Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2019) 43: 627-635
© TÜBİTAK
doi:10.3906/vet-1903-75

Impact of light-emitting diode and compact fluorescent lighting type and cage tier on layers reared in an enriched cage system, part 2: some welfare traits

Gülsüm TÜNAYDIN, Bilgehan YILMAZ DİKMEN*
Department of Animal Science, Faculty of Agriculture, Bursa Uludağ University, Bursa, Turkey

Received: 26.03.2019 • **Accepted/Published Online:** 05.08.2019 • **Final Version:** 02.10.2019

Abstract: The aim of this study was to determine the effects of lighting type [light-emitting diode (LED) and compact fluorescent (FLO) light] and cage tier on welfare traits such as feather score, body and comb wounds, bumble foot and footpad dermatitis, beak damage, keel bone deformity, finger damage, aggressive pecking behavior, and the avoidance distance test (ADT) in laying hens reared in an enriched cage system. A total of 400 layers were used to determine these traits at 25 and 45 weeks of age. A total of 80 layers were used to determine tonic immobility (TI) duration and induction number. The dust accumulation rate (DAR I and DAR II) was recorded to determine the activity of layers under different lighting sources at 25, 35, and 45 weeks of age. The highest DAR I and DAR II were determined in the FLO group at 35 and 45 weeks of age ($P < 0.05$). The worst comb wound and highest ADT were found in the FLO group at 25 weeks of age ($P < 0.05$). In the FLO group the mean feather score, comb wound, and finger damage were worse than in the LED group ($P < 0.01$). In addition, aggressive pecking behavior ($P < 0.01$) was observed more in the FLO group at 45 weeks of age ($P < 0.05$). The breast and vent feather scores ($P < 0.001$), mean body feather score, comb wound, and footpad dermatitis of hens at 45 weeks of age ($P < 0.05$) were worse in lower cage tiers. In conclusion, using LED light in poultry houses helps to increase some of the welfare parameters. Cage tier significantly affects the welfare parameters, and this effect is clearer around 45 weeks of age in layers.

Key words: LED, compact fluorescent, cage tier, welfare, egg layer

1. Introduction

Light-emitting diode (LED) light bulbs have been gaining popularity for use in poultry house lighting in recent years [1]. The LED lamps have low energy consumption, a long life, and produce monochromatic light [2]. The different lighting sources and light intensity used in poultry houses lead to changes in physical activity and behavior in hens, and also affects their welfare [3–5]. Long et al. [4] reported that the layers housed under LED lights had a worse vent and back-region feather status than layers under fluorescent light. The light intensity may affect the activity of chickens and feather pecking behavior [5]. On the other hand, lighting also affects jumping from perches and safe landing behavior among birds [6], and it may cause an increase in keel bone deformations [7]. Different monochromatic and mixed-color lighting also had an effect on the fear behavior of chickens; thus, there was a difference in tonic immobility (TI) duration reaction of broilers [8]. Gallegos and Archer [9] reported that the LED lighting group had a greater TI duration and induction number than the compact fluorescent lighting (FLO) group. The dense dust production in a poultry house is affected by environmental factors, animal age, litter material, as well as bird activity, which is associated with feeding and lighting programs [10]. The dense dust negatively affects the health of both the workers and the chickens in the poultry house, in particular, it affects respiratory systems and reduces animal welfare and productivity [11,12]. In addition, the dust may cover the lamps and cause a decrease in light intensity inside the poultry house. There was limited study of animal activity, which was one of the factors that affecting dust production in poultry houses [4,12].

Although the goal is to provide homogeneous distribution of environmental factors, such as lighting and ventilation, in commercial egg production it is difficult to provide this in parallel with the number of cage tiers. Thus, cannibalism is observed in layers due to the high light intensity in the upper cage tier, and there may also be an increase in the number of vent prolapse cases, small eggs, and shell-quality– and shape-index–defective eggs in the field studies [13]. Moreover, the control of these situations in the upper cage tiers of multitier cage systems is difficult and often overlooked.

* Correspondence: bilgehan@uludag.edu.tr

There are various studies on lighting in conventional cage systems. However, there are few studies on the effects of LED light on layers reared in alternative rearing systems [9,14]. Moreover, there is little information about the effect of LED and fluorescent lighting on production performance, egg quality, stress, and fear in hens [9,14,15]. Additionally, different light intensity levels were reported on different levels of the cage tiers, and this may affect the welfare parameters in layers [13]. The objective of the present study was to determine the effects of lighting type (LED and FLO) and cage tier on feather score, body and comb wounds, bumble foot and footpad dermatitis, beak damage, keel bone deformity, finger damage, aggressive pecking, and avoidance distance test (ADT) in laying hens reared in an enriched cage system. In addition, the dust accumulation rate was recorded to determine the activity of layers under different light source at 25, 35, and 45 weeks of age. Production performance and egg quality were also investigated, and the results were presented in [16].

2. Materials and methods

2.1. Animals and experimental design

The study was started in Nick Chick White Egg layers at 16 weeks of age in a fully automated control cluster (23 °C in-house temperature, 40% relative humidity) at a private commercial egg production enterprise. The practices regarding the care and use of animals were approved by the animal use and ethics committee of Bursa Uludağ University (certification number: 2016-10/02).

In the study, the poultry house was divided into two equal parts. The light source in the first part was a mini compact fluorescent lamp (cool daylight, 6500 K), and in the second part an LED lamp (white 6000–6500 K) was used for lighting. The light intensity was measured with a digital luxury meter (Extech Instruments, light meter LT300, Boston, MA, USA) at three different points at the eye level of the layers (under the lamp, inside the feeder, and inside the cage), and these values were averaged for each cage section.The light intensity measurements were recorded at 17, 25 and 45 weeks of age. The 14 L:10 D photoperiod program was applied, and feed and water was supplied ad libitum to layers.

