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The Effect of Light Intensity and Temperature-Humidity Index on Egg Performance and Growth Rate in Laying Hens Raised in Different Cage Tiers*

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Abstract: The aim of this research is to evaluate the effects of light intensity and the temperature-humidity index (THI) on egg performance and growth rate in laying hens reared on different cage tiers. Additionally, the study seeks to understand the sensitivity and efficiency of chickens' comfort conditions under various climatic environmental conditions. Brown layer Hyline Brown hens were used as the animal material. In the experiment, 392 hens were housed in a total of 56 cages, with 7 hens per cage in a 4-tier cage system. During the experiment, live weights, growth rates, egg production, and egg weights of the hens were recorded and correlated with the THI and light intensity values measured in front of each cage. The results indicated that hens on the upper tiers had higher live weights, body weight gains, growth rates, egg production, and egg weights compared to those on the lower tiers. A negative relationship was found between the THI value and both growth rate and egg production. Increasing THI values negatively affected both body weight and egg production. Significant positive relationships were observed between light intensity and egg weight, egg production, and average egg production. In conclusion, environmental management and physiological factors are crucial in optimizing the performance of laying hens. Appropriate housing conditions, including optimal light intensity, and temperature management, are essential for maximizing both growth and reproductive performance. Additionally, achieving an ideal body weight at the beginning of the productive period is a crucial for egg production.
Keywords: Cage tier, egg production, growth rate, light intensity, temperature-humidity index

Farklı Kafes Katlarında Yetiştirilen Yumurtacı Tavuklarda Işık Şiddeti ve Sıcaklık-Nem İndeksinin Yumurta Performansı ve Büyüme Hızına Etkisi

Öz: Bu araştırmanın amacı, farklı kafes katlarında yetiştirilen yumurtacı tavuklarda ışık şiddeti ve sıcaklık-nem indeksinin yumurta performansı ve büyüme hızı üzerine etkilerini değerlendirmektir. Ayrıca çalışma, çeşitli iklimsel çevre koşulları altında tavukların konfor koşullarının hassasiyetini ve verimliliğini anlamayı amaçlamaktadır. Hayvan materyali olarak kahverengi yumurtacı Hyline Brown tavukları kullanıldı. Denemede 4 katlı kafes sisteminde kafes başına 7 tavuk olacak şekilde toplam 56 kafese 392 tavuk yerleştirildi. Tavukların canlı ağırlıkları, büyüme oranları, yumurta üretimleri ve yumurta ağırlıkları kaydedilerek her kafesin önünden ölçülen THI ve ışık şiddeti değerleri ile ilişkilendirildi. Araştırmada, üst kattaki tavukların canlı ağırlık, büyüme hızı, yumurta üretimi ve yumurta ağırlığı değerleri alt kattakilere göre daha yüksekti. THI değeri ile hem büyüme hızı hem de yumurta üretimi arasında negatif bir ilişki bulundu. THI değerinin artması hem canlı ağırlığı hem de yumurta üretimini olumsuz etkiledi. Işık şiddeti ile yumurta ağırlığı, yumurta üretimi ve ortalama yumurta üretimi arasında önemli pozitif ilişkiler gözlendi. Sonuç olarak, çevre yönetimi ve fizyolojik faktörler yumurtacı tavukların performansının optimize edilmesinde çok önemlidir. Optimum ışık şiddeti ve sıcaklık yönetimi de dâhil olmak üzere uygun barınma koşulları, hem büyüme hem de üreme performansını en üst düzeye çıkarmak için gereklidir. Ayrıca, üretim dönemi başında ideal canlı ağırlığa ulaşılması yumurta üretimi için çok önemlidir.
Anahtar kelimeler: Büyüme hızı, ışık şiddeti, kafes katı, sıcaklık-nem indeksi, yumurta verimi

Introduction

Chickens are sensitive to environmental conditions (Anderle et al., 2023). Therefore, understanding the optimal environmental requirements for chickens is crucial for enhancing both productivity and animal welfare (Kim and Lee, 2023; Qi et al., 2023; Küçüktopçu et al., 2024). Moreover, providing ideal environmental conditions is also vital for effective care-management and health protection practices (Qi et al., 2023). This necessitates rigorous control and monitoring of the climatic environment in poultry houses (Küçüktopçu et al., 2024).

