Effects of Cage Location and Tier Level with Respect to Light Intensity in Semiconfined Housing on Egg Production and Quality During the Late Laying Period

A. Yıldız,*[1] E. Laçin,* A. Hayirli,† and M. Macit‡

*Departments of *Animal Husbandry and †Animal Nutrition and Nutritional Disorders, College of Veterinary Medicine, Atatürk University, Erzurum 25700, Turkey; and ‡Department of Animal Sciences, College of Agriculture, Atatürk University, Erzurum 25100, Turkey*

Primary Audience: Poultry Scientists, Agricultural Engineers

SUMMARY

This experiment was conducted to determine the effects of cage location and tier level with respect to light intensity on egg production and egg quality of hens housed in a semiconfined facility. Hens (ISA Brown, n = 225) at 75 wk of age were placed into 3-tier cages as top (T), middle (M), and bottom (B) tiers located in cages illuminated artificially (EI), by window (FW), or between corridors (C) for 2 mo. Light intensity was measured monthly for each cage at 5 cm from feeders every 6 h. Egg production was recorded daily and egg quality was assessed biweekly. Light intensity was the greatest for cages in the FW group (151.9, 119.8, and 89.8 lx for tiers T, M, and B, respectively), followed by EI (52.6, 54.5, and 51.0 lx for tiers T, M, and B, respectively), and C (44.5, 23.4, and 4.7 lx for tiers T, M, and B, respectively). Hens at location EI had greater egg production than hens at FW and C. Egg production for hens at tier T was also greater than for hens at tiers M and B. Egg production for hens at EI and C decreased quadratically, whereas that for hens at FW decreased linearly from tiers T to B. Cage location, but not tier level, affected egg weight. Hens at EI and FW produced heavier eggs than hens at C. Shape index, yolk color, and yolk index were independent of cage location and tier level. Hens at EI and FW produced eggs with thinner and weaker shells than hens at C. Moreover, eggshell strength increased linearly from tier T to B. Both albumen index and Haugh unit were the greatest for hens at FW, followed by EI and C. Their responses to cage location varied with tier levels. In conclusion, variation in light intensity in multitier cage systems in semiconfined laying hen houses may be a contributing factor for depressed laying performance and egg quality.

Key words: cage location, tier level, light intensity, egg production, egg quality, late laying hen

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DESCRIPTION OF PROBLEM

Depending upon economic conditions and climatologic constraints, egg production normally takes place in either fully confined or semiconfined housing. Several studies dealing with the effect of various levels of light intensity on laying performance are available [1, 2]. Natural

[1]Corresponding author: ahmtstar@hotmail.com

daylight is the main factor for developing a lighting program for laying hens in semiconfinement houses. Thus, artificial light is provided to compensate for shortened daylight hours [3]. Intensity of light is also one of the most important aspects of egg production [4, 5].

A threshold light intensity (2 lx) is crucial for stimulating hypothalamic receptors responsible for photosexual variables. In consideration of the welfare of hens and workers, the recommended light intensity is 10 lx [6, 7]. Despite welfare concerns, cage systems remain sustainable due to efficient use of land and labor. Cages are usually constructed in varying tiers. Because there is an unavoidable variation in light intensity among tiers in multitier cage systems, a balance is needed between providing sufficient light at the bottom tier and avoiding excessive light intensity at the top tier [8]. When light intensity was set to be 10 lx, it was measured to be 11.1, 23.9, 23.9, and 31.3 lx at the first, second, third, and fourth tiers, respectively, resulting in the top tier having 3 times more light intensity than recommended [9]. This could lead to compromised egg production and egg weight due to variability in rate of lay. Provision of homogeneous illumination to each tier is an inevitable challenge in semiconfined laying hen houses.