Only the bottom four cage tiers were used in the eight-tier enriched cage unit in this study. The enriched cage tiers were coded I, II, III, and IV from bottom to top. A total of 20 layers were placed in each cage section, and 400 layers were used for each type of light group. A total of 800 layers were used, until 45 weeks of age.

2.2. Determination of welfare traits

A total of 400 layers were used to determine the welfare traits. At 25 weeks of age, 100 hens were randomly selected from each lighting type and were visually observed by the same person for feather scoring, according to Tauson et al. [17]; body–comb wound and foot lesions were scored according to Ekstrand et al. [18]; and beak score, keel bone deformity, and finger damage were scored according to Welfare Quality [19]. Moreover, layers were scored for aggressive pecking behavior with an adaptation of the Welfare Quality method [19], with 0 signifying no aggressive behavior and 1 signifying aggressive behavior. The ADT was applied to assess the response of layers at different cage tiers to an approaching human under the FLO and LED lighting systems, according to Welfare Quality [19].

A total of 80 layers (10 layers per cage tier group) were tested individually for TI reaction at 45 weeks of age. A few seconds after the layers were caught, a TI test was induced, according to Ghareeb et al. [20], and a maximum score of 600 s was given for the duration.

The dust accumulation rates (DAR I and DAR II) were calculated to determine the activity of layers under different lighting types at 25, 35, and 45 weeks of age. The petri dishes (5.2 cm in diameter) were placed on the top of the cage tier at three different points during six days at each age. Then petri dishes were collected and dried at 105 °C for 24 h in the oven. The dry dust weight was determined according to Long et al. [14].

2.3. Statistical analysis

All categorical data (body feather scores, welfare traits, and agressive behavior) were analyzed with using PROC NPAR1WAY procedure of SAS 9.4.M6 [21], and the Kruskal–Wallis test was used to determine the differences among effects (lighting type, cage tier, and their interaction). Continuous variables were analyzed with two-way ANOVA using the GLM procedure of statistical analysis software [22]. The model included lighting type and cage tier as the fixed effects. The DAR I and DAR II data were analyzed with one-way ANOVA [22] to assess the main effect of the lighting type. Differences were considered significant at $P < 0.05$. Significant differences among group means were determined by Tukey's test. Data were presented as mean ± standard error (SE) in all of the tables.

3. Results and discussion

3.1. Light intensity

At the beginning of the study (17 weeks), the light intensities of the LED and FLO groups were 12.67 ± 1.21 and 15.94 ± 1.21 lux ($P > 0.05$), respectively. For the cage tiers it was 8.29 ± 1.72, 11.72 ± 1.72, 20.87 ± 1.72, and 16.35 ± 1.72 lux, respectively, from bottom to top of the cage tier ($P < 0.01$).

3.2. Body feather score

In poultry the feathers play a role in maintaining a balanced body temperature as well as protecting the skin surface against various bumps. Severe feather pecking and feather loss in chickens is undesirable in commercial poultry production. While feather loss usually occurs in advanced age layers, it can also occur at an early age depending on rearing conditions [23]. The feather pulling and pecking behavior amongst chickens is a problem that is affected by many factors [24]. Lighting affects these behaviors in chickens [25]; hence, light has a strong effect on the general feather condition of hen bodies [26]. Lighting and light-intensity management errors in poultry production cause cannibalism among hens. The chicken body feather score is used as a welfare parameter [26]. Long et al. [4] reported that layer feathers were worse in the LED group than in the fluorescent group. The effects of different lighting types and cage tiers on the body feather score of layers at 25 and 45 weeks of age were given in Table 1. Full body-feather scores of layers were similar in the LED and FLO groups at 25 weeks of age (P > 0.05); however, the mean feather score value was better in the LED group than in the FLO group at 45 weeks of age (P < 0.01). This may be a result of the lower light intensity in the LED group at this age. In the study, the neck (P < 0.001) and tail-area feather scores of layers were better in the LED group than in the FLO group (P < 0.0001). Aggressive behaviors, such as feather pulling and pecking of layers, increased under high light intensity [27]. In the study, the effects of cage tier on the body-feather scores of layers were similar at 25 weeks of age (P > 0.05), but the mean feather score values of layers were best in cage tier IV at 45 weeks of age (P < 0.05). The worst breast feather score was determined in cage tier II, and the worst vent feather score was in cage tier I (P < 0.001). However, Kjaer and Vestergaard [3] reported that the light intensity did not affect feather condition. The effect of lighting type and cage–tier interaction on the feather scores of layers was not significant at 25 weeks of age (P > 0.05), but there were interactions among the neck, breast (P < 0.0001), vent, tail (P < 0.001), and mean feather scores of layers at 45 weeks of age (P < 0.01).

The effects of lighting type and cage–tier interaction on the neck, breast, vent, and tail feather scores at 45 weeks of age were given in Figure 1. A better neck feather score was found in the LED group (P < 0.01) at all levels, except cage tier I, which was similar to the FLO group. On the other hand, a better breast feather score was found in the FLO group (P < 0.0001) at all levels, except cage tier II, when compared to the LED group. Better vent feather scores were found in cage tiers II–IV of LED and FLO groups (P < 0.01); however, layers in cage tier I had worse

Table 1. The effects of different lighting type and cage tier on body feather score of layers (mean ± SE).