Temperature and humidity are critical environmental conditions in poultry production (Kim et al., 2021; Amaripadath et al., 2023). As homothermic organ-

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isms, poultry must maintain a stable body temperature (Kim and Lee, 2023). The effort to regulate body temperature is directly related to the environmental temperature (Kim et al., 2021). Significant deviations in environmental temperature can cause metabolic and physiological changes aimed at preserving heat balance (Kim and Lee, 2023). The thermal comfort zone for adult chickens is reported to be 18-22°C (Pawar et al., 2016; Sarıca et al., 2018). Chickens can stabilize their body temperature at ambient temperatures between 10-27°C (the homoeothermic zone) through metabolic and physiological adjustments (Sarıca et al., 2018). Outside this range, chickens may experience hypothermia or hyperthermia, leading to yield losses, health deterioration, and even mortality (Farag and Alagawany, 2018; He et al., 2018).

Poultry exhibit greater tolerance to humidity than heat (Sarıca et al., 2018). However, humidity tolerance is influenced by temperature. Ideal humidity in poultry houses is between 40-70% (Oloyo, 2018; Sarıca et al., 2018). Low humidity can cause dust and respiratory diseases, while high humidity can lead to damp litter, increased ammonia levels, and condensation on the roof and walls during winter. In summer, high humidity combined with high temperatures impedes heat dissipation through evaporation, increases perceived temperature, and exacerbates heat stress effects (Oloyo, 2018; Kim et al., 2021; Elghardouf et al., 2023). Therefore, evaluating temperature and humidity together is crucial for maintaining an optimal environment in poultry houses. The Temperature-Humidity Index (THI) is a valuable tool for assessing the combined effects of temperature and humidity on animals (Kim and Lee, 2023; Loengbudnark et al., 2023). THI quantitatively evaluates environmental factors affecting animal health, productivity, and welfare, thereby playing a critical role in effective environmental management strategies (Shin et al., 2024). Different THI formulas exist for various animal species and environments, with values classified into normal, alert, danger, and emergency zones for poultry (Zulovich and DeShazer, 1990; Kim and Lee, 2023).

Lighting is another crucial environmental factor in poultry houses. Light stimulates ovarian activity in hens, promoting sexual maturity and egg production (Mohammed, 2019; Nega, 2024). It also influences growth, behaviour, physiological processes, and immune health (Erensoy et al., 2021; Bahuti et al., 2023). Key lighting factors include photoperiod and light intensity (Barros et al, 2020; England and Ruhnke, 2020). In extensive farming, hormonal stimulation typically occurs in spring when natural light duration is 10-12 hours, prompting egg-laying. In commercial intensive farming, a daily lighting duration of 14 hours or more is desired (Sarıca et al, 2018; Nega, 2024). Light intensity plays a crucial role in chicken welfare (Mohammed, 2019); low intensities can reduce activity levels and productivity, while high intensities can increase aggression (Mohammed, 2019; Barros et al., 2020; Erensoy et al., 2021).

Maintaining temperature balance and providing uniform illumination are essential to prevent negative environmental impacts and ensure optimal production (Küçüktopçu et al., 2024). Modern poultry houses are equipped with systems for climatic control. Despite welfare concerns, cage systems are frequently used in commercial egg production for economic and sustainability reasons (Şekeroğlu et al., 2014; Erensoy et al., 2021; Majewski et al., 2024). These cages can have 3-8 tiers (Adegbenro et al., 2023). Despite efforts to provide homogeneous environmental conditions (Sarıca et al., 2018; Özentürk and Yildiz, 2021; Özentürk et al., 2023), it is challenging to maintain uniform conditions across all cage tiers (Yildiz et al., 2006; Şekeroğlu et al., 2014; Türker et al., 2021). Therefore, understanding the environmental differences between cage tiers is crucial to ensuring equal conditions for all chickens and achieving optimal production.

This study aimed to evaluate the effects of light intensity and the Temperature-Humidity Index on egg performance and growth rate in laying hens reared in different cage tiers. Additionally, the study sought to understand the sensitivity of hens to comfort conditions and their productivity, providing insights into the climatic conditions under which hens are most productive.

