

Hygienic importance of light in dairy farming - a review

Хигиенно значение на светлината в млечното говедовъдството – обзор

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Received: November 14, 2025; accepted: April 14, 2026

ABSTRACT

Lighting within dairy housing serves as a key determinant of behavioral patterns, health, and yield. Specifically, the parameters of light intensity and photoperiod duration exert a substantial influence on the overall physical condition and productive lifespan of the cows. A long-day photoperiod (LDPP) is characterized by 16 to 18 hours of continuous light exposure followed by a 6 to 8-hour period of darkness. Conversely, a short-day photoperiod (SDPP) is defined as 8 hours of light followed by a continuous 16-hour dark period. Lactating cows exposed to a long-day photoperiod (16 h light / 8 h dark) via LED lighting exhibited significantly higher milk yields compared to those under natural conditions (14.2 h light / 9.4 h dark at < 10 lux). Specifically, daily yields increased by 8.6 kg, 7.7 kg, and 3.6 kg per cow at illumination levels of 50 lux, 100 lux, and 200 lux, respectively. The recommended illumination level for milking parlors, specifically within the pits and near the udder, is approximately 540 lux. This intensity ensures that any abnormalities in milk color or consistency are easily detectable, allowing for timely intervention and corrective measures.

Keywords: illumination level, dairy cows, milking parlour, welfare

АБСТРАКТ

Осветлението в млечните помещения служи като ключов фактор за поведенческите модели, здравето и добива. По-конкретно, параметрите на интензитета на светлината и продължителността на фотопериода оказват съществено влияние върху цялостното физическо състояние и продуктивния живот на кравите. Дългодневният фотопериод (LDPP) се характеризира с 16 до 18 часа непрекъснато излагане на светлина, последвано от 6 до 8 часа период на тъмнина. Обратно, краткодневният фотопериод (SDPP) се определя като 8 часа светлина, последвани от непрекъснат 16-часов период на тъмнина. Кърмещите крави, изложени на дълъг дневен фотопериод (16 часа светлина / 8 часа тъмнина) чрез LED осветление, показват значително по-висок добив на мляко в сравнение с този при естествени условия (14,2 часа светлина / 9,4 часа тъмнина при < 10 лукса). По-конкретно, дневните добиви се увеличават с 8,6 кг, 7,7 кг и 3,6 кг на крава при нива на осветление съответно 50 лукса, 100 лукса и 200 лукса. Препоръчителното ниво на осветление за доилните зали, по-специално в доилните ями и близо до вимето, е приблизително 540 лукса. Тази интензивност гарантира, че всякакви аномалии в цвета или консистенцията на млякото са лесно откриваеми, което позволява навременна намеса и коригиращи мерки.

Ключови думи: ниво на осветеност, дойни крави, доилна зала, хуманно отношение

INTRODUCTION

Light and noise are critical factors influencing animal welfare and environmental quality, triggering various psychological and physiological responses. Numerous studies have demonstrated the impact of light on the morphology, physiology, and behavior of various species (Hayes, 2007). Consequently, the lighting microclimate is an essential component of environmental characterization. Enhanced cow productivity, ensured welfare, and safer working conditions render lighting a vital feature of the microclimate in livestock housing. In well-illuminated facilities, cows navigate technological zones and entrances more freely, while personnel benefit from better orientation and the ability to monitor and care for animals more accurately (Harner et al., 2008). Barn illumination is a critical determinant influencing the duration and dynamics of primary behavioral patterns, health status, and productivity in dairy cows. As a microclimatic factor, it serves as an effective tool for optimizing housing conditions, thereby enhancing both milk yield and overall farm profitability. Consequently, lighting within dairy facilities must be strictly managed in terms of duration and intensity throughout the entire lifecycle of the animal, from birth to culling (Penev et al., 2014).

According to Dahl et al. (2000) and Dahl (2005), light exposure stimulates milk productivity in cows. The resulting increase in energy requirements prompts animals to exhibit dominant feeding behavior and higher feed intake.

Establishing optimal light conditions is essential for successful cattle farming and requires strict compliance with relevant zoohygiene standards. As a primary factor directly influencing animal welfare, illumination is an integral component of the indoor microclimate within production facilities (Šoch, 2005).