Parameters	Lighting type			Cage tier					P		
25 weeks of age	LED	FLO	SE	I	II	III	IV	SE	L	C	L × C
Neck	3.80	3.90	0.04	3.82	3.84	3.84	3.90	0.06	NS	NS	NS
Breast	3.99	3.97	0.01	3.96	3.96	4.00	4.00	0.02	NS	NS	NS
Vent	4.00	4.00	0.00	4.00	4.00	4.00	4.00	0.00	NS	NS	NS
Back	4.00	4.00	0.00	4.00	4.00	4.00	4.00	0.00	NS	NS	NS
Wings	4.00	3.99	0.01	3.98	4.00	4.00	4.00	0.01	NS	NS	NS
Tail	4.00	4.00	0.01	4.00	4.00	4.00	4.00	0.01	NS	NS	NS
Mean	3.97	3.98	0.01	3.96	3.97	3.97	3.98	0.01	NS	NS	NS
45 weeks of age											
Neck	2.68^{a}	2.39^{b}	0.05	2.54	2.56	2.54	2.50	0.08	***	NS	**
Breast	2.78^{b}	3.07^{a}	0.05	2.80^{bc}	2.72^{c}	3.06^{ab}	3.12^{a}	0.07	***	***	****
Vent	3.96	3.96	0.02	3.86^{b}	3.98^{a}	4.00^{a}	4.00^{a}	0.03	NS	***	**
Back	4.00	4.00	0.00	4.00	4.00	4.00	4.00	0.00	NS	NS	NS
Wings	4.00	3.98	0.01	3.96	4.00	4.00	4.00	0.01	NS	NS	NS
Tail	3.68^{a}	3.35^{b}	0.05	3.48	3.58	3.48	3.52	0.07	****	NS	***
Mean	3.52^{a}	3.46^{b}	0.02	3.44^{b}	3.47^{ab}	3.51^{ab}	3.52^{a}	0.02	**	*	**

[a,b,c]; Mean values within lines with different superscripts are significantly different (P < 0.05).
*P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001; NS: not significant
L: Lighting type; C: cage tier; LED: light-emitting diode, FLO: compact fluorescent;
I: 1st tier (bottom), II: 2nd tier, III: 3rd tier, IV: 4th tier (top)
Body feather score ranged from 1 to 4, with 1 signifying severe damage and 4 signifying no damage to feathers.

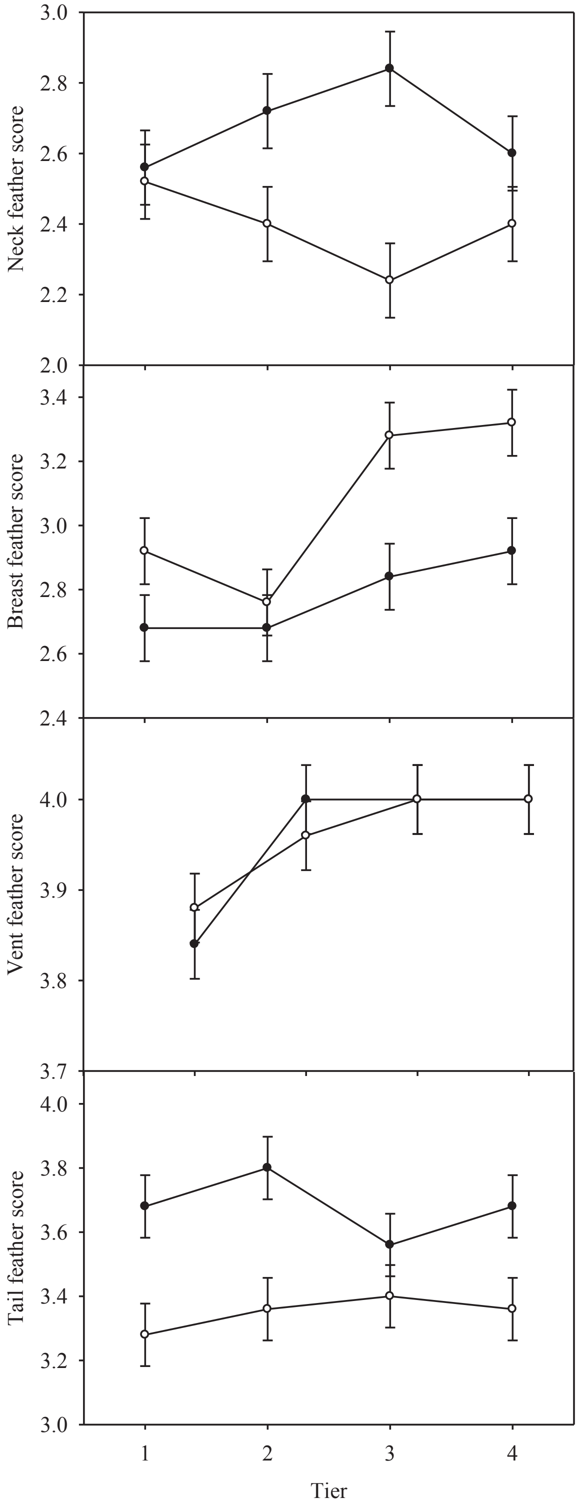

Figure 1. The interactions between lighting type and cage tier on neck, breast, vent, and tail feather scores of layers at 45 weeks of age. LED (closed circle) and FLO (open circle), cage tier (I, II, III, and IV)

vent feather scores in both lighting groups (P < 0.01). A better tail feather score was found in the LED group (P < 0.001) at all levels of cage tier.

The effect of lighting type and cage–tier interaction on mean body feather score at 45 weeks of age is given in Figure 2. A better mean body feather score was found in the LED group (P < 0.01) at all cage tiers, when compared to layers in the FLO group.