It was hypothesized that the lack of a homogeneous light intensity in multitier systems and each cage location in semiconfined laying hen houses adversely affects egg production and quality. By mimicking fully confined housing system in terms of providing homogeneous light intensity, this experiment was conducted to determine the effects of cage location and tier level on egg production and egg quality parameters during the late laying period in hens raised in semiconfined facility with multitier cage system.

MATERIALS AND METHODS

Birds, Diet, and Management

This research was conducted at the Atatürk University Research Farm in accordance with approval by the Ethics Committee on Research Animal in Erzurum, a city in northeastern Turkey (39°55′N, 41°16′W). A total of 225 ISA Brown hens, 75 wk of age with uniformity of 94% (the number of hens weighing between 0.9 and 1.1% of the mean BW), were placed into 3-tier cages (50 × 46 × 46 cm).

Table 1. Ingredient and chemical composition of the experimental diet

Ingredient	%
Corn	45.00
Soybean meal (44% CP)	21.00
Wheat	7.00
Barley	3.05
Wheat bran	9.50
Molasses	2.00
Sunflower oil	1.00
Limestone	9.50
Dicalcium phosphate[1]	1.00
Salt	0.30
Vitamin-mineral premix[2]	0.35
Lysine	0.10
Methionine	0.10
Antioxidant[3]	0.10
Nutrient	
DM, %	89.21
ME, kcal/kg of DM	2,530.00
CP, %	15.66
Ether extract, %	3.61
Ash, %	13.53
Ca, %	3.86
P, %	0.61

[1]Contains per kilogram: Ca, 24% and P, 17.5%.
[2]Contains per kilogram: vitamin A, 15,000 IU; cholecalciferol, 1,500 ICU, vitamin E (DL-α-tocopheryl acetate), 30 IU; menadione, 5.0 mg; thiamine, 3.0 mg; riboflavin, 6.0 mg; niacin, 20.0 mg; pantothenic acid, 8.0 mg; pyridoxine, 5.0 mg; folic acid, 1.0 mg; vitamin B_{12}, 15 μg; Mn, 80.0 mg; Zn, 60.0 mg; Fe, 30.0 mg; Cu, 5.0 mg; I, 2.0 mg; and Se, 0.15 mg.
[3]Ethoxyquin.

The diet (Table 1) was formulated to meet NRC recommendations [10]. During the experimental period (56 d), hens were fed ad libitum and feed was added to the feeders at 0730 h daily. Water was available at all times. From January 24 to March 24, average daylight and darkness were 12:35 and 11:25 h/d, respectively. A total photoperiod of 17L:7D cycle (natural + artificial light) was maintained by cool-white fluorescent long tube type lamps (F40W/54 with 2,450 K) located at 3 m above the ground level for all hens. Four weeks before laying and early and mid laying phases, hens were subjected to 18L:6D and 17.30L:6.30D photoperiods as recommended by the breeder.

Treatments

Cage location and tier level were experimental treatments: 1) hens in the first location (**EI**) were illuminated by fluorescent lamps located at 150 cm distance from the cages and faced to feeders of each tier and surrounded by nontransparent material to impede the reflection of other lights (for this group, lamps hung from the ceiling were not turned on during the experimental period); 2) hens in the second location (**FW**) were exposed to natural light through windows (150 × 100 cm) that were located at 150 cm from the cages; and 3) hens in the third location (corridor side; **C**) were exposed to a lower level of daylight from the window. Artificial illumination by lamps hung on ceiling was available for the last 2 experimental groups. There were 3 tiers in each location as top (**T**), middle (**M**), and bottom (**B**). There were 5 cages in each tier level of the 3 experimental illumination types, each containing 5 hens.

Data Collection

The light intensity was measured using a Megatron DL3 [11] with a type-M photocell (color corrected at peak spectral response of 560 nm) at feeders at 0500, 0900, 1300, 1700, and 2100 h on d 1, 28, and 56 relative to initiation of the experiment.

