Physiological condition and productivity of hens, depending on the provision area for keeping in cages

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Abstract

The minimum required level of egg cross-laying area has been determined for keeping hens in multi-tier cage batteries. The research was conducted in the conditions of the modern industrial complex of Ukraine on production of food eggs on laying hens of 3 groups of cross ”Hy-Line W-36”, created in the USA. Each group of hens was kept in a separate poultry house with an area of 2640 m^2 (110 × 24 m, h = 13.5 m), equipped with 12-tier cage batteries (”Salmet”, Germany). The batteries consisted of 18,144 cages with an area of 7506 cm^2 (120.00 × 62.55 cm). Hens of the 1st group were placed 18 birds in each cage, the 2nd – 19, in the 3rd – 20. Therefore, their initial number in the 1st group was 326592 hens, in the 2nd – 344736 hens, in the 3rd – 362880 hens, or 18144 and 36288 hens more. The provision of hens with the area was 417,395 and 375 cm^2/bird. In the 1st group it met the normative requirements in Ukraine (400–450 cm^2/bird), and in the experimental ones (2 and 3 gr.) – it was slightly lower. The experiment lasted 44 weeks, namely until the laying hens reached 62 weeks of age. Hens of 1st and 2nd groups surpassed their counterparts of 3rd group (239.8 eggs, $p < 0.05$), in terms of the number of eggs obtained per initial laying hen at 62 weeks of age (249.4 eggs). They surpassed them in the level of preservation (93.4–94.2% and 85.4%). 31837 eggs were received from laying hens of 1st group from 1 m^2 of the area of a poultry house for the period of experiment, from the 2nd group – 32918 eggs, from the 3rd group – 32832 eggs. Egg mass was obtained from 1 m^2 area: 1st group – 2002.6 kg, 2nd group – 2073.8 kg and 3rd group – 2071.7 kg. The efficiency of egg production in 1st group was 21.2 c.u., in the 2nd – 21.5 c.u., in the 3rd – 20.5 c.u. The conclusion was made about the possibility of making adjustments to the regulations governing the provision of the area of laying hens of egg-laying crosses. In particular, the lower limit of security should be set at 395 cm^2/birds for their content in 12-tier cage batteries. It has been suggested that the excess of the reference values of aspartateaminotransferase and lactatedehydrogenase activity in the blood of hens is associated with a decrease in their safety and productivity, which is due to insufficient provision of their space for multi-tier cage batteries.

Key words: hens productivity, egg-laying, area provision, preservation, cage batteries, normative requirements

Introduction

The provision of poultry area on farms in Ukraine is regulated by the norms of technological design in poultry (VNTP-APK-04.05.) depending on the species, age, method of keeping and other parameters. As for the hens of the industrial herd of white-egg crosses, they can vary in the range of 400–450 cm^2/bird when kept in cages. This corresponds to a retention density in the range of 22–25 birds/m^2. But nowadays there is a need to reconsider the parameters of the minimum (400 cm^2/birds) area for two main reasons. First, these parameters were scientifically substantiated more than 50 years ago for keeping laying hens in cages of 1–3-tier batteries. Second, the live weight of laying hens of modern egg crosses is much smaller (Hy-LineW-36 Final Hybrid Content Guide, 2019) than it was in those days, which is a consequence of selection to reduce feed costs and reduce the age of puberty. Under this circumstance, there are prerequisites for increasing the density of laying hens for more efficient use of existing production capacity (Roiter and Burova, 2019), namely to obtain as many products as possible from 1 m^2 of poultry area (Sakhatsky et al., 2020). But experimentally, this theoretical assumption has not yet been confirmed, including the use of modern multi-level cage equipment. This is hindered by the official position of the developers of modern egg crosses, which, in accordance with EU directive (Council Directive 1999/74/EC), recommend keeping hens in cages of increased comfort and provide them with an area of 490–750 cm^2/bird.

