# Effects of different wavelengths of light on the biology, behavior, and production of grow-out Pekin ducks

C. L. Campbell,* S. Colton,* R. Haas,* M. Rice,* A. Porter,* A. Schenk,* A. Meelker,* S. M. Fraley,*,† and G. S. Fraley*,[1]

*Biology Department, Hope College, 35 East 12th St., SC3065, Holland, MI 49423; and †South Crossing Veterinary Center, Caledonia, MI 49316

**ABSTRACT** Previous research has shown that red light conditions may improve growth and decrease aggressive behaviors in chickens and turkeys; however, more recent studies suggest that blue–green light may improve production of broilers over red light. To date, no research has been conducted to examine whether different wavelengths of light have an impact on production in the Pekin duck. To determine this, we raised Pekin ducks under aviary conditions that were similar to standard commercial barns. The ducks were kept in 3 different pens: red light (approximately 625 nm), blue light (approximately 425 nm), and white light. Light sources in each pen were standardized to produce a peak energy at $1.6 \times 10^3$ $\mu$M photons/m$^2$/s at the level of the ducks' heads. Ducks were given ad libitum access to water and commercial duck diet, and were housed on pine shavings at a density of 0.43 m$^2$/duck. Ducks were evaluated weekly for BW and condition and a subjective measure of the duck's anxiety levels was determined. We found that ducks housed under blue light had significantly ($P < 0.01$) reduced BW at every age until the end of the study (processing age; 35 d). Unlike ducks housed under red or white light, ducks housed in the blue pen showed a higher level of anxiety; while evaluators were in the pen a majority of them began panting, they were much less inquisitive than other ducks, they took longer to exhibit normal social behavior once evaluation was completed, and they frequently "swarmed" when no people were present. There were no differences in any measurements between the red and white-lighted pens. These data suggest that unlike the chicken, blue lights may be inappropriate for raising Pekin ducks in a commercial setting.

**Key words:** stress, growth hormone, corticosterone, growth rates

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## INTRODUCTION

Light is a very important factor in housing poultry. Specific wavelengths of light have been investigated to improve performance in turkeys (Leighton and Potter, 1969; Gill and Leighton, 1988; Levenick and Leighton, 1988; Felts et al., 1990; Hulet et al., 1992), laying chickens, and broilers (Max et al., 1995; Rozenboim et al., 2004; Bailey and Cassone, 2005; Halevy et al., 2006). In these studies, red light showed an improvement in egg production whereas growth performance was enhanced under blue–green light (Rozenboim et al., 1998; Gongruttananun, 2011; Baxter et al., 2014). Commercial laying hens experience decreased levels of aggression when housed under red light (Huber-Eicher et al., 2013). However, high intensity red light was also found to increase aggression and activity when compared to blue light in broiler chickens (Prayitno et al., 1997a,b). The effect of red or blue lighting has not been studied in ducks, leading to speculation as to whether red or blue light would improve the ducks' production, performance, and well-being.

Information regarding environmental light is perceived by the brain through photoreception via well described pathways from the pineal gland and retina. However, photoreceptivity by the brain is not limited to these 2 structures. In birds there is evidence for nonretinal photoreception. Neither bilateral enucleation and/or pinnealectomy affect the seasonal changes in reproductive status (Oliver and Bayle, 1982). Thus, in birds there is compelling evidence that nonvisual photoregulation of physiological homeostasis may be mediated—at least in part—by deep encephalic photoreceptors (**DEP**; (Li and Kuenzel, 2008). Although the relative contribution of the retina compared to the DEP in immature, grow-out ducks is not known, alterations in photoneuroendocrine factors that affect feeding and growth could ultimately alter production yields and meat quality.

