Can Lighting Programs be Manipulated in the Growing Phase to Improve the Skeletal Integrity of Commercial Egg Layers

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Introduction

Osteoporosis, a progressive decrease in the amount of mineralized structural bone, leads to skeletal fragility and susceptibility to bone fracture in egg laying strains of chickens. Approximately 5% of birds grown in conventional cages were shown to have old breaks and 29% of all hens have one or more broken bones during time spent in cages, depopulation, and transport for processing (Gregory and Wilkins, 1989). In addition to the bone breakage of live birds, economic losses arise due to high fracture incidences during carcass processing. Because of bone splinters in the meat of spent hens, the egg industry has lost the majority of its market to companies manufacturing chicken based soup products. Most soup companies now use broiler meat in place of spent hen meat.

Delaying sexual maturity may be a way to improve the structural integrity of laying hens. Attempts have been made to delay sexual maturity by feed restriction and photostimulation. Gregory et al. (1990) restricted feed from 6 to 14 wk of age and additionally delayed photostimulation by 2 wk to extend onset of sexual maturity by 10 d; however, the incidence of broken bones at 88 wk of age was unaffected by delaying sexual maturity through these methods. On the other hand, Silversides et al. (2006) demonstrated that delayed photostimulation improved the bone strength characteristics of the radius in different strains of white and brown egg layers. This delayed photostimulation was achieved by placing pullets in conventional egg laying cages at 20 wk in comparison to those placed typically at 18 wk of age.

What is not known is if delaying development during the earlier stages of pullet growth through photostimulation can subsequently have long-term health benefits in reducing osteoporosis in egg laying chickens at end of lay. Our hypothesis is that a slower more gradual decline in light hours from 2 to 17 wk of age as compared to a rapid decline in light hours will improve skeletal integrity by delaying sexual maturity or age of first egg laid. By delaying sexual maturity, the pullet skeleton will have the opportunity to develop structural bone more fully prior to the initiation of egg laying. Therefore, the purpose of this study was to determine if photostimulation during the growing phase of egg laying strains of pullets can be altered to allow for improved skeletal integrity without detrimentally affecting egg production and other traits of economic importance to the egg industry.

Materials and Methods

Experiment 1. Two strains of White Leghorns, Hy-Line W36 and W98, were each exposed to 1 of 3 varying step-down lighting programs during growth (2 to 17 wk of age) referred to as slow, moderate, and rapid. After the growing period, all hens were exposed to the same standard step-up lighting program to induce egg laying.

Pullets of the slow lighting regimen were exposed to a very gradual decline in light hours beginning with 20 h of light at 2 wk of age and reaching a 10 h photoperiod by 17 wk of age. With the moderate lighting program, pullets were subjected to 1 h weekly decreases in photoperiod from 2 to 12 wk of age until a 9 h photoperiod was achieved where it remained at this level until 16 wk of age. Pullets of the rapid lighting program experienced a 4 h decrease in photoperiod at 2 wk of age (from 20 to 16 h of light) and then again at 3 wk of age (from 16 to 12 h of light). At 4 wk of age, light hours were decreased to 9 h and held constant until 16 wk of age for pullets of the rapid lighting regimen. Lights were not stepped up until 18 wk of age for pullets of the slow lighting regimen, unlike the pullets of the moderate and rapid lighting regimens in which light hours were stepped up at 17 wk of age by one hour. Beginning at 18 wk of age, all pullets experienced an identical photoperiod of 10.5 h with 1/2 h increases in the photoperiod at weekly intervals until 25 wk of age. Subsequent weekly 20 min increases in photoperiod beginning at 26 wk of age occurred until a 16 h photoperiod was achieved at 31 wk of age. The 16 h photoperiod was maintained for all hens until termination of the study at 66 wk of age.

