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Effect of Exposing Layer and Broiler Eggs to Red or White Light During Incubation

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Abstract: Previous study has shown that layer and broiler eggs filter light. It was hypothesized that due to the difference in pigment of the eggshells that utilizing red light would improve hatch in white eggs similarly to that observed in brown eggs using white light. To determine we incubated chicken eggs (n = 2592) under either no light (dark), red light, or white light; the light level was 250 lx and equal numbers of layer and broiler eggs were used. White light was observed to increase (p = 0.05) hatch of fertile (92.5±1.3%) over dark and red light incubated broiler eggs (86.1±2.2 and 86.1±2.6%). White light had no effect on hatch of fertile when compared with dark incubated white layer eggs (68.11±12.8%); however, red light (88.0±4.8%) showed an increased (p = 0.05) hatch of fertile over dark incubated white layer eggs. Brown eggs exposed to white (0.85±0.02) or red (0.80±0.02) improved (p<0.05) the proportion of non-defect chicks over dark (0.52±0.02) incubated eggs. Similarly, white eggs show the same trend of white (0.79±0.02) or red (0.72±0.04) improved (p<0.05) the proportion of non-defect chicks over dark (0.51±0.02) incubated eggs. Chick length was not affected (p>0.05) by any treatment. These results indicate that red light is possibly the key spectrum to improving hatchability.

Key words: Layer, broiler, incubation, light, hatchability

INTRODUCTION

Poultry eggs and meat are increasing in demand around the world. This means the poultry industry has an increased demand for hatching more chicks and more good quality chicks. This is magnified when the fact that there is an increased demand for birds to be raised without antibiotics and in systems with historically higher mortality rates. This leaves the poultry industry a few options to meet the increased demand. The industry could simply increase breeder numbers which will be costly. They could try to increase breeder production which could take a long time. Finally they can try to increase efficiency at the hatchery. While all are viable options increasing hatchery efficiency may be the most cost effective method.

To improve hatchery efficiently the primary focus is to optimize hatchability of fertile poultry eggs by optimizing the temperature, humidity, turning and even carbon dioxide concentrations during incubation. While all of those factors may be utilized there is evidence that another environmental factor, light, can have an effect on development of the embryo and hatchability as well as effects later in life (Archer *et al*., 2009; Ozkan *et al*., 2012; Archer and Mench, 2014a). Providing light during incubation has been shown to result in a reduction in fear responses (Dimond, 1968; Archer and Mench, 2014b) and a decrease in stress indicators (Archer *et al*., 2009; Archer and Mench, 2013, 2014b) which improves the welfare of chickens and is an important factor to consumers. The addition of light during incubation has been shown to increase overall hatchability as well (Cooper, 1972; Shafey and Al-Mohsen, 2002; Shafey, 2004; Archer and Mench, 2014a,b), though the degree of effectiveness has varied with the type of light or strain of bird.

One this is clear though light is an import stimuli that can greatly influence the development of avian embryos and is evolutionary important. This is evident as the embryo's ability to sense light is at 2 days of incubation, where light exposure stimulates mitosis in neural crest mesoderm (Cooper *et al*., 2011) which leads to the development of the central nervous system (Isakson *et al*., 1970). The pineal gland, which forms at day 3 of incubation in chickens (Cooper *et al*., 2011) is also sensitive to light. Furthermore, the light sensing opsins (photoreceptor molecules) have been detected in an embryonic chick at 14 days of development, with development completing on day 18 (Bruhn and Cepko, 1996). Light exposure during incubation of avian embryos results in circadian rhythms (Hill *et al*., 2004; Cooper *et al*., 2011) and brain differentiation (Rogers and Krebs, 1996) the importance that light can play during the physiological development of an avian embryo.

