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Evaluation of laying hen breeding conditions on the farm and egg quality in the cage and cage-free systems in the period after the peak of laying

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ABSTRACT

The study aimed to examine laying hens in the cage and cage-free breeding systems, the quality of table eggs and energy consumption in the hall after the peak of laying. In the research, the following were investigated and statistically evaluated welfare of laying hens Bovans Brown was monitored in three different rearing systems based on resources and animals. The research was designed into the post-peak laying period, at the age of laying hens from 34 to 47 weeks and a rearing system of enriched cages on deep litter and in aviaries. Statistical analyses of the measured data of the established indicators were performed with the SAS program package, version 8.2, for statistical characteristics, significance, and correlation relations. The proportion of laying hens dying was lower in aviaries compared to cages and on deep litter ($p \leq 0.05$); in cages and on deep litter was comparable ($p > 0.05$). The weight of laying hens was comparable ($p > 0.05$). Feed consumption per hen, day, and egg was highest on deep litter ($p \leq 0.05$). The proportion of eggs with a cracked shell and contaminated with dropping was highest on litter ($p \leq 0.05$). Energy consumption in the hall expressed per layer and day was comparable in all three breeding systems ($p \leq 0.05$). Among some selected indicators of laying hen welfare, egg quality and energy consumption in the hall during breeding and correlation relations ($p \leq 0.05$) were statistically significant within individual breeding systems. The question of laying hen welfare and improving cage-free systems because of the adopted legislation banning breeding in a cage system requires further research to adopt best practices regarding resource-based, management- and animal-based parameters. Based on the results about welfare conditions, including energy consumption in halls and egg quality, it is an open question for comprehensive, interdisciplinary research.

Keywords: laying hen, breeding system, quality, welfare, egg

INTRODUCTION

EU legislation **[1]** banned the breeding of laying hens in conventional cages, but breeding in enriched cages is still possible. The use of enriched cages varies in individual European Union member states. Some large investments in this breeding system have shifted the decision in favour of the cage-free system. In recent times, large retailers and food companies have seen a shift towards sourcing eggs and egg products from egg producers from cage-free farming systems by 2025.

Laying hens' health and welfare significantly impact egg production and farm economics. From this point of view, ensuring the good living conditions of laying hens can help producers achieve economic benefits. Europeans prefer stricter animal welfare standards and are willing to pay more for products with high animal welfare. This is leading major food businesses and retailers to commit to using only eggs produced in cage-free systems by 2025 at the latest. These include retailers such as Tesco in the UK and Central Europe, Camst in Italy, Monoprix and Carrefour in France, international food services such as Sodexo and Compass Group, and food multinationals such as Nestlé **[2]**, **[3]**. Some member states and regions of the European Union have even introduced a legislative ban on cages in egg production. Austria has banned enriched cages from 2019, Wallonia and the Netherlands from 2021. The Netherlands has allowed the so-called "colony cages". These larger cages are suitable for breeding, usually 40 to 80 laying hens. Germany has announced a ban on enriched cages from 2025. Farmers who have switched to enriched cages to comply with European Union legislation have made significant investments to meet the changed system requirements from conventional to enriched cages. Cage-free systems can offer laying hens to perform their natural activities **[4]**. Egg producers are currently debating ways to diversify the market supply and the replacement of litter eggs with enriched cage eggs is likely to create "value line" (or cheapest) production volumes **[5]**. The acceptability of eggs from the litter system to the general public varies from country to country **[6]**. The most recent manifestation of the trend that led to changes in selection criteria for laying hens are accelerated changes in housing systems and bans on management practices such as beak trimming in several countries of the European Union (Austria, Germany, the Netherlands, etc.). The traditional approach, which focused only on the economic aspects of egg production, has shifted **[7]**. European legislation sets the rules for three alternative breeding systems (cage-free), namely barn, free-range and organic. Breeding systems are marked by law on each individual eggshell and on the egg packaging with the code system defined in Commission regulation **[8]**. The relevant legal provisions for alternative systems are set out in several European Union legislation. There is a lot of research on using animal-based measures to assess animal welfare **[9]** (and others from recent years).

The biggest initiative is the Welfare Quality® project. This project differed from the views of the European Food Safety Authority in that its philosophy was not to identify factors that lead to good or bad living conditions. The Welfare Quality® project focused primarily on animal-based measures that can be monitored and used during a single farm visit by an independent observer to assess current levels of welfare, i. e. at a specific time **[10]**. Consumers are interested in the origin of poultry products. Surveys confirm, as shown by the Eurobarometer results, that most people support the improvement of the living conditions of laying hens in production systems **[11]**. Consumers' perception of animal welfare can influence product purchasing decisions. Up to 43% of consumers claim to consider animal welfare and protection when making a food purchase **[10]**. Egg production, defined as the number of eggs laid in each period, or the laying rate (the number of eggs laid divided by the number of days in a given period), is the main criterion of the selection scheme, which is evaluated for the laying hen. Egg production is influenced by the environment, mainly seasonality, but also depends on the genetic component **[12]**. Genetic variability in egg production has contributed to the current production level in laying hens capable of laying more than 300 eggs per year **[13]**. The table egg is considered an available source of protein, and it provides about 314 kJ or 75 kcal.egg^{-1}. Eggs are a high-quality human protein source due to their high digestibility and balanced amino acid composition. It is not restricted by the prohibitions of most religions and is, therefore a staple human food product that is commonly consumed worldwide. Asia is the world's leading producer (53.3% of world production in 2018), ahead of the European Union (10% of world production) and the United States (8.6%) **[14]**. China alone accounted for 32% of global production in 2018 **[15]**. Annual world consumption is about 150 eggs per year per capita. European consumption averages 217 eggs per year and per capita, with a large difference between countries (from 141 to 183 eggs in Greece and Poland to 301 in Denmark). The French annual consumption of 218 eggs per year per inhabitant in 2018 is like the European consumption, which corresponds to an average daily consumption of 30 g.day^{-1}, which corresponds to 60% of the consumption part of 60 g of eggs **[14]**.

The study aimed to examine, compare and evaluate the research results on the welfare of laying hens from cage and cage-free breeding systems, the quality of table eggs, and the economic indicator of energy consumption in the hall in the period after the peak of laying.

Scientific Hypothesis

The resources for the living conditions of laying hens are improved in cage-free rearing systems on deep litter and in aviaries in terms of performing natural activities compared to the cage system.

Egg damage in cage-free, deep litter and aviary systems is higher than in cage systems.

The economic costs of laying hens and egg production are higher in a cage system than in cage-free systems on deep litter and aviaries.

MATERIAL AND METHODOLOGY

Samples

The research was investigated and statistically evaluated:

- the welfare of laying hens in three different breeding systems expressed in number in the dead laying hens and the weight of laying hens, feed and water consumption recorded in the farm records during the duration of the research,
- egg weight, and damaged eggs with cracked shells and contaminated with dropping monitored on the farm in three different breeding systems during the duration of the research,
- energy consumption in the hall on the farm in three different breeding systems from the farm records during the research duration.