Meat quality is an important concern within the poultry industry. Light is involved in growth and


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[1]Corresponding author: fraley@hope.edu

enhanced myoblasts that can alter myofiber formation (Halevy et al., 2006). Green–blue light has been found to improve the structure of muscles in growing broiler chickens (Karakaya et al., 2009). While red and green–blue light are found to be beneficial to turkey and chicken production, information on how colored lighting affects ducks is very limited. There have been no previous studies done on how colored lighting affects the growth, well-being, and carcass quality of Pekin ducks; thus, we have focused on the effects of the 2 near-ends of the visible spectrum, red and blue light, respectively. We set out to test the hypothesis that blue light would improve duck welfare, growth rates, and carcass quality.

## MATERIALS AND METHODS

### Animals and Housing

One-day-old ducklings (n = 110) were obtained from Maple Leaf Farms, Inc. (Leesburg, IN) and placed in a controlled environment aviary at Hope College (Holland, MI) within 5 h hatching. The aviary conditions adhered to industry standards for 18L:6D cycle, temperature, humidity, ad libitum access to commercial feed and pin-metered water (nipple lines), and duck density (~0.16 $m^2$/duck). Ducklings were placed into one of 3 pens: pens with red light (peak at 650 nm, range = 600 to 710 nm), blue light (peak at 450 nm, range 395 to 480 nm) and white light (range of 390 to 720 nm; approximately 25 lx). All lights were from fluorescent bulbs and the energy of all lights was normalized to the quantal energy of $1.6 \times 10^3$ $\mu$M photons/$m^2$/s at the level of the ducks' heads as determined by spectrophotometry. Although the red and blue light sources did not emit a single wavelength of light, the range of wavelengths does fall within the visible red and blue spectra, respectively. Ducks were raised on pine litter and fresh litter was spread twice daily over the entire pen. All housing and study procedures were approved by the Hope College Animal Care and Use Committee following the Institutional Animal Care and Use Committee guidelines.

### Study Design

The 3 pens were light-proofed in order to prevent light contamination among pens. The ducks were video-recorded continuously for 5 d each week, centered around d 7, 14, 21, 28, and 32. Weekly, 15 ducks/pen were weighed and body-condition scored (Fraley et al., 2013; Karcher et al., 2013). Body-condition scoring was performed each week using a published rubric (Colton and Fraley, 2014; Fraley et al., 2013; Karcher et al., 2013). Researchers used gates to randomly select 15 ducks in each pen each week. All 15 ducks were scored on eyes, nostrils, feet, feather quality, and feather cleanliness according to the rubric previously mentioned. Each week, blood samples were collected from the same 15 birds that were body-condition scored. At the conclusion of the study, ducks were transported to Maple Leaf Farms, Inc. (Milford, IN) for carcass analyses by technicians unaware of treatment groups. Carcasses were analyzed for total BW, hanging carcass weight, weight of breast meat, total carcass fat, and percent skin and fat over the breast. The study was repeated 3 times, in which the location of the light treatment was rotated among pens. The final n per light treatment = ~225 ducks/light treatment.

### Collection of Behavioral Data

The ducks were video-recorded continuously for 5 d each week, centered on d 7, 14, 21, 28, and 32. The video footage was analyzed in 5-min segments, from 0600 to 1200 hrs. The activity level of each pen was determined on a qualitative scale of 1 to 5 (1 = inactive; 5 = very active). Preening, drinking, eating, and foraging behaviors were also observed and quantified.

### Plasma Hormone Analyses

Plasma was collected from the same birds each week and stored at −20°C until analyzed for circulating corticosterone (**cort**) and growth hormone (**GH**) levels. Plasma levels of cort in ducks were measured by ether extraction and radioimmunoassay at the Endocrine Technology and Support Core Lab at the Oregon National Primate Research Center/Oregon Health and Science University (Rasmussen et al., 1984). Briefly, samples for cort, 4 to 20 $\mu$L, were extracted in 5 mL ether in 13 × 100 glass tubes (baked at 500°C for 30 min), dried under forced air, and analyzed by specific cort radioimmunoassay. Hormonal values were corrected for extraction losses determined by radioactive trace recovery at the same time as sample extraction; hot recovery usually is better than 90%. The sensitivity was 5 pg/tube for the cort radioimmunoassay. All samples were analyzed in one assay with intra-assay variation of 6.3% based on an ETSC serum pool as internal controls (n = 8). The value of the Endocrine Technology and Support Core Lab serum pool in this assay was within 10% of previous cort assays (n = 20).

