INFLUENCE OF PARTIAL REPLACEMENT OF SOME INORGANIC MINERALS WITH GLYCINE COMPLEX AND VITAMIN D₃ SOURCE ON PERFORMANCE, SLAUGHTER TRAITS, SENSORY AND PHYSICO-CHEMICAL CHARACTERISTICS OF PHEASANT MUSCLES (*PHASIANUS COLCHICUS* L.) DEPENDING ON GENDER*

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Abstract

The aim of the study was to determine the effect of these substitutions on body weight and slaughtering performance, post-mortem changes, sensory characteristics and chemical composition of selected muscle groups of male and female pheasants. The tests were carried out on pheasants during 5–16 weeks of rearing in enclosed aviaries. Four groups of 8 females and 8 males were formed, and the experimental factor was the supplementation of calcium, iron, zinc and copper salts with glycinate of these elements. The control group received a feed blend containing 100% of the mineral requirement as salts. In the E-25 group, 25% of the salts were replaced by glycinate, in the E-50 group 50% of the salts were replaced, and in the E-75 group only glycinate comprising 75% of the total mineral content were used and no salts were included, with vitamin D₃ replaced by calcitriol. For the duration of the study, feeding was at will and the birds had free access to water. In addition, pheasants were weighed at the age of 4, 8, 12 and 16 weeks. Daily feed intake was monitored. At the end of the experiment, when all the pheasants were 16 weeks old, they were weighed and decapitated. The breast, thighs and drumsticks and the heart, liver and gizzard were removed from the chilled carcasses. Supplementation of calcium, iron, zinc and copper salts with 50% glycinate in feed mixtures for pheasants over a period of 5–16 weeks resulted in a slight improvement in the slaughter weight of birds and a significant increase in crude ash, calcium and zinc, while at 75% supplementation and when calcitriol was used instead of vitamin D₃, increased phosphorus levels were found in the pheasant muscles analysed. Males had higher body weight, body weight gain, carcass, liver and gizzard weights, and their muscles had more magnesium and potassium and less calcium, sodium and iron than females.

Key words: pheasant, chelates, meat quality, minerals

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The pheasant is not a native species of European fauna. In Poland, pheasants appeared in the 16th century and were initially only kept on indoor-rearing farms in the region of Silesia. Due to its considerable utility, it quickly became an attractive species for natural habitats and a game bird (Beeger et al., 2017; Glutz et al., 1973). Because of their very high usefulness and, above all, nutritious and low-fat meat, besides being raised in indoor-rearing hatcheries and destined for repopulation, pheasants are being increasingly raised on fattening farms (Gašparovič et al., 2017; Gugala and Flis, 2018; Mieczkowska et al., 2015; Tucak et al., 2008). In pheasants used this way, some important aspects are the weight of the birds, the slaughter yield and the physical and chemical characteristics of the individual muscle groups for culinary use. Better nutritional solutions are sought in terms of optimising reproduction processes, bird growth rate, meat quality and its subsequent fitness for consumption or viability for storage (Biesiada-Drzazga et al., 2011; Gugala et al., 2019; Kokoszyński et al., 2012; Kuźniacka et al., 2007; Mieczkowska et al., 2015; Šperanda et al., 2008). Attempts are being made to optimise the content of protein, energy, vitamins and minerals as well as the inclusion of various additives in mixtures for pheasants (Flis et al., 2019 a; Gašparovič et al., 2017; Gugala et al., 2019; Hanzal et al., 2016; Kokoszyński et al., 2011; Nowaczewski and Kontecka, 2005). Pheasant nutrition, including protein and energy levels and the amount and source of minerals (Baloch et al., 2017; Bhoyar, 2015; Hofbauer et al., 2010; Kokoszyński et al., 2011) is an important factor in determining production results, especially meat quality.

Minerals added to bird feed are mostly found in inorganic compounds: oxides, chlorides, sulphates and phosphates. Organic compounds of minerals are currently being introduced into feed, which may contribute to their better assimilation and bioavailability (Bai et al., 2017; Baloch et al., 2017; Bhoyar, 2015; Świątkiewicz et al., 2014; Vieira, 2008), thus leading to more precise dosing and their lower excretion in faeces and urine. The bioavailability of minerals, especially calcium and phosphorus, is influenced by calciferols, especially the active form of vitamin D₃ in the form of calcitriol (Bhoyar, 2015; Castro et al., 2018; Garcia et al., 2013). In previous works the beneficial effects of the use of organic forms of the glycine chelate variety on hatching and survival rates of chicks was demonstrated, as well as the effect on the skeletal system by increasing the bone mass and density and the mechanical strength of individual bones (Gugala et al., 2019; Flis et al., 2019 a). Increasing the bioavailability of dietary nutrients, including minerals, can affect metabolic processes and health and thus contribute to improving animal production rates and to growth and slaughter performance, sensory and physico-chemical characteristics of meat from pheasant breasts and legs (Adamski and Kuźniacka, 2006; Kokoszyński et al., 2014; Łukasiewicz et al., 2011; Suchý et al., 2008; Yalçın et al., 2006).