Chemicals

Chemicals were not used in these experiments.

Animals, Plants and Biological Materials

The object of investigation was laying hens of the Bovans Brown hybrid line reared in three different systems, namely in enriched cages with an initial state of 30,892 pcs, on deep bedding with an initial state of 11,130 pcs, and in aviaries with an initial state of 27,958 pcs. The research was situated in the period after reaching the peak of laying at the age of hens from 34 to 47 weeks during three calendar months, namely in August, age of hens from 34 to 38 weeks, in September, age of hens from 39 to 43 weeks and in October, age of hens from 43 to 47 weeks.

Figure 1 Housing laying hens on deep litter (Petrovič, 2022).

Figure 2 Laying hens in aviaries (Petrovič, 2022).

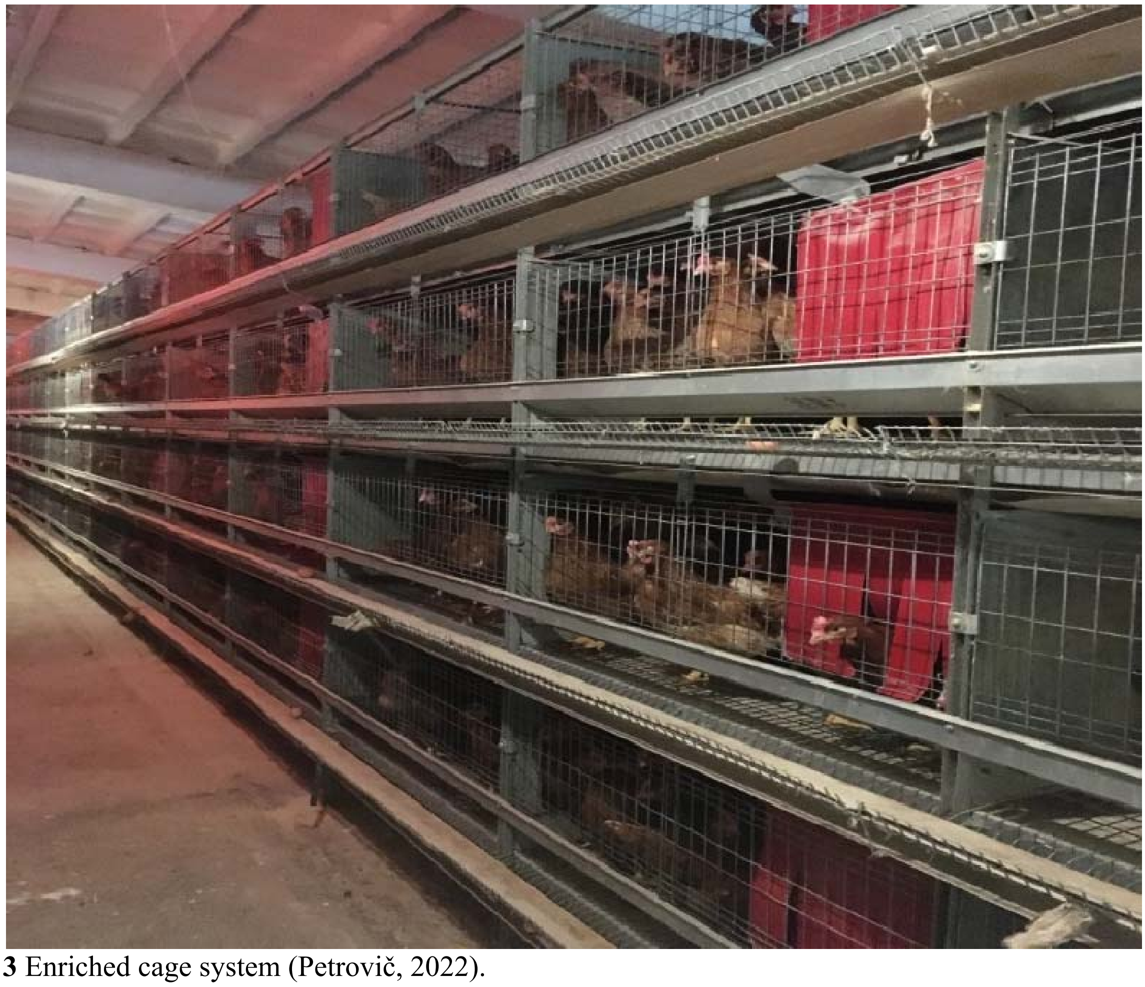

Figure 3 Enriched cage system (Petrovič, 2022).

Instruments

Instruments for indicators based on management and animals: A check was carried out daily with records of the state of the water meter and, electricity meter, feed consumption, based on which the consumption value for the previous day was calculated and recorded. The functionality of the ventilation system and other electrical equipment were checked, i. e. feeding and hall lighting equipment. After entering the breeding area, the laying hens were checked and the dead individuals were collected, which were stored in the waste container for dead animals. The laying hens were weighed weekly, the results of which were compared with the standard recommended by the producer of the hybrid combination.

Instruments for egg quality indicators: KERN PCB scale with an accuracy of d ±0.001 g was used to weigh the eggs. Damaged eggs with cracked shells and soiled with dropping were assessed visually during egg sorting in the egg sorting department of the hall.

Laboratory Methods

Research and evaluation of welfare conditions from the observation of deviations from the normal behavior of laying hens in the practical conditions of a breeding farm in a cage and two different cage-free breeding systems according to selected indicators based on resources, management and animals was carried out according to the **[16]**.

The number of dead laying hens and the weight of the hens: The number of dead laying hens was assessed daily based on evidence in the farm records in each monitored breeding system and confirmed by the veterinarian during the research period following legislative measures **[17]**.
Based on the number of dead laying hens per day, the proportion of dead laying hens from the total number of laying hens on the same day was calculated according to the formula (the proportion of dead laying hens, %):

$$\% = \frac{\text{number of dead laying hens (pcs)}}{\text{the number of laying hens in the breeding system (g)}} \times 100 \quad (1)$$

The weight of the laying hens was determined by weighing at weekly intervals on a digital scale, type Salter 1102 GNBLDR, with an accuracy of d ±1.0 g and a maximum weight of 5 kg.

Feed consumption was determined daily by checking consumption using a strain gauge installed on the strength of each hall and recorded values using a digital scale, type DGT Weight Transmitter.

