CHEMICAL ENGINEERING TRANSACTIONS
VOL. 107, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Petar S. Varbanov, Bohong Wang, Petro Kapustenko

ISBN 979-12-81206-07-6; **ISSN** 2283-9216
DOI: 10.3303/CET23107021

Yield Performance, Laying Behaviour Traits and Egg Quality of a Crossbred Laying Hen in Alternative Housing Systems

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One aim of this study was to investigate a crossbred laying hen line (400 hens) in two alternative housing systems in two replicates between 20-72 weeks of age. One rearing system was deep litter (D) with artificial light. Hens from Group R were housed in a poultry house with windows on deep litter and access to a runway without artificial light. Birds were fed ad libitum with a concentrate layer feed (18.0 % protein, 11.6 MJ). The egg production was influenced by the housing system. Lower average egg weight was observed in Group R. The feed consumption was also lower here, but the FCR was better compared to D. Floor egg did not cause any problem in the examined systems. The shell strength decreased with age in both systems. However, the rate was higher in Group D. The albumen height and HU value were higher in Group R at the end of the experiment (72^{nd} week of age). Some differences were found in the fatty acid profile between the two housing systems. Another goal of the study was to observe the behaviour patterns of animals kept under different conditions. Behavioural traits were monitored for 100 hens in total on the two farms that applied different housing technologies (50-50 birds with or without outdoor access). Birds with outdoor access showed 0.23±0.81 aggression-related traits per hour, whereas chickens without outdoor access produced 0.15±0.76 of the same traits ($p>0.05$). Hens with outdoor access showed 2.30±4.65 activity-related traits, whereas, for hens without outdoor access, 0.72±1.83 observations were recorded per hour ($p<0.05$). Comfort behaviour was similar ($p>0.05$) in the two groups. In conclusion, the housing system has a complex effect on the assessed crossbred laying hen line.

1. Introduction

A significant part of global greenhouse gas (GHG) emissions comes from household food consumption. The egg is an important daily protein source for consumers worldwide, and environmental and economic sustainability are closely intertwined in table egg production. Effective processing of its by-products (e.g. feather, poultry litter) may be a good element in the circular economy – e.g. by pyrolysis (Isemin et al., 2019) and odour treatment (Haerens et al., 2022). Profitability comes from efficiency, which also can support sustainability goals. However, it needs to consider that poultry breeding has undergone considerable changes due to the growing preferences for alternative production systems, especially in commercial table egg production (Ricke et al., 2022). In 2018, 49.6 % of the European laying hen population was produced in cage-free technologies (e.g. aviaries, volier, or barn systems). Approximately 50.4 % were kept in refurbished or enriched cages (Augère-Granier, 2019). According to National Food Chain Safety Office statistics (2022), more than 70 % of the Hungarian laying hen populations were kept in enriched cages in 2022. An increase in the ratio of alternative production systems is expected in Hungary, as well, mainly as a consequence of the successful launch of the European Citizens' Initiative called 'End the Cage Age' that urges the European Commission to provide a ban on cages used in the housing of various farm animal species (European Commission, 2022).

The housing environment is a fundamental external factor that influences the production and quality of eggs. Therefore, different genotypes could be produced differently under various management conditions in alternative housing environments (Sharma et al., 2022).

Paper Received: 26 June 2023; Revised: 22 July 2023; Accepted: 25 October 2023
Please cite this article as: Zsedely E., Szalai K., Takács G., Lencsés-Varga E., Szabó-Sárvári L.C., Tempfli K., 2023, Yield Performance, Laying Behaviour Traits and Egg Quality of a Crossbred Laying Hen in Alternative Housing Systems, Chemical Engineering Transactions, 107, 121-126 DOI:10.3303/CET23107021

