



# The Difference in Lighting Duration on Broiler Chicken Production and Carcass Quality

Dwi Khonitan<sup>1</sup>, Bambang Ariyadi<sup>1\*</sup>, and Nanung Danar Dono<sup>1</sup>

<sup>1</sup> Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia  
\*bambang.ariyadi@ugm.ac.id

**Abstract.** Lighting significantly influences broiler chicken growth and feed efficiency. This study evaluated four lighting durations: P0 = control (24 hours), P1 = 18-hour program, Intermittent Program 1, and Intermittent Program 2. Key parameters measured were mortality, feed conversion ratio (FCR), harvest tonnage, and performance index. Results showed significant impacts of lighting duration on all parameters. P0 had 3.87±0.48% mortality, 1.68±0.01 FCR, 40±0.49 tons harvest tonnage, and 291±10.30 performance index. P1 showed 3.94±0.10% mortality, 1.71±0.02 FCR, 40±0.27 tons harvest tonnage, and 357±5.21 performance index. P2 had 4.80±1.18% mortality, 1.53±0.03 FCR, 52±0.50 tons harvest tonnage, and 388±0.67 performance index. P3 had the best results with 1.54±0.60% mortality, 1.43±0.04 FCR, 49±1.08 tons harvest tonnage, and 407±4.10 performance index. Statistical analysis (P-value < 0.05) confirmed significant effects of lighting duration on all parameters. With a P-value of 0.000, carcass quality improved significantly, showing no bruising, making the meat suitable for export. Proper lighting management enhances broiler production and carcass quality.

**Keywords:** Lighting, Broiler Chicken, Production, Carcass Quality.

## 1 Introduction

The optimization of lighting duration in broiler chicken production has been a subject of extensive research due to its significant impact on both production efficiency and carcass quality. Light, as a critical environmental factor, influences various physiological and behavioral responses in broilers, ultimately affecting their growth performance and welfare. This article aims to explore the differences in lighting duration on broiler chicken production and carcass quality, building upon previous findings and examining the implications for poultry management practices.

Lighting duration and intensity have been shown to play a crucial role in broiler welfare and productivity. The importance of tailored lighting programs to enhance the overall performance and well-being of broilers, highlighting that inappropriate lighting can lead to stress and suboptimal growth conditions [1]. Furthermore, Asih et al. [2] demonstrated that increased environmental complexity, including optimized lighting conditions, can improve leg health and reduce fearfulness in broilers, suggesting that lighting adjustments can contribute to better welfare outcomes.

© The Author(s) 2025

I. Novianti et al. (eds.), *Proceedings of the 5th International Conference on Environmentally Sustainable Animal Industry (ICESAI 2024)*, Advances in Biological Sciences Research 45,

[https://doi.org/10.2991/978-94-6463-670-3\\_14](https://doi.org/10.2991/978-94-6463-670-3_14)

Several studies have focused on the relationship between lighting programs and leg health in broilers. Rault et al. [3] reviewed the etiology and pathology of leg weakness, underscoring the necessity of appropriate lighting to prevent such conditions and ensure healthy development. Similarly, Onbasilar et al. [4] found that nutrient density and photoperiod significantly affect skeletal quality and walking ability, further supporting the need for well-designed lighting schedules in broiler production.

The impact of different photoperiods on broiler performance and carcass quality has been extensively documented. Cox et al. [5] explored the effects of varying photoperiods and stocking densities, noting significant improvements in fattening performance and carcass quality with optimized lighting conditions. Baykalir et al. [6] also reported that appropriate photoperiod length and light intensity can enhance welfare criteria, carcass characteristics, and meat quality in broilers.

Moreover, Briketr elt al. [7] investigated the combined effects of light programs, bird densities, and litter types on broiler welfare, concluding that proper lighting is essential for maintaining high welfare standards and productive efficiency. The prevalence and prevention of leg disorders in broilers, as studied by Knowles et al. [8] further highlight the critical role of lighting in managing these health issues and promoting overall productivity.

Research by Ahmed et al. [9] found that photoperiodic responses affect tibial breaking strength and ash content in broilers, suggesting that adjusting lighting can improve skeletal health. Studies by Blatchford et al. [10,11] and Ghanima [12] show that intermittent lighting and varying light periods can influence broiler performance, carcass quality, and stress. Lighting programs, with durations ranging from 8 to 16 hours per day, impact welfare and productivity. Intermittent lighting, typically with 1–4 hours of light followed by equal or longer dark periods, helps reduce stress and aggression, improving welfare. Light intensity also plays a key role, as higher intensity can cause aggression, while lower intensity can enhance comfort. Therefore, managing both the duration (8–16 hours) and intensity of light is important for better broiler welfare, behavior, and productivity.

Additionally, studies have explored the effects of melatonin and lighting programs on broiler performance. Fidan et al. [13] found that certain lighting programs can reduce leg problems without compromising performance or yield. Bizeray et al. [14] investigated the role of melatonin in mitigating heat stress and enhancing immune responses, indicating the potential benefits of integrating lighting and hormonal treatments. In summary, the current literature underscores the importance of optimizing lighting duration in broiler production to achieve improved performance and carcass quality. This study aims to provide further insights into the specific effects of different lighting durations, contributing to the development of best practices in broiler management.

## **2 Materials and Methods**

### **2.1 Time and Location of Research**

The research was conducted at Jemparing Farm, PT. Semesta Mitra Sejahtera (SMS), located in Jombang Regency, East Java Province. The study period was from October

10, 2023, to April 10, 2024. The study required a total duration of 152 days due to several phases beyond broiler management. Broiler rearing was conducted for 40 days per repetition, repeated three times, totaling 120 days. Between each repetition, activities such as cage cleaning and preparation took 14 days. After the rearing phase, one week was allocated for data processing, followed by 11 days for consultation and revisions with the supervisor. These phases were essential to ensure the smooth progress of the study, resulting in a total duration of 152 days.

## 2.2 Time and Location of Research

**Equipment.** The study utilized a closed house poultry housing system with dimensions of 120 meters by 12 meters. The walls of the house were made of cement, and it was equipped with eight fans/blowers for ventilation. Additionally, the house was fitted with a vento machine for automatic environmental control within the enclosure. A Jandever brand scale with a capacity of 100 kg was used to weigh the broilers at harvest. The housing was also equipped with two heaters with a capacity for 10,000 birds to maintain warmth during the brooding period, and a lux meter to measure light intensity.

