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PRODUCTIVITY OF LAYING HENS IN DIFFERENT PRODUCTION SYSTEMS

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ABSTRACT

The aim of the study was to evaluate the productivity of laying hens of different origin and breeding type (commercial hybrids, native breeds, Araucana) kept in the barn, free-range and organic systems. Three experiments were conducted with a total of 1200 hens, including native breed Greenleg Partridge (Z-11), Rhode Island Red (R-11) and Sussex (S-66) hens included in the gene pool protection programme in Poland; Araucana hens, kept by amateur breeders or raised organically; and Hy-Line Brown commercial layers, typically kept under intensive systems. It was found that the production system and hen genotype have a significant effect on productivity. The Hy-Line Brown commercial layers achieved the best laying performance in the barn and organic systems, but showed a considerably higher level of mortality compared to the other layers. In the free-range system, R-11 hens had no mortality while showing best laying performance and lowest feed consumption per egg. Raising Araucana hens under organic conditions was not effective because they showed the lowest egg production and the highest feed consumption per egg.

Key words: laying hens, production systems, productivity

INTRODUCTION

The economic efficiency of egg production depends primarily on individual layer performance, number of eggs per square meter of the production area, as well as market circumstances when eggs are sold [Krawczyk 2009].

Individual hen performance and health are determined by genetic and environmental factors. In turn, the environmental conditions on a farm are significantly affected by the hen production system [Newberry et al. 2007, Herbut 2009]. Today, intensive production of table eggs involves the use of different commercial lines and varieties of laying hens, which are high-yielding hybrids of different breeds, kept in battery cage or barn systems. Recent years have seen huge breeding progress of around 0.94% in the number of eggs/hen/year, which increases the overall scale of egg production with a smaller increase in the number of layers [Preisinger 2018]. Increased laying performance and better and better quality of compound feeds contribute to decreasing feed consumption per kg of eggs.

Genetic predisposition to high egg production in layers may show only under optimum environmental conditions. Numerous studies confirm the genotype × environment interaction, which is important for laying hen productivity and determines production profitability [Groen 2003]. Following the introduction of provisions concerning improved hen welfare, it is interesting to know egg production efficiency in extensive production systems, which may increase their share due to restrictions on the sale of cage eggs in large retail chains, as is already the case on the German market.

In the free-range and organic hen production system, microclimate conditions are dependent on weather, which shows considerable variation. Under this production system, native breed hens characterized by lower egg pro-

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duction but more resistant to harsh environmental conditions, are often used [Krawczyk 2016a].

The effect of production system on the course and results of egg production has been the subject of much research, mainly in countries which banned the use of battery cages [Damme 2000, Tauson 2005, Horne 2008], while the number of Polish publications in this area is small and mainly concerns egg quality. Distinct differences in the course and results of egg production were observed between the cage and barn systems [Sokołowicz and Krawczyk 2007, Horne 2008], but fewer studies are available on variation in productivity between different alternative (non-cage) systems.

The aim of the study was to evaluate the productivity of laying hens of different origin and breeding type (commercial hybrids, native breeds, ornamental hens) kept in the barn, free-range and organic systems.

MATERIAL AND METHODS

Three experiments were conducted with a total of 1200 hens, including native breed Greenleg Partridge (Z-11), Rhode Island Red (R-11) and Sussex (S-66) hens included in the gene pool protection programme in Poland; Araucana hens, kept by amateur breeders or raised organically; and Hy-Line Brown commercial layers, typically kept under intensive systems. The study was conducted on three different farms: in a barn system (experiment 1), in a barn system with outdoor access (experiment 2), and in an organic system (experiment 3).

All the experiments were carried out from 18 to 64 weeks of age. The experimental layout is shown in Tables 1–3.

Hens from groups I and II were fed the same complete layer diet (16.04% protein, 11.4 MJ $\cdot$ kg^{-1}), and hens from group III received an organic hen diet (16.00% protein, 11.2% MJ $\cdot$ kg^{-1}).

In experiments 1 and 2, hens were fed the same complete diet, and in experiment 3 they received an organic layer diet. In experiments 2 and 3, layers has access to the free range. The nutritive value of the diets is presented in Table 4. In all the experiments, the birds received natural light supplemented to 16 h daily with artificial light.

