Effects of different LED light colors on growth performance and harmful gas emission of broilers breeding in a digital rearing chamber

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Abstract: Refined management is an inevitable trend in the development of livestock husbandry. Accurate acquisition of breeding environment parameters is beneficial to improve breeding efficiency while reducing environmental pollution. Light is an important breeding environmental factor during broiler breeding. In this study, a short-term broiler breeding experiment was conducted with different light color illumination environments in a digital breeding chamber under lab conditions. According to experimental results, the Red Light (RL) group was conducive to the growth of broilers at 30 d of age with low NH_3 emission concentration; the Green Light (GL) group inhibited the broiler growth; the Yellow Light (YL) group showed the highest average emission concentration of NH_3 and lowest daily average emission concentration of CO_2. According to the analysis of moisture content, pH value, and C/N in the broiler manure, it can be concluded that the physical and chemical properties of broiler defecation quantities were different under various light color illuminations, resulting in the difference in broiler growth conditions and harmful gas emissions. The study results could provide a research basis and ideas of reference to establish a relationship between LED illumination information, broiler growth performance, and harmful gas emission.

Keywords: broiler, growth properties, harmful gas, ammonia, illumination environment
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1 Introduction

In recent years, the poultry industry has developed rapidly. However, the expansion of the breeding scale has led to increasingly severe environmental pollution from emissions of poisonous and harmful gases during the breeding process. During broiler breeding, many harmful gases such as NH_3, CO_2, and NO_2 are generated[1-3]. Massive emission of NH_3 can cause eutrophication and ecosystem acidification[4]. Greenhouse gases like CO_2, CH_4, and N_2O are the main sources that cause global warming[5,6]. According to existing studies, NH_3 is the most harmful gas in the broiler house. high-concentration of NH_3 is not only harmful to the health of poultry's respiratory and digestive systems but also decreases production performances like feed intake and weight increment[7,8]. In addition, NH_3 also has impacts on the broiler's immunity[9], meat quality[10], genetic expression[11-13], and animal welfare[14]. With fast growth, strong metabolism, and high oxygen demand, broilers also generate much CO_2. However, a high concentration of CO_2 might cause brain edema and damage to the lungs and cardiovascular system[14], thereby affecting its growth performance[15,16]. Therefore, it is necessary to reduce the harmful gas emission during the livestock and poultry breeding process to achieve environmental protection strategy and healthy and sustainable development of animal husbandry.

As animal husbandry is developing on a large scale, precise management has become a trend in livestock and poultry breeding, and light environment control is a common means to help animal growth and improve breeding efficiency. Compared with mammals, poultry is more sensitive to light information thanks to its complex eye structure, photosensitive imaging system, and a large number of photoreceptors. The light stimulates retina photoreceptors and generates bioelectrica signals. Or the extraretinal photoreceptors can be simulated directly through the skull, which simulates the hypothalamus secretes gonadotropin to release the hormone. This acts on the pituitary gland to control and adjust the secretion of hormones in the body, thereby controlling the body's metabolism and behavior characteristics[17]. Therefore, light is closely associated with the broiler's life activities[18-20]. A recent study conducted from the perspective of optogenetic theory[21] showed that the animal's life activities can be adjusted by simulating the neuronal activities with lights of different wavelengths. However, for poultry, light can generate effective photoperiodic effects only when it can penetrate the skull, and is sensed by the hypothalamus photoreceptor. Light penetration varied based on different wavelengths, thus exerting different effects on broilers. The LED lighting technology has gotten more and more attention in broiler breeding in recent years.

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During modern chicken production, artificial intervention light is often used to improve broiler breeding efficiency. Some studies revealed that different LED illumination environments might improve broiler quality[22] and immunity[23], reduce stress reaction[24], enhance the mucosal structure of the small intestine and immunologic barrier[25], and boost growth performance[26].