It is well known that birds are affected differentially by varying lighting spectra. For instance, red light has been shown to stimulate reproduction and activity while blue/green light has been shown to stimulate growth. Furthermore, it has been observed that different spectra can have an impact on birds during embryogenesis (Veterany *et al*., 2007). Making the matter even more complex the pigment of the eggshell can influence which

wavelengths of light pass through the shell and reach the embryo. For instance, differences in hatch time have been observed when using different types of florescent lights and has attributed to the eggshell filtering certain light spectrums (Ghatpande *et al*., 1995) and that only some of the light reaching the embryo. Shafey *et al*. (2005) found that hatchability in lightly pigmented eggs was the highest at ~89% when exposed to low levels (900-1380 lux) of light, as opposed to medium and dark pigmented eggs that only reached ~81 and ~85% hatchability, respectively. However, when Shafey *et al*. (2005) exposed the eggs to high intensity (1430-2080 lux) light, the hatchability of lightly and medium pigmented eggs was reduced, while dark pigmented eggs were not affected. Spectral analysis of pigmented and non-pigmented eggshells shows that on average 99.8% of light will be absorbed by the shell, with absorption in the near-ultraviolet spectrum being higher than the near-infrared (Shafey and Al-Mohsen, 2002).

Huth and Archer (2015) observed that broiler eggs saw an increase in hatchability when exposed to white LED light while white layer eggs so no improvement in hatch over eggs incubated in darkness. Huth and Archer (2015) concluded that this may be related to how the broiler and layer eggs filter the light differently due to the shell pigments or lack thereof. Archer (2015) observed that two different types of white light both increased hatch and were filtered similarly into more of the red frequency range. Veterany *et al*. (2007) tested monochromatic lighting during incubation of broiler eggs and found red light produced a higher hatchability than blue, with white light having the highest overall hatchability. Huth and Archer (2015) hypothesized that the red spectrum of light was possibly responsible for the increased hatch in broiler eggs and may be utilized to increase hatch in layer eggs.

As little research has been done on how lighted incubation affects eggs from different chicken breeds or what is the optimum frequency of light for each breed; therefore we conducted an experiment to investigate this. The objective of this study was to determine if utilizing mono-chromatic red LEDs could result in improved hatchability that is seen in broiler eggs that are exposed to white LED light. Previously, it has been shown that the majority of white light is filtered to the red spectrum as it passes through a broiler egg shell. Therefore, it is hypothesized that broiler eggs incubated under red or white light will hatch better than when they are incubated in darkness. Furthermore, it is hypothesized that white layer eggs incubated under red LED light will hatch better than white layer eggs incubated under white LED lights or in darkness.

MATERIALS AND METHODS

General procedures: Three replications were conducted to investigate the differential effects of providing white LED light, red LED light, or no illumination during incubation on hatchability, chick. All methods were approved by the Texas A and M Institutional Animal Care and Use Committee (AUP # 2012-211 and # 2013-0256).

The study was conducted using Cobb500 broiler eggs (N = 3096) and White Leghorn (Hy-line W-36, N = 3096). Three GQF 1500 incubators and three GQF 1550 hatchers (GQF Manufacturing, Savannah, GA) were used in each trial and their front windows were blacked out with cardboard to prevent light intrusion into the machines. One incubator were operated with the traditional dark method of incubation (0L:24D, DARK), while the other two incubators were outfitted with cool white (7500 K) LED strips (Superbrightleds WFLS-X3 Saint Louis, MO; White) or red LED strips (Superbrightleds WFLS-RGBX2 Saint Louis, MO; RED). LED lights were on each level, with 2 strips running the length of the racks. The strips were attached to metal frames, which were in turn attached to the bottom of the rack above them. For the top rack, light strips were held up by a metal frame made to rest on the top rack. The lights were operated by a timer, with a 12L:12D light schedule at 250 lux at egg level as measured using a light meter (Extech 401027, Extech Instruments, Nashua, NH). Two egg trays were set on each rack with each tray holding either 43 broiler eggs or 48 layer eggs, for a total of six trays over 3 levels equaling 128 broiler eggs and 144 layer eggs per incubator. The incubators were maintained at standard temperature and humidity levels of 99.5°F and 55% relative humidity. The eggs were incubated for 18 days, at which time they were moved into the hatchers. The hatchers had no lights and the eggs were in complete darkness.

All of the chicks were weighed and counted at hatch. The quality of the live chicks was assessed and they were categorized and counted as either no defect, having an unhealed navel, having leg abnormalities, weak, dirty, having traits a hatchery would cull, or having any other abnormality. The remaining unhatched eggs were broken out and counted as pipped, broken, infertile, early dead, mid dead and late dead. A subset of 60 chicks per treatment per trial were measured for chick length. This was done by measuring the chick from the tip of the beak to the tip of the middle toes after the chick had been euthanized.