The objective of this research is to evaluate the applied global lighting standards in dairy cattle farming and to analyze illumination levels in milking parlors specifically concerning the requirements of the personnel.

Effect of the duration of the light part of day on health status and productivity in dairy cows

Enhanced facility lighting and exposure to a long-day photoperiod (16–18 hours) contribute to improved health, superior nutrient utilization, increased milk yield, and enhanced reproductive performance. Furthermore, these conditions provide longer resting (lying) periods, which help mitigate the risk of lameness and enable the earlier detection of clinical signs of other health issues (Dahl et al., 2000; Cook, 2011).

Beyond the lactation period, photoperiod duration substantially influences the growth of replacement heifers and the recovery of dry cows. Exposure to longer days has been shown to enhance heifer development, allowing them to reach puberty earlier due to accelerated growth rates and structural body changes (Dahl et al., 2000). In contrast to lactating cows, research suggests that dry cows benefit from a short-day photoperiod (Aharoni et al., 2000). Specifically, Dahl (2006) demonstrated that cows maintained under short-day conditions from the beginning to the middle of the dry period exhibited higher dry matter intake compared to those under long-day regimes. Producers can leverage this to ensure optimal body condition scores prior to calving. Furthermore, limiting light exposure to 8 hours daily during the dry period has been found to increase subsequent milk yield by 3% post-calving (Biewenga and Winkel, 2003).

Buyserie et al. (2001) suggest that milk production can be optimized by managing the photoperiodic exposure of dairy cows. Within a 24-hour cycle, a Long-Day Photoperiod (LDPP) is defined as 16–18 hours of continuous light followed by 6–8 hours of darkness, whereas a Short-Day Photoperiod (SDPP) consists of 8 hours of light and 16 hours of darkness (practically any period with less than 12–13 hours of light). Lactating cows housed under LDPP consistently exhibited an 8–10% increase in daily milk yield—averaging 2.5 kg/cow—regardless of their baseline productivity. Similarly, Piva et al. (1992) found that a 16-hour light regime increased milk yield by 5–16% and feed intake by approximately 6% compared to a photoperiod of 13.5 hours or less, while reproductive functions remained unaffected.

Illumination intensity and duration exert a fundamental impact on the health and longevity of dairy cows (Doležal et al., 2002; Šoch, 2005). Evidence suggests that cows prefer well-lit areas within the barn over darker zones; adequate lighting and visual contact likely facilitate the maintenance of social hierarchy and reduce the incidence of injuries. Auchtung et al. (2003) demonstrated that a short-day photoperiod during the dry period not only boosts subsequent milk yield but also enhances immune response, leading to a lower incidence of mastitis and metritis during the first 10 days post-calving. Furthermore, the authors observed a significant reduction in somatic cell counts (SCC) from drying-off through calving under short-day conditions.

Research by Lawson and Kennedy (2001) indicates that light intensities exceeding 50 lux tend to suppress melatonin secretion compared to total darkness (0 lux). Conversely, Bal et al. (2008) observed that older cows exposed to 40–60 lux at night showed no significant reduction in melatonin levels compared to a 0–5 lux baseline; furthermore, dry matter intake and milk yield remained consistent between these groups. Cook (2011) emphasizes that while upgrading dairy lighting requires initial capital investment, the payback periods are relatively short, particularly when offset by the energy efficiency of modern systems. Ultimately, improved lighting and extended photoperiods enhance milk yield, reproductive metrics, and operational efficiency. However, such measures must be part of a holistic management approach, as their efficacy depends on the adequacy of nutrition, animal comfort, and facility design.

There is a certain contradiction in the literature regarding the threshold light intensity levels that affect the endocrine profile of animals. While Lawson and Kennedy (2001) identify 50 lux as a critical threshold for the suppression of nocturnal melatonin in heifers, Bal et al. (2008) find no significant difference in hormone levels in adult cows exposed to similar intensity (40–60 lux). This suggests that age and physiological status are determining factors for the sensitivity of the photoreceptor system, which must be taken into account when designing lighting regimes for different groups within the herd.

