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Kafesli Yumurta Tavuğu Kümesinde Aydınlatma Yeterliliğinin Teorik ve Uygulamalı Karşılaştırılması

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Abstract: Commercial farms provide most of the egg production in Turkey, and artificial lighting in commercial poultry houses is widespread. Lighting is an essential part of the physical environmental conditions that control and regulate the health and behaviour of poultry production. It is necessary to have a proper lighting plan to provide adequate lighting in the poultry house to facilitate the daily work and to create favourable conditions for the welfare of the animals, productivity and sustainability of the production and the workers. This study aims to measure the current lighting level in a conventional cage system laying hen house in Bursa and to compare it with the calculation of the amount of lighting required in theory. The calculated lighting power per unit area is 1.6 W m^{-2} practical and 2.2 W m^{-2} theoretical. It was found that the illuminance measured with a lux meter on the cage floors was close to the theoretically calculated values. It was considered that 16 reflectors of 40 W would be sufficient according to the luminous flux method. In practice, however, it was found that 24 fluorescent lamps of 36 watts provided a lighting level close to the theoretical level. Furthermore, the significance of the differences between the measured illuminance levels between the areas (corridor and floor) and the times (seasons and months) were assessed using analysis of variance. A statistically significant difference was observed between season and day.

Keywords: Artifical lighting, conventional cage, Bursa, lux, laying hen

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Öz: Türkiye’de yumurta üretiminin büyük çoğunluğu ticari işletmeler tarafından gerçekleştirilmektedir ve ticari kümeslerde genel olarak yapay aydınlatma kullanılmaktadır. Kanatlı yetiştiriciliğinde hayvanların sağlık ve davranışlarının kontrolü ve düzenlenmesinde, fiziksel çevre koşullarından aydınlatma önemli rol oynamaktadır. Kümes içerisine yeterli aydınlatma sağlanmasıyla günlük işlerin yapılmasında kolaylık sağlanması, hayvanların refahı, verimliliği, üretimin sürdürülebilirliği ve çalışanlar için uygun koşullar yaratmak için doğru bir aydınlatma planının olması gerekmektedir. Yapılan çalışmada, Bursa’da faaliyet gösteren geleneksel kafes sistemli bir yumurta tavuğu kümesinde uygulanan mevcut aydınlatma düzeyinin ölçülmesi ve teoride gerekli olan aydınlatma miktarının hesaplanmasıyla karşılaştırılması amaçlanmaktadır. Birim alan başına hesaplanan aydınlatma gücü uygulamada 1.6 W m^{-2}, teoride ise 2.2 W m^{-2}’dir. Kafes katlarına göre lüksmetre ile ölçülen aydınlık şiddetlerinin ise teoride hesaplanan değerlere yakın olduğu belirlenmiştir. Aydınlatma düzeyinin ışık akısı yöntemine göre 40 Watt gücündeki 16 adet lambanın yeterli olduğu hesaplanmıştır. Ancak uygulamada 24 adet 36 Watt gücündeki floresan lambanın kullanılması, teoride hesaplanan değerlere yaklaşık olarak aydınlatma ihtiyacının karşılandığı belirlenmiştir. Ayrıca ölçülen aydınlık şiddeti değerlerinde konumlar arasındaki (koridor ve kat) ve zamana göre (mevsim ve ay) farklılıkların önemliliği varyans analizi ile değerlendirilmiştir. Kafes sıraları koridorlarında ve katlarında ölçülen aydınlık değerleri ve mevsimler arasındaki farklılıklar istatistiksel açıdan önemli bulunmuştur.

Anahtar Kelimeler: Bursa, geleneksel kafes, lüks, yapay aydınlatma, yumurta tavuğu

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INTRODUCTION

Livestock activities are critical in supplying animal-based food and by-products in agriculture. Especially in poultry production, advantages such as having a shorter production period and obtaining more product than production input are the most critical reasons breeders prefer poultry products. In addition, the demand for poultry products such as white meat and eggs is higher in terms of being more economical and versatile for consumers. Considering the increase in population and demand, it is essential to have continuity and efficiency in poultry production.