Spectrum analysis of eggs: Twenty brown broiler eggs and twenty White Leghorn eggs were obtained and the contents emptied, making sure the large half of the egg remained intact. After the shells air dried for 10 min, they were individually placed over the sensor of an MK350 (UPRTek, Jhunan Taiwan) LED meter and illuminated with a either the White or RED LED strip lighting held 5 cm over the sensor. The spectrum was measured for light passing through all 40 eggs. Then a small flat

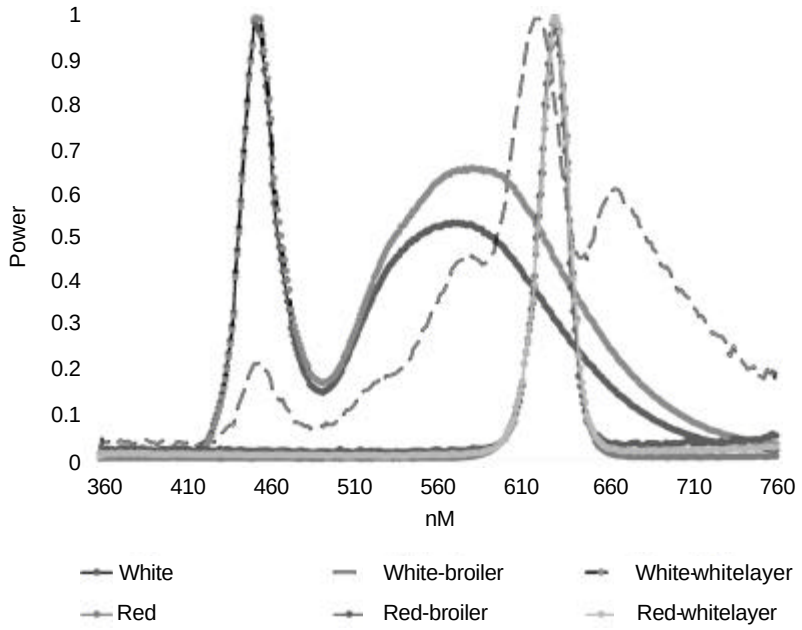

Fig. 1: Light frequency spectrum for red LED and white LED lights filtered by broiler and white leghorn egg shells and unfiltered

piece of shell just large enough to cover the sensor was broken off each egg and measured in the same way, in order to test if there was a difference between light passing through a curved shell or a flat shell segment. A final measurement of unfiltered light was taken as a control and all duplicated readings were averaged. This analysis is presented for informational purposes only (Fig. 1), no statistical analysis was performed.

Statistical methods: The GLM procedure was used to test Trial, Treatment and Treatment x Trial. Trial and Treatment x Trial were found to be non-significant ($p>0.05$) for all measures so a simpler One-way ANOVA was used to investigate treatment effects on hatchability, embryo mortality, chick quality. The least significant difference test was used to test all planned comparisons. All of the assumptions of ANOVA were tested (Shapiro-Wilk test for normality, Levene's test for homogeneity of variance). No transformations were needed to meet assumptions. All analyses were performed using SAS 9.5 for Windows (SAS Institute Inc).

RESULTS

No differences ($p>0.05$) between treatments were observed in embryo mortality with the exception of percentage of pipped eggs in the layer eggs (Table 1). Dark layer eggs were observed to have more ($p<0.05$) pipped eggs than RED layer eggs with White layer eggs being intermediate of the two other layer treatments. However, overall hatchability of fertile eggs was affected by treatment in both layer and broiler eggs (Fig. 2). In the broiler eggs, the White broiler treatment had a higher rate of hatchability of fertile eggs than DARK broiler treatments ($p>0.05$) with the RED broiler treatment being intermediate. In the layer eggs, the RED layer treatment to have a higher rate of hatchability of fertile eggs than the DARK layer treatments ($p = 0.05$) with the white layer eggs being intermediate.

