EFFECTS OF LIGHT ON THE PERFORMANCE
OF MEAT- AND EGG-TYPE CHICKENS

BY

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INTRODUCTION

Man has known for many years that light stimulates, in some unknown manner, productivity in birds. Records show that the ancient Chinese made their canaries sing more by placing a lighted candle by the cage at night. Much later, early in the 1900's, poultry farmers in the state of Washington found that they could increase winter egg production by placing a lighted lantern in the chicken house for a few hours each evening.

Research has shown that light intensity and daylength produce favorable responses associated with egg and meat production, although recommendations vary in regard to the length of the light period in 24-hour light and dark cycles. Maximum egg production under natural conditions ordinarily could be attained during the spring months, preceding the time of the longest days of the year. For many years, this relationship between daylength and egg production was attributed to increased feed consumption and increased muscular activity. Wetham (1933) has shown that production trends vary for flocks located at different latitudes with the maximum production occurring during the season with the longest daylengths. Early investigations on the shape of the egg production curve of the hen at different latitudes throughout the world revealed a close correlation between the daylength and egg production curves, although the upward trend of the latter tended to precede that of the former. For example, the greatest production per bird occurred in March at latitude 45 N. The average daylength for this month was 11.48 hours whereas the maximum hours of daylight was 15.34 in June.

At a latitude of 25 S, greatest production occurred in September when the average hours of daylight was 11.48 compared to 12.52 in October. These results suggest that the response of the hen to increasing daylengths may be explained on the same basis as that of the response of wild birds subjected to increasing doses of light during the normal period of gonadal inactivity and that relative light, not absolute light, is the causative factor.

Poultrymen also use light to stimulate growth in chickens and turkeys, to prevent cannibalism, to calm birds during the catching and loading of broilers, and to stimulate embryonic development.

PHYSIOLOGICAL BASIS OF LIGHT STIMULATION

It was thought for many years that the role of light was primarily a matter of increasing the "work day" of the bird which resulted in increased feed consumption and increased muscular activity. Researchers now know that the action of light on birds has a physiological basis, light striking the eye of the bird stimulates the hypothalmus gland which in turn stimulates the pituitary gland to secrete the hormones necessary for egg production. The increased activity of the anterior lobe of the pituitary gland, located at the base of the brain, causes the release of the follicle-stimulating hormone (FSH) which in turn causes growth of the ovarian follicles.

Sturkie (1976) reported that light is transmitted through the transparent retina and passes through most of it before forming an image at the pigmented epithelium. The light is absorbed by the pigment molecules of the photoreceptor cells and is transduced into nervous impulses. The sensitivity of the eye consists of an ability to respond to weak stimuli or a capacity for continuing to respond to light that is slowly dimmed. Shutze (1866) as cited by Sturkie (1976) suggested that the rods in the eye might be receptors of dim light (scoptopic vision) and cone receptors of bright light (phototopic vision).

Armington and Thiede (1956) demonstrated a purkinje shift in birds. The eye of the pigeon subjected to darkness for at least 45 min becomes dark adapted and responds maximally to light at 534 to 664 mu. Honingmann (1921) as cited by Sturkie (1976) reported that the maximum sensitivity of the chick eye is at 560 mu and that of the adult fowl at 580 mu.

Focusing of light on the retina can be explained in terms of basic geometric optics. As light enters the eye it is refracted by the cornea, the aqueous humor, the lens, and the vitreous humor and an inverted image is formed at the retina. The cones of most avian retinas contain brightly colored oil droplets in their inner segments, immediately adjacent to the outer segments. According to Walls and Judd (1933), and Portmann (1951) as quoted by Sturkie (1976), most light reaching the outer segments has probably passed through a corresponding oil drop. This anatomical arrangement has led to the suggestion that the droplets (orange, yellow, or red) act as intra-ocular light filters, intensifying similar colors but reducing the discrimination of others (violet and blue).

COLOR OF LIGHT

Light is generally represented by wavelengths between 400 and 700 mu. Chickens have color vision with indications that they see better when the illumination is from rays at the long end of the spectrum, such as red, orange, yellow, and perhaps green. Thus color of the light rays has an effect on productivity of chickens.

Sturkie (1976) referring to the behavioral experiments done by Hess (1912), where grain was sprinkled on a floor and illuminated with six colors projected in a spectrum, reported that the chickens ate the grain illuminated by red, yellow and green light but not the grain illuminated by the blue and violet light. Later Honingmann (1921) and others as cited by Sturkie (1976), working with stained and illuminated rice grains, observed that chickens ate the blue and violet stained grains, albeit less avidly than they did the others. Hess (1956) also reported that chicks have a bimodal preference for color, with one peak occurring in the orange range of the spectrum and a second in the blue region.

Benoit and Ott (1944) carried out a series of experiments to determine the relationship between visible wavelength and gonadal development in drakes, and reported that light from the red region of the spectrum was more effective in stimulation of gonadal development in intact birds than from the blue region. They also reported that orange and red lights penetrated deeper into the tissues of the brain than did blue light, and they were more effective in intact birds in stimulating reproductive development. Similarly, Woodard et al. (1969) reported that sexual maturity was hastened in coturnix quail brooded under red light of either high or low intensity. Thus there is little doubt that the red portion of the visible spectrum stimulates reproductive development, but the mechanism for this action remains to be elucidated. In contrast, sexual maturity in chickens was hastened by light from the blue-green region of the spectrum Harrison et al. (1969). Scott and Payne (1937) reported that white light induced earlier sexual maturity in turkeys than other colors.

Foss et al. (1972) reported that there was a significant increase in body weight gain of chicks grown under green lights having a peak energy at 545 mu. This faster growth was observed without any concurrent increase in feed consumption, indicating a more efficient utilization of nutrients. However, Kondra (1961) reported no difference in growth of chickens and turkeys grown under heat bulbs colored green, white, or red. A possible explanation for this apparent discrepancy between these results lies in the different light sources used. The use of the colored incandescent bulbs provided the birds with a broad spectrum of radiant energy as compared to the use of narrow band. Woodard et al. (1969) reported that different wavelengths had no effect on growth of male coturnix. Similarly, Harrison et al. (1970) reported no differences in body weight of White Leghorn cockerels subjected to several wavelengths. Although the results were somewhat confounded by age, photoperiods, and slightly different filter systems, it would seem that there is evidence for a breed difference in addition to the species differences (Harrison and McGinnis, 1967).

In spite of improvement in some color categories of light, white light is used almost entirely for illumination of chickens. Red light is used occasionally for broilers in light-tight houses to reduce cannibalism (North, 1984). But if the house has open sides or windows, the use of red lights is a disadvantage because the birds cannot readily adjust, especially to the dim light, after the bright, intense light of the daytime. North (1984) has summarized the relationship between color of light rays and certain production factors in chickens (Table 1).

Table 1. Relationship between color of light and select production factors

	Color of Light Rays				
Factor	Red	Orange	Yellow	Green	Blue
Improves growth				x	x
Depresses feed efficiency			x	x	x
Lowers age at sexual maturity				x	x
Increases age at sexual maturity	x	x	x		
Enlarges the eye					x
Reduces nervousness	x				
Lowers cannibalism	x				
Increases egg production	x	x			
Lowers egg production			x		
Increases egg size			x		
Improves male fertility				x	x
Lowers male fertility	x				

Source: North (1984).

LIGHT INTENSITY

Methods of Measurement.

It is important to know the exact amount of light that chickens are exposed to. There are so many factors that influence light intensity that any recommendation can only be a guide. Light intensity can be expressed in various specific ways. Those commonly used in poultry management according to North (1984) are: 1). Candela. The word is derived from "candle." A candle is the unit of luminous intensity of a light source in a specified direction; 2). Lumen. The lumen is defined as the rate at which light falls on a square foot from a source whose intensity is 1 foot-candle. A lumen is a standard measurement of the light intensity from electric bulbs of various types and sizes; 3). Lux. A lux of light intensity is equal to 1 lumen per square meter and the term is used regularly in some countries. One lux is equal to .0929 foot-candle. One foot-candle equals 10.76 lux; 4). Foot-Candles. Illumination on a surface is measured in foot-candles. A foot-candle is defined as the density of light striking each and every point on a segment of the inside surface of an imaginary 1 foot radius sphere with a 1 candle power source at the center. Thus, 1 foot-candle equals 1 lumen per square foot; and 5). Lumen Efficiency. The amount of electricity necessary to light a bulb is measured in watts. The number of lumens of light per watt of bulb is an indicator of the efficiency of the light source.

