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Research Article

Comparative analysis of the effects of monochromatic LED light on jejunum morphology in Japanese quails

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ABSTRACT

It is known that environmental influences such as different light sources have effects on the digestive systems of avians. This study examined the effects of different light sources (blue, white, and green) on the jejunal structure of Japanese quails. Twenty-one male quails were exposed to LED lights emitting specific wavelengths from hatching until they reached 42 days of age. Histological analyses of jejunal tissues focused on villus length, crypt depth, and the villus length-to-crypt depth ratio (VL/CD index). The results revealed that green light exposure had the longest villi, while blue light exposure had in the shallowest crypts. Furthermore, these results showed that the VL/CD index was significantly higher under green light compared to blue and white light. These findings indicate that manipulating the light spectrum could enhance intestinal health and improve nutrient absorption efficiency in quail, offering potential benefits for optimising poultry production.

INTRODUCTION

The quail (*Coturnix coturnix*) is a migratory poultry species widely distributed across Eurasia and Africa. Its distinct flavour, rapid reproductive capacity, and potential for quick financial returns have led to the development of new hybrid breeds through selective breeding initiatives. Quail meat and eggs have broad market appeal; however, managing quail presents several challenges. These include management issues in large-scale or intensive production systems, as well as factors such as lighting requirements, housing density, and other welfare considerations (El-Sabry et al., 2022).

In recent years, the demand for poultry products, including chicken meat and eggs, has increased significantly. Chicken meat production, currently at 117 million metric tonnes, is projected to reach 132 million metric tonnes by 2026 (Van Boeckel et al., 2015). This growing demand has driven technological advancements aimed at increasing output, including a transition from traditional lighting sources to LEDs. According to Xie et al. (2008), this transition can substantially reduce energy consumption, enhance animal well-being, improve growth efficiency, and reduce stress. Poultry possess highly developed visual systems and exhibit strong light sensitivity (Bian et al., 2019). Light, as a key environmental stimulus, can disrupt the circadian rhythm of chickens, affecting endocrine pathways, oxidative stress levels, and metabolic activities (Yang et al., 2020). Research also highlights the influence of coloured light sources on chick growth and development. For example, green light exposure may accelerate cell division and T lymphocyte growth, while blue light promotes small intestine development and the maintenance of its protective lining (Liu et al., 2010; Guo et al., 2017; Zhang et al., 2022). However, studies have shown that chicks raised under red light exhibit poor growth performance, higher oxidative stress levels, and lower growth hormone levels (Li et al., 2015).

The relationship between intestinal health and the length of villi and crypt depth is well established (Pluske, 1996). An increased villus height-to-crypt depth ratio may reduce maintenance requirements and improve growth efficiency by decreasing intestinal mucosa turnover (Van Nevel et al., 2005).

Recent research highlights strong correlations between gut microbiota and various physiological factors, including metabolite balance (Xie et al., 2008), immune system health (Yang et al., 2020), growth and development processes (Yeoman et al., 2012), and overall well-being (Zhang et al., 2022). However, data on the effects of monochromatic light on jejunal microbiota composition and function are limited. Most studies investigating the influence of light on gut microbiota focus on chicks, specifically their caeca (Zhang et al., 2022).

In line with the increasing demands of the poultry industry,

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this study aimed to investigate the effects of blue, white, and green light on the jejunum, one of the crucial part of the digestive system, in Japanese quails.

MATERIALS and METHODS

Animals and Experimental Design

This study examined the jejunum of 21 male Japanese quails, which were exposed to LED light for a period of 42 days from hatching. At the end of the experiment, the quails were 42 days old, with an average weight of 211.3 ± 29.97 g (range: 177.4–266.0 g). The birds were divided into three groups of seven and housed under LED lights emitting wavelengths of 480 nm (blue), 400–770 nm (white), and 560 nm (green) throughout the entire experimental period. The research was approved by the Aydın Adnan Menderes University Animal Experiments Local Ethics Committee (No. 645583101/2023/37).

Histological Procedures

Jejunal tissues were fixed in 10% formaldehyde solution. Following fixation, the tissues were processed by embedding them in paraffin wax after treatment with a series of alcohol solutions of increasing concentrations (70%, 80%, 90%, 96%, and 100%) and successive applications of xylene. Thin sections (4–5 µm) were cut using a microtome (Leica RM 2135), mounted on slides, and stained with haematoxylin and eosin (HE) following Luna's method (1968). The slides were examined under an Olympus BX51 light microscope.

Measurements

Villus length: Measured from the base to the tip (Figure 1). Measurements were taken from well-oriented, intact villi to ensure accuracy.

Villus width: Measured at the midpoint (Figure 1). Only fully visible and undamaged villi were included.

Crypt depth: Measured parallel to the villus length (Figure 1). Crypts were selected based on clear structural visibility and intact epithelium.

VU/CD: Calculated by dividing villus length by crypt depth.