Differences were observed between lighting treatment ($p<0.05$) in chick quality in both broilers and layers (Table 2). In the broiler eggs, the DARK broiler treatment had more unhealed navels than both the RED and White broiler treatments ($p<0.05$). The DARK broiler treatment also had more ($p<0.05$) chicks with leg problems then the Red broiler treatment with the White broiler treatment being intermediate. There were no treatment differences ($p>0.05$) observed in dirty, cull, other abnormalities, chick weight or chick length in the broiler eggs. In the layer eggs, the DARK layer treatment had the most ($p<0.05$) unhealed navels compared to both the other treatments; however, the other two treatments differed as well with the White layer treatment having the least ($p<0.05$) unhealed navels. The DARK treatment had less dirty chicks and cull chicks than both other treatments ($p<0.05$). There were no treatment differences ($p>0.05$) observed in leg issue, other abnormalities, or chick length in the broiler eggs. Chick weight did differ between treatments. The RED layer treatment weighed less ($p<0.05$) than White layer treatment with the DARK layer treatment weighing in the middle of the other two treatments. There was also an overall effect on no defect

Table 1: Embryo mortality for broiler and layer eggs incubated under either red or white LEDs or in complete dark (Mean±SE)

Treatment	Early dead (%)	Mid dead (%)	Late dead (%)	Pipped (%)
Dark broiler	5.18±0.93	0.00±0.00	3.10±0.78	1.29±0.56
Red broiler	2.70±0.76	0.26±0.26	4.75±1.32	3.55±0.93
White broiler	3.13±1.71	0.26±0.26	3.65±0.74	1.64±0.59
Dark layer	4.14±1.24	0.49±0.33	7.81±2.36	16.65±6.93^{A}
Red layer	3.20±1.67	1.03±0.58	7.75±2.13	5.11±2.29^{B}
White layer	3.59±1.64	0.51±0.33	8.11±1.74	8.05±3.51^{AB}

^{A,B}Differing letters within column and bird type are significantly different ($p<0.05$)

Table 2: Chick quality for broiler and layer eggs incubated under either red or white LEDs or in complete dark (Mean±SE)

Treatment	Unhealed navels (%)	Leg problems (%)	Dirty feather (%)	Cull chicks (%)	Other (%)	Chick wt. (g)	Chick length (mm)
Dark broiler	45.09±2.87^{A}	2.98±1.41^{A}	0.35±0.35	0.00±0.00	0.00±0.00	47.57±0.42	189.97±0.58
Red broiler	19.47±2.36^{B}	0.30±0.30^{B}	0.36±0.36	0.36±0.36	0.30±0.30	47.64±0.44	189.25±0.74
White broiler	15.24±1.80^{B}	0.88±0.44^{AB}	0.33±0.33	0.00±0.00	0.00±0.00	46.29±0.60	190.21±1.06
Dark layer	50.02±3.32^{A}	0.32±0.32	0.24±0.24^{A}	0.00±0.00^{A}	0.24±0.24	42.27±0.57^{AB}	183.17±1.63
Red layer	28.06±4.55^{B}	0.00±0.00	2.11±1.02^{B}	0.52±0.52^{B}	0.00±0.00	40.81±0.58^{A}	184.28±1.15
White layer	19.18±2.26^{C}	0.00±0.00	1.99±0.86^{B}	1.56±1.06^{B}	0.00±0.00	43.10±0.96^{B}	182.94±0.85

^{A,B,C}Differing letters within column and bird type are significantly different ($p<0.05$)

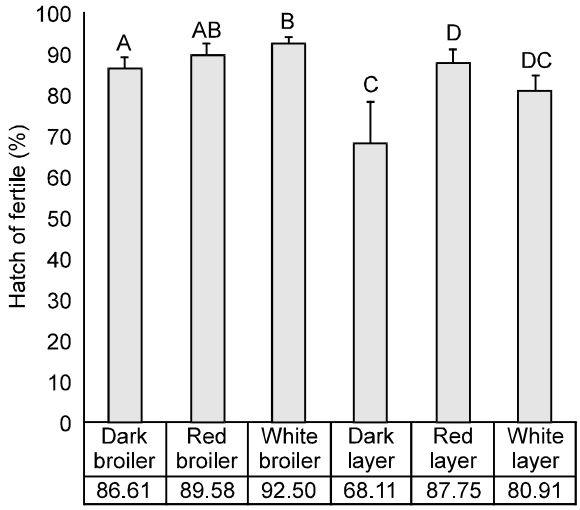

Fig. 2: Hatch of fertile of broiler and layer eggs incubated under either RED or White LED lights or in the DARK. Bars with different letters (A or B) are significantly different $p<0.05$. Bars with different letters (C or D) are significantly different $p = 0.05$