GH analyses in duck plasma were also performed by the Endocrine Technology and Support Core Laboratory, Oregon National Primate Research Center (Beaverton, OR), using a ELISA kit assay specifically formulated for ducks (Creative Diagnostics Inc., Catalog No. CDN-GH1-F6954, Shirley, NY). The assay has a sensitivity of 0.16 ng/mL and a range of detection to 10 ng/mL. A duck serum pool spiked with duck GH to about 2 ng/mL was included as internal controls (n = 4) in each of the 2 assays for all samples in the study. Parallelism of serial dilution of the spiked serum pool with the standard curve was validated. The averaged intra-assay and inter-assay variation for the 2 assays was 5.4 and 13.5%, respectively.

## Statistical Analyses

Behavioral data were analyzed using the pen (n = 3/treatment) as the statistical unit using Kruskall–Wallace ANOVA. All other data were analyzed using the duck (n = ~225/treatment) as the statistical unit using a one-way ANOVA with a Fisher's Protected Least Significant Difference post-hoc test. A $P < 0.05$ was considered significant.

# RESULTS

## Duck Biological Measures

***Body condition scoring*** No differences were observed for eye scores, feather quality or cleanliness, or foot pad scores. All scores for these variables were quite excellent and well within industry standards (data not shown; (Fraley et al., 2013; Karcher et al., 2013). However at d 14 and 28, we did find that ducks housed under red light showed slightly higher, thus poorer, nostril scores (Figure 1; $P = 0.042$) than ducks under blue or white light. These scores were due to bedding within the nares not due to mucus or other signs of illness.

***Body weight*** On the day of hatch, no differences were observed among ducks when placed into pens. Ducks raised under white and red lights gained weight similarly at a rate comparable to that seen in other studies and in industry (Colton and Fraley, 2014; Fraley et al., 2013; Karcher et al., 2013). Ducks raised under blue lights, however, showed reduced BW (Figure 2) compared to both ducks under white and red lights each week during the study.

***Duck behaviors*** There were no differences in the amount of time ducks spent feeding among any of the light treatments (Figure 3A). Some differences were observed in the amount of time ducks spent drinking at the pin-metered water lines; at age 14 days ducks under red light drank more ($P = 0.013$) than the other treatments and ducks under blue light drank less than the

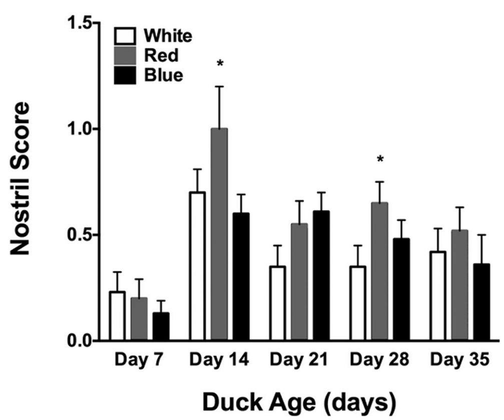


**Figure 1.** Body condition was scored as an indirect measure of duck well-being. No differences were found among treatments for eye, feather quality, feather cleanliness, or foot pads and all scores were excellent. Differences were observed in nostril scores due primarily to bedding within the nares, not due to illness. * = $P < 0.05$.