Any discomfort caused by malnutrition, technological stress due to rising temperatures, overcrowding or other environmental factors leads to a decrease in poultry productivity (Olubodun et al., 2015; Infante et al., 2017; Shevchuk et al., 2018). The flock is usually monitored in order to identify negative factors and prevent losses due to reduced productivity of birds, including the general physiological condition of a number of individuals for serum biochemical parameters (Kudair and Al-Hussary, 2010; Nwaigwe et al., 2020; Kraus et al., 2021; Ruiz-Jimenez et al., 2021). It is believed that certain biochemical parameters of blood serum adequately reflect the state of health of hens, certain physiological and even pathological changes that occur in their body (Koronowicz et al., 2016) and adversely affect viability and egg productivity (Pavlík et al., 2007).

The aim of the work is to study the productivity and physiological condition of laying hens, depending on their provision with space for keeping 12-tier batteries in cages.

Material and methods

Hy-Line W-36 commercial egg layers were used as the object of research. Experiments with animals were performed in accordance with the rules of the European Convention for the Protection of Vertebrate Animals (Official Journal of the European Union L276/33 2010).

In the conditions of a modern complex for the production of eggs formed 3 groups of laying hens (Table 1), each of which was kept in a separate poultry house-analogue in area (2640 m^2), equipped with 12-tier cage batteries ”Salmet” (Germany), consisting of 18144 cages with an area of 7506 cm^2 (120.00 × 62.55 cm).

The stocking density of hens of the 1st group met the Ukrainian standards (VNTP-APK-04.05.) – 22–25 birds/m^2 (area – 400–450 cm^2/bird), hens of the 2nd and 3rd groups were kept with high stocking density. The housing density was regulated by the number of hens in the cage, which led to different feeding.

Table 1. The scheme of the experiment

Characteristic	Groups of laying hens		
	1	2	3
Number of hens in the cage	18	19	20
Number of hens in the group	337013	348446	361456
Provision of area, cm^2/bird	417	395	375
Stocking density, birds/m^2	24	25	27
Feeding front, cm	6.7	6.3	6.0

During the experiment, laying hens were provided with drinking water, complete feed of the same composition (Table 2) and kept in accordance with the requirements (Hy-Line W-36 Final Hybrid Content Guide, 2019).

During the experiment, the number of laid eggs and laying intensity, the number of rejected hens (due to death and culling) were determined daily in groups and the preservation of livestock was determined. Once a week, the weight of eggs and live weight of laying hens were measured from certain labeled cages which were at least 100 ($n \geq 100$). The coefficient of efficiency of egg production (Kavtarashvili, 2013) was determined by the formula:

$$E_{er} = (1.4 \times M) - (0.35 \times C),$$

where: E_{er} – Efficiency ratio, c. u.; 1.4 and 0.35 – constant values; M – egg mass (egg mass), kg/hen; C – feed costs for the production of 1 kg of egg mass, kg.

Thirty blood samples were taken from laying hens of each group at the age of 62 weeks. 1.0–1.5 ml of blood was taken from the axillary vein in an EDTA tube. Biochemical markers and activity of serum enzymes of laying hens were determined on a biochemical analyzer BioChem FC-360 (High technology Inc., USA), namely the content of total protein, glucose, creatinine, urea,

Table 2. The composition of feed for laying hens in the productive period, %

Component	Egg-laying intensity, %			
	95–100	93	88	85
Wheat	20.418	19.336	12.000	10.566
Corn	37.053	45.399	54.330	52.334
Sunflower meal	20.754	22.278	18.166	23.533
Soybean meal	7.000	0.000	3.000	0.000
Soybean oil	0.959	0.661	0.000	0.500
Shell 0–3 mm	10.701	9.922	10.25	11.088
Salt	0.210	0.200	0.200	0.210
Monocalcium phosphate	1.193	0.811	0.805	0.532
Sodium sulfate	0.160	0.117	0.120	0.095
Methionine	0.186	0.105	0.088	0.076
Lysine sulfate	0.637	0.585	0.516	0.579
Threonine	0.127	0.095	0.057	0.065
Loxidan TD 100	0.000	0.010	0.000	0.000
Millersheim	0.013	0.015	0.011	0.000
Globamax 1000	0.100	0.000	0.000	0.000
ProActive	0.000	0.000	0.150	0.150
Enteronormin Detox	0.150	0.150	0.000	0.000
Mastersorb	0.150	0.130	0.130	0.000
Mycocide Pro	0.000	0.000	0.000	0.090
Choline chloride	0.050	0.050	0.040	0.035
Cronozyme	0.000	0.000	0.000	0.011
Yellow carnation	0.003	0.003	0.003	0.003
Red carnation	0.003	0.003	0.003	0.003
Mineral complex	0.100	0.100	0.100	0.100
Vitamin complex	0.033	0.030	0.030	0.030
Total	100.000	100.000	100.000	100.000