Pullets were reared in littered pens (2 pens per lighting program) during the growing period and transferred to the layer house at 17 wk of age. The layer house was environmentally controlled. Each cage dimension was 25.4 x 35.6 x 40.6 cm with 1 hen placed in each cage for the purpose of maintaining individual egg records. Each cage was equipped with 1 drip nipple. A phase feeding program was used according to the Hy-Line Commercial Management Guide (2004-2006). Corn-soybean meal based diets were fed during the growing period (crumbles) and laying period (mash).

At 66 wk of age, spent hens were euthanized, BW were determined, and the left drum stick and part of the left wing (radius and ulna) were collected. The scanning of bones was performed using dual energy X-ray absorptiometry (DEXA). The bone mineral density (BMD, g/cm^2), bone mineral content (BMC, g), and bone area (cm^2) of the left drum (tibia and fibula), radius, and ulna were determined from the DEXA scans (Schreiweis et al., 2003).

Data were analyzed using an analysis of covariance with a split plot for type of bone (radius, ulna, and tibia/fibula of a bird). Body weight was the covariate for BMD, BMC, and bone area. Lighting program (rapid, moderate, or slow), strain of bird (W36 or W98), and bone (radius, ulna, and tibia/fibula) of the bird were considered fixed effects. Two replicate pens per lighting program and strain were employed, and the replicate served as the experimental unit to test for the main effect of lighting regimen. The BW was analyzed as an ANOVA with the split plot for type of bone removed from the model.

Means were partitioned using differences of least square means or Tukey-Kramer. The mixed model procedure of the SAS® system was utilized (SAS Institute, 2003).

Experiment 2. A second lighting trial was conducted using the Hy-Line brown and W98 strains of egg laying chickens. The lighting treatments, housing, and diets were the same as experiment 1. The same bones were scanned as described for experiment 1 with the addition of the humerus. The bones of the right wing and right tibia were scanned unlike experiment 1 in which the left radius and ulna and drum were scanned. The BMD, BMC, bone area, bone length (mm), and bone width (mm) of bones were determined from the DEXA scans (Schreiweis et al., 2003). Data were statistically analyzed as described for Experiment 1. An analysis of covariance was conducted on all bone traits**.**

Results and Discussion

Experiment 1. Hens exposed to a rapid lighting program as pullets had greater BMD than hens of the slow lighting programs ($P = 0.03$, Table 1). The BMD of hens exposed to rapid lighting as pullets was similar to the BMD of hens of the moderate lighting program. Lighting program did not affect BMC, bone area, or BW. With respect to BMD and BMC, interactions of lighting program with strain of hen or type of bone was non-significant indicating that both strains and all 3 bones responded the same to the lighting treatment as pullets.

The bone area of the tibia of the W98 strain of laying hen was larger than that of the W36 strain, while bone area of the radius and ulna were similar between strains (strain x bone interaction, $P < 0.0001$, data not presented). The body frame of the W98 hen is considered to be larger than that of the W36, and this larger body size was reflected in the BW of the W98 (mean of 1882 g, SEM = 20) as compared to the W36 (mean of 1808 g, SEM = 21, $P < 0.04$).

Table 1. The effect of pullet lighting program on bone traits and BW of 66 wk-old laying hens (experiment 1)

Lighting program	Bone mineral density[1] (g/cm^2)	Bone mineral content[1] (g)	Bone area[1] (cm^2)	BW[2] (kg)
Rapid	0.144^{a}	1.40^{a}	8.31^{a}	1798^{a}
Moderate	0.143^{ab}	1.40^{a}	8.42^{a}	1848^{a}
Slow	0.140^{b}	1.37^{a}	8.44^{a}	1891^{a}
SEM	0.001	0.02	0.04	25
n[3]	817	745	744	282
P	0.03	0.63	0.08	0.10

[1]Values represent the least square means averaged over 3 bones (tibia, radius, and ulna) and 2 strains of egg laying hens (Hy-Line W36 and W98).

[2]Values represent the least square means averaged over 2 strains of egg laying hens (Hy-Line W36 and W98).
[3]Average number of observations per lighting program.
[a-b]Means within a column with no common letters are significantly different ($P < 0.05$).

