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Original Article

Influence of Cage Density and Hen Age on Performance and Egg Quality in Traditional Systems

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ABSTRACT

This study aims to evaluate the impact of different cage densities and ages on the growth performance and quality traits of eggs for Hy-Line laying hens. For this experiment, a total of 216 laying hens were divided into three groups, with 9 replicates each. The cage densities were 1353 cm2/hen, 677 cm2/hen, and 451 cm2/hen representing groups T1, T2 and T3, respectively. The results of the study showed that feed conversion ratio (FCR) was significantly improved and egg weights were significantly increased in hens with low cage density ($p<0.05$). Moreover, cage density significantly affected final body weight. At the end of the experiment, hens in group T1 were about 35 and 70 g heavier than those in groups T2 and T3, respectively. On the other hand, cage density had no significant ($p>0.05$) effect on egg shape index, yolk index, albumin index, Haugh unit, eggshell thickness, yolk color, and shape index. In conclusion, high space availability for hens had positive effects on feed conversion and egg weight.

INTRODUCTION

Dramatic improvements have been occurred in egg production systems, including the application of new technologies in housing, management, breeding, and nutrition. The new technologies have been applied in egg collection, lighting, ventilation, and waste management (Blokhuis *et al.,* 1998; Blokhuis, 2004). Hy-line is the most widely used hybrid laying hen in Palestine because of its ability to adapt to environmental conditions and achieve high egg yield and weight. The use of full house space was employed to increase egg production (Jalal *et al.,* 2006) by increasing density of the birds per cage (Nahashon *et al.,* 2006). However, the expected increase in income was associated with negative impacts on birds due to overcrowding and cannibalism (Adams & Craig, 1985; Sarica *et al.,* 2008). Cage systems are currently used for egg production all over the world because these systems result in less disease and parasite exposure to hens and produce cleaner eggs (De Reu *et al.,* 2006; Mallet *et al.,* 2006).

EU 1998 and 2002 regulations recommended that cages for laying hens should have an area of 550 cm^2 per bird, 10 drinkers, and 2 nipple drinkers. Cage slope should be less than 8% and cage height should be 40 cm (Tauson, 2005).

In respect to small Leghorn hens, animal welfare guidelines published by the United States Egg Producers recommended a cage density of 432 cm^2/bird (Atlanta, GA), while in 2001 a cage density 336-348 cm^2/hen was recommended (Jalal *et al.,* 2006). A study by Erensoy *et al.* (2021) recently found that sustainable production can be achieved if hens are provided with a light intensity of 500-600 lux and a cage floor area of 700-800 cm^2.

The effects of different cage densities on performance and egg quality parameters in laying hens have been investigated in several studies (Jalal *et al.,* 2006; Ozenturk & Yildiz, 2020). Several studies have shown that a reduction in floor density (cm^2 per bird) was associated with a drop in egg weight, egg production, and feed intake, as well as an increase in mortality and feather pecking (Sandoval *et al.,* 1991; Hester *et al.,* 1996; Huber-Eicher & Seboe, 2001; Anderson *et al.,* 2004; Onbasilar & Aksoy, 2005; Jalal *et al.,* 2006; Nahashon *et al.,* 2006; Nicol *et al.,* 2006; Sarica *et al.,* 2008). However, more studies are needed to evaluate the effects of different stocking densities on the growth performance of hens and the quality traits of eggs, particularly in traditional systems where there is no control on environmental conditions in the farm. Laying hen houses based on traditional systems are widely used in Palestine. The aim of the present study was to investigate the effects of different cage densities on hen performance, egg production, and quality characteristics of eggs in laying hens in a traditional cage system.

MATERIALS AND METHODS

The present study was carried out at a farm belonging to An-Najah National University (Tulkarm, Palestine). Two hundred and sixteen 32-week-oldHy-Line W-80laying hens were used in this study. The hens were reared in three different cage densities of 1353 cm^2/hen, 677 cm^2/hen, and 451 cm^2/hen representing groups T1, T2 and T3, respectively. Nine replicates out of a total of 108 cages were used, representing a total of 216 hens. The floor dimension of the cage was 33 x 41 cm and the linear feeding distance was 33 cm per cage. All hens were reared under similar environmental and management conditions (lighting program: 16 hours of light x 8 hours of darkness). The diet was formulated according to the nutrient requirements of laying hens shown in Table 1.

