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Effect of dietary supplementation with insect meal on anatomical and morphological traits of pheasants (*Phasianus colchicus*)

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SUMMARY

The study aimed to determine the effect of the use of insect meal in the diet of pheasants in aviary breeding on anatomical and morphological traits which can affect their survival in natural conditions and their suitability for introduction. The study consisted of measurements of the weight and length of selected body parts of pheasants (hens and cocks) from two groups – control and experimental. The control group consisted of 15 individuals (7 cocks and 8 hens) fed a traditional diet, and the experimental group comprised 15 birds (7 cocks and 8 hens) receiving a diet supplemented with insect meal. The weight of the following body parts was measured: body, carcass, breast muscles, whole thighs, thigh muscles, drumstick muscles, drumstick and thigh bones, heart, liver, stomach muscle, and head. The length of the spur (left), whole leg, humerus, forearm, femur, tibia, and sternum was also measured. The use of insect meal contributed to increased leg muscle weight, which should be regarded as a positive trait in this species, given the threat of predation in natural conditions.

KEY WORDS: pheasant, insect meal, dietary supplementation, anatomical and morphological traits

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INTRODUCTION

Pheasants in Europe are not native species, as they were introduced to the continent in the 16th century. They were initially regarded as ornamental park animals, but they later became a permanent element of hunting fauna and are currently regarded as a game bird species. Given the considerable decline in the number of small game, including pheasants, multi-faceted breeding programs have recently been implemented in many European countries, with the introduction of farmed birds into natural habitats playing a critical role. Farm breeding focuses on optimizing rearing to ensure high numbers of birds and provide material with specific anatomical, morphological, and behavioural traits. This is of paramount importance for the subsequent adaptation of these birds to environmental pressure, which leads to the death of large numbers of birds, especially within the first few days after their release, and to ecological and economic losses (Glutz et al., 1973; Robertson et al., 1993; Czyżowski 2003; Dordevic et al., 2010; Beeger et al., 2017; Madden et al., 2018).

In breeding conditions, the nutrition provided to birds, i.e. the composition and quality of the diet components, determines their health, fitness, and slaughter and laying performance (Amerah and Ravindran 2008; Traineau et al., 2013; Husveth et al., 2015; Jankowski et al., 2016; Flis and Gugała 2021; Biesek et al., 2021; Biesek et al., 2022).

The diet of free-living birds comprises plants, mainly cereal grains, and various insects and their larvae. The diet composition depends on the type and degree of habitat management (Dzięciołowski et al., 1971; Mróz 2003). The intensification of agriculture is regarded as an essential element of the decline in the reproductive success of pheasants (especially in young individuals), which is caused by the unavailability of invertebrates, an indispensable element of the diet of these birds (Tucker 1992; Wilson 1996; Geaumont et al., 2017). Pheasants in aviary farming receive mainly diets based on cereal grains supplemented with soybean, rapeseed, sunflower, and linseed meal or legume seeds as protein sources (Grela and Czech, 2019; Gugała et al., 2019; Hanzal et al., 2016). However, the main limiting factor is breeding losses. These have increased in ground-nesting birds due to an increase in the number of predators following vaccination against rabies (Flis et al. 2017).

To make diets for farmed pheasants similar to the nutrition available in the natural habitat and provide ingredients that will be part of their natural diet after their release into the natural environment, various protein components, including those of animal origin, e.g. larvae or insect meals, have recently been introduced in their diets (Melin and Larbier 1988; Hudeckova et al., 2009). Behavioural and physiological traits, especially those associated with finding an appropriate amount and quality of food, are the leading causes of the low efficiency of the introduction of pheasants into natural habitats. The lack of an appropriate diet based on animal protein in combination with behavioural habits acquired during farm breeding based solely on plant-based feed, especially in young pheasants and offspring-rearing females, results in high mortality rates of birds released at various stages of life (Whiteside et al., 2015; Madden et al., 2018). Also significant is the lack of microflora in the lower digestive tract, which limits the ability to digest natural plant food, i.e. with higher fibre content. Farmed birds have altered gastrointestinal morphology and digestive physiology, resulting in a reduced ability to absorb nutrients (Putaala and Hissa 1995).