3.3. Other welfare traits related to the body

General foot problems in poultry are footpad dermatitis, bumble foot, hyperkeratosis, and excessive nail growth. Bumble foot is an inflammation of the tissue in the footpad [28]. Keel bone deformity is mostly seen in commercial systems and represents one of the most significant welfare problems in production [29]. The effects of different lighting types and cage tiers on other welfare traits related to layer bodies at 25 and 45 weeks of age were given in Table 2. In the study, comb wounds in layers were worse in the FLO group than the in LED group (P < 0.05), and body wounds, bumble foot, footpad dermatitis, beak status, keel bone deformity, and finger damage in layers were similar in both lighting groups at 25 weeks of age (P > 0.05). Worse comb wounds and finger damage in layers were found in the FLO group than the LED group at 45 weeks of age (P < 0.05). Beak status in layers was worse in the LED group than the in FLO group at 45 weeks of age (P < 0.0001). This may be a result of hens spending their time using search behavior and pecking the cage environment, due to the low light intensity in the LED group. Body wounds, bumble foot, footpad dermatitis, and keel bone deformity in layers were similar in both lighting groups at 45 weeks (P > 0.05).

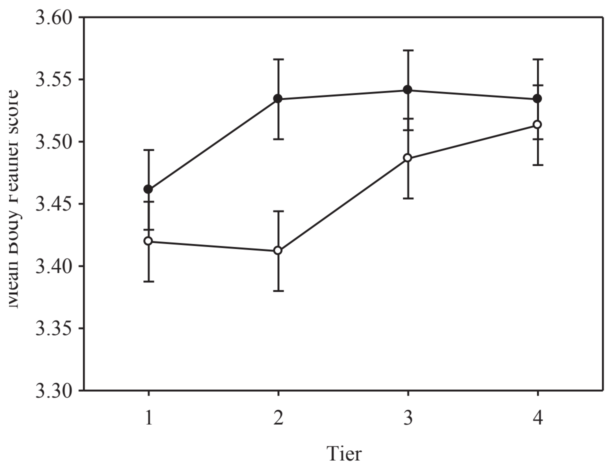

Figure 2. The interactions between lighting type and cage tier on mean body feather scores of layers at 45 weeks of age. LED (closed circle) and FLO (open circle), cage tier (I, II, III, and IV)

Table 2. The effects of different lighting type and cage tier on other welfare traits related to bodies of layers (mean ± SE).

Parameters	Lighting type			Cage tier					P		
25 weeks of age	LED	FLO	SE	I	II	III	IV	SE	L	C	L × C
Body wound[1]	3.00	2.99	0.01	3.00	3.00	2.98	3.00	0.01	NS	NS	NS
Comb wound[1]	2.74[a]	2.60[b]	0.05	2.74	2.64	2.62	2.68	0.07	*	NS	NS
Bumble foot[2]	2.90	2.79	0.04	2.96[a]	2.94[a]	2.78[ab]	2.70[b]	0.05	NS	***	***
Footpad dermatitis[2]	2.50	2.55	0.05	2.56	2.62	2.42	2.50	0.07	NS	NS	NS
Beak status[3]	0.17	0.08	0.04	0.20	0.20	0.06	0.04	0.06	NS	NS	*
Keel bone deformity[4]	0.01	0.00	0.01	0.02	0.00	0.00	0.00	0.01	NS	NS	NS
Finger damage[5]	0.05	0.05	0.02	0.02	0.04	0.02	0.12	0.03	NS	NS	NS
45 weeks of age											
Body wound[1]	2.81	2.89	0.04	2.82	2.86	2.86	2.86	0.06	NS	NS	NS
Comb wound[1]	2.38[a]	2.21[b]	0.05	2.38[ab]	2.42[a]	2.22[ab]	2.16[b]	0.06	*	*	**
Bumble foot[2]	2.35	2.34	0.05	2.36	2.32	2.32	2.38	0.07	NS	NS	NS
Footpad dermatitis[2]	2.26	2.18	0.04	2.36[a]	2.16[b]	2.20[ab]	2.16[b]	0.06	NS	*	*
Beak status[3]	1.13[a]	0.88[b]	0.04	1.00	1.04	1.00	0.98	0.06	****	NS	**
Keel bone deformity[4]	0.06	0.06	0.02	0.02	0.10	0.06	0.06	0.03	NS	NS	NS
Finger damage[5]	0.49[b]	0.63[a]	0.05	0.48	0.68	0.56	0.52	0.07	*	NS	***

[a,b]; Mean values within lines with different superscripts are significantly different (P < 0.05).
*P < 0.05; ** P < 0.01; *** P < 0.001; **** P < 0.0001; NS: not significant
L: Lighting type; C: cage tier; LED: light-emitting diode, FLO: compact fluorescent;
I: 1st tier (bottom), II: 2nd tier, III: 3rd tier, IV: 4th tier (top)
[1]Body and comb wound score ranged from 1 to 3, with 1 signifying severe damage and 3 signifying no lesions on body and comb.
[2]Foot score (bumble foot and footpad dermatitis) ranged from 1 to 3, with 1 signifying severe hyperkeratosis and 3 signifying no lesions on foot.
[3]Beak score ranged from 0 to 2, with 0 signifying no lesions and 2 signifying anomaly on the beak.
[4]Keel bone deformity score ranged from 0 to 2, with 0 signifying no deformation and 2 signifying deformation on keel bone.
[5]Finger damage score ranged from 0 to 2, with 0 signifying no deformation and 2 signifying deformation on finger and claw.