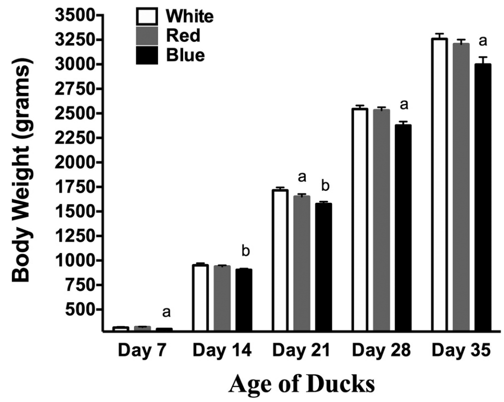


**Figure 2.** Differences in BW were observed in ducks under blue light. At each age measured, ducks housed under blue light had reduced BW compared to ducks housed under white or red lights. At d 21, ducks under red light also showed reduced BW compared to ducks under white light, although still heavier than ducks under blue light. Letters indicate statistically different groups at each age. $P < 0.05$.

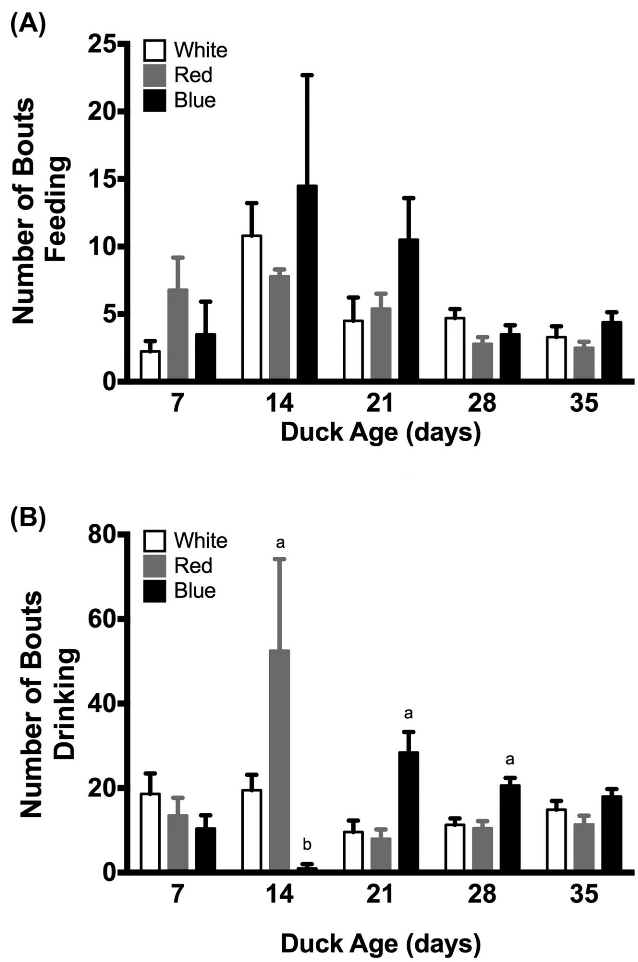


**Figure 3.** Duck behavioral analyses part 1. A) No differences were observed in the frequency that ducks were observed feeding each week of age. B) Some differences were observed in the number of times ducks were observed drinking at the nipple line at different ages, although the reason for this remains unclear. Letters indicate statistically different groups at each age. $P < 0.01$.