cholesterol, phosphorus, calcium, aspartate aminotransferase, alkaline phosphatase, lactate dehydrogenase and gamma-glutamyltransferase in the laboratory "Bald" (certificate № LB/02/2016). Concentration of the biochemical constituents was calculated according to the manufacture instruction. Reference values biochemical markers and activity of serum enzymes of laying hens according to Nasonov I. V. (Nasonov et al., 2014).

Significance of group differences was assessed using one-way analysis of variance (ANOVA) and Tukey-Cramer multiple comparison test as a post-hoc test tool. The data in the tables are presented in the form of M ± SEM (Mean ± Standard Error of Mean). Verification of the distribution of sample data for normality was performed according to the Kolmogorov-Smirnov test. The nonparametric Mann-Whitney U-test was used if the data distribution was significantly different from normal. Differences between groups were considered significant at $p < 0.05$.

Results and discussion

It was found (Table 3) that the survival of hens for 62 weeks of life (44 weeks of productivity) in all groups ranged from 85.4 to 94.2% and was less than 96.4% – the level inherent in this cross (Hy-Line W-36 Final Hybrid Content Guide, 2019).

Probably the conditions of keeping in extremely high (12-tier, h = 13.5 m) cage batteries of large mass of birds (337–361 thousand/poultry house) did not meet the requirements of laying hens of this cross. The lowest survival rate was in laying hens of 3rd group (85.4%), who's starting provision, with area (375 cm^2/bird) and feeding front (6.0 cm/bird) was the lowest. However, the final provision of laying hens of 3rd group with the area was slightly higher than the control group (1 gr.), due to their increased care during the 44-week period of the experiment.

Table 3. Egg productivity of hens and parameters of other signs depending on their area in cages of 12-tier batteries

Characteristics	Groups of laying hens		
	1 (control)	2	3
Starting parameters (18 weeks of life):			
– planted hens in total, birds	337013	348446	361456
– in 1 cage, birds	18	19	20
– provision with area, cm^2/bird	417	395	375
– planting density, birds/m^2	24	25	27
Finishing parameters (62 weeks of life):			
– hens were killed and culled, birds	22243	20210	52773
– their final number, in total, birds	314770	328236	308683
– in 1 cage, birds	17,3	18,1	17,0
– provision with area, cm^2/bird	434	414	442
– planting density, birds/m^2	23	24	23
Preservation for 62 weeks of life, %	93.4 ± 0.04^a	94.2 ± 0.04^b	85.4 ± 0.06^{bc}
Received eggs per laying hen, eggs			
– initial, for 52 weeks of life	197.5 ± 0.06^a	195.7 ± 0.14^b	188.8 ± 0.03^{bc}
– initial, at 62 weeks of age	249.4 ± 0.01^a	249.4 ± 0.01^a	239.8 ± 0.05^b
– average, for 52 weeks of life	209.2 ± 0.14^a	205.7 ± 0.11^b	210.2 ± 0.06^{bc}
– average, for 62 weeks of life	267.0 ± 0.03^a	264.9 ± 0.07^b	280.6 ± 0.02^{bc}
Weight of eggs, g/egg, aged			
– 52 weeks old	62.9 ± 0.14^a	63.0 ± 0.01^a	63.1 ± 0.12^a
– 62 weeks old	63.5 ± 0.04^a	63.4 ± 0.06^a	63.5 ± 0.03^a
Live weight of hens at 52 weeks. age, g	1572 ± 1.49^a	1544 ± 1.87^b	1563 ± 0.92^{bc}
Feed consumption per day, g/bird			
– at the age of 52 weeks	122.5 ± 0.04^a	121.2 ± 0.01^b	118.8 ± 0.42^{bc}
– at the age of 62 weeks	118.1 ± 0.01^a	108.1 ± 0.03^b	111.8 ± 0.58^{bc}