For Egg Production.

Light intensity requirements for maximum egg production over a prolonged period have not been established. Dabie *et al.* (1946) found no significant difference in total egg production of White Leghorns over a 24-week period with light intensities varying from 10.76 to 336.92 lx. Nicholas *et al.* (1944) also reported that intensity of illumination varying from 5.38 to 409.04 lx at a central point in the working area had no effect on the degree of reproductive response in either White Leghorn or Barred Rock hens over a year's period.

For Growth.

The amount of light that a growing broiler needs is only that amount necessary to enable the bird to move about and to see to eat and drink. Activity should be reduced to a minimum. The intensity of illumination should be about .35 to .50 foot-candle. Guhl (1953) reported that chicks would start feeding when the light intensity was 1 foot-candle and would begin to peck one another when it was 2 foot-candles. Illumination above the optimum induces cannibalism, excess activity, and piling. For these reasons, open housing is a decided disadvantage unless some method can be used to restrict some of the natural daylight (North, 1984).

SOURCES OF LIGHT

The three most common sources of light and their advantages and disadvantages are: 1). *Incandescent*. Is the cheapest to install, has low light efficiency, requires reflectors for maximum efficiency, and has a short bulb life (750 to 1000 hours); 2). *Fluorescent*. Is 3 to 4 times more efficient than incandescent light, has a much higher light level for power used, is more expensive to install than incandescent, and has up to 9 times longer bulb life than incandescent; and 3). Mercury Vapor. Is almost as efficient as fluorescent, is better than fluorescent when temperature changes, has a long (24,000 hours) bulb life, has a low initial investment and operating costs, but must be mounted at a height of not less than 8 feet (could cause a problem in poultry houses) and is slow to reach full brightness.

North (1984) stated that fluorescent lights are satisfactory for poultry house lighting. When they are used, the intensity of light should equal the recommendations for incandescent lighting. He further stressed that it is important to purchase fluorescent fixtures that are "thermal protected" to prevent fires. As shown in Table 2, there is variability of illuminating power of white incandescent and white fluorescent bulbs when compared on a per-watt basis.

Table 2. Comparison of the illuminating power of white incandescent vs. white fluorescent bulbs on a per-watt basis

	Incandescent	Fluorescent
Watts	Lumens	
15	150	500 - 700
24	225	800 - 1000
40	430	2000 - 2500
50	655	
60	810	
75		4000 - 5000
100	1,600	
150	2,500	
200	3,500	10,000 -12,000

Source: North (1984)

Although recent evidence indicates that light greater than 0.5 foot-candle with some red in it will support egg production, it is noteworthy that not just any light will produce optimum results. For example, the light we receive from the sun has little ultraviolet radiation. An incandescent light very closely mimics sunlight but with a large portion of its energy in the infrared as heat, not light.

Recently El-Begearmi et al. (1983) tested circular 22-watt warm white fluorescent lights in laying houses in the place of 40-watt incandescent lights and reported a 46% reduction in electrical usage without adverse effects on egg production. Similarly, Darre (1986), in a study to validate the energy and monetary savings of Phillips PL-9 fluorescent bulbs compared to 60-watt commercial incandescent bulbs, suggested that the use of the new PL-lamps will not adversely affect egg production, egg size, feed efficiency or normal hen behavior.

The biggest advantage of these lamps is the economic savings over the life of the bulb. Once the initial investment is paid back, which is claimed to be done in less than 6 months, the increased electrical economy makes such bulbs the most logical way to light poultry houses. The rated life of the PL bulb is more than 10,000 hours, which is equal to 2 years of 14 hours/day, while most incandescent bulbs have a life expectancy of a year. A comparison of 40-watt incandescent bulbs and 12-watt PL fluorescent bulbs on a 14-hour per day basis revealed that energy usage was .56 kwh/bulb/day (40 watt) as against .168 kwh/bulb/day for 12-watt PL-9 fixtures.

LIGHT MANAGEMENT

Egg-Type Pullets.

Egg formation, sexual maturity, and seasonal trends in egg production are regulated by the daily duration and intensity of exposure to light. Penquite and Thompson (1933) reported that continuous light (CL) changed the seasonal distribution of egg production. Using morning light to increase daylength was shown to stimulate egg production during the fall and winter months, with production during the spring months being lower than that for non-lighted flocks.

North (1984) stated that the ultimate aim of controlling the light-day during growth and egg production is to delay onset of egg production and to increase production efficiency. It is daylength, not light intensity, that alters the age of the bird at the time the first eggs are laid. Decreasing the daylength, be it natural autumn daylight or artificial step-down lighting, as the pullets go through their growing period delays the age at sexual maturity and results in improved egg production. Increasing daylength during this period hastens maturity, (King, 1961; Shutze *et al.*, 1961; Smith and Noles, 1963; Harrison *et al.*, 1970).

Very early sexual maturity is no longer believed necessary to receive maximum egg income per hen, however, if birds start to lay before they are physically mature, fewer and smaller eggs will be laid. Payne (1975) indicated that early sexual maturity resulted in higher egg production and lower egg weight. He asserted that this difference in performance is not a clear benefit to production of hatching eggs as a portion of the additional eggs are of substandard size and would not be set for incubation. On the other hand, Leeson and Summers (1980) concluded that early light stimulation of pullets had no effect on age at sexual maturity. They observed that pullets gave the best response to increased light if they were grown on short daylengths. Those raised on long daylengths were not as responsive to increasing daylengths in the laying house and did not lay well. Morris (1962) suggested that an increasing photoperiod can advance the age at first eggs of Leghorn pullets. This relationship is best described as curvilinear with maximum stimulation resulting from 16- to 17-hour photoperiods (Morris, 1967). Other workers have indicated similar concerns of reduced pullet growth with long photoperiods (Siegel et al., 1963; Goldrosen and Buckland, 1977). But, according to Leeson and Summers (1980), the success with early maturing pullets depends on attainment of adequate body weight at time of sexual maturity. Data in Table 3 show the influence of several different growing-laying light programs on several production factors.

Also of interest is the relationship between the light threshold and the onset of lay. Gradually reducing daylength during the growing period of egg-type pullets is not effective unless the daylength is reduced below the threshold of 11 to 12 hours. Gradually reducing daylength from 22 to 16 hours is ineffective in delaying sexual maturity, but gradually reducing it from 22 to 9 hours is effective. It is a common observation that when pullets are delayed in the onset of egg production, the

Table 3. Influence of light treatment on sexual maturity, laying house mortality, and egg production

Light treatment		Days to reach 10% egg production	Days to reach 50% egg production	Laying house mortality (%)	Eggs produced during 17 wk of lay
Growing period	Laying period				
1. Gradually decreased from 22hr to 16hr	Gradually increased from 16hr to 22hr	156	172	3.3	225
2. Gradually decreased from 22hr to 9hr	Gradually decreased from 9hr to 22hr	172	186	3.3	220
3. Gradually decreased from 16hr to 9hr	Gradually decreased from 9hr to 16hr	171	191	3.8	220
4. Gradually decreased from 16hr to 9hr	Suddenly increased from 9hr to 16hr	163	176	5.0	230
5. Started on constant 16hr then suddenly decreased to constant 9hr	Suddenly increased from 9hr to 16hr	165	176	4.6	227
6. Constant 16hr	Constant 16hr	156	171	5.0	224