The broiler's digestion process is extremely complex, which is associated with the broiler's age, related in vivo hormones, enzyme activity, small intestine structure, and environmental conditions. The illumination environments can change several basic functions of poultry, such as promoting various metabolic modes like ingestion and digestion and affecting the digestive absorption of various nutrients in the feed, thus resulting in various growth performances. For broiler feeding, the quantity change in undigested organics and microorganisms in the intestinal tract and excreta can directly affect harmful gas emissions. Other influencing factors include the moisture content, C/N, and pH value in the broiler manure[27]. Therefore, breeding under different light colors affects the feed metabolism in the broiler body, giving rise to a difference in broiler behaviors like ingestion, drinking, and defecation, as well as manure composition and defecation quantity. In addition, related organics in the manure are decomposed by microbial activities, which cause different emissions of harmful gases, thus affecting broiler growth. At present, most studies on accurate animal husbandry breeding environments focus on the real-time sensing technology of breeding environment information, emission reduction measures, or animal growth performance. There are a few basic research about the coupling relationship between multiple parameters (such as lighting conditions, and harmful gases) and livestock and poultry in an accurate environment. In this study, research was conducted based on a digital breeding chamber under lab conditions to study the broiler growth performances and harmful gas emissions under different light color illuminations, and to analyze the relationship between light color and broiler growth and harmful gas emission.

The aim of this study was to improve broiler breeding efficiency and to reduce emissions of harmful gases like NH_3, CO_2, and N_2O from sources through light environment control. It could provide a reference basis for correct and reasonable utilization of light control to achieve energy conservation and emission reduction and for the preparation of scientific and healthy broiler breeding and feeding management systems.

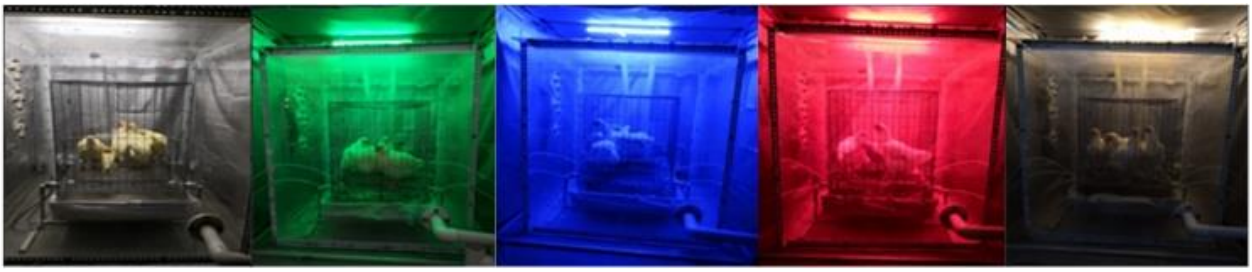
2 Materials and methods

2.1 Broiler breeding process

The broilers (Arbor Acres, AA) were selected from a farm in Jiangxia District, Wuhan City, Hubei Province in China (114.3°E, 30.3°N). Twenty-five broilers at 30 d of age were randomly selected from the farm, with five broilers placed in each illumination breeding chamber.

The digital breeding chamber was made of 6 mm-thick transparent acrylic sheets. The size of the chamber was 1.2 mL×1.2 mW×1.2 mH, and it was located in the environmental control laboratory. An iron cage (0.85 mL, 0.65 mW, 0.6 mH) was placed inside, which was located on the stainless steel base. An axial flow fan (SE-A100, Shenzhen Shengshida Electronics Co., Ltd., Shenzhen) was installed at the air outlet to ventilate the system under negative pressure. To measure the temperature and humidity in the laboratory and feces, an intelligent temperature and humidity recorder (SMTDOG260, Embedded Science and Trade Beijing Co., Ltd., Beijing, China) was installed. Cantilever weight sensors were installed at the bottom of the food trough and water trough, the four corners of the breeding iron cage, and the manure pan for real-time monitoring of growth performance indexes like broiler weight increment, defecation quantity, feed intake, and water intake, and the gas sampling points were designed inside the breeding chamber to detect the concentration of harmful gases such as NH_3, H_2S, CO_2, and N_2O. Five LED light illumination groups involved in the experiment were divided into white light (WL, 400-760 nm), green light (GL, 500-565 nm), blue light (BL, 435-500 nm), red light (RL, 630-760 nm), and yellow light (YL, 565-600 nm). The illumination intensity during the experiment period was 10 lx, and the photoperiod was 16 h light (6L):8 h dark (8D) based on the feeding specification. The experimental setup was shown in Figure 1. The experiment period was 10 d, including the first 3 d as the adaptation period. The broilers were raised for a short period under different light colors in the lab for real-time monitoring of growth performance indexes like broiler weight increment, defecation quantity, feed intake, and water intake, as well as concentrations of harmful gases (NH_3, CO_2, and N_2O).

