

NOVEL LIGHTING SYSTEMS STIMULATING GONADAL DEVELOPMENT AND EXPEDITING SEXUAL MATURITY OF MALE AND FEMALE CHICKENS

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Summary

Ten-week-old White Leghorn immature males and females were exposed to four lighting regimens: a constant light (12L:12D); repeated up and slow down (13 min. up and 1 min. down per day for 13 consecutive days, and repeated on two-week cycle) lighting; repeated slow up and down (1 min. up per day for 13 consecutive days and 13 min. down, and repeated on two-week cycle) lighting; and step-up (14 min. up every second week) lighting. At 15 weeks of age, significantly larger testis and comb weights and significantly higher concentrations of plasma LH and testosterone were observed in the cockerels under the repeated slow up and down lighting regimen than those under the other lighting regimens. At 20 weeks of age, significantly larger oviduct weights and significantly higher concentrations of plasma estradiol were observed in the pullets under the repeated up and slow down, and the step-up lighting regimens than those under the other lighting regimens.

(Key Words: Lighting Systems, Sexual Maturity, Gonadal Development, Chickens, LH, Gonadal Hormones)

Introduction

Artificial light controls for chickens were studied by King (1958) and Morris and Fox (1958) and Bowman (1960). They sought to retard sexual maturity in the growing period, and to increase egg production of pullets in the laying period. Lighting in the growing period must be reduced to less than eight hours to retard sexual maturity, and followed the step-up lighting by 18 minutes per week (King, 1958), or by 10, 15 and 20 minutes per week (Bowman, 1960) for increasing egg production.

It is possible that immature males and pullets will react to a prolonged light length more than 10 minutes per day under less than 12 hour light

per day condition (King, 1958; Morris and Fox, 1958; Bowman, 1960), but they can not react to shortening light length less than one minute per day for a short period. This work was conducted to establish novel lighting systems to expedite sexual maturity of immature males and pullets during rearing period.

Materials and Methods

Experiments were conducted with White Leghorn (Line 09 × Line 04, maintained at Gifu Prefectural Experiment Station) immature males and pullets housed in individual cages in a windowless house with a forced ventilation systems. Incandescent light was provided by one 60 W bulb per room. Light intensity close to the birds ranged from 20 to 30 lux. The feed was Gifu Prefectural Poultry Experimental Station's standard ration containing 15.8% crude protein and 2640 kcal metabolizable energy. Water were provided *ad libitum*. Data from experiments were statistically analyzed using Duncan's multiple range test (Harter, 1960).

Experiment 1

Forty-six ten week-old White Leghorn immature males, hatched on May 14, 1988, were kept

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under a 12L:12D photoperiod were exposed to four lighting regimens (11-12 birds per each regimen): (1) A constant light:12L (lights on 5:30):12D; (2) repeated up and slow down: 11 h. 54 min. + 13 min. for Day one, 11 h. 54 min. + 12 min. for Day 2, 11 h. 54 min. + 11 min. for Day 3, ---- 11 h. 54 min. for Day 14, repeated every 14 days; (3) repeated slow up and down: 11 h. 54 min. for Day one, 11 h. 54 min. + 1 min. for Day 2, 11 h. 54 min. + 2 min. for day 3, ---- 11 h. 54 min. + 13 min. for Day 14, repeated every 14 days; (4) step-up: first two weeks, 12 h. + 14 min., second two weeks, 12 h. + 28 min., ---- fifth two weeks, 12 h. + 70 min., from 10 to 20 weeks of age. The four lighting regimens in this experiment are illustrated in figure 1.