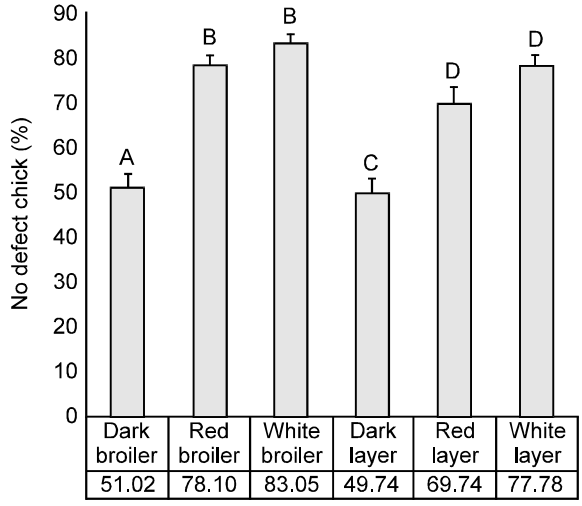

Fig. 3: Hatch of fertile of broiler and layer eggs incubated under either RED or White LED lights or in the DARK. Bars with different letters (A or B) within broiler eggs are significantly different $p<0.05$. Bars with different letters (C or D) within layer eggs are significantly different $p<0.05$

chicks in both layers and broilers (Fig. 3). In both broilers and layers both lighting treatments had more ($p<0.05$) no defect chicks than the DARK treatment.

DISCUSSION

The aim of this study was to determine if the red spectrum of visible light was important range of light for improvement in hatchability and chick quality in chickens. Previous work has shown that providing white light during incubation could improve hatch overall hatchability (Cooper, 1972; Shafey and Al-Mohsen, 2002; Shafey, 2004; Archer and Mench, 2014a,b), though Huth and Archer (2015) observed that white layer eggs did not see this improvement while broiler chicken eggs did. They concluded that it could be because of how the egg shells filter the light differently. It was observed in this study that white light was filtered differently while red light was not filtered by either shell type.

As birds are affected differentially by varying lighting spectra the color of light actually reaching the embryo may have varying effects. In fact, Veterany *et al.* (2007) observed that different spectra can have an impact on birds during embryogenesis. Ghatpande *et al.* (1995) attributed differences in hatch time while when using different types of florescent lights to the fact that the eggshells were filtering certain light spectrums (Ghatpande *et al.*, 1995). Furthering the importance of

the type of light spectrum being used is that eggshells on average absorb 99.8% of light, with absorption in the near-ultraviolet spectrum being higher than the near-infrared (Shafey and Al-Mohsen, 2002). Archer (2015) observed that two different types of white light both increased hatch and were filtered similarly into more of the red frequency range.

The DARK broiler had lower hatch of fertile percentage than the White broiler LED treatment which is consistent with previous research (Archer, 2015; Huth and Archer, 2015). The RED broiler treatment did not improve hatchability of fertile eggs compared to the DARK broilers but was found to be intermediate. It is possible that a difference could have been observed with more replication. The red light did however improve hatchability in the layer eggs with the RED layer treatment having a higher hatch rate than the DARK layer treatment. The White layer treatment did not have an improved hatch compared to the DARK treatment which is similar to the results of Huth and Archer (2015). The improved hatch in the layers via red light exposure demonstrates that this frequency of light appears to be important for the viability and hatchability of chicken embryos. While the RED broiler treatment did not show this same effect it is clear that the light reaching the broiler embryos is likely more red than any other part of the spectrum.

The improvement of hatch rate and chick quality are important factors but adding more to the picture the fact that other research shows that lighted incubation affects the birds long-term (Archer *et al*., 2009; Ozkan *et al*., 2012; Archer and Mench, 2014). Providing light during incubation reduces fear responses (Dimond, 1968; Archer and Mench, 2014a,b) and decreases stress susceptibility (Archer *et al*., 2009; Archer and Mench, 2013, 2014a,b) post hatch. Utilizing this simple management technique in the hatchery can improve production efficiency and also improve animal welfare.

The results of this study illustrate that the optimum light during incubation may include white light but with the addition of red light a single LED light could be used to improve hatch of pigmented and unpigmented eggs. This needs future research to confirm but if one light could be used for all colors of eggs it would make this technology more feasible for the poultry industry to implement. Research continues to demonstrate that the use of light during incubation can improve hatchability, chick quality and even improve animal welfare post-hatch making it a tool that the poultry industry should consider.

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