All experiments with animals were carried out in strict accordance with the recommendations in the guide for the Care and Use of Laboratory Animals of the Ministry of Science and Technology of the People's Republic of China. The protocols were approved by the Committee on the Ethics of Animal Experiments of the Diagnostic Center for Animal Disease of Huazhong Agricultural University. The feeding method and vaccination in the lab were the same as on the farm. Those broilers were fed with food and water at 8:00, 12:00, and 17:00 every day. During the experiment, the digital breeding chambers were in the control lab of a healthy livestock and poultry breeding environment. The lab temperature was controlled by the air conditioner at (25±2)°C.



a. White light b. Green light c. Blue light d. Red light e. Yellow light

Figure 1 Experiments of different color LED lights in broiler breeding

2.2 Determination of harmful gases

The concentrations of harmful gases like NH_3, CO_2, and N_2O inside the breeding chamber were determined during the short-term experiment period. The multi-point gas sampling apparatus (INNOVA1409, LumaSense, Denmark, up to 24 detection points) was used for gas sampling in 6 different light color breeding chambers through a Teflon tube (1/4 inch), and a filter (diameter: 4.5 cm, 4.5 μm) was installed in the sampling pipe. The infrared acoustic spectrum gas detection analyzer (INNOVA1412, LumaSense, Denmark) with a detection precision of 1 $\mu g/m^3$ was used to detect the emission concentrations of NH_3, CO_2, and N_2O in the sampling gas. Before the experiment, the gas dilution calibrator (S4000, Environics, America) was used for instrument zeroing and calibration at a measurement interval of 10 min.

2.3 Determination of chemical index of manure

After the experiment, 500 g of chicken manure was picked up from the dropping tray with the 5-point sampling method for later determination of the physical and chemical properties. The pH value was measured by an acidity meter (PHS-3E, Shanghai INESA Scientific Instrument Co., Ltd., China); TC was measured by a carbon-nitrogen analyzer (HT1300, Analytik Jena AG, Germany); TN was determined by an auto chemical analysis machine (SmartChem200, AMS Group Company, Italy) after digestion by the microwave digester (MARS-6, CEM Company, America); and the moisture content was measured with the oven-drying method.

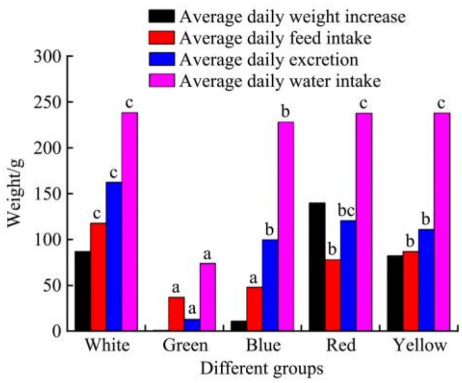
2.4 Data analysis and method software

In the experiment, broiler weight, defecation quantity, feed intake, and water intake were analyzed and processed by Excel and Origin software, and they were displayed in a figure.

3 Results and discussion

3.1 Broiler growth performance

The broiler growth performance was represented by weight increment, feed intake, defecation quantity, and water intake. Figure 2 shows the average values of broiler weight increment, feed intake, defecation quantity, and water intake under different light colors during the short-term experiment period.



Note: Bars with the same letters are not significantly different at $p<0.05$ within each index.

