The effect of color light and stocking density on tibial measurements and levels of calcium and phosphorus in bone and serum of broilers and layers chickens

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ABSTRACT

A total of 675 Ross 308 one day old broiler chicks were used in this study and exposed to white light (WL) as a control , red light (RL), blue light (BL), green light (GL), and Blue – Green mix light (BGL) by a light-emitting diode system (LED) which applied for 24 hours daily in separated rooms with light intensity 5 watt/m^2. The birds were randomly housed into 9 wooden sealed pens of 1m^2 in three replicates for each density 12, 15 and 18 broilers/m^2.In the second experiment, a total of 180 Isa Brown layers were raised under control condition from 25 week until 36 week of age. They divided into 5 treatments with an average of 36 birds for each of five color light rooms (16 hours light- 8 hours dark) in three replicates for each density 5 and 7 birds/m^2 in the room.The present study indicated no differences on levels of calcium (Ca) and phosphorus (P) in the tibia bone of broilers but a significant increase was recorded in the bone length (cm) under BL and bone weight (gm) and density (gm/cm) under BGL.The effect of color light on the concentration of serum calcium in broilers was not significant, but phosphorus concentration was higher in BGL. For layers, a significant effect of WL in the level of serum calcium and phosphorus was recorded, whereas no effects for stocking density on these traits were observed.

Keywords: color light, stocking density, calcium, phosphorus, tibia, broilers, laying hens

الملخص باللغة العربية

أجريت هذه الدراسة في حقل تربية الدواجن في كلية الطب البيطري بجامعة البصرة. في التجربة الأولى على فروج اللحم وفي التجربة الثانية على الدجاج البياض بهدف معرفة تأثير لون الضوء وكثافة الطيور في بعض معايير عظم القصبة وتركيز الكالسيوم والفسفور في العظام وفي مصل الدم.
في التجربة الأولى تمت تربية (675) فرخا من فروج اللحم سلالة Ross 308 غير مجنس وبعمر يوم واحد لمدة (35) يوما. قسمت الأفراخ إلى خمس معاملات من الإضاءة الملونة المستمرة وبشدة إضاءة 5 واط/ م^2 هي الضوء الأبيض (سيطرة)، الضوء الأحمر، الضوء الأزرق، الضوء الأخضر ومزيج من الضوء الأزرق والأخضر وبواقع (135) طائرا لكل معاملة. ربيت الطيور في غرف مستقلة تحتوي كل غرفة على (9) أقنان، مساحة القن الواحد متر مربع، وقسمت الطيور تبعا لكثافة التربية إلى (12، 15 و 18) طيرا/ م^2 وفي ثلاث مكررات لكل كثافة. في التجربة الثانية تم تربية (180) دجاجة بياضة سلالة Isa Brown بعمر (25) أسبوعا لغاية عمر (36) أسبوعا، حيث تم توزيع الطيور إلى خمس معاملات حسب لون الإضاءة في برنامج (16 ساعة ضوء : 8 ساعة ظلام) وشدة إضاءة 5 واط/ م^2 وبمعدل (36) طائر للمعاملة. تمت تربية الدجاج البياض تحت كثافتين (5 و 7) طيور/ م^2 وبواقع ثلاث مكررات لكل كثافة.
أظهرت نتائج الدراسة في فروج اللحم عدم وجود تفوق معنوي للون الضوء المستخدم وكثافة الطيور في مستوى الكالسيوم والفسفور في عظم القصبة، بينما تم تسجيل تفوق معنوي لطول العظم في معاملة الضوء الأزرق وتفوق معاملة المزج بين الضوء الأزرق والأخضر في وزن وكثافة عظم. أما تركيز الكالسيوم في مصل فروج اللحم فلم تكن النتائج معنوية، بينما سجلت معاملة الفروج المربية تحت تأثير مزج الضوء الأزرق والأخضر تفوقا معنويا في مستوى الفسفور في مصل الدم. من ناحية أخرى أظهرت النتائج في الدجاج البياض تفوقا معنويا في تركيز الكالسيوم والفسفور في مصل الدجاج المربية تحت تأثير الضوء الأبيض ولم يكن لكثافة الطيور تأثير معنوي.