The formula was used to calculate feed consumption per laying hen and day:

$$\text{Feed consumption per laying hen and day (g)} = \frac{\text{total feed consumption (g)}}{\text{number of laying hens (pcs)}} \quad (2)$$

Feed consumption per egg was determined daily by calculation according to the formula:

$$\text{Feed consumption per egg (g)} = \frac{\text{total feed consumption (g)}}{\text{number of eggs (pcs)}} \quad (3)$$

Water consumption per laying hen and day was determined daily based on checking water consumption on a water meter, type Enbra EV-1, and calculating according to the formula:

$$\text{Water consumption per laying hen and day (ml)} = \frac{\text{total water consumption (ml)}}{\text{number of laying hens (pcs)}} \quad (4)$$

Description of the Experiment

Sample preparation: Preparation of the samples based on welfare and animals – taking over from the farm record data. Preparation of the egg quality samples taken from the farm record data.

Number of samples analyzed: Number of samples for the evaluation of the welfare of laying hens – the number of dead laying hens was evaluated from the total number of hens during the research for 92 days in cages, 92 days on deep litter and 92 days in aviaries.

Number of samples for evaluation of the weight of laying hens – a sampling of the weight of laying hens was carried out weekly from the total number of laying hens during the 92-day research period based on the same number of randomly selected pieces in each of the three months of August, September, and October, i. e. total n = 14 in cages, n = 14 on deep litter and n = 14 in aviaries.

Number of samples for evaluation of feed and water consumption – the number of samples of feed and water consumption was evaluated daily during the duration of the research based on the total feed consumption of the number of laying hens, i. e. 92 days in cages, 92 days on deep litter and 92 days in aviaries.

Number of samples for evaluation of egg weight – from the total number of eggs laid, the number of eggs weighed from randomly selected eggs was from 30 to 31 pieces during each of the three calendar months during the duration of the research, i. e. total n = 92 in cages, 92 on deep litter and 92 in aviaries.

Number of samples for evaluation of damaged eggs, i. e. with a cracked shell and contaminated with droppings was evaluated daily during the duration of the research from the total number of eggs laid, i. e. 92 days in cages, 92 days on deep litter and 92 days in aviaries.

Number of samples for evaluation of energy consumption – energy consumption was evaluated daily during the research period of 92 days in cages, 92 days on deep litter and 92 days in aviaries.

Number of repeated analyses: 1

Number of experiment replication: 1

Design of the experiment: The experiment was carried out in practical conditions on a poultry farm breeding laying hens in the Slovak Republic. Design of the experiment is shown in Table 1.

Table 1 Disign of the experiment.

Hall with laying her breeding system	Same conditions	Different conditions
Enriched cages	Hybrid combination of Bovans Brown hens Feed mixture HYD 10 – *ad libitum*	initial state 30,892 pcs
Deep litter	Microclimatic conditions – lighting, ventilation, and temperature	initial state 11,130 pcs
Aviaries	Age of laying hens from 34 to 47 weeks The same research indicators	initial state 27,958 pcs

Selected indicators of animal welfare, quality of table eggs and electricity consumption in halls were compared and evaluated during the research period under the same nutritional conditions, microclimatic conditions and with the same hybrid combination of Bovans Brown. The hybrids were reared in three different rearing systems, namely in enriched cages with an initial condition of 30,892 pcs, on deep litter with an initial state of 11,130 pcs and in aviaries with an initial state of 27,958 pcs in the period after reaching the peak of laying. Experiments were carried out at the age of laying hens from 34 to 47 weeks during three calendar months, namely in August, age of laying hens from 34 to 38 weeks, in September, the age of laying hens from 39 to 43 weeks and in October, the age of laying hens from 43 to 47 weeks.

Statistical Analysis

Statistical analyzes of the measured data of the established indicators were performed with the SAS program package, version 8.2. The SAS system program sorted the data, ordering observations according to the values of specific quantities. The SAS program sorted the data in a certain order in the first operation of mathematical-statistical calculations. A SAS file and a sorting procedure were created from the data. From the data sorted by the SAS program, mathematical-statistical calculations of descriptive characteristics of the indicators according to the breeding systems of laying hens were performed based on the values of certain quantities such as arithmetic mean, standard deviation, and coefficient of variation. The Scheffe's test was used to test the statistical significance of differences in the indicator between breeding systems of laying hens at the level of significance $p \leq 0.05$. The basic set in each compared statistical set represented statistical units in the research on the farm n = 92, i. e. n >30 as a large statistical set and n = 14, i. e. n ≤30 (only body weight of laying hens) as a small statistical set. The statistical method Scheffe's test is a commonly used method for evaluating the difference in the means of more than two groups. The p-value, which was set in the SAS program for the Scheffe's test, represents the probability of an error caused by accepting the researcher's hypothesis about the existence of a difference between the researched laying hen systems. It is the probability of error that the null hypothesis of no difference between the groups was rejected if this was indeed true. Within individual systems of laying hens, the correlation between the determined indicators was determined according to the Pearson coefficient (r in the range of 1 to -1), which expresses the degree of tightness in linear regression, if they are determined on an interval scale. The correlation coefficient results were verified by statistical evidence at the level of significance $p \leq 0.001$, $p \leq 0.01$, $p \leq 0.05$. According to the scale **[18]** to interpret the correlation coefficient result, a linear relation of 0.9 – 1 means almost perfect, 0.7 – 0.9 very strong, above 0.5 strong, 0.3 – 0.5 medium, 0.1 – 0.3 weak and below 0.1 trivial, simple, light.

RESULTS AND DISCUSSION

Historically, animal welfare has been defined by the absence of negative experiences such as disease, hunger, thirst, stress, or reduced fitness **[19]**. Most animal welfare research over the past 40 years has focused on avoiding negative states. However, there is increasing interest and research in experiences with positive animal welfare states **[20].** This shift in animal welfare science has led to the understanding that animal welfare cannot be achieved without experiencing positive affective states such as comfort, pleasure, and a sense of control **[21]**. Public attention to the welfare of laying hens in the last two decades has been stimulated by the gradual transition from conventional cage systems with an increase in the proportion of enriched cages that provide them with more space for movement, nest, perch and bedding substrate and cage-free systems in some countries, initially in the European Union **[1]**, and subsequently outside Europe. For example, as of March 2020, nearly 24% of all layers in the United States were housed in cage-free systems, up from 12% in 2016 to 4% in 2010 **[22]**. Considering the ethical dimension in this sector has led to many examples of major changes in how eggs are produced to respond to society's demands. The main changes in the breeding system relate to the gradual retreat from cage systems **[23].** A breeding system can cause social problems when it causes frustration. The opportunity for hens to exhibit the behaviours they are motivated to engage in is key to achieving positive welfare states **[24]**.

Mortality of the laying hens: The average value of the proportion of the laying hen mortality from the total number in the cage breeding system, on the deep litter and in the aviaries, and the statistical evaluation of the proportion of the laying hen mortality are shown in Table 2.

Table 2 The average value of the proportion of laying hen mortality from the total number in the cage system, on the deep litter and in aviaries, % and statistical evaluation of the proportion of laying hens dying.