Furthermore, in Bal et al. (2008), differences in night-time lighting regimes (0–5 lux versus 40–60 lux) did not lead to changes in dry matter intake or milk yield, indicating that not every physiological influence (such as a slight change in melatonin) leads to an economically measurable result.

According to Chastain and Hiatt (1998), the gains from increased milk productivity are sufficient to amortize the initial capital investment—including the installation, operation, and maintenance of the lighting system, as well as the costs of additional feed consumption—in less than one year.

Peters et al. (1978) (Table 1) investigated the effects of supplemental lighting on lactation in cattle, demonstrating that a 16-hour daily photoperiod using fluorescent lighting (114–207 lux) followed by 8 hours of darkness increased milk production by 2 kg/cow/day compared to natural photoperiods of 9–12 hours (39–93 lux). Notably, the measurement height was not specified in their initial report. However, in a subsequent study, Peters et al. (1981) reported that cows under a 'long-day' regime produced 1.4 kg more milk daily than those under natural light. This long-day treatment consisted of 16 hours of fluorescent light (averaging 462 lux, measured horizontally at cow eye level), while natural light conditions ranged from 9 to 12 hours (averaging 555 lux at cow eye level).

These findings are further corroborated by Dahl et al. (1997), who observed that a long-day photoperiod (18 h light / 6 h dark) increased milk yield by 2.2 kg/cow/day compared to a natural winter photoperiod (max 13 h light). In this study, light intensity was maintained at 350 lux (fluorescent, measured horizontally at cow eye level). The authors conclude that this productivity boost is driven by the physiological cascade triggered by LDPP: the suppression of pineal melatonin—which serves as the neuroendocrine signal for day length—leads to an increase in circulating insulin-like growth factor-I (IGF-I), a potent galactopoietic hormone crucial for mammary function and growth. In accordance with the above mentioned study, the elevation of IGF-I levels correlates directly with enhanced mammary cell activity and meta-

bolic efficiency, establishing a clear biological foundation for the reported 2.2 kg increase in milk yield. Additionally, the regulatory role of prolactin is essential; photoperiodic stimulation modulates prolactin secretion, which is critical for sustaining mammary tissue responsiveness. This effect is particularly significant during the physiological transition from the dry period to active lactation, ensuring the mammary gland is primed for peak production.

A study by Lim et al. (2021) demonstrated that lactating cows exposed to a long-day photoperiod (16 h light / 8 h dark) via LED lamps achieved significantly higher milk yields compared to natural conditions (14.2 h light / 9.4 h dark at < 10 lux). Specifically, daily yields increased by 8.6 kg, 7.7 kg, and 3.6 kg per cow at illumination intensities of 50, 100, and 200 lux, respectively. Furthermore, a lighting level of 100 lux was positively associated with increased milk fat content. All light measurements were standardized at a height of 0.90 m above floor level.

Analysis of the data in Table 1 reveals a considerable discrepancy in the definition of 'control groups' (natural photoperiods) across studies. While the control in Peters et al. (1978) ranged from 9 to 12 hours, Lim et al. (2021) utilized a baseline of 14.2 hours. Notably, the most substantial yield increase (8.6 kg) occurred in the study with the smallest photoperiodic delta—a mere 1.8-hour difference in Lim et al. This suggests that the spectral quality or specific characteristics of the light source (LED) may be a more decisive factor in stimulating productivity than the absolute duration of the photoperiod.

While a long-day photoperiod is beneficial during lactation, the dry period - defined as the phase where milk production ceases to prepare the cow for the next cycle (Lim et al., 2021) - requires a contrasting approach. During this stage, a short-day photoperiod is recommended to facilitate physiological recovery and mammary gland involution, which are essential for optimizing subsequent milk yields.

Establishing an adequate light regime is a pivotal factor in modern dairy management. While natural sunlight significantly enhances dairy cows' well-being, supplemental artificial lighting becomes imperative when natural exposure is insufficient. Failure to maintain optimal illumination levels leads to a marked deterioration in both the physiological health and the productive performance of the herd.

The substantial variation in milk yield gains reported in Table 1—ranging from 1.4 kg to 8.6 kg—highlights several multifaceted factors that influenced the specific outcomes of these studies.

