LIGHTING GROWING PULLETS – GET IT WRONG AT YOUR PERIL

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Summary

The balance between egg numbers and egg weight for egg-type hybrids and broiler breeders is mainly decided by the age and body weight of a pullet on the day it lays its first egg. The timing of this event is strongly influenced by the lighting programme applied during the rearing period. The earliest maturity for egg-type pullets reared on constant photoperiods is achieved on 10-h days. Maturity occurs about 7 d later for birds reared on 8-h days, and is marginally delayed on photoperiods > 10-h. Broiler breeders respond to constant photoperiods quite differently from egg-type pullets because they still exhibit photorefractoriness. Although the earliest maturity for constant photoperiod pullets still occurs at 10 h, first egg is delayed by about up to 3 weeks for photoperiods between 10 and 13 h, with smaller delays thereafter, and delayed by about 2 d for each 1-h reduction in photoperiod below 10 h. Egg-type pullets are not responsive to a transfer to long-days before 5 or 6 weeks, are most responsive by 9 to 10 weeks. Responses become progressively weaker thereafter, until no response 10 d before spontaneous maturation. In contrast, maturity is delayed by 3-4 weeks in broiler breeders photostimulated before 10 weeks, and complete photosensitivity does not occur in a flock until at least 18 weeks of age. From 19 weeks onwards the advance in maturity becomes steadily smaller until spontaneous maturation at about 30 weeks. A transfer from 8 h to 14 or 15 h provides maximum stimulation for both egg-type and broiler breeder pullets. Many egg-laying hybrids reach 50% egg production by 21 weeks of age without photostimulation, and so maturity cannot be retarded simply by delaying the first increase in photoperiod; some form of step-down lighting is required.

1. INTRODUCTION

Age at first egg exerts a large influence on the balance between egg numbers and egg weight, with a 7-d difference in maturity resulting in a 1-g change in mean egg weight and a 5-6 difference in egg numbers. Light is unquestionably the most potent environmental factor controlling the rate of sexual development in ad libitum fed egg-type pullets, and a major factor in control-fed broiler breeders. Precocious pullets will always lay eggs that are below breeder specification and retarded pullets rarely meet egg-number targets. Thus the main function of a lighting programme during the rearing period is to achieve optimum sexual maturation. There is no set time for sexual maturity, but there is an optimum time to achieve the balance of egg numbers and egg weight appropriate for a particular market. If an incorrect lighting programme is used, and sexual maturity occurs at the wrong time, there is little that can be done to rectify matters once egg production has started; you only get one chance to get it right.

There is a big difference in the philosophy for lighting for egg-type pullets and broiler breeders. Laying hens are no longer seasonal breeders, and so do not necessarily need to be reared on short days. In contrast, broiler breeders still are seasonal breeders, and, like turkeys, need to be given a period of short days to dissipate juvenile photorefractoriness to make them responsive to a transfer to stimulatory photoperiods.

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A further objective of a lighting programme for egg-type pullets is the encouragement of an appetite that achieves the desired growth curve. Commonly, producers have difficulty in getting modern egg-type pullets to target body weight, but it appears that generally the reverse applies in Australia, where over-weight pullets are reported to be a problem after 6 weeks of age.

In broiler breeders, growth is almost totally controlled by the feeding programme, and so lighting has little influence on body weight gain. However, lighting during the rearing phase has a huge effect on the timing of sexual development, irrespective of growth. Broiler breeders cannot simply be regarded as large chicken - they are more like small turkeys – and so lighting considerations are completely different from egg-laying stock. Getting it wrong for broiler breeders can be very costly.

II. EGG-TYPE PULLETS

a) Constant photoperiods

Constant photoperiods not only affect sexual maturation through the photosexual response, but also by modifying feed intake and growth. The earliest age at first egg (AFE) is achieved by rearing on 10-h photoperiods. AFE is delayed by about 0.3 d for each 1-h longer photoperiod, but by 4.2 d for each 1-h shorter photoperiod. This rate of change below 10 h is far steeper for modern hybrids than for early genotypes of pullet, when AFE was delayed by less than 2 d/h (Figure 1). Cumulative feed intake to 16 weeks increases by about 180 g for each 1-h extension of the photoperiod, but to mean AFE (analogous to 50% rate of lay) it is influenced by both the photoperiod and AFE, and is described by the equation: $y = -12000 +221p +133A$, where $p =$ photoperiod during rearing and $A =$ mean age at first egg (d).