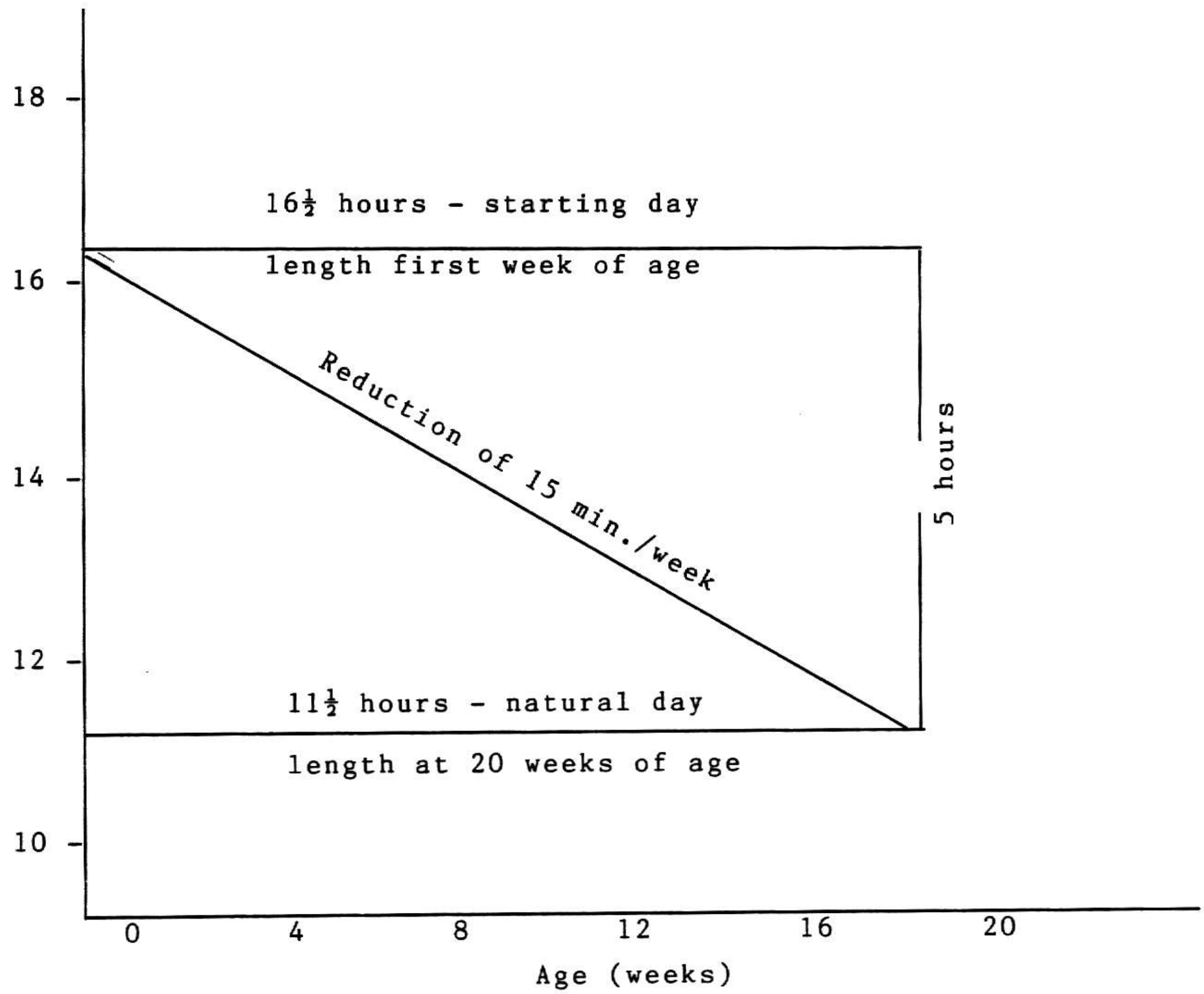
Source: North (1984)

first eggs are larger. The delay may be produced by restricting feed consumption or by using a proper lighting program North (1984). He suggested providing 8 hours of artificial light each day after the 2nd day until egg-type strains reach 20 weeks of age.

Pullets raised in windowless houses should be started on 14-18 hours of light per day for the 1st week so the chicks learn to eat and drink (Berg and Shoffner, 1974). Beginning the 2nd week, they recommended the daylength be reduced either abruptly or by 1 hour per day until an 8-hour daylength is reached (Figure 1). This daylength should be maintained for egg-type strains until at least 20 weeks of age. Alteration of the daylength during this period is not recommended. Raising pullets on a short daylength reduces feather picking, delays sexual maturity, and makes pullets more responsive to increasing daylengths during the laying cycle. Other advantages include pullets coming into production more uniformly with larger eggs and greater production.

Pullets reared under natural light conditions must be treated differently than those reared in windowless houses. No supplemental artificial light should be given to pullets reared in windowed or curtain-sided houses between March 1 and August 31 (North, 1984). Chicks hatched between September 1 and February 28 should be exposed to either constant daylengths or decreasing daylengths. In the former system, determine the length of the longest natural daylength before the pullets reach 20 to 22 weeks of age. Use this daylength from the 3rd day to 20 to 22 weeks.

Figure 1. Lighting program for pullets reared in a windowless house



Source: Berg and Shoffner (1974).

For the decreasing daylength system, determine the daylength when the pullets will reach 20 to 22 weeks and add 7 hours. The total represents the daylength to use starting at the 3rd day. Then reduce the daylength 20 min each week. This approximates 7 hours in 20 to 22 weeks. It is suggested that the daylength be increased by 1 hour at 20 weeks of age for meat-type bird with hourly increases made each week thereafter until the hens receive 15 hours of light per day in light-proof houses or 15-1/2 hours in windowed houses. Increase daylength to 16 hours for egg-type strains.

Berg and Shoffner (1974) recommended avoiding placement of chicks during the period of December through February in a windowed or curtain-sided house. When these birds mature in May - July, the natural daylength is so long it is difficult to bring these birds into production properly. Data in Figure 1 give an example of calculations for a decreasing light program. For example, birds hatched on October 14 would be 20 weeks old on March 5. Five hours added to the natural daylength of 11-1/2 hours on March 5 equals 16-1/2 hours, which is the starting daylength at dayold.

Windowless houses are preferred for the year-round rearing of pullets so light can be controlled. Pullets in windowed or curtain-sided houses will be exposed to increasing daylengths under natural lighting of layers.

It is important for egg producers to realize the appropriate time to change from the growing to the laying lighting program. North (1984) suggested that the lighting program be changed at the time the first eggs are laid which is usually 20 weeks for egg-type pullets.

The traditional lighting system for layers has been exposure to light-dark (L:D) ratios varying from 14 to 17 hours of light per 24 hours. The minimum threshold for stimulation appears to be 12 hours with 14 hours needed for maximum productivity.

Although the use of intermittent lighting (IL), short L:D cycles per 24 hours, programs were proposed several years ago, its use by the commercial egg production industry is recent because of rising electrical costs (Mather, 1986). IL has been shown to result in economic saving through reduced feed intake and lowered energy inputs (Moreng et al., 1968; Bell and Moreng, 1973; Riskowski et al., 1977). Anonymous (1980) indicated that electrical and feed costs can be reduced on a regimen of as little as 15 min L:45 min D each hour during part of the laying cycle instead of the more conventional 16 hours L:8 hours D.

Sauveur and Mangin (1983) reported that the use of 1.5 L:4.5 D cycles from 4 to 18 weeks of age followed by 6 hours of increasing L:D ratios between 18 and 22 weeks resulted in gain in egg weight which appeared as early as the first egg; an apparent effective method of increasing egg weight at the beginning of the laying cycle. The use of this system did not modify age at sexual maturity. Leeson et al. (1982) carried out an experiment to study the performance of laying hens subjected to IL initiated at 24 weeks. Control birds received 10 hours of light during week 21, then the photoperiod was increased by 15 min per week to a maximum of 17 hours of light per day. Results indicated that

IL caused a significant reduction in feed intake when compared to the controls (Table 4). This reduction in feed consumption was associated with a nonsignificant, but consistent reduction in egg production. These data confirm the observation of Engster et al. (1979), who reported that egg mass was depressed when IL programs were initiated prior to 35 weeks of age. These results support the recommendation that IL for layers should not be initiated until after peak egg production.