The study aimed to determine the effect of the use of insect meal in pheasant nutrition in aviary breeding on anatomical and morphological traits that may impact the birds' survival in natural conditions and their suitability for introduction.

MATERIALS AND METHODS

Animals

Pheasants (*Phasianus colchicus*) hatched in 2022 and kept on a commercial farm in two groups (8 females and 7 males) were the experimental material. After four weeks of rearing with standard diets, at a body weight of 175–185 grams, insect meal was used to replace the soybean, sunflower, and linseed meals. During the experiment, the birds were kept outdoors in cages with dimensions of 8.5 m length × 5.0 m width × 3.5 m height. Each cage had two nipple drinkers and an automatic feeder (40 cm long, i.e., 4.0 cm of feeder edge per bird). All pheasants were kept on a complete diet, ad libitum. The nutritive value of the diet was determined according to the National Research (Council 1994). Water was supplied with automatic drinkers.

Feed

The diet provided to the control group of pheasants kept on aviary farms consisted of plant ingredients (Table 1). The experimental group received 200 g of insect meal in place of vegetable protein components (soybean meal, sunflower meal, and linseed). Insect meal from HiProMine S.A. containing approx. 52% crude protein was used in the experiment (Table 2). All feed ingredients were mixed and granulated (diameter 0.5 mm) at a temperature of 60°C.

Table 1.
Composition of ingredients (g/kg) in the diet of pheasants

Ingredients, g	Control	20% insect meal
Corn	291.5	359.9
Wheat	222.0	222.0
Soybean meal	180.0	0.0
Garden pea	50.0	50.0
Insect meal	0.0	200.0
Linseed	40.0	0.0
Sunflower meal	80.0	30.0
Sorghum	50.0	60.0
Soya oil	10.0	0.0
Salt	3.0	3.0
Dicalcium phosphate	10	10.0
Limestone	60	60.0
Mineral-vitamin premix	2.5	2.5
DL-methionine	0.0	0.7
L-lysine chloride	1.0	1.9
Total	1000	1000

The mineral-vitamin premix in the control group provided (in 1 kg diet) Mn 60 mg, I 1 mg, Fe 50 mg, Zn 100 mg, Cu 12 mg, Se 0.2 mg, vit. A 10,000 IU, vit. D_3 2500 IU, vit. E 50 mg, vit. K_3 2 mg, vit. B_1 1.5 mg, vit. B_2 4.5 mg, vit. B_6 3 mg, vit. B_{12} 0.015 mg, biotin 0.1 mg, folic acid 0.8 mg, nicotinic acid 20 mg, pantothenic acid 12 mg, and choline 300 mg.

Table 2.
Essential nutrients and fatty acid composition of the insect meal and pheasant diets

Nutrient	Insect meal	Control	20% insect meal
Dry matter, g	978.6	894.8	898.7
Crude protein, g	518.8	186.8	192.5
Lysine, g	24.6	9.52	9.49
Methionine + cysteine, g	11.2	6.45	6.38
Crude fibre, g	90.8	47.4	42.5
Crude ash, g	119.7	43.4	51.9
Calcium, g	9.4	25.7	26.5
Total phosphorus, g	8.5	5.96	6.12
Crude fat, g	110.6	51.7	42.5
Lauric acid, 12:0. %	37.96	0.01	7.61
Myristic acid, 14:0. %	8.37	0.12	1.77
Palmitic acid, 16:0, %	15.31	11.28	12.68
Stearic acid, 18:0, %	3.03	2.19	1.88
Oleic acid, 18:1, n-9, %	14.51	20.63	19.64
Linoleic acid, 18:2, n-6, %	12.99	48.89	41.85
Linolenic acid, 18:3, n-3, %	1.16	4.81	1.56
AMEn, MJ kg^{-1} *	11.82	11.63	11.88

*AMEn – metabolizable energy at zero nitrogen balance was calculated with the Fisher and McNab (1987) equations.