![Figure 1. Mean age at first egg for ad libitum fed early (o) and modern (●) hybrids maintained on constant photoperiods](image1)

![Figure 2. Mean age at first egg for modern pullets maintained on 8, 13 or 18-h photoperiods (solid bars), or given a 5-h increase or decrease (open bars) at 12 weeks.](image2)
It is common commercial practice to provide growing pullets with a short period of step-down lighting before growing them on a constant short-day to ensure the chicks have explored their environment and satisfactorily started eating and drinking. Maturity will be delayed by 1 to 2 d for each extra week taken to reach the constant short-day, depending on the stimulatoriness of the subsequent lighting regimen; the less stimulatory the programme the bigger the retarding effect of the step-down lighting (Morris, 1980). Whilst this initial phase of longer photoperiods results in higher feed intakes and faster initial growth, it does not give any improvement in total egg yield, simply fewer but larger eggs as a result of the delay in AFE (Leeson et al., 2005).

b) Changing photoperiods

Growing pullets respond more to a change in photoperiod than to the initial or final photoperiods themselves, irrespective of whether the change is an increase or a decrease. Data for white-egg pullets maintained on 8-, 13- or 18-h photoperiods, or transferred from 8 to 13 h, 13 to 18 h, 18 to 13 h or 13 to 8 h at 12 weeks provide a good example (Lewis et al., 1996). Figure 2 shows that whereas there was only a 3-d difference in AFE for pullets given constant photoperiods, more than 43 d separated the earliest treatment (an increase from 8 to 13 h) from the latest maturing group (a decrease from 13 to 8 h).

These data also demonstrate that the influences of the initial and final photoperiod are more powerful than the size of the change. Although both increments in this trial were 5 h, the transfer from 8 to 13 h advanced AFE by 22 d, whereas the transfer from 13 to 18 h advanced it by less than a day. Likewise, the decrease from 18 to 13 h delayed maturity by only 1 d, while the decrease from 13 to 8 h delayed AFE by 23 d; all maturities relative to pullets maintained on the initial photoperiod. This shows that the effect of a change in photoperiod depends on the stimulatoriness of the two photoperiods. A change between two stimulatory or between two non-stimulatory photoperiods has a lesser effect on AFE than a change between a stimulatory and a non-stimulatory photoperiod, irrespective of the direction. The rate of change in maturity for a given change in age at photostimulation can be calculated by the equation:

\[ b = k_1 (0.1338 + 0.1496C - 0.01884C^2 + 0.0009683C^3 - 0.00001941C^4 - 0.22396M + 0.05028M^2 - 0.00365M^3 + 0.00008216M^4) \]

where \( b \) = the change in AFE (d) for each 1-d delay in applying the change in photoperiod, \( C \) = difference between the initial and final photoperiod (h), \( M \) = mean of the initial and final photoperiods (h), and \( k_1 \) = adjustment for the difference in responsiveness between the given genotype and ISA Brown hybrids.

The other important factor affecting the timing of sexual maturation is the age at which the changes in photoperiod are given (Lewis et al., 2002). Modern full-fed pullets do not respond to an increment in photoperiod until about 5 weeks of age, and not all birds within the flock are photoresponsive to an increase until about 9 weeks (Figure 3). The likely reason why increments in photoperiod at very young ages do not advance AFE, despite their ability to induce an increase in plasma luteinising hormone (LH) concentration, is that the hypothalamic-pituitary axis is insufficiently developed to stimulate the release of follicle stimulating hormone (Lewis et al., 1998); a consequence, in part, of suboptimal plasma concentrations of oestrogen (Lewis et al., 1996; Dunn et al., 2003). The effect of photostimulation after 9 weeks becomes progressively weaker until the time that a pullet is within about 10 d of spontaneously laying its first egg (in response to the initial photoperiod), after this time AFE will be the same as that of
non-photostimulated pullets. The steadily increasing effect between 5 and 9 weeks of a transfer to a long day for a group of birds is the result of more individuals within the group becoming photosensitive and not a change in individual responsiveness. The AFE following an increment in photoperiod can be predicted by the equation:

\[ A_m = (1-p)A + p(1-m)[A-b(A-t)] + pmA \]  

(2)

where \( A_m \) = predicted mean age at first egg (d), \( A \) = mean AFE (d) for pullets maintained on the initial photoperiod, \( p \) = proportion of birds sensitive to an increment in photoperiod, \( m \) = proportion of birds that have spontaneously started rapid gonadal development in response to the initial photoperiod and are within 10 d of laying their first egg, \( b \) = the rate of change in AFE (d) for a 1-d delay in transferring the pullets to the final photoperiod, and \( t \) = the age (d) at which the increase or decrease in photoperiod is given.