Experiment 2. Results indicate that the lighting programs had no affect on BMD, BMC, and width of bones of 66-wk-old hens (Table 2). Hens on the rapid lighting program had shorter bone length ($P < 0.0001$) and less bone area ($P = 0.001$) than those on the moderate or slow lighting programs. The 66-wk-old BW of hens exposed to the rapid lighting program as pullets were less ($P < 0.001$) than the BW of chickens subjected to the moderate or slow lighting programs.

Results on bone size traits suggest that the slow and moderate lighting programs were effective in delaying sexual maturity, most likely due to delayed growth plate closure, resulting in larger bones.

Table 2. The effect of pullet lighting program on bone traits and BW of 66 wk-old laying hens (experiment 2)

Lighting program	Bone mineral density[1] (g/cm^2)	Bone mineral content[1] (g)	Bone area[1] (cm^2)	Bone length[1] (mm)	Bone width[1] (mm)	BW[2] (g)
Rapid	0.140[a]	1.46[a]	9.04[b]	78.9[b]	5.76[a]	1833[b]
Moderate	0.138[a]	1.46[a]	9.21[a]	80.1[a]	5.90[a]	1908[a]
Slow	0.136[a]	1.45[a]	9.33[a]	80.7[a]	5.94[a]	1931[a]
SEM	0.002	0.02	0.004	0.2	0.06	12
n[3]	519	514	512	512	511	315
P	0.42	0.80	0.001	< 0.0001	0.06	< 0.0001

[1]Values represent the least square means averaged over 4 bones (tibia, humerus, radius, and ulna) and 2 strains of egg laying hens (Hy-Line Brown and W98).
[2]Values represent the least square means averaged over 2 strains of egg laying hens (Hy-Line Brown and W98).
[3]Average number of observations per lighting program.
[a-b]Means within a column with no common letters are significantly different ($P < 0.05$).

Our hypothesis was that a slower more gradual decline in light hours, i.e. the slow lighting program, would improve skeletal integrity by delaying sexual maturity. Although the slow as compared to the rapid lighting regimen delayed sexual maturity as indicated by age of first egg laid (Arango et al., 2007) and decreased bone length and area (experiment 2) most likely through later growth plate closure, it did not culminate into improved bone mineralization. In fact, results of experiment 1 indicate that pullets exposed to the rapid lighting programs have better BMD at 66 wk of age than birds of the slow lighting regimen (Table 1). With the exception of the Hy-Line Brown, the earlier

sexual maturity of pullets exposed to the rapid lighting program led to a higher peak in egg production (to 39 wk of age) when compared to birds of the slow and moderate lighting programs. Egg production (to 39 wk of age) of the Hy-Line Brown hens subjected to the rapid lighting regimen also had higher egg production than hens of the moderate, but not the slow lighting regimen (Arango et al., 2007 and personal communication with Hy-Line International). This earlier peak in egg production by hens exposed to the rapid lighting program as pullets (Arango et al., 2007) may lead to lower egg production by end of lay. The end result would be similar total egg output for hens on each of the 3 lighting regimens. If this scenario proves to be true, then hens of the rapid lighting program would have lower egg production at the end of lay (66 wk) than those hens that were subjected to the slow lighting program. The lowered end of lay egg production of hens of the rapid lighting program would result in less demand for bone calcium leading to improved bone mineralization at 66 wk of age. It is possible that lighting program in the growing stage of a pullet may not impact the occurrence of osteoporosis later in the laying or life cycle as much as egg production status. The results on bone mineralization of hens at 66 wk of age could be more affected by number of eggs laid and the amount of shell produced by hens at the end of lay. Our experimental results are based solely on bones collected at 66 wk of age after one complete laying cycle. If data were collected during the exposure to the lighting treatments, in addition to collection from layers throughout the laying life cycle, a better timeline could be developed for a laying hen's skeletal integrity.

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