Note: a, b, c – indicate values that significant differed in one row of the table ($P < 0.05$)

As for the potential of experimental cross hens in egg productivity, according to its characteristics (Hy-LineW-36 Final Hybrid Content Guide, 2019), the number of eggs obtained for the initial laying should vary between 204.1–209.6 eggs for 52 weeks of life and 262.2–268.7 eggs – for 62 weeks, and for the average – 206.9–212.5 eggs and 267.0–273.6 eggs. In fact, the specified number of eggs per initial laying hen was not obtained in the experiment in any of the groups. Hens of the 3rd group had the lowest egg production ($p < 0.05$) at 52 weeks of life (188.8 eggs/bird) and at 62 weeks of life (239.8 eggs/bird). The highest laying (197.5 eggs/bird) had control group of laying hens (1 gr.) at 52 weeks of age. However, their advantage over the 2nd experimental group ($p < 0.05$) was lost at the age of 62 weeks due to lower egg intensity during the last 10 weeks of the experiment.

The number of eggs obtained per average laying hen is a secondary feature because its parameters are significantly affected by the level of preservation of hens. That is why the parameters of the 3rd group of laying hens were higher at 52 weeks of their lives (210.2 eggs/bird) and 62 (280.6 eggs/bird) weeks of their lives than in 1st and 2nd hens of groups. They were also higher than the level typical for laying hens of this cross (Hy-LineW-36 Final Hybrid Content Guide, 2019) by 52 weeks of life (204.1–209.6 eggs/bird) and by 62 (262.2–268.7 eggs/bird) weeks of life. As for hens of 1st and 2nd groups, their egg-laying at 52 weeks of life (205.7–209.2 eggs/bird) and at 62 (264.9–267.0 eggs/bird) weeks of life on the average laying hen corresponded to parameters characteristic of the cross Hy-LineW-36.

The weight of eggs and live weight of hens of control and experimental groups met the requirements for cross (Hy-LineW-36 Final Hybrid Content Guide, 2019). According to these requirements, the weight of eggs at 52 weeks of life should be 62.9 g, at 62 weeks of life – 63.4 g, and live weight of laying hens at 52 weeks of life – vary between 1.54–1.58 kg/bird. It is well known that the level of development of these characteristics (egg weight and live weight of hens) depends mainly on the influence of genotypic factors. Therefore, it seems logical to assume that the paratypic factor is not influential within the limits studied by us (375–417 cm^2/bird), namely the provision of hens area.

The experimental groups of laying hens differed slightly from the control group in terms of feed consumption, but the parameters of this trait did not correlate with their provision with feeding front and area. In general, feed consumption in all groups was higher than the level typical for laying hens Hy-Line W-36, which at 52 weeks of life should be 97–103 g/bird per day, and in the 62-weeks of life – 96–102 g/bird.

According to the results of biochemical studies, it was found that the parameters of total protein, urea, total cholesterol, inorganic phosphorus and total calcium were within the reference values in all groups, indicating no deviations from the normal physiological state of animals (Table 4). The content of glucose and creatinine in the serum of hens of 3rd group slightly exceeded (by 4.5% and 2.8%) the upper limit of the reference level. In our opinion, the increase of serum glucose occurs due to increased destructive processes in hens under conditions of overcompaction, as well as the action of hormones – glucocorticoids and catecholamines (Downing, 2012; Kraus et al., 2021). The findings are consistent with the results of other studies describing hyperglycemia as a reaction of the bird to chronic (Gupta et al., 2017; Kraus et al., 2021) and acute stress (Mert & Yildirim, 2016), as well as the experimental introduction of adrenocorticotropic hormone (Puvadolpirod & Thaxton, 2000). Research conducted by Kang H. K. with co-authors confirm that increasing the stoking density from 5 to 10 birds/m^2 of floor (Kang et al., 2016) and from 13 to 19 birds/m^2 of aviary (Kang et al., 2018) does not cause changes in serum glucose levels in laying hens, however further overcompaction is the cellular content of laying hens, the authors did not determine. At the same time, there are reports that an increase in serum glucose is not observed of cyclic heat stressor (Laganá et al., 2007; Bueno et al., 2017).