Analytical procedures

The study consisted of measurements of the weight and length of selected anatomical body parts of the pheasants (hens and cocks) from the two groups – control and experimental. The control group consisted of 15 individuals (7 cocks and 8 hens) fed a traditional diet, while the experimental group comprised 15 birds (7 cocks and 8 hens) receiving a diet supplemented with insect meal. All pheasants were kept on the same commercial farm in Wierzchowiny near Parczew, Lublin region. The birds were dissected by the methodology proposed by Ziołecki and Doruchowski (1989). The weight of the following body parts was measured: body, carcass, breast muscles, whole thighs, thigh muscles, drumstick muscles, drumstick and thigh bones, heart, liver, stomach muscle, and head.

The length of the spur (left), whole leg, humerus, forearm, femur, tibia, and sternum was also measured. The body and carcass were weighed using a laboratory scale to within 0.1 kg, and the muscles, bones, and internal organs were determined to within 0.1 g. The length of the body parts was measured with a measuring tape to within 1 mm.

Statistical analysis

The normality of the distribution of the analysed traits was determined using the Shapiro–Wilk test. Statistical significance was assumed at $p \leq 0.05$. The significance of differences between the mean values for the sexes was assessed using the t-test for normally distributed variables and the non-parametric Mann–Whitney U-rank test for variables with non-normal distribution. The analysis was performed using Statistica 13.3 (TIBCO Software Inc.).

RESULTS

The comparison of the mean values of the measurements of pheasant cocks from the control and experimental groups showed statistically higher mean body weight and carcass weight in the birds receiving the insect meal supplementation (experimental group) than in the control group (Table 3). A similar tendency was observed for the weight of the thigh muscles and drumstick muscles. No significant differences in the weight of internal organs were found between groups. In the case of the length of the body parts, significant differences were found only for the forearm bone and the sternum, with higher values in the experimental group than in the control.

Table 3.
Comparison of mean values of measurements of pheasant cocks from the control and experimental groups

Parameters	Control group		Experimental group		p-value (type of test)
	Mean	SEM	Mean	SEM	
Body weight [kg]	1.3	0.02	1.4	0.01	**0.040(t)**
Carcass weight [g]	889.1	12.52	945.3	15.29	**0.015(t)**
Breast muscle weight [g]	266.0	4.23	251.0	2.07	**0.008(t)**
Thigh weight [g]	131.4	3.45	180.9	12.23	**0.007(U)**
Thigh muscle weight [g]	118.1	3.28	133.8	2.85	**0.004(t)**
Drumstick muscle weight [g]	80.2	1.11	85.3	2.07	**0.049(t)**
Drumstick and thigh bone weight [g]	35.7	1.26	36.1	0.35	0.820(t)
Heart weight [g]	6.2	0.15	6.5	0.23	0.367(t)
Liver weight [g]	25.8	0.84	27.1	0.77	0.260(t)
Head weight [g]	47.0	1.22	48.1	0.73	0.449(t)
Spur length [mm]	93.4	5.15	76.7	6.17	0.060(t)
Whole leg length [mm]	136.8	3.19	132.3	1.35	0.224(t)
Humerus length [mm]	8.4	0.13	8.6	0.17	0.489(t)
Forearm bone length [mm]	7.7	0.17	8.2	0.13	**0.025(t)**
Femur length [mm]	95.0	2.04	95.3	1.69	0.932(t)
Tibia length [mm]	120.1	2.59	114.0	1.96	0.086(t)
Sternum length [mm]	11.7	0.25	12.3	0.13	**0.038(t)**

Bold type indicates significant values for p <0.05., mean/SEM (standard error of the mean); (t) - independent sample t-test, (U) - Mann–Whitney U test

The measurements of the same body parts in the pheasant hens showed statistically higher mean body weight and carcass weight in the group receiving feed supplemented with insect meal in comparison with the control group (Table 4). The breast muscle weight was lower in the experimental group, but the values did not differ significantly between groups. The mean thigh weight of the hens from the experimental group was significantly higher. Liver weight was statistically significantly higher in the hens from the control group. The linear measurements of the skeletal elements revealed higher forearm and drumstick length values in the experimental group of hens.