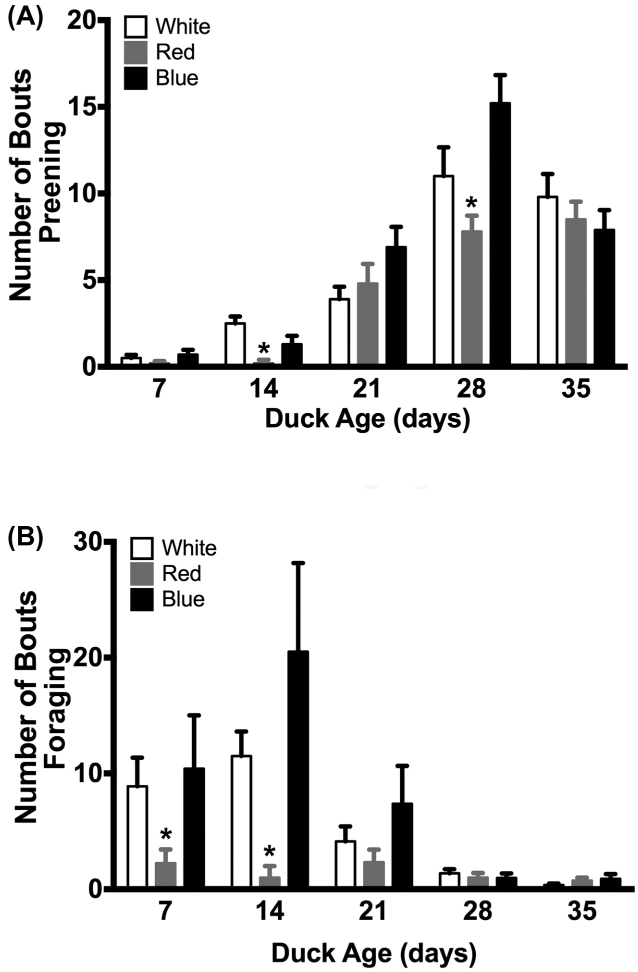


**Figure 4.** Duck behavioral analyses part 2. A) Ducks under red light showed a reduced amount of preening compared to ducks under white or blue lights. However, these differences did not translate to reduced feather quality or cleanliness. B) Similarly, ducks under red light also showed reduced amounts of foraging behaviors compared to ducks under white or blue lights. * = $P < 0.05$.

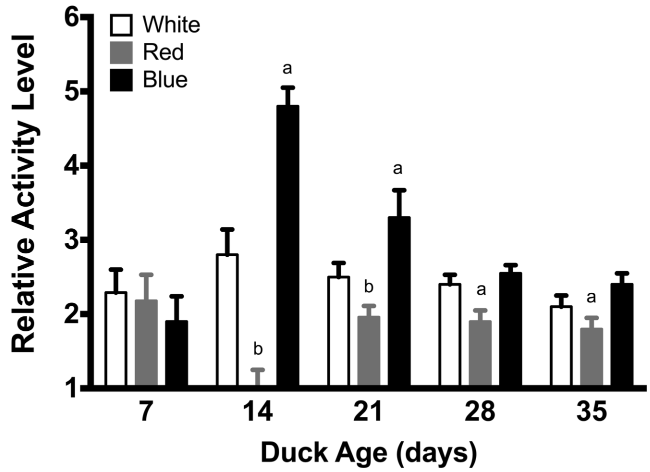


**Figure 5.** Duck behavioral analyses part 3. Overall, ducks housed under blue light showed considerably increased activity compared to ducks under red or white lights particularly around d 14 and 21. Ducks under red light showed reduced motor activity compared to other treatments beginning at d 14 and continuing until the end of the study. The reduced activity may be a factor in the reduced preening and foraging behaviors observed (Figure 4). Letters indicate statistically different groups at each age. $P < 0.01$.

other 2 treatments. However, at ages 21 ($P = 0.012$) and 28 ($P = 0.023$) ducks under blue light were observed drinking more often than ducks raised under white or red lights (Figure 3B). At various ages, ducks raised under red lights were observed to show fewer ($P = 0.032$) preening and foraging behaviors compared to ducks raised under white or blue lights (Figure 4A and B, respectively). At all ages after d 7, ducks raised under red light showed much less ($P < 0.0105$) activity compared to ducks under white or blue lights. However, at days 14 and 21, ducks under blue light showed extremely high levels of activity ($P < 0.0087$) compared to the other 2 light treatment groups. Figure 5 illustrates our observations of duck activity.

***Hormone data*** By d 7, ducks raised under blue light showed considerably higher ($P = 0.0009$) plasma corticosterone levels compared to ducks raised under white or red lights. Conversely, ducks raised under blue lights also showed lower ($P < 0.021$) levels of plasma GH compared to ducks under white or red lights. Figure 6 illustrates the levels of circulating cort and GH.

### *Duck Carcass Data*

Ducks raised under all three light systems showed similar carcass yields. However, ducks raised under blue lights showed a lower percentage of breast meat ($P < 0.05$) and a slightly lower percentage of breast skin ($P < 0.10$), fat, and total carcass fat ($P < 0.10$). Figure 7 illustrates these data.