Figure 2 Growth parameters of broilers under different color LED lights

As shown in Figure 2, green light had the greatest impact on the broiler growth, with defecation quantity and water intake significantly lower than the values of the remaining groups ($p<0.05$), and weight decrease was observed ($p<0.05$). In addition to Green Light (GL) group, broilers in other groups showed weight increase, with minimum weight increment in Blue Light (BL) group; the broilers in Red Light (RL) group increased weight by 139.82 g/broiler significantly higher than the values of remaining groups ($p<0.05$); White Light (WL) group's feed intake was significantly higher than other groups ($p<0.05$), and the defecation quantity was also the highest; in addition to GL group, water intakes under other light colors was no significantly ($p>0.05$). Among the researches on the impact of light color on broiler growth performances, few were about yellow light[28]. This experiment showed that there was no significant difference in weight increment between the GL group and the WL group. However, the feed intake and defecation quantity of the GL group were significantly lower than those of the WL group. The water intake, feed intake, and defecation quantity under red light were close to the results under yellow light, with a sharp increase in the weight increment. Therefore, in this experiment, the red light was more conducive to the growth of broilers at 30 d of age from the perspective of growth performance indexes, and was considered a preferred light color; the green light and blue light, however, inhibited the broiler growth; yellow light showed little influence.

The broiler received photostimulation through the eyeball's retina photoreceptor and the extraretinal hypothalamic photoreceptor. Lights with different wavelengths had different efficiencies to reach the hypothalamus through optic nerve or direct penetration of the skull. Photons with long wavelengths (700-750 nm) were more effective to simulate the hypothalamus than those with short wavelengths (400-450 nm). Therefore, poultry was more prone to induce the generation of photoperiodic effect under red light[28]. As the age of broilers increased, the red light had better action on the hypothalamic photoreceptor than the blue light and green light due to increasing penetration resistance of brain tissue against light and broiler head issue's absorption and scattering for light. Moreover, the rapid compensation action of red light in the later growth of broilers can increase the broiler weight.

Some researchers[22,25,29] reported that compared with light with a longer wavelength, light with a shorter wavelength was more capable of increasing broiler production performance. This finding was inconsistent with the results of this study, and the difference might be attributed to the growth and development speed of different varieties of broilers, life habits at different growth stages, and different demands and degrees of sensitivity for illumination. In this study, the illumination intensity was 10 lx; the photoperiod was 16L:8D; the LED source was 60 cm from the broiler head. Although the poultry's hypothalamic photoreceptor was most sensitive to blue and green light, it might be that the light intensity in this study was not so strong that the blue-green light only simulated the broiler eyes, with the less light signal received by the hypothalamus. As a result, the long-wavelength light (such as red light) was more likely to be sensed by the hypothalamus, generating compensation effects to compensate for the difference in photoreceptor sensitivity. Studies showed that[30,31] short-waveform lights like green light were harmful to body health. During the experiment period, mental sluggishness was observed in broilers under green light, which was consistent with the above results[32]. Lights with different wavelengths could affect the mucosal structure of the small intestine and broilers' absorption of nutriments[25], which is directly related to feed consumption during the broiler breeding process. Therefore, the defecation quantity under different light colors was associated with water intake, feed intake, as well as broiler digestion rate.

3.2 Impact of light color on harmful gas emissions

3.2.1 Ammonia emission

The NH_3 emissions under different light colors are shown in Figure 3. As shown, the NH_3 emissions under white light increased in the early stage of the experiment (1-2 d) and tended stable in the middle and later stages (3-7 d). This tendency might be associated with broiler defecation quantity and surface area of emission[33]. In the early stage of the experiment, there was less defecation quantity and the surface area of emission was smaller; as defecation quantity accumulated, the surface area of emission gradually increased; therefore, a rapid increase in NH_3 emission was observed in the early stage of the experiment; however, as the fresh manure covered the original manure surface, but the surface area of emission was not changed with defecation quantity accumulation, the NH_3 concentrations tended stable in the middle and later stages. The maximum concentration of NH_3 under white light was 14 mg/m^3, and the average value during the experiment was (7.2±3.1) mg/m^3.