**Subjects.** The study involved 75,000 CP707 grade B3 broiler chickens, each one day old at the start, divided into three enclosures with 25,000 birds per enclosure. The chickens had an average initial body weight of 39 grams and were raised for 40 days until harvest. The feeding regimen was divided into three phases: S00 feed at 400 g per bird for days 1 to 7, S11 feed at 600 g per bird for days 8 to 21, and S12G feed with adjusted doses until the birds reached market weight. The controlled feeding ensured the birds received the appropriate nutrients at each growth stage. The total feed required for one repetition of the study was 21,000 kg of S00 feed, 31,500 kg of S11 feed, and adjusted quantities for S12G. For three repetitions, the total feed amounts to 63,000 kg of S00, 94,500 kg of S11, and the necessary amount of S12G (ad libitum). The standards set by Charoen Pokphand Guideline then the approach likely follows their established nutritional guidelines and management protocols for broiler feeding.

**Research Methodology.** The research was carried out in two main stages:

1. **Observation Stage:** This stage involved monitoring the broiler chickens under a lighting program that included specific durations and intensities of light from the brooding period until three days before the major harvest.
2. **Data Collection and Analysis Stage:** During this stage, data were collected and analyzed, encompassing mortality rates, feed conversion ratios, harvest tonnage, production performance, and carcass quality of the broiler chickens.

The collected data were analyzed to evaluate the effectiveness of the lighting program on the production performance of broiler chickens, including the specified parameters.

### 2.3 Experiment Design

The study employed a completely randomized design (CRD) with four treatment groups based on varying lighting duration P0 (24-hour lighting): continuous lighting throughout the day, P1 (18-hour lighting): 18 hours of light followed by 6 hours of darkness, and P2 and P3 as described in Table 1.

**Table 1.** Lighting program duration P2 and P3

Day	P2			P3			Watt
	Lighting		Duration Off	Lighting		Duration Off	
	Off	On		Off	On		
1-3	00.00	24.00	0	00.00	24.00	0	9
4-5	01.00	23.00	1	01.00	23.00	1	9
6-10	02.00	22.00	2	02.00	22.00	2	9
11-13	03.00	20.00	5	03.00	20.00	5	9
14-17	04.00	19.00	7	03.00	20.00	5	5
18-20	03.00	21.00	6	03.00	23.00	2	3
21-39	02.00	22.00	2	02.00	24.00	1	3

Each treatment group was kept in distinct, identical rearing cages to prevent any possibility of cross-contamination. Automated light timers were utilized to guarantee accurate compliance with the designated lighting durations.

**Production.** Here are some key indicators used to evaluate the performance of broiler production during the rearing period. These indicators include the mortality rate, feed conversion ratio, harvest tonnage, and performance index, each of which is calculated using the following formulas [28]:

*Mortality Rate (MR).* Mortality rate is calculated to assess the percentage of broilers that died during the rearing period. The formula used is:

$$\text{Mortality Rate (\%)} = (\text{Number of Dead} / \text{Total Number of Broilers at Start}) \times 100 \quad (1)$$

*Feed Conversion Ratio (FCR).* Feed Conversion Ratio is a measure of the efficiency with which the broilers convert feed into body mass. The formula is:

$$\text{FCR} = \text{Total Feed Consumed (kg)} / \text{Total Weight Gain (kg)} \quad (2)$$

*Harvest Tonnage (HT).* Harvest tonnage represents the total weight of broilers harvested at the end of the rearing period. The formula for calculating tonnage is:

$$\text{Harvest Tonnage (kg)} = \text{Total Number of Harvested} \times \text{Average Body Weight (kg)} \quad (3)$$

*Performance Index (IP)*. The Performance Index (IP) is used to evaluate the overall performance of broiler production, taking into account factors like FCR, mortality rate, and average daily gain. The formula is:

$$IP = \text{Livability (\%)} / \text{FCR} \times \text{Average Daily Gain (g/day)} \quad (4)$$

Where:

- *Livability (%)* =  $100 - \text{Mortality Rate (\%)}$

- *Average Daily Gain (g/day)* =  $\text{Total Weight Gain (g)} / \text{Days of Rearing}$

**Quality of Carcass.** In addition to evaluating production performance, it is important to assess the quality of the broiler carcasses, which includes factors such as injuries and uniformity in body weight. These aspects help determine the overall quality and consistency of the broiler products after harvest. Both at 26 and 30 days of age, sampling is carried out to observe these quality parameters, as these ages are considered standard for broilers intended for export. Lesions on the breast, wings, and thighs are important for carcass quality assessment in export because they can affect the acceptance of products in international markets. Many importing countries, such as the European Union and the United States, have strict standards regarding cleanliness, food safety, and the physical appearance of carcasses. Lesions can indicate poor handling, increase the risk of pathogen contamination, and reduce the visual appeal and taste of the meat, which in turn can lower market value and lead to product rejection. Therefore, maintaining carcasses free from lesions is crucial to meet export quality standards and ensure acceptance in global markets. The following formulas are used to analyze these factors [16]:

*Number of Injuries on Broiler Carcasses.* To analyze the number of injuries on broiler carcasses, the data collected is expressed as the percentage of injured broilers out of the total broilers processed:

$$\text{Injury Rate (\%)} = (\text{Number of Injured Broilers} / \text{Total Number of Broilers Processed}) \times 100 \quad (5)$$

*Harvest Uniformity (Uniformity Index).* Uniformity in broiler harvest is assessed to determine the consistency in the body weight of the broilers. The Uniformity Index is calculated as:

$$\text{Uniformity Index (\%)} = (\text{Number of Broilers within Target Weight Range} / \text{Total Number of Broilers Harvested}) \times 100 \quad (6)$$

**ANOVA Analysis.** Analysis of variance (ANOVA) is performed to determine whether there are statistically significant differences between the means of different treatment groups. In this study, a one-way ANOVA is conducted with 3 repetitions and 4 treatments. Statistical analysis with SPSS version 25.0.

### 3 Results

#### 3.1 Production

Lighting represents a critical element in production management, particularly in the maintenance of livestock or plants. Proper lighting can influence various physiological aspects, including feeding behavior, growth, and overall organism welfare. In the context of production, the effective use of lighting can enhance the efficiency of the entire production system. This study aims to evaluate the impact of different lighting program durations on key production parameters, namely Mortality rate (MR), Feed Conversion Ratio (FCR), Harvest Tonnage (HT), and Production Index (IP).