Nutrient content of the diet was calculated from tabular values of feedstuffs for chickens [12]. Egg production was recorded daily and expressed as hen-day egg production. A sample of 2 eggs was randomly collected every 2 wk from each experimental group to assess egg quality parameters [13], which were shape index, shell strength, shell thickness, albumen index, yolk index, yolk color, and Haugh unit [14]. Before determination of egg weight, eggs were stored for 24 h at room temperature. Data analysis is described elsewhere [15].

RESULTS AND DISCUSSION

Light Intensity and Egg Production

The light intensity was the greatest at location FW, followed by locations EI and C. Despite great variability, there was no difference in light intensity across the tier levels within location FW. Artificial illumination diminished variation

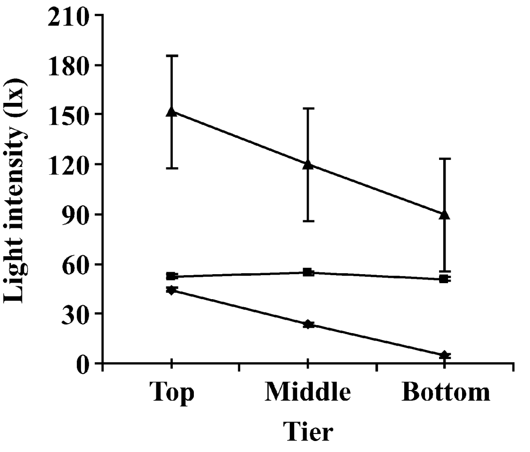

Figure 1. Light intensity (lx) in cage location (—■—, EI = cages at experimentally illuminated location; —▲— FW = cages facing window; and —◆—, C = cages located at corridor side).

in light intensity among tier levels at location EI. At location C, light intensity was the lowest at tier B and linearly decreased from tier T to B (Figure 1). The mean light intensity values were 52.6, 54.5, and 51.0 lx for tiers T, M, and B at location EI; 151.9, 119.8, and 89.8 lx for those at location FW; and 44.5, 23.4, and 4.7 lx for those at location C, respectively. In agreement with this experiment, Vovensy [9] reported great variability among tiers facing windows.

Hens at location EI had 28.5% greater egg production than hens at locations FW and C ($P < 0.0001$; Table 2). Egg production for hens at tier T was 17.8% greater than for hens at tiers M and B ($P < 0.0001$; Table 2). Decrease in egg production from tier T to B was in a quadratic fashion for hens at locations EI and C, whereas the decrease was linear for hens at location FW ($P < 0.03$; Figure 2, panel A). Moreover, regressing log light intensity on egg production [$y = 17.21 + 28.09LI - 3.85LI^2$, $R^2 = 0.43$; where y = egg production and LI = natural log of light intensity as lx] showed a quadratic relationship between light intensity and egg production ($P < 0.05$; Figure 2B). The first derivation of this equation estimated that egg production was maximal when light intensity was equal to 38.4 lx.

The effect of light intensity on egg production in the literature is inconsistent. Although recommended light intensity ranges from 5 to

Table 2. The effects of cage location and tier level on egg production and egg quality parameters of hens during the late laying period

Variable[2]	Experimental groups[1] EI			FW			C				Statistical significance, $P <$[3]		
	T	M	B	T	M	B	T	M	B	SEM	L	Ti	L × Ti
HDP, %	79.3	71.2	76.2	65.7	58.0	53.4	69.4	54.1	52.5	1.0	0.0001	0.0001	0.03
EW, g	64.1	64.8	65.4	64.3	64.0	66.0	63.1	62.2	60.8	1.0	0.001	0.90	0.27
SI, %	75.9	77.4	74.9	76.9	76.4	77.7	76.57	77.0	77.2	1.0	0.44	0.90	0.38
ST, mm × 10^{-2}	0.360	0.361	0.359	0.358	0.360	0.365	0.395	0.390	0.409	0.010	0.0001	0.39	0.65
SS, kg/cm^2	0.89	1.12	1.31	1.14	0.98	1.36	1.20	1.79	1.88	0.18	0.001	0.02	0.36
YC	8.57	8.77	8.83	9.13	9.07	9.13	9.10	9.30	9.13	0.24	0.08	0.82	0.94
YI, %	45.9	44.0	45.6	44.4	44.9	45.0	44.3	43.7	43.2	0.8	0.09	0.38	0.16
AI, %	9.62	8.39	9.16	8.74	9.78	10.24	8.25	7.60	7.87	0.37	0.0001	0.23	0.02
HU	86.3	82.2	84.4	83.0	87.2	88.1	80.3	77.6	78.8	1.5	0.0001	0.49	0.04