Genetic ability is 30% effective in livestock production, while environmental and physical factors are 70%. Achieving sustainable production requires proper planning of indoor housing conditions. Poultry, in particular, is a physiologically sensitive animal. Thus, lighting in poultry houses should be managed with great sensitivity (Olgun, 2016; Yaylı and Kılıç, 2021).

Adequate lighting is essential for maintaining productivity, ensuring energy efficiency, promoting good animal performance and reducing energy costs in poultry houses (Demir et al., 2020). Using natural and artificial lighting should be preferred first while lighting is provided as natural and artificial lighting. However, artificial lighting is recommended since creating a uniform and orderly environment day and night is important for production and welfare (Olgun, 2016). If artificial lighting is used during the day when natural light cannot be used, there should be a 100 watt light source for a floor area of 40-50 m^2 (Yıldız, 2013).

As laying hens require different lighting intensities according to their growing period, it is recommended to apply various lighting programmes throughout the period. In particular, intermittent lighting should be used in closed houses during the early stages of chick growth. Increasing the light duration during the rearing period may cause egg production to start earlier than expected, so the light duration should not be increased. During the production period, a minimum of 14 hours and a maximum of 16 hours of light should be provided to ensure adequate feed consumption by laying hens.

Light is an important environmental stimulus that affects the behaviour, immunity, physiological status and productivity of poultry. In commercial layers, the light intensity required by hens for egg production is 5-20 lux. Lighting duration, intensity and the wavelength of light used are very important. More than adequate lighting can reveal the cannibalistic instinct in chickens (Appleby et al., 2004).

This study aims to compare and evaluate the caged laying hen house in the Bursa region with the current lighting and using the light flux method theoretical lighting level.

MATERIAL AND METHOD

The study was conducted in a commercial laying hen house in the Nilüfer region of Bursa province. The area has a warm and temperate climate. The average annual temperature is 14.9˚C, and the average sunshine duration is 5.6 hours. There are approximately 110 rainy days per year in the region. The average rainfall is 719.1 mm (MGM, 2024).

This study examined a farm with 3300 laying hens in conventional cage systems. The farm comprises three lines of cages, and there are four corridors. Cages are three floors, approximately one and a half metres height (see Figure 1). The chickens are of the Leghorn breed; they are brought in at 20 weeks old and start producing eggs after a few weeks.

Figure 1. Location and pictures of the laying hen farm where the study was carried out.
Şekil 1. Çalışmanın yürütüldüğü yumurta tavuğu çiftliğinin konumu ve resimleri.

The ratio of window area to floor area of the henhouse is 4.5%. Lighting in the henhouse, is supplied by natural light during part of the day and by artificial fluorescent lighting when daylight is inadequate. Lighting is provided between 05.00-08.00 in the morning and between 20.00-22.00 in the evening. In winter, when natural lighting is insufficient or on cloudy days, artificial lighting is set manually and no special program is used. In total, 24 fluorescent lamps of 36 W each are used to provide lighting. On average, they are used 5 to 6 hours per day, while natural light from windows and roof vents provides daylight throughout. Jácome et al. (2014) stated that it is not appropriate for hens to be in darkness for more than 10 hours in the layer house, and that there should be at least 14 hours of lighting to ensure good egg production.

The present study used a luxmeter (Testo 540, Testo GmbH, Germany) to measure the illumination in the cage lines for one year (Figure 2). Measurements were taken between 13:00 and 17:00 with the lux meter held perpendicular to the cages. The adequacy of the lighting was assessed by comparing the measurements of the artificial lighting used and the level of illumination of the cages with the luminous flux method.

Figure 2. Testo 540 Luxmeter.
Şekil 2. Testo 540 Lüksmetre.