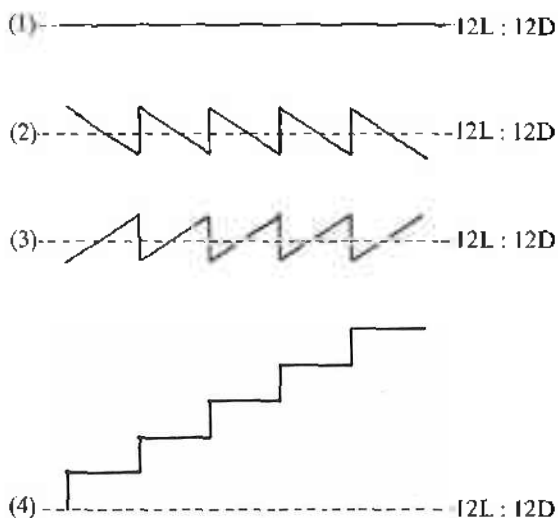


Figure 1. Diagrammatic representation of the four lighting regimens: (1) a constant light (12L:12D), (2) the repeated up and slow down (13 min. up and 1 min. down per day for 13 consecutive days, and repeated on two-week cycle, except the first cycle: 7 min. up and 1 min. down per day for 13 consecutive days) lighting, (3) the repeated slow up and down (1 min. up per day for 13 consecutive days and 13 min. down, and repeated on two-week cycle, except the first cycle: 6 min. down and 1 min. up per day for 13 consecutive days) lighting, and (4) the step-up (14 min. up per two weeks) lighting.

Immature males were kept under the four lighting regimens described above. Twenty-one birds were killed at 15 weeks of age, and 24 birds were killed at 20 weeks of age. A blood sample (3 ml) was taken from each bird at 15 and 20 weeks of age. The plasma was separated by centrifugation (3000 r.p.m.) and stored at -20°C until used for hormone assays. The testes and comb were removed from each bird and weighed. Plasma LH and testosterone concentrations were measured with radioimmunoassays described in the previous papers (Tanabe et al., 1983; Tanabe et al., 1986).

In a similar experiment (1A), 11 White Leghorn immature males, hatched on June 1, 1989, kept under a 12L:12D photoperiod, were exposed to two of the lighting regimens (5 or 6 birds per regimen) from the first experiment: the repeated slow up and down, and the step-up. The birds were killed at 15 weeks of age.

Experiment 2

Eighty White Leghorn (Line 09 \times Line 04) pullets, hatched on May 30, 1988, and initially kept under a 12L:12D photoperiod were exposed to the same four lighting regimens as in experiment 1 (20 birds per regimen).

Half the pullets kept on each lighting regimen were killed at 15 and 20 weeks of age, and the other half at 20 weeks of age. At slaughter blood sample (3 ml) was taken and the ovary and oviduct were removed from each bird and weighed. The plasma was separated by centrifugation (3000 r.p.m.) and stored at -20°C until used for LH, progesterone and estradiol assays (Tanabe et al., 1983; Tanabe et al., 1986).

Results

Experiment 1

Body, comb and testis weights of cockerels are given in table 1 for cockerels raised under the four lighting regimens. Differences in body weight were not significant at 15 weeks of age, but 20 weeks of age, cockerels raised under the step-up regimen were significantly ($p < 0.05$) heavier than those raised under the constant light (12L:12D), and the repeated slow up and down lighting regimens. The cockerels raised under the repeated up and slow down lighting regimen were significantly ($p < 0.05$) heavier than those raised

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TABLE 1. BODY, COMB AND TESTIS WEIGHT (MEAN ± SE) OF WHITE LEGHORN COCKERELS REARED UNDER FOUR LIGHTING REGIMENS AT 15 AND 20 WEEKS OF AGE

Photoperiodic regimens	Body weight (kg)		Comb weight (g)		Testes weight (g)	
	15 weeks	20 weeks	15 weeks	20 weeks	15 weeks	20 weeks
Constant light (12L : 12D)	1.46 ± 0.04(11) ^a	1.46 ± 0.03(6) ^{ab}	25.4 ± 6.3(5) ^a	59.6 ± 4.2(6) ^a	1.87 ± 1.36(5) ^a	16.2 ± 2.67(6) ^a
Repeated up and slow down	1.43 ± 0.04(12) ^a	1.60 ± 0.13(6) ^{bc}	31.0 ± 4.9(6) ^{ab}	54.4 ± 5.0(6) ^a	0.83 ± 0.27(6) ^a	16.9 ± 3.46(6) ^a
Repeated slow up and down	1.46 ± 0.03(12) ^a	1.30 ± 0.07(6) ^a	44.6 ± 3.7(5) ^b	70.8 ± 3.4(6) ^b	13.70 ± 1.14(5) ^b	15.3 ± 2.63(6) ^a
Step-up	1.45 ± 0.04(11) ^a	1.71 ± 0.06(6) ^c	33.1 ± 5.6(5) ^{ab}	61.2 ± 2.6(6) ^{ab}	1.35 ± 0.49(5) ^a	20.4 ± 2.43(6) ^a