In experiment 1, hens were kept in the barn system all year round. The poultry house was equipped with automatic ventilation but had no automated climate control system. Depending on the season, average indoor temperature ranged from 15 to 20°C with relative humidity of 60–70%.

In experiment 2, hens were kept in the barn system with year-round access to a fenced range area. The range was covered with vegetation and flanked by trees.

In experiment 3, hens were allowed access to grass paddocks following organic farming recommendations.

Experimental measurements

To evaluate production results in the layer groups under study, the number of eggs per group, number of dead and culled birds, and amount of feed fed were recorded daily, which were used to generate egg production curves and to calculate basic production parameters. The results were compared and statistically analysed by Statistic ver. 13.1 (StatSoft). Arithmetic means were used to analyse the production results. Significant differences between means in the groups for laying rate, number of eggs per layer and feed consumption were analysed with Duncan's test, and mortality results with non-parametric Kruskal-Wallis test. Differences were considered significant when $P \leq 0.05$ and marked with small letters (a, b), and highly significant when $P \leq 0.01$ and marked with capital letters (A, B).

RESULTS AND DISCUSSION

Our results show that the different production and feeding systems had a significant effect on the productivity of hens. In the barn system, egg production at 20 weeks of age was lowest for Z-11 hens (31.33%) and highest for Hy-Line Brown layers (36.34%). The highest peak egg production in Hy-line Brown hens (85.71%) was 17.49% higher than in R-11 and 29.51% higher than in Z-11 hens (Fig. 1). The egg production curve for Hy-line Brown hens mostly exceeded 80%, which is the optimal level of economic profitability [Krawczyk 2009].

The R-11 barn hens reached peak egg production at 25 weeks, Z-11 hens at 30 weeks, S-66 hens at 38 weeks, and Hy-line Brown hens at 41 weeks of age (Fig. 1). The Z-11 and S-66 birds are kept in flocks covered by the gene pool protection programme, where no selection is practised for performance traits; this results in low egg production, which was also reported by Krawczyk [2016a, 2016b].

The egg production rate averaged 76.4% in Hy-line Brown hens and was higher by 29.0% than in Z-11 hens, by 19.3% than in S-66 hens, and by 17.9% than in R-11 hens, with statistically significant differences ($P \leq 0.01$) (Table 5).

The number of eggs per Hy-line Brown layer to 64 weeks of age, in relation to hen-housed and hen-day egg production, was significantly higher compared to the other hen groups ($P \leq 0.01$). Up to 64 weeks, Hy-line Brown hens produced 60 more eggs compared to R-11 hens, 65 more eggs than S-66 hens, and 95 more eggs in relation to Z-11 hens. The egg production results in the commercial Hy-line Brown layers from our experiment are much better than those of the hens included in the gene pool protection programme, but slightly worse than those obtained by intensively reared commercial hybrids [Preisinger 2018].

Table 1. Design of experiment 1 – barn system

Tabela 1. Układ doświadczenia 1 – chów ściółkowy

Item Wyszczególnienie	Group – Grupa			
	I Greenleg Partridge Zielononóżka kuropatwiana (Z-11)	II Sussex (S-66)	III Rhode Island Red (R-11)	IV Hy-line Brown
No. of hens per group Liczba kur w grupie	120	120	120	120
No. of subgroups Liczba podgrup	4	4	4	4
No. of hens per subgroup Liczba kur w podgrupie	30	30	30	30
Stocking density Wielkość obsady	6 hens per m^2 6 kur na m^2			

Table 2. Design of experiment 2 – barn system with free-range access

Tabela 2. Układ doświadczenia 2 – chów ściółkowy z dostępem do wybiegu

Item Wyszczególnienie	Group – Grupa			
	I Greenleg Partridge Zielononóżka kuropatwiana (Z-11)	II Sussex (S-66)	III Rhode Island Red (R-11)	IV Hy-line Brown
No. of hens per group Liczba kur w grupie	90	90	90	90
No. of subgroups Liczba podgrup	3	3	3	3
No. of hens per subgroup Liczba kur w podgrupie	30	30	30	30
Stocking density Wielkość obsady	Barn – 6 hens per m^2; free range – 1 hen per 4 m^2 W kurniku – 6 kur na m^2; na wybiegu – 1 kura na 4 m^2			