Materials and Methods

The research was ethically approved by the Atatürk University Faculty of Veterinary Medicine Unit Ethics Committee (Protocol no: 2024/10, dated 28.03.2024).

Study Location and Design

The research was conducted at the Poultry Unit of Atatürk University Food and Livestock Application and Research Centre. The poultry house utilized a battery cage system with 4 tiers (numbered 4, 3, 2 and 1 from top to bottom) and 2 rows. Each tier contained 14 cage compartments, symmetrically arranged into right (7 compartments) and left (7 compartments) sides, making a total of 56 cage compartments. The right side of the cage unit faced the windows, while the left side faced the aisle. All cage compartments have identical dimensions, made of galvanized sheet and wire, allowing for light and air circulation. The 7° inclined base wires allowed eggs to roll to the egg collection band easily. The cage dimensions are as follows: depth 60 cm, width 62.5 cm, back height 46 cm, front height 51 cm, and feeder length 62.5 cm. Each cage compartment has two water nipple systems, and feed and water were provided ad libitum. Ventilation was managed via windows on the side walls, ventilation shafts on the ceiling, and a 140 cm x 140 cm electric negative pressure fan. Lighting was provided by white fluorescent lamps on the ceiling, with a lighting program of 16 hours of light and 8 hours of darkness per day.

Animal Material

The study used Hyline Brown layers. Each of the 56 cage compartments housed 7 birds, resulting in a total of 392 birds.

During the productive period, the hens were fed ad libitum with granule form feed: 1st Term egg feed at 20-45 weeks (2750 ME, 16.26% HP), 2nd Term egg feed at 46-60 weeks (2720 ME, 15.83% HP), and 3rd Term egg feed at 61-72 weeks (2720 ME, 15.65% CP).

Determination of Body Weights and Growth Rate

The hens were weighed before the production period (at 18 weeks of age) and divided into two body weight groups based on high uniformity: high body weight (≥1700 g) and low body weight (<1500 g). Starting at 24 weeks of age, body weights were measured every four weeks until 72 weeks of age, and the average weight per cage was recorded. The Gompertz growth model was used to determine the growth rate (k) using average body weights (Gonzalez Ariza et al., 2021; Mancinelli et al., 2023).

The Gompertz growth model is given by:
Wt = Wmax ((exp-b) (exp(-kt)))

The terms in the mathematical model are:

- W_t: observed weight at *t* weeks of age
- *t:* weekly age
- W_{max}: asymptotic body weight
- *b:* initial weight
- *k:* growth rate

The *W*max was determined as 2.17 and *b* as 3.43, with *k* estimated by keeping *W*max and *b* constant. The coefficient of determination (R^2) of the functions averaged 0.97 ± 0.02.

Determination of Egg Performance

Eggs from each cage were collected and recorded daily from 24 to 72 weeks of age. Weekly average egg weights were determined by weighing the eggs each week. Average daily egg production (g) per cage was calculated based on egg production and average egg weights.

Determination of Light Intensity and Temperature Humidity Index (THI)

Light intensity, temperature, and humidity values were measured in front of the cages at 09:00, 12:00, and 15:00 once a week. The average light intensity and THI values were recorded. The THI formula used was (Elshafaei et al., 2020):

$$THI=0.8T_{db} + (RH\ (T_{db}-14.3)/100) + 46.3$$

where:

- T_{db} = air dry-bulb temperature (ºC)

RH = relative humidity of air (%)

Statistical Analyses

The effects of cage side, cage tier, and body weight group on average daily egg production (g), egg yield (%), egg weight (g), body weight at the start and end of the experiment, percentage of body weight change, and growth rate (k) per cage were analyzed using the General Linear Model (GLM). Duncan multiple comparison was used for multiple comparison test. Pearson correlation was used to calculate the relationship between these values and THI and light intensity. Multiple linear regression analysis with a forward approach was used to analyze the effects of light intensity and THI on average egg production (g), egg yield (%), and growth rate (k) per cage. The variables were normally distributed and demonstrated a linear relationship. No multicollinearity was detected among the independent variables, with the highest correlation coefficient being r = 0.572. The collinearity was further assessed using the Variance Inflation Factor (VIF), which ranged from 1.195 to 1.959. The standardized residuals fell within the acceptable range, with the lowest value being -2.204 and the highest 1.911. Additionally, the errors of the estimates were normally distributed. For regression analysis, the assumptions of collinearity, VIF, and normal distribution of errors were verified. Statistical analyses were performed using SPSS software.