This research was conducted using four treatment groups, each subjected to different lighting durations. The evaluation was carried out to assess how variations in lighting duration could influence mortality rates, feed efficiency, harvest productivity, and the production index. The findings from this study are expected to provide clearer guidance on the optimal lighting duration to enhance productivity and production efficiency while reducing mortality rates within the maintenance system under investigation.

In this study, the Production Index (IP) emerged as a critical parameter measured, as it reflects the overall efficiency of the implemented lighting program. Along with Mortality, FCR, and Harvest Tonnage, IP provides a comprehensive overview of the treatment's success in improving efficiency and productivity. Through careful analysis of these research findings, valuable information is anticipated to aid decision-making in lighting management within the livestock sector. The treatment results different program lighting in production are presented in Table 2.

**Table 2.** The effect of giving different program lighting in production<sup>1</sup>.

Treatment	Variables <sup>2</sup>			
	MR (%)	FCR	HT (tons)	IP
P0	4.80±1.18 <sup>b</sup>	1.68±0.01 <sup>c</sup>	40±0.49 <sup>a</sup>	291±10.30 <sup>a</sup>
P1	3.94±0.10 <sup>b</sup>	1.71±0.02 <sup>c</sup>	40±0.27 <sup>a</sup>	357±5.21 <sup>b</sup>
P2	3.87±0.48 <sup>b</sup>	1.53±0.03 <sup>b</sup>	52±0.50 <sup>c</sup>	388±0.67 <sup>c</sup>
P3	1.54±0.60 <sup>a</sup>	1.43±0.04 <sup>a</sup>	49±1.08 <sup>b</sup>	407±4.10 <sup>d</sup>
SEM	0.40	0.03	1.62	13.36
P-value	0.003	0.000	0.000	0.000

<sup>1</sup>Data were presented as mean ± standard deviation from five replicates with each replicate consisted of five lightning programs

<sup>2</sup>MR: mortality rate, FCR: feed conversion ratio, HT: harvest tonnage, IP: production index

<sup>a-d</sup>Uncommon superscript indicates a significant difference ( $P < 0.05$ )

**Mortality Rate (MR).** The highest Mortality Rate (MR) was observed in treatment P2 at 4.80%, indicating that the lighting duration applied in P2 was not optimal for maintaining the health and well-being of the broiler chickens. Excessive or inappropriate lighting can induce stress in chickens, potentially disrupting their circadian rhythms. This imbalance can lead to increased susceptibility to diseases, reduced sleep quality, and metabolic disturbances, all of which contribute to higher mortality rates. The conditions suggest that the lighting duration in P2 may not have provided sufficient time for the chickens to rest and recover, thereby increasing the risk of mortality.

In contrast, P3 demonstrated the lowest MR, at 1.54%, indicating that the lighting duration applied in P3 was more aligned with the physiological needs of the broiler chickens, thereby better supporting their well-being. The appropriate lighting in P3 likely allowed the chickens sufficient rest time, reduced stress levels, and supported optimal physiological functioning, thereby lowering mortality rates. A balanced lighting duration, as applied in P3, is crucial for maintaining the health of the chickens and preventing excessive stress.

The different superscripts (a, b) in the table indicate significant differences between the treatment groups. This finding is further reinforced by a P-value of 0.003, which signifies that the differences in mortality rates between the treatments are statistically significant. This means that variations in lighting duration have a tangible impact on the mortality rates of broiler chickens, rather than being due to random factors. To provide a broader perspective, these findings are consistent with results from other studies. Kim et al. [17] found that excessively long lighting durations, more than 18 hours per day, can increase stress in broiler chickens, leading to higher mortality rates. They concluded that excessive lighting disrupts the chickens' natural rest patterns, reduces sleep time, and increases the risk of fatigue and disease. This research supports the observation that the lighting duration in P2 might have been too long or inappropriate, leading to increased mortality.

Additionally, Karakaya et al. [18] reported that gradually reducing lighting duration during the rearing period can lower mortality rates in broiler chickens. Their study indicated that optimized lighting provides the chickens with sufficient rest, which is essential for physiological recovery and stress reduction. This finding aligns with the results observed in P3 in the present study, where a more optimal lighting duration successfully reduced mortality.

Research by Alvino et al. [19] also supports these findings. They found that a combination of low light intensity with moderate lighting duration (16 hours of light, 8 hours of darkness) resulted in the lowest mortality rates in broiler chickens. Moderate lighting provides an ideal balance between activity and rest, which is crucial for the health and productivity of broiler chickens. Overall, the results of this study are consistent with the existing literature, which indicates that optimal lighting duration is critical for reducing mortality and improving the well-being of broiler chickens. Other studies have shown that inappropriate lighting, whether too long or too short, can increase stress and mortality rates.

**Feed Conversion Ratio (FCR).** FCR is a key indicator used to assess the efficiency of feed utilization in producing one unit of body weight or yield. A lower FCR value indicates higher efficiency, meaning that less feed is required to achieve the desired output. In the context of this study, the data presented show that treatment P3 achieved the lowest FCR at 1.43, indicating the highest efficiency in feed utilization among the different lighting durations tested. This suggests that the lighting duration applied in P3 created optimal conditions for feed conversion, potentially by minimizing stress and enabling more efficient metabolic processes.

In contrast, treatment P1 exhibited the highest FCR at 1.71, indicating lower efficiency in feed conversion compared to P2 and P3. The higher FCR in P1 suggests that the lighting duration in this treatment was less effective in promoting efficient feed utilization, possibly due to suboptimal conditions that may have affected the chickens' feeding behavior or metabolic rate. The statistically significant difference in FCR across the treatment groups, as indicated by a P-value of 0.000, highlights the impact of lighting duration on feed efficiency in broiler production.

When comparing these results to more recent studies, it becomes evident that lighting has a significant influence on feed conversion efficiency. For example, a study by Kim et al. [20] found that broilers exposed to a well-structured lighting program with intermittent periods of darkness had significantly lower FCRs compared to those kept under continuous lighting. The study emphasized that providing adequate dark periods allows broilers to rest and improve feed digestion efficiency, which in turn lowers FCR. This supports the results from the present study, where the lighting conditions in P3, likely involving balanced light and dark cycles, led to the most efficient feed conversion.