Table 3. Design of experiment 3 – organic system

Tabela 3. Układ doświadczenia 3 – chów ekologiczny

Item Wyszczególnienie	Group – Grupa			
	I Greenleg Partridge Zielononóżka kuropatwiana (Z-11)	II Araucana	III Rhode Island Red (R-11)	IV Hy-line Brown
No. of hens per group Liczba kur w grupie	90	90	90	90
No. of subgroups Liczba podgrup	3	3	3	3
No. of hens per subgroup Liczba kur w podgrupie	30	30	30	30
Stocking density Wielkość obsady	6 hens per m^2 of hen house; free range – 1 hens per 5 m^2 6 kur na m^2 kurnika; na wybiegu – 1 kura na 5 m^2			

In the studied period from 20 to 64 weeks of age, mortality was highest (2.4%) in the group of Hy-line Brown hens, but in the flocks of Z-11 and R-11 hens it was low and did not exceed 1%. The highest survival (100%) was observed for S-66 hens. Studies by Krawczyk [2016a and 2016b] indicate that protected breeds of hens are characterized by low mortality percentage. Flock mortality is

Table 4. Nutritive value of the diets fed to hens in experiments 1–3

Tabela 4. Wartość pokarmowa mieszanek paszowych stosowanych w żywieniu kur w doświadczeniach 1–3

Item Wyszczególnienie	Experiment Doświadczenie		
	I	II	III
Crude protein, % Białko ogólne, %	16.04	16.04	16.00
Crude fibre, % Włókno surowe, %	2.62	2.62	4.50
Crude ash, % Popiół surowy, %	13.50	13.50	12.20
Crude fat, % Tłuszcz surowy, %	2.10	2.10	2.50

Table 5. Laying performance of barn hens

Tabela 5. Wyniki nieśności kur w chowie ściołowym

Item Wyszczególnienie	Group – Grupa			
	Z-11	S-66	R-11	Hy-line Brown
Average laying rate, % Średnie tempo nieśności, %	47.4^{aA}	57.1^{bB}	58.5^{bB}	76.4^{cC}
No. of eggs to 64 weeks of age in relation to hen-housed egg number, pcs. Liczba jaj do 64. tygodnia życia w stosunku do st. początkowego, szt.	149^{aA}	180^{bB}	184^{bB}	239^{cC}
No. of eggs to 64 weeks of age in relation to hen-day egg number, pcs. Liczba jaj do 64. tygodnia życia w stosunku do st. średniego, szt.	150^{aA}	180^{bB}	185^{bB}	245^{cC}
Mortality to 64 weeks of age, % Udział padnięć do 64. tygodnia życia, %	0.4^{AB}	0^{aA}	0.6^{AB}	2.4^{bB}
Mean feed consumption to 64 weeks of age, g per egg Średnie zużycie paszy do 64. tygodnia życia, g per egg	236^{aA}	214^{bB}	208^{bB}	157^{cC}

a, b – values in rows with different letters differ significantly within breed (P < 0.05).
A, B – values in rows with different letters differ significantly within breed (P < 0.01).

one of the indicators to show if a production system meets the welfare needs of laying hens [Herbut, 2009].