Statistical Analysis

Statistical analyses were performed using SPSS 22.0 (Inc., Chicago, IL, USA). First, the normal distribution of the data was checked with the Shapiro-Wilk test. One-way analysis of variance (ANOVA) was employed to compare jejunal data between light groups. In the case of non-parametric data, the Kruskal-Wallis test was applied. The homogeneity of variances was checked with the Levene test. Since the variances were homogeneous, Oneway-ANOVA test results and posthoc-LSD test results were used in all comparisons.

RESULTS

Image analysis revealed that villus length and width was greatest in quails exposed to green light. Crypt depth was shallowest in quails exposed to blue light (Figure 2). The VC/CD index was highest under green light compared to white and blue light, with statistically significant differences (p = 0.031) (Figure 3 and Table 1).

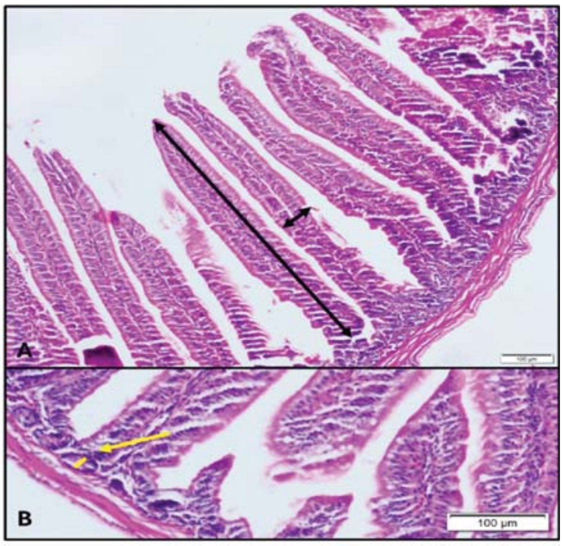

Figure 1. Presentation of measurement locations. Big black two-pointed arrow; villus length, small black two-pointed arrow; villus width (A), yellow line; on the leading edge of the yellow arrow crypt depth (B).

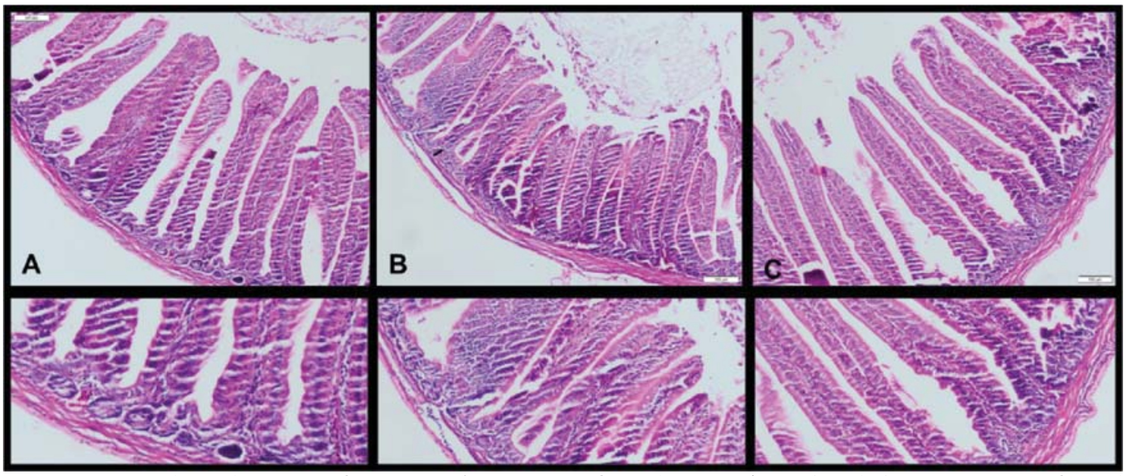

Figure 2. Histological images of jejunum. A; jejunum of quail exposed to white light, B; jejunum of quail exposed to blue light, C; jejunum of quail exposed to green light.

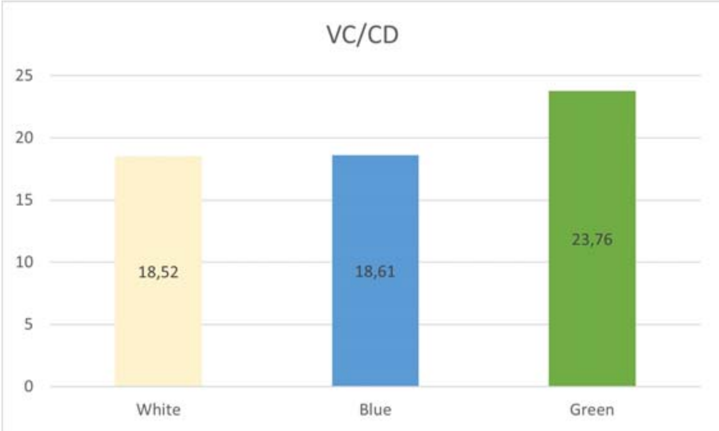

Figure 3. Graphical representation of villus length / crypt depth.