In addition, Guo Y. and co-authors (Goel, 2021) noted an increase in serum creatinine in laying hens with increasing stoking density, which is confirmed by the study data. Bueno J. P.

and others (Bueno et al., 2017), who studied the response of broiler chickens to cyclic heat stress, as well as Abo Ghanima M. M. (Abo Ghanima et al., 2020), who studied the response of ducks to increased stoking density, did not notice an increase in their creatinine levels.

According to the analysis of enzymatic activity in the serum of hens found exceeding the reference values for aspartate aminotransferase and lactate dehydrogenase in hens of the third group (Table 5). Similar results have been obtained by many researchers (Park et al., 2018; Kraus et al., 2021), who describe the increase in the activity of aspartate aminotransferase as a reaction of the chickens to the action of technological stressors. According to Everds N. E. et al. (Everds et al., 2013), constant stress leads to an increase in the activity of aspartate aminotransferase and at the same time to an increase in the concentration of glucose in the serum of hens at cages keeping, which is confirmed by the study data.

Table 6 shows the data for determining the efficiency of egg production depending on the conditions of keeping hens during the 44 weeks of the productive period, until reaching 62 weeks of age.

As mentioned above, different laying hens were planted according to the conditions of experience in 3 similar poultry houses in terms of area and cage equipment. In the experimental groups there was 3.4–7.3% more than in the control groups. However, at the end of the experiment in 3rd group there were 6087 fewer laying hens than in the control group due to low survival (85.4% compared to 93.4% in the control group). 52,773 laying hens dropped out in 3rd group, which is 2.4 times more than in the con-

Table 4. Parameters of serum biochemical markers in laying hens

Markers	Groups of laying hens			Reference value*
	1 (control)	2	3	
Total protein, g/l	52.21 ± 0.80[a]	52.46 ± 0.26[a]	53.12 ± 0.45[a]	43.00–59.00
Glucose, mmol/l	5.02 ± 0.55[a]	6.31 ± 0.44[a]	8.12 ± 0.11[b]	4.44–7.77
Creatinine, µmol/l	30.24 ± 1.38[a]	32.36 ± 0.61[a]	41.12 ± 1.28[b]	23.00–40.00
Urea, mmol/l	1.04 ± 0.04[a]	0.86 ± 0.01[a]	0.88 ± 0.04[a]	0.70–2.40
Total cholesterol, mmol/l	3.51 ± 0.19[a]	3.82 ± 0.05[a]	3.90 ± 0.19[a]	3.44–4.99
Inorganic phosphorus, mmol/l	1.41 ± 0.07[a]	1.53 ± 0.06[a]	1.58 ± 0.08[a]	1.38–2.55
Total calcium, mmol/l	4.53 ± 0.19[a]	4.59 ± 0.14[a]	4.51 ± 0.17[a]	3.50–5.50

*Note: a, b – indicate values that significant differed in one row of the table ($P < 0.05$); * – Reference values according to Nasonov I.V. (Nasonov et al., 2014)*

Table 5. Activity of serum enzymes in laying hens

Enzyme	Groups of laying hens, units/l			Reference value, units/l
	1 (control)	2	3	
Aaspartate aminotransferase	206.42 ± 5.90[a]	208.21 ± 5.99[a]	248.67 ± 3.22[b]	125–210
Gamma-glutamyltransferase	22.28 ± 1.11[a]	21.94 ± 1.21[a]	22.19 ± 2.19[a]	–
Alkaline phosphatase	659.56 ± 46.07[a]	673.21 ± 25.07 [a]	778.65 ± 23.64[b]	350–830
Lactate dehydrogenase	1508.83 ± 29.27[a]	1625.32 ± 26.36[b]	2235,60 ± 27.09[c]	636–1960

*Note: a, b, c – indicate values that significant differed in one row of the table ($P < 0.05$); * – Reference values according to Nasonov I.V. (Nasonov et al., 2014)* trol group (22,243 birds), which is due to their insufficient (375 cm²/bird) provision of area, that is, with overcompaction.