Calculation of Cage Lighting Level by the Luminous Flux Method

In the study, Equation (1) was used to calculate the lighting level using the luminous flux method. In this method, different coefficients for a number of influencing factors are used. The E_m value is based on the lowest intensity of lighting used in cage-reared laying hens. For the V value, the relevant coefficient was taken considering the degree of dustiness of the farm, considering that the cleaning interval of the farm is infrequent and working conditions are dirty (Yıldız et al., 2010).

$$\Phi t = \frac{(Em)\ x\ (A)}{(\eta t)\ x\ (V)}\ x\ 100 \qquad (1)$$

Φt: total luminous flux (lm)

Em: required light intensity in the plane of illumination (lux)

A: Area of area to be illuminated (m^2)

ηt: Lighting efficiency

V: Correction factor according to the degree of dust

ηt, calculated by Equation (2). The lighting efficiency (ηt) is influenced by the type of lighting, the colour of the ceiling and the walls, and the room index. The values of the room index ($a\ h^{-1}$, $b\ h^{-1}$) refer to the long side and the short side of the house, and h refers to the vertical distance between the lamp and the lighting plane. ηa and ηb were calculated considering these values (Yıldız et al., 2010).

$$\eta t = \eta a + 1/3\,(\eta b - \eta a) \qquad (2)$$

RESULTS AND DISCUSSION

Measurement of Current Light Levels in the Henhouse

During the year 2021, the average lighting values of the weekly measurements taken from each cage floor with a lux meter according to the months are given in Table 1. Windows throughout the henhouse help provide light during the day. However, during the periods in which the measurements were taken, it was observed that the level of effect of the lighting was reduced when the weather was overcast. There are two large fans at the end of the hen house, but they were not included in this study because the areas where the fans are located do not affect natural lighting While the cage line specified as the 1st corridor in the table is located on the side of the air inlet opening, the 3rd is located on the ventilation exit side of the henhouse. In the lines of cages, the 1st floor represents the lower floor, while the 3rd floor represents the upper floor. It has been observed that the illuminance measured on the first floor and on the second floor is at the lower levels. Weak light sources cause inadequate lighting on the lower and middle floors. On the top floor, especially in the cages on the upper floors of the second line, the sunlight from the windows in the ridge gap of the henhouse provided higher lighting. In addition, high values were obtained in measurements made close to the reflectors, especially in cloudy and overcast weather due to the illumination.

Table 1. Intensity of lighting on floors and corridors (lux).
Çizelge 1. Kafes kat ve koridorlarında gerçekleşen aydınlatma şiddetleri.

Month	Cage Floor	Light intensity in the corridor of the cage		
		1. Corridor	2. Corridor	3. Corridor
January	1st Floor	28.3	3.3	14.3
	2nd Floor	23.3	5.7	18.7
	3th Floor	42.0	148.7	93.7
February	1st Floor	33.5	3.5	16
	2nd Floor	41.5	4.5	16
	3th Floor	52	176	416.5
March	1st Floor	42.4	6	31.4
	2nd Floor	40	6.2	35.2
	3th Floor	82.6	70	95.2
April	1st Floor	21.5	5	19.5
	2nd Floor	27.8	9	25.5
	3th Floor	54.3	100	86.75
May	1st Floor	26.0	6.3	35.0
	2nd Floor	19.3	9.7	23.7
	3th Floor	44.3	109.7	83.3
June	1st Floor	40.3	8.3	26.7
	2nd Floor	26.7	11.0	23.0
	3th Floor	58.7	116.3	100.3
July	1st Floor	41.0	23.7	22.3
	2nd Floor	33.0	17.3	26.3
	3th Floor	49.7	147.7	149.3
August	1st Floor	35.5	8.3	23.3
	2nd Floor	29.0	9.5	19.8
	3th Floor	58.3	156.3	103.0
September	1st Floor	28.3	9.0	26.3
	2nd Floor	35.8	13.3	17.3
	3th Floor	52.8	245.0	170.8
October	1st Floor	48.8	7.0	17.0
	2nd Floor	32.3	13.0	15.0
	3th Floor	53.3	296.8	214.3
November	1st Floor	42.5	7.3	20.0
	2nd Floor	26.5	11.8	16.8
	3th Floor	71.0	250.0	283.3
December	1st Floor	55.4	6.4	17.2
	2nd Floor	38.2	8.0	20.4
	3th Floor	60.4	208.4	153