Results

Temperature and humidity values were measured in front of each cage and THI value and light intensity were determined for each cage (Table 1). The light intensity was higher on the window side and on the upper tiers. The average THI value was 72.36 (min: 71.60- max 73.17) and the THI values of the aisle side and middle (2 and 3) tiers were found to be higher.

Table 1. Light intensity and THI values of the cage tiers

		Light intensity (lux)			THI		
			95% Confidence Interval			95% Confidence Interval	
Cage side	**Cage tier**	**Mean**	**Lower Bound**	**Upper Bound**	**Mean**	**Lower Bound**	**Upper Bound**
Window	**Tier 4**	460.66	434.194	487.134	71.95	71.753	72.148
	Tier 3	225.61	199.140	252.080	71.97	71.777	72.171
	Tier 2	108.52	82.053	134.993	72.00	71.803	72.197
	Tier 1	62.52	36.053	88.993	72.07	71.870	72.264
Aisle	**Tier 4**	106.52	80.046	132.986	72.64	72.447	72.841
	Tier 3	78.80	52.333	105.273	72.86	72.662	73.056
	Tier 2	52.39	25.923	78.863	72.80	72.604	72.998
	Tier 1	37.05	10.576	63.516	72.56	72.360	72.754
	SEM	13.16			0.10		

The average egg production (g), egg yield (%), and average egg weight (g) values according to cage tier, cage side and body weight groups are presented in Table 2. The highest average egg weight was obtained from hens reared on the upper tiers (P<0.01). Egg yield was lower in the hens reared on the lower tier (P<0.05). For average daily egg production (g) per hen, which is a function of average egg weight

Table 2. Mean egg production (g), egg yield (%), and egg weight (g) values of the groups (x̄ +SE)

Cage side	Cage tier	Body weight group	Average egg production (g)	Egg yield (%)	Average egg weight (g)
Window	**Tier 4**	**High**	57.32±0.98	87.61±0.71	65.27±0.49
		Low	56.63±0.85	86.19±0.67	64.94±0.47
	Tier 3	**High**	55.93±0.97	86.75±0.71	63.65±0.49
		Low	53.46±0.86	85.33±0.68	63.32±0.47
	Tier 2	**High**	53.91±0.98	86.12±0.71	63.48±0.49
		Low	53.87±0.85	84.71±0.67	63.15±0.47
	Tier 1	**High**	53.44±1.00	84.67±0.71	63.06±0.49
		Low	51.30±0.84	83.26±0.67	62.73±0.47
Aisle	**Tier 4**	**High**	56.03±0.85	87.62±0.67	65.57±0.47
		Low	56.76±0.98	86.21±0.71	65.24±0.49
	Tier 3	**High**	56.09±0.85	86.76±0.67	63.95±0.47
		Low	53.15±0.98	85.35±0.71	63.62±0.49
	Tier 2	**High**	54.12±0.85	86.13±0.67	63.78±0.47
		Low	54.71±0.98	84.72±0.71	63.45±0.49
	Tier 1	**High**	54.77±0.86	84.68±0.68	63.36±0.47
		Low	52.40±0.97	83.27±0.70	63.03±0.49
	Tier 4		56.69±0.46[a]	86.91±0.56[a]	65.25±0.39[a]
	Tier 3		54.66±0.46[b]	86.05±0.56[a]	63.64±0.39[b]
	Tier 2		54.15±0.46[bc]	85.42±0.56[ab]	63.47±0.39[b]
	Tier 1		52.98±0.46[c]	83.97±0.56[b]	63.05±0.39[b]
		High	55.20±0.33	86.29±0.40	64.02±0.28
		Low	54.04±0.33	84.88±0.40	63.68±0.28
			P Value		
			Average egg production (g)	**Egg yield (%)**	**Average egg weight (g)**
Cage side			0.562	0.984	0.447
Cage tier			<0.001	0.020	0.001
Body weight group			0.011	0.013	0.402