Lighting programmes do not include decreases in photoperiod at the end of the rearing period by design; but they can occur inadvertently. For example, when spring-hatched pullets are reared in non-lightproof or naturally ventilated rearing facilities on 'short days', transferred to a lightproof laying house, and maintained on short days for a period before the planned photostimulation, they could, in reality, receive a reduction of 4-8 h in photoperiod depending on the natural daylength at the time of transfer. Decreases in photoperiod result in a delay in AFE, but the amount of delay progressively increases as the bird gets older at a rate dependent on the initial and final photoperiod (equation 1) until a pullet is within about 10 d of spontaneously laying its first egg (in response to the initial photoperiod). The potential of a decrease in photoperiod to retard is double that of an increase to advance AFE (Figure 4). In a flock of modern egg-type pullets, the delaying effect continues uniformly until about 15 weeks, after which some pullets will mature spontaneously in response to the initial long day, whilst others will be further delayed. This can make management very difficult, especially the nutrition, with <3-month between the early and late birds maturing. A further problem with such a flock is the suboptimal peak rate of lay (because some individuals are past their peak whilst others have yet
to mature) and large variation in egg weight caused by the wide spread of individual AFE. Mean AFE is predicted by the following equation:

$$A_m = (1-m)(A+bt)+mA$$  (3)

(see equation 2 for explanation of symbols)

II. BROILER BREEDERS

a) Constant photoperiods

Broiler breeders are not fed ad libitum, and respond differently to photoperiodic treatments when they are managed to achieve different growth profiles. However, when birds are given constant photoperiods, Figure 5 shows that the response is specific to photoperiod, and lower body weights simply delay maturity for all photoperiods (Lewis et al., 2004a). Broiler breeding stock exhibit photorefractoriness, and so sexual maturity in response to constant non-stimulatory photoperiods (≤ 10 h) is similar to that for egg-type birds, but it is markedly different for birds exposed to longer photoperiods (> 10 h). Broiler breeders are hatched in a state of juvenile photorefractoriness, and the rate of its dissipation is proportional to the stimulatoriness of the photoperiod and not to its length (as reported for exotic avian species). Figure 6 shows that the earliest sexual maturity is achieved by providing 10-h photoperiods and the latest when birds are maintained on constant 13 or 14 h daylengths.

Figure 5. Mean age at 50% lay for broiler breeders grown to reach 2.1 kg body weight at 17 (○) or 21 (●) weeks of age and maintained on 10, 11, 12, 13, 14 or 16-h photoperiods (Lewis et al., 2004)

Figure 6. Mean age at sexual maturity for broiler breeders maintained on various constant photoperiods, adjusted by least squares to the response of birds reaching 2.1 kg body weight at 20 weeks (Lewis et al., 2004)

b) Changing photoperiods

Growth exerts its own effect on, but does not interact with, the reproductive response to constant photoperiod, but it does interact profoundly with a broiler breeder’s response to an increase in daylength. One reason is that a bird cannot respond to an increase in light until it has fully dissipated juvenile photorefractoriness, and the rate at which this is achieved is dependent on the degree to which body weight is controlled. Another is that the degree of feed restriction necessary to control growth for satisfactory subsequent egg production is such that its influence is ten-fold that of the effect of the age at which a broiler breeder is photostimulated. However,
the age at which a broiler breeder is photostimulated still has a major influence on the timing of sexual maturity. When pullets are grown according to a typical primary company’s body-weight