In this study, while cage tier did not affect body and comb wounds, footpad dermatitis, beak status, keel bone deformity, or finger damage of layers (P > 0.05), the worst bumble foot was recorded in cage tier IV at 25 weeks (P < 0.001). The fewest comb wounds in layers were found in cage tier II, and the highest number of wounds was found in cage tier IV at 45 weeks (P < 0.05). The worst footpad dermatitis in layers was found in cage tiers II and IV, and the fewest affected layers were found in cage tier I at 45 weeks (P < 0.05). Body wounds, bumble foot, beak status, keel bone deformity, and finger damage in layers were similar in all cage tiers at 45 weeks (P > 0.05). Our findings were similar to those of Vits et al. [30], who found that the claws of hens from the 4th cage tier were longer than those from other cage tiers, whereas there were no differences among the cage tiers in keel bone deformities.

The effects of lighting type and cage–tier interaction on comb wound, footpad dermatitis, beak status, and finger damage scores at 45 weeks of age were given in Figure 3. The lowest occurrence of comb wound was found in the LED group (P < 0.01) at all levels, except cage tier IV. The lowest occurrence of footpad dermatitis in layers was found in cage tier I of the LED group (P < 0.05). The beak status score was higher in the LED group (P < 0.01), compared the FLO group. The worst finger damage in layers was found in cage tier II of FLO at 45 weeks of age (P < 0.001).

3.4. Some welfare behavior traits

The effects of lighting type and cage tier on some welfare behavior traits of layers at 25 and 45 weeks of age were given in Table 3. In the study, the effect of light type on aggressive behaviors in layers at 25 weeks of age was not significant (P > 0.05), while it was found to be significant at 45 weeks of age (P < 0.01). According to some LED manufacturers, LED lights make birds calm and less aggressive than other light sources [14]. Thus, more aggressive behavior was found in the FLO group than the LED group at 45 weeks of age (P < 0.01). Light intensity

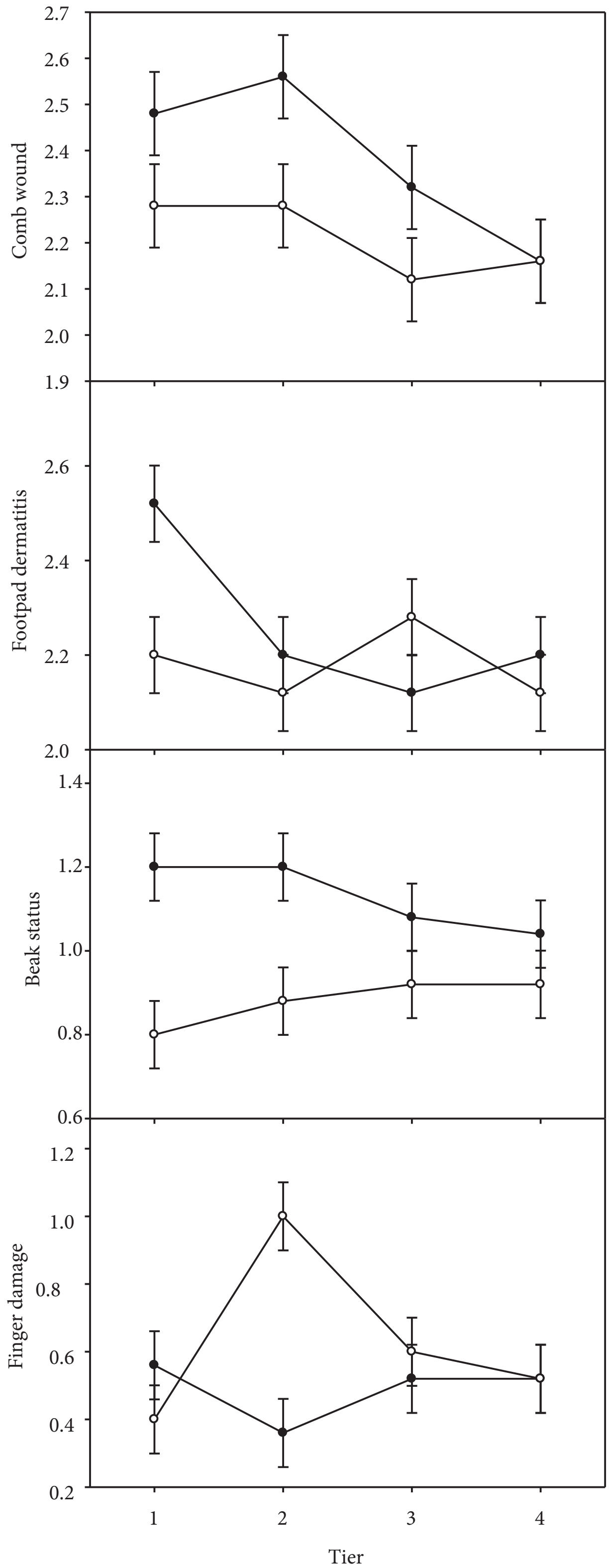

Figure 3. The interactions between lighting type and cage tier on comb wounds, footpad dermatitis score, beak status, and finger damage of layers at 45 weeks of age. LED (closed circle) and FLO (open circle), cage tier (I, II, III, and IV)

was higher in the FLO group at 45 weeks of age; this is supported in these findings. There was no effect of cage tier on aggressive behavior of layers at 25 and 45 weeks of age (P > 0.05). The effect of lighting type and cage–tier interaction on aggressive behaviors was not significant at 25 weeks of age (P > 0.05).

The effect of lighting type and cage–tier interaction on aggressive behavior of layers at 45 weeks of age was given in Figure 4. The most aggressive behavior was found in the FLO group at 45 weeks of age (P < 0.01) at all levels of cage tier.