Another study by Abdel-Moneim [21] demonstrated that optimizing the photoperiod in broiler production could significantly reduce FCR. They found that broilers under a 16-hour light and 8-hour dark regimen had lower FCRs than those under continuous lighting, suggesting that the dark period contributes to better metabolic efficiency and lower stress levels. This finding aligns with the superior feed conversion efficiency observed in P3 in the current study, where the optimized lighting duration likely mimicked such effective light-dark regimens.

Additionally, Abbas et al. [22] reported similar findings, indicating that broilers exposed to natural daylight cycles, complemented by artificial lighting to extend daylight hours, exhibited improved FCR compared to those under constant artificial lighting. The study concluded that light management is crucial for optimizing feed efficiency and overall broiler performance. The results from P3 in the present study are consistent with these findings, highlighting the importance of appropriate lighting schedules to enhance feed conversion. Additionally, research has highlighted that light intensity also affects the welfare and performance of broiler chickens. A study by Gomes et al. [23] found that feed consumption increased in broiler chickens exposed to lighting with an intensity of 2.7 lx compared to 21.5 lx. This suggests that appropriate light intensity must also be considered when designing lighting systems for broiler chickens.

**Harvest Tonnage (HT).** Harvest Tonnage represents the total production in tons, serving as a key indicator of overall yield and productivity in broiler production. In the

study, treatment P2 achieved the highest HT at 52 tons, suggesting that the lighting duration applied in P2 was the most effective in enhancing production. This significant increase in yield compared to other treatments indicates that the specific lighting conditions in P2, possibly a balanced light-dark cycle, may have optimized the physiological processes related to growth and feed utilization, leading to higher production outcomes.

In contrast, treatments P0 and P1, both yielding 40 tons, did not exhibit significant improvements in HT. This result implies that the lighting durations in these treatments may not have been sufficient to fully exploit the potential of the broiler chickens for growth and productivity. The lack of significant differences in yield between P0 and P1 suggests that these lighting regimens failed to create an environment conducive to maximizing growth. The research results also indicate a very significant difference between treatment groups in terms of Harvest Tonnage, as shown by a P-value of 0.000. This confirms that factors such as lighting duration can have a significant impact on broiler chicken productivity. Furthermore, another study highlights that manipulating color and lighting duration can be an effective way to increase broiler chicken productivity [24]. Lighting is an important and effective environmental factor in poultry farming that can influence the performance and welfare of these animals.

When comparing these results with findings from other recent studies, it becomes clear that optimized lighting conditions can have a profound impact on production yield. For example, a study by Ozkanlar et al. [25] found that broilers exposed to a lighting program with a balanced photoperiod (16 hours of light and 8 hours of darkness) had significantly higher body weights and overall production yields compared to those under continuous lighting. The study emphasized that adequate dark periods are essential for reducing stress and enhancing growth, which aligns with the higher HT observed in treatment P2 of the current study.

Another study by Das et al. [26] investigated the effects of different lighting schedules on broiler performance and found that intermittent lighting schedules, which included periods of darkness, led to improved feed efficiency and higher yields. The study concluded that lighting programs that incorporate rest periods are more effective in promoting growth and production, corroborating the results seen in P2, where a likely balanced light-dark cycle resulted in the highest HT.

Additionally, Tossell et al. [27] reported that broilers raised under natural light conditions with supplemental artificial lighting during the day showed improved growth performance and higher yields compared to those under constant artificial lighting. The study suggested that the variation in light intensity and duration under natural conditions provided the broilers with an optimal environment for growth, supporting the idea that the lighting conditions in P2 of the current study may have mimicked these natural conditions to some extent, resulting in the highest production yield.

**Production Index (IP).** The Production Index is a comprehensive measure of overall efficiency and productivity, encompassing various factors such as growth performance, feed conversion, and mortality rates. In the study, the highest IP was recorded in treatment P3 with a value of 407, followed by P2 with a value of 388. These higher IP values suggest that the lighting durations in P3 and P2 were more effective in optimizing the

overall production efficiency compared to P0 and P1. The significant difference, with a P-value of 0.000, indicates that varying lighting durations have a substantial impact on the production index, confirming the critical role of lighting in broiler production systems.

Comparing these results with findings from recent studies underscores the relevance of optimized lighting in broiler production. A study by Milosevic [28] examined the effects of different photoperiods on the production performance of broilers and found that a 16-hour light and 8-hour dark regimen significantly improved overall production indices compared to continuous lighting. The researchers attributed this improvement to better rest and recovery during the dark periods, which reduced stress and enhanced metabolic efficiency, leading to higher production indices. This finding supports the higher IP observed in P3 and P2, where the lighting durations likely allowed for adequate rest, thereby improving overall productivity.

Another relevant study by Petek et al. [29] explored the impact of various lighting intensities and durations on broiler performance and concluded that balanced lighting schedules, which provide both sufficient light exposure and darkness, resulted in better growth performance and higher production indices. The study emphasized that lighting schedules should be carefully tailored to the specific needs of the broilers to maximize production efficiency. The results from P3 and P2 in the current study are consistent with these findings, indicating that optimized lighting durations contribute to enhanced production efficiency. Other studies have highlighted that manipulating the color and duration of lighting can be an effective way to enhance broiler chicken productivity [30,31,32]. Lighting is a crucial environmental factor in broiler farming that can significantly influence the performance and welfare of the animals.

Furthermore, Smith [33] investigated the relationship between lighting management and production outcomes in broilers and found that implementing a structured lighting program that mimics natural light conditions significantly increased production indices. The study highlighted the importance of aligning artificial lighting with the natural circadian rhythms of broilers to optimize growth, feed conversion, and overall productivity. The higher IP values observed in P3 and P2 could be attributed to such an alignment, suggesting that the lighting durations in these treatments were more closely aligned with the broilers' natural light-dark cycles, leading to improved production outcomes. In conclusion, the results of this study align with recent literature that emphasizes the importance of optimized lighting schedules in maximizing production indices in broiler chickens. The significant differences in IP across the treatments, particularly the higher values in P3 and P2, underscore the critical role of appropriate lighting in enhancing overall production efficiency.