[a-c]: Different letters within one column are significantly different (P<0.05).

and yield, the lowest values were obtained from hens reared on the 1st and 2nd tier, followed by the 3rd tier, with the highest egg production observed in hens reared on the 4th tier (P<0.001). No significant difference was observed in egg production and egg weight in hens reared on the window and aisle sides (P>0.05). Although hens from different body weight groups produced eggs with similar weights, hens with lower body weight had lower egg production (P<0.05), resulting in fewer eggs throughout their production life in terms of average egg production (g) (P<0.05).

Growth rate and body weight values according to cage tier, cage side and body weight groups are presented in Table 3. The hens that started the laying period with low body weight had lower body weight at the end of the period (P<0.001). The rate of weight gain was higher in the hens with low body weight (P<0.001). During this period, it was observed that hens with low body weight performed compensatory growth. The k value of the hens in the high body weight group was calculated as higher because they reached the targeted weight faster (P<0.001). The rate of weight gain (P<0.05) and k value (P<0.01) of the hens reared on the upper tiers were determined to be the highest. The final body weight (P<0.001), weight gain rate (P<0.001) and k value (P<0.05) of the hens reared on the window side were lower (P<0.001).

The correlation coefficients between light intensity and THI with egg production and growth characteristics are given in Table 4. There was a moderate negative correlation (r=-0.399) between THI value and growth rate (k) (P<0.01). It was determined that those with higher body weight at the beginning of the experiment had higher egg production (r=0.552; P<0.01), therefore those with higher k value had higher egg production (r=0.582; P<0.01). It was determined that the average egg weight (r=0.531), egg yield (r=0.500) and therefore the average egg production per cage (r=0.572) increased with increasing light intensity (P<0.01). The increase in THI value caused a decrease in egg production (r = -0.268) as well as k value (P<0.05).

Table 3. Growth rate and body weight values of the groups ($\bar{x}$ +SE)

Cage side	Cage tier	Body weight group	Initial body weight (g)	Final body weight (g)	Weight gain rate (%)	Growth rate (k value)
Window	Tier 4	High	1728.82±12.16	2210.02±28.75	29.39±1.77	0.152±0.003
		Low	1398.81±14.04	2087.05±30.17	50.26±1.86	0.116±0.003
	Tier 3	High	1693.39±12.16	2160.84±28.75	27.43±1.77	0.144±0.003
		Low	1372.33±14.04	2037.86±30.17	48.31±1.86	0.108±0.003
	Tier 2	High	1672.14±12.16	2108.13±28.75	24.72±1.77	0.142±0.003
		Low	1376.90±14.04	1985.16±30.17	45.60±1.86	0.106±0.003
	Tier 1	High	1689.64±12.16	2076.78±28.75	23.04±1.77	0.143±0.003
		Low	1336.19±14.04	1953.81±30.17	43.92±1.86	0.107±0.003
Aisle	Tier 4	High	1700.05±14.04	2341.83±30.17	36.62±1.86	0.157±0.003
		Low	1392.29±12.16	2218.86±28.75	57.50±1.77	0.121±0.003
	Tier 3	High	1699.76±14.04	2292.65±30.17	34.67±1.86	0.149±0.003
		Low	1395.75±12.16	2169.67±28.75	55.54±1.77	0.113±0.003
	Tier 2	High	1706.67±14.04	2239.94±30.17	31.96±1.86	0.147±0.003
		Low	1385.89±12.16	2116.97±28.75	52.83±1.77	0.111±0.003
	Tier 1	High	1701.19±14.04	2208.60±30.17	30.27±1.86	0.148±0.003
		Low	1396.54±12.16	2085.62±28.75	51.15±1.77	0.112±0.003
	Tier 4		1555.80±6.87	2214.44±23.98^{a}	43.44±1.48^{a}	0.137±0.002^{a}
	Tier 3		1540.92±6.87	2165.26±23.98^{ab}	41.50±1.48^{ab}	0.128±0.002^{b}
	Tier 2		1534.49±6.87	2112.55±23.98^{bc}	38.78±1.48^{b}	0.127±0.002^{b}
	Tier 1		1532.63±6.87	2081.20±23.98^{c}	37.10±1.48^{b}	0.127±0.002^{b}
		High	1699.52±4.89	2204.85±17.04	29.78±1.05	0.148±0.002
		Low	1382.40±4.89	2081.88±17.04	50.64±1.05	0.112±0.002
P Value						
			Initial body weight (g)	**Final body weight (g)**	**Weight gain rate (%)**	**Growth rate (k value)**
Cage side			0.053	<0.001	<0.001	0.027
Cage tier			0.085	0.001	0.019	0.006
Body weight group			<0.001	<0.001	<0.001	<0.001