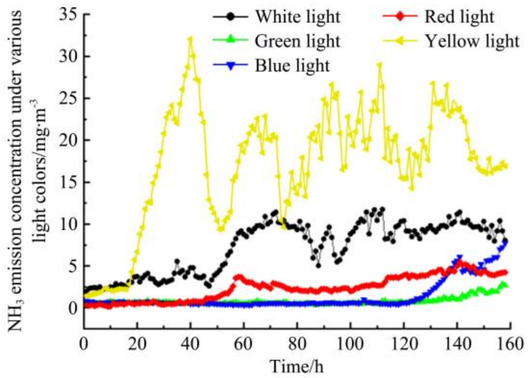


Figure 3 NH_3 emission concentration under different light colors

The NH_3 emission trends under green light and blue light were similar with no significant difference (p>0.05), which tended stable in the early and middle stages of the experiment (1-5 d), and increased in the later stage (6-7 d). The NH3 emission concentrations under blue light and green light (3.8 mg/m^3 and 10.7 mg/m^3 respectively) were significantly lower than that under white light (p<0.05). According to the analysis from Table 1, the broiler feed intake and defecation quantity under blue light and green light were less, which might be a reason for the low NH_3 emission concentration.

Table 1 Physical and chemical indicators of feces got from the broilers breeding in different color lights

Physical and chemical indicators	Different light colors				
	White	Green	Blue	Red	Yellow
Moisture content/%	69.6	43.3	67.5	81.6	61.9
pH	6.84	6.65	7.07	7.38	7.61
TC/mg g^{-1}	319.1	318.7	320.5	342.4	316.1
TN/mg g^{-1}	36.6	47.4	27.7	30.5	16.6
C/N	8.7	6.7	11.6	11.2	19.0
Total excretion/g	8121	645	4985	6017	5543

The NH_3 concentration under red light rose slowly in the middle and later stages (3-7 d) with a maximum value of 5.3 mg/m^3, and the NH_3 concentration under red light was lower than those of other light colors. As shown in Figure 2, the broiler growth and defecation quantity were normal under red light. To this end, it can be inferred that, in addition to defecation quantity, there were other factors that might affect NH_3 emission concentration under red light. After the experiment period, a further analysis was conducted for broiler manure to explore whether the light color would affect the broiler digestion process, the change in the physical and chemical properties of manure, and the NH_3 emission concentration.

The NH_3 emission trend under yellow light was similar to the one under the white light, but with a significant difference in the emission concentration (p<0.05). The emission concentration under yellow light was far higher than in the other light colors with a maximum value of 32 mg/m^3. The descending order of different light colors in terms of average emission concentrations of NH_3 was LED yellow light, LED white light, LED red light, LED blue light, LED green light.

Studies believed that[12], the NH_3 concentration in the broiler house should be lower than 19 mg/m^3, Therefore, the reason for feed intake decrease under yellow light might be that the penetration of ammonia in blood changed the blood pH, thus inhibiting breath[11], reducing breathing rate and energy demand[34]. Studies also found that the feed intake and defecation quantity under yellow light were lower than those under white light. A possible reason might be that due to higher NH_3 emission concentration under yellow light (as shown in Figure 3), and the increased ammonia content in broilers consumes a lot of energy for the detoxification of ammonia, which limits the growth of broilers[35]. As a result, energy for growth and development was reduced, affecting the broiler weight increment. This finding was also consistent with the fact that broiler feed intake under yellow light was lower than that under white light.

3.2.2 Carbon dioxide emission

The CO_2 emissions under different light colors are shown in Figure 4. According to the analysis of Figure 4, the main fluctuation ranges of CO_2 concentration under white light, green light, and blue light, as well as red light and yellow light were 1000-2600 mg/m^3, 1200-1800 mg/m^3, and 1200-2000 mg/m^3 respectively. The ANOVA analysis showed a significant difference among different groups (p<0.05).