Table 4. Effect of intermittent lighting on laying performance over a 13-month period

Lighting system	Feed intake	Egg production	Egg wt	Egg shell deformation
	(g/bird/day)	(% HD)	(g)	
			Ns	Ns
Control	114.6[a][1]	77.4[a]	56.8	25.7
Intermittent	110.2[b]	72.9[b]	56.8	25.3

[1]Columns containing means with different superscripts differ significantly ($P<.05$).

Source: Leeson et al. (1982)

In a recent study to determine the use of IL to supplement natural daylengths in open housing, Mather (1986) reported that 2 hours of supplemental light added to natural daylength from 0330 to 0430 and 1930 to 2030 hours, thus increasing light from 15 to 17 hours per day, was not detrimental to production and fertility of breeder hens.

Herrick and Ross (1986) have shown that hens in open houses laid more eggs and returned more net income than hens on low-density IL in controlled air and light (CAL) houses (Table 5).

They observed that the higher egg production of the hens in the open house was offset by the lower feed utilization of the hens in the CAL houses, but this advantage was offset by the higher electrical costs of the CAL houses (Table 5).

Table 5. Mean performance and income data[1] of three strains of layers exposed to three environments from 21-65 weeks of age

Characteristics	Enclosed (CAL) houses: Low Intensity light	Enclosed (CAL) houses: Intermittent light	Open house: Natural & artificial light
Egg production (%)			
Hen day	78.4[a][2]	79.9[ab]	81.0[b]
Hen housed	76.2[a]	77.2[ab]	79.0[b]
Feed/doz eggs (lb)	3.20[a]	3.13[a]	3.35[b]
Income			
Eggs (92 cents/doz)	$9,542.71	$9,545.18	$9,833.25
Spent hens (25 cents each)	128.50	126.20	125.75
Total	9,671.21	9,671.38	9,959.00
Expenses			
Replacement pullets ($3.95 each)	1,999.20	1,999.20	1,999.20
Feed ($230/ton)	4,246.27	4,169.17	4,453.84
Electricity			
Fans	287.90	287.90	---
Lights	189.96	240.22	206.54
Total	6,723.33	6,696.49	6,659.58
Income over cost of replacement pullets, feed and electricity	2,947.88	2,974.89	3,299.42
Income per hen housed over cost of replacement pullets, feed and electricity	4.72	4.77	5.29
Income per cage over cost of feed and electricity	14.16	14.30	15.86

[1]Based on prices and costs obtained during trials.

[2]Columns containing means with different superscripts differ significantly (P<.05).

Source: Herrick and Ross (1986)

Feed efficiency was not significantly affected by lighting treatment in CAL houses, although hens in the open house were far less efficient than those in either of the enclosed houses. This indicated a relationship existed between bird activity and feed utilization, with the lower efficiency in the open house being due to increased bird activity. In support of their hypothesis, the authors cited an earlier study by (Anonymous, 1980) in which it was suggested that an inverse relationship existed between activity and gain; hens exposed to low intensity light in a CAL house showing noticeably less activity than hens exposed to IL in a CAL house or open house.

A recent innovation for lighting of layers is ahemeral light cycles. An ahemeral light cycle is one that contains less or more than 24 hours of light and dark. L:D cycles of less than 24 hours are of interest to geneticists who wish to provide new environments in which to select for higher rates of lay. Cycles longer than 24 hours have been used in attempts to get better yields from existing stocks.

The proposition usually made on the effect of ahemeral cycles on the rate of lay is that because a hen sometimes has to wait for the clock to come around before ovulation of a ripe follicle can occur, she therefore fails to reach her full potential rate of lay. However, this has been questioned in view of the situation inside the hen. There is evidence indicating that yolk deposition in the ovary proceeds at a steady pace and is not interrupted on the day of lapse between clutches (Gilbert, 1972; Redshaw and Follett, 1972). However, clutch length can easily be changed by manipulation of the L:D cycles, but this does not imply a change in rate of lay.

Byerly and Moore (1941) first suggested that chickens might be able to lay more eggs, if instead of a 24-hour day, they were given a L:D cycle which more nearly coincided with the average interval between eggs on consecutive days within a clutch. Their assumption was that such birds would have the ability to lay eggs at a rate of one every 26 hours but is tripped up because the world goes around once every 24 hours. They compared rates of lay for small numbers of pullets and hens under 24 vs. 26 hour L:D cycles and reported a 19% advantage in mean rate of lay for the birds on the ahemeral cycle. In contrast, Van Albada (1958) as quoted by Morris (1973) found little difference in performance of hens on 14L:12D vs. a 14L:10D cycle. However, Morris (1973) argued that one can make changes from 24-hour cycles to ahemeral cycles without adverse effects on the flocks and so, within limits, manipulate egg weight and shell thickness at will.

Short photoperiods can be stimulatory when they are combined with long dark periods in ahemeral cycles (Morris, 1978). He reported that pullets transferred from 6L:18D in the growing period to 6L:21D came into lay sooner than pullets kept on 16L:18D. This suggested that 6L:21D provided more photoperiodic stimulus than 16L:18D. It was also noticed that birds failed to peak in production as expected when they were changed from a 27-hour to a 24-hour cycle with the same amount of light.

Morris (1973) stated that the main effect of ahemeral light cycles is to limit maximum frequency of ovulation to one egg cycle and thus lower mean rate of lay in highly productive flocks and to improve shell thickness of older hens' eggs. In addition, Leeson and Summers (1985), in an unpublished report using 14L:10D and 14:14D on the effect of egg size, reported that there was a significant increase in egg weight, though the magnitude of the response was somewhat less than 5%. Although data is not available, they also noted that early transfer to laying cages (15 vs. 19 wk) also resulted in significant ($P<.01$) loss of egg numbers and weight gain.

Egg size was improved ($P<0.01$) with ahemeral lighting; although shell quality, as assessed by deformation was inferior ($P<0.01$). A clear trend emerged for the effect of pullet body weight on feed intake and egg size; as body weight increased there were significant increases in both feed intake and egg size. They also reported that response to ahemeral lighting is dependent on the age of the bird, and therefore suggested to utilize this program only for a short initial period where loss in early egg numbers will likely be compensated for by reduced numbers of eggs.

These results suggest that ahemeral lighting can be used successfully with pullets, although loss in egg numbers counter-balance the advantageous effect of increased egg size. While longer photoperiods of 14 vs. 8 hr. used during rearing can stimulate growth, onset of production is tempered due to reduced photo-stimulatory effect incurred in the move to adult photo-periods.

Effect on Feed Consumption. Research suggests that fowl make use of an endogenous biological clock to regulate their feeding behavior and that the clock is set by "sunset" in each light-dark cycle. Duncan and Hughes (1975) reported that laying hens show a circadian rhythm of feeding activity under continuous lighting. Hens exposed to a 24-hour L:D cycle, showed a characteristic diurnal feeding in which rate of feed intake increases gradually with the onset of light, decreases in the middle of the lighted period and then increases to a maximum of a few hours before the lights are out (Siegel et al., 1962; Woodard and Wilson, 1970). Savory (1976a,b) studied feeding behavior in broilers given 12L:12D and 12L with simulated dawn and dusk and found a similar diurnal feeding pattern.

Ballard and Biellier (1975) carried out shift experiments under 14L:10D in order to study the relative importance of the dark to light and light to dark transitions on the synchronization of food intake rhythms in laying hens. They concluded that the light to dark transition "sunset" served as a primary timing cue for the peak food intake which is normally seen a few hours before lights go out. It has been known that short-term fluctuations in food intake may reflect physiological processes involved in egg production (Morris and Taylor, 1961). It is surprising that the release of lutenizing hormone is associated with an increase in concentration of circulating steroid hormones such as estrogen, progestrone and testosterone, some of which have been shown (Horne and Wood-Gush, 1970) to increase food intake. However, when hens are kept on a L:D cycle, the release of luteunizing hormones will normally occur during the hours of darkness (Wilson and Sharp, 1973) which is of necessity, a period of low or negligible feeding activity. It may be that this association continues even under CL because all these different events continued to be coordinated by some "control" clock.