Table 4.
Comparison of mean values of measurements of pheasant hens from the control and experimental groups (independent sample t-test)

Parameters	Control group		Experimental group		p-value (type of test)
	Mean	SE	Mean	SE	
Body weight [kg]	0.9	0.01	1.0	0.02	**0.003(t)**
Carcass weight [g]	640.7	10.55	678.2	8.22	**0.014(t)**
Breast muscle weight [g]	199.2	2.83	191.9	7.05	0.355(t)
Thigh weight [g]	99.2	2.42	107.0	1.08	**0.011(t)**
Thigh muscle weight [g]	88.7	2.05	96.8	1.00	**0.003(t)**
Drumstick muscle weight [g]	58.2	0.89	57.2	1.16	0.485(t)
Drumstick and thigh bone weight [g]	25.6	0.40	27.0	0.34	**0.019(t)**
Heart weight [g]	4.8	0.18	4.2	0.27	0.090(t)
Liver weight [g]	22.6	0.59	19.6	0.89	**0.013(t)**
Head weight [g]	32.6	0.78	34.6	0.59	0.058(t)
Whole leg length [mm]	121.2	1.28	123.0	0.43	0.215(t)
Humerus length [mm]	7.6	0.08	7.5	0.07	0.232(t)
Forearm bone length [mm]	6.9	0.10	7.4	0.10	**0.003(t)**
Femur length [mm]	82.4	0.75	86.4	2.54	0.161(U)
Tibia length [mm]	106.6	1.16	111.9	1.60	**0.018(t)**
Sternum length [mm]	10.1	0.15	10.5	0.16	0.135(t)

Bold type indicates significant values for p <0.05.

DISCUSSION

Nutrition providing animals with all nutrients necessary for life, growth, and development is one of the most critical factors in bird rearing. Previous research on farmed pheasants has mainly focused on optimizing the energy value of feed, the level of proteins, and the amino acid profile (Wise, 1994; Krystianiak and Torgowski, 1998; Straková et al., 2011; Grela et al., 2021).

In recent years, frequent attempts have been made to balance diets for poultry through supplementation with protein components of animal origin, mainly from insects. This is due to the increasing shortage of protein feeds and the current availability of a wide range of insects that can be used as protein sources for poultry (Sun et al., 2013; Makkar et al., 2014; Khan, 2018; Iqbal et al., 2019; Gkarane et al., 2020; Van Huis 2020). Insect meal contains higher amounts of essential amino acids than conventional plant-based feeds. Additionally, insect larvae produce antimicrobial peptides; hence, this type of dietary supplementation may improve weight gain, nutrient digestibility, and immunity in poultry (Elahi et al., 2022). Adding insect meal to broiler chicken diets has been reported to increase body weight gain, daily gains, and feed consumption, especially in the final fattening phase (Hartinger et al., 2022). Similar results were obtained in a study on broiler chickens by Kareem et al. (2018).