Breeding system	n	% ± SD	c_v, %
Cages	92	$0.02^a \pm 0.010$	36.11
Deep litter	92	$0.02^a \pm 0.010$	48.04
Aviaries	92	$0.01^b \pm 0.003$	31.77
F-test		(7.72^{++}, $p \leq 0.01$)	

Note: n – multiciplity, % – mean in percentage, SD – standard deviation, c_v – coefficient of variation, ++ or $p \leq 0.01$ means a statistically highly significant difference, different letters in the superscript mean a statistically significant difference $p \leq 0.05$, the same letters in the superscript mean a statistically non-significant difference $p > 0.05$.

The variances of the proportion of the mortality of laying hens in the three monitored different breeding systems differed statistically significantly ($F = 7.72^{++}$, $p \leq 0.01$), which was confirmed by the result of the F-test, which verified the assumption of the equality of the variances. The null hypothesis H0 of no difference between the laying systems was rejected.

The average mortality of laying hens was 0.02% in the cage system and 0.02% in the deep litter system and 0.01% in the aviaries. The difference in the proportion of the mortality of laying hens was statistically significant ($p \leq 0.05$) by comparing the cage system of breeding with aviaries and deep litter breeding with aviaries. Comparing the cage breeding system with the deep litter breeding system, no statistically significant difference was found ($p > 0.05$). The statistical evaluation of the proportion of laying hen mortality expressed by the standard deviation revealed the same fluctuation of values in cages and on deep litter and smaller in aviaries (SD = 0.01, 0.01 and 0.003) and by the coefficient of variation a larger fluctuation of values in order on deep litter, in cages and in aviaries (c_v = 48.04, 36.11 and 31.77).

Enriched cage and cage-free systems allow laying hens to move around and exhibit natural behaviour, but concerns have been raised regarding the observation of higher mortality rates in cage-free systems **[25]**, **[26]**. The mortality of laying hens is considered one of the most important indicators of health **[27]** since a higher mortality would indicate a deteriorated health status. However, a thorough understanding of the causes of mortality in different breeding systems is needed to substantiate such a claim. If confirmed, it would mean that the health and welfare of laying hens could be partially compromised after the transition to cage-free systems. However, it is not yet clear whether the death rate is higher in cage-free systems. Information on mortality is not systematically collected in laying hen farms producing table eggs and few reviews have focused on this topic **[28]**. Therefore, knowledge is considered inconsistent. Where mortality differences were found between breeding systems **[25]**, they were non-significant when the confounding effect of beak trimming status was controlled (although beak trimming is a painful procedure with a significant negative impact on hen welfare) **[29]**, its effect on reducing mortality due to harmful feather pecking is well known **[22]**. In study **[30]** is reported, based on the results of the research project, that the mortality rate of laying hens was lower in enriched cages than in litter stalls. The observation of a strong association between laying hen mortality and breeding system was replicated with different meta-analytic models and in different sensitivity analyses. Using two independent data sets, a strong and significant decrease in mortality in cage-free aviaries was observed over time. These results also find support in various previous observations **[31]**. Leenstra et al. **[32]**. also report data showing a decrease in the mortality of laying hens reared in aviaries. Our research results also confirm a statistically significant reduction in the mortality of laying hens in aviaries compared to the mortality of laying hens in the cage system and on deep litter. In a study by Saldaña et al. **[33]** mortality during the laying phase is reported to be 1.8% in hybrid Lohmann Brown Classic and unrelated to treatment (data not shown).

Feed consumption per laying hen and day: The average feed consumption per laying hen and day in the cage breeding system, on deep litter and in aviaries and the statistical evaluation of feed consumption per laying hen and day are shown in Table 3.

Table 3 The average feed consumption per laying hen and day in the cage breeding system, on the deep litter and in aviaries, g and statistical evaluation of feed consumption per laying hen and day.

Breeding system	n	g ±SD	c_v, %
Cages	92	$111.51^a \pm 4.18$	3.75
Deep litter	92	$116.75^b \pm 2.55$	2.18
Aviaries	92	$108.31^a \pm 7.81$	7.21
F-test		(9.59^{+++}, $p \leq 0.001$)	

Note: n – multiciplity, % – mean in percentage, SD – standard deviation, c_v – coefficient of variation, +++ or $p \leq 0.001$ means a statistically very highly significant difference, different letters in the superscript mean a statistically significant difference $p \leq 0.05$, the same letters in the superscript mean a statistically non-significant difference $p > 0.05$.

The variances of feed consumption per laying hen and day in the three different breeding systems were statistically very significantly different ($F = 9.59^{+++}$, $p \leq 0.001$), which was confirmed by the F-test result, which verified the assumption of the equality of variances. The null hypothesis H0 of no difference between the laying systems was rejected.

The average feed consumption per laying hen per day was 111.51 g in the cage system, 116.75 g in the deep litter system and 108.31 g in the aviaries. The difference in feed consumption per laying hen and day was statistically significant ($p \leq 0.05$), comparing the cage system with the litter system and the litter system with aviaries. No statistically significant difference was found by comparing the breeding cage system with aviaries ($p > 0.05$). Statistical evaluation of feed consumption per laying hen and day, expressed by standard deviation and coefficient of variation, revealed fluctuations in values from the largest in order in aviaries, cages and on deep litter (SD = 7.81, 4.18 and 2.55, c_v = 7.21, 3.75 and 2.18).

Feed consumption per egg: The average feed consumption per egg in the cage breeding system, on the deep litter and in the aviaries, and the statistical evaluation of the feed consumption per egg are shown in Table 4.

Table 4 The average feed consumption per egg in the cage breeding system, on deep litter and in aviaries, g and statistical evaluation of feed consumption per egg.

Breeding system	n	g ±SD	c_v, %
Cages	92	$130.01^a \pm 4.18$	12.76
Deep litter	92	$165.32^b \pm 2.55$	9.79
Aviaries	92	$142.47^a \pm 21.32$	14.97
F-test		(15.01^{+++}, $p \leq 0.001$)	

Note: n – multiciplity, % – mean in percentage, SD – standard deviation, c_v – coefficient of variation, +++ or $p \leq 0.001$ means a statistically very highly significant difference, different letters in the superscript mean a statistically significant difference $p \leq 0.05$, the same letters in the superscript mean a statistically non-significant difference $p > 0.05$.

The variances of feed consumption per egg in the three different breeding systems were statistically very significantly different ($F = 15.01^{+++}$, $p \leq 0.001$), which was confirmed by the F-test result, which verified the assumption of the equality of variances. The null hypothesis H0 of no difference between the laying systems was rejected.

The average feed consumption per egg was 130.01 g in the cage breeding system, 165.32 g in the deep litter system and 142.47 g in the aviaries. The difference in feed consumption per egg was statistically significant ($p \leq 0.05$) comparing the cage system with the litter system and the litter system with aviaries. No statistically significant difference was found by comparing the breeding cage system with aviaries ($p > 0.05$). Statistical evaluation of feed consumption per egg, expressed by standard deviation and coefficient of variation, revealed a fluctuation of values from the largest in order in aviaries, cages and on deep litter (SD = 21.32, 16.59 and 16.19, c_v = 14.97, 12.76 and 9.79).