In addition, animal welfare is just as important aspect as the production parameters in the evaluation process of a rearing system. Lay et al. (2011) assessed the effect of rearing systems (conventional cages, furnished cages, non-cage systems, and outdoor systems) on several parameters (e.g., disease, health, nutrition, and behaviour). They stated that specific attributes of each system are shown to affect welfare, and further research is needed to clarify the role of all factors in different production schemes. No single breed of laying hen is perfectly adapted to all types of housing systems. Cage-free production systems for laying hens provide the possibility for the birds to express natural and social behaviour; however, the emergence of social aggression in large populations of cage-free animals poses the risks of increased feather pecking and cannibalism. Blokhuis (2006) reported that aggressive feather pecking and cannibalism occurred in 40-80 % and 20-40 % of different cage-free populations. Alternative cage-free systems have long been associated with increased mortality rates when compared to conventional – or even enriched – cages; however, recent findings suggest that experience accumulated over the last decades considerably decreased mortality rates in cage-free systems that are now practically producing without any difference compared to the mortality rates of enriched cages (Schuck-Paim et al., 2021). With the rapidly increasing ratio of cage-free egg production facilities, the relevance and importance of behavioural studies with special regard to social aggression under various housing technologies is also growing. Behavioural data is essential for the development of suitable technologies and for the selection of new breeds, hybrids and lines better suited to sustainable cage-free egg production.

As egg is a basic component of a healthy diet, the quality (physical and chemical characteristics) of the egg is essential for consumers and industry. Da Silva Pires et al. (2021) summarised the consequences of 50 European research articles in a systematic review of production systems and egg quality. Much discrepancy was found in the results and the necessity of more research to understand the effects of housing systems on the different parameters of egg quality.

To summarise these statements, an important challenge is to improve such alternative egg production systems, which offer good egg quality for consumers, high animal welfare conditions for hens, promote carbon footprint reduction, and last but not least, get profit for farmers. An adequate hybrid has a key role in implementing it.

So, the aims of this study were to investigate the production, the egg quality, and the behaviour of a Hungarian crossbred laying hen line in two alternative housing systems (deep litter and deep litter with runway) between 20-72 weeks of age. Our results help to find a suitable hybrid for a sustainable Hungarian alternative table egg housing system.

2. Materials and methods

2.1 Birds and housing

At 19 weeks of age, 400 hens (2 treatments in two replicates) of a crossbreed genotype from Bábolna Tetra Ltd. were assigned to the following housing systems: deep litter (Group D) and deep litter with runway (Group R). The birds of Group D were housed in a poultry house with windows (window area to-floor area ratio was 1:16) in deep litter, and a lighting programme regulated the light hours period (14 h/day), and stocking density was 6 hens/m^2. Hens from Group R were housed in a poultry house with windows (window area to-floor area ratio was 1:8) without artificial light and a runway with 3 hens/m^2 stocking density. All birds consumed a concentrate layer feed (18.0 % protein, 11.6 MJ) ad libitum during the evaluated period.

One week was an accommodation period, and data were collected between 20-72 weeks of age.

Egg production (with a ratio of floor egg), feed consumption and mortality of each group were registered daily, and all egg was weighed once a week.

2.2 Egg quality assessment

Egg samples were collected on the 30th, 60th and 72nd week of age to assess the effect of the housing system on the egg quality. The egg nutrient content (protein, fat and fatty acid profile, ash) was evaluated using 14 eggs/treatment and physical parameters of 40 eggs/treatment (eggshell strength, L*, a*, b* of eggshell, albumen height, Haugh units) was determined.

Eggs were analysed for moisture, crude protein, ether extract, and ash contents following the AOAC (2012) methods. Lipids were extracted from the egg yolk using chloroform/methanol (2:1, vol/vol). After evaporation of solvents, samples were saponified with 1 n NaOH at 100 °C. Boron-trifuoride-methanol was used for the esterification of fatty acids, and then the samples were solved in hexane, centrifuged, and dissolved prior to injection. The separation of fatty acids was carried out by using an Agilent Technologies 6890 N Network gas chromatograph (Agilent Technologies, Inc. Headquarters, Santa Clara, USA) equipped with Supelco SP 2560 Fused Silica Capillary Column (length: 100 m, i.d: 0.25 mm, film thickness: 0.2 μm) and a flame ionisation detector. The operating conditions of the gas chromatograph were as follows: the temperature of the thermostat was from 170 to 215 °C, of the injector was 240 °C, and of the detector was 250 °C. Helium was used as carrier gas at 176.8 kPa. The flow was 35 mL/min for H, 30 mL/min for N, and 300 mL/min for air. Fatty acids were