The aim of the study was to determine the effect of substituting calcium, iron, zinc and copper salts with glycine chelates of these elements in the amounts of 25 and 50% of the dietary needs for these minerals, and also substituting them with chelates in the amount of 75% of the requirement without 25% in mineral salts to complement them and replacing vitamin D₃ with calcitriol. The foci for effect observation were body weight and slaughter traits, post-mortem changes, sensory characteristics and chemical composition of selected muscle groups of male and female pheasants.

Material and methods

Ethical approval

The experimental procedures used throughout this study were approved by the Local Ethics Committee on Animal Experimentation of the University of Life Sciences in Lublin, Poland (Resolution no. 22/2016 of 13 May 2016).

Feed and nutrition

All feed components were mixed and pelleted (0.5-mm diameter) at 60°C. The mix was put into two feeders set up in the flight pen area. The ingredient and chemical composition of the experimental basal diets are presented in Table 1. The nutritive value of this breeder diet was prepared according to the National Research Council's recommendations (1994). Copper, zinc, iron and calcium in the form of salts or glycine chelates were introduced into the mineral and vitamin premix, which contained none of these minerals. The Cu, Zn, Ca and Fe supplemented in the feed mixtures were based on the dietary recommendations of the National Research Council (1994). Glystar Forte chelate (Arkop Sp. z o. o., Bukowno, Poland) was used in the experiment and contains 16% Zn and 36% glycine, 16% Cu and 37% glycine, 16% Fe and 42% glycine, and 20% Ca and 46% glycine (Table 2).

Table 1. Ingredient (g kg⁻¹) and nutritional compositions of basal diets used for control group of pheasants

Components	Starter (0–4 weeks)	Grower (5–8 weeks)	Finisher (9–16 weeks)
1	2	3	4
Corn	333.3	316.2	318.6
Wheat	130.0	160.0	290.0
Soybean meal	300.0	280.0	140.0
Garden pea	20.0	50.0	50.0
Linseed	40.0	40.0	40.0
Sunflower meal	50.0	80.0	80.0
Fish meal	70.0	10.0	0.0
Sorghum	20.0	30.0	50.0
Dicalcium phosphate	12.0	13.0	13.0
Calcium carbonate	15.0	12.0	10.0
Sodium chloride	5.0	5.0	5.0
Mineral–vitamin premix ¹⁾	2.5	2.5	2.5
DL-methionine	1.2	0.5	0.3
L-lysine chloride	1.0	0.8	0.6
Analysed nutrients:			
dry matter (g kg ⁻¹)	878.8	877.2	877.3
crude protein (g kg ⁻¹)	265.1	232.6	183.7
lysine (g kg ⁻¹)	13.8	11.7	10.9
methionine (g kg ⁻¹)	5.37	4.05	3.76

Table 1 – contd.

1	2	3	4
Crude ash (g kg ⁻¹)	71.5	65.3	65.1
calcium (g kg ⁻¹)	11.4	9.5	8.7
total phosphorus (g kg ⁻¹)	7.5	6.9	6.8
iron (g kg ⁻¹)	107.4	102.3	100.5
zinc (g kg ⁻¹)	79.8	79.5	78.4
copper (g kg ⁻¹)	5.8	5.6	5.5
crude fat (g kg ⁻¹)	39.5	37.4	37.1
AMEn ²⁾ (g kg ⁻¹)	10.89	10.67	10.69

¹⁾1 kg of vitamin–mineral premix provided 10,000 IU retinol, 2,500 IU D₃, 20 mg α -tocopherol, 0.5 mg thiamine, 5.0 mg riboflavin, 20 mg niacinamide, 1.0 mg pyridoxine, 0.02 mg cobalamin, 0.5 mg folic acid, 7.0 mg pantothenic acid, 2.5 mg menadione, 300 mg choline chloride, 45 mg Fe, 60 mg Mg, 50 mg Zn, 0.25 mg Se and 1.3 mg I.

²⁾Apparent metabolisable energy (AMEn) was calculated by Fisher and McNab (1987) equations.

Table 2. Experimental design in relation to source of minerals and vitamin used in respective dietary groups (Gugała et al., 2019)

Item	Dietary groups (D)			
	Control	E-25	E-50	E-75
Calcium carbonate	100 ¹⁾	75	50	–
Copper sulphate pentahydrate	100	75	50	–
Ferrous sulphate heptahydrate	100	75	50	–
Zinc sulphate heptahydrate	100	75	50	–
Calcium glycine ²⁾	–	25	50	75
Copper glycine	–	25	50	75
Ferrous glycine	–	25	50	75
Zinc glycine	–	25	50	75
Vitamin D ₃ (IU kg ⁻¹)	2500	2500	2500	–
Calcitriol (IU kg ⁻¹)	–	–	–	2500

¹⁾Percentage of provision of dietary need for minerals (NRC, 1994).