Water consumption per laying hen and day: The average water consumption per laying hen and day in the cage breeding system, on the deep litter and in the aviaries, and the statistical evaluation of feed consumption per laying hen and day are shown in Table 5.

Table 5 The average water consumption per laying hen and day in the cage breeding system, on deep litter and in aviaries, ml and statistical evaluation of water consumption per laying hen and day.

Breeding system	n	ml ± SD	cv, %
Cages	92	226.95^{a} ±31.45	13.86
Deep litter	92	209.20^{a} ±27.84	13.31
Aviaries	92	194.78^{a} ±23.32	11.97
F-test		(2.36^{-}, $p > 0.05$)	

Note: n – multiciplity, ml – mean in percentage, SD – standard deviation, cv – coefficient of variation, - or $p > 0.05$ means a statistically non-significant difference, the same letters in the superscript mean a statistically not significant difference $p > 0.05$.

The variances of water consumption per laying hen and day in three different breeding systems differed statistically non-significantly (2.36^{-}, $p > 0.05$), which was confirmed by the result of the F-test, which verified the assumption of the equality of variances. The null hypothesis H0 of no difference between the laying systems was rejected.

The average value of water consumption per laying hen per day was 226.95 ml in the cage system, 209.20 ml in the deep litter system and 194.78 ml in the aviaries. The difference in water consumption per laying hen and day was not statistically significant ($p > 0.05$) by comparing the monitored different laying hen breeding systems. Statistical evaluation of water consumption per laying hen and day expressed by standard deviation and coefficient of variation revealed a fluctuation of values from the largest in order in cages, on deep litter and in aviaries (SD = 31.45, 27.84 and 23.32, c_v = 13,86, 13.31 and 11.97).

In the study **[34]**, a laying hen's average water consumption is 215 $ml.day^{-1}$ for hybrids Lohmann Selected Leghorn and Lohmann Brown. This is in close agreement with the measured drinking water intake of adult brown and white leghorn laying hens (from 214 to 228 $ml.day^{-1}$) **[35]**. Our results of the average water intake of laying hens in the cage system agree with those mentioned. We have noted lower water consumption in the system of rearing laying hens on deep litter or in aviaries compared to the literature sources mentioned above. This fact may also be related to the laying hen hybrid; in our case, it was Bovans Brown.

Body weight of laying hens: The average body weight of laying hens in the cage breeding system, on the deep litter and in the aviaries, and the statistical evaluation of the body weight of the hens are shown in Table 6.

Table 6 The average weight of laying hens in the cage breeding system, on the deep litter and in aviaries, g, and statistical evaluation of the weight of hens.

Breeding system	n	g ±SD	c_v, %
Cages	14	1790.21^{a} ±31.87	1.78
Deep litter	14	1789.21^{a} ±104.58	5.84
Aviaries	14	1786.43^{a} ±57.99	3.25
F-test		(0.59^{-}, p >0.05)	

Note: n – multiciplity, ml – mean in percentage, SD – standard deviation, cv – coefficient of variation, - or p >0.05 means a statistically non-significant difference, the same letters in the superscript mean a statistically non-significant difference p >0.05.

The variances of laying hen weight in three different rearing systems differed statistically non-significantly (0.59^{-}, p >0.05), which was confirmed by the F-test result, which verified the assumption of equality of variances. The null hypothesis H0 of no difference between the laying systems was rejected.

The average weight of laying hens was 1790.21 g in the cage breeding system, 1789.21 g in the deep litter breeding system and 1786.43 g in the aviaries. The difference in the weight of laying hens was not statistically significant (p >0.05) by comparing the observed different breeding systems. The statistical evaluation of the weight of laying hens expressed by the standard deviation and the coefficient of variation revealed a fluctuation of the values from the largest in order on deep litter, in aviaries and cage (SD = 104.58, 57.99 and 31.87, c_v = 5.84, 3.25 and 1.78).

In study **[36]**, the body weight of laying hens in a floor system is higher than hens in cage systems. The study **[37]** reported that laying hens in a free-range system achieves a higher final body weight than hens in enriched cages.

Egg weight: The average egg weight in the cage breeding system, on the deep litter and in the aviaries, and the statistical evaluation of the egg weight are shown in Table 7.

Table 7 The average weight of eggs in the cage breeding system, on deep litter and in aviaries, g and statistical evaluation of egg weight.

Breeding system	n	g ±SD	c_v, %
Cages	92	130.01^{a} ±0.20	0.33
Deep litter	92	165.32^{b} ±0.39	0.62
Aviaries	92	142.47^{c} ±2.24	3.90
F-test		(15.01^{+++}, p ≤0.001)	

Note: n – multiciplity, % – mean in percentage, SD – standard deviation, c_v – coefficient of variation, +++ or p ≤0.001 means a statistically very highly significant difference, different letters in the superscript mean a statistically significant difference p≤0.05, the same letters in the superscript mean a statistically non-significant difference p >0.05.

The variances of feed consumption per egg in the three different rearing systems were statistically very significantly different (109.77^{+++}, p ≤0.001), which was confirmed by the F-test result, which verified the assumption of the equality of variances. The null hypothesis H0 of no difference between the laying systems was rejected.

The average egg weight was 60.88 g in the cage-rearing system, 63.22 g in the deep litter breeding system and 57.44 g in the aviaries. The difference in egg weight was statistically significant (p ≤0.05) by comparing the monitored different laying systems. A statistical evaluation of the weight of eggs expressed by the standard deviation and the coefficient of variation revealed a fluctuation of values from the *l*argest in order in aviaries, on deep litter and in cages (SD = 2.24, 0.39 and 0.20, c_v = 3.90, 0.62 and 0.33).

In published studies, it is stated that egg weight is influenced by the breeding system of laying hens **[38]**, **[39]**, **[40]**.

Damaged eggs with cracked shells: The average value of the proportion of damaged eggs with a cracked shell in the cage breeding system, on deep litter and in aviaries, and the statistical evaluation of the proportion of damaged eggs with a cracked shell are shown in Table 8.

Table 8 The average proportion of damaged eggs with a cracked shell in the cage breeding system, on deep litter and in aviaries, % and statistical evaluation of the proportion of damaged eggs with a cracked shell.

Breeding system	n	% ±SD	c_v, %
Cages	92	1.96^a ±0.54	27.78
Deep litter	92	3.20^b ±0.74	23.09
Aviaries	92	1.16^a ±0.25	21.52
F-test		(37.57^{+++}, p ≤0.001)	

Note: n – multiciplity, % – mean in percentage, SD – standard deviation, c_v – coefficient of variation, +++ or p ≤0.001 means a statistically very highly significant difference, different letters in the superscript mean a statistically significant difference p ≤0.05, the same letters in the superscript mean a statistically non-significant difference p >0.05.