The avoidance distance test is used to assess the response of hens to an approaching human, i.e. human–hen interaction [14]. There was no difference between the LED and fluorescent lighting types on the response of hens to novel objects and avoidance distance [4,9]. Long et al. [14] reported that the LED group had more avoidance distance than the fluorescent group at 36 weeks of age, although there was no difference in both lighting groups at 60 weeks of age. In the current study, ADT was found to be higher in FLO group than in the LED group at 25 weeks of age (P < 0.05) (Table 3); layers in FLO group noticed the approaching person earlier and ran into their cages. However, there was no difference in ADT between lighting groups at 45 weeks of age (P > 0.05). The highest ADT was found in cage tier IV at 25 and 45 weeks of age (P < 0.01). The effect of lighting type and cage–tier interaction on ADT at 25 weeks of age is given in Figure 4. The highest ADT was found in cage tier IV of the FLO group, and the lowest ADT was found at cage tiers I and II of the LED group (P < 0.05).

Tonic immobility duration is used for measuring fear behavior in hens, and the stress level of chickens [31]. Gallegos and Archer [9] reported that there was a longer TI duration in hens raised under LED lighting, i.e. they showed more stress and fear. Huth and Archer [32] reported that TI duration in broilers was higher in the compact fluorescent group than in the LED group, i.e. broilers in the compact fluorescent light group had higher stress and fear levels than the LED groups. In the study, the TI induction number and duration were found to be similar in both lighting groups (P > 0.05) (Table 3). However, the TI number and duration was numerically higher in the FLO group. There was no difference for TI duration and induction number among the cage tiers (P > 0.05). However, numerically higher TI induction numbers were found in cage tier III, and TI duration was longer in cage tier IV. Layers reared on the top of the cage tiers were closer to the light and had less interaction with house workers, which can cause stress and fear in layers. The effect of lighting type and cage–tier interaction on TI duration and induction number was not significant at 45 weeks of age (P > 0.05). However, Şekeroğlu et al. [33]

Table 3. The effects of different lighting type and cage tier on some welfare behavior traits of layers (mean ± SE).

Parameters	Lighting type			Cage tier					P		
25 weeks of age	LED	FLO	SE	I	II	III	IV	SE	L	C	L × C
Aggressive behavior[1]	0.19	0.25	0.04	0.10	0.22	0.26	0.30	0.06	NS	NS	NS
ADT[2], cm	27.90^{b}	30.73^{a}	0.91	20.38^{c}	21.90^{c}	32.32^{b}	42.66^{a}	1.28	*	**	*
45 weeks of age											
Aggressive behavior[1]	0.17^{b}	0.41^{a}	0.04	0.42	0.28	0.18	0.28	0.06	**	NS	**
ADT[2], cm	34.32	33.91	1.22	22.82^{c}	23.78^{bc}	29.86^{b}	60.00^{a}	1.73	NS	**	NS
Induction number	1.53	1.73	0.15	1.70	1.45	1.80	1.55	0.21	NS	NS	NS
Tonic immobility, s	305.2	306.8	32.10	332.5	254.7	283.1	353.6	45.40	NS	NS	NS

^{a,b,c}; Mean values within lines with different superscripts are significantly different ($P < 0.05$). *$P < 0.05$; ** $P < 0.01$; NS: not significant
L: Lighting type; C: cage tier; LED: light-emitting diode, FLO: compact fluorescent;
I: 1st tier (bottom), II: 2nd tier, III: 3rd tier, IV: 4th tier (top)
[1]Aggressive behavior ranged from 0 to 1, with 0 signifying no aggressive behavior and 1 signifying aggressive behavior.
[2] ADT: Avoidance distance test

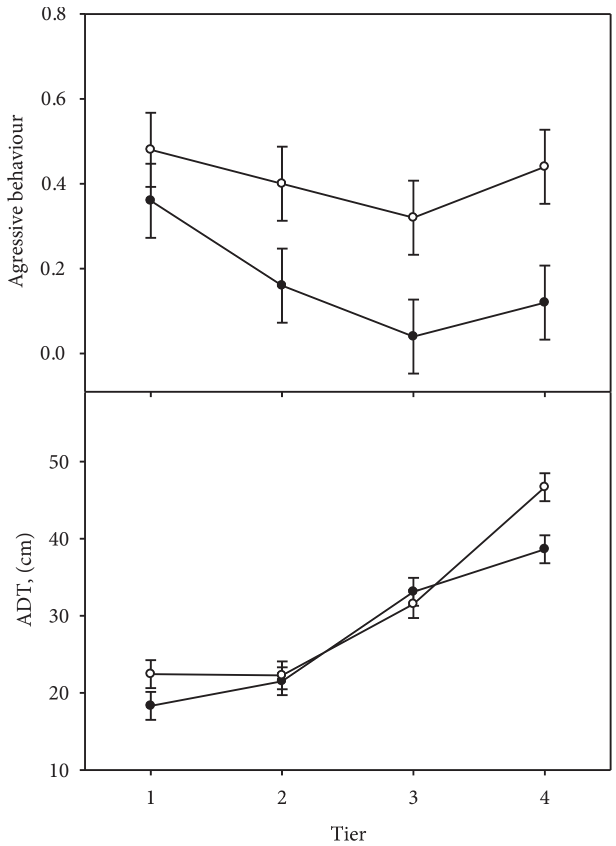

Figure 4. The interactions between lighting type and cage tier on aggressive behavior of layers at 45 weeks of age and avoidance distance test (ADT) of layers at 25 weeks of age. LED (closed circle) and FLO (open circle), cage tier (I, II, III, and IV)

reported that the shortest TI duration was found in low level cage tiers at 30 weeks of age. They also reported that there was no difference between the cage tiers regarding TI duration of layers at 45 weeks of age; however, TI duration was numerically lower at bottom cage tiers as aging progressed.