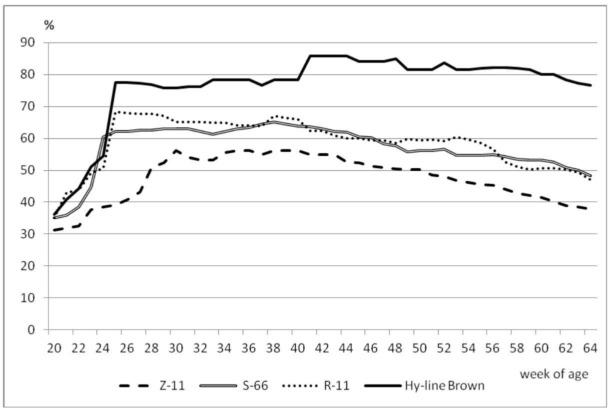

Fig. 1. Course of egg production in barn hens

Rys. 1. Przebieg nieśności kur w chowie ściołowym

The health status of birds reflects their welfare, but the welfare of hens influences their health. When considering the results of the study from this aspect, it can be asserted that the barn system was most comfortable, because mortality percentage in this system was lowest regardless of layer genotype (Tables 5–7). For the Hy-line commercial hybrids, the highest level of discomfort occurred in the organic system (10% mortality). The mortality of these hens was also high (6.7%) in the free-range system, which is over 4% more than in the barn system (Tables 5–7, Fig. 4c). The mean feed consumption per egg was 236 g in the group of Z-11 hens, 22 g lower for S-66 hens, and 28 g lower for R-11 hens. The lowest feed consumption per egg in the Hy-line Brown flock was 79 g lower than for Z-11 hens and the differences were significant ($P \leq 0.01$). According to Preisinger [2018], feed consumption in the intensive system is low and in the years 2010–2015 it gradually decreased from 2.20 to 2.13 kg/kg of eggs.

In the free-range system, hens began egg production at 20 weeks of age with a mean egg production of 19.05% (Fig. 2). The egg production curves were uneven, showing large variation throughout the studied period with low egg production, and Z-11 and S-66 hens from this system did not exceed 80% egg production (Fig. 2).

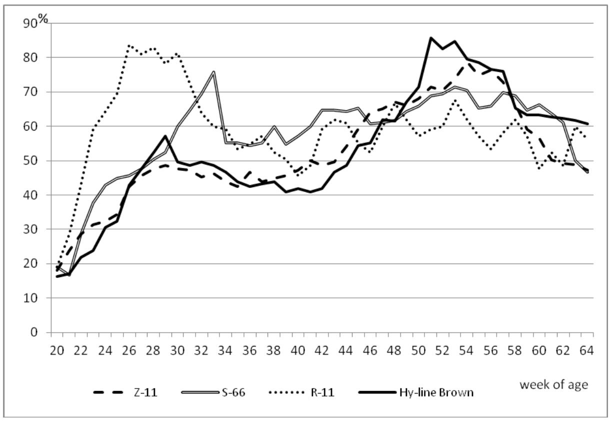

Fig. 2. Course of egg production in free-range hens

Rys. 2. Przebieg nieśności kur w chowie wybiegowym

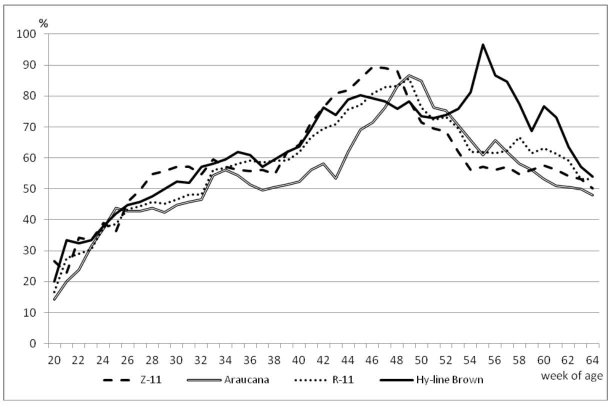

Fig. 3. Course of egg production in organically raised Z-11, Araucana, R-11 and Hy-line Brown hens

Rys. 3. Przebieg nieśności kur Z-11, Araucana, R-11 i Hy-line Brown w warunkach chowu ekologicznego

R-11 hens from the free-range system reached peak egg production at 26 weeks and their egg production exceeded 80% for four weeks, whereas Hy-line Brown layers came to peak egg production at 51 weeks and their egg production exceeded 80% for three weeks (Fig. 2).

In the free-range system, the highest mean egg production rate in the studied period was noted in R-11 hens (58.5%) and the lowest (52%) in Z-11 hens ($P \leq 0.05$) (Table 6). Up to 64 weeks of age, most eggs in relation to hen-housed and hen-day egg production, was obtained from R-11 hens compared to the other hen groups ($P \leq 0.01$) (Table 6).

Similar to our study, Cywa-Benko [2002] and Calik [2011] reported that age at sexual maturity was closely related to the egg production curve and percent egg production. The later the layers come into egg production, the fewer the eggs they lay.