The variances of damaged eggs with a cracked shell in the three different breeding systems were statistically very significantly different (37.57^{+++}, p ≤0.001), which was confirmed by the F-test result, which verified the assumption of the equality of variances. The null hypothesis H0 of no difference between the laying systems was rejected. The average value of the proportion of damaged eggs with a cracked shell was 1.96% in the cage breeding system, 3.20% in the deep litter breeding system and 1.16% in the aviaries. The difference in the proportion of damaged eggs with a cracked shell was statistically significant (p ≤0.05) by comparing the observed different laying systems. A statistical evaluation of the proportion of damaged eggs with a cracked shell expressed as a standard deviation, revealed a fluctuation of values from the largest in order on deep litter, in cages and in aviaries (SD = 0.74, 0.54 and 0.25) and the coefficient of variation from the largest in order in cages, on deep litter and in aviaries (c_v = 27.78, 23.09 and 21.52).

The study [38] found that the proportion of damaged eggs with cracked shells did not differ in cage, free-range, barn and organic systems. The proportion of damaged eggs with cracked shells out of all eggs laid was higher in an enriched cage system compared to free range. This may be since egg collection occurred once a day, and the distance between the nest and the egg belt may have increased the risk of egg damage **[37]**. In the study **[41]** is found a higher percentage of cracked eggs (p ≤0.01) in a breeding system with enriched cages (7.8%) compared to the alternative system (4.1%).

Damaged eggs contaminated with dropping: The average value of the proportion of damaged eggs contaminated with dropping in the cage breeding system, on bedding and in aviaries, and the statistical evaluation of the proportion of damaged eggs contaminated with dropping are shown in Table 9.

Table 9 The average proportion of damaged eggs contaminated with dropping in the cage breeding system, on deep litter and in aviaries, % and statistical evaluation of the proportion of damaged eggs contaminated with dropping.

Breeding system	n	% ±SD	c_v, %
Cages	92	1.56^a ±0.36	22.87
Deep litter	92	3.41^b ±0.88	25.72
Aviaries	92	0.12^c ±0.06	48.03
F-test		(90.31^{+++}, p ≤0.001)	

Note: n – multiciplity, % – mean in percentage, SD – standard deviation, c_v – coefficient of variation, +++ or p ≤0.001 means a statistically very highly significant difference, different letters in the superscript mean a statistically significant difference p ≤0.05.

The variances of the damaged eggs contaminated with dropping in the three different breeding systems were statistically very significantly different (90.31^{+++}, p ≤0.001), which was confirmed by the F-test result, which verified the assumption of the similarity of the variances. The null hypothesis H0 of no difference between the laying systems was rejected. The average proportion of damaged eggs contaminated with dropping was 1.56% in the cage system, 3.41% in the deep litter system and 0.12% in the aviaries.

The difference in the proportion of damaged eggs contaminated with dropping was statistically significant (p ≤0.05) by comparing the monitored different laying hen breeding systems. The statistical evaluation of the damaged eggs contaminated with dropping expressed by the standard deviation revealed a fluctuation of the values from the largest in order on deep litter, in cages and in aviaries (SD = 0.88, 0.36 and 0.06) and the coefficient of variation from the largest in order in aviaries, on deep litter and in cages (c_v = 48.03, 25.72 and 22.87).

Contaminated eggs have been a problem in free-range systems. The main factors affecting these results are nest contamination or egg laying on litter **[42]**, **[43]**. The study **[37]** reported that the proportion of dirty eggs higher in the free-range system compared to the cage system, especially in the hens' last phase of the production period, could be related to unfavorable rainy weather conditions. In another study **[41]**, no statistically significant differences in the proportion of dirty eggs between enriched cages and cage-free systems were observed.
Also, other studies **[44]**, **[45]** is found contaminated eggs eggshells were more contaminated with aerobic bacteria in an aviary compared to an enriched cage system and is found significantly lower bacterial counts in eggshells from enriched cages compared to an alternative laying hen rearing system **[41]**.

Energy consumption per laying hen and day: The average energy consumption per laying hen and day in the cage breeding system, on the deep litter and in the aviaries, and the statistical evaluation of the energy consumption per laying hen and day are shown in Table 10.

Table 10 The average energy consumption per laying hen and day in the cage breeding system, on deep litter and in aviaries, kW and statistical evaluation of energy consumption per laying hen and day.

Breeding system	n	g ±SD	c_v, %
Cages	92	0.01^{a} ±0.004	38.62
Deep litter	92	0.01^{b} ±0.003	29.66
Aviaries	92	0.01^{a} ±0.002	23.40
F-test		(9.05^{+++}, p ≤0.001)	

Note: n – multicipliity, % – mean in percentage, SD – standard deviation, c_v – coefficient of variation, +++ or p ≤0.001 means a statistically very highly significant difference, different letters in the superscript mean a statistically significant difference p ≤0.05, the same letters in the superscript mean a statistically non-significant difference p >0.05.

The variances of energy consumption per laying hen and day in the three different breeding systems were statistically very significantly different (F = 9.05^{+++}, p ≤0.001), which was confirmed by the F-test result, which verified the assumption of the equality of variances. The null hypothesis H0 of no difference between the laying systems was rejected.

The average value of energy consumption per laying hen and day was the same 0.01 kW in all three observed different laying hen breeding systems. Statistical significance (p ≤0.05) in energy consumption per hen per day was recorded by comparing the cage system with the litter system and the litter system with aviaries. No statistical significance was found by comparing the cage breeding system with aviaries (p >0.05). Statistical evaluation of energy consumption per laying hen and day expressed by standard deviation and coefficient of variation revealed a fluctuation of values from the largest in order in cages, on deep litter and in aviaries (SD = 0.004, 0.003 and 0.002, c_v = 38.62, 29.66 and 23.40).

At European level, significant data are available on production levels, production patterns **[46]**, **[47]** and livestock financial accounts [**48**] maintained in the EU. However, relatively little information is available on the energy consumption associated with animal products in the EU and for specific livestock categories. For the development and implementation of the goals and to achieve the goals set in the Green Deal and the Farm to Fork Strategy, a clear understanding of the energy concentrations used in the livestock sector in production systems and production phases is a necessary condition, especially in this period **[49]**.

There is also relatively little EU information on table egg production concerning energy consumption, making it difficult to conclude. A study **[48]** is investigated four egg production systems in the Netherlands, although geographically limited, covered the main production systems in the EU. This study stated that from 20.5 to 23.5 MJ of energy inputs were required to produce 1 kg of eggs and that in all cases, at least 50% of all energy inputs were associated with feed.

Correlation relations between variables studied on the laying hen farm

When evaluating the dependence between variables in the system of breeding hens in cage and cage-free breeding systems, we focused on the strength of dependence r = above 0.5 and -0.5 with statistical significance ($p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$).