INTRODUCTION

Light is as an important management tool to regulate broiler production. Artificial lighting for broilers consists of 3 aspects: photoperiod, wavelength, and light intensity (1). Day light has relatively wavelengths between 400 and 700 nanometer (nm). Birds sense light through their eyes (retinal photoreceptors) and through photosensitive cells in the brain (extra-retinal photoreceptors) (2). The color of light is determined by the relative power of different wavelengths in the visible part of the light spectrum (3). Among new lighting technologies emerging on the market are light emitting diodes. LEDs are highly monochromatic, only emitting a single pure color in a narrow frequency range (4), and becoming increasingly more popular for use in poultry barns (5). Stocking density is inherently confounded with either the number of animals in a group, or with the total amount of space available to this group (6). Application of the intermittent light regime and lower stocking density at the same time increased the broiler gains in every week (7).

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Normal bone development in birds is influenced by nutritional factors, genetics, gender and the absolute growth rate (8). A number of invasive (bone ash, breaking strength, weight and bone volume) and noninvasive methods (ultrasound) exist to determine the bone mineralization in poultry (9). About 99% of total body Ca and 75% (80-85% in bones and teeth) of total body P are found in the skeleton (10), therefore the Calcium: Phosphorus ratio (Ca/P ratio) of 2.5:1 may favor elongation of tibial bone (11). According to (7), quality of tibia improved with increased physical activity of chickens reared in lower stocking density. Also (12) investigated whether photoperiod : scotoperiod affected leg weakness in broiler chickens and found no clear relationship between photoperiod and gait scoring but foot pad burns were reduced by longer photoperiod. The levels of Ca in both bones femur and tibiotarsus were in the range from 180.4 ±8.57 to 181.6 ± 12.32 g/kg, being higher in females (181.7 ± 9.17 to 183.8 ± 14.71 g/kg), as compared to males (179.2 ± 7.80 to 179.3 ± 8.91 g/kg) (13).Tibia length in broilers was 1.8 times greater at 15 days of age compared to hatch and only 2 times longer at 43 days of age compared to the length at 15 days of age (14).The researcher (15) referred that lighting programs had a similar effect, broilers provided with 12L: 12D had a higher percentage of bone Ash (50.47%) compared with those provided with 20L: 4D (49.89%). Furthermore, (16) observed improved gait scores and less angular deformity of the legs of female broilers that were reared under high intensity red light early in the growth period, although the same effect was not seen in broilers raised under high intensity blue light. The author speculated that this improvement in leg health may have been due to the increased activity of the broilers reared with high intensity red light. Bone strength was reduced in treatment Late Red, which appeared to be related to the lower body weights of birds in this treatment. Bone length, weight, and torsion were not affected by treatment, but the tibia plateau angle was reduced by Early Red light in female birds. All blue, there was a high incidence of gait abnormalities, which was reduced by Early and Late Red light. Serum biochemistry is a labile biochemical system which can reflect the condition of the organism and the changes happening to it under influence of internal and external factors (17). The total concentration of calcium in the laying hens serum ranges between 20-30 mg/100 ml. The normal plasma concentration of calcium for most birds ranges between 8 and 11 mg/dl while the normal plasma phosphorus concentration for most birds range between 5 and 7 mg/dl. (18). Serum Ca include 60 % ionized, 35% bound to protein and 5% citrate, bicarbonate and phosphate complexes. In plasma, 85% phosphate ions ($H_2PO_4^-$, HPO_4^{--}), 10% protein bound and 5% Ca and Mg complexes (10). On the other side (19) recorded that the levels of serum calcium in laying hens was (18.10+2.64 mg/dl) and in broilers (6.25-13.75 mg/dl).

The aim of this study was to investigate the effect of color light and stocking density on some bone parameters and the level of serum calcium and phosphorus of broilers and layers.

MATERIALS AND METHODS

Birds and husbandry

A total of 675 Ross 308 one-day-old broiler chicks were used in this study. The chicks were raised under control condition from day one until 35 days of age in the poultry farm at the College of Veterinary Medicine, Basra University. Broiler chicks were reared into five light groups in separated rooms 3x3x 4 meters with an average of