If the ability to feed at will is a constraint on egg production, one could postulate that a feeding period during darkness might be beneficial. There is some experimental evidence that this may be so (Van Tienhoven and Ostrander, 1973). They found that laying hens on a regime of 8H:16D with 2-hour light periods toward the middle of the dark part of the cycle produced 3.8% more eggs than controls on a 14L:10D regime.

Entrainment of oviposition in the fowl using light - dark cycles. Light regulates the timing of oviposition in the fowl because an "open period" in which ovulation inducing hormones may be released is determined by an endogenous biological clock, the phase of which is set by external light and dark signals (Morris, 1973; Bhatti and Morris, 1977). The entrainment of oviposition by cyles of light and darkness has been described by several authors (Larson, 1960; Wilson et al., 1964; Bhatti and Morris, 1977, 1978). Circadian periodicity can easily be imposed on hens by providing a short exposure to bright light with a background of continuous dim-light, but the signal must be increased by providing a greater contrast between bright and dim lights and/or a longer period of bright and dim lights and/or a longer period lighting to entrain oviposition when the cycle diviates from the natural period of 24 hours.

Morris (1977) reported that with photoperiod of less than 1 hour, entrainment could easily be achieved when the period of bright light started at 1400 hour. This presumedly reinforced other environmental signals which tend to synchronize oviposition under conditions of constant illumination. When a short bright period was placed at 0200 hour, thus running counter to other environmental signals, entrainment was less easily achieved. Even 30 min of bright light did not consistently produce full entrainment, although mean times of lay for the 15 and 30 min treatments were in the late evening, indicating that the light signal was dominated to other environmental influences. When light and darkness were altered, more than 80% of the ovipositions occurred in the model 8 hours for cycles of 23 hours or more. With 21-hour cycles, the maximum proportion of ovipositions found in an 8-hour segment was 72% which reflects the bimodal distribution of egg laying on this short cycle. Under continuous lighting, 30 to 50% of the eggs were recorded in the model 8 hours.

In a similar experiment, (Bhatti and Morris, 1978) reported that in 21-hour cycles, full entrainment is reached when about 70% of the eggs are laid in the model 8 hours. This degree of phase setting according to them was achieved with a 6-hour bright period using a bright: dim ratio of 300:1. A 3-hour bright period with a bright: dim ratio of 300:1 did not give full entrainment, although they found 3 hours to be a sufficient photoperiod for entrainment to a 21-hour L:D cycle, with long bright periods, hens were fully entrained by 13L: 8D (dim).

From these results, it appears that, when using a short photoperiod in a cycle which deviates markedly from the 24-hour norm, a L:D system provides a more potent signal than bright and dim lighting, even if the bright:dim ratio is as wide as 300:1. With long photoperiods, hens are as readily entrained by a bright-dim system as by light and darkness, although a minimum scotoperiod of about 8 hours is required for full entrainment to 21-hour cycles, whether the scotoperiod is dim lighting or darkness. Morris and Bhatti (1978) further suggested that to entrain hens to a 24-hour cycle it is sufficient to give one mu of light (50 lx) every 24 hours against a background of continuous dim light (0.3 lx) provided that the flash of light occurs during the working day.

When length of the light periods equalled those of the dark periods (3L: 3D), equal distribution of oviposition between the four daily L:D periods occurred (Duplaix et al., 1981; Nys and Mongin, 1981). However when the short L:D cycles were asymmetrical (1.5L: 4.5D), regular distribution no longer existed and ovipositions were much more frequent during the first half day (Nys and Mangin, 1981). But when a flock of hens is maintained under continuous white light, oviposition times are scattered randomly throughout the 24 hours (Warren and Scott, 1936; Morris, 1973). Payne et al. (1965) confirmed this finding and showed in addition that ovipositions became cyclic when they were synchronized by a diurnal change in temperature. However, Fraps et al. (1947) found that hens under CL continued to lay at a time corresponding to their previous "day".

MEAT-TYPE CHICKENS

Effect on Growth. Light management for broilers is very important. The type of lighting system will be determined by the type of housing--whether an open sided or light tight house is involved. However, the objective is to provide sufficient light to enable the birds to move about to feed and make fast growth and efficient feed conversion. Recently, it has been shown that in addition to saving of energy costs, broilers reared under IL regimes were heavier and more efficient in feed utilization than those subjected to CL. But Deaton et al. (1976) reported that approximately 3 billion broilers are grown annually in the U.S. in window or curtain-sided houses where light intensity during the day cannot be controlled.

There are a number of reports showing the effect of different lighting regimes on the performance of broilers. Two systems mentioned frequently are CL in windowless or windowed houses and IL in windowless houses. According to North (1984), CL in windowed houses involves providing CL for the first 48 hours. Then the use of dim artificial light during all dark hours, except for 1 hour at midnight. This 1 hour trains the birds to darkness so that there will be no panic should there be an electrical failure. The light intensity at floor level should be .35 to .50 foot-candle which can be supplied by one 150-watt bulb for each 1,000 square feet of floor area. He cautions against the use of less light because the eye of the chicken is less adaptable to lower intensities when there is bright light during the day. Illumination above the optimum induces cannibalism, excess activity, and piling.

In continuing efforts to attain maximum productivity with least cost, many forms of feed restriction have been imposed on chickens during all phases of production, and recently IL has received much attention with respect to broiler production. Buckland (1975) suggested that improved feed efficiency may be the most consistent advantage of using IL programs for broiler production.

According to Ota (1967), the better growth rate obtained from birds maintained under IL may be due to less energy used by the birds, moreover, he asserted that there was about 25% less heat production from birds in the dark periods as compared with the light periods.

Table 6. Effect of continuous versus intermittent light on growth rate of broilers

		Gain		
Light regimen	Sex	4 wk wt	4 wk to 8 wk g	8 wk wt.
Continuous	♂	815.6[b] [1]	1232.9[b]	2047.5[b]
	♀	700.0[c]	901.8[d]	1601.8[d]
Intermittent	♂	863.4[a]	1328.7[a]	2192.1[a]
(15min.L/90min.D24)	♀	726.4[c]	983.2[c]	1709.6[c]

[1]Means containing different superscripts are significantly different (P<0.05).

Source: McDaniel *et al.* (1977)

Data from Table 6 indicate at 4 weeks of age, males grown under IL were significantly heavier ($P<0.05$) than males grown under CL (McDaniel et al., 1977). Although not significant, the data show that females grown under IL were slightly heavier at 4 weeks than those grown under CL. However, at 8 weeks of age, weights of both male and female grown under IL were significantly ($P<0.05$) heavier than those grown under CL. It could be observed that the rate of gain between 4 to 8 weeks of age for both males and females was greater ($P<0.05$) for birds on the IL treatment than those on CL. The results obtained in this experiment showed that the accepted practice of using continuous low-intensity light (Moore, 1957; Shutze et al., 1960; Kruger et al., 1963; Beane et al., 1962; 1965) for heavier broiler growth may not be the best lighting regimen for growing birds.

The reasons for improved growth of broilers with IL has been attributed to increased feed consumption resulting from altered feeding patterns (Cohn and Joseph, 1960). North (1984) has suggested that by giving chickens a meal (short feeding period) followed by a longer period of time for digesting the meal (darkness), the efficiency of feed utilization is improved. The continuous eater excretes more protein than does the bird given a meal at regular intervals, thus wastes protein.