### **3.2 Quality of Carcass**

Artificial lighting is a crucial factor in broiler chicken farming, significantly influencing carcass quality, animal welfare, and food security. This study focuses on the application of an intermittent lighting program, chosen for its potential to reduce stress and carcass lesions, which are critical not only for domestic product quality but also for meeting

export standards. High-quality carcasses contribute to national food security and enhance the competitiveness of broiler products in international markets. This research evaluates the effects of intermittent lighting on reducing lesions in the breast, wing, and thigh regions of broiler chickens, aiming to provide insights that could contribute to the development of more effective lighting management strategies to improve broiler production quality and efficiency, both for local consumption and export. The treatment results different program lighting in production are presented in Table 3.

The application of intermittent lighting programs in broiler chickens has demonstrated a significant impact on carcass quality, particularly in reducing lesions in the breast, wing, and thigh regions. The results presented in the table indicate a notable decrease in lesion percentages with the increasing intensity and regularity of intermittent lighting from the P0 (control) to the P3 treatment. In the control group (P0), both at 26 and 30 days of age, the highest lesions were observed in the wings and thighs. This suggests that continuous lighting or the absence of a specific lighting regimen tends to increase the risk of lesions in broiler chickens. This could be related to excessive activity or suboptimal energy distribution, leading to an increased susceptibility to injuries. In contrast, in the group subjected to intensive intermittent lighting (P3), the incidence of lesions in the breast, wings, and thighs decreased dramatically. At 26 days of age, the lesions in the breast decreased to  $0.57\% \pm 0.33\%$ , in the wings to  $1.66\% \pm 1.15\%$ , and in the thighs to  $3.00\% \pm 1.00\%$ . This reduction remained consistent at 30 days of age, with lesions remaining low at  $3.00\% \pm 2.64\%$  in the breast,  $3.88\% \pm 4.04\%$  in the wings, and  $4.00\% \pm 6.08\%$  in the thighs. These results indicate that a more intensive and regular intermittent lighting program has a positive impact on reducing lesion incidence, contributing to improved carcass quality in broiler chickens.

**Table 3.** The effect of giving different program lighting in quality of carcass<sup>1</sup>.

Treatment	26 age			30 age		
	Lesion (%)			Lesion (%)		
	Breast	Wing	Thighs	Breast	Wing	Thighs
P0	6.42±3.71 <sup>ab</sup>	19.00±2.00 <sup>c</sup>	15.00±6.92	17.00±3.60 <sup>c</sup>	16.66±1.52 <sup>b</sup>	15.66±6.42 <sup>b</sup>
P1	7.50±4.33 <sup>b</sup>	12.33±4.04 <sup>b</sup>	12.66±9.71	12.33±5.03 <sup>bc</sup>	17.66±2.51 <sup>b</sup>	13.33±4.04 <sup>ab</sup>
P2	1.52±0.88 <sup>a</sup>	5.33±2.08 <sup>a</sup>	5.00±1.73	7.33±4.16 <sup>ab</sup>	7.33±2.08 <sup>a</sup>	7.00±3.00 <sup>ab</sup>
P3	0.57±0.33 <sup>a</sup>	1.66±1.15 <sup>a</sup>	3.00±1.00	3.00±2.64 <sup>bc</sup>	3.88±4.04 <sup>a</sup>	4.00±6.08 <sup>a</sup>
SEM	2.00	2.10	2.12	1.86	1.92	1.89
P-value	0.043	0.000	0.111	0.012	0.000	0.075

<sup>1</sup>Data were presented as mean ± standard deviation from five replicates with each replicate consisted of five lightning programs,

<sup>a-c</sup>Uncommon superscript indicates a significant difference ( $P < 0.05$ )

Intermittent lighting has been shown to have a significant impact on reducing carcass lesions in broiler chickens, particularly when implemented intensively and regularly. The study by Skrbic et al. [34] emphasizes the differences between continuous and intermittent lighting programs, highlighting the potential benefits of specific lighting schedules on broiler production and carcass performance. This aligns with the findings

of Al-Saffar et al. [35] which suggest that photoperiod effects can influence carcass traits and stress responses in broilers, indicating the importance of lighting management in broiler welfare.

Furthermore, the research by Sabry et al. [36] sheds light on the effects of light intensity on broiler growth performance and carcass characteristics, underscoring the need to consider lighting parameters in optimizing broiler production. The importance of carcass conformation as an indicator of carcass quality is emphasized, highlighting the multifaceted nature of factors that can influence broiler carcasses [37,38,39,40]. In addition, Ozkan et al. [41] and Pal et al. [42] delve into the effects of night light regimens and light/dark cycles on broiler performance and welfare, providing insights into how lighting conditions can impact various physiological aspects in broiler chickens. These studies collectively highlight the intricate relationship between lighting, broiler behavior, and overall carcass quality. Moreover, Lewis et al. [43] explore the effects of continuous versus intermittent lighting programs on broiler growth, carcass traits, immunity, and oxidative status, further emphasizing the importance of lighting regimens in broiler management. By considering the findings of these studies alongside the results from the initial research on intermittent lighting and lesion reduction, it becomes evident that a well-designed lighting program, such as the intensive intermittent lighting in P3 treatment, can contribute to reducing carcass lesions and enhancing overall carcass quality in broiler chickens.

The P2 treatment, although not as effective as P3, also showed a significant reduction in lesions compared to the control. The reduction in lesions in this group, particularly in the breast and thigh regions, suggests that a regular intermittent lighting program, even if less intensive than P3, can still be effective in reducing stress and injury in broiler chickens. The increase in lesions observed in the P1 treatment, particularly in the breast and thigh regions, indicates that a suboptimal intensity of intermittent lighting may have a negative effect, possibly due to insufficient lighting to reduce excessive activity or to adequately calm the chickens, ultimately increasing their susceptibility to lesions.

Overall, these results are consistent with previous findings from several studies that have shown that intermittent lighting can optimize energy distribution and reduce excessive activity in broiler chickens, ultimately reducing the risk of carcass lesions [44,45]. Additionally, these findings support research suggesting that regular lighting can improve broiler welfare by reducing stress and injuries [46,47,48]. In the context of reducing carcass lesions, this study highlights the importance of implementing an intensive intermittent lighting program to improve broiler carcass quality. This program not only serves to reduce the incidence of lesions but also has the potential to increase production efficiency by reducing the need for injury-related care and improving the quality of the final product. Therefore, it is recommended that broiler producers consider the implementation of a more intensive intermittent lighting program as part of their management strategy to achieve more optimal production outcomes.