²⁾Glycinate chelate, Glystar Forte Ca, Cu, Fe and Zn.

Animals

The research was carried out on experimental groups of male and female game pheasants (*Phasianus colchicus* ssp) bred for fattening. The pheasants used in the research had been reared for many generations in pheasantries. Four groups with different nutrition were established: one control group and three experimental groups (Table 2). The pheasants as eight males and eight females together treated as a study group were kept in flight pens measuring 8.5 m long $\times$ 5.0 m wide $\times$ 3.5 m high. The experiment was carried out on four-week-old pheasants, which were fed *ad libitum*. A 3-phase feeding program was used, while the starter was fed until the 28th day of age (Table 1). After this period, grower and finisher diets were used with different

amounts of salt and zinc, copper, calcium and iron chelates for the respective dietary groups. During experiment, all animals received feed and water *ad libitum*. The pheasants' welfare was ensured in terms of zoohygienic and nutritional conditions. No behavioral anomalies were observed. In the course of the experiment, birds were weighed at weeks 4, 8, 12 and 16, while feed intake was monitored daily by weighing the mixture into feeders and recording the weight of any unconsumed feed. At the end of the experiment (16 weeks of age), the pheasants were weighed, decapitated and re-weighed after exsanguination. Before slaughter, pheasants were stunned by immersing the head and neck of tethered birds in an electrical waterbath for at least 4 seconds, in accordance with EC Regulation 1099 (2009). Another weighing was carried out after the pheasants had been plucked and eviscerated. In addition, the edible offal was weighed, i.e. the heart, liver and gizzard after it had been cleaned. Three groups of meat were prepared from carcasses: breast, thigh, and drumstick. The pH of individual muscle groups was then measured immediately after slaughter (pH_{0.15}), after an hour (pH_{1.0}), and after 24 hours (pH₂₄). Measurements were made with a CP-401 portable pH meter fitted with an ERH-12-6 combination electrode (Elmetron, Zabrze, Poland). After a period of 24 hours, the muscles were vacuum-packed in perforated plastic bags using a device intended for the preparation of food products for further storage (FoodSaver Model V 1020, Sunbeam Products Inc, Boca Raton, FL, USA) and then stored in a refrigerator at 4°C until chemical analysis.

Analytical procedures

The dry matter (method 934.01), crude ash (method 942.05), crude protein (method 976.06), crude fibre (method 978.10), crude fat (method 920.39), and lysine and methionine amino acids (method 994.12) in the basal diets and in muscles were analysed according to Association of Official Analytical Chemists (AOAC) procedures (2005). Mineral content (Cu, Fe, Zn, and Ca – method 968.08) in the feed and muscle samples was determined using the AAS flame technique in a Unicam 939 AA Spectrometer (Solaar/TJA, Germany) apparatus, after incineration at 550°C, according to the methods adopted by the AOAC (2005). In addition, total P content in the feed was determined colorimetrically (method 965.17) with a Helios Alpha UV–VIS apparatus (Spectronic Unicam, Leeds, United Kingdom).

The sensory properties of meat (flavour, taste, smell, succulence and fibrousness) were assessed on the Barylko-Pikielna scale (1975). The samples for evaluation were cooked in a 0.6% solution of salt, with a water-to-meat ratio of 2:1. After cooking, the sample was cooled to 60°C and subjected to evaluation at room temperature by a trained five-person panel (Krełowska-Kulas, 1993).

Statistical analysis

A two-way analysis of variance was performed to determine the differences between the average values of the traits analysed by nutrition group and sex. In order to determine the differences between the muscles, ANOVA single-factor analysis was performed. The Newman–Keuls test was used in Statistica 10.0 (StatSoft, Tulsa, OK, USA) to verify the significance of the differences between the mean values. The effect of nutrition, sex and muscle type was found to be notable at the significance level ($P \leq 0.05$).

Results

As shown in Table 3, the body weight of the birds at the start of the study (after four weeks of rearing) was similar (190 ± 5 g), with sexual dimorphism evident (178 g for females vs. 203 g for males). After 12 weeks of fattening, pheasants in the E-50 and E-25 groups achieved the highest body weight, but differences between all experimental groups were not statistically significant. During the entire period of the research (5–16 weeks) the average daily weight gain ranged from 10.6 to 11.1 g. Males had significantly higher weight gain (12.1 g d^{-1}) than females (9.6 g d^{-1}). The intensity of the growth rate decreased with the age of the birds regardless of sex. During the entire period (5–16 weeks), pheasants in each group ate an average of 54.25 g of the diet per day, with increasing consumption as the birds aged.