A primary factor is the light source itself. The most substantial yield increases (8.6 kg and 7.7 kg) were reported using LED technology (Lim et al., 2021). By contrast, earlier studies utilizing fluorescent lamps (Peters et al., 1978, 1981) or metal-halide lamps (Dahl et al., 1997) recorded significantly lower gains, ranging between 1.4 kg and 2.2 kg. This disparity suggests that the technological advantages of LEDs - specifically their unique spectral distribution and superior light uniformity - exert a more potent stimulatory effect on the physiolog-

Table 1. Relationship between photoperiod length, lighting level and milk performance

Authors	Photoperiod (h)	Lighting level (lux)	Lighting source	Darkness (h)	Increased milk productivity (kg/cow/day)
Dahl et al. (1997)	18	350 at the cows' eye level	Metal halide	6	2.2
Lim et al. (2021)	16	50 at 0.90 m from the floor	LED lighting	8	8.6
Lim et al. (2021)	16	100 at 0.90 m from the floor	LED lighting	8	7.7
Lim et al. (2021)	16	200 at 0.90 m from the floor	LED lighting	8	3.6
Peters et al. (1978)	16	114-207 not mentioned	Fluorescent lamps	8	2
Peters et al. (1981)	16	462 at the cows' eye level	Fluorescent lamps	8	1.4

ical mechanisms of lactation compared to conventional lighting.

Regarding light intensity, Lim et al. (2021) identified an inverse relationship with productivity. Their findings showed that the lowest tested intensity (50 lux) yielded the most significant increase in milk production (8.6 kg), whereas at 200 lux, the gain diminished to 3.6 kg. This is consistent with Peters et al. (1981), who applied a substantially higher intensity of 462 lux but recorded a minimal increase of only 1.4 kg. This discrepancy suggests that higher intensity does not linearly correlate with productivity; rather, an optimal illumination threshold likely exists, beyond which physiological responses reach a plateau or begin to decline.

A significant portion of the variation in increased milk yield can be attributed to differences in experimental design and the method of measuring light intensity. While Dahl et al. (1997) and Peters et al. (1981) measure light at the cow's eye level, Lim et al. (2021) take measurements at 0.90 m from the floor. Due to the fact that light intensity decreases with distance from the source, the two methodologies cannot be compared directly, and this may lead to a change in the actual light levels that the animals perceive.

Regarding photoperiod duration, the most pronounced effect was observed with a 16-hour day (Lim et al., 2021). In contrast, Dahl et al. (1997) utilized an 18-hour photoperiod, yet reported a relatively weaker increase in milk yield. This raises the critical question of whether an 18-hour exposure exceeds the physiological optimum for certain conditions or specific breeds. It suggests that a minimum period of darkness is essential to maintain the sensitivity of the neuroendocrine system, and extending light beyond 16 hours may lead to a diminishing stimulatory response.

While Buyserie et al. (2001) posited that a long-day photoperiod enhances milk yield regardless of baseline productivity, empirical data from the analyzed studies suggest a more complex interaction. The superior yields observed in recent research (exceeding 7–8 kg) likely reflect the enhanced genetic potential of modern dairy

cattle. Contemporary high-yielding cows may exhibit greater sensitivity to environmental optimizations—such as advanced lighting regimes, precision nutrition, and improved welfare standards—compared to the populations studied in the late 20th century. This suggests a synergistic effect between genetic merit and environmental management.

Although the quantitative results for milk yield presented in the literature are significant, the lack of detailed information regarding sample sizes and standard error in some of the older sources limits the possibility for a full statistical evaluation of their reliability. An exception is the work of Dimov (2019), where a statistically significant effect of the farm and season factors on illumination was reported, highlighting the need for a more rigorous statistical approach when analyzing the lighting microclimate.

The practical application of supplemental lighting involves a careful balance between investment and returns. While the installation of modern systems requires capital, research suggests that the resulting increase in milk yield can cover these costs, along with higher feed expenses, in less than a year.

However, it is critical to adopt a holistic approach; lighting should not be viewed as a standalone solution. Since light-stimulated cows exhibit higher feed intake and energy requirements, the success of any lighting regime is strictly dependent on adequate nutrition, animal comfort, and overall farm management.