1st floor: top floor, 2nd floor: middle floor, 3rd floor: bottom floor, 1st line: east side of the henhouse, 3rd line: west side of the henhouse

Based on the observations made in the hen house during the study, it can be said that uniform lighting could not be achieved in the hen house and on the floor. While the average lighting level was lowest in the winter (27.9 lux), it was highest in the summer (35.7 lux). In autumn, the average illuminance is 33.5 lux; in spring, it is 28.8 lux. Yıldız et al. (2006) found in their study that a light intensity between 35 and 55 lux in laying hens improved the production and quality of the eggs. Demir et al. (2020) compared lighting conditions in cattle farms with international standards. The study on two farms found an average illuminance of 31 lux and reported that according to ASAE (American Society of Agricultural and Biological Engineers) standards illuminance were insufficient.

Calculating the Required Lighting Level in the Henhouse Using the Luminous Flux Method

The theoretically applicable illuminance was calculated using the luminous flux method, and the use factor in the hen house was studied. Luminous flux, also known as the efficiency method, estimates the area of the barn, ceiling and wall colour, structural features that may affect reflectance, dust, moisture, daily lighting conditions, etc., characteristics that should be identified. Lighting levels and methods, reflective surfaces and types, and correction coefficients depending on the company's dust levels are then selected from existing coefficients. Finally, the room index determines the total luminous flux and number of lamps theoretically required.

As a result of the calculations made using this method, we see that an average of 16 lamps with a power of 40 watts will be sufficient (Table 2). The illumination provided by 16 lamps in the henhouse is calculated to be 19.27 lux on the 1st and 2nd floor and 20.7 lux on the 3rd floor, depending on the floor. It is calculated as 29.5 lux on the 1st floor, 29.6 lux on the 2nd floor and 31.1 lux on the 3rd floor, assuming that the 24 lamps in the henhouse have a power of 40 watts. In a study, the available lighting power in the henhouse was reported to be 2.4 W m^{-2}, and the efficiency by floor was calculated to be 49.3% for the lower floor, 52.5% for the middle floor and 53% for the upper floor (Yaylı and Kılıç, 2021).

Table 2. Values calculated according to the luminous flux method.
Çizelge 2. Işık akısı yöntemine göre hesaplanan değerler.

Cage Floor	Number of lamp	Total luminous intensity (lux)	Current illumination intensity (lux)	Current lighting power (W)
1st Floor	16	19.7	29.5	48
2ndFloor	16	19.7	29.6	47
3th Floor	15	20.7	31.1	45

Comparison of the Real Measurements and the Theoretical Calculation

The study compared the current lighting level in the henhouse with the theoretical lighting level (Table 3). Theoretically, 16 lamps with a power of 40 watts would be sufficient, whereas 24 lamps with 36 watts operate in the henhouse. Table 3 shows that the measured and calculated illuminances were relatively close. It should be 8 W m^{-2} for incandescent lamps and 1.6 W m^{-2} for fluorescent lamps for the required number of luminaires to provide a sufficient illumination intensity (Özaydınlı, 2018). It is seen that the theoretically measured light intensity per unit area is higher than the practical light intensity, but the applied lighting program also provides a sufficient limit value.

Table 3. Comparing luminous fluxes and measurements values.
Çizelge 3. Işık akısı ve ölçüm sonuçlarının karşılaştırılması.