identified using Supelco 37 Component FAME Mix fatty acid standard (Catalog No. 47885-U Sigma Aldrich Chemie GmbH).
Egg-Shell-Tester from FUTURA measured the eggshell strength, the unit was Newton. Konica Minolta Chroma Meter CR-400 was applied to determine eggshell colour. The equipment was calibrated to white tile before each session of measurements. The CIELAB L* (lightness) a* and b* (green-red and blue-yellow colour indices) colour space was used to determine the colour; the L*, a* and b* value of eggshell. Werner Fürste from FUTURA provided the results of albumen height and calculated the Haugh units (HU).

2.3 Behaviour

Behavioural monitoring was done for 100 Rhode Island white-type laying hens at 37 weeks of age: 50 experimental animals were kept in deep-litter barns without outdoor access (Group D), and 50 birds were kept in deep-litter barns with outdoor access (Group R). Behavioural traits were recorded by three persons through 1 h periods for groups of ten randomly selected birds separated by means of a portable fence. Observations were recorded after 30 min adaptation periods. The application of coloured footbands facilitated individual identification. Recorded observations included aggression (e.g. feather pecking, fighting), activity (e.g. scratching, running, jumping, flying up, fleeing), and comfort (e.g. preening, resting, stretching, sleeping, wing flapping) related behavioural patterns. Animal handling was conducted in accordance with the standards recommended by the 2010/63/EU Directive.

2.4 Statistical analysis

Statistical analysis of performance, egg quality and recorded behavioural observations was carried out in SPSS v.16 for Windows (SPSS Inc., USA). Normal distribution was tested by Kolmogorov–Smirnov tests. Differences between D and R observations were analysed by independent samples t-tests. Statistical significance was considered at $p<0.05$.

3. Results and discussions

3.1 Performance data

The egg production was investigated during the trial, and the results are shown in Figure 1. Hen day egg production (HDEP) in the early phase (until the 30th week of life) was similar; 50 % was exceeded on the 22nd week of age, and the egg production rate reached 90 % on the 25th week of life. The yield of Group R decreased in the next phase (between 31-56 weeks of age) because there was not any artificial light, and the light hours of the day decreased until December (48th week of age). After that, its performance improved and was higher than Group D from the 53rd week of life. The production of Group D was not influenced by the weather due to the housing system and varied between 80-90 % HDEP until the 52nd week of age, and after that, its range was only 60-70 % in the last phase. Egg production/hen was 287 and 281. Egg weight was 61±3 and 59±3 g (in Groups D and R). Furthermore, the feed consumption was 120±18 and 111±8 g/day/hen in Groups D and R, the difference was significant. However, the feed conversion ratio was not influenced by the rearing system (2.7 and 2.5 kg/kg in Group D and R). The mortality was registered lower than 5 %, and the floor egg was less than 1 % in both rearing systems, which are favourable in alternative systems.