In the case of pheasants intended for introduction into habitats, which is conducted in many European countries, special attention should be paid both to the type of diet used on breeding farms before the birds are released and to the anatomical and morphological traits that allow the birds to cope with the environmental pressure experienced after release into the new habitat (Santilli and Bagliacca 2008; Flis 2012; Robertson et al., 2017). As highlighted by Whiteside et al. (2016), even minor alterations in pheasant rearing impact the fitness of adult birds and determine their survival after release. The primary behavioural traits mentioned by the authors include the ability to fly, as the critical determinant of survival after release. Therefore, body weight and some elements of the anatomical structure are important flight-related factors contributing to the subsequent survival of released birds. In the experimental group of birds, the addition of 20% insect meal to the feed ration led to a 0.1 kg increase in the body weight of both males and females. It is noteworthy that the increase in body weight was associated with an increase in the weight of the leg muscles, with a concurrent decline in breast muscle weight, which may contribute to difficulty in flight and thus affect the survival of reintroduced birds. The present data on the body weight of pheasant cocks receiving the experimental feed are similar to results obtained for the body weight of wild pheasants and lower than that of wild adult male pheasants (Flis et al., 2019). The same authors reported that the body weight of wild adult females was 1040 g, with a mean value of 992 g, similar to the values recorded in the females from the experimental feeding group in the present study. The birds receiving feed supplemented with 20% insect meal had higher values for the skeletal measurements, i.e. the length of the leg, wing, and sternum bones, which determines the ability to cope with environmental pressure and escape from predators. In the model of deciding to escape proposed by Ydenberg and Dill (1986), which assumes that the prey assessing a threat begins to flee only when the cost of fleeing and remaining are equal, elements supporting the ability to initiate a flight are essential for survival. Nevertheless, most behavioural observations indicate that pheasants choose to escape by running, while flight is a last resort. This is undoubtedly linked to the fact that flight requires more energy than escape on foot (Butler 2016).

The results of studies on flight ability conducted in the British Isles indicate that lighter birds are better able to fly (Robertson et al., 1993). However, investigations of four species of birds, including pheasants, have demonstrated that so-called take-off power is proportional to body weight, and that the power specific to breast muscle weight decreases in proportion to body weight and is directly proportional to the wing-beat frequency. Therefore, the weight-specific power of breast muscles is not directly related to body weight but does affect flight ability (Tobalske and Dial, 2000). It should also be mentioned that, in addition to cereal grains, the diet of wild pheasants is dominated by animal protein derived from insects and their larvae present in the natural habitat. This protein plays a vital role, especially in younger birds. Thus, a diet consisting of feed of plant origin supplemented with insect protein contributes to improved growth parameters in farm rearing and helps released birds to adapt to the intake of food of animal origin available in the new habitat (Tucker 1992; Thomas et al., 2001; Mróz 2003). Thus, the present results confirm the specificity of interrelations between many anatomical and morphological traits and the efficiency of the introduction and survival of birds in their natural habitat.

CONCLUSION

The study showed that the inclusion of 20% insect meal in the diet of farmed pheasants intended for introduction influenced some anatomical and morphological traits in both males and females. The increase in body weight was not associated with higher breast muscle weight, while the sternum length increased. Therefore, in our opinion, the increase in total weight should not significantly affect the ability to fly, which is the final element of escape in response to the threat of predation. The use of insect meal contributed to an increase in the weight of the leg muscles, which should be considered a positive feature of meat pheasants. Given the threat of predation in natural conditions, a decrease in breast muscle weight accompanied by an increase in leg muscle weight may allow for faster escape in the initial stages of danger, but will negatively affect the ability to fly, and thus survive. The proposed supplementation of plant-based diets with 20% insect meal for birds reared for introduction purposes seems optimal, because it improves the individual condition of birds expressed as body weight as a general indicator. However, with regard to the possibility of survival in the natural environment (breast and leg muscle weight), such supplementation cannot be viewed as advantageous. This amount of insect meal should positively affect the physiological functioning of the digestive tract, adapting it to intake of natural food with a significant proportion of invertebrates, especially insects and their developmental stages. In our opinion, it may also result in increased searching for animal protein following release, which to a minor extent could reduce problems with the digestion of natural food of plant origin and prevent weight loss following release, thus improving the chance of survival.