In the studied productive period, mortality was 0% in R-11 hens, 3.3% in Z-11 hens, and as much as 10% in the group of S-66 hens (Table 6).

The mean feed consumption per egg was 239 g for Z-11 hens, and 18 g and 31 g lower in S-66 and R-11 hens, respectively, with significant ($P \leq 0.01$) differences (Table 6).

When comparing feed consumption in the free-range and barn systems (Tables 5 and 6), it is evident that this parameter persists at a similar level among the native breeds, but for the Hy-line commercial hybrids it is higher by as much as 79 g. Our observations indicate that native breed hens make efficient use of the free range as feed, and they achieve good feed conversion when feeders are properly placed [Krawczyk et al. 2005].

In the organic system, the egg production curve took a different form than in the two production systems discussed earlier (Fig. 3). All the hens were very late to achieve peak egg production. Z-11 hens came to peak egg production at 43 weeks and their egg production exceeded 80% for 6 weeks. R-11 hens reached peak egg production at 46 weeks and their egg production over 80% was 4 weeks long. Araucana layers reached the peak of lay at 48 weeks of age and their egg production exceeded 80% for three weeks, whereas Hy-line Brown hens achieved peak egg production at 54 weeks of age and their egg production exceeded 80% for four weeks (Fig. 3). The highest peak egg production was obtained by Hy-line Brown hens (96.55%) and this value was 7.03% higher than in Z-11 layers, 9.89% higher than in Araucana hens, and 10.84% higher compared to R-11 hens. After reaching the peak of lay, all the hens experienced a considerable decrease in the egg production rate. At 20 weeks of age, egg production was 26.67% in Z-11 hens, 6.67% lower in Hy-line Brown layers, 10.00% lower in R-11 hens, and 12.38% lower in Araucana hens.

The mean egg production rate was highest in organically raised Hy-line Brown hens, but significant differences occurred only in comparison with Araucana hens (54.3%) (Table 7). A similar egg production rate of Hy-line Brown hens was reported for the results of testing in the field [Wyniki oceny…, 2015].

Weather conditions in Poland, due to long winters, high precipitation and large number of windy days, are not conducive to year-round outdoor use by hens. Hegelund et al. [2005] show that during bad weather, as much as 50% layers per group do not use the range area and it is difficult to objectively interpret the impact of this system on performance of the entire flock.

During the period to 64 weeks of age, the largest number of eggs in relation to hen-housed egg number was obtained from Hy-line Brown hens (194), followed by R-11 and Z-11 hens (9 fewer eggs) and Araucana hens (24 fewer eggs) (Table 7). Also in relation to the average flock size, most eggs were obtained from Hy-line Brown hens (208), followed by Z-11 (192), R-11 (191), and Araucana hens (176) (Table 7), with statistically significant diffe-

Table 6. Laying performance of free-range hens

Tabela 6. Wyniki nieśności kur w warunkach chowu wybiegowego

Item Wyszczególnienie	Group – Grupa			
	Z-11	S-66	R-11	Hy-line Brown
Average laying rate, % Średnie tempo nieśności, %	52.0[a]	57.4	58.8[b]	53.2
No. of eggs to 64 weeks of age in relation to hen-housed egg number, pcs. Liczba jaj do 64. tygodnia życia w stosunku do st. pocz., szt.	161[aA]	174[bB]	185[cC]	163[aA]
No. of eggs to 64 weeks of age in relation to hen-day egg number, pcs. Liczba do 64. tygodnia życia w stosunku do st. średniego, szt.	166[aA]	180[bcdBCD]	185[cC]	175[dD]
Mortality to 64 weeks of age, % Udział padnięć do 64. tygodnia życia, %	3.3	10[aA]	0[bB]	6.7
Mean feed consumption to 64 weeks of age, g per egg Średnie zużycie paszy do 64. tygodnia życia, g per egg	239[aA]	221[bB]	208[cC]	236[aA]

a, b – values in rows with different letters differ significantly within breed ($P < 0.05$).
A, B – values in rows with different letters differ significantly within breed ($P < 0.01$).