One egg was used from each cage every four weeks during the 32-52-week yield period (total of 108 eggs for each sampling date) to determine egg quality characteristics. Analyzes were performed after the collected eggs were stored overnight at room temperature. Eggs were first analyzed for external quality (egg weight, shape index, and shell thickness). To determine internal quality parameters, the eggs were broken on a glass tray and examined for their yolk index, albumin index, Haugh unit, and yolk color.

Table 1 – Experimental ration fed to laying hens during experiment, kg.

Ingredient	Content (Kg)
Corn	447
Wheat	167
Soybean meal	243
Stock oil	20
Limestone	100
Methionine	1.5
Lysine	0.8
Layers premix*	5
Sodium carbonate	2.2
DCP	13
Salt	8
Calculated chemical composition (%)	
Dry matter	88
Crude protein	17
Crude fat	4.5
Crude fiber	4.1
Total Ca	3.1
Total P	0.8
ME, MJ/ kg	11.0

*Premix provided per kg of premix: 6 000 000 IU vitamin A; 6 000 IU vitamin D3; 20 000 IU vitamin E; 2 g vitamin K2; 1.3 g vitamin B1; 2.2 g vitamin B2; 1.9 g vitamin B6; 14 mg vitamin B12; 8 g niacin; 320 mg folic acid; 3 g calcium pantothenic acid; 46 mg D-Biotin.: 75 g Mn; 28 g Fe; 65 g Zn; 5 g Cu; 0.2 g I. DCP:Dicalcium Phosphate.

Feed Conversion Ratio (FCR)

Feed intake was weekly recorded, being determined by the feed weight differences between feed offered and remaining feed every week. The feed intake and egg weights were recorded to determine the feed conversion ratio (feed intake/egg mass; g/g).

External quality of eggs

Egg weight

The weight of eggs was determined by using an analytical balance (with a sensitivity of 0.001 g).

Egg shape index

The index of egg shape was measured by the index measuring device developed by Rauch. The index represents the ratio between the width and length of the egg.

Egg shell thickness

Egg shell thickness was measured after removing the membranes in three points from the blunt, middle and pointed parts of the eggs with the use of a micrometer. The mean egg shell thickness value was calculated and recorded as a single thickness value (mm).

Internal quality of eggs

Yolk index

A digital caliper was used to measure egg yolk diameter. A three-legged micrometer (0.1 mm sensitivity) (ORKA, Digital Huagh tester) was employed to measure yolk height. The yolk index was calculated using the following formula:

Yolk index (%) = (Yolk height / yolk diameter) x 100.

Egg white index

Egg white width and egg white length were measured using a digital caliper. A three-legged micrometer (ORKA, Digital Huagh tester) with a sensitivity of 1/100 mm was used to determine egg white height. Egg white index was calculated using the following formula:

Albumen index (%) = [Albumen height/(Average of albumen length and width)] x 100.

Haugh unit

Egg and egg albumen weight was measured to estimate Haugh units. Egg height was measured and the index was calculated using the following formula introduced by Eisen *et al.* (1962): Haugh unit=100 log $(H + 7.57 - 1.7 \times W^{0.37})$.

Where, H =egg albumen height (mm); W =egg weight (g).

Determination of yolk color

The yolk color was evaluated using the Roche Yolk Color Fan (Hoffman-La Roche Ltd., Basel, Switzerland), which has 15degrees of yellow shades (15 = dark orange; 1 = light pale). All color evaluations were carried out by the same person under controlled lighting conditions.

Statistical analysis

All treatments were designed as completely randomized experimental designs. All results were analyzed by one-way ANOVA using the GLM procedure of SAS (2004). Distribution normality and homogeneity of variance were calculated to evaluate the results. Duncan's multiple range test was used to separate the mean value of the variables. Results were considered significant if *p*-values were <0.05.