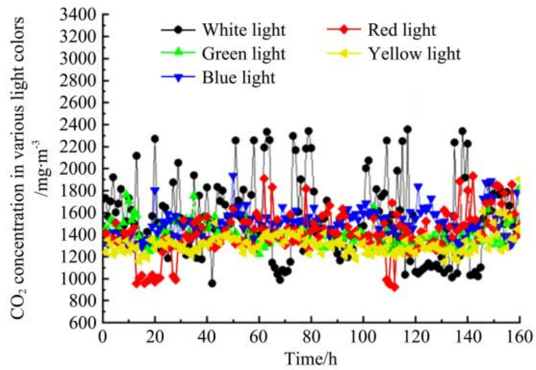


Figure 4 CO_2 emission concentration under various light colors

There was a large fluctuation in CO_2 concentration under white light and fewer fluctuations under other light colors. By analyzing the CO_2 concentration under white light shown in Figure 3, it can be found that high CO_2 concentration often appeared 2 h after food and water feeding and at about 12:00 a.m. During broiler breeding, CO_2 was mainly generated from broiler digestion and metabolism and was released by respiration. The analysis for Figure 2 showed that the broiler feed intake under white light was higher than those under other light colors. As a result, it can be inferred that more CO_2 was generated during digestion due to high feed intake under white light. In addition, the broiler self-metabolism was strong within 2 h after food and water feeding and before dawn, causing higher CO_2 concentration in this stage. By contrast, the broiler feed intakes were less, generating less CO_2 during digestion and showing small fluctuation under other light colors. The CO_2 concentration under yellow light has maintained at a low level, which certified the inference in Section 2.2.1, high NH_3 concentration inhibited the broiler respiration, reduced growth performance, and slowed down metabolism, thus reducing CO_2 emission.

3.2.3 N_2O emission

The N_2O emissions under different light colors are shown in Figure 5. As observed, the N_2O emissions showed significant differences in concentration under different light colors(p<0.05). In addition, the concentrations of each group were low (<1 mg/m^3) during the experiment with small fluctuations.

N_2O was mainly generated from nitration reaction, which needs aerobic conditions; and the N_2O generated from denitrification was limited[36]. Nitration reaction was not likely to occur in broiler manure because of high moisture content, small porosity, and poor oxygen diffusivity, which caused oxygen deficit. During the short-term breeding experiment under different light colors, the breeding chamber was well-ventilated and there was almost no anaerobic environment on the manure surface, resulting in almost no generation and emission of N_2O. According to existing studies[37], there was a certain difference in the N_2O emission results during broiler production. The low N_2O emission concentration determined during the broiler production process of this study was consistent with the results of some researchers[38]. This indicated that, apart from manure treatment and microenvironment conditions, N_2O emission during broiler breeding was closely associated with the breeding method and regional conditions.

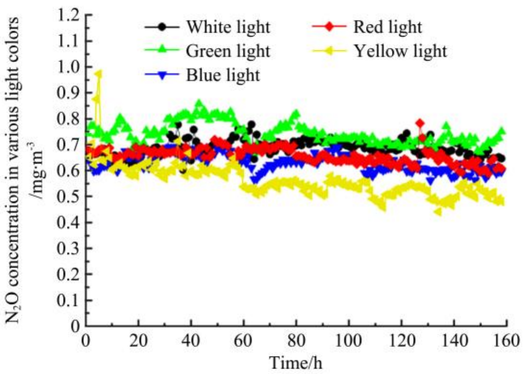


Figure 5 N_2O emission concentration under various light colors

3.3 Determination and analysis of physical and chemical indexes of manure sample

3.3.1 Broiler digestion

The broiler digestion varied under different light colors. A broiler's growth speed depended on its feed intake[38], high feed intake lowered the proportion for maintaining metabolic energy so that broiler had more energy for growth. In combination with broiler growth conditions in Figure 2, it can be seen that the broiler weight increment was greatly affected by feed intake and defecation quantity. The NH_3 concentration increase could affect the broiler's feed intake and weight[12]. The broiler weight increment was highest in the LED red light breeding experiment. Despite the high digestion rate for fat, however, the feed intake was low under green light, causing mental sluggishness and lower activity capacity. What's more, the green light might affect other performances of broilers, which also decreased broilers' weight. A possible explanation might be that LED illumination increased the digestion rate of broiler for the crude protein in feed, thus lowering the nitrogenous substance content in manure and NH_3 emission.