As shown in Table 4, carcass weight, carcass dressing and the weight of the gizzard, heart and liver were not susceptible to the dietary factors used. Males had significantly higher carcass, gizzard and liver weights. In addition, in Table 5 the results showed that the active acidity (pH) of individual muscles was not dependent on diet or gender. However, a significant decrease in pH value was found with time after slaughter. The use of calcium, iron, zinc and copper glycinate contributed to an increase in crude ash in the breast and thigh muscles of E-50 pheasants. The use of the same had the same increasing effect in the breast muscle of the E-75 group, where only chelates of these elements were used and supplied a 75% amount of the dietary needs, but where active vitamin D was included in the form of calcitriol (Table 6). Males had higher muscle raw ash content, but the differences were statistically confirmed only for the thigh muscle. The water, protein and fat content of pheasant muscles was not dependent on the dietary factors used. More fat and less protein were found in the thigh and drumstick muscles than the breast muscle (Table 6).

As shown in Table 7, the use of Ca glycine chelate in mixtures for growing pheasants contributed to the increase in calcium content ($P \leq 0.05$) in the muscles of birds of the E-50 and E-75 groups. The administration of calcitriol in addition to chelates led to an increase in phosphorus content in the E-75 group. The thigh and drumstick muscles had higher sodium content than the breast muscle. Also, male pheasants had lower calcium and sodium content and higher magnesium and potassium content, while there were only statistically insignificant differences in phosphorus and calcium content in thigh muscles between the sexes. As shown in Table 8, the results showed that iron, copper and manganese content of pheasant muscles were not statistically significantly dependent ($P \leq 0.05$) on the dietary treatment used, while only the zinc content was higher in the breast and thigh muscles of birds receiving glycine chelates in the diet, with values found to be statistically significantly different between the E-50 group and the control and E-75 groups. Much larger differences were observed between the different muscles and sexes than between the nutrition groups. Significantly more iron, zinc, copper and manganese were found in leg muscles than breast muscles. Females had significantly higher iron content in the three muscles analysed and evidenced a trend ($P = 0.063\text{--}0.072$) for increased zinc content as compared to males.

Table 3. Body weight, average daily gains, and feed intake of growing pheasants

Item	Dietary groups (D)				Gender (G)		P value		
	Control	E-25	E-50	E-75	Female	Male	D	G	D×G
Body weight (g)									
at start (at 4 weeks)	189	192	191	190	178 a	203 b	0.434	0.041	0.542
at 8 weeks	525	532	548	528	491 a	575 b	0.095	0.019	0.204
at 12 weeks	850	871	885	848	787 a	941 b	0.071	0.003	0.215
at 16 weeks	1093	1109	1121	1084	983 a	1221 b	0.084	0.002	0.211
Avery daily gain (g)									
5–8 weeks	12.0 x	12.1 x	12.8 x	12.1 x	11.2 ax	13.3 bx	0.094	0.038	0.211
9–12 weeks	11.6 x	12.2 x	12.0 x	11.4 x	10.6 ax	13.1 bx	0.059	0.014	0.214
13–16 weeks	8.7 y	8.5 y	8.4 y	8.4 y	7.0 ay	10.0 by	0.071	0.002	0.289
5–16 weeks	10.8	10.9	11.1	10.6	9.6 a	12.1 b	0.074	0.004	0.208
Feed intake (g d ⁻¹)									
5–8 weeks	40.7 x	40.5 x	40.9 x	40.7 x	39.6 x	41.8 x	0.314	0.079	0.092
9–12 weeks	58.9 y	58.7 y	58.9 y	58.6 y	56.1 ay	61.5 by	0.373	0.039	0.102
13–16 weeks	72.1 z	72.3 z	72.5 z	72.4 z	70.4 az	74.2 bz	0.385	0.045	0.094
5–16 weeks	57.2	57.2	57.4	57.2	55.4 a	59.2 b	0.361	0.043	0.106

a, b – different letters in rows and within a factor mean statistically significant differences at P≤0.05.

x, y, z – different letters in columns and within a factor mean statistically significant differences at P≤0.05.

Table 4. Body weight at slaughter, slaughter performance and heart, liver and gizzard weight of growing pheasants

Item	Dietary groups (D)				Gender (G)		P value	
	Control	E-25	E-50	E-75	Female	Male	D	D × G
Body weight at slaughter (g)	1083	1098	1108	1075	971 a	1211 b	0.085	0.208
Body weight after bleeding (g)	1039	1052	1063	1044	932 a	1167 b	0.086	0.203
Carcass weight (g)	778	792	801	781	697 a	879 b	0.083	0.211
Carcass dressing (%)	71.8	72.1	72.3	72.6	71.8	72.6	0.071	0.112
Heart weight (g)	4.9	5.0	5.1	5.1	4.8	5.2	0.124	0.311
Liver weight (g)	17.1	17.4	17.7	17.3	16.7 a	18.1 b	0.096	0.267
Gizzard weight (g)	14.6	14.5	14.8	15.1	14.2 a	15.3 b	0.094	0.184

a, b – different letters in rows and within a factor mean statistically significant differences at $P \leq 0.05$.