## DISCUSSION

The purpose of this study was to test the hypothesis that, similar to chickens, (Rozenboim et al., 2004; Zhang et al., 2014), ducks raised under blue light may show improved performance and decreased stress. To test this hypothesis, we housed hatchling ducklings under blue or red light from hatch until 35 d age. We then compared biological, behavioral, and performance variables to ducklings housed under white light. We observed very few differences between ducks raised under red light compared to white light; however, ducks raised under blue light had considerably increased activity and plasma corticosterone levels, suggesting increased stress in these ducks. We also observed that ducks under blue lights showed lower BW, carcass values, and plasma GH levels compared to ducks raised under red or white lights. Our data suggest that unlike broilers, blue wavelengths of light may be detrimental to Pekin duck growth, performance, and welfare.

In order to partially determine the ducks' well-being or welfare, we analyzed several behaviors of the ducks during our study. We did not observe any differences in the number of bouts of feeding among treatment groups. Pekin ducks are dabbling ducks and feed by grazing throughout photophase and scotophase, not in meals as do galliforms (Cherry and Morris, 2005;

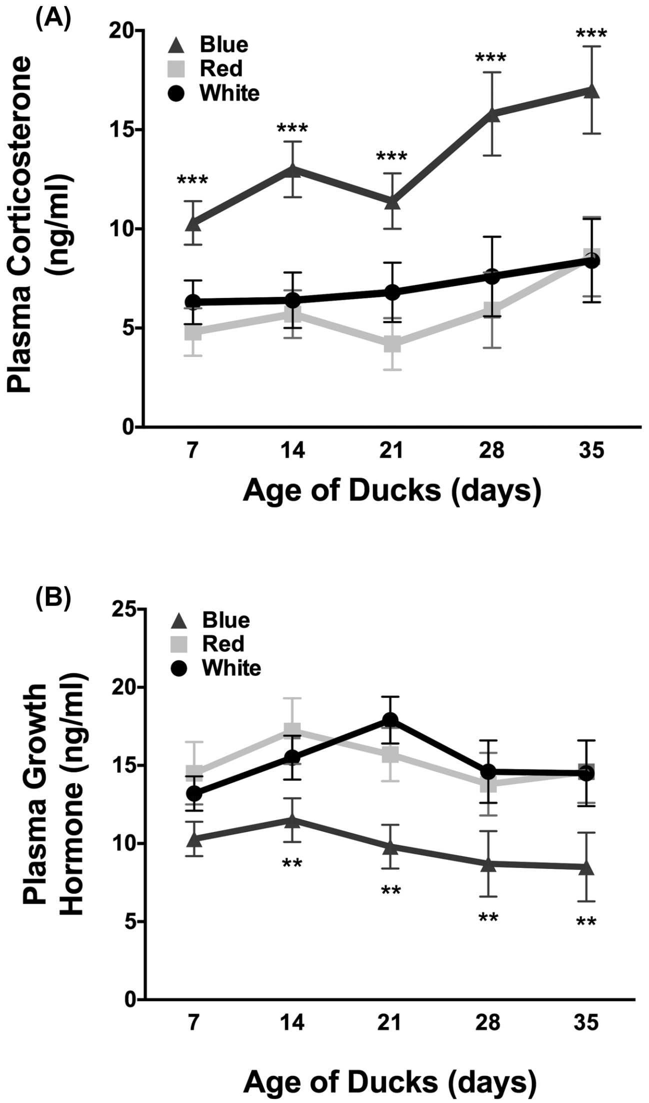


**Figure 6.** Plasma hormone analyses. Ducks under blue light showed increased circulating A) corticosterone and reduced B) growth hormone levels compared to ducks under red or white light. $^{**} = P < 0.01$; $^{***} = P < 0.001$.