135 chicks in each room under LED color lights: white light as a control, red light (660 nm), blue light (480 nm), green light (560 nm) and blue – green mix light. Stocking density of (12, 15 and 18 birds/m^2) was housed into 9 wooden sealed pens of 1m^2 in three replicates in the room. Light sources were equalized on the intensity of 5 watt/ m^2 (20 lux) at bird head level and light period of 24 hours daily. Room temperature was initially 34°C and was subsequently reduced by 2°C/week to 26°C at 35 day. In the second experiment, a total of 180 Isa Brown layers were raised under control condition from 25 week until 36 week of age. They divided into 5 treatments with an average of 36 birds for each of five color light rooms (16 hours light- 8 hours dark) in three replicates for each density 5 and 7 birds/m^2 in the room. In broilers, three dietary pellet rations were used consisted of starter, grower, and finisher diets. Total dietary metabolic energy for the starter, grower and finisher were 2925, 3111and 3171 kcal/kg respectively while the values of crude protein were 22.21, 20.14 and 18.08 % respectively. For layers, total dietary metabolic energy was 2759 kcal/kg and 17.75% crude protein according to Isa Brown programs (20). Half cylinder plastic feeders were placed in each pen. The birds were supplied with feed and water *ad libitum,* and diets were formulated to meet the nutrient recommendations for poultry according to Nutrient Research Center NRC (21), and the feeders were checked twice daily and feed was weighed and manually added when needed. A nipple water drinking system was set up in each pen and was manually adjusted as birds grew to ensure the watering system was kept at a proper level**.**

Bone and serum measurements

At 35th day of broilers age, one bird from each replicate were randomly selected and slaughtered according to Islamic religion conditions by a knife. The tibias of the individual birds were excised and boiled for 5 minutes to loosen muscle tissue according to the method of (22). Tibias were dried at105°C for 24 hours and then weighed and the length was recorded. The bone weight/bone length index is a simple index of bone density obtained by dividing bone weight by its length (23). Tibia ash content was determined by ashing the bone in a muffle furnace for 5 hours at 600°C, bone ash was weighed and prepared according to (24).Calcium and phosphorus content was measured by atomic absorption spectrophotometry after processing by the method of (25). At the end of 5 week age for broilers and 36 week for layers, 1 birds of average weight from each replicate were selected and blood was collected from the wing vein. The samples were taken in test tubes without anticoagulant to get serum for biochemical tests. Calcium and phosphorus values were measured by the method of (26).

RESULTS AND DISCUSSION

Bone measurements of broilers

Bone mineral density is one of the most important parameters to be measured when evaluating bone quality (27). Calcium, phosphorus, and vitamin D^3deficiencies and imbalances are the major causes of skeletal problems (28). Table (1) referred to the effect of light color and stocking density in the measurements of tibia bone in broilers at different experimental groups at 35 days. The values of calcium and phosphorus were not significantly differed ($p > 0.05$) in all examined birds. The non-significant effect of color light on the levels of calcium and phosphorus of tibia bone agreed with (15), who showed that the use of different lighting programs did not have a significant effect on the levels of the ashes of bone. The table also showed no significant effect ($p > 0.05$) of stocking density in the level of calcium and phosphorus of tibia bone. The results of the effect of stocking density is consistent with (29), who tested two strains of broiler chickens (Arbor Acres and Cobb 500) in the level of density 12 and 16 birds/m^2 in different lighting and he did not score a significant effect of lighting program and the stocking density in the concentration of calcium of tibia. The physical properties of the tibia were assumed to be indicators of skeletal growth and structural changes (30).There was significant increase ($P <0.05$) in the length of tibia bone in broilers reared under the influence of BL. The increase of tibia length may reflect the high body weight of broilers under the influence of BL. The result is agreed with the finding of (31) who referred to a positive relationship between the length of the leg and thigh and carcass weight bone. The tendency for higher growth rates of chickens in blue light than red maybe due to the increase in activity of birds in red than blue light confirms the results of a comparison of color effects on broiler behavior by (32).As shown in table (1), a significant effect ($P <0.05$) of color light was recorded in the weight of tibia in broilers of different experimental groups at the age of 35 days, and reached its highest rate in the treatment of chickens reared under the influence of BGL while lower rate was recorded in the treatment of broilers reared under the influence of RL. The results of the present study agreed with the results of (33) and (34) who proved that the hypothalamic photoreceptors of chicken are more sensitive to blue/green light when illuminated directly. Also, (35) found both blue and green lights were more effective to stimulate testosterone secretion and myofiber growth which increased body. On the other hand, (36) reported that longitudinal bone growth occurs as the pullet grows in size. Cartilage cells in the growth plates at the ends of the bones divide, resulting in increased bone length. The existence of a significant decrease in tibia weight under the influence of red light are consistent with that of (16),who reported an apparent correlation existed between bone strength, bone weight, and body weight: birds given bright red light in treatment Late Red had the lightest final body weight and tended to have the lightest average bone weight. The effect of color light in the bone density of broilers at 35 days of age was significantly higher (P <0.05) and recorded the highest rate in the bones of broilers reared under the influence of BGL. These findings are consistent with the significant increase in weight and the length of the tibia in broilers reared under the influence of BGL while the low values recorded in the treatment of chickens reared under the influence of red. These results were supported by (37), who reported that bone density is a reflection of the weight and the length of the bone. A study conducted by (38) showed that switching environmental light spectra from green to blue at 10 days of age accelerate growth of male broiler chicks. In parallel in this study he found early age acceleration in growth in the green light reared birds, and, in addition shifting the GL birds to BL environment caused further increase in both growth rate and body weight. In accordance, quails raised under blue or green fluorescent lamps gained significantly more weight than those reared under red or white fluorescent lamps (39). The absence of stocking density effect on tibia measurements agreed with the result of (29) on broilers of Arbor Acres and Cobb 500 genotypes reared to 42 days of age in floor system, and two stocking densities:12birds/m^2 and 16 birds/m^2. Results of the trial indicate absence of significance of differences between trial groups of broilers in regard to their walking ability, condition of skin and legs, and stress indicators. The results of the current study disagreed with (6), who evaluated the effect of stocking density on bone quality and fluctuating asymmetry. Birds were stocked at densities of 2.4, 5.8, 8.8, 12.1, 13.6, 15.5, 18.5, and 21.8 birds/m^2 from 1 until 39 day of age. Increased stocking density had a negative effect on some aspects of bone. Tibias were shorter at high density, possibly due to increased curvature. Positive effect was recorded by (40) and (41) of lower stocking density on length of tubular bones, development and roundness of breast, development of hind extremities. Breast angle, although it represents genetic trait, was improved in conditions of lower stocking density.