Furthermore, the implementation of high-intensity lighting (e.g., 540 lux) in milking areas is a dual-purpose investment, enhancing both product quality control and occupational safety.

Applied light exposure in dairy farming affecting humans

Microclimatic and illumination conditions are paramount, as deficiencies in these areas often form the etiology of various occupational diseases (Frazzi and Lodigiani, 1996). Research indicates that a significant number of farms fail to maintain satisfactory standards for both natural and artificial lighting. Optimal illumina-

tion in livestock housing is essential not only for safeguarding animal welfare but also for ensuring a safe and healthy environment for farm workers (Miteva, 2012). As noted by Josefsson (2000), inadequate lighting during non-nocturnal working hours contributes to the incidence of preventable workplace accidents, such as slips and falls, within the barn facility. Such workplace injuries can occasionally be fatal; however, adequate illumination enables personnel to effectively detect obstacles and hazardous, slippery surfaces. Furthermore, optimized lighting facilitates the early identification of health abnormalities, such as anorexic cows or contaminated and scattered feed. Beyond physical safety, a well-lit environment significantly enhances psychological well-being, potentially increasing overall labor productivity. Reliable lighting is indispensable for the seamless execution of technological processes and the maintenance of rigorous hygienic standards. Consequently, lighting parameters—specifically intensity and spectral wavelength—are mandated by building and hygiene regulations and remain a cornerstone in the formal hygienic assessment of dairy facilities (Miteva, 2012).

According to the American Society of Agricultural Engineers (ASAE, 2006), the recommended illumination level in milking parlors—specifically in the pits and near the udder—is approximately 540 lux. This intensity is vital for ensuring that any deviations in milk color or consistency are immediately detected, allowing for timely corrective measures. These standards remain mandatory regardless of the housing system, whether tied-housing or parlor-based milking. Furthermore, adequate lighting serves a dual purpose: it directly influences bovine physiology and worker performance while simultaneously guaranteeing the safety and quality of the raw milk at the primary production stage (Dimov et al., 2020; Harner and Zulovich, 2014). Continuous monitoring of raw milk quality is indispensable for ensuring product safety. Optimal illumination is a prerequisite for the thorough cleaning and disinfection of teats prior to milking, thereby significantly reducing the risk of microbial contamination. Furthermore, adequate light levels empower per-

sonnel to detect subtle behavioral signals from the cows, facilitating early intervention and proactive herd management (Dimov et al., 2020a). Many producers observe that enhanced lighting quality improves bovine locomotion; cows traverse entrances and exits more confidently when illumination is uniform. Consequently, managers, veterinarians, and caretakers report more efficient monitoring and superior animal care within a safer, ergonomically optimized workplace (Miteva, 2012). In conclusion, while optimal illumination clearly enhances operational performance in dairy farming, the primary challenge remains identifying the 'golden mean' between the requirements of the cattle and those of the workforce. It is a fundamental physiological fact that light perception in humans and cattle differs significantly. While humans rely on visual acuity for complex tasks, cattle are more sensitive to specific wavelengths and contrast. Therefore, a successful lighting strategy must integrate these diverging sensory profiles to harmonize animal welfare with occupational efficiency.

Light intensity in dairy cattle farming

In the International System of Units (SI), illumination is measured in lux. To provide environmental context, direct sunlight reaches intensities of approximately 100,000 lux, while overcast conditions drop to around 5,000 lux. In contrast, nocturnal environments are significantly dimmer, with street lighting providing 10–30 lux and moonlight contributing a mere 0.25 lux (Starby, 2006). Crucially, the lux unit is calibrated to the photopic spectral sensitivity of the human eye; therefore, it may not accurately reflect the luminous perception or biological response of cattle, whose visual systems possess different spectral characteristics (Hjalmarsson, 2014). This methodological problem is further compounded by the fact that the unit 'lux' is based on human spectral perception. The lack of studies in the current review that utilize units of measurement specific to bovine vision is a limitation that future research must overcome in order to define more precisely the "hygienic standards" for light in premises.