Figure 7. Mean age at sexual maturity for broiler breeders grown to achieve different body weights at 20 weeks and transferred from 8 to 16-h photoperiods at various ages. The solid line represents the mean response for pullets grown to achieve a typical 20-week body weight. The dotted line represents the common slope for all body-weight groups (unpublished from Univ. KwaZulu-Natal)

recommendation, the first birds are unlikely to respond to an increment in photoperiod until 10 weeks, and it will be at least 18 weeks before all the birds in a flock are photoresponsive (Figure 7). Thereafter, there is a progressive weakening of the response until, by about 30 weeks, all birds will have matured in response to the rearing photoperiod. Transfers to a stimulatory photoperiod before a pullet has dissipated photorefractoriness will delay and not advance AFE, because they mature as if reared on constant long days. Although the shape of the response profile is similar to that for egg-type pullets, events happen at different ages, and early stimulated pullets mature later and not earlier than late stimulated birds because of photorefractoriness. Between 10 and 18 weeks (for pullets grown to reach 2.1-2.2 kg at 20 weeks), there will be a bimodal distribution, as for egg-type pullets, but the consequences for broiler breeders are more severe. Figure 8 shows that photostimulation before 18 weeks results in a spread of more than 4 months in individual AFE. This will give poor peaks and a marked reduction in egg numbers to depletion age. However, unlike the response to a constant photoperiod, the age-related response to photostimulation varies with body weight. A relaxation of feed restriction facilitates a more rapid dissipation of juvenile photorefractoriness and allows the bird to respond to photostimulation at a younger age, and, as a consequence, mature earlier than normal growth broiler breeders (Figure 9).

The effect of photoperiod between 6 and 10 h during the rearing period has minimal practical effect on sexual maturity or egg production to 60 weeks when birds are photostimulated at 20 weeks, though birds reared on 8 h mature 3 to 4 d significantly earlier than those reared on 6 or 10 h (Lewis et al., in press).

The critical and saturation photoperiods for initiating gonadotrophin release in photosensitive normal and dwarf broiler breeders are similar, at 10.5 to 12.75 h, and 12.75 to 15.25 h respectively. This is reflected in the earliest age at sexual maturity being achieved by a transfer from 8 to 15 h in both types of stock (Figure 10).
Figure 9. Effect of growing birds to 2.1 kg (left) or 2.8 kg (right) at 20 weeks on age at sexual maturity in broiler breeders transferred from 8 to 16 h at various ages between 10 and 18 weeks. Black lines indicate an almost complete response and grey lines a partial or no response (unpublished data from University of KwaZulu-Natal).

A multiple regression of age at sexual maturity on body weight at 20 weeks, age and body weight at photostimulation, and final photoperiod for broiler breeders reared on 8-h photoperiods, and using data from University of KwaZulu-Natal, is described by the equation:

\[ y = 549.2 - 1.9092PA + 0.00625PA^2 - 0.0445PB + 0.0000126PB^2 - 0.0342BW - 12.82p + 0.0397p^2 \]

\( r^2 = 0.938, P < 0.001, \text{SD} = 4.99 \)

where \( y \) = mean age at 50% lay or mean first egg (d), \( PA \) = age at photostimulation (d), \( PB \) = body weight at photostimulation (g), \( BW \) = body weight at 20 weeks (g), and \( p \) = final photoperiod (h). Using this model, Figure 11 shows that a 10% increase or decrease in body weight at 20 weeks not only affects the mean age at first maturity but also the photostimulation age that achieves the largest advance in maturity. Additionally, it shows that the optimal age for photostimulation advances linearly as growth is accelerated.

Figure 10. Sexual maturity in broiler breeder (●, solid line) and egg-type (broken line) pullets transferred from 8 h to various size photoperiods

Figure 11. Effect of photostimulation age and 20-week body weight on sexual maturity (dotted line = 10% decrease, broken line = 10% increase from normal body weight at 20 weeks). The hatched line indicates the earliest age at maturity for a given body weight.
Many producers are wary of giving an abrupt increase in photoperiod, and typically broiler breeding companies recommend a 3 to 4-h increment at about 20 weeks followed by weekly increases of 30 min to 1 h to reach a 15 or 16-h maximum. However, evidence from University of KwaZulu-Natal shows that there is minimal difference in rate of lay between an abrupt and a step-up lighting regimen (Figure 12). These findings agree with those reported by Morris et al. (1995) for egg-type hybrids transferred abruptly from 8 to 11 h or given a step-up programme from 18 weeks. Furthermore, evidence from three trials conducted at University of KwaZulu-Natal shows that there is nothing to be gained from increasing the photoperiod beyond 11 h, in terms of egg production, and that going to 16 h may result in inferior rates of lay after peak and fewer eggs to 60 weeks despite a 3 to 4-d earlier sexual maturity (Figure 12). However, there is a risk that hens on 11-h photoperiods could produce more floor eggs because a larger proportion of eggs will be laid before the lights come on (Lewis et al., 2004b).

REFERENCES