Table (1): Effect of color light and stocking density on some bone measurements of broilers at 35th day of age (M±SE)

Bone parameters	Color light / Stocking density	WL	RL	BL	GL	BGL	Effect of stocking density
Calcium ppm	12 bird/m^2	2435±6.35	2905± 3.46	3257± 4.61	3359±4.04	3156±2.88	3022±4.26
	15 bird/m^2	3111± 2.30	2818± 1.73	3723± 1.73	3389±6.92	3110±2.30	3230±2.99
	18 bird/m^2	3153± 3.46	2537± 3.46	2511± 6.35	3856±6.35	3731±9.23	3157±5.77
	Effect of color light N. S.	2899± 4.03	2753± 2.88	3163± 4.23	3534±5.77	3332±4.80	N. S.
Phosphorus ppm	12 bird/m^2	37.16±0.03	22.79±0.00	45.91±0.02	45.21±0.07	42.62±0.01	38.75±0.02
	15 bird/m^2	34.43±0.08	49.67±0.19	44.39±0.01	33.35±0.01	47.44±0.01	41.85±0.06
	18 bird/m^2	28.62±0.00	47.08±0.02	49.32±0.09	49.67±0.06	39.46±0.05	42.83±0.04
	Effect of color light N. S.	33.40±0.03	39.84±0.07	46.54±0.04	42.74±0.04	43.17±0.02	N. S.
Bone length (cm)	12 bird/m^2	9.66± 0.16	10.00±0.57	10.50±0.50	9.66±0.60	10.00±0.50	9.96± 0.46
	15 bird/m^2	9.33±0.33	9.50±0.57	10.16±0.16	9.66±0.33	10.00±0.50	9.73± 0.37
	18 bird/m^2	9.33±0.88	9.33±0.33	10.16±0.16	9.83±0.60	10.50±0.28	9.83± 0.42
	Effect of color light *	9.44^{b}±0.45	9.61^{ab}±0.49	10.27^{a}±0.27	9.72^{ab}±0.51	10.16^{a}±0.42	N. S.
Bone weight (gm)	12 bird/m^2	17.66±0.66	14.66±3.17	19.66±1.33	16.33±3.28	17.66±2.84	17.20±2.25
	15 bird/m^2	14.33±1.45	13.33±1.85	17.00±1.52	15.33±0.66	18.33±4.17	15.66±1.93
	18 bird/m^2	14.33±4.05	13.33±2.33	17.33±1.66	17.00±3.00	19.66±1.20	16.33±2.44
	Effect of color light *	15.44^{b}±2.05	13.77^{b}±2.45	18.00^{a}±1.50	16.22^{b}±2.31	18.55^{a}±2.73	N. S.
Bone density (gm/cm)	12 bird/m^2	1.82±0.08	1.43±0.23	1.86±0.04	1.65 ±0.25	1.74±0.20	1.70± 0.16
	15 bird/m^2	1.52±0.10	1.39±0.13	1.67±0.14	1.58 ±0.01	1.79±0.34	1.59± 0.14
	18 bird/m^2	1.47±0.31	1.41±0.19	1.70±0.15	1.70 ±0.19	1.87±0.11	1.63± 0.19
	Effect of color light *	1.60^{ab}±0.16	1.41^{b}± 0.18	1.74^{a}± 0.11	1.64^{ab}±0.15	1.80^{a}± 0.21	N. S.