Scientific recommendations for nocturnal illumination levels vary significantly based on whether the focus is physiological or behavioral. Buyserie et al. (2001) argue that intensity should not exceed 10 lux, asserting that cows do not require light for basic orientation toward feed and water. This is supported by Muthuramalingam et al. (2006), who suggest that 5–10 lux maintains normal physiological functions without disrupting the endocrine system. Conversely, Phillips et al. (2000) emphasize the importance of visibility for natural locomotion, noting that reduced light alters movement patterns; they recommend a substantially higher range of 39–119 lux for traffic alleys. To balance these needs, Cook (2011) proposes a standardized regime: at least 160 lux during the 'light' period (at 1 m height) and a maximum of 54 lux during the 'dark' period.

Harner (2008) emphasizes the need for zone-specific lighting within dairy facilities, recommending an intensity of 200 lux above the stalls and feeding alleys. To ensure behavioral comfort, a uniformity variance of only 25% to 45% is advised to eliminate shadows and dark spots, which can impede animal movement. This spatial complexity is supported by Dimov (2019), who identified that factors such as farm infrastructure, seasonality, and the specific time of day exert a statistically significant influence on illumination levels across three key technological zones: feeding alleys, manure alleys, and stalls. Furthermore, maintaining natural walking behavior is contingent on light intensity; as Phillips et al. (2000) observed, reduced visibility leads to an increased stepping rate, suggesting that intensities between 32 lux and 119 lux are necessary to sustain rhythmic, stress-free locomotion.

Empirical evidence from Ulimbashev (2011) reinforces the case for an optimal illumination threshold, identifying 150 lux as the point where maximal milk productivity is harmonized with robust health status. In practical terms, cows exposed to this intensity yielded an additional 614 kg of milk per lactation - a significant 14.8% increase over the control group. These findings validate the hypothesis that a 150 lux regime serves as a physio-

logical optimum, effectively satisfying the metabolic requirements of high-yielding dairy cattle while maintaining systemic well-being.

Current Bulgarian regulations mandate a minimum illumination level of 100 lx within milking parlors (MAFWE, 2006). However, contemporary research suggests that these standards may be insufficient for optimal operational efficiency. Authors such as Clarke and House (2006) propose higher minimum requirements, recommending 100 lux specifically for the pre-milking holding areas, but increasing this to 200 lux within the milking parlor itself. This higher threshold is supported by Miteva (2012), highlighting a growing consensus that doubling the local statutory minimum is necessary to ensure both animal welfare and precise technological execution during the milking process. Lighting in dairy facilities is categorized into two distinct functional types: physiological and occupational (working). Physiological lighting is primarily essential for the biological welfare and metabolic homeostasis of the organism. In contrast, occupational lighting is designed to create favorable ergonomic conditions and facilitate rigorous hygienic environmental assessments (Dolezal et al., 2004; Kunc et al., 2007; Chloupek and Suchy, 2008). For the general housing areas, a baseline of 60 lux is considered compulsory to satisfy both physiological and basic working requirements. However, more intensive occupational lighting—at a minimum of 200 lux - is mandatory for milking parlors to ensure operational precision and sanitary control (Dolezal et al., 2004).

CONCLUSION

In conclusion, light is an integral component of the holistic microclimate within dairy cattle housing and milking parlours. Both the intensity of illumination and the duration of the photoperiod exert a profound influence on the cow's organism, modulating critical physiological processes that fundamentally govern productivity, reproductive efficiency, and overall health. Managing the light regime is therefore not only a technical requirement, but a strategic imperative for optimizing the bio-

logical potential of dairy cattle. While the benefits of optimized photoperiods and intensities are evident, several critical gaps remain for future research. First, there is an urgent need for studies utilizing animal-specific spectral measurements rather than human-centric lux units to better understand bovine photoreception. Second, the international literature lacks comprehensive data from the last decade regarding the long-term physiological effects of specific LED spectra on hormonal pathways involving prolactin and IGF-I. Future research should prioritize investigating the interaction between light regimes and animal welfare in automated milking systems. Addressing these gaps will provide the scientific basis for developing concrete, evidence-based guidelines for light management that harmonize the biological needs of dairy cows with the occupational safety and efficiency of farm workers.

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