REFERENCES

1. Amerah A.M., Ravindran V. (2008). Influence of method of whole-wheat feeding on the performance, digestive tract development and carcass traits of broiler chickens. Animal Feed Science and Technology, 147: 326–339.
2. Beeger S., Wójcik M., Flis M., Marecki M., Pyrkosz R., Dziedzic R. (2017). Anatomo-morphological features of free-living and farmed pheasant. Medycyna Weterynaryjna, 73: 370–374. http://dx.doi.org/10.21521/mw.5702.
3. Biesek J., Banaszak M., Adamski M. (2021). Ducks' growth, meat quality, bone strength, and jejunum strength depend on zeolite in feed and long-term factors. Animals, 11: 1015. http://doi.org/10.3390/ani11041015.
4. Biesek J., Banaszak M., Wlaźlak S., Adamski M. (2022). The effect of partial replacement of milled finisher feed with wheat grains on the production efficiency and meat quality in broiler chickens. Poultry Science, 101: 101817. http://doi.org/10.1016/j.psj.2022.101817 .

5. Butler P.J. (2016). The physiological basis of bird flight. Philosophical Transactions of the Royal Society B. Biological Science, 371: 20150384. http://doi.org/10.1098/rstb.2015.0384.
6. Council N.R. (1994). Nutrient requirements of poultry. National. Academies Press, Washington, DC, USA.
7. Czyżowski P. (2003). Functioning of pheasant (*Phasianus colchicus* L.) population in western Lublin region. Pt. 1. Effects of introduction. Annales Universitatis Mariae Curie-Sklodowska. Sectio EE Zootechnica, 57: 31-38.
8. Dordevic M., Pekec S., Popovic Z., Dordevic N. (2010). Influence of dietary protein levels on production results and mortality in pheasants reared under controlled conditions. Acta Veterinaria, 60: 79-88.
9. Dzięciołowski R., Kowalina E., Plata Z., Sikorski J. (1971). Bażant – hodowla i użytkowanie. PWRiL Warszawa, pp. 5-126.
10. Elahi U., Xu C.C., Wang J., Lin J., Wu S.G., Zhang H.J, Qi G.H. (2022). Insect meal as feed ingredient for poultry. Animal Bioscience, 35: 332-346. http://doi.org/10.5713/ab.21.0435 .
11. Flis M. (2012). Efektywność wsiedleń bażantów z hodowli wolierowych na Wyżynie Lubelskiej. Przegląd Hodowlany, 10-12: 23-25.
12. Flis M. Grela E.R., Gugała D. (2017). Occurrence of rabies in Poland in 2011-2015 in relation to the free-living fox population. Medycyna Weterynaryjna, 73(1): 43-47. http://doi.org/10.21521/mw.5624.
13. Flis M., Grela E.R., Gugała A., Kołodziejski A. (2019). Skład tuszki i profil kwasów tłuszczowych mięśni piersiowych samców i samic bażanta łownego (*Phasianus colchicus*). Żywność Nauka Technologia Jakość, 26: 111-124.
14. Flis M., Gugała D. (2021). Effect of organic minerals and alpha-ketoglutarate in pheasant diet on performance, hatchability and the composition of eggs. Medycyna Weterynaryjna, 77: 605-611. http://dx.doi.org/10.21521/mw.6598.
15. Gašparovič M., Hrnčár C., Gálik B. (2017). The effect of feed additives in pheasants fattening: A review. Journal of Central European Agriculture, 18: 749-761.
16. Geaumont B.A., Sedivec K.K, = Schauer C.S. (2017). Ring-necked Pheasant use of post – conservation reserve program lands. Raneland Ecology and Management, 70: 569-575. https://doi.org/10.1016/j.rama.2017.04.003.
17. Gkarane V., Ciulu M., Altmann B.A., Schmitt A., Mörlein D. (2020). The effect of alge or insect supplementation as alternative protein sources on the volatile profile of chicken meat. Food, 9: 1235, https://doi.org/10.3390/foods9091235.
18. Glutz V., Blotzheim U.N., Bauer K., Bezzel E. (1973). Handbuch der Vögel Mitteleuropas. Akademisches Glutz von Blotzheim, U. N., Bauer, K. M., and Bezzel, E. (1980). Handbuch der vögel mitteleuropas. Akademisches Verlagsgesselschaft, Frankfurt am Main 322-372.
19. Grela E.R., Czech A. (2019). Pasze alternatywne w odniesieniu do soi genetycznie modyfikowanej w żywieniu zwierząt. Wiadomości. Zootechniczne, 57: 66-77.
20. Grela E.R., Gugała D., Flis M. (2021). 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. Annals Animal Science 21: 245-265.