Table 5. pH value of the muscles of growing pheasants

Muscle	pH value	Dietary groups (D)				Gender (G)		P value	
		Control	E-25	E-50	E-75	Female	Male	D	D × G
Breast	pH _{0.15}	5.98 x	5.88 x	5.84 x	5.89 x	5.89 x	5.90 x	0.236	0.289
	pH _{1.0}	5.57 y	5.50 y	5.49 y	5.58 y	5.52 y	5.56 y	0.062	0.231
	pH ₂₄	5.31 z	5.21 z	5.23 z	5.37 z	5.29 z	5.32 z	0.059	0.215
	pH _{0.15}	6.06 x	6.12 x	6.14 x	6.21 x	6.18 x	6.11 x	0.189	0.105
Thigh	pH _{1.0}	5.77 y	5.81 y	5.80 y	5.91 y	5.83 y	5.81 y	0.074	0.167
	pH ₂₄	5.49 z	5.53 z	5.47 z	5.51 z	5.52 z	5.50 z	0.107	0.178
	pH _{0.15}	5.93x	5.94 x	5.89 x	5.86 x	5.91 x	5.90 x	0.205	0.296
	pH _{1.0}	5.57 y	5.54 y	5.56 y	5.55 y	5.56 y	5.56 y	0.274	0.428
Drumstick	pH ₂₄	5.50 z	5.49 z	5.51 z	5.50 z	5.50 z	5.51 z	0.421	0.395

x, y, z – different letters in columns and within a factor mean statistically significant differences at $P \leq 0.05$.

Table 6. Chemical composition of the muscles of growing pheasants

Item	Muscle	Dietary groups (D)				Gender (G)		P value		
		Control	E-25	E-50	E-75	Female	Male	D	G	D × G
Moisture	Breast	73.11	73.05	72.99	73.02	73.01	73.07	0.174	0.368	0.314
	Thigh	72.89	72.83	72.76	72.72	72.62	72.98	0.168	0.104	0.289
	Drumstick	72.81	72.84	72.77	72.59	72.51	72.99	0.156	0.085	0.258
Total protein	Breast	24.62 x	24.65 x	24.69 x	24.71 x	24.61 x	24.73 x	0.206	0.187	0.286
	Thigh	22.56 y	22.61 y	22.63 y	22.65 y	22.44 y	22.78 y	0.197	0.105	0.311
	Drumstick	23.11 y	23.14 y	23.15 y	23.17 y	22.93 y	23.35 y	0.214	0.101	0.289
Crude fat	Breast	0.46 x	0.47 x	0.46 x	0.48 x	0.49 x	0.45 x	0.142	0.54	0.187
	Thigh	2.67 y	2.65 y	2.68 y	2.79 y	2.84 y	2.56 y	0.178	0.057	0.216
	Drumstick	2.21 z	2.17 z	2.19 z	2.27 z	2.34 z	2.08 z	0.093	0.052	0.215
Crude ash	Breast	1.21 ax	1.23 abx	1.26 bx	1.25 bx	1.23 x	1.25 x	0.041	0.079	0.215
	Thigh	1.37 ay	1.40 aby	1.42 by	1.39 aby	1.37 ay	1.42 by	0.043	0.042	0.198
	Drumstick	1.37 y	1.38 y	1.39 y	1.38 y	1.37 y	1.39 y	0.092	0.086	0.189

a, b – different letters in rows and within a factor mean statistically significant differences at $P \leq 0.05$,
x, y, z – different letters in columns and within a factor mean statistically significant differences at $P \leq 0.05$.

Table 7. The content of mineral macroelements (g kg⁻¹ of dry matter) in the muscles of growing pheasants

Minerals	Muscle	Dietary groups (D)				Gender (G)		P value		
		Control	E-25	E-50	E-75	Female	Male	D	G	D × G
Calcium	Breast	0.18 a	0.20 ab	0.22 b	0.22 b	0.23 a	0.18 b	0.032	0.021	0.128
	Thigh	0.19 a	0.21 ab	0.23 b	0.23 b	0.23	0.20	0.037	0.057	0.182
	Drumstick	0.21 a	0.23 ab	0.25 b	0.24 b	0.25 a	0.21 b	0.041	0.034	0.205
Magnesium	Breast	1.12	1.11	1.11	1.12	1.07 a	1.16 b	0.283	0.031	0.034
	Thigh	1.06	1.06	1.05	1.07	1.01 a	1.11 b	0.212	0.027	0.028
	Drumstick	1.04	1.03	1.05	1.05	1.00 a	1.08 b	0.195	0.041	0.085
Potassium	Breast	12.82	12.81	12.76	12.81	12.11 a	13.15 b	0.219	0.021	0.118
	Thigh	12.14	12.15	12.13	12.08	11.57 a	12.75 b	0.202	0.041	0.121
	Drumstick	12.03	11.96	12.02	12.11	11.63 a	12.43b	0.193	0.039	0.132
Sodium	Breast	1.75 x	1.76 x	1.75 x	1.75 x	1.78 ax	1.69 bx	0.312	0.034	0.159
	Thigh	2.32 y	2.33 y	2.31 y	2.32 y	2.38 ay	2.26 by	0.293	0.031	0.175
	Drumstick	2.38 y	2.37 y	2.39 y	2.38 y	2.45 ay	2.31 by	0.278	0.029	0.203
Phosphorus	Breast	3.13 a	3.12 a	3.14 a	3.32 b	3.12	3.20	0.042	0.062	0.241
	Thigh	2.94 a	2.92 a	2.93 a	3.08 b	2.92	3.01	0.043	0.065	0.184
	Drumstick	2.97 a	2.96 a	2.96 a	3.19 b	3.00	3.07	0.034	0.069	0.127

a, b – different letters in rows and within a factor mean statistically significant differences at $P \leq 0.05$.x, y, z – different letters in columns and within a factor mean statistically significant differences at $P \leq 0.05$.