Correlation relations between variables studied on the laying hen farm in the caged system:

Correlation relations between variables studied on the laying hen farm in the caged system are shown in Table 11.

Table 11 Correlation relations between variables studied on the laying hen farm in the cage system.

Variable	Feed, hen.day^{-1}	Feed, pc.egg^{-1}	Water hen.day^{-1}	Body weight, g	Egg weight, g	Cracked egg, %	Droping egg, %	Energy in kW, hen.day^{-1}
Mortality	0.73^{++}	0.60^{+}	-0.41^{-}	0.0004^{-}	-0.28^{-}	-0.59^{+}	0.58^{+}	-0.44^{-}
Feed, hen.day^{-1}		0.69^{++}	-0.47^{-}	-0.10^{-}	-0.40^{-}	-0.74^{++}	0.40^{-}	-0.71^{++}
Feed, pc.egg^{-1}			-0.70^{++}	-0.54^{+}	-0.84^{+++}	-0.68^{++}	0.005^{-}	-0.76^{+++}
Water hen.day^{-1}				0.68^{++}	0.76^{+++}	0.66^{++}	0.25^{-}	0.83^{+++}
Body weight, g					0.72^{++}	0.40^{-}	0.55^{+}	0.56^{+}
Egg weight, g						0.61^{+}	0.25^{-}	0.72^{++}
Cracked egg, %							0.02^{-}	0.78^{+++}
Droping egg, %								0.08^{-}

Note: the numerical data means the result of the correlation coefficient (r), - means a statistically non-significant linear relation between two compared variables ($p > 0.05$), + means a statistically significant linear relation between two compared variables ($p \leq 0.05$), ++ means statistically highly significant linear relation between two compared variables ($p \leq 0.01$), +++ means statistically very highly significant linear relation between two compared variables ($p \leq 0.001$).

By evaluating the correlation relationship between two variables for monitored, selected indicators on the farm in the system of breeding laying hens in cages, the power was found from linear positive trivial (r = below 0.1) to linear positive and negative weak (r = 0.1 to 0.3 and -0.1 to -0.3) or linear positive and negative medium (r = 0.3 to 0.5 and -0.03 to -0.05) to linear positive and negative strong (r = above 0, 5 and -0.5), but with a different level of statistical significance or without statistical significance.

A strong linear positive correlation, statistically highly significant $p \leq 0.001$, was noted between water consumption per hen and day and egg weight, also between water consumption per hen and day and energy consumption per hen and day, but also between the proportion of eggs with a cracked shell and energy consumption per laying hen per day.

A strong linear positive correlation, statistically highly significant $p \leq 0.01$, was found between the mortality rate of laying hens and feed consumption per hen, also between feed consumption per hen and day and feed consumption per egg, between water consumption per hen and day and weight laying hens, between water consumption per hen and day and the proportion of eggs with a cracked shell, further between hen weight and egg weight, but also between egg weight and energy consumption per hen and day.

A strong linear positive correlation, statistically significant $p \leq 0.05$, was noted between the proportion of laying hens mortality and feed consumption per egg, also between the proportion of laying hens mortality and the proportion of eggs contaminated with dropping, but also between the weight of laying hens and the proportion of eggs contaminated with dropping, between the weight hens and energy consumption per hen per day and also between egg weight and the proportion of eggs with cracked shells.

A strong linear negative correlation, statistically very highly significant $p \leq 0.001$, was found between feed consumption per egg and egg weight and between feed consumption per egg and energy consumption per hen per day.

A strong linear negative correlation, statistically highly significant $p \leq 0.01$, was found between feed consumption per hen and day and the proportion of eggs with a cracked shell, also between feed consumption per hen and day and energy consumption per hen and day, further between consumption feed per egg and water consumption per hen and day, but also between feed consumption per egg and the proportion of eggs with a cracked shell.

A strong linear negative correlation, statistically significant $p \leq 0.05$, was noted between the proportion of laying hens' mortality and eggs with cracked shells and between feed consumption per egg and laying hen weight.

Correlation relations between variables studied on the laying hen farm in the deep litter system: Correlation relations between variables studied on the laying hen farm in the deep litter system are shown in Table 12.

Table 12 Correlation relations between variables studied on the laying hen farm in the deep litter system.

Variable	Feed, hen.day^{-1}	Feed, pc.egg^{-1}	Water hen.day^{-1}	Body weight, g	Egg weight, g	Cracked egg, %	Dropping egg, %	Energy in kW, hen.day^{-1}
Mortality	0.19^{-}	0.06^{-}	0.34^{-}	0.31^{-}	-0.37^{-}	-0.08^{-}	-0.20^{-}	-0.51^{-}
Feed, hen.day^{-1}		0.05^{-}	0.13^{-}	0.06^{-}	-0.32^{-}	0.06^{-}	-0.45^{-}	0.21^{-}
Feed, pc.egg^{-1}			-0.54^{+}	-0.004^{-}	0.54^{+}	0.67^{++}	0.63^{+}	-0.46^{-}
Water hen.day^{-1}				0.68^{++}	-0.81^{+++}	-0.70^{++}	-0.55+	0.82^{+++}
Body weight, g					-0.42^{-}	-0.20^{-}	-0.24^{-}	0.63^{+}
Egg weight, g						0.74^{++}	0.73^{++}	-0.94^{+++}
Cracked egg, %							-0.43^{-}	-0.61^{+}
Droping egg, %								-0.68^{++}

Note: the numerical data means the result of the correlation coefficient (r), - means a statistically non-significant linear relation between two compared variables ($p > 0.05$), + means a statistically significant linear relation between two compared variables ($p \leq 0.05$), ++ means statistically highly significant linear relation between two compared variables ($p \leq 0.01$), +++ means statistically very highly significant linear relation between two compared variables ($p \leq 0.001$).

By evaluating the correlation relation between the two variables for the monitored, selected indicators on the farm in the system of breeding hens on the deep litter, the power was found from linear positive and negative trivial (r = under 0.1a -0.1) through linear positive and negative weak (r = 0 .1 to 0.3 and -0.1 to -0.3) or linear positive and negative moderate (r = 0.3 to 0.5 and -0.03 to -0.05) to linear positive and negative strong (r = above 0.5 and -0.5), but with a different level of statistical significance or without statistical significance.

A strong linear positive correlation, statistically very highly significant $p \leq 0.001$, was noted between water consumption per layer and energy consumption per layer per day.

A strong linear positive correlation, statistically highly significant $p \leq 0.01$, was found between feed consumption per egg and the proportion of eggs with a cracked shell, further between water consumption per hen and day and weight of laying hens, also between egg weight and proportion of eggs with cracked shells by the shell, but also between the weight of the eggs and the proportion of eggs contaminated with dropping.

A strong linear positive correlation, statistically significant $p \leq 0.05$, was noted between feed consumption per egg and egg weight, also between feed consumption per egg and the proportion of eggs contaminated with dropping.