21. Gugała D., Flis M., Grela E.R. (2019). The effect of zinc, iron, calcium, and copper from organic sources in pheasant diet on the performance, hatching, minerals, and fatty acid composition of eggs. Poultry Science, 98: 4640-4647. http://doi.org/10.3382/ PS/pez162.
22. Hanzal V., Divišová M., Murawska D., Janiszewski P. (2016). The effect of dietary bio-alginate supplementation of the growth rate and body weight of common pheasant (Phasianus colchicus) chicks. Polish Journal of Natural Sciences, 31: 363–371.
23. Hartinger K., Fröschl K., Ebbing M.A., Bruschek-Pfleger B., Schedle K., Schwarz C., Gierus M. (2022). Suitability of *Hermetia illucens* larvae meal and fat in broiler diets: effects on animal performance, apparent ileal digestibility, gut histology, and microbial metabolites. Journal of Animal Science and Biotechnology, 13: 50. https://doi.org/10.1186/s40104-022-00701-7
24. Hudeckova P., Zapletal D., Vitula F., Kroupa L. (2009). The growth intensity of pheasant chickens fattened with different diets. Proc. MendelNet'09 Agro Conference, 210-216.
25. Husveth F., Pal L., Galamb E., Acs K.C., Bustyahazai L., Wagner L., Dublecz F., Dublecz K. (2015). Effects of whole wheat incorporated into pelleted diets on the growth performance and intestinal function of broiler chickens. Animal Feed Science and Technology, 210: 144–151. https://doi.org/10.1016/j.anifeedsci.2015.09.021.
26. Iqbal A., Qudoos A., Çetingül I.S., Shah S.R.A., Bayram I. (2019). Insects as alternative feed materials for poultry nutrition. - *Journal of Animal Science* 2: 30–37.
27. Jankowski J., Zduńczyk Z., Juśkiewicz J. (2016). Whole grain in turkey nutrition. Part 2: Production results in different feeding systems. World's Poultry Science Journal, 72: 563-572.
28. Kareem K.Y., Abdulla N.R., Foo H.L., Zamri A.N.M., Shazali N., Loh T.C., Alshelmani M.I. (2018). Effect of feeding larvae meal in the diets on growth performance, nutrient digestibility and meat quality in broiler chicken. Indian Journal of Animal Sciences, 88: 1180–1185.
29. Khan S.H. (2018). Recent advances in role of insects as alternative protein source in poultry nutrition. Journal of Applied Animal Research, 46: 1144–1157. https://doi.org/10.1080/09712119.2018.1474743.
30. Krystianiak S., Torgowski J. (1998). The effect of two feeding systems on rearing results of pheasants (*Phasianus colchicus* L.) of Polish and French varieties. Applied Scientific Reports. 36: 201-209.
31. Madden J.R., Hall A., Whiteside M.A. (2018). Why do many pheasant released in the UK die, and how can we best reduce their natural mortality? European Journal of Wildlife Research, 64: 40. https://doi.org/10.1007/s10344-018-1199-5.
32. Makkar H.P.S., Tran G., Heuzé V., Ankers P. (2014). State-of-the-art on use of insects as animal feed. Animal Feed Science and Technology, 197: 1–33. https://doi:10.1016/j.anifeedsci.2014.07.008.
33. Melin J.M., Larbier M. (1988). Effect of protein level in starter diet on growth and feathering performance of pheasant. Annales de Zootechnie, 37: 143-150.
34. Mróz E. (2003). Bażanty. Oficyna Wydawnicza „HOZA", Warszawa, pp. 5–128.
35. Putaala A., Hissa R. (1995). Effects of hand-rearing on physiology and anatomy in the grey partridge. Wildlife Biology, 1(1), 27-31.
36. Robertson P.A., Wise D.R., Blake K.A. (1993). Flying ability of different pheasant strains. Journal Wildlife Management, 57: 778-782.