McDaniel (1972), and Hoopaw and Goodman (1972) reported significantly greater weight gains in broilers reared on IL regimes when compared to those kept under CL. Male broilers grown under CL were significantly heavier at 56 days of age than males exposed to periods of darkness. McDaniel et al. (1977)

reported that broilers receiving IL (15 min on and 90 min off) were significantly heavier than those subjected to low-intensity (1.6 lx) CL. Cherry and Barwick (1962) showed a significant weight advantage for broilers at 8 weeks of age as the L:D ratio in the cycle was increased from 1:2 to 1:7. They reported that the females contributed most to this effect. According to McDaniel et al. (1977), female broilers differed slightly from the males in their response to shorter repetitive L:D cycles (Table 6). It is apparent that the difference in the weight of the females between the two treatments at 8 weeks was due primarily to the difference in rate of gain between 4 and 8 weeks of age. The effect was similar and offers some explanation for the significant interaction effect between treatment and sex for body weight and feed intake. The results of this experiment suggest that the female broiler requires a different lighting regime than the male in order to achieve optimal feed conversion during the latter stages of growth. In a similar experiment, the male:female body weight differences were reported to be the result of differences in body fat content (Powell et al., 1973). Their results suggested that the differential response of sexed broilers to physical environmental factors may add further evidence that female broilers also differ from their male counterparts in their physiological adjustment to environmental factors such as light.

CL in light-tight houses requires 3.5 foot-candles intensity at floor level for the first 5 days (North, 1984). This is necessary for the chicks to develop their eating habits and to fully learn the location of the feeders and waterers. Then light intensity should be reduced to .35 foot-candle on the 6th day. To be effective, he recommends supplying 125 watts for each 1,000 square feet of floor area. CL (23 hours at .35 foot-candle:1 hour darkness) or dim IL (1 hour at .35 foot-candle:3 hours of darkness) can also be used with this system. The latter provides 6 hours of feeding time each 24 hours. The feeding time should be increased during hot weather. Another alternative is to provide 1-1/2 hours of dim light and 3 hours of darkness each cycle.

Perry (1981) reported that while CL may increase the time available for birds to ingest feed voluntarily, it may be counter-productive in terms of the efficiency with which feed is converted to body weight. The prolonged photoperiod may cause excessive locomotor activity which could utilize sufficient energy so that feed conversion efficiency is impaired.

Effect on Feed Efficiency. In addition to the effect of lighting programs on growth of broilers, it also affects their feed efficiency. Deaton *et al.* (1976) summarized the feed conversion of mixed sexed broilers reared under IL or CL regimes (Table 7). Feed conversion of the mixed-sexed broilers reared on IL from 1 to 56 days of age (Treatment 2) was significantly better than that of broilers reared under CL (Treatment 1) at 35 and 56 days age. These results are similar to those reported by Quarles and Kling (1974). But the body weight at 35 and 56 days of age for birds grown on the two IL treatments did not differ significantly. In a second study, they (Deaton *et al.*, 1976)

Table 7. The effect of intermittent versus continuous light on body weight and feed conversion

		Average body weight(g)			
Treatment[1]	Age (days)	Male	Female	Mean	Feed conversion
1	35	977^{c} [2]	876^{c}	927	1.86^{c}
2	35	1008^{c}	874^{c}	941	1.75^{d}
1	56	2102^{c}	1754^{c}	1928	2.16^{c}
2	56	2134^{c}	1727^{c}	1931	2.09^{d}

[1]The treatments from 0-8 weeks of age were:

1). Continuous light at an intensity of 12.9 lx.

2). Fifteen minutes of light at 12.9 lx, followed by 105 minutes of darkness.

[2]Within each age and sex group, differing letters denote significance at the $P<.05$ level of probability.

Source: Deaton et al. (1976)

reported that body weight at 28 and 54 days age was not significantly affected by light treatment (Table 8). But there was a significant difference in percent breast trims at 54 days of age, birds on IL having significantly more breast trims (16.18 vs. 9.94%) than those reared on CL.

Savory (1976a) suggested that a regime in which gradual dawn and dusk lighting conditions were used may have lead to an increase in feed intake, although the difference reached significance only during the first 3 weeks of life. This result is perhaps not too surprising since Cherry and Barwick (1962), and Tabong and Shirley (1976) had previously shown that the lack

Table 8. The effect of intermittent versus continuous light on body weight, feed conversion, and breast trims (males only)

Treatment[1]	Age	Body weight	Feed conversion	Breast trims	
	(days)	(g)		No.	%
1	28	760[c][2]	1.68[c]	...	...
2	28	775[c]	1.57[c]	...	...
1	54	2120[c]	2.14[c]	231/2323[c]	9.94
2	54	2135[c]	2.09[d]	374/2311[d]	16.18

[1]Treatments from 0-8 weeks of age were: 1). 12 h of light at 237 lx and 12 h of light at 7.5 lx; and continuous light at an intensity of 75 lx for the first 9 days, and 2) 15 minutes of light at 7.5 lx, followed by 105 darkness.

[2]Columns containing different superscripts differ significantly ($P<.05$).

Source: Deaton et al. (1976)

of illumination was not detrimental to birds. Also, Savory (1976b) reported that birds on a 12-hour photoperiod did not eat during the dark hours. Bird activity also varied between birds receiving different light intensities with activity increasing as intensity increased. Clegg and Sanford (1951) and Ota (1967) reported that there was a 25% less heat production from birds during the dark periods than the light periods. Differences in feed conversion between birds on different lighting programs was reported by Grimbergen (1974) to be due to excess energy use by the more active birds. Buckland (1975) reported that there was not a single instance in which broilers grown on IL had poorer feed conversion than those grown on CL. Results of similar studies by Quarles and Kling (1974), Dorminey and Nakaue (1977), and Goodman (1978) suggested that the longer the light-dark cycle the better the feed conversion.

Results of research on the influence of light on abdominal fat is extremely variable. Buckland et al. (1971) reported that the percent undergrades for fat was significantly greater in IL than CL birds. A similar trend, especially in females, was observed by Beane et al. (1979). In contrast, Malone et al. (1977) reported that IL birds had less abdominal fat, particularly the females, than the CL birds. There was a trend for liver and gizzard weights to be slightly larger in the IL than the CL birds of both sexes.

Effect of Light on Leg Abnormalities. In the early stages of intensive broiler production, leg disorders were considered a minor problem. They occurred incidently and were usually caused by nutritional deficiencies, such as an imbalance between calcium and phosphorous, or by infectious arthritis. Now leg problems occur more frequently and sometimes cause considerable economic loss from increased mortality, poor performance, and downgrading of carcasses. It is suggested that genetics, nutrition, and pathogenic organisms contribute to the total incidence of leg disorders.

Simmons (1982) observed a lower incidence of twisted legs in chickens reared on IL vs. CL. The main influence of IL on the appearance of twisted legs occurred in the first 2 weeks of life (Wilson et al., 1984). Although no quantitative data were provided, they reported fewer and less severe leg abnormalities in IL vs. CL birds. They concluded that the IL birds were much more active when the light was on than were the CL birds. Regular exercise induced by IL may have contributed to stronger leg development. Simmons and Haye (1985) reported on the influence of housing systems and sex on the incidence of twisted legs in broilers giving different lighting regimes. Cockerels in battery cages appeared to be twice as susceptible to twisted legs as females and the incidence appeared to be much higher on wire mesh floors than on litter covered floors. Twenty four hour-light produced the highest incidence of twisted legs whereas a IL:3D cycle gave the lowest.

From their (Simmons and Haye, 1985) data it can be concluded that mean body weight at 6 weeks of age of birds on 24 hours of CL was always lower than for those on the other lighting regimes. This may be partly explained by the higher number of CL birds with severe twisted legs which interfered with normal feed intake. They also reported that birds with 1L:3D showed a higher amount of activity per hour during the light periods. They concluded that of all regimes investigated, 1L:3D proved to be the most effective (Table 9). In another experiment on the influence of shorter light periods on stimulation of activity, they (Simmons and Haye, 1985) reported that shorter light periods failed to stimulate more activity and twisted leg incidence was lower than with 1L:3D (Table 10). In summary, it appears that all regimes consisting of 1 hour light combined with 2 to 7 hours of darkness showed a favorable effect on reducing incidence of twisted legs. It is note worthy that the incidence of twisted

Table 9. Effects of duration of dark periods on body weight, feed conversion and incidence of twisted legs with male broilers in cages reared with intermittent lighting regimes

Lighting time	Body weight 6 wks	Feed conversion 6 wks	Twisted legs % 6 wks
	(1979)		
1L/1D	1713	1.89	17
1L/2D	1769	1.92	12
1L/3D	1803	1.86	12
1L/4D	1778	1.88	13
	(1980)		
1L/3D	1820	1.85	12
1L/5D	1801	1.84	16
1L/7D	1839	1.82	12
1L/11D	1802	1.82	16
1L/23D	1759	1.82	20

Source: Simmons and Haye (1985)

Table 10. Effects of shorter lighting periods (1h) on body weight, feed conversion and incidence of twisted legs with male broilers on cages compared to 24L and 1L/3D

Lighting regime	Body weight 6 wks	Feed conversion 6 wks	Twisted legs % 6 wks
24L	1611	1.86	20
1/2 L/1D	1634	1.85	14
1/2 L/2-1/2 D	1627	1.83	13
1L/3D	1640	1.85	9

Source: Simmons and Hayes (1985)

legs with 1L:23D was almost the same as with 24 hours of CL. However, feed conversion improved with the increasing length of dark periods with an optimum being 7 hours or more.