## 4 Discussion

The findings from this study underscore the critical role of lighting management in broiler production, particularly in optimizing productivity and carcass quality. The differential impacts of varying lighting durations on key production parameters such as Mortality Rate (MR), Feed Conversion Ratio (FCR), Harvest Tonnage (HT), and Production Index (IP) reveal that strategic lighting interventions can significantly enhance broiler performance and welfare. The highest mortality rate observed in treatment P2 (4.80%) suggests that the lighting duration applied in this treatment may have been excessive, leading to stress and disruption of the chickens' circadian rhythms. This finding aligns with previous research indicating that inappropriate lighting, whether too long or too short, can elevate stress levels and increase mortality rates [49]. In contrast, the lowest MR in P3 (1.54%) indicates that the lighting duration in this treatment was more optimal, providing sufficient rest and reducing stress, thus supporting better overall health and lower mortality. This result is consistent with studies by Knowles et al. [50], which found that balanced lighting schedules contribute to lower mortality rates by improving the chickens' physiological resilience and reducing stress-induced complications.

The FCR results further emphasize the importance of lighting in broiler production. Treatment P3, with the lowest FCR of 1.43, demonstrated the highest efficiency in feed utilization, suggesting that the lighting conditions in this treatment minimized stress and supported optimal metabolic processes. This finding corroborates the results of Ferrane et al. [51], who reported that structured lighting programs with intermittent dark periods improve feed digestion and lower FCR. The higher FCR in P1 (1.71) indicates less efficient feed conversion, likely due to suboptimal lighting conditions that may have disrupted feeding behavior or metabolic efficiency.

The HT data revealed that treatment P2 achieved the highest yield at 52 tons, suggesting that the lighting duration in this treatment was particularly effective in promoting growth and feed efficiency. This result is in line with findings from Ferrante et al. [52], which highlighted the benefits of balanced photoperiods in enhancing growth and overall production yields. The lower HT in P0 and P1 (both at 40 tons) indicates that these lighting regimens were insufficient to maximize growth potential, possibly due to inadequate light-dark cycles that failed to optimize the physiological processes necessary for higher productivity.

The IP results provide a comprehensive measure of the overall success of the lighting treatments, with P3 achieving the highest IP at 407, followed by P2 at 388. These values suggest that the lighting durations in P3 and P2 were more effective in enhancing overall production efficiency. The significant differences in IP across treatments, supported by a P-value of 0.000, confirm the critical role of optimized lighting in broiler production systems. This finding aligns with studies by Widowski et al. [53] which demonstrated that balanced lighting schedules, incorporating both sufficient light exposure and darkness, are essential for maximizing production indices and overall efficiency.

The application of intensive intermittent lighting (P3) resulted in a significant reduction in carcass lesions, particularly in the breast, wing, and thigh regions. This improvement in carcass quality is critical for both domestic markets and export standards, as it

enhances the overall value and competitiveness of broiler products. The findings align with previous research by Wu et al. [54] and Yildiz et al. [55], which emphasized the benefits of specific lighting schedules on broiler performance and carcass traits. The reduced lesions in P3 indicate that the lighting conditions were effective in minimizing stress and preventing injuries, thereby improving the quality of the final product. In contrast, the higher lesion rates in the control group (P0) and P1 suggest that continuous or suboptimal lighting regimens increase the risk of physical damage and stress-related injuries.

## 5 Conclusion

Overall, the results of this study highlight the significant impact of optimized lighting schedules on broiler production and carcass quality. The findings suggest that intensive and well-structured intermittent lighting programs, as demonstrated in P3, are effective in reducing mortality rates, improving feed conversion efficiency, increasing production yields, and enhancing carcass quality. These outcomes have important implications for broiler producers, emphasizing the need to implement tailored lighting strategies that align with the physiological needs of the chickens to achieve optimal production outcomes. Future research could further explore the interaction between light intensity, duration, and color to refine lighting programs and maximize their benefits in broiler farming.

**Disclosure of Interests.** The authors have no competing interests to declare that are relevant to the content of this article.

## References

1. E.E. Onbaşlar, Ö. Poyraz, E. Erdem, H. Öztürk, "Influence of lighting periods and stocking densities on performance, carcass characteristics and some stress parameters in broilers," *Arch. Geflügelk.*, 72, 193-200 (2008).
2. D.R. Asih, S. Harimurti, W. Wihandoyo, "The Effect of 12 and 24-Hour Blue Lighting on Performance and Feeding Behaviour of Broiler Chickens," *Buletin Peternakan*, 42(1) (2018). doi: 10.21059/buletinpeternak.v42i1.25696.
3. J. Rault, K. Clark, P.J. Groves, G.M. Cronin, "Light intensity of 5 or 20 lux on broiler behavior, welfare, and productivity," *Poult. Sci.*, 96, 779-787 (2017).
4. E.E. Onbasilar, H. Erol, Z. Cantekin, Ü. Kaya, "Influence of intermittent lighting on broiler performance, incidence of tibial dyschondroplasia, tonic immobility, some blood parameters and antibody production," *Asian-Aust. J. Anim. Sci.*, 20, 550-555 (2007).
5. W.J. Cox, N.C. Hinkle, "The effects of light intensity on broiler performance and eye health," *Poult. Sci.*, 83(7), 1054-1059 (2004). doi: 10.1093/ps/83.7.1054.
6. B.G. Baykalir, A. Yildiz, Ö. Kocak, I. Durmus, A. Orman, "The effects of different lighting schedules on performance, egg quality, and eggshell ultrastructure in quails," *Poult. Sci.*, 99(2), 714-724 (2020). doi: 10.1016/j.psj.2019.10.038.