37. Robertson P., Mill A., Rushton S., McKenzie A., Sage R., Aebischer N. (2017). Pheasant release in Great Britain: long-term and large-scale changes in the survival of a managed bird. European Journal of Wildlife Research, 63: 100. https://doi.org/10.1007/s10344-017-1157-7.
38. Santilli F., Bagliacca M. (2008). Factors influencing pheasant Phasianus colchicus harvesting in Tuscany, Italy. Wildlife Biology, 14: 281-187. https://doi.org/10.2981/0909-6396(2008)14[281:FIPPCH]2.0.CO;2.
39. Straková E., Suchý P., Karásková K., Jámbor M., Navrátil P. (2011). Comparison of nutritional values of pheasant and broiler chicken meats. Acta Veterinaria Brno, 80: 373-377.
40. Sun T., Long R.J., Liu Z.Y. (2013). The effect of a diet containing grasshoppers and access to free-range on carcase and meat physicochemical and sensory characteristics in broilers. British Poultry Science, 54: 130–137. https://doi.org/10.1080/00071668.2012.756575.
41. Thomas S.R., Goulson D., Holland J.M. (2001). Resource provision for farmland gamebirds: the value of beetle bank. Annals of Applied Biology, 139: 111-118.
42. Tobalske B.W., Dial K.P. (2000). Effects of body size on take-off flight performance in the Phasianidae (AVES). Journal of Experimental Biology, 203: 3319-3332. https://doi.org/10.1242/jeb.203.21.3319.
43. Traineau M., Bouvarel I., Mulsant C., Roffidal L., Launay C., Lescoat P. (2013). Effects of performance of ground wheat with or without insoluble fiber or whole wheat in sequential feeding for laying hens. Poultry Science, 92: 2475-2486. https://doi.org/10.3382/ps.2012-02871.
44. Tucker G.M. (1992). Effects of agricultural practice on field use by invertebrate-feeding birds in winter. Journal of Applied Ecology, 29: 779-790.
45. Van Huis A. (2020). Insects as food and feed, a new emerging agricultural sector: a review. Journal of Insects as Food and Feed, 6: 27–44. https://doi.org/10.3920/JIFF2019.0017.
46. Whiteside M.A., Sage R., Madden J.R. (2015). Diet complexity in early life affects survival in released pheasants by altering foraging efficiency, food choice, handling skills and gut morphology. Journal Animal Ecology, 84: 1480-9, https://doi:10.1111/1365-2656.12401.
47. Whiteside M.A., Sage R., Madden J.R. (2016). Multiple behavioural, morphological and cognitive developmental changes arise from a single alteration to early life spatial environment, resulting in fitness consequences for released pheasant. Royal Society open Science, 3: 160008. https://doi.org/10.1098/rsos.160008.
48. Wilson J.D., Taylor R., Muirhead L.B. (1996). Field use by farmland birds in winter: an analysis of field type preferences using resampling methods. Bird Study, 43: 320-332. https://doi.org/10.1080/00063659609461025.
49. Wise D.R. (1994). Weight, carcase composition and reproductive performance of pheasants (*Phasianus colchicus*) fed restricted or unrestricted diets. Research in Veterinary Science, 57: 119-124.
50. Ydenberg R.C., Dill L.M. (1986). The economics of fleeing from predators. Advances in the Study of Behavior, 16: 229-249. https://doi.org/10.1016/S0065-3454(08)60192-8.
51. Ziołecki J., Doruchowski W. (1989). Metodyka oceny wartości rzeźnej drobiu. Wyd. COBRD, Poznań.