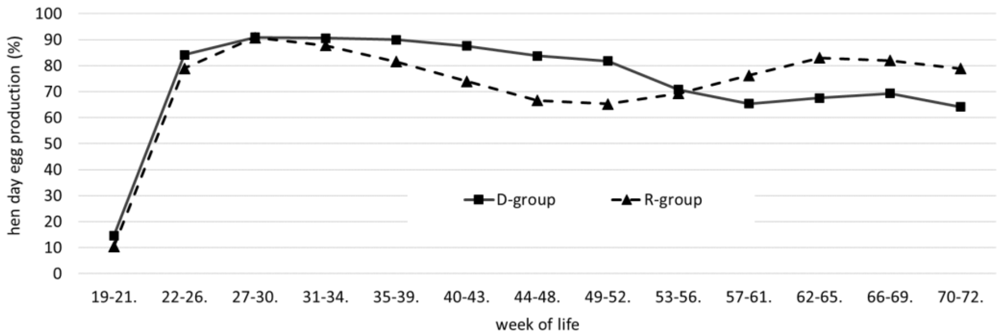

Figure 1.: Hen day egg production (HDEP) in the experiment

The performance of the examined laying hen strain was similar in the two different alternative housing systems, which agreed with the conclusions of Sharma et al. (2022), who observed similar HDEP (86.9 % and 87.6 %) and FCR (1.71 kg feed/dozen of egg) when enriched cage and free-range production system were compered using two different Leghorn-type laying hen strain in their experiment.

Three different brown egg layer hen strains were tested by Alig et al. (2023) in five housing systems (cage, enrichable colony, enriched colony, cage-free, free-range) between 17-92 weeks of age. Hens in free range reached the most favourable production parameters (82.0±0.4 % hen day and 80.0±0.7 % hen housed egg production) and the significantly largest egg (63.7 g v. 60.5-61.1 g). Feed consumption (105.7-113.1 g/day/hen) and FCR (2.14-2.26 kg/kg) of all housing systems were better (105.7-113.1 g/day/hen) than those of our trial. The mortality of the free range was 6.7 %, which is like our value. Higher mortality (17.2-36.9 %) was registered in other treatments.

3.2 Egg quality

Table 1: Physical parameters of eggs (mean±SD)

	Group D (without outdoor access)	Group R (with outdoor access)
Shell strength (N)	36.56±12.20	39.36±12.12
L*	60.41±3.42[b]	62.08±4.72[a]
a*	20.98±3.02[a]	18.60±3.44[b]
b*	31.58±2.53[a]	30.42±2.49[b]
Albumen height (mm)	7.24±1.26	7.26±1.33
Haugh units	83.28±8.38	85.03±8.39

[a,b] Different superscripts in the same row indicate significant ($p<0.05$) difference

Some characteristics of eggs were measured in the experiment, and results were presented in Table 1. The rearing system did not influence the shell strength, the albumen height and Haugh units, but the shell colour was measured significantly lighter (higher L* and lower a* and b*) in Group R than in D. Minelli et al. (2007) published significant impact of housing system (cage vs. free range) on shell colour (L*, a*, b*), Haugh units and shell strength also. Sokolowicz et al. (2018) reported the same conclusions in the matter of shell colour, albumen height and Haugh units. The rearing system (litter, free-range, organic) influenced the shell strength, and values varied between 29.32 and 37.06 N in their experiment. Shell strength was reduced by increasing the week of life in our trial. The rate was higher in Group D (45.4 → 27.5 N) than in R (47.7 → 32.5 N).

Water, protein, fat, and ash represent about 76.1 %, 12.6 %, 9.5 % and 1.1 % in a whole fresh egg (Réhault-Godbert et al., 2019). As Table 2. presented, the average water and protein content were measured similarly (76.2 %, 12.2 %) in the examined samples. On the contrary, lower values were determined in fat and ash content. The housing system seems to not have any effect on egg nutrients. Minelli et al. (2007) observed higher ($p<0.0001$) dry matter and protein content in Hyline brown hen eggs from organic production compared to that of the cage. In the review article of da Silva Pires et al. (2021), it was reported that alternative production systems have had a variable impact on the internal quality of the table egg.