Table 7. Laying performance of organically raised hens

Tabela 7. Wyniki nieśności kur w warunkach chowu ekologicznego

Item Wyszczególnienie	Group – Grupa			
	Z-11	Araucana	R-11	Hy-line Brown
Average laying rate, % Średnie tempo nieśności, %	59.0	54.3[a]	59.1	63.4[b]
No. of eggs to 64 weeks of age in relation to hen-housed egg number, pcs. Liczba jaj do 64. tygodnia życia w stosunku do st. pocz., szt.	185[aA]	170[bB]	185[aA]	194[cC]
No. of eggs to 64 weeks of age in relation to hen-day egg number, pcs. Liczba do 64. tygodnia życia w stosunku do st. średniego, szt.	192[aA]	176[bB]	191[aA]	208[cC]
Mortality to 64 weeks of age, % Udział padnięć do 64. tygodnia życia, %	3.3[aA]	6.7	6.7	10.0[bB]
Mean feed consumption to 64 weeks of age, g per egg Średnie zużycie paszy do 64. tygodnia życia, g per egg	208[aA]	227[bB]	208[aA]	199[cC]

a, b – values in rows with different letters differ significantly within breed ($P < 0.05$).
A, B – values in rows with different letters differ significantly within breed ($P < 0.01$).

rences. Hy-line Brown hens, despite their higher productivity when compared to the other breeds/lines of hens, achieved low egg production in the free-range and organic systems in relation to their genetic potential [Wyniki oceny. . . 2015].

In the organic production system, mortality was lowest in Z-11 hens (3.3%) compared to 6.7% in Araucana and R-11 hens, and 10% in Hy-line Brown layers. This may suggest that intensively raised Hy-line Brown layers are less adapted to adverse environmental conditions of organic farming than the hens covered by the gene pool protection programme (Table 7).

The highest feed consumption per egg was observed in the flock of Araucana hens (227 g) and the differences in relation to the other groups were statistically significant.

Figures 4 a-c present the production results obtained by the different breeds/lines of hens according to rearing system. During the egg production period to 64 weeks of age, the highest number of eggs in relation to hen-housed egg number was obtained from barn hens (191), and the lowest from free-range hens, which laid 21 fewer eggs during the same period (Fig. 4a). Z-11 hens produced the most eggs in the organic system, Hy-line Brown layers in the barn system, and for R-11 the production had no significant effect on productivity. Studies by Hegelund et al. [2006] and Leenstra et al. [2014] indicate that in the organic production system, hens lay fewer eggs than in the other systems.

The profitability of layer farming includes not only the number of eggs laid, but also efficient feed conversion, because in egg production, feed costs form 60–70% of the total costs, and feed prices show a steady upward trend [Krawczyk 2009].

The highest feed consumption per egg was obtained in the flock of free-range hens; it was 28 g higher compared to the lowest feed consumption in the barn system, and 23 g higher than in the organic system (Fig. 4c). These results are consistent with the findings of other authors who observed that the higher feed consumption in the free-range system is associated with higher activity of the birds [Tauson 2005, Michel and Huonnic 2003] and greater heat loss by the layers [Herbut, 2009]. Leenstra et al. [2014] indicate that in Holland, the development of alternative hen production systems is paralleled by the improvement of layer feeding and management technique programmes, which reduced the differences between organic and cage systems in feed consumption per kg of eggs from 0.50 kg in 2008 to 0.29 kg in 2013.