[1]Experimental groups: EI = cages at experimentally illuminated location; FW = cages facing window; C = cages located at corridor side; T = top tier; M = middle tier; B = bottom tier.
[2]Variables: HDP = hen-day production; EW = egg weight; SI = shape index; ST = shell thickness; SS = shell strength; YC = yolk color; YI = yolk index; AI = albumen index; HU = Haugh unit.
[3]Statistical significance: L = location effect; Ti = tier effect; L×Ti = location by tier interaction effect.

10 lx [6, 7], Abdelkarim and Biellier [17] noted a significant improvement in egg production as light intensity was increased progressively from 32 to 40 up to 343 to 409 lx during the 8-mo laying period. Cavalchini et al. [18] also reported a linear increase in egg production as light intensity increased from 4 to 25 lx. Renema et al. [19] tested the effects of various light intensity on laying performance. As light intensity increased from 1 to 500 lx (1, 5, 50, and 500 lx), egg production increased quadratically, being highest at the intensity of 50 lx. After log transformation, however, egg production decreased linearly in hens exposed to light intensities of 0.2, 1, 5, and 25 lx [20]. Skoglund et al. [21] also provided light intensities of 5.4, 21.5, and 53.8 lx to hens for a period of 50 wk and reported that egg production was the highest at locations with lowest light intensity. In other studies testing the effect of light intensity that ranged from 9.3 to 337 lx [22] and from 2 to 45 lx [23], no effect on egg production was reported. Using a large database, Lewis and Morris [6] developed a quadratic regression line perfectly fitting to describe relationship between egg production and light intensity ($y = 0.80 + 0.067LI - 0.020LI^2$, with $R^2 = 0.88$ and $P = 0.0001$; where y = egg production and LI = log of light intensity as lx). According to this model, egg production is at a maximum level when light intensity is equal to 43.4 lx.

Egg Quality

Table 2 summarizes the effect of cage location and tier level on egg quality parameters. Cage location ($P < 0.001$), but not tier level, affected egg weight. Hens at locations EI and FW produced an average of 2.8-g heavier eggs than hens at location C, suggesting that light intensity level exponentially decreased egg weight. Leeson and Lewis [24] and Cavalchini et al. [18], however, reported no difference in egg weight of hens exposed to light intensity varying from 3 to 25 lx. By providing light intensities of 1, 5, 50, and 500 lx, Renema et al. [19] reported linear decreases in egg weight (from 74.4 to 58.5 g) and greater percentage of smaller eggs (<56 g, 40.2 to 25.1%). Using raw data from several experiments published, Lewis and Morris [6] fitted the relationship between egg weight and light intensity to a linear regression