3.5. Dust accumulation ratio

The lighting management in poultry house affects hen activity [12]. Thus, it also affects dust levels in poultry houses. Long et al. [4,14] reported that the dust accumulation rate was similar under LED and FLO lighting groups. However, the dust accumulation rate in the FLO group was numerically higher than in the LED group [14]. The effects of different lighting types and cage tier on the DAR I and DAR II were given in Figures 5 and 6, respectively. While the effect of LED and FLO lighting on the DAR I and DAR II were not significant at 25 weeks of age ($P > 0.05$), the effect was higher in the FLO group than in the LED group at 35 and 45 weeks of age ($P < 0.05$). According to these results, it might be inferred that there was more activity among layers in the FLO group than in older age groups.

Conventional cage systems have been questioned for a long time in the field of animal welfare, and many European Union member countries have begun to use enriched cages or other alternative systems for egg production. In Turkey, the transition to enriched cage systems for egg production has begun. Along with this new cage system, the effects of lighting and light sources on egg production, egg quality, and welfare parameters have started to gain importance.

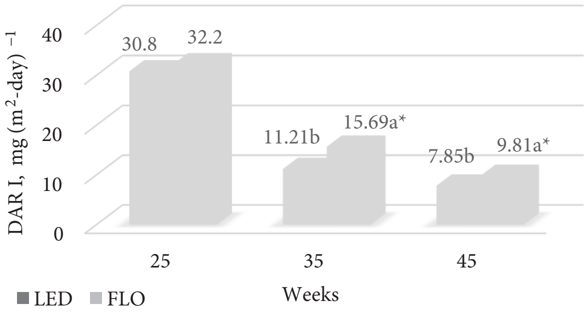

Figure 5. The effect of different lighting types on dust accumulation rate I (DAR I).

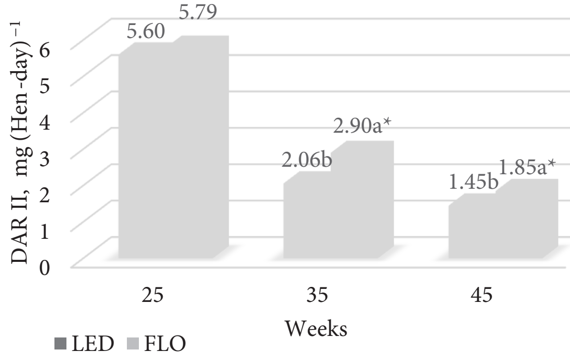

Figure 6. The effect of different lighting types on dust accumulation rate II (DAR II).

With new technological developments, the lighting systems used in hen houses are continually evolving. The use of LED lights in large capacity commercial farms is critical in terms of energy savings and economy due to their long life and low maintenance costs.

In conclusion, the LED group fares better in terms of some welfare parameters such as feather score, comb wound, finger damage, aggressive pecking behavior, and avoidance distance and dust accumulation rate. The effect of cage tier on some welfare parameters was, in general, significant at 45 weeks of age, and the difference between cage tiers varied according to the age of the hens. The new LED lamp technology, which is becoming more widely used due to its monochromatic light emission, long life, and low electricity consumption, will contribute to animal welfare, especially in layers reared in enriched cage systems. It is also clear that this study will be an essential source for producers interested in determining appropriate light management.

Acknowledgments

The authors would like to acknowledge employees of the company for providing the support necessary for this study. The authors also appreciate the financial support of Matlı Burdan Yumurta Üretim A.Ş., Bursa, Turkey. This manuscript is part of the MSc thesis of Gülsüm Tünaydın.

References

1. Bayraktar H, Altan A. Effects of light wavelength on broiler performance. Journal of Animal Production 2005; 46 (2): 22-32 (in Turkish with an abstract in English).
2. Rozenboim I, Zilberman E, Gvaryahu G. New monochromatic light source for laying hens. Poultry Science 1998; 77 (11): 1695-1698. doi: 10.1093/ps/77.11.1695
3. Kjaer JB, Vestergaard KS. Development of feather pecking in relation to light intensity. Applied Animal Behaviour Science 1999; 62 (2-3): 243-254. doi: 10.1016/S0168-1591(98)00217-2
4. Long H, Zhao Y, Wang T, Xin H, Ning Z. Comparative evaluation of light-emitting diode (LED) vs. fluorescent (FL) lighting in commercial aviary hen houses. In: Proceedings of the ASABE and CSBE/SCGAB Annual International Meeting; Montreal, Quebec, Canada; 2014. pp. 1-15.
5. Kristensen HH. The effects of light intensity, gradual changes between light and dark and definition of darkness for the behaviour and welfare of broiler chickens, laying hens, pullets and turkeys. Scientific Report for the Norwegian Scientific Committee for Food Safety 2008; (June): 1-44.
6. Moinard C, Statham P, Haskell MJ, McCorquodale C, Jones RB et al. Accuracy of laying hens in jumping upwards and downwards between perches in different light environments. Applied Animal Behaviour Science 2004; 85 (1-2): 77-92. doi: 10.1016/j.applanim.2003.08.008
7. Harlander-Matauschek A, Rodenburg TB, Sandilands V, Tobalske BW, Toscano MJ. Causes of keel bone damage and their solutions in laying hens. World's Poultry Science Journal 2015; 71(3): 461-472. doi: 10.1017/S0043933915002135
8. Sultana S, Hassan MDR, Choe HS, Ryu KS. The effect of monochromatic and mixed LED light colour on the behaviour and fear responses of broiler chicken. Avian Biology Research 2013; 6 (3): 207-214. doi: 10.3184/175815513X13739879772128
9. Gallegos K, Archer GS. Comparison of the effect of light-emitting diode (LED) versus compact fluorescent lamp (CFL) lighting on hen production, egg quality, fear, and stress. Poultry Science 2014; 93 (E-Suppl. 1): 95.