	Measurements values	Luminous fluxes values
Number of lamp	24	16
Lighting power (watt)	36	40
Illuminance (lux)		
1st Floor	29.5	30.5
2nd Floor	29.6	31.8
3th Floor	31.1	32.1
Luminous power per unit (W m^{-2})	1.60	2.2

Figure 3 shows a monthly comparison of the data measured in the chicken house with the theoretical values determined by the luminous flux method. It was observed that the henhouse was lit with more electricity than the theoretical lighting requirement. It is also seen that the illumination in practice shows a more fluctuating course, whereas in theoretical lighting, the illumination should be monitored more steadily.

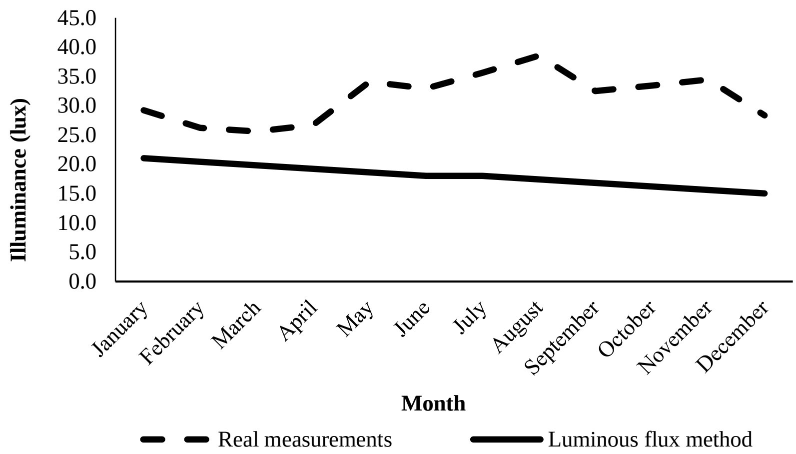

Figure 3. Comparison of theoretical and measured illumination values.
Şekil 3. Teorik ve ölçülen aydınlatma değerlerinin karşılaştırılması.

Statistical Analysis of Light Intensity Data Measured in the Henhouse

Differences between light intensities measured indoors were evaluated by analysis of variance using JMP 7.0 (SAS Institute Inc.). Seasonal, monthly, corridor and floor differences were analysed using one-way (Table 4) and multiway (Table 5) ANOVAs to determine whether they were statistically significant. Statistically significant differences (P<0.05) were found between the means indicated by different letters. The highest light intensity was measured in the autumn and winter seasons in February and November. Artificial lighting was used because natural light is not sufficient during the cold seasons when the day length is short. In addition, higher values were measured on the top floor. Windows closer to the roof provide daylight to the upstairs cage lines more effectively.

Table 4. One-way ANOVA test Statistical analysis of light intensity according to different factors.
Çizelge 4. Aydınlık şiddetinin çeşitli faktörlere göre tek yönlü Anova testi istatistiksel analizi.

Factor	Degree	Mean	Standart error	95% Confidence		Minimum	Maximum
				Lower Bound	Upper Bound		
Month	January	42.0^{abc}	15.2	12.1	71.8	0.00	244.0
	February	84.4^{ab}	18.6	47.8	120.6	1.0	761.0
	March	45.4^{bc}	11.8	22.3	68.6	2.0	163.0
	April	38.8^{c}	13.1	12.9	64.7	0.0	150.0
	May	39.7^{bc}	15.2	9.8	69.7	1.0	140.0
	June	45.7^{abc}	15.2	15.8	75.6	7.0	140.0
	July	56.7^{abc}	15.2	26.8	86.6	9.0	268.0
	August	49.2^{abc}	13.1	23.3	75.1	5.0	171.0
	September	66.5^{abc}	13.1	40.6	92.33	6.0	317.0
	October	77.5^{ab}	13.1	51.6	103.3	4.0	401.0
	November	81.0^{a}	13.1	55.1	106.8	4.0	465.0
	December	63.0^{abc}	11.8	39.9	86.2	4.0	352.0
Season	Winter	61.0^{ab}	8.3	44.7	77.3	0	761
	Spring	41.8^{b}	7.6	26.9	56.6	0	163
	Summer	50.4^{ab}	8.3	34.1	66.7	5	268
	Autumn	*75.0^{a}*	7.6	60.1	89.8	4	465
Floor	**1**	22.75^{b}	5.3	12.18	33.32	0	126
	2	21.1^{b}	5.3	10.53	31.67	1	96
	3	127.7^{a}	5.3	117.08	138.22	21	761
Corridor	**Entrance**	42.5^{b}	6.8	29.06	56.03	2	160
	Middle	62.7^{a}	6.8	49.24	76.21	0	352
	Exit	66.2^{a}	6.8	52.74	79.71	3	761