Table 8. The content of selected mineral microelements (mg kg⁻¹ dry matter) in the muscles of growing pheasants

Minerals	Muscle	Dietary groups (D)				Gender (G)		P value		
		Control	E-25	E-50	E-75	Female	Male	D	G	D × G
Iron	Breast	72 x	75 x	78 x	71 x	81 ax	67 bx	0.087	0.021	0.125
	Thigh	104 y	106 y	110 y	102 y	113 ay	98 by	0.061	0.032	0.194
	Drumstick	108 y	109 y	112 y	102 y	115 ay	102 by	0.072	0.037	0.173
Zinc	Breast	38 ax	41 abx	48 bx	37 ax	43 x	39 x	0.039	0.065	0.043
	Thigh	71 ay	74 aby	79 by	70 ay	76 y	71 y	0.048	0.063	0.045
	Drumstick	72 ay	74 aby	78 by	72a y	76 y	72 y	0.041	0.072	0.069
Copper	Breast	5.4 x	5.5 x	5.6 x	5.3 x	5.5 x	5.4 x	0.073	0.216	0.148
	Thigh	6.9 y	7.1 y	7.2 y	6.9 y	7.1 y	7.0 y	0.081	0.229	0.174
	Drumstick	7.2 y	7.3 y	7.4 y	7.1 y	7.3 y	7.2 y	0.082	0.221	0.187
Manganese	Breast	0.81 x	0.80 x	0.79 x	0.80 x	0.79 x	0.81 x	0.213	0.183	0.106
	Thigh	0.92 y	0.92 y	0.91 y	0.93 y	0.92 y	0.93 y	0.227	0.195	0.208
	Drumstick	0.91 y	0.91 y	0.91 y	0.92 y	0.91 y	0.91 y	0.231	0.418	0.317

a, b – different letters in rows and within a factor mean statistically significant differences at P≤0.05.

x, y – different letters in columns and within a factor mean statistically significant differences at P≤0.05.

Moreover, neither were notable differences evident between different dietary groups in the assessment of the flavour, smell, and fibrousness when the same muscle was compared (Figures 1a–3b). Only muscle succulence was slightly higher in the E-50 and E-75 groups. A much greater variation in sensory qualities was observed for individual muscles when comparing muscle characteristics of females and males. Thigh and drumstick muscles scored higher in terms of taste and succulence than breast muscles (Figures 1a–3b) and the breast muscles of the females were more succulent (Figures 1a and 1b). The sensory qualities of the thigh muscles in terms of flavour, smell, succulence and fibrousness were slightly superior for females, and in terms of taste, sensory quality they were better for males (Figures 2a and 2b). Higher scores of succulence and taste were reported for females (Figures 3a and 3b).