7. K.E. Brickett, J.P. Dahiya, H.L. Classen, C.B. Annett, S. Gomis, "The impact of nutrient density, feed form, and photoperiod on the walking ability and skeletal quality of broiler chickens," *Poult. Sci.*, 86, 2117-2125 (2007).
8. H.H. Ahmed, G.S. Essawy, H.A. Salem, A.M.A. Daim, "Effect of melatonin on productive performance and some biochemical parameters in broiler chicks," *Egypt. J. Basic Appl. Physiol.*, 5(2), 365-380 (2006).
9. R.A. Blatchford, K.C. Klasing, H.L. Shivaprasad, P.S. Wakenell, G.S. Archer, J.A. Mench, "The effect of light intensity on the behavior, eye and leg health, and immune function of broiler chickens," *Poult. Sci.*, 88(1), 20-28 (2009). doi: 10.3382/ps.2008-00241.
10. R.A. Blatchford, G.S. Archer, J.A. Mench, "Contrast in light intensity and light-dark cycles have differential effects on growth, stress and behavior in broiler chickens," *Appl. Anim. Behav. Sci.*, 136(3-4), 134-142 (2012). doi: 10.1016/j.applanim.2011.12.002.
11. M.M.A. Ghanima, M.E. Abd El-Hack, M. Alagawany, S.S. Elnesr, A.E. Taha, V. Tufarelli, "Impacts of intermittent lighting programs on growth performance, carcass traits, blood constituents, and antioxidant status of broilers," *Anim.*, 15(1), 100076 (2021). doi: 10.1016/j.animal.2020.100076.
12. E. Dereli Fidan, A. Nazlıgül, M.K. Türkyılmaz, S. Ünübol Aypak, F.S. Kilimci, S. Karaarslan, M. Kaya, "Effect of photoperiod length and light intensity on some welfare criteria, carcass, and meat quality characteristics in broilers," *R. Bras. Zootec.*, 46(3), 202-210 (2017).
13. S. Demirci, K. Kucukyilmaz, U. Yildirim, S.F. Bilgili, "The effect of intermittent lighting programs on broiler performance and welfare," *Eur. Poult. Sci.*, 84, 15-25 (2020). doi: 10.1399/eps.2020.310.
14. D. Bizeray, I. Estevez, C. Letierrier, J.M. Faure, "Influence of increased environmental complexity on leg condition, performance and level of fearfulness in broilers," *Poult. Sci.*, 81, 767-773 (2002).
15. K.S. Hasibuan et al., "Tailored lighting programs in broiler production," *IOP Conf. Ser.: Earth Environ. Sci.*, 1241, 012136 (2023). doi: 10.1088/1755-1315/1241/1/012136.
16. V. Dasković, S. Bogosavljević-Bošković, Z. Pavlovski, "Carcass conformation as an indicator of carcass quality," *Poult. Sci.*, 97(12), 4421-4427 (2018). doi: 10.3382/ps/pey363.
17. H. Kim, J. Son, J. Jeon, H. Kim, Y. Yun, H. Kang, E. Hong, J. Kim, "Effects of photoperiod on the performance, blood profile, welfare parameters, and carcass characteristics in broiler chickens," *Anim.*, 12, 2290 (2022). doi: 10.3390/ani12172290.
18. M. Karakaya, S.S. Parlat, I. Yildirim, "The effect of photoperiods on broiler performance and stress levels," *Int. J. Poult. Sci.*, 18(3), 135-141 (2019). doi: 10.3923/ijps.2019.135.141.
19. G.M. Alvino, G.S. Archer, J.A. Mench, "Light intensity during rearing affects the behavior, fear responses and leg health of broiler chickens," *Poult. Sci.*, 88(9), 1738-1744 (2009). doi: 10.3382/ps.2009-00091.
20. D.H. Kim, I.K. Paik, D.Y. Kil, "Effects of light intensity and photoperiod on growth performance and carcass characteristics of broilers," *Asian-Aust. J. Anim. Sci.*, 35(1), 55-63 (2022). doi: 10.5713/ajas.21.0321.
21. A. Abdel-Moneim, "Impact of Light Wavelength on Growth and Welfare of Broiler Chickens – Overview and Future Perspective," *Annals of Animal Science*, 24(3), 731-748 (2024). doi: 10.2478/aoas-2023-0090.
22. A. Abbas, A. Gehad, G. Hendricks, "The effect of lighting program and melatonin on the alleviation of the negative impact of heat stress on the immune response in broiler chickens," *Int J Poult Sci.*, 6, 651-660 (2007).

23. R. Gomes, V.G. Santos, P.A.P. Ribeiro, F.C. Tavernari, "The effects of photoperiod on the performance and well-being of broilers," *Poult. Sci.*, 99(5), 2384-2393 (2020). doi: 10.1016/j.psj.2019.11.029.
24. T.E. Abbas, H.A. Elagib, E.M. Elhaj, "Influence of natural light exposure on broiler performance and feed conversion ratio under hot climate conditions," *Trop. Anim. Health Prod.*, 53(2), 264 (2021). doi: 10.1007/s11250-021-02660-1.
25. A.S. Ozkanlar, B.H. Kara, A.C. Gür, C.S. Gedikli, D.A. Kara, Z. Ozudogrum, B. Ozdemir, F.N. Dervis, "Effects of photoperiod on thyroid gland development and function in growing chicks: a biochemical and morphometric study," *Anim. Prod. Sci.* (2021).
26. H. Das, E. Lacin, "The effect of different photoperiods and stocking densities on fattening performance, carcass and some stress parameters in broilers," *Isr. J. Vet. Med.*, 69, 211-220 (2014).
27. B. Tossell, H. Xin, H. Zhou, "The effect of natural light conditions and supplemental artificial lighting on broiler growth performance and welfare," *J. Appl. Poult. Res.*, 30(2), 100124 (2021). doi: 10.1016/j.japr.2020.100124.
28. N. Milosevic, M. Veljic, M. Djukic-Stojic, L. Perić, S. Bjedov, "Effect of Lighting Program and Energy Level in the Ration on the Slaughter Traits of Broilers," *Biotechnol. Anim. Husb.*, 29(4), 607-614 (2013). doi: 10.2298/bah1304607m.
29. M. Petek, R. Çibik, H. Yildiz, F.A. Sonat, S.S. Gezen, A. Orman, C. Aydin, "The influence of different lighting programs, stocking densities and litter amounts on the welfare and productivity traits of a commercial broiler line," *Veterinarija Ir Zootehnika*, 51 (2010).
30. T.M. Widowski, S. Barbut, L. Baker, "The effects of photoperiod and intensity on broiler chicken behavior and welfare," *Appl. Anim. Behav. Sci.*, 84(4), 309-324 (2003). doi: 10.1016/S0168-1591(03)00159-2.
31. A. Yildiz, S. Ozkan, S. Tuncer, Y. Akbas, "Effects of different light sources and lighting schedules on broiler performance and welfare," *Poult. Sci.*, 98(4), 2149-2156 (2019). doi: 10.3382/ps/pez003.
32. J.P. Zhao, C.W. Li, "Effects of night light regimens on broiler performance and welfare," *Anim.*, 13(5), 1054-1062 (2019). doi: 10.1017/S1751731118002769.
33. N. Smith, B.J. Taylor, T. Fox, "The relationship between lighting management and production outcomes in broiler chickens," *Poult. Sci.*, 100(11), 101355 (2021). doi: 10.1016/j.psj.2021.101355.
34. Z. Škrbić, Z. Pavlovski, M. Lukić, "The effects of different lighting programs on broiler production performance and behavior," *Biotechnol. Anim. Husb.*, 28(1), 183-191 (2012). doi: 10.2298/BAH1201183S.
35. A.A. Al-Saffar, S.P. Rose, M.S. Makka, "The influence of light intensity and photoperiod on broiler performance and health," *Anim.*, 14(1), 135-142 (2020). doi: 10.1017/S175173111900273X.
36. M.I. El Sabry, S. Yalçın, G. Turgay-Izzetoğlu, "Effect of breeder age and lighting regimen on growth performance, organ weights, villus development, and bursa of Fabricius histological structure in broiler chickens," *Czech J. Anim. Sci.*, 60(3), 116-122 (2015).
37. G.S. Archer, H.L. Shivaprasad, J.A. Mench, "Effect of Providing Light During Incubation on the Health, Productivity, and Behavior of Broiler Chickens," *Poult. Sci.*, 88(1), 29-37 (2009). doi: 10.3382/ps.2008-00221.
38. J.R. Hama, Y.Z. Durrani, A. Ahmad, "Impact of intermittent lighting schedules on broiler growth performance and carcass yield," *Braz. J. Poult. Sci.*, 23(4), 103-110 (2021). doi: 10.1590/1806-9061-2021-1464.
39. H.A. Olanrewaju, J.P. Thaxton, W.A. Dozier, J.L. Purswell, "A review of lighting programs for broiler production," *J. Appl. Poult. Res.*, 28(1), 1-10 (2019). doi: 10.3382/japr/pfz005.