Table 1. Statistical the comparison of morphometric data for the jejunum was performed. The mean ± standard deviation values for villus length, crypt depth, villus width, and villus length/crypt depth (VL/CD) index were obtained from quails exposed to white, blue, and green light, along with their 95% confidence intervals.

	White *(n=7)* Mean±Std (95% CI	Blue *(n=7)* Mean±Std (95% CI)	Green *(n=7)* Mean±Std (95% CI)	P
Villus length (µm)	491.26±160.33 (402.13-592.44)	430.19±99.71 (376.37-48685)	541.47±138.01 (460.23-619.65)	0,171
Crypt depth (µm)	26.29±4.45 (24.02-29.09)	23.03±2.55 (21.69-24.54)	23.09±3.19 (21.30-24.87)	0,061
Villus width (µm)	92.60±15.06 (83.85-100.99)	89.80±12.41 (83.16-96.87)	102.52±14.88 (94.62-112.43)	0,103
VL/CD	18.52±4.31 [a] (15.88-20.98)	18.61±3.70 [a] (16.58-20.80)	23.76±6.62[b] (19.82-27.92)	0,031

DISCUSSION

In terms of intestinal health, the thickness and composition of the mucus layer vary along the intestine, playing a crucial role in protecting the intestines from mechanical, enzymatic, and chemical factors, as well as facilitating lubrication (Sharma and Schumacher, 1995). Long villi are generally associated with optimal intestinal health, high absorption efficiency, and a healthier intestinal system in poultry (Alfaro et al., 2007). The villus height-to-crypt depth ratio (VH:CD) reflects the superior digestion and absorption capacity of the avian small intestine, owing to its larger absorptive surface area, which enhances nutrient uptake (Van Nevel et al., 2005).

The histological findings of our study are both consistent with and, in certain respects, divergent from existing literature. For example, studies by Liu et al. (2010) and Guo et al. (2017) demonstrated that green light enhances mitotic activity and T lymphocyte proliferation in chickens. Our study also supports the beneficial effects of green light on intestinal health. Additionally, Zhang et al. (2022) reported that green light promotes intestinal development and mucosal integrity. In line with these findings, we observed that green light increased villus length and reduced crypt depth.

However, studies on the effects of blue light have produced conflicting results. For instance, research by Yang et al. (2020) and Zhang et al. (2022) suggested that blue light may have beneficial effects on the intestinal microbiota and metabolic functions. In contrast, our findings showed that blue light did not increase villus length or reduce crypt depth; instead, it decreased the villus length-to-crypt depth ratio. These results suggest that the effects of blue light on intestinal health may vary between species or depend on specific experimental conditions.

Reviewing other studies, Simsek et al. (2020) reported that green light increased villus length, while blue light resulted in shorter crypt depth in quails. Similarly, Xie et al. (2011) observed increased villus height in chickens exposed to green and blue light compared to the white light group. They noted that chicks raised under 560 nm green light exhibited increased mitotic activity in crypt cells and higher proliferation activity in T lymphocytes, with these beneficial effects being most pronounced under 480 nm blue light in later stages (Zhang et al., 2022).

The results of our study offer valuable insights for optimizing lighting strategies in poultry production. Specifically, the use of green light may enhance growth performance and overall health by supporting intestinal health. These findings align with Pluske's (1996) research on intestinal health and growth efficiency. A higher villus length-to-crypt depth ratio results in a slower turnover of the intestinal mucosa, leading to greater growth efficiency (Van Nevel et al., 2005).

This study examined the effects of different coloured light sources on the jejunal structure of Japanese quail. The findings highlight the significant impact of light colour on intestinal health and microscopic structure. Specifically, green light may find to increase villus length and decrease crypt depth, suggesting potential positive effects on quail intestinal health. Additionally, blue light resulted in the shortest crypt depth and the lowest villus length-to-crypt depth ratio. These results demonstrate the distinct effects of various light colours on intestinal morphology.

This study is limited to the effects of specific LED wavelengths (blue, white, and green), excluding the potential influences of other light spectra. Furthermore, the experimental duration was restricted to 42 days, preventing an assessment of long-term effects.

CONCLUSION

This study demonstrates the significant effects of monochromatic light on the jejunal structure of Japanese quails. Green light positively influences intestinal health, providing insights for optimising lighting strategies in poultry production. Future research should explore the long-term effects of various light spectra and intensities on intestinal health to achieve optimal welfare and performance.

DECLARATIONS

Ethics Approval

The study was conducted with the decision and permission of Aydın Adnan Menderes University Animal Experiments Local Ethics Committee dated 09.03.2023 and numbered 64583101/2023/37.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Consent for Publication

Not applicable.

Author contributions

Idea, concept and design: FTY

Data collection and analysis: FTY, UC, ANA

Drafting of the manuscript: FTY, UC

Critical review: FTY, ANA

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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