10. Nielsen BL, Litherland M, Nøddegaard F. Effects of qualitative and quantitative feed restriction on the activity of broiler chickens. Applied Animal Behavior Science 2003; 83 (4): 309-323. doi: 0.1016/S0168-1591(03)00137-0

11. Al Homidan A, Robertson JF, Petchey AM. Review of the effect of ammonia and dust concentrations on broiler performance. World's Poultry Science Journal 2003; 59 (3): 340-349. doi: 10.1079/WPS20030021

12. Calvet S, Van den Weghe H, Kosch R, Estellés F. The influence of the lighting program on broiler activity and dust production. Poultry Science 2009; 88 (12): 2504-2511. doi: 10.3382/ps.2009-00255

13. Yıldırım İ, Parlat SS, Aygün A, Yetişir R. The effects of hanging type lighting systems in apartment type cages on performance, egg quality traits and stress level in commercial brown layers. Selçuk Tarım ve Gıda Bilimleri Dergisi, 2008; 22 (44): 7-11 (in Turkish with an abstract in English).

14. Long H, Zhao Y, Wang T, Ning Z, Xin H. Effect of light-emitting diode vs. fluorescent lighting on laying hens in aviary hen houses: part 1—operational characteristics of lights and production traits of hens. Poultry Science 2016a; 95 (1): 1-11. doi: 10.3382/ps/pev121

15. Long H, Zhao Y, Xin H, Hansen H, Ning Z et al. Effect of light-emitting diode (LED) vs. fluorescent (FL) lighting on laying hens in aviary hen houses: part 2—egg quality, shelf-life and lipid composition. Poultry Science 2016b; 95 (1): 115-124. doi: 10.3382/ps/pev306

16. Tünaydın G, Yılmaz Dikmen B. Impact of light emitting diode and compact fluorescent light source type and cage tier on layers reared in an enriched cage system, Part 1: Production performance and egg quality. Turkish Journal of Veterinary and Animal Sciences 2019; 43: 615-626.

17. Tauson R, Kjaer J, Maria GA, Cepero R, Holm KE. Applied scoring of integument and health in laying hens. Animal Science Papers and Reports 2005; 23 (Suppl. 1): 153-159.

18. Ekstrand C, Carpenter TE, Andersson I, Algers B. Prevalence and control of foot-pad dermatitis in broilers in Sweden. British Poultry Science 1998; 39 (3): 318-324. doi: 10.1080/00071669888845

19. Welfare Quality. Welfare quality assessment protocol for poultry (broiler, laying hens). Welfare Quality Consortium, Lelystad, Netherlands; 2009. pp. 110.

20. Ghareeb K, Awad WA, Sid-Ahmed OE, Böhm J. Insights on the host stress fear and growth responses to the deoxynivalenol feed contaminant in broiler chickens. Plos One 2014; 9 (1): e87727. doi: 10.1371/journal.pone.0087727

21. SAS. A User's Guide to SAS V9.4.M6. SAS Institute, Inc., 2019.

22. Minitab. Statistical Software 17.1.0., Minitab Inc. 2013.

23. De Haas EN, Bolhuis JE, De Jong IC, Kemp B, Janczak AM et al. Predicting feather damage in laying hens during the laying period. Is it the past or is it the present? Applied Animal Behaviour Science 2014; 160: 75-85. doi: 10.1016/j.applanim.2014.08.009

24. Rodenburg TB, Van Krimpen MM, De Jong IC, De Haas EN, Kops MS et al. The prevention and control of feather pecking in laying hens: identifying the underlying principles. World's Poultry Science Journal 2013; 69 (2): 361-373. doi: 10.1017/S0043933913000354

25. Ruis MAW, Reuvekamp BF, Gunnink H, Binnendijk GP. The effect of optimized lighting conditions on feather pecking and production of laying hens. Wageningen UR Livestock Research, Lelystad, Report 335, April 2010, p. 38.

26. Bilcik B, Keeling LJ. Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. British Poultry Science 1999; 40 (3): 444-451. doi: 10.1080/00071669987188

27. Mohammed H, Ibrahim M, Saleem AS. Effect of different light intensities on performance, welfare and behavior of turkey poults. Journal of Advanced Veterinary and Animal Research 2016; 3 (1): 18-23.

28. Lay DC Jr, Fulton RM, Hester PY, Karcher DM, Kjaer JB et al. Hen welfare in different housing systems. Poultry Science 2011; 90 (1): 278-294. doi: 10.3382/ps.2010-00962

29. FAWC. Opinion on Osteoporosis and Bone Fractures in Laying Hens. Farm Animal Welfare Council, London; 2010. p. 12.

30. Vits A, Weitzenburger D, Hamann H, Distl O. Influence of different tiers in furnished cages and small group system on production traits, mortality, egg quality, bone strength, claw length and keel bone deformities. Archiv Für Geflügelkunde 2006; 70 (4):145-154.

31. Yalçın S, Özkan S, Çabuk M, Siegel PB. Criteria for evaluating husbandry practices to alleviate heat stress in broilers. Journal of Applied Poultry Research 2003; 12(3): 382-388. doi: 10.1093/japr/12.3.382

32. Huth JC, Archer GS. Effects of LED lighting during incubation on layer and broiler hatchability, chick quality, stress susceptibility and post-hatch growth. Poultry Science 2015; 94 (12): 3052-3058. doi: 10.3382/ps/pev298

33. Şekeroğlu A, Duman M, Tahtalı Y, Yıldırım A, Eleroğlu H. Effect of cage tier and age on performance, egg quality and stress parameters of laying hens. South African Journal of Animal Science 2014; 44 (3): 288-297. doi: dx.doi.org/10.4314/sajas.v44i3.11