RESULTS AND DISCUSSION

The effect of different cage densities on the body weight of laying hens is shown in Table 2. The study showed that there was no effect for cage density on the initial body weight of hens between experimental groups. However, cage density had a significant effect on final body weight (BW). Group T1 had significantly higher body weight (1509.17 vs. 1439.95 g, $p<0.05$) than group T3. Moreover, there were moderately significant differences in body weight between groups T1 and T2. Overall, the results showed that an increase in cage density resulted in a decrease in body weight. The obtained results were consistent with the results of previous studies (Heckert *et al.,* 2002; Keeling *et al.,* 2003; Mtileni *et al.,* 2007; Onbasılar & Aksoy, 2005; Geng *et al.,* 2020). In contrast, Jalal *et al.* (2001) found that cage density did not cause an increase in hen body weight.

Table 2 – Effect of different cage densities on the body weight of laying hens.

Week	T1	T2	T3	*p* value
Initial body weight, g	1561.02±14.34	1531.74±15.82	1521.67±21.02	0.22
Final body weight, g	1509.17^{a}±19.20	1474.44^{ab}±16.37	1439.95^{b}±13.99	<0.05

*Values in the column represent mean value ± SEM (Standard Error of Mean). Different letters in the same row indicate significant differences ($p<0.05$). 1353 cm^2/hen, 677 cm^2/hen, and 451 cm^2/hen representing groups T1, T2 and T3, respectively.

Egg production was not affected by cage density (Table 3). Similar results were obtained in previous studies, where no significant decrease in egg production was found among different cage densities (Anderson *et al.,* 2004). On the contrary, Sarica *et al.* (2008) found that the best egg production was obtained in birds reared at low cage density. However, Kueçuekyılmaz *et al.* (2012) concluded that egg production may be influenced by the genotype of the laying hen rather than the housing conditions and environment. Hens in

Table 3 – Effect of different cage densities on egg production (%).

Week	T1 Eggs count	T2 Eggs count	T3 Eggs count	*p* value
32	73±1.53	72±0.88	69±2.65	0.21
36	73±1.16	71±1.45	68±2.19	0.14
40	72±0.88	69±1.45	68±1.53	0.20
44	70±0.88	68±1.33	66±2.40	0.28
48	72±1.16	69±1.86	67±1.45	0.15
52	74±1.00	67±2.33	66±2.85	0.16

*Values in the column represent mean value ± SEM (Standard Error of Mean). 1353 cm^2/hen, 677 cm^2/hen, and 451 cm^2/hen representing groups T1, T2 and T3, respectively.

lower space allowances reached yield age significantly earlier than hens in the high space allowances (Sarica *et al.,* 2008). Recently, Sharma *et al.* (2022) found that egg production in conventional cages was higher than in free-range or enriched colony cages.

FCR was significantly affected by cage density ($p<0.05$), as shown in Table 4. FCR was improved by 8 and 13% at low cage density compared to medium and higher densities, respectively. The reported results showed that increasing the cage density from 1 hen/cage to 3 hens/cage led to a significant increase in FCR. Similar results were recently obtained by Erensoy *et al.* (2021). It was found that low cage density hens had a better FCR than high density ones, a result observed by several researchers (Sohail *et al.,* 2001; Saki *et al.,* 2012). This result can be explained by the reduction of forage area per hen when the density of hens in the cage increases (Sohail *et al.,* 2001; Onbasilar & Aksoy, 2005; Jalal *et al.,* 2006; Nicol *et al.,* 2006). The results showed that egg weight decreased significantly when the number of hens in the cages was increased. However, egg weight did not change significantly when hen age was increased from week 32 to week 52 in all treatments.

External egg quality

External egg quality characteristics are shown in Table 4. Eggshell thickness and shape index were not affected by cage density ($p>0.05$), whereas average egg weight was significantly affected by cage density ($p<0.001$). Guesdon *et al.* (2006) found that there were significant differences in egg weight and shell quality between laying hens housed in cages with 5 and 6 hens that had 660 cm^2 of space per hen. Regardless of cage density, a slight decrease in eggshell thickness was observed with increasing hen age. In this context, it was found that eggshell quality decreased with increasing hen age (Park & Sohn, 2018). In our study, age had no effect on egg weight. Ozenturk & Yildiz (2020) reported that egg weight exhibited a tendency to increase with time due to the development of physiological structures with age progress, especially the development of the reproductive tract. Moreover, Sarica *et al.* (2008) reported in their study using four different cage density groups (2000, 1000, 667, and 500 cm^2/hen) that there was no significant difference in density for any parameter but shape index.