^{a,b,c} Means in each column with different letters are significantly different at $p < 0.05$.

under the repeated slow up and down lighting regimen.

Significantly larger testis and comb weights were recorded for 15-week-old cockerels from the repeated slow up and down lighting regimen than those from the other lighting regimens. Testis weights of cockerels from the repeated slow up and down lighting regimen were seven times greater than those from birds raised under the constant lighting regimen. On the other hand, testis weight of cockerels under the repeated up and slow down lighting regimen was 2.3 times less than that under the constant lighting regimen. At 20 weeks of age, testes weights of the cockerels from the step-up regimen were heavier than those under the other lighting regimens, but

differences were not statistically significant.

The concentrations of LH and testosterone in the plasma of 15- and 20 week old cockerels are shown in table 2.

At 15 weeks of age, a significantly ($p < 0.05$) higher concentration of plasma LH was observed in the cockerels from the repeated slow up and down lighting regimen than those from the repeated up and slow down lighting regimen. A significantly ($p < 0.05$) higher concentration of plasma testosterone was observed in cockerels from the repeated slow up and down lighting regimen than those from the other lighting regimens.

At 20 weeks of age, significantly ($p < 0.05$) higher concentrations of plasma LH and testos-

TABLE 2. EFFECTS OF FOUR LIGHTING REGIMENS ON PLASMA LH AND TESTOSTERONE CONCENTRATIONS (MEAN ± SE) OF WHITE LEGHORN COCKERELS AT 15 AND 20 WEEKS OF AGE

Photoperiodic regimens	LH (ng/ml)		Testosterone (ng/ml)	
	15 weeks	20 weeks	15 weeks	20 weeks
Constant light (12L : 12D)	6.27 ± 1.51(11) ^{ab}	6.37 ± 2.75(6) ^a	1.38 ± 0.22(11) ^a	0.89 ± 0.45(6) ^a
Repeated up and slow down	4.51 ± 0.44(12) ^a	7.84 ± 3.16(6) ^{ab}	0.98 ± 0.19(12) ^a	3.21 ± 1.45(6) ^{ab}
Repeated slow up and down	10.43 ± 1.46(12) ^b	1.83 ± 0.17(6) ^a	7.12 ± 1.24(12) ^b	0.16 ± 0.03(6) ^a
Step-up	7.45 ± 1.18(11) ^{ab}	17.66 ± 3.05(6) ^b	2.12 ± 1.18(11) ^a	5.62 ± 0.82(6) ^b

^{a,b} Means in the same column with different letters are significantly different ($p < 0.05$) from each other at the same age.

terone were observed in cockerels from the step-up lighting regimen than in those from the constant and the repeated slow up and down lighting regimens.

Comb and testis weights, and plasma LH and testosterone concentrations, of White Leghorn cockerels from experiment 1A at 15 weeks of age are given in table 3. Significantly heavier testis weights were observed in cockerels raised under the repeated slow up and down lighting regimen than those under the step-up lighting

regimen, while the difference in comb weight between the two photoperiodic regimens was not significant.

A significantly higher plasma testosterone concentration was observed in the cockerels from the repeated slow up and down lighting regimen than the step-up lighting regimen. A higher plasma LH concentration was also observed in the cockerels from the former photoperiodic regimen than that the latter, but the difference was not statistically significant.