*Differences between the means indicated with different letters are statistically significant at the P<0.05 level.

The illuminance was evaluated by multiple analyses of variance by location (floor and corridor) and time (season and month). Table 5 shows that the effects of floor-season, corridor-floor and season-month-corridor-floor interactions on illuminance were statistically significant (p<0.05). As the distance of the cages from the light source varies, the illuminance varies between cage floors and blocks. It was found that there was no significant relationship between the combination effect of other sources and illuminance.

Table 5. Variation in illuminance by source.
Çizelge 5. Aydınlatma şiddetinin varyasyon kaynaklarına göre değişimi.

Source of variation	Nparm	Degress of freedom	Sum of squares	f-value	Prob>F
corridor*season	6	6	35233.03	0.9815	0.4374
tier*season	6	6	156670.11	4.3642	0.0003*
corridor*month	22	22	70974.74	0.5144	0.9677
tier * month	22	22	211070.56	1.5297	0.0613
corridor* tier	4	4	311360.53	14.0122	<.0001*
season*corridor*tier	12	12	91300.340	1.2182	0.2680
month*corridor*tier	44	44	180731.18	0.6261	0.9704
season*month*corridor*tier	132	48	485778.18	1.7579	0.0023*

*indicates that it is significant at the P<0.05 level.

Energy Consumption

The theoretically calculated energy consumption is an average of 0.64 kW h^{-1}. The energy consumption caused by the lighting program applied in the hen house was 35% higher, 0.86 kW h^{-1}. As lighting consumes more energy, an additional cost of TL 450 per month is charged to the bills.

Excessive electricity consumption not only creates a financial burden for the producer but also has negative consequences in terms of environmental sustainability. Increasing production to ensure greater consumption increases resource consumption and pressures natural resources. In addition to comparing lighting levels for production adequacy in the hen house, this study shows that lighting above adequate levels puts pressure on resource inputs and can harm environmental health. Concerning sustainable resource use, sustainable environment and sustainable agriculture, it is recommended that optimal conditions are provided and implemented where necessary to support truly sustainable development.

CONCLUSION

Factors such as the productivity and physiological movements of chickens (access to food and water, growth rates, daily rhythmic movements, etc.), production periods, and the welfare of animals and employees are affected by the lighting in the henhouse. This study was designed to calculate and compare the theoretical illumination level in a henhouse illuminated with fluorescent lamps and to evaluate the factors affecting the illumination intensity in the henhouse environment.

It has been found that the number of lamps required for the current lighting used in the hen house is higher than the number of lights that should theoretically be used. The fact that the actual lamp wattages on the farm are lower than the theory calculations will reduce the lighting level per unit of area. However, from a general point of view, it can be said that the lighting level applied in the hen house is sufficient compared to the adequacy calculated in theory.

Differences in lighting intensity according to corridors and floors are essential. Uniform lighting should be provided on the cage floors and in the corridors of the establishment. Using the correct, sufficient wattage and number of lamps is also essential. This will reduce seasonal variations and provide uniform artificial lighting. It is also necessary to clean the lights regularly, as soiling and cleaning frequency will reduce the brightness of the lamps.

CONFLICT OF INTEREST

Authors declared no conflict interest.

DECLARATION OF AUTHOR CONTRIBUTION

The authors contributed equally to the article.

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