Buckland _et al._ (1973) also observed that males on CL had a higher percentage of leg abnormalities at 14 weeks of age than those grown on IL. Other factors that may affect the relationship between light treatments, activity, and leg disorders include age at which light treatments are applied, flock size, bird density, barn temperature, and types of leg disorders prevalent (Simmons, 1982; Wilson _et al._, 1984).

Table 11. Effects of different lighting regimes on body weight, food conversion and incidence of twisted legs with male broilers in cages and on litter

Lighting time	Mean body weight 6 wks	Feed conversion 6 wks	Twisted legs % 6 wks
	Cage (1978)		
24L	1535	2.00	30
18L/6D	1537	2.02	16
3L/1D	1589	2.01	20
1L/3D	1572	1.98	12
	Litter (1979)		
24L	1689	1.93	5.7
1L/2D	1718	1.92	2.7

Source: Simmons and Haye (1985).

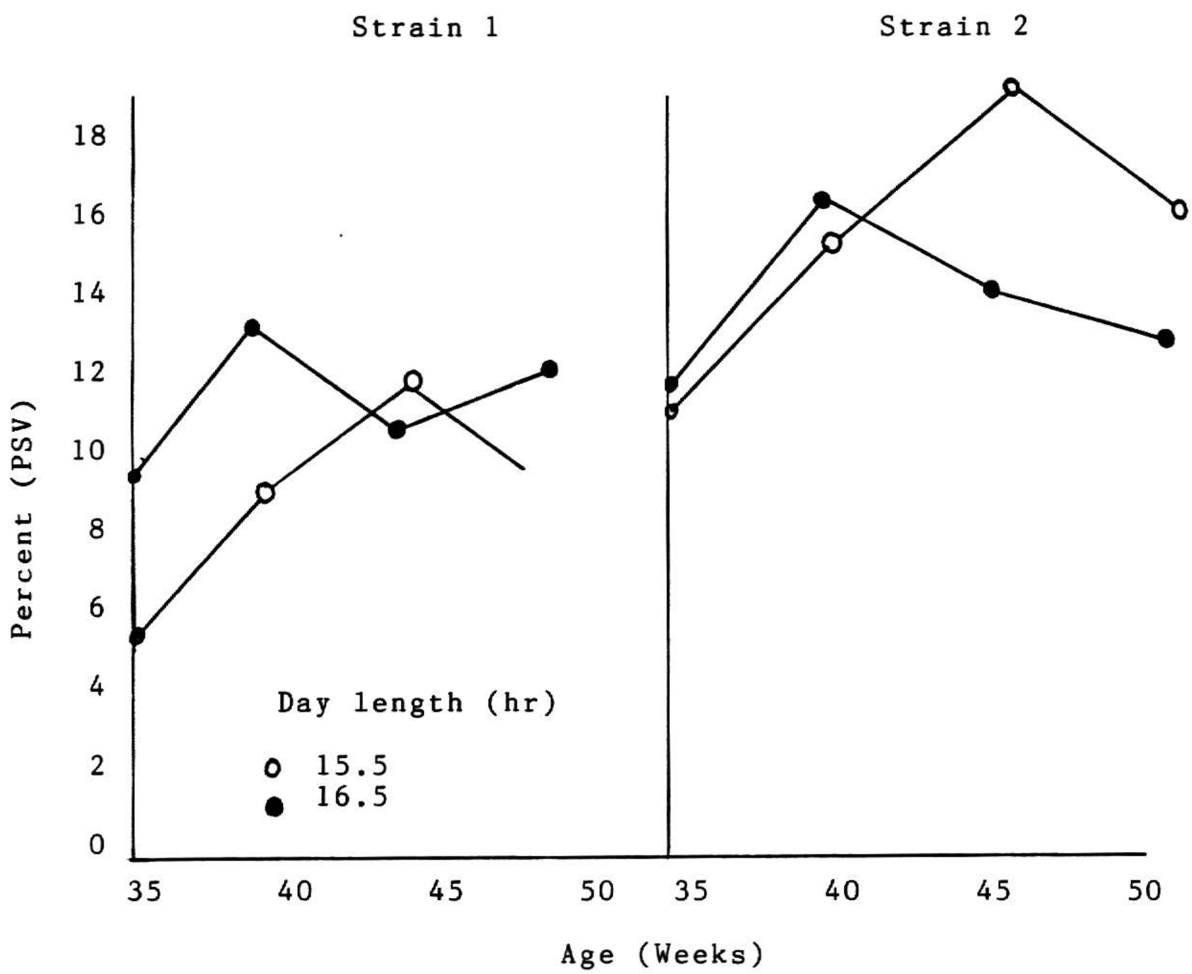
The data in Table 11, presented by Simmons and Haye (1985), show that the incidence of twisted legs in broilers on litter is generally much lower than for those in cages. Yet an important effect of lighting regimes could be shown on the incidence of twisted legs of broilers grown on litter. The frequency was twice as high under CL than under IL. Feed conversion was only slightly affected, but body weight was improved under IL. They concluded that their experiments on both cages and litter, particularly in the later stages of growth, revealed a more favorable effect of 1L:3D than 23 hours CL on incidence of twisted legs and feed conversion.

Light For Catching Birds. North (1984) suggested that producers use a small amount of red or blue light during catching broilers and roasters for market. These types of light enables the catchers to see, while the chickens will not be prompted to move about, especially during night time.

ROLE OF LIGHT IN REPRODUCTION

Fertility in broiler breeder flocks at various ages is dependent upon the number of cockerels in semen production, the number and quality of spermatazoa, and the number of completed matings. Siegel *et al.* (1969a) reported that the response to light by meat-type cockerels after 20 weeks of age was due to the stimulation of incremental change and longer daylengths. North (1984) reported that daylength has significant effects on males during the breeding season. He suggested that the lower the light intensity the lower the volume of semen produced. However, the point has no practical application since the intensity necessary for the pullets in the breeding pen to produce adequate

Figure 2. Effects of daylength on the packed sperm volume (PSV) of semen per collection as related to age.



Source: Harris et al. (1984)

numbers of eggs is also satisfactory for the production of high semen volume and good fertilization.

Data in Figure 2 by Harris et al. (1984) show the effect of daylength and strain on the percentage of cockerels in semen production and justify the concept that longer daylengths are beneficial for semen quality. These data indicate that the percent of packed semen volume (PSV) of the heavier strain 1 males was significantly affected by the light program. Males of this strain on the 16.5-hour daylength produced significantly more spermatazoa at 35 and 40 weeks of age than males on the 15.5-hour daylength. Because of the strain differences in response to light, strain 2 cockerels had a significantly higher PSV at 35, 40, 44, and 48 weeks of age than strain 1 cockerels. The daily photoperiod affected the age at peak PSV, both strains reaching a peak 4 weeks earlier on a daylength of 16.5 hours than on a 15.5-hour daylength. However, mean PSV was higher at all age periods for strain 2 cockerels than for strain 1. Strain 2 cockerels attempted significantly more matings than strain 1. However, the cockerels on the 16.5-hour daylength had significantly fewer completed matings than those on the 15.5-hour daylength.