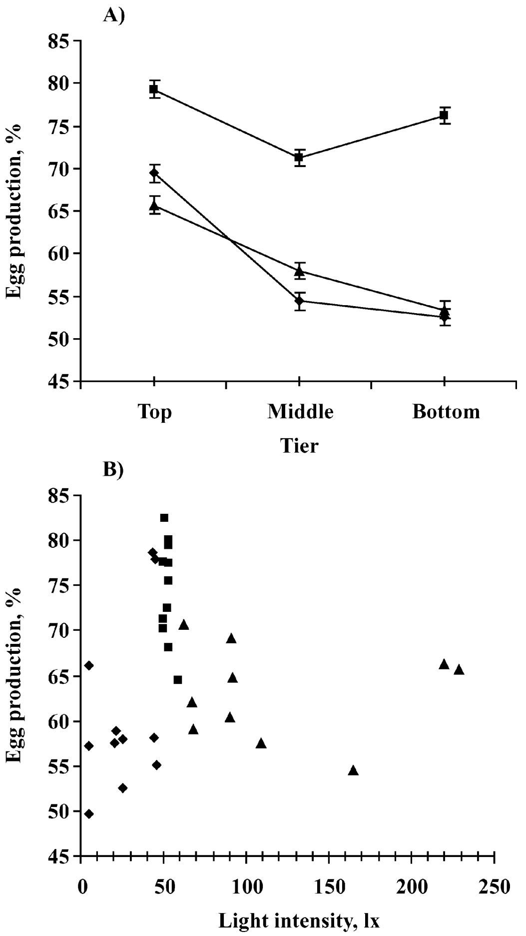

Figure 2. Egg production for hens caged at different cage locations and tier levels with varying the light intensity from A) ANOVA, and B) regression approach (—■—, EI = cages at experimentally illuminated location; —▲—, FW = cages facing window; and —◆—, C = cages located at corridor side).

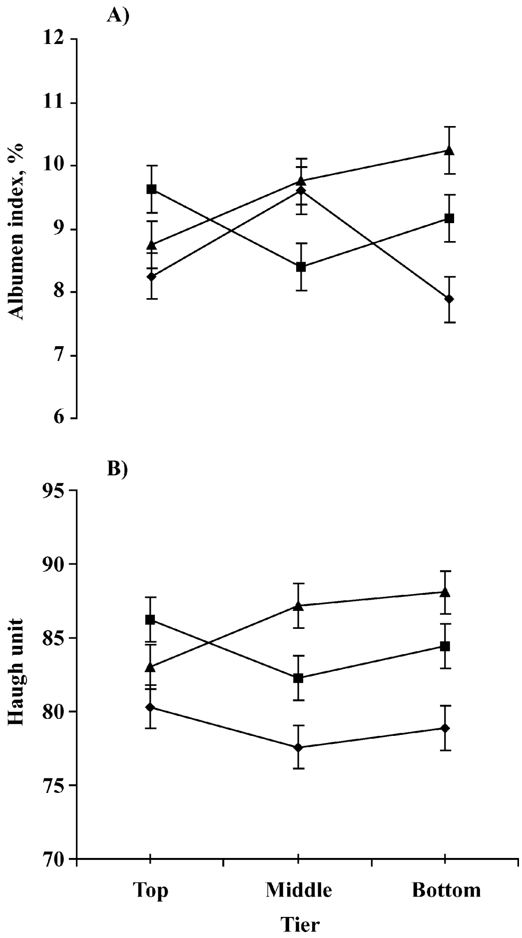

Figure 3. A) Albumen index, and B) Haugh unit (for hens caged at different cage locations and tier levels with varying the light intensity (—■—, EI: cages at experimentally illuminated location; —▲—, FW: cages facing window; and —◆—, C: cages located at corridor side).

line (y = 63.8 − 0.0127LI, R^2 = 0.97 and P = 0.0005; where y = egg weight and LI = light intensity as lx). Because egg weight is negatively correlated with egg production, it seems that effect of light intensity on egg weight is through its effect on egg production and possibly feed intake, which was not measured in the present experiment.

In contrast to egg weight, hens at locations EI and FW produced eggs with thinner (P < 0.001) and weaker (P < 0.001) shell than hens at location C. Moreover, eggshell strength increased linearly from tier T to B (P < 0.02), suggesting that as light intensity decreased eggshell got thicker and stronger. A negative correlation between light intensity and eggshell thickness is reported [17]. However, eggshell quality was reported to be independent of light intensity in other experiments involving hens [24] and Pekin ducks [25].