However, the 2nd group was not inferior to the control group (93.4%) in terms of the preservation of chickens (94.2%), despite a slightly lower provision of their area (395 and 417 cm²/bird). This indicates that the reduction in the level of provision of hens with an area of 5 cm²/bird (1.2%) from the lower limit (400 cm²/bird), which is set by the current regulatory requirements in Ukraine (VNTP-APK-04.05.), does not lead to negative consequences for their safety and provides an increase in egg and egg production mass, including 1 m² of poultry house. During the experiment (44 weeks of laying eggs, or 62 weeks of life) from hens of this group (2 g) from 1 m² of poultry house area received more eggs (32918 eggs) and egg mass (2073.8 kg) than from the control group (31838 eggs and 2002.6 kg) and the 3rd group (32838 eggs and 2071.7 kg) at lower feed costs. Therefore, the coefficient of efficiency of egg production in the 2nd group (21.5 c. u.) was higher than in the control group (21.2 c. u.) and in the 3rd group (20.5 c. u.).

Thus, the reduction to 395 cm²/bird of the level of supply of cross-country hens”Hy-Line W-36” with the area of the cage for their content in 12-tier batteries supplied to the Ukrainian market by ”Salmet” (Germany), does not lead to severe consequences and provides for the receipt of more than 1080 (3.4%) eggs or 71.2 kg (3.5%) of egg mass from 1 m² of poultry area at a higher (2.5 c. u.) than in the control group, their production rate. In total, in 44 weeks of the experiment, almost 2.9 million more eggs were obtained from hens of 2nd group than from their counterparts in the control group, which indicates a more rational use of available production space.

Conclusions

It is established that the lower limit of providing hens of white-egg cross ”Hy-Line W-36” with a cage area (not less than 400 cm²/bird), set by current regulations in Ukraine (VNTP-APK-04.05.) and it is advisable to adjust to 395 cm²/bird for their maintenance in 12-tier batteries manufactured by ”Salmet” (Germany). This makes it possible to obtain an additional 2.9 million eggs in each poultry house with an area of 2640 m² for 44 weeks of productivity, namely for the period from the beginning of laying eggs at 18 weeks of life until the hens reach 62 weeks of life pieces from 1 m² of its area at a higher level of efficiency of their production. This ef-

Table 6. Efficiency of egg production depending on the provision of laying hens with the area for their keeping in the cages of 12-tier batteries

Characteristics	Groups of laying hens		
	1 (control)	2	3
Hens planted, total, birds	337013	348446	361456
– including ± to control, birds	–	+11433	+24443
Hens were killed and culled, birds	22243	20210	52773
Hens at 62 weeks age, total, birds	314770	328236	308683
– including ± to control, birds	–	+13466	–6087
Received eggs in total, eggs	84051042	86902432	86677149
– including ± to control, eggs	–	+2851390	+2626107
Obtained egg mass, total, kg	5286811	5474853	5469328
– for the initial laying hen, kg/bird	15.7	15.7	15.1
Obtained from 1 m² of poultry house eggs	31838	32918	32832
– egg mass, kg	2002.6	2073.8	2071.7
Feed costs, total, kg	12418757	12263922	12900556
– per 1 kg of egg mass, kg	2.35	2.24	2.36
Egg production efficiency ratio, c. u.	21.2 ± 0.07^a	21.5 ± 0.07^a	20.5 ± 0.07^b

Note: a, b – indicate values that significant differed in one row of the table (P < 0.05) fect is provided by planting 19 hens (not 18, as required by current requirements in Ukraine) in each of the 18,144 cages of 12-tier batteries located in a poultry house with an area of 2640 m^2. Exceedance of reference values of activity of aspartate aminotransferase and lactate dehydrogenase in the blood of hens against the background of reduced conservation and productivity due to insufficient area, which should be investigated in the future to determine the relationship between the parameters of these characteristics.

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