3.3.2 Physical and chemical indexes of manure

Through the analysis in 2.1 and 2.2, it can be found that different light colors would have an obvious impact on the broiler growth performance index and the emission of NH_3, CO_2, and other harmful gases. This study inferred that the impact of light color on broiler digestion resulted in a difference in broiler growth performance index and manure characteristics, which finally caused different emissions of NH_3 and CO_2. To verify the above inference, the C/N, pH, and moisture content in broiler manure were further determined after the broiler breeding experiment.

The decomposition of nitrogenous substances in livestock and poultry manure and the generation of NH_3 were complex, in which, physical properties (moisture, surface temperature) and chemical properties (total nitrogen, total carbon, and pH) of manure were important factors affecting the emission of harmful gases (NH_3, N_2O, and CO_2)[39-41]. In the NH_3 generation through decomposition of uric acid or urea, water is needed in several steps, and the emission of NH_3 showed a trend of first increasing then decreasing as the manure moisture content increased, and the moisture content ranging from 40% to 60% was best for microbial activities[41,42]. The enzymic catalytic reaction is an important part of the generation of NH_3, and the reaction formula is shown in Equation (1). Under an acid environment, the lower pH value would decrease the NH_3 emissions[43]. The more suitable poultry manure C/N for microbial activities, the more NH_3 emissions[44].

$$C_5H_4N_4O_3(\text{uric acid}) + O_2 + 6H_2O + C_2H_2O_3(\text{glyoxylic acid}) + H_2O_2 \xrightarrow[\text{allantoicase, uricase}]{\text{uricase, allantoinase,}} 3CO_2 + 4NH_3 \quad (1)$$

As shown in Table 1, the descending order of different light colors in terms of broiler manure moisture content was red light (81.6%), white light (69.6%), blue light (67.5%), yellow light (61.9%), green light (43.3%). According to the analysis in Section 2.2.1, the descending order of different light colors in terms of average emission concentrations of NH_3 was yellow light, white light, red light, blue light, and green light. The manure moisture content under yellow light was right within the best range for microbial activities. In combination with Table 1, it can be found that defecation quantity under yellow light was far more than that under green light (only 645 g). The previous studies[45] showed that the more the accumulated manure, the more NH_3 emissions. This explained why NH_3 emission under green light was far less than that under yellow light although its manure moisture content was also within the best range for microbial activities. According to the comparison and analysis of moisture contents under each light color in this experiment, the manure moisture content under green light was 43.3%, and the values under other light colors were higher than 60%. This might be greatly attributed to the broiler water intakes under different light colors. As shown in Figure 2, broiler water intake under green light was the least (only 73.84 g/broiler·d), while the water intakes under other light colors were basically the same. The descending order of different light colors in terms of NH_3 average emission concentrations according to the measured data in this experiment was yellow light, white light, red light, blue light, and green light. The NH_3 emission concentrations under other light colors were the same as the research results of Koerkamp except for the blue light and green light experiments[41]. As inferred by this paper, the reason might be that the broiler growth was affected by blue light and green light, making the broiler defecation quantities under these two light colors (12.9 g/broiler d and 99.7 g/broiler d respectively) far less than those of other light colors.

The manure moisture content was associated with broiler water intake and self-metabolism. The stronger the digestion and metabolism, the higher the manure moisture content was, and the manure moisture content was affected by the nutrients in broiler excreta[46] Different light colors had different simulations on the broiler hypothalamus, leading to different digestion and metabolism of broilers, and thus the manure moisture content was affected. According to existing studies[47], when the manure moisture content was maintained above 60%, nitrogen conversion was mainly represented by the generation of nitrogen through denitrification, which can inhibit the generation of N_2O. The broiler manure moisture contents under different light colors were basically higher than 60%, which might be one of the reasons for almost no N_2O emission.