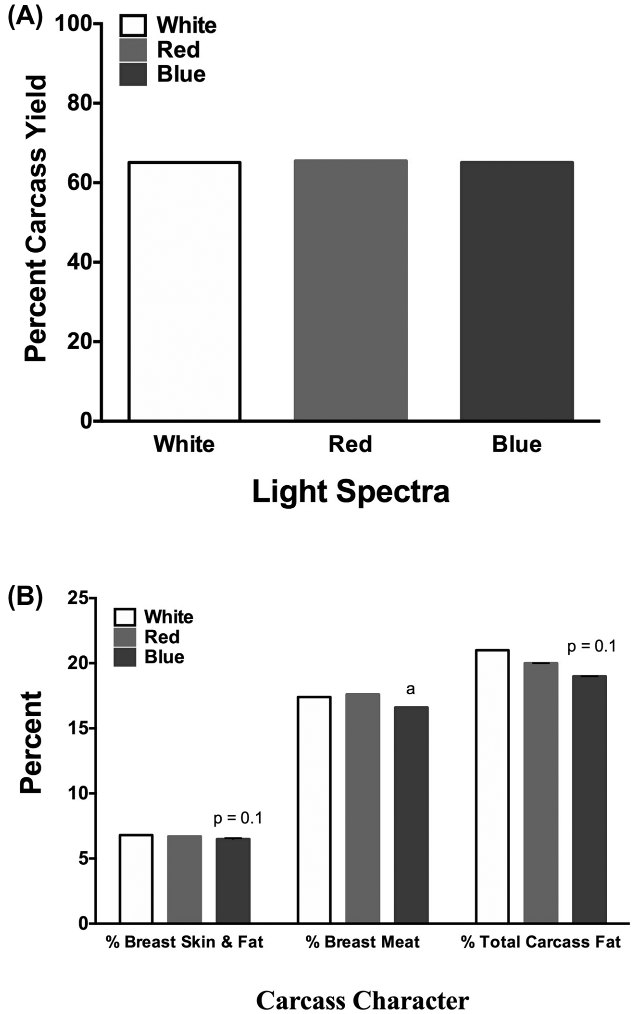


**Figure 7.** Duck carcass analyses. A) No differences were observed in carcass yields. B) Ducks raised under blue light showed somewhat reduced levels of skin and fat percent and in total carcass fat percent compared to ducks under red or white lights. Ducks under blue light also showed reduced percentage of breast meat compared to other groups. $^{*} = P < 0.05$.

Cherry and Morris, 2008). Thus, it is difficult to measure exact food intake when housed in floor pens. However, no differences were observed in the number of times ducks fed during the observation period regardless of the color of light under which the ducks were housed. We did observe differences in the bouts of the amount of drinking at the nipples lines sporadically across the study among the various groups; thus, these data are impossible to interpret at this time. Feather picking and pecking is an issue with ducks and may be ameliorated by blue-colored enrichment devices (Colton and Fraley, 2014). Although these self- and conspecific-destructive behaviors may be affected by colored objects and/or colored light, these behaviors were not observed in our study at all. Therefore, we cannot address whether colored lights may affect these behaviors. We did, however, observe increased motor activity at most of the ages in ducks housed under blue light. In production facilities, stressed ducks are typically observed to perform mass circling behaviors (Cherry and Morris, 2008). Increased activity in floor pens may be related to circling behaviors observed in barns when ducks are stressed. The possibility that the increased activity is due to an increased perceived stress in ducks under blue light is bolstered by how ducks visually perceive light.