Data in Table 12 show that hatchability was significantly higher for strain 1 than for strain 2 birds. The lower hatchability of total eggs of strain 2 males was partially the results of lower fertility. This fertility loss may be related to the higher PSV of strain 2 semen since Marks (1981) reported that selection for a higher PSV resulted in lower fertility with natural matings.

Table 12. Effects of strain and daylength on percent fertility and hatchability

Week	Percent fertility				Percent hatchability[1]			
	Daylength		Strain		Daylength		Strain	
of age	15.5hr	16.5hr	1	2	15.5hr	16.5hr	1	2
32	...	...	...	...	86.1	86.6	89.8	82.0
37	...	...	...	...	87.6	86.1	87.8	85.8
43	95.9	94.8	96.4	94.2	88.9	87.0	88.8	87.1
48	95.4	94.0	95.9	93.4	85.3	85.6	86.4	84.5
Mean	95.6[a]	94.4[a]	96.1[a]	93.8[a]	87.0[a]	86.1[a]	88.[2]a	84.8[b]

[a,b]Means for light program or strain with different superscripts are significantly different ($P \leq .05$)

[1]Total eggs set.

Source: As cited by Harris et al. (1984).

ROLE OF LIGHT IN EMBRYONIC DEVELOPMENT

Although environmental factors such as relative humidity, temperature, gaseous exchange, rotation and light, have long been identified to influence the development of the chick embryo; numerous authors have shown that use of light actually accelerates embryonic development in diverse avian species, including the White Plymouth Rock chickens (Siegel et al., 1969b), turkeys (Cooper, 1972), and broiler-type chickens (Walter and Voitle, 1972). It has been shown that eggs incubated in darkness hatched 8 hours earlier than those incubated in colored light (Shutze et al., 1962). Siegel et al. (1969b) reported that light during the 1st week of incubation had a more pronounced effect than light during the 2nd or 3rd weeks and that acceleration of development was apparent by 10 hours of incubation.

Tamimie (1967), and Tamimie and Fox (1967) reported reduced hatchability, lower hatching weights, and less deformed feet, legs, eyes and mandibles in those chicks exposed to light during incubation. The longer the photoperiod the more spectacular were the abnormalities. However, embryonic and post-embryonic viability were not reported to be deleteriously affected by the presence of light during incubation (Lauber and Shutze, 1964). Chicks that hatched early in response to light were more mature at time of hatch than those receiving no light and going to full term (Voitle, 1970), while Siegel _et al._ (1969a) found that hatchability was unaffected.

The effect of light during incubation on the embryonic and post-embryonic development of egg-type chickens has been reviewed by Walter and Voitle (1972). They reported that eggs incubated in CL (24L:OD) required significantly fewer hours of incubation than the controls given no light (Table 13).

Table 13. Response of length of incubation and navel score to photoperiod during incubation

	Hours of incubation			Navel score		
Experiment	Treatment[1]					
	24L-0D	12L-12D	0L-24D	24L-0D	12L-12D	0L-24D
1.	485^{a}[2]	490^{b}	498^{b}	1.9	1.9	1.9
2.	485^{a}	487^{ab}	490^{b}	1.6	1.8	2.0

[1] Sources as cited by Walter and Voitle (1972).

[2]Columns containing means with different superscripts differ significantly (P<.05).

Those incubated under a diurnal light cycle (12L:12D) were intermediate in hatching time. They also reported that the degree of healing of the navel at time of hatching was further progressed in those chicks incubated in CL (24L:OD). Those chicks incubated in continuous darkness had the poorest navel score rating, while those hatched under a diurnal light cycle had intermediate navel scores. However, the authors noted that the navel scores in Experiment 1 were identical regardless of the light treatment. Additionally, Walter and Voitle (1972), and Voitle (1970) suggested that the embryos exposed to light grew faster, matured earlier, and consequently hatched earlier, but did not attain a greater weight at hatching, than those exposed to continuous darkness. They assumed that the early hatching may have been the result of pre-incubation.

Coleman et al. (1977) compared the effectiveness of incandescent and fluorescent lights in incubation of avian eggs, and reported that although incandescent light has more energy than fluorescent, this additional energy was in the photoactivation. They further asserted that incandescent light is more compact and bright than fluorescent, but less efficient in converting electrical energy to light. This and other reasons make it impossible to equate the two in terms of watts of power used. However, fluorescent tubes perform better in incubation of avian eggs, since it is harder to control temperature in the incubators when incandescent bulbs are used. Moreover, the major portion of light from incandescent bulbs is in the visible spectrum, that has the added disadvantage (Lauber and Shutze, 1964; Lauber,

1975) that light composed entirely of wavelengths within the visible spectrum is not as effective as light also containing additional wave lengths outside the visible region in accelerating embryonic development.

When egg shells are monitored for absorption of light, there are relatively strong absorption bands at 345 nm and 385 nm (Coleman et al., 1977). Variations of embryo weights are greater at these two wavelengths. Therefore, if one were to use a light source, it would be advisable to use cool white fluorescent tubes instead of incandescent bulbs to avoid overheating of the eggs. For acceleration of embryonic weight and embryonic age, the light should be placed as close to the eggs as possible so that the light source is no further than 12 cm from the top of the eggs. Gold and Kalb (1976) indicated that secondary heating of the germinal disc contributed to acceleration of development. As indicated by Tamime (1967) and Tamime and Fox (1967), overheating was probably a contributing factor to the high abnormalities in their studies. However, when incubating with the large end up, the air cell may act as an insulator to protect the germinal disc from the overheating as reported by Gold and Kalb (1976).

Photoinduced Bupthalmic Avian Eyes: Continuous Darkness. Buphthalmia (ocular enlargement), induced by photoperiodic extremes was first documented by Jensen and Matson (1957) in chickens reared in CL. But recently, Whitley et al. (1985) reported that chickens raised from 2 to 14 weeks of age in continuous darkness (OL:24D) developed shallow anterior chambers and buphthalmos (megaloglobos). Although the etiology of the photoinduced buphthalmia was not ascertained in this study, the authors believed the ocular changes may have been secondary to an increase in vitreous volume. An increase in vitreous volume would cause anterior displacement of the lens and iris, and a concurrent narrowing of the iridocorneal angle. As the vitreous volume increases, the tunics of the plastic young life would stretch.

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EFFECTS OF LIGHT ON THE PERFORMANCE

OF MEAT- AND EGG-TYPE CHICKENS

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Light influences a number of physiological processes in chickens that have economic significance to poultrymen, namely, growth, egg production, sexual maturity, embryonic development, semen production, and bird activity.

Chickens are more responsive to the long end of the light spectrum, such as the red, orange, and yellow rays, than the short. Because birds do not see well in blue light, it can be used when catching birds. Red light is used to prevent cannibalism. Layers need a minimum of .5 foot-candle intensity for maximum production while broilers need only an intensity that will enable them to find food and water. Fluorescent light is considered superior to other sources for chickens, although incandescent light has certain economic advantages.

The type of lighting system used depends on such variables as open or windowed vs. windowless houses, ratio of light to dark hours per 24 hours, and continuous vs. intermittent light. For pullets, an increase in daylength during the growing period stimulates and a decrease in daylength delays sexual maturity. For mature layers, an increase in daylength stimulates and a decrease suppresses egg production.

Intermittent light has been shown to stimulate performance in layers and broilers when compared to continuous light. Ahemeral light, light-dark cycles of more or less than 24 hours, has been shown to increase egg weight at the expense of egg numbers and to improve egg shell thickness of old hens' eggs.

Eggs incubated in continuous light or diurnal light cycles require fewer light hours of incubation than those given no light.

Timing of oviposition in the fowl is set by external light and dark signals, and when length of light period equals those of dark periods, equal distribution of oviposition will occur. Lighting regimes can have an important influence on the skeletal development in meat-type chickens. It is generally believed that IL stimulates more bird activity than CL, resulting in a lower incidence of twisted legs.

Daylength has significant effects on males during the breeding season. The lower the light intensity the lower the volume of semen produced. It has also been reported that extreme use of continuous darkness or CL causes ocular enlargement in birds.