$^{a-c}$: Different letters within one column are significantly different (P<0.05).

Table 4. Relationship between egg production and growth characteristics with light intensity and THI

	Growth rate (k)	Weight gain rate (%)	Initial body weight (g)	Final body weight (g)	Avg. egg weight (g)	Egg yield (%)	Avg. egg produc-tion (g)	Light intensity (lux)
Weight gain rate (%)	-0.631**							
Initial body weight (g)	0.922**	-0.810**						
Final body weight (g)	0.638**	0.090	0.510**					
Average egg weight (g)	0.222	0.021	0.213	0.388**				
Egg yield (%)	0.582**	-0.288*	0.552**	0.515**	0.647**			
Average egg produc-tion (g)	0.432**	-0.137	0.410**	0.493**	0.919**	0.896**		
Light in-tensity (lux)	0.140	-0.082	0.091	0.042	0.531**	0.500**	0.572**	
Total THI	-0.399**	0.645**	-0.454**	0.164	-0.025	-0.268*	-0.155	-0.487**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The coefficient of determination of the multiple regression model for growth rate (k value) was calculated as 0.499. In the model, the beta coefficient (b) of egg yield to growth rate was 0.007 and the coefficient of THI value was -0.012 (Table 5).

Table 6 shows the result of multiple regression analysis for daily egg production (R^2 =0.544). It was determined that light intensity, k and THI values were effective on average daily egg production.

Table 5. Estimated parameter and significance levels in multiple linear regression analysis for k value

Predictor	Coefficient	SE of coefficient	t	P-value
Constant	0.349	0.413	0.844	0.402
Egg yield	0.007	0.002	4.646	<0.001
THI	-0.012	0.005	-2.375	0.021

R^2= 0.499

Table 6. Estimated parameter and significance levels in multiple linear regression analysis for average egg production (g) value

Predictor	Coefficient	SE of coefficient	t	P-value
Constant	-18.432	10.986	-1.678	0.099
Light intensity (lux)	0.003	<0.001	6.375	<0.001
Growth rate (k)	13.945	2.950	4.727	<0.001
THI	0.478	0.149	3.202	0.002

R^2= 0.544

In the multiple regression model for egg yield (R^2 = 0.250) and average egg weight (R^2 = 0.354), light intensity was found to be the effective factor (Tables 7 and 8).

Table 7. Estimated parameter and significance levels in multiple linear regression analysis for egg yield (%) value

Predictor	Coefficient	SE of coefficient	t	P-value
Constant	84.874	0.234	362.800	<0.001
Light intensity (lux)	0.005	0.001	4.247	<0.001

R^2= 0.250

Table 8. Estimated parameter and significance levels in multiple linear regression analysis for average egg weight (g) value

Predictor	Coefficient	SE of coefficient	t	P-value
Constant	5.415	23.857	0.227	0.821
Light intensity (lux)	0.006	0.001	5.384	<0.001