Neither cage location nor tier level affected shape index, yolk color, or yolk index. The effect of light intensity on inner egg quality parameters is largely unknown. In agreement with the present experiment, no differences in yolk weight and eggshell weight were reported in hens exposed to light intensities of 1, 5, 50, and 500 lx [19]. Pavlovski and Masic [26] housed late laying hens in individual cages as 3-tier with rows facing (light) or not facing (dark) windows and reported no differences in shape index. The effect of cage location on albumen index and Haugh unit was similar ($P < 0.0001$ for both), and both parameters were the greatest for hens at location FW, followed by locations EI and C. Haugh unit was positively correlated with albumen index ($r = 0.87$, $P < 0.0001$). This is not surprising because albumen index, an important characteristic of internal egg quality for grading eggs, is 1 of 2 major determinants of Haugh unit [27]. Despite a lack of effect of tier level, there were significant cage location by tier level interaction effects on albumen index ($P < 0.02$) and Haugh unit ($P < 0.04$). Albumen index for hens at location FW increased linearly, for hens at location EI decreased quadratically, and for hens at location C increased quadratically (Figure 3A). Haugh unit for hens at location FW increased quadratically, for hens at location EI decreased quadratically, and for hens at location C remained unchanged (Figure 3B). Increasing light intensity from 3 to 25 lx was shown to not influence albumen index [24]; this level of light intensity was much lower than that achieved at locations FW and EI in the present study.

CONCLUSIONS AND APPLICATIONS

1. Cages exposed to natural daylight through windows had the greatest light intensity, followed by those artificially illuminated, and those by corridor side. Variation in light intensity was the greatest for cages exposed to natural daylight through windows and the lowest for artificially illuminated cages.
2. Light intensity linearly decreased from top tier to bottom tier.
3. Egg production increased quadratically, egg weight decreased exponentially, and eggshell thickness and strength decreased linearly as light intensity increased.
4. Neither cage location nor tier level affected shape index, yolk color, and yolk index. Albumen index and Haugh unit were the greatest for hens at rows exposed to natural daylight, artificially illuminated, and by corridor side.
5. Results of the present experiment suggest that provision of variable light intensity ranging from 35 to 55 lx improves egg production and quality.
6. The uncontrollable degree of variability in light intensity in semiconfined laying hen houses may be responsible for depressed laying performance and egg quality.

REFERENCES AND NOTES

1. Dorminey, R. W., J. E. Parker, and H. W. McClusky. 1970. Effect of light intensity on Leghorn pullets during the development and laying periods. Poult. Sci. 49:1657–1661.

2. Tucker, S. A., and D. R. Charles. 1993. Light intensity, intermittent lighting and feeding regimen during rearing as affecting egg production and egg quality. Br. Poult. Sci. 34:255–266.

3. Lewis, P. D., G. C. Perry, T. R. Morris, and J. English. 2001. Supplementary dim light differentially influences sexual maturity, oviposition time, and melatonin rhythms in pullets. Poult. Sci. 80:1723–1728.

4. Lewis, P. D., T. R. Morris, and G. C. Perry. 1999. Light intensity and age at first egg in pullets. Poult. Sci. 78:1227–1231.

5. Morris, T. R. 1994. Lighting for layers: What we know and what we need to know. World's Poult. Sci. J. 50:283–287.

6. Lewis, P. D., and T. R. Morris. 1999. Light intensity and performance of domestic pullets. World's Poult. Sci. J. 55:241–250.

7. Morris, T. R. 2004. Environmental control for layers. World's Poult. Sci. J. 60:163–175.

8. Awoniyi, T. A. M. 2003. The effect of housing on layer chicken's productivity in the 3-tier cage. Int. J. Poult. Sci. 2:438–441.