Table 4 – Effect of laying hens' cage density on external egg quality parameters (egg weight, shape index, and shell thickness) and FCR during the experimental time (32-52 days).

	Week	T1*	T2*	T3*	*p* value
Mean egg weight (g)	32	66.57^{a}±0.27	63.20^{b}±0.60	62.50^{b}±0.30	<0.05
	36	64.77^{a}±0.07	63.31^{ab}±0.25	61.45^{b}±0.08	<0.05
	40	64.40^{a} ±0.24	62.53^{ab}±0.24	60.78^{b}±0.66	<0.05
	44	65.25^{a}±0.66	62.39^{b}±0.73	62.37^{b}±0.24	<0.05
	48	68.05^{a}±0.21	64.75^{b}±0.19	64.16^{b}±0.66	<0.05
	52	66.82^{a}±0.59	64.25^{b}±0.22	63.81^{b}±0.09	<0.05
FCR (g feed/g egg)	32	1.55^{b}±0.02	1.65^{ab}±0.06	1.75^{a}±0.01	<0.05
	36	1.59^{b}±0.02	1.68^{ab}±0.05	1.82^{a}±0.05	<0.05
	40	1.63^{b}±0.01	1.75^{ab}±0.02	1.82^{a}±0.07	<0.05
	44	1.65^{b}±0.02	1.78^{ab}±0.06	1.84^{a} ±0.03	<0.05
	48	1.55^{b} ±0.02	1.69^{ab}±0.02	1.76^{a}±0.07	<0.05
	52	1.55^{b}±0.02	1.65^{ab}±0.06	1.75^{a}±0.01	<0.05
Egg shape index	32	74.42±0.40	74.17±0.56	75.83±0.94	0.20
	36	76.00±0.76	74.25±0.89	75.42±0.63	0.25
	40	72.67±1.76	74.58±0.60	75.67±0.76	0.17
	44	72.58±0.92	73.67±1.11	74.08±0.91	0.53
	48	72.08±0.62	73.50±0.50	79.25±5.19	0.23
	52	72.92±0.80	73.83±0.51	72.42±0.60	0.28
Shell thickness (mm)	32	0.401±0.01	0.412±0.01	0.399±0.01	0.64
	36	0.354±0.01	0.364±0.01	0.371±0.01	0.50
	40	0.373±0.01	0.378±0.01	0.368±0.01	0.53
	44	0.372±0.01	0.375±0.01	0.381±0.01	0.49
	48	0.373±0.02	0.391±0.01	0.371±0.00	0.25
	52	0.371±0.01	0.367±0.01	0.362±0.01	0.72

*Values in the column represent mean value ± SEM (Standard Error of Mean). Different letters in the same row indicate significant differences ($p<0.05$). 1353 cm^2/hen, 677 cm2/hen, and 451 cm^2/hen representing groups T1, T2 and T3, respectively.

Internal Egg Quality

The obtained results (Table 5) showed that cage density had no effect ($p>0.05$) on yolk index, albumin index, Haugh unit score and yolk color. These results were consistent with a previous study (Saki *et al.* 2012). The findings of this research showed that yolk index was not affected by cage density. In contrast, yolk index was significantly ($p<0.05$) increased from 39.63 to 41.39 by increasing the number of hens from 1 to 4 per cage (Suto *et al.,* 1997; Saki *et al.,*2012).