TABLE 3. COMB AND TESTIS WEIGHTS AND PLASMA LH AND TESTOSTERONE CONCENTRATIONS (MEAN \pm SE) OF WHITE LEGHORN COCKERELS REARED UNDER THE REPEATED SLOW UP AND DOWN AND THE STEP-UP LIGHTING REGIMENS AT 15 WEEKS OF AGE

Photoperiodic regimens	Comb weight (g)	Testis weight (g)	LH (ng/ml)	Testosterone (ng/ml)
Repeated slow up and down	30.7 \pm 4.1(6)	12.76 \pm 0.80(6) ^b	14.5 \pm 3.7(6)	7.25 \pm 1.12(6) ^b
Step-up	24.1 \pm 3.5(5)	3.92 \pm 1.39(5) ^a	10.0 \pm 2.1(5)	1.68 \pm 0.43(5) ^a

^{a,b} Means in the same column with different letters are significantly different at $p < 0.05$.

Experiment 2

Body, ovary and oviduct weights of the pullets are given in table 4. No significant differences of body weight among the lighting regimens were observed in 15- and 20-week-old pullets.

At 15 weeks of age, no significant difference of ovarian weights was observed. At 20 weeks of age, a significantly heavier ovarian weight was observed in the pullets from the step-up lighting

regimen than those from the other lighting regimens.

At 15 weeks of age, a significantly heavier oviduct weight was observed in the pullets from the repeated up and slow down lighting regimen than those from the constant lighting regimen. At 20 weeks of age, oviduct weights of the pullets from the repeated up and slow down, and the step-up lighting regimens were significantly heavier

TABLE 4. BODY, OVARY AND OVIDUCT WEIGHTS (MEAN \pm SE) OF WHITE LEGHORN PULLETS REARED UNDER FOUR LIGHTING REGIMENS AT 15 AND 20 WEEKS OF AGE

Photoperiodic regimens	Body weight (kg)		Ovary weight (g)		Oviduct weight (g)	
	15 weeks	20 weeks	15 weeks	20 weeks	15 weeks	20 weeks
Constant light (12L:12D)	0.98 \pm 0.02(20) ^a	1.17 \pm 0.05(15) ^a	0.42 \pm 0.04(5) ^a	0.50 \pm 0.04(5) ^a	0.27 \pm 0.05(6) ^a	1.69 \pm 0.47(5) ^a
Repeated up and slow down	0.98 \pm 0.02(20) ^a	1.19 \pm 0.03(14) ^a	0.47 \pm 0.04(5) ^a	3.25 \pm 1.88(5) ^a	0.82 \pm 0.50(5) ^b	16.53 \pm 3.90(5) ^c
Repeated slow up and down	0.98 \pm 0.02(20) ^a	1.17 \pm 0.03(15) ^a	0.44 \pm 0.05(5) ^a	0.63 \pm 0.08(4) ^a	0.59 \pm 0.30(5) ^{ab}	3.02 \pm 1.66(4) ^b
Step-up	1.00 \pm 0.01(20) ^a	1.27 \pm 0.08(15) ^a	0.41 \pm 0.09(5) ^a	16.66 \pm 5.88(5) ^b	0.30 \pm 0.02(5) ^{ab}	27.17 \pm 5.38(5) ^c

^{a,b,c} Means in the same column with different letters are significantly different at $p < 0.05$.

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than those from the repeated slow up and down, and the constant lighting regimens. Oviduct weights of pullets from the constant lighting regimen remained the lightest level among the four lighting regimens.

The concentrations of LH, progesterone and estradiol in the plasma of 15- and 20-week-old pullets are given in table 5.

At 15 weeks of age, no significant differences of LH, progesterone and estradiol levels were observed among cockerels raised under the four lighting regimens.

At 20 weeks of age, a significantly higher

plasma LH concentration was observed in the pullets from the constant lighting regimen than those from the other lighting regimens. A significantly higher plasma progesterone concentration was observed in pullets from the step-up lighting regimen than those under the other lighting regimens. Significantly higher plasma estradiol concentrations were observed in the pullets from the repeated up and slow down, and the step-up lighting regimens than those from the constant, and the repeated slow up and down lighting regimens.