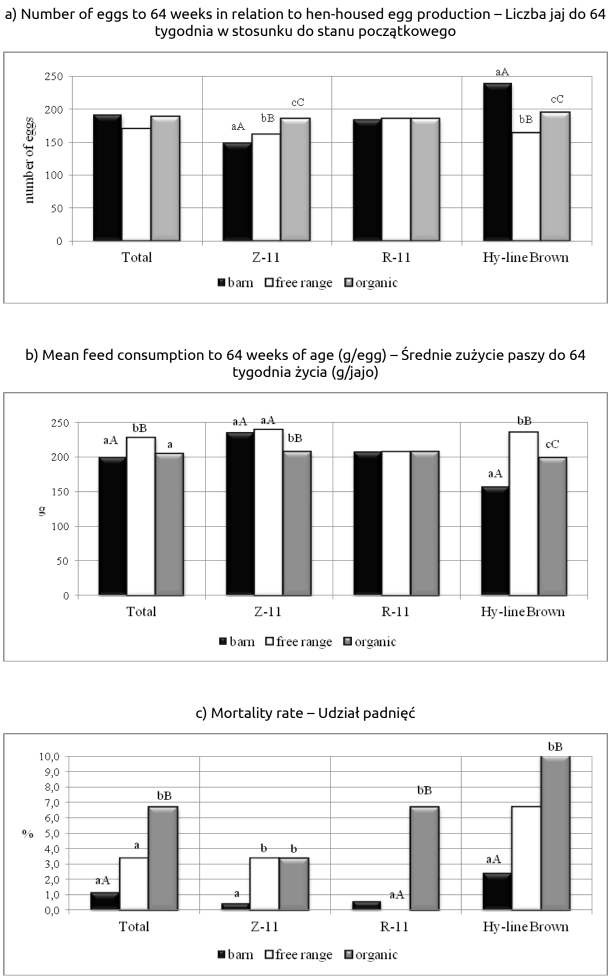

Fig. 4. Effect of production system on performance of hens of different origin. Legend: Total – mean for Z-11, R-11 and Hy-line Brown; a, b – values in rows with different letters differ significantly within breed (P < 0.05); A, B – values in rows with different letters differ significantly within breed (P < 0.01)

Rys. 4. Wpływ systemu chowu na wyniki produkcyjne kur o różnym pochodzeniu. Legenda: Total – średnia dla Z-11, R-11 i Hy-line Brown; a, b – wartości w rzędach oznaczone różnymi literami różnią się istotnie w obrębie rasy (P < 0,05); A, B – wartości w rzędach oznaczone różnymi literami różnią się istotnie w obrębie rasy (P < 0,01)

Regardless of the production system, the level of mortality was not high; it was much lower than reported by Leenstra et al. [2014] for many flocks of hens in Holland. During the studied period, from 20 to 64 weeks of age, the lowest mortality was noted in the barn system (1.1%). The mortality percentage in the free-range system (3.3%) was twice as low as in the organic system (Fig. 4c).

CONCLUSIONS

It was found that the production system and hen genotype have a significant effect on productivity. The Hy-Line Brown commercial layers achieved the best laying performance in the barn and organic systems, but showed a considerably higher level of mortality compared to the other layers. In the free-range system, R-11 hens had no mortality while showing best laying performance and lowest feed consumption per egg. Raising Araucana hens under organic conditions was not effective because they showed the lowest egg production and the highest feed consumption per egg.

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PRODUKCYJNOŚĆ KUR NIEŚNYCH W RÓŻNYCH SYSTEMACH CHOWU

STRESZCZENIE

Celem badań była ocena produkcyjności kur różnego pochodzenia i statusu hodowlanego (mieszańce towarowe, rasy rodzime i Araucana) w chowie ściółkowym, wybiegowym i ekologicznym. Przeprowadzono trzy doświadczenia, w których materiał badawczy stanowiło łącznie 1200 kur w tym kury rasy rodzimej Zielononóżka kuropatwiana (Z-11), kury Rhode Island Red (R-11) i Sussex (S-66) objęte w Polsce programem ochrony zasobów genetycznych zwierząt oraz kury rasy Araucana spotykane w chowie amatorskim lub ekologicznym, a także zestaw towarowy o handlowej nazwie Hy-line Brown, typowe dla chowu intensywnego. Stwierdzono istotny wpływ systemu chowu i genotypu kur na produkcyjność. Kury zestawu towarowego o handlowej nazwie Hy-line Brown osiągnęły najlepsze wyniki nieśności w systemie ściołowym i ekologicznym, przy znacznie większym poziomie upadków w porównaniu z pozostałymi nioskami. w chowie wybiegowym wśród kur R-11 nie odnotowano żadnych upadków i równocześnie najlepszą nieśność i najniższę zużycie paszy na 1 jajo. Chów kur Araucana w warunkach ekologicznych był nieefektywny, bowiem nioski uzyskały najmniejszą nieśność przy największym zużyciu mieszanki paszowej w przeliczeniu na 1 jajo.

Słowa kluczowe: kury nieśne, systemy chowu, produkcyjność