. The iron content was 7.76 and 8.91 mg/100 g, and copper WAS 0.23 I 0.26 mg/100 g. Pheasants were characterized by a higher content of iron, zinc, and copper, which may be caused by the supply of these elements for farm birds and their availability in the wild.

Interestingly, Loponte *et al. (*2017) conducted a study to determine the content of selected minerals in the blood of 64-day-old Barbary partridges fed with soybean meal. The amounts of phosphorus, magnesium and iron were 6.59 mg/dl, 4.41 mg/dl and 359 mgc/dl, respectively, irrespective of sex. Szymczyk and Zalewski (2003) analysed the content of some minerals in pheasant liver and observed zinc content of 2.4 mg/100 g and copper content of 0.6 mg/100 g, which was less than in the current study. In Sevillano-Morales *et al*. (2020) the muscles of red-legged partridge contained from 0.14 mg/100g to 0.16 mg/100g of copper. The age of animals and the muscle in which the content of copper was tested were not given. The recommended dietary allowance (RDA) of copper is 0.9 mg per day for an adult, which means that consuming partridge meat will not result in toxicity (Wojtasik *et al*., 2020).

Kokoszyński *et al.* (2013) reported that the breast muscles of the 32-week-old male partridges had a lower pH value (6.32) than female muscles (6.45). In the current study, the pH value of the male breast muscles was equal to that of the females (6.0). Kokoszyński *et al.* (2013) observed that leg muscles from female grey partridges aged 32 weeks had a lower pH value (6.55) compared with the males (6.49), but in the study the male leg muscles exhibited a higher pH value (6.78) than the female ones (6.71). The differences might be the result of a lower water content of the male leg muscles. Stęczny and Kokoszyński

(2019) demonstrated that the breast muscles of 42-day-old female broiler chickens were characterized by higher electrical conductivity compared with the male breast muscles. In turn, the male leg muscles showed higher EC_{24} values than the female leg muscles. The study revealed that the female breast and leg muscles were characterized by a higher cooking loss than the male muscles. Meanwhile, Stęczny and Kokoszyński (2019) reported that the breast and leg muscles from 42-day-old male broilers showed higher cooking loss compared with the females. Balowski *et al.* (2015) found a lower cooking loss (14.10%) in the breast muscles from the male grey partridges aged 5 months compared with the present study. In Secci *et al.* (2018), 64-day-old Barbary partridge fed diets in which 25% and 50% of the dietary crude protein provided by soybean meal was replaced with *Tonebrio molitor* or *Hermetia illucens* and found the carcass pH unaffected by the diet and similar to that observed in the current study. Culerre *et al.* (2016) suggested a pH range (5.75 - 6.2) in which the meat is in good quality. A pH below 5.7 is associated with pale, sift and exudative meat, whereas a pH above 6.2 is generally found in dark hard and dry meat. The high pH of the meat promotes the growth of microorganisms. The pH value obtained in the current study and in Secci *et al.* (2018) suggested that the meat was of good quality.

In Secci *et al.* (2018) colour was measured at three places of the carcass. The results differ from the results from the current study. The most similar value of the L* parameter was found in TM25 group of Barbary partridge (L* was 53.00). The a* measurement was the most similar to that obtained from the current study in the TM25 group (a* was 4.39) and b* also in the TM25 group (b* was 5.74). Colour is influenced by and factors such as age, sex, diet. For this reason, the values differed from the current study. Unlike the current results, Hofbbauer *et al.* (2010) obtained a higher L* and b* value in male partridges. Yamak *et al.* (2016) studied the effect of production system on carcass traits in Chukar partridge *(Alectoris chukar)* and found the colour of breast muscles of free-range Chukar varied according to age. The lowest L*, a*, and b* values were obtained for the birds of both sexes at 16 weeks old. The highest L* value was observed in males aged 14 weeks, a* value in males and females aged 18 weeks, and b* value in 14-week-old males and 18-week-old females. Wen *et al. (*2020) studied the colour of meat depending on the amount of intramuscular fat among 18-week-old Chukar partridges *(Alectoris chukar)* and not on gender. Intramuscular fat content <0,5% parameter L* was 48.12 and >2,5% was 47.41 (more than in the current studies). Parameter a* with the same fat content was 6.52 and 6.91 (less than in the current studies) and parameter b* was 8.46 and 8.74 (more than in the current studies). The differences in meat colour were reflected in the pH measurements, unlike the fat content. With a fat content <0,5%, the pH was 5.99, and with a fat content >2,5% the pH was 6.04. In the current studies the pH was 6 (in each muscle). The pH influences the colour parameters and the quality of the meat. Parameter L indicates a pale colour that may be associated with poor meat quality. The a* parameter indicates the concentration of the myoglobin. Parameter b* indicates the yellowness value. In the current studies higher a* parameter was obtained, which showed the good quality of grey partridges compared with the Chukar partridges studied by Wen *et al. (*2020). Additionally, it could be concluded that the content of intramuscular fat did not affect he pH and colour of the meat. Tekce *et al.* (2019) studied the effects of various amounts of *Lactobacillus Reuteri* E81 (LRE) in the daily feed ration of male Chukar partridge on the colour and pH parameters at slaughter 21 and 42 days. In one group the heat shock was induced. The results of the L* parameter most similar to those from the current own research were obtained in the control group at 37 °C after 21 days of rearing (39.21), the pH was 6.21, and in the current research was 6.0. In a*, the most similar results were obtained by Tekce *et al.* (2019) in the 25 °C group after 42 days of rearing in the group with the addition of 400 mg/kg LRE (17.87, pH was 6.02, which was similar to the pH from the current research), and in b* the results differed significantly from the current research. The most similar results were in the 25 °C group with the addition of 400 mg/kg of LRE (b* was 10.17 at pH 6.27). The addition of LRE did not have a large effect on the colour parameters, but it influenced the growth of animals under heat stress.

Differences in the histological structure of birds contribute to the texture of the meat, mainly tenderness, with the myofibrillar and connective tissue components being most important. Balowski *et al.* (2015) observed similar values of cohesiveness (0.323), springiness (1.15 cm), chewiness (7.95 N x cm) and gumminess (7.08 N) of the *Pectoralis major* muscle in 5-month-old wild grey partridge compared with the present examination. The results differed only for hardness value (20.17 N, compared to 29.7 N in the study).

Conclusions

There was little evidence for sexual dimorphism of grey partridge when the birds were 36 weeks old.

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Authors' Contributions

KW and DK wrote the manuscript; DK developed the methodology; MS, MK and PDW described the methods used to determine the traits for methodology and laboratory analyses. DK did the calculations. Finally, all the authors addressed comments from the reviewers.

Conflict of Interest Declaration

None of the authors of this work has a financial or other relationship with people or organizations that could influence or bias the contents of this paper inappropriately.

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