TABLE 5. EFFECTS OF FOUR LIGHTING REGIMENS ON PLASMA LH, PROGESTERONE AND ESTRADIOL CONCENTRATIONS (MEAN \pm SE) OF WHITE LEGHORN HENS AT 15 AND 20 WEEKS OF AGE

Photoperiodic regimens ^a	LH (ng/ml)		Progesterone (pg/ml)		Estradiol (pg/ml)	
	15 weeks	20 weeks	15 weeks	20 weeks	15 weeks	20 weeks
Constant light (12L:12D)	4.82 \pm 0.90(14) ^a	5.57 \pm 0.34(6) ^b	221.7 \pm 28.1(14) ^a	296.5 \pm 40.5(9) ^a	124.6 \pm 6.5(14) ^a	268.3 \pm 38.2(9) ^a
Repeated up and slow down	3.49 \pm 0.50(13) ^a	4.05 \pm 0.37(5) ^a	172.3 \pm 21.3(12) ^a	331.6 \pm 56.8(8) ^a	153.0 \pm 16.4(11) ^a	456.1 \pm 84.8(9) ^b
Repeated slow up and down	3.06 \pm 0.45(11) ^a	3.89 \pm 0.38(5) ^a	243.5 \pm 21.3(12) ^a	274.0 \pm 44.7(6) ^a	145.3 \pm 13.9(14) ^a	247.9 \pm 39.6(9) ^a
Step-up	4.91 \pm 0.61(12) ^a	4.17 \pm 0.41(6) ^a	183.1 \pm 14.5(13) ^a	594.8 \pm 107.2(6) ^b	158.0 \pm 11.8(14) ^a	489.8 \pm 89.0(9) ^b

^{a,b} Means in the same column with different letters are significantly different at $p < 0.05$.

Discussion

The present study demonstrated more rapid growths of testes and comb, and higher concentrations of LH and testosterone in the plasma of 15-week-old cockerels raised under a repeated slow up and down lighting regimen than those raised under a repeated up and slow down lighting regimen from 10 weeks of age.

Sharp et al. (1977) showed that with 14 hour constant lighting, testicular and comb weights of cockerels started to grow after 16 weeks of age and that the plasma level of LH started to rise after 16 weeks of age, whereas the level of testosterone did not increase until 20 weeks of age.

The present study showed that sexual maturity in ovarian and oviductual weights in 15-week-old

pullets was more advanced with repeated up and down, and step-up lighting regimens, than with the repeated slow up and down, or constant lighting regimens. However, the study also demonstrated that significantly larger testis and comb weights, and significantly higher plasma levels of LH and testosterone were observed in 15-week-old cockerels from a repeated slow up and down lighting regimen than those from 12 hour constant lighting and step-up lighting regimens.

In the present study, the sexual maturity of the pullets under the repeated up and slow down lighting regimen was more accelerated than those under the repeated slow up and down lighting, and a constant lighting regimens, but less accelerated than those under the step-up lighting regimen. This is the reversal of the results

for cockerels in the present study. It is plausible that males are more sensitive to slowly increasing light than females.

In wild birds, the development of photorefractoriness is induced by prolonged exposure to a long daylength, causing the development of central nervous inhibition of LHRH from the hypothalamus (Nichols et al., 1988). Similar mechanisms may be applicable to the female domestic fowl (Sharp and Dunn, 1988).

The present study shows that the apply of step-up lighting regimen was not so effective in expediting sexual maturity of the cockerel, whereas repeated slow up and down lighting was very effective. It is plausible that repeated slow up and down lighting can dissipate "photorefractoriness" to prolonged daylight in the cockerel.

It is concluded that the best lighting regimens are "repeated slow up and down" for cockerels, and "repeated up and slow down" for pullets, because both the regimens increase reproductive functions of the birds, and also fit circadian rhythms of men as keepers of the birds.

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