The pH value of broiler manure would affect the balanced relationship between NH_4^+ and NH_3, and was a major affecting factor for NH_3 volatilization. As shown in Table 1, it was found that broiler manure pH values under different light color experiments can be divided into three gradients, high pH value gradient under natural light illumination and yellow light illumination. Another gradient under blue light and red light; low pH value gradient under white light and green light. When the temperature remained unchanged, the balance between NH_{4+} and NH_3 was determined by pH value. According to related literature[48], the balanced relationship between NH_3 and NH_4^+ is shown in Equation (2).

$$NH_4^+ \overset{pH,T}{\Leftrightarrow} H^+ + NN_3 \tag{2}$$

The manure pH value was higher and the NH_3 emission concentration was highest under yellow light; the manure pH value was low under white light, and the NH_3 emission concentration was higher than that under red light, which showed a high pH value; as shown in Table 3, the manure moisture contents under white light and red light were 69.6% and 81.6% respectively; thus, the manure moisture content under white light was more suitable for microbial activities than that under red light[41]; moreover, the broiler defecation quantity was largest under white light (increased by 25.9% compared with that under red light), and the increase of defecation quantity[46] was the main reason for high NH_3 emission. The urine pH value can be changed by controlling the electrolyte balance in diets[49]. The significant difference in pH value of broiler manure under different light colors might be attributed to the impact of light color on the broiler's digestive process.

The C/N in broiler manure was affected by the digestion of proteins and other organics in the feed by broilers. According to the analysis in Table 1, the descending order of different light colors in terms of C/N in broiler manure was yellow light (19.0), blue light (11.6), red light (11.2), white light (8.7), and green light (6.7). The descending order of different light colors in terms of NH_3 average emission concentrations was: yellow light, white light, red light, blue light, and green light. In Yellow Light (YL) group with the highest C/N, the N content was 16.6 mg/g, which was the lowest among all light colors. It can be seen from Figure 3 that NH_3 emission concentration is highest under yellow light, indicating that N is lost in the form of NH_3. In addition, the NH_3 emission concentrations under white light were inconsistent with the theory, which might also be attributed to defecation quantity. Namely, the broiler defecation quantity under white light was highest (162.4 g/broiler d) among all light colors, causing higher NH_3 emission concentration.

To sum up, the generation and emission of NH_3 during the broiler breeding process are affected by a variety of factors, including defecation quantity, pH value, C/N, and moisture content. During the experiment period, the manure moisture content is associated with broiler digestion, water intake, and physiological activities; C/N is related to the contents of proteins and other organics in manure, which are also affected by broiler digestion. Research results diet can affect gut microflora[50], fecal microflora[51], litter moisture content[52], litter pH[53], and litter water activity[54] all of which may affect the emission of odorants from litter[27]. Therefore, this study suggests that different light colors might cause different simulations on the broiler hypothalamus, leading to a difference in broiler digestion and physiological activities, which in return, influence the broiler's absorption of nutrients. This further brings about different manure moisture content and contents of proteins and other organics, and such difference in physical and chemical characteristics results in varied microbial activities in manure, thus affecting the emission of harmful gases like NH_3 and CO_2.

4 Conclusions

1) Red light was the better color light. The red light was good for the growth of broilers at 30 d of age, showing the highest eight increments, less feed intake, and normal defecation quantity and water intake, making it a preferred light color that can improve breeding efficiency. Green light and blue light had a certain inhibitory effect on the growth of broilers in this experiment.

2) Light color had a greater impact on NH_3 emission and less impact on CO_2 and NO_2 emission. The NH_3 emission concentration under red light was just higher than that under green light and lower than those under other light colors. The NH_3 emission concentration under yellow light was higher than those under other light colors, showing no emission reduction effects. Different light colors had little influence on the N_2O emission concentration during the broiler breeding process. There was a large fluctuation in CO_2 concentration under white light and fewer fluctuations under other light colors.

3) Different light colors led to different hypothalamus simulations that caused different digestive conditions, which affect the broiler's absorption of nutrients and exert a further impact on the emission of NH3 and other harmful gases. This experiment lacked in the determination of digestion for nutrients (crude fat, crude protein, calcium, and phosphor) as well as the study on the broiler nerve signal conduction and change in internal organs. Therefore, further experimental verification is needed.

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