**a, b, c Means in horizontal rows with different superscripts were significantly different of light color and in vertical rows of stocking density at (p<0.05). SE: standard error. N.S. not significant*

Serum calcium and phosphorus of broilers and layers

Table (2) shows the effect of light color and stocking density on calcium and phosphorus concentration on blood serum of broiler chickens in the different experimental treatments at the age of 35 days. The results of calcium were not significantly affected (p > 0.05) by color light, nor there significant differences between the various levels of density. The non-significant effect of color light and broiler density in the calcium concentration of broiler serum may be due the absence of stressful environmental factors that adversely affect the level of calcium in blood serum. As (42) referred that plasma Ca concentration measured showed a significant decrease during heat stress period while PH levels increased during the same period. A significant effect (P <0.05) of color light in the concentration of phosphorus was recorded and reached its highest rate in the serum of broilers reared under the influence of BGL, while the least rate recorded in the serum of chickens reared under WL. As for the effect of stocking density in the concentration of phosphorus in the blood serum it emerges from the table (2) absence of significant differences between the various treatments. A superiority in the level of phosphorus in the serum of broilers reared under the influence BGL may reflect the elevation of feed consumption in this group compared to white and red groups. This is consistent with the results of (43), who showed that low feed consumption also leads to low in the level of phosphate in the blood. The table also showed a significant effect (P <0.05) for the color light in the C/P ratio which reached its highest score in the treatment of broilers reared under the influence of GL whereas, density levels were not significantly affect the C/P ratio in various treatments. Table (2) indicated a significant effect (P <0.05) of color light in the level of serum calcium of layers reared under the influence of WL. This result was inconsistent with the results of (2), who showed that ultraviolet light had significantly higher plasma Ca level than fluorescent and infrared lights in turkey at 25 and 40 week of age. The results of this study confirm what referred to by (44) that calcium and phosphorus in the blood serum in laying hens are related to the status of the egg-laying and layer of strain, so the high level of calcium in the blood serum of layers reared under the influence of WL reflect an increase in the productivity of eggs. The analysis of variance referred to the presence of significant interaction (P <0.05) between light color and stocking density in the level of calcium in blood serum as it recorded the highest rate in layers reared under the influence of WL and the level of density 7 birds/m^2 while the least average recorded in layers reared under the influence of the RL and the level of density 7 birds/m^2. Table (2) also showed that color light positively affected (P <0.05) the concentration of serum phosphorus in layers reared under the influence of WL while least average recorded in serum of layers reared under the influence of BL.A significant effect (P <0.05) was also recorded for the color light in the C / P ratio of layers of BL and BGL. These ratios reflect the rates recorded for the concentrations of calcium and phosphorus in various treatments. The result of this study revealed that different values of serum calcium and phosphorus of layers studied were not differed significantly within various bird densities.

Table (2): Effect of color light and stocking density on the level of calcium and phosphorus in blood serum of broilers and layers (M±SE)