In this study, Haugh unit was not affected by cage density or hen age. In contrast, Ozenturk & Yildiz (2020) revealed that the highest egg Haugh unit valuewas observed at 24-28 weeks, while the lowest one was observed at 64-68 weeks. The changesobserved over time may be attributed to the heavier weight of albumen as compared to the yolk, as well as to the increase in egg weight due to age. This pattern was reported by Onbaşılar *et al.* (2018). Altan *et al.* (2002) showed that different stocking densities in white layers (640, 480, and 384 cm^2/hen; 3, 4, 5 hens/cage) caused significant effects on Haugh unit values, but not in brown layers (640, 480 cm^2/hen; 3 and 4 hens/cage). Süto *et al.* (1997) found no statistical difference in Roche color values and shell-thickness. In a study employing four different housing densities, it was found that there were no differences in internal and external quality parameters at 29 and 36weeks of age (Geng *et al.,* 2020). In this context, several studies showed that these parameters were not affected by age (Lacin *et al.,* 2008; Ledvinka *et al.,* 2012; Petek & Yeşilbağ, 2017; Dikmen *et al.,* 2017; Günlü *et al.*, 2018). On other hand, Jahanian & Mirfendereski (2015) found that cage density affected all egg quality parameters. Kang *et al.* (2016) observed similar results for all parameters except eggshell destruction resistance. In our study, no significant effects on shell thickness and yolk color were found in the eggs. Our results are in agreement with previous findings (Ledvinka *et al.,* 2012; Petricevic *et al.,* 2017). Samiullah *et al.* (2017) reported that hens at 44, 64, and 73 weeks of age had significant changes in shell thickness and yolk color.

CONCLUSIONS

In conclusion, the results recommend improving housing conditions for laying hens to optimize feed utilization and achieve a high egg weight that is economically sufficient for the farmer. The balance between the additional cost incurred by reducing cage density and gaining high egg weight should be considered in the local context of egg producers to evaluate feasibility.

Table 5 – Internal egg quality parameters under different cage densities.

	Week	T1*	T2*	T3*	*p* value
Yolk index (%)	32	43.83±0.61	44.58 ± 0.65	43.33 ± 1.08	0.52
	36	43.83±0.63	43.42 ± 0.66	43.17 ± 0.82	0.78
	40	44.33±0.64	44.08 ± 0.48	43.67 ± 0.60	0.69
	44	44.50±0.62	44.17 ± 0.71	43.25 ± 0.88	0.46
	48	42.42±0.60	44.25 ± 0.46	43.42 ± 0.78	0.11
	52	40.83±0.37	41.08 ± 0.45	40.42 ± 0.34	0.45
Albumin index (%)	32	12.17±0.73	11.42 ± 0.54	12.83 ± 0.32	0.18
	36	13.17±0.27	12.92 ± 0.34	13.17 ± 0.27	0.82
	40	12.67±0.33	12.75 ± 0.33	13.17 ± 0.21	0.46
	44	12.92±0.37	12.58 ± 0.42	13.00 ± 0.21	0.65
	48	12.42±0.39	12.42 ± 0.38	11.75 ± 0.33	0.40
	52	11.58±0.19	11.75 ± 0.22	11.67 ± 0.19	0.82
Haugh unit	32	95.42±1.83	94.00 ± 1.65	94.17 ± 1.19	0.80
	36	95.83±0.93	95.58 ± 0.99	97.67± 0.77	0.24
	40	94.67±0.82	94.50 ± 1.22	96.42 ± 1.10	0.41
	44	95.92±0.84	94.50 ± 1.14	95.08 ± 0.87	0.55
	48	93.67±0.92	93.00 ± 0.91	91.58 ± 1.18	0.32
	52	89.33±0.81	89.75 ± 0.71	90.67 ± 0.51	0.36
Yolk color	32	10.25±0.18	10.50 ± 0.20	10.33 ± 0.23	0.65
	36	10.75±0.13	10.67 ± 0.14	10.67 ± 0.14	0.90
	40	10.83±0.11	10.83 ± 0.11	10.58 ± 0.15	0.34
	44	10.75±0.13	10.75 ± 0.13	10.92 ± 0.08	0.57
	48	10.92±0.08	11.00 ± 0.00	11.00 ± 0.00	0.44
	52	10.92±0.08	11.00 ± 0.00	10.80 ± 0.11	0.32

*Values in the column represent mean value ± SEM (Standard Error of Mean). 1353 cm^2/hen, 677 cm^2/hen, and 451 cm^2/hen representing groups T1, T2 and T3, respectively.

CONFLICTS OF INTEREST

The authors declare no potential conflicts of interest.

ETHICS APPROVAL

The study has been performed in accordance to the ethical standards of An-Najah National University, and the animal welfare committee has approved the experiment protocol. The experiment has been carried out taking in consideration the International Guidelines for research involving animals (Directive 2010/63/EU).

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