A strong linear negative correlation, statistically highly significant $p \leq 0.001$, was found between water consumption per hen and day and egg weight and between egg weight and energy consumption per hen and day.

A strong linear negative correlation, statistically highly significant $p \leq 0.01$, was found between water consumption per hen and day and the proportion of eggs with cracked shells and between the proportion of eggs contaminated with dropping and energy consumption per hen and day.

A strong linear negative correlation, statistically significant $p \leq 0.05$, was recorded between feed consumption per egg and water consumption per hen and day, also between water consumption per hen and day and the proportion of eggs contaminated with dropping, further between the proportion of eggs with a cracked shell and energy consumption per laying hen per day.

Correlation relations between variables studied on the laying hen farm in the system aviaries:

Correlation relations between variables studied on the laying hen farm in the system aviaries are shown in Table 13.

Table 13 Correlation relations between variables studied on the laying hen farm in the system aviaries.

Variable	Feed, hen.day^{-1}	Feed, pc.egg^{-1}	Water hen.day^{-1}	Body weight, g	Egg weight, g	Cracked egg, %	Droping egg, %	Energy in kW, hen.day^{-1}
Mortality	-0.09^{-}	0.42^{-}	-0.47^{-}	-0.63^{++}	-0.45^{-}	-0.38^{-}	0.00	-0.25^{-}
Feed, hen.day^{-1}		0.13^{-}	0.53^{+}	0.34^{-}	0.42^{-}	-0.15^{-}	0.05^{-}	-0.08^{-}
Feed, pc.egg^{-1}			-0.54^{+}	-0.55^{+}	-0.45^{-}	-0.34^{-}	-0.71^{+}	-0.66^{++}
Water hen.day^{-1}				0.77^{++}	0.57^{+}	0.36^{-}	0.38^{-}	0.55^{+}
Body weight, g					0.83^{+++}	0.20^{-}	0.51^{-}	0.53^{+}
Egg weight, g						0.17^{-}	0.35^{-}	0.22^{-}
Cracked egg, %							-0.04^{-}	0.03^{-}
Droping egg, %								0.57^{-}

Note: the numerical data means the result of the correlation coefficient (r), - means a statistically non-significant linear relation between two compared variables ($p > 0.05$), + means a statistically significant linear relation between two compared variables ($p \leq 0.05$), ++ means statistically highly significant linear relation between two compared variables ($p \leq 0.01$), +++ means statistically very highly significant linear relation between two compared variables ($p \leq 0.001$).

By evaluating the correlation relationship between two variables for monitored, selected indicators on the farm in the system of breeding laying hens in aviaries, the power from no dependence (r = 0) to linear positive and negative trivial (r = under 0.1 and -0.1) or linear positive and negative weak (r = 0.1 to 0.3 and -0.1 to -0.3) or linear positive and negative medium (r = 0.3 to 0.5 and -0.03 to -0 .05) to linear positive and negative strong (r = above 0.5 and -0.5), but with a different level of statistical significance or without statistical significance.

A strong linear positive correlation, statistically very highly significant $p \leq 0.001$, was noted between hen weight and egg weight.

A strong linear positive correlation, statistically significant $p \leq 0.01$, was found between water consumption per hen per day and hen weight.

A strong linear positive correlation, statistically significant $p \leq 0.05$, was recorded between water consumption per hen and day and egg weight, also between water consumption per hen and day and energy consumption per hen and day, further between hen weight and energy consumption per laying hen and day.

A strong linear negative correlation, statistically significant $p \leq 0.01$, was found between laying hen mortality and hen weight, also between feed consumption per egg and energy consumption per hen per day.

A strong linear negative correlation, statistically significant $p \leq 0.05$, was noted between feed consumption per egg and hen weight and between feed consumption per egg and the proportion of eggs contaminated with dropping.

In the study **[50]** it is stated that the mortality of laying hens and the production of eggs per housed hen are negatively correlated; as a result, the reduction of mortality will increase the productivity per housed hen, even without increasing the production of eggs per present hen. In this research, a linear negative relation was confirmed, but with medium strength without statistical significance ($p > 0.05$) in the system of breeding hens in cages and aviaries (respectively r = -0.45, r = -0.42). A linear positive trivial dependence (r = 0.02) was noted for the laying hen system on deep litter.

A positive correlation exists between the body weight of laying hens and egg weight **[51]**. The results of our research confirmed a positive linear relationship with a strong dependence r = 0.72 statistically highly significant ($p \leq 0.01$) the opinion of the study mentioned above in the system of breeding laying hens in cages and r = 0.83 statistically very highly significant ($p \leq 0.001$) in the system breeding of laying hens in aviaries.
A linear negative medium dependence (r = -0.42) was recorded in the laying hen breeding system on deep litter without statistical significance.

CONCLUSION

In conclusion, we can state that the issue of welfare and its improvement in cage-free systems requires further research to adopt best practices in terms of resource-based, management- and animal-based parameters.

Investigating the effect of microbial indicators on the hygiene of the production of table eggs is an open question for further research both from the aspect of the health of egg consumers and the quality of eggshells.

On the basis of the ongoing evaluated results in practical conditions on the farm, we can state that after the peak of laying at the age of hens 34 to 47 weeks in the months of August, September and October 2022:

- the share of the death of laying hens from the total number of laying hens monitored daily was statistically demonstrably lower in aviaries compared to cages and on deep bedding; in cages and on deep litter was comparable without statistical evidence,
- the intensity of laying was statistically unprovably highest in cages compared to lower in aviaries and statistically lowest compared to deep bedding; in aviaries compared to deep litter it was statistically demonstrably higher,
- feed consumption per laying hen and day was statistically significantly higher on deep bedding than lower in cages and statistically lowest in aviaries; in cages compared to aviaries it was statistically unprovably higher,
- feed consumption per egg was statistically significantly higher on deep litter than lower in aviaries and lowest in cages; in aviaries compared to cages it was statistically unprovably higher,
- water consumption per laying hen and day was statistically unprovably highest in cages, lower on deep bedding and lowest in aviaries,
- the weight of laying hens was comparable in all three monitored breeding systems without statistical evidence,
- the weight of the eggs was statistically significantly higher on litter than lower in cages and lowest in aviaries; in cages compared to aviaries it was statistically demonstrably higher,
- the share of eggs with a cracked shell out of the total number of eggs laid was statistically significantly higher on litter than lower in cages and lowest in aviaries; in cages compared to aviaries it was statistically demonstrably higher,
- the proportion of eggs contaminated with droppings from the total number of eggs laid was statistically significantly higher on bedding than lower in cages and lowest in aviaries; in cages compared to aviaries it was statistically demonstrably higher,
- energy consumption per laying hen per day was statistically demonstrably comparable on deep litter versus cages and aviaries; in cages versus aviaries was statistically comparable without being proven.

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The farm on which we carried out the research is registered by the State Veterinary and Food Administration of the Slovak Republic and is regularly supervised by the fertility control authorities.

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