	Serum traits	Color light Stocking density	WL	RL	BL	GL	BGL	Effect of stocking density
Broilers	Calcium (mg/100 ml)	12 bird/m^2	7.83 ±0.21	8.56 ±0.14	8.76 ±0.29	9.83± 0.71	10.33±1.08	9.06 ±0.78
		15 bird/m^2	8.00 ±0.10	8.73 ±0.66	8.53 ±0.29	9.66 ±0.56	11.26±1.14	9.24 ±0.55
		18 bird/m^2	8.36 ±0.03	9.20 ±0.25	9.13 ±0.14	10.16±0.6	10.13±0.46	9.40 ±0.30
		Effect of color light N. S.	8.06 ±0.11	8.83 ±0.35	8.81± 0.24	9.88 ±0.63	10.57±0.89	N. S.
	Phosphorus (mg/100 ml)	12 bird/m^2	4.96 ±0.31	±5.33 0.40	5.93 ±0.35	5.20 ±0.05	6.66±0.12	5.62± 0.24
		15 bird/m^2	4.46 ±0.37	5.06 ±0.12	5.56 ±0.54	5.00± 0.34	7.03±0.24	5.42 ±0.32
		18 bird/m^2	4.80 ±0.49	4.93 ± 0.39	5.20 ±0.60	5.90 ±0.66	6.80±0.34	5.52 ±0.49
		Effect of color light *	4.74^{c}±0.3	5.11^{bc}±0.3	5.56^{b}±0.4	5.36^{bc}±0.3	6.83^{a}±0.2	N. S.
	Ca : P ratio	12 bird/m^2	1.58 ± 0.09	1.62 ±0.11	1.47 ±0.03	1.89 ±0.14	1.55 ±0.18	1.62 ±0.11
		15 bird/m^2	1.81 ±0.15	1.72 ±0.10	1.55 ±0.13	1.94 ±0.15	1.59 ±0.12	1.72 ±0.13
		18 bird/m^2	1.78 ± 0.19	1.88 ±0.18	1.80 ±0.23	1.75 ±0.18	1.50 ± 0.14	1.74 ±0.18
		Effect of color light *	1.72^{ab}±0.1	1.74^{ab}± 0.1	1.60^{ab}±0.1	1.86^{a}±0.1	1.54^{b}±0.1	N. S.

Layers	**Calcium (mg/100 ml)**	5 bird/m^2	11.60 $\pm$0.2	11.63$\pm$0.8	12.00$\pm$0.2	11.43$\pm$0.2	12.03 $\pm$0.6	11.74$\pm$0.4
		7 bird/m^2	12.76$\pm$0.1^{A}**	10.23$^{B}\pm$0.2	11.06$\pm$0.2	11.20$\pm$0.4	11.33$\pm$0.14	11.32$\pm$0.2
		Effect of color light *	12.18$^{a}\pm$0.1	10.93$^{b}\pm$0.5	11.53$^{ab}\pm$0.	11.31$^{b}\pm$0.3	11.68$^{ab}\pm$0.3	N. S.
	Phosphorus (mg/100 ml)	5 bird/m^2	5.60 $\pm$0.11	5.53 $\pm$0.40	4.43 $\pm$0.14	4.56 $\pm$0.14	4.56 $\pm$0.12	4.94$\pm$0.18
		7 bird/m^2	5.43 $\pm$0.41	5.06 $\pm$0.18	4.30 $\pm$0.11	4.66 $\pm$0.28	4.40 $\pm$0.15	4.77$\pm$0.22
		Effect of color light *	5.51$^{a}\pm$0.26	5.30$^{a}\pm$0.29	4.36$^{b}\pm$0.12	4.61$^{b}\pm$0.21	4.48$^{b}\pm$0.13	N. S.
	Ca : P ratio	5 bird/m^2	2.06 $\pm$0.03	2.10 $\pm$0.01	2.70 $\pm$0.10	2.50 $\pm$0.02	2.64 $\pm$0.19	2.40 $\pm$0.07
		7 bird/m^2	2.58 $\pm$0.18	2.01 $\pm$0.04	2.57 $\pm$0.12	2.42 $\pm$0.20	2.58 $\pm$0.11	2.43 $\pm$0.13
		Effect of color light *	2.32$^{bc}\pm$0.1	2.05$^{c}\pm$0.0	2.64$^{a}\pm$0.1	2.46$^{ab}\pm$0.1	2.61$^{a}\pm$0.1	N. S.

a, b, c Means in horizontal rows with different superscripts were significantly different of light color and in vertical rows of stocking density at ($p<0.05$). SE: standard error. N.S. not significant.A, B, C Means with different superscripts were significantly different of interaction between light color and stocking density at ($p<0.05$).*

CONCLUSION

The results of the present study suggested that the use of blue, green and mixed blue and green would be relevant for birds comfort and may benefit performance, which reflected a significant increase in the bone length, weight and bone density. For layers, a significant effect of white light in the level of serum calcium and phosphorus should be considered, whereas no effects for stocking density on these traits were observed.

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