Figure 1a. Sensory features of the breast muscle of male pheasants

Figure 1b. Sensory features of the breast muscle of female pheasants

Figure 2a. Sensory features of the thigh muscle of male pheasants

Figure 2b. Sensory features of the thigh muscle of female pheasants

Figure 3a. Sensory features of the drumstick muscle of male pheasants

Figure 3b. Sensory features of the drumstick muscle of female pheasants

Discussion

One of the most important factors in the rearing and breeding of birds is nutrition, i.e. providing the animals with all the nutrients they need for life, growth and development. Previous research on pheasants in closed breeding operations has mainly focused on optimising the energy value of mixtures, the level of protein and the amino acid profile (Gašparovič et al., 2017; Krystianiak and Torgowski, 1998; Straková et al., 2011; Wise, 1994). Far fewer reports can be found regarding the impact of quantity and quality of minerals on production results and meat quality (Šperanda et al., 2008; Świątkiewicz et al., 2014). In recent years, researchers' interest has been focused on how the use of minerals in organic compounds manifests in production results, meat quality and mineral content mainly in broiler chicken muscles (Baloch et al., 2017; Khatun et al., 2019; Świątkiewicz et al., 2014) and much less in those of pheasants (Flis et al., 2019 b; Gugala et al., 2019). It is believed that the use of organic compounds of mineral elements promotes better bioavailability and more precise balancing of mineral components, especially micronutrients such as selenium, copper or zinc (Dayyani et al., 2013; Mohanta and Garg, 2014). In addition, minerals contained in chelates can contribute to improving animal health and achieving better production results with the coaction of organic compounds such as amino acids, proteins or polysaccharides (Baloch et al., 2017; Mohanta and Garg, 2014). In the results presented, the average body weight of 16-week-old pheasants was not affected by the extent of Ca, Zn, Cu and Fe salt replacement with glycinate of these elements, but significant weight differences were yielded between females (983 g) and males (1,221 g). Information presented by various authors confirms significant gender effect for differences in body weight, with differing values noted in the literature for body weights of slaughtered pheasants (Biesiada-Drzazga et al., 2011; Górecki et al., 2012; Kokoszyński et al., 2014). Yamak et al. (2019) reported a lower body weight for 16-week-old females, which ranged from 841.1 to 910.7 g, and for males, which ranged from 1,087.5 to 1,100.2 g. Biesiada-Drzazga et al. (2011) found a similar trend in a study for 20-week-old pheasants (813 g for females and 1,039 g for males). A similar body weight for females (999.8 g) but a significantly higher one for males (1,349.4 g) was reported by Górecki et al. (2012). Other studies reported that the body mass of slaughtered pheasants depends on sex (Kokoszyński et al., 2014), the age at which birds are slaughtered (Franco and Lorenzo, 2013), the intensity of feeding (Kokoszyński et al., 2018) and the location of the bird's origin, e.g. a farm vs the wild (Beeger et al., 2017; Flis et al., 2019 b).

The daily weight gain of growing pheasants at 5–16 weeks old ranged from 10.6 to 11.1 g d⁻¹, with the highest being achieved by E-50 group pheasants. Significant variation resulted between males and females ($P=0.002$), with more intense gains occurring between 5 and 12 weeks of age than in older birds, regardless of sex. Similar trends are confirmed by research by Kokoszyński et al. (2018). The intake of feed was not dependent on the mineral additives used, but the age and sex of pheasants had a significant impact. The carcass weight and slaughter yield of the 16-week-old pheasants was also not influenced by the type of mineral additives. The carcasses

of males were significantly larger than those of females. The dressing percentage of males (72.6%) and females (71.8%) was similar to that reported by Kokoszyński et al. (2018), and slightly higher than those in studies by Mieczkowska et al. (2015) and Biesiada-Drzazga et al. (2011). Flis et al. (2019 b) found higher dressing percentages for young wild female pheasants under one year of age (74.2%) than for those older (70.5%). In the present study, the feeding of glycinate to pheasants instead of Ca, Fe, Zn and Cu salts did not have a significant effect on gizzard, heart or liver mass. Sex was a differentiator, however, and males had higher liver and gizzard weights. The values obtained in the current investigation are slightly lower than those given by Biesiada-Drzazga et al. (2011) for heart weight regardless of bird sex, and lower also than those published by Flis et al. (2019 b) for liver and gizzard for farmed males compared to their wild counterparts regardless of their age.

In addition to the chemical composition of meat as a quality assessment basis there is also its active acidity. The $\text{pH}_{0.15}$ values determined in pheasant females in this research are similar to those reported by Kokoszyński et al. (2014) for 17-week-old females and lower by 0.16 than those for males. It emerged from research by Mieczkowska et al. (2015) that the $\text{pH}_{0.15}$ value of leg muscles was higher than the results obtained for both drumstick and thigh muscles. In 10-month-old pheasants reared extensively, the breast muscle had a pH_{24} of 5.69 and the drumstick muscle 5.84 (Franco and Lorenzo, 2013). The authors' own present results showed a higher pH_{24} in leg muscles than in breast muscle, which according to Hofbauer et al. (2010) arises from the degradation of glycogen and its lower concentration in leg muscles after slaughter. Supplementation of mineral salt dietary components with Ca, Fe, Cu and Zn glycinate had no significant effect on pH values assessed at 15 minutes, 1 hour and 24 hours.

The nutrient content of individual muscle groups, including minerals, allows the nutrition intake of the birds to be assessed, and in particular, the availability of amino acids, fatty acids, vitamins and minerals from feed. The results showed a slight variation in moisture, protein and fat content in the analysed muscles of male and female pheasants fed a mixture including salt or calcium, copper, zinc and iron glycinate. However, significant differences in protein and fat content were found between the breast muscles and those of the thigh and drumsticks. The breast muscles had a higher protein and lower fat content compared to the leg muscles. This comparative picture of breast muscle and leg muscle is confirmed by research from other authors (Biesiada-Drzazga et al., 2011; Franco and Lorenzo, 2013; Hofbauer et al., 2010; Vecerek et al., 2005). The highest content of the mineral compounds making up crude ash was found in the muscles of the E-50 group, in whose diet 50% of the salt was replaced by Ca, Zn, Cu and Fe glycinate to provide overall levels of these elements as in the control group mixture. It should also be noted that the leg muscles had higher crude ash content than the breast muscles, and males had more of this component in the drumstick muscle than females (Kotowicz et al., 2012; Straková et al., 2011). Straková et al. (2011) reported a similar relationship in the differentiation of ash content for the breast muscles and thighs of pheasants. Also research by Kotowicz et al. (2012) showed higher ash content in males in both breast and leg muscles.