9. Vovensy, V. 1990. The effect of light intensity on egg yield in hens. Zivocisna Vyroba 35:643–650.

10. National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.

11. Megatron Ltd., London, UK.

12. Jurgens, M. H. 1996. Animal Feeding and Nutrition. 8th ed. Kendall/Hunt Pub. Co., Dubuque, IA.

13. Ergün, A., S. Yalçın, I. Çolpan, T. Dikicioğlu, and S. Yıldız. 1987. Utilization of vetch by laying hens. J. Fac. Vet. Med. U. Ankara. 34:449–466.

14. Egg quality parameters were assessed using following formulas [13]: Shape index (%) = [egg width (cm)/egg length (cm)] × 100; shell strength (kg/cm^2) was determined by using machine with spiral pressure system; shell thickness (mm) was determined in 3 different parts (upper and lower ends and middle) by using micrometer; albumen index (%) = [albumen height (mm)/average of albumen length (mm) and albumen width (mm)] × 100; yolk index (%) = [yolk height (mm)/yolk diameter (mm)] × 100; yolk color was determined by using commercially available yolk color fan according to the CIE

standard colorimetric system; Haugh unit = $100 \times \log(H + 7.57 - 1.7 \times W^{0.37})$, where H = albumen height (mm) and W = egg weight (g).

15. This experiment was arranged in a complete randomized design. Then, 2-way ANOVA was employed using the GLM procedure [16]. Before statistical analysis, data were reduced to overall means. The linear model to test the effects of 3×3 factorial arrangements of treatments (3 locations and 3 tiers) on egg production and egg quality parameters included the main effect of cage location and tier level and cage location by tier level interaction. Statistical significance ($P < 0.05$) was attained using the LSD option.

16. SAS Institute. 1998. SAS User's Guide: Statistics. Version 7. SAS Inst. Inc., Cary, NC.

17. Abdelkarim, M. R., and H. V. Biellier. 1982. Effect of light intensity and photoperiod on chicken laying hens. Poult. Sci. 61:1403–1404.

18. Cavalchini, L. G., P. Pignatelli, and G. Sartore. 1976. L'influenza della luca galline ovaiole. Rivista de Zootechnia e Veterinaria. 2:159–162.

19. Renema, R. A., F. E. Robinson, J. J. Feddes, G. M. Fasenko, and M. J. Zuidhof. 2001. Effects of light intensity from photostimulation in four strains of commercial egg layers: 2. Egg production parameters. Poult. Sci. 80:1121–1131.

20. Morris, T. R. 1967. Light intensity for growing and laying pullets. World's Poult. Sci. J. 23:246–251.

21. Skoglund, W. C., D. H. Palmer, C. J. Wabeck, and J. N. Verdaris. 1975. Light intensity required for maximum egg production in hens. Poult. Sci. 54:1375–1377.

22. Roberts, J., and J. S. Carver. 1941. Electric light for egg production. Agric. Eng. 22:357–360.

23. Hill, J. A., D. R. Charles, H. H. Spechter, R. A. Bailey, and A. J. Ballontyne. 1988. Effects of multiple environmental and nutritional factors on laying hens. Br. Poult. Sci. 29:499–511.

24. Leeson, S., and P. D. Lewis. 2004. Changes in light intensity during the rearing period can influence egg production in domestic fowl. Br. Poult. Sci. 45:316–319.

25. Davis, G. S., C. R. Parkhurst, and J. Brake. 1993. Light intensity and sex ratio effects on egg production, egg quality characteristics, and fertility in breeder Pekin ducks. Poult. Sci. 72:23–29.

26. Pavlovski, Z., and B. Masic. 1992. Effect of cage site within the battery on some egg characters in heavy-type hens. Anim. Breed. Abstr. 60:6120.

27. Eisen, E. J., B. B. Bohren, and H. E. McKean. 1962. The Haugh unit as a measure of egg albumen quality. Poult. Sci. 41:1461–1468.