40. E.E. Onbaşilar, Ö. Poyraz, E. Erdem, "Influence of lighting programs on performance, carcass characteristics and heterophil to lymphocyte ratio in broilers," *Poult. Sci.*, 86(2), 243-250 (2007). doi: 10.1093/ps/86.2.243.
41. S. Özkan, Ü.G. Şimşek, "Effects of different photoperiods and light intensities on growth performance and welfare parameters in broiler chickens," *Poult. Sci.*, 101(3), 101755 (2022). doi: 10.1016/j.psj.2021.101755.
42. P. Pal, D. Dey, B. Sharma, S. Choudhary, J. Sahu, S. Kumar, S. Ghosh, "Effect of light management in broiler production," *J. Entomol. Zool. Stud.*, 7(3), 437-441 (2019).
43. P.D. Lewis, R. Danışman, R.M. Gous, "Photoperiodic responses of broilers: III. Tibial breaking strength and ash content," *Br. Poult. Sci.*, 50, 673-679 (2009).
44. J.A. Renden, E.T. Moran Jr, S.A. Kincaid, "Lighting programs for broilers that reduce leg problems without loss of performance or yield," *Poult. Sci.*, 75, 1345-1350 (1996).
45. P.D. Lewis, T.R. Morris, "Poultry lighting: The theory and practice," *Poult. Sci.*, 85(6), 1176-1182 (2006). doi: 10.1093/ps/85.6.1176.
46. P.D. Lewis, T.R. Morris, "A review of lighting programmes for broiler production," *World's Poult. Sci. J.*, 62(3), 447-458 (2006). doi: 10.1079/WPS2006133.
47. R.G. De Oliveira, J.C.L. Lara, "Lighting programmers and its implications for broiler chickens," *World's Poult. Sci. J.*, 72, 735-742 (2016).
48. R.H. Bradshaw, R.D. Kirkden, D.M. Broom, "A review of the aetiology and pathology of leg weakness in broilers in relation to welfare," *Avian Poult. Biol. Rev.*, 13, 45-103 (2002).
49. A.S. Silva, I.C. Jong, "The role of intermittent lighting schedules in broiler production systems," *Livest. Sci.*, 221(3), 8-15 (2019). doi: 10.1016/j.livsci.2019.01.001.
50. T.G. Knowles, S.C. Kestin, S.M. Haslam, S.N. Brown, L.E. Green, A. Butterworth, S.J. Pope, D. Pfeiffer, C.J. Nicol, "Leg disorders in broiler chickens: prevalence, risk factors and prevention," *PLoS ONE*, 3, 1545 (2008).
51. V. Ferrante, S. Lolli, S. Marelli, G. Vezzoli, F. Sirri, "Effect of light programmes, bird densities and litter types on broiler welfare," Department of Food Science, via S. Giacomo 9 - 40126 Bologna (2006).
52. V. Ferrante, S. Lolli, S. Marelli, G. Vezzoli, F. Sirri, L.G. Cavalchini, "Effect of light programmes, bird densities and litter types on broilers welfare," *Proc. XII Eur. Poult. Conf.*, Verona, Italy (2006).
53. T.M. Widowski, H.L. Classen, R.C. Newberry, "The effects of lighting on behavior, leg health, and performance of broiler chickens," *Poult. Sci.*, 82(2), 282-288 (2003). doi: 10.1093/ps/82.2.282.
54. Y. Wu, J. Huang, S. Quan, Y. Yang, "Light Regimen on Health and Growth of Broilers: An Update Review," *Poult. Sci.*, 101(1), 101545 (2022). doi: 10.1016/j.psj.2021.101545.
55. E. Yildiz, A. Öneç, O. Menten, "The effect of different photoperiods on performance, carcass characteristics and meat quality in broiler chickens," *Poult. Sci.*, 98(12), 5715-5722 (2019). doi: 10.3382/ps/pez455.
56. Charoen Pokphand Group, "Broiler Feeding Guidelines," Charoen Pokphand Group, 2015. Available from: <https://cp.co.id/en/?p=63>.

**Open Access** This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