The Pekin duck, due to its Mallard ancestry, may have a preference for blue-colored objects due to the anatomy and physiology of the retina. The preference for the blue wavelengths may reflect the types of colors the ducks are most capable of visualizing. In a series of studies by the Hart lab (Hart, 2001; Hart and Hunt, 2007; Hart et al., 1999; Hart and Vorobyev, 2005; Hegmann et al., 1974; Odeen et al., 2009), the retinas of avians typically have 4 to 5 sets of cones for color visualization (ultraviolet sensing), short wavelength sensing 1 and 2, medium wavelength sensing, and long wavelength sensing; (Hart and Vorobyev, 2005). In these articles, Hart and colleagues demonstrate that many shorebirds, including ducks, have a preponderance of short wavelength sensing (blue-sensitive) cones and relatively few long wavelength sensing (red-sensitive) cones. Other taxa of birds, such as galliformes and columbiformes, have a much higher percentage of long wavelength sensing cones (Hart et al., 1999). Hart et al. (1999) further demonstrate that the evolutionary selection for color sensitive vision may reflect factors such as diet, behaviors, and environment (e.g., land vs. water dwelling). These observations of retinal physiology make sense in terms of the respective birds' natural history. Galliformes, such as chickens and turkeys, utilize red pigmentation of the skin and feathers as a measure of developing social hierarchies and mating, whereas, Mallards (anseriformes) do not contain red pigments but rather utilize the blue–green plumage during the reproductive season. Thus, if ducks' retinas have relatively more surface area devoted to seeing blue wavelengths, it is possible under blue lighting that most of the visualized details that aid in object recognition are lost. Our study did not investigate the green wavelengths as our focus was on the 2 spectral extremes, red and blue; green either alone or in combination with blue may have either elicit beneficial or further detrimental results; these possibilities will be the focus of future studies. Regardless of the proximate cause for the increased stress in ducks under blue light, the observed increase in circulating corticosterone may have impacted carcass parameters.

Hormone cort is the major adrenal hormone related to feedback mechanisms for the body to maintain physiological homeostasis in response to stress. Hormone cort has many biological actions that affect the immune system, growth rates, and meat quality. Hormone cort levels are known to increase in ducks in response to stressful stimuli (Arnaud et al., 2010; Bourgeon et al., 2006; Faure et al., 2003; Harvey et al., 1980; McNeill et al., 1975). Hormone cort inhibits GH secretion and stimulates somatostatin. We similarly saw significantly reduced GH levels in birds housed under blue light. Altered GH and cort milieu in these birds may have contributed to the observed altered carcass yields by affecting myoblast and thus myofiber formation, relative fat deposition, or even overall metabolic rate.

An important variable that is still unknown in any species is the function of the deep brain photoreceptors during post-hatch growth and development. It is important to understand the neural mechanisms between DEP and hypothalamic–pituitary–adrenal axis or somatotropic axes as well as the behavioral processes in growing birds when attempting to improve meat animal performance while maintaining their well-being. Both retinal photoreceptors and DEP use light as their ligand in a manner similar to that of any membrane bound receptor. The actions of light acting on photoreceptors are related to the wave–particle duality of light. The specific wavelength of light that activates a given photoreceptor can be thought of as analogous to the 3-dimensional shape of a hormonal ligand, and the quantal energy of that wavelength similar to the molar concentration of a hormonal ligand. Just like 2 separate hormonal ligands can only be compared biologically on an equimolar basis, different wavelengths of light must also be compared on a quantal molar basis. For these reasons over the last 10 yr or more, those who are investigating the biological effects of light have agreed that normalizing light "treatments" based upon quantal energy units, rather than lux, are necessary (Bailey and Cassone, 2004; Bellingham et al., 2006; Chaurasia et al., 2005; Halford et al., 2009; Heath et al., 1997; Kang et al., 2010; Kasahara et al., 2002; Nakane et al., 2010).

Our study set out to determine if blue or red light would improve duck growth and wellbeing compared to ducks raised under white light. Although there may be some small advantages to red light in terms of reduced activity, the reduced activity does not translate to improved growth rates or carcass quality. Interestingly, unlike chickens, housing ducks under blue light appears to have detrimental effects in terms of behavior, growth rate, and carcass quality. The negative gross effects of blue light were also observed in the endocrine profiles of the hypothalamic–pituitary–adrenal and somatotropic axes. Thus, it appears that under aviary conditions, the white light provides the best environmental conditions for grow-out ducks. This study also further underscores the need to consider an animal's biology and physiology when considering changes in the environment and impact on well-being and welfare.

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