The results obtained in the authors' present study of calcium, sodium, potassium, zinc and iron levels in the breast and leg muscles of females and males are confirmed by Mieczkowska et al. (2015), and the phosphorus, sodium, potassium, and magnesium content in male and female breast muscles were similar to those reported by Kokoszyński et al. (2014). Straková et al. (2011) reported significantly higher values for calcium and phosphorus in the breast and leg muscles of males and females. In addition, a significantly lower content of zinc and iron was presented by Kokoszyński et al. (2014). It emerges from the publications of many authors that the mineral content of poultry muscles, including pheasants, depends on the mineral composition of the diet, the source of the minerals (inorganic vs organic), the enzymes used (phytase), the intensity of feeding, the sex, the location of the bird's origin (farmed or wild birds) and the type of muscle (Baloch et al., 2017; Cheng et al., 2004; Mieczkowska et al., 2015; Šperanda et al., 2008; Świątkiewicz et al., 2014; Vecerek et al., 2005). The use of Ca, Zn, Cu and Fe glycine chelates in mixtures for growing pheasants contributed to an increase in calcium content in the muscles of birds of the E-50 and E-75 groups. The addition of calcitriol instead of vitamin D₃ to the feed of the latter group resulted in higher phosphorus content in the muscles of birds in the group. Research by some authors (Castro et al., 2018; Cheng et al., 2004; Garcia et al., 2013) indicates an important role of vitamin D₃ in phosphorus metabolism, and a substantial role in particular of its active analogues calcitriol and calcidiol in depositing this element in tissues and organs. For active forms of vitamin D₃ to be produced, it must be converted into 25-hydroxycholecalciferol (calcidiol) in the liver and subsequently into its active metabolite 1,25-dihydroxycholecalciferol (calcitriol) in the kidneys (Khan and Mukhtar, 2013; Kochupillai, 2008). Content of other macroelements, i.e. potassium, sodium and magnesium was not susceptible to change in any interrelation with sources of calcium, iron, zinc and copper in feed mixtures. Females had higher levels of calcium and sodium and lower levels of magnesium, phosphorus and potassium than males in the present study. Research by Straková et al. (2011) also showed more calcium in the female bird's breast muscle than the male bird's, while almost twice as much of this element was found in the leg muscle than the breast muscle.

The substitution of zinc sulphate (sulphate heptahydrate) with glycinate in a 50% proportion of the dietary zinc requirement contributed to a significant increase in its content in all three muscles in the relevant (E-50) group. No such effect was observed with 25% supplementation (the E-25 group) or with 75% exclusively comprised of zinc glycinate without supplementation with sulphate (the E-75 group). Supplementation of copper and iron sulphate with glycinate of these elements only indicated a mild trend of increased content of these elements in pheasant muscles, especially in the E-50 group. Zinc, iron, copper and manganese content varied according to the specific pheasant muscle, with the leg muscles having a higher content than the breast muscles.

In terms of sensory qualities of the breast muscle, the muscles of the females were significantly better in all experimental groups. A comparative analysis of leg and breast muscles showed that regardless of the sex of the birds, leg meat had higher succulence and taste indices. These results are partially consistent (in succulence

and taste) with those of Franco and Lorenzo (2013) and slightly different from those reported by Kokoszyński et al. (2018), where the succulence and taste of the breast and leg muscles were similar. As assessed for this study, the breast and thigh muscles of females had a higher rate of fibrousness, and for the drumsticks, the value was the same for males and females. The fibrousness indices for leg muscles are comparable to those reported by Franco and Lorenzo (2013), but were significantly lower for both male and female breast muscles. The results obtained for breast muscle were higher in terms of taste and lower in terms of succulence than those reported by Augustyńska-Prejsnar et al. (2019). The use of glycines instead of calcium, iron, zinc and copper salts in the pheasant diet contributed to the improvement of succulence, which directly affects the fitness of the individual pheasant muscle groups for consumption. Between the sexes, the muscles of the females emerged in this investigation as having better sensory qualities. The appraisals of succulence and taste of the individual muscle groups showed that the thighs and drumsticks had higher sensory qualities than the pectoral muscles. This is confirmed by other authors (Cepero, 2002; Franco and Lorenzo, 2013) expressing the belief that the breast muscles are less succulent and lack a distinct taste, and these muscles scored lower in sensory evaluation.

Conclusion

Supplementation of calcium, iron, zinc and copper salts with 50% glycines in diets for growing pheasants over a period of 5–16 weeks resulted in a slight improvement in the slaughter weight of birds and a significant increase in crude ash, calcium and zinc, while at 75% supplementation and when calcitriol was used instead of vitamin D₃, increased phosphorus levels were found in the pheasant muscles analysed.

Males had higher weight gain and higher carcass, liver and gizzard weight, and their muscles showed higher levels of magnesium and potassium and lower levels of calcium, sodium and iron than females.

Conflict of Interests

The authors declare no conflict of interests.

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