Table 2: Nutrient content of whole egg and fatty acid profile of egg yolk (mean±SD)

	Group D (without outdoor access)	Group R (with outdoor access)
Dry matter (g/kg eggs)	236.63±10.24	238.09±8.73
Protein (g/kg eggs)	122.31±5.52	121.74±5.40
Fat (g/kg eggs)	74.75±7.80	75.85±6.26
Ash (g/kg eggs)	9.14±0.51	8.99±1.23
% of total fatty acids		
C16:0	28.92±3.39	28.16±1.97
C18:0	7.02±2.12	7.44±2.38
Sum saturated fatty acids	36.18±3.50	36.28±2.60
C16:1	4.24±1.26	4.45±0.88
C18:1	37.41±6.05	40.25±2.08
Sum of monounsaturated fatty acids	43.96±6.13	46.67±2.40
C18:2 n6	10.88±1.44	10.77±1.15
C18:3 n3	0.22±0.06[b]	0.30±0.06[a]
Sum of polyunsaturated fatty acids	14.99±2.69	14.24±1.82
n6	13.91±2.31	13.20±1.57
n3	1.08±0.42	1.04±0.30
n6/n3	13.68±2.48	13.40±3.18

[a,b] Different superscripts in the same row indicate significant ($p<0.05$) difference

The fatty acid profile is an important part of egg quality. Palmitic (C16:0) and stearic acid (C18:0) were found to be the most important saturated fatty acids (SFA) in the egg yolks. The presence of a runway had no impact on this fatty acid group. A similar observation was stated in the monounsaturated fatty acids ratio. Its most important components were oleic (C18:1) and palmitoleic acid (C16:1). The ratio of linolenic acid (ALA, C18:3 n3) was significantly higher in Group R, which means a nutritional benefit. It was an unexpected observation because the feed was the same in both groups, and the fatty acid composition was first influenced by nutrition. Zita et al. (2022) published similar SFA lower MUFA fatty acid values, but PUFA and their fatty acids were almost two times higher. Its reason is that their trial was conducted in organic production methods, and the hens were provided with outdoor free-range circumstances throughout the whole year, so they consumed green feeds besides mixed feed.

3.3 Behaviour

Aggressive peckings were observed with remarkably low frequency (Table 3). Most of the recorded aggressive peckings were directed towards the body (neck and back) of the victims, while fewer peckings were recorded on the head. Fighting between animals only occurred in Group R during the monitoring period. Activity-related patterns, scratching and jumping, were observed on significantly ($p<0.05$) more occasions in Group R, implying that hens provided with outdoor access demonstrate greater overall activity.

Concerning that aggression in chickens might be highly or moderately heritable – with h^2 estimates up to 0.57 according to Siegel (1960), or up to 0.38 as reported by Kjaer and Sorensen (1997) – optimal breed or hybrid selection plays a pivotal role in the potential reduction of social aggression in large populations.

Table 3: Behavioural traits (hourly number of recorded observations; mean ± standard deviation) in the experimental groups

Trait	Group D (without outdoor access)	Group R (with outdoor access)
Aggressive pecking (total)	0.16±0.76	0.24±0.81
Aggressive pecking (body)	0.12±0.71	0.16±0.65
Aggressive pecking (head)	0.04±0.31	0.06±0.38
Fighting	not observed	0.02±0.17
Activity (total)	0.72±1.83^b	2.30±4.65^a
Scratching	0.56±1.17^b	1.84±3.07^a
Running	0.10±0.35	0.24±0.45
Jumping	0.04±0.19^b	0.18±0.49^a
Comfort (total)	12.56±9.40	11.94±9.34
Preening	9.30±7.04	8.36±6.85
Resting	1.94±2.15	1.78±2.24
Stretching	1.18±2.31	1.64±2.44

^{a,b} Different superscripts in the same row indicate significant ($p<0.05$) difference

4. Conclusions

Our results presented that the tested brown egg layer strain performance was similar in the two alternative production systems (deep floor and deep floor+runway). Egg quality was good, and only eggshell colour and linolenic acid content were significantly diverse between the two tested production systems. Based on behavioural observations and the low recorded level of aggression-related patterns, the experimental Rhode Island White line is – from the viewpoint of social aggression – optimal for cage-free deep litter housing in closed barns and on farms with outdoor access, as well. This hybrid may have a key role in the development of sustainable egg-rearing systems in Hungary.

Acknowledgement

This study was supported by the 2018-1.3.1-VKE-2018-0004 project.

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