R^2= 0.354

Discussion and Conclusion

The results indicate a significant effect of cage tier on body weights. Hens on the top tier exhibited the highest final body weights, while those on the bottom tier had the lowest. Consequently, the body weight gain rate and growth rate were higher for hens on the upper tier. There was also a notable difference between cage sides in terms of body weight gain. Similarly, Karaman et al. (2013) reported body weight gains of 8.81%, 11.06%, and 15.39% for tiers 1, 2, and 3, respectively, with a significant difference among tiers (Karaman et al., 2013). Sogunle et al. (2022) also noted higher body weight gain in chickens on the upper tier, although this was not statistically significant (Sogunle et al., 2022). This may be attributed to the higher feed intake observed in chickens on the upper tier (Adegbenro et al, 2023). Natural lighting, which can affect appetite and feeding behaviour, is more abundant on the top tier, potentially promoting feed intake and growth (Sogunle et al., 2022). Factors such as temperature, light intensity, ventilation, and stress levels may contribute to body weight differences between cage tiers and sides (Erensoy et al., 2021; Adegbenro et al., 2023). Upper tiers typically benefit from better temperature and ventilation conditions, while cages facing windows receive more natural light and potentially better airflow (Yildiz et al., 2006; Karaman et al., 2013). These conditions likely contribute to the higher growth rates and body weights in chickens on the upper tiers and window-facing sides of the cage units. Conversely, Şekeroğlu et al. (2014) found lower body weights on upper tiers compared to lower tiers at 30 weeks of age, though no significant difference was noted at 42 weeks (Şekeroğlu et al., 2014). Other studies have reported no significant differences in live weight between tiers at various ages (Onbaşılar and Aksoy, 2005). The experiment also revealed significant differences between body weight groups in terms of growth rate. Hens starting the yield period with higher body weight had a 29.78% weight gain, whereas those starting with lower body weight experienced a 50.64% weight gain, indicating compensatory growth in the lower weight group.

Differences in egg production and egg weight were observed between cage tiers, with the top tier yielding higher egg production and weight, and the lowest values recorded for hens on the bottom tier. These findings align with previous studies indicating that hens on the top tier produce more eggs than those on the bottom tier (Yildiz et al., 2006; Türker et al., 2021; Sogunle et al., 2022; Adegbenro et al., 2023). The better light illumination in upper tiers likely stimulates egg production through hormonal mechanisms. Additionally, environmental factors such as temperature, ventilation, and stress levels may influence these differences (Akkuş and Yıldırım, 2018; Adegbenro et al., 2023). Hens on upper tiers benefit from optimal environmental conditions, enhancing metabolic activity and hormonal regulation, leading to higher egg production and greater egg weight (Karaman et al., 2013; Eleroğlu, 2019; Erensoy et al, 2021). In contrast, sub-optimal conditions in lower tiers may reduce productivity and egg weight. Some studies, however, reported no effect of cage tiers on egg production (Durmuş and Kamanlı, 2012; Sahin, 2012; Karaman et al., 2013; Şekeroğlu et al., 2014). Yıldırım et al. (2008) noted a negative impact of excessive light intensity on egg production, highlighting the importance of optimal lighting conditions (Yıldırım et al., 2008). Consistent with our results, Dereli Fidan and Nazlıgül (2012) observed that egg weight was significantly influenced by cage tier, with the highest weights recorded on the top and middle tiers (Dereli Fidan and Nazligul, 2012). Similarly, Onbaşılar and Aksoy (2005) found higher egg weights on the top tier compared to the bottom tier (Onbaşılar and Aksoy, 2005). Eleroğlu (2019) also reported higher egg weights from the upper tier at 24 week of age (Eleroğlu, 2019). However, some studies found no difference in egg weights across cage tiers (Yıldırım et al., 2008; Durmuş and Kamanlı, 2012; Sahin, 2012; Karaman et al., 2013; Şekeroğlu et al., 2014; Türker et al., 2021; Sogunle et al., 2022; Adegbenro et al., 2023).

In our study, the cage side did not significantly affect egg production or egg weight. Sahin (2012) also found no significant differences in these parameters between window-facing and aisle-facing cages (Sahin, 2012). However, Yildiz et al. (2006) reported heavier eggs from window-facing hens, possibly due to increased light intensity (Yildiz et al., 2006). Variations in study results regarding the effect of cage tiers on egg production, egg weight, and body weight are often attributed to differing environmental conditions such as light, temperature, humidity, and ventilation (Karaman et al., 2013; Akkuş and Yıldırım, 2018; Eleroğlu, 2019; Erensoy et al., 2021; Türker et al., 2021). However, the relationship between these conditions and performance parameters remains inconsistent in the literature.

In our study, THI values, calculated from temperature and humidity data, averaged 72.36 (range: 71.60-73.17), with higher values on the aisle side and middle tiers. The THI chart classifies stress into four levels: comfort (THI < 70), alert (THI 70–75), danger (THI 76–81), and emergency (THI > 81) zones (Zulovich and DeShazer, 1990; Kim and Lee, 2023). These THI values fall into the alert category (THI 70-75), indicating potential heat stress. A moderate negative correlation between THI and growth rate and a negative correlation between THI and egg production were observed, suggesting that higher THI negatively impacts body weight and egg production. Multiple regression models explained 49.9% of the variability in growth rate and 54.4% of the variability in egg production, indicating moderate to high predictability. High THI levels challenge thermoregulation in hens, leading to heat stress and various physiological disturbances (Amaripadath et al., 2023; Kim and Lee, 2023; Loengbudnark et al., 2023; Shin et al., 2024). These disturbances reduce feed intake, impair nutrient absorption, cause hormonal imbalances, and decrease metabolic efficiency (Kim et al., 2021; Elghardouf et al., 2023). Consequently, hens experience slower growth rates and reduced egg production. Temperature and humidity differences between cage tiers were also significant, with higher temperatures and humidity recorded in the middle tier (Kılıç and Şimşek, 2008; Eleroğlu, 2019). These environmental variations may explain differences in egg performance and quality (Akkuş and Yıldırım, 2018).

Light intensity significantly influenced egg weight, egg yield, and average egg production. It emerged as a key factor in multiple regression models for both egg production and average egg weight. Light intensity regulates photoperiod, affecting reproductive hormones in poultry (England and Ruhnke, 2020; Erensoy et al., 2021). Adequate light intensity ensures proper secretion of hormones essential for ovulation and egg production, such as LH and FSH, leading to increased egg production and egg size (Bahuti et al., 2023). Proper light intensity also promotes feeding, providing necessary nutrients for egg formation (Adegbenro et al., 2023; Nega, 2024) and helps maintain the circadian rhythm, essential for optimal laying cycles (Saad et al., 2024). These factors might explain the relationship between light intensity, egg production, and egg weight observed in the study. Studies support that, variations in lighting conditions between cage floors and blocks, due to proximity to light sources, can affect performance (Yildiz et al., 2006; Kılıç and Şimşek, 2008; Karaman et al., 2013; Erensoy et al., 2021). Light intensity did not affect the growth rate of the chickens. This may be because the chickens were already in the laying period, where the physiological and hormonal effects of light intensity are aimed at reproduction rather than growth.

Higher body weights at the start of the experiment were correlated with higher egg production, indicating that hens with higher growth rates also had higher egg production. This is consistent with another study linking body weight to egg weight and production (Durmuş and Kamanlı, 2012). Higher body weights may reflect better nutrient reserves, physiological maturity, and advantageous genetics, contributing to increased egg production. Additionally, efficient feed conversion and metabolic health in hens with higher growth rates may result in higher egg production. A significant positive correlation between egg production and egg weight was observed, indicating efficient resource allocation and hormonal regulation. This finding contradicts another study, which reported a negative relationship between these parameters (Durmuş and Kamanlı, 2012).

In conclusion, this study has shown that pullets failing to achieve the required growth rates before the laying period exhibit lower yields during production periods. Therefore, improved management practices are necessary to achieve optimal growth targets during the pullet phase. Despite efforts to maintain controlled environmental conditions for laying hens, similar conditions are not always present in all cages due to the influence of light from windows and ventilation systems. Consequently, block trial designs should be employed in scientific studies to account for these variations. Although the THI showed minor variations throughout the poultry house, it significantly impacted the growth of the chickens. High THI resulted in slower growth, likely due to less efficient feed utilization, and led to decreased egg production in smaller hens. More efficient use of ventilation systems can substantially increase productivity in multiple ways. Appropriate housing conditions encompassing optimal light intensity, ventilation, and temperature management are essential for maximizing both growth and reproductive performance. Addressing these factors allows poultry producers to enhance the productivity and welfare of their flocks, ultimately leading to improved overall performance and economic benefits.

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