THE EFFECT OF VARIOUS LIGHTING TECHNIQUES ON AVIAN EGG PRODUCTION, SHELL QUALITY AND HATCHABILITY

by

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INTRODUCTION

Much interest has been stimulated by recent reports on the effect of increasing the daily light period throughout the year for increasing egg production by as much as four to five dozen eggs per hen. If this technique would work under Kansas conditions, it could be of considerable benefit to the Kansas egg producer.

The importance of light to the domestic fowl has been known for centuries (Benoit and Ott, 1944). Within the last 35 years, much experimental work has been conducted to determine and prove its influence on reproduction. This experimentation has been conducted on domestic fowl, wild birds and seasonal breeding mammals. Although much has been learned of its effect, the exact physiological influence of light on laying hens is not completely understood. Much more intensive work in this field needs to be done before man can use artificial light to his greatest benefit.

REVIEW OF LITERATURE

The use of artificial light has become a widely accepted practice among modern poultrymen. The usual recommendation is to provide the laying flock with a minimum of 13-14 hours of artificial light in a windowless house or supplementing natural daylight during the short days of fall and winter. The recommended minimum level is a 40-watt incandescent bulb per 200 square feet of floor space or equivalent (Card, 1952).

Artificial light has been proven valuable in increasing fall and winter egg production when egg prices are highest (Dobie, et al., 1946; Gutteridge, et al., 1944; Kable, et al., 1928; Kennard and Chamberlin, 1931; Ogle and Lamoreaux, 1942; Penquite and Thompson, 1940; Riley and Byerly, 1943; Tomhave and Mumford, 1927). Artificial light brought about a more even distribution of annual egg production (Souba, et al., 1922).

Skoglund and Tomhave (1948) reported that pullets with 14 hours of light produced 15 more eggs per year than non-lighted birds. Other workers reported that artificial lighting produced no significant change in annual egg production.

Artificial light did not appreciably affect the feed consumption, egg production or live weights of the pullets during hot weather. Heywang (1945) has reported no stimulation of feed consumption or egg production, and that no great difference in live weight resulted from using artificial light all night instead of from midnight to daylight.

The maximum rate of egg production is reached when the laying hens receive a minimum of 13 to 14 hours of light (Byerly, 1957; Roberts and Carver, 1941; Kable, et al., 1928; Dobie, et al., 1946). There is no significant difference in the effect on egg production of using light intensities between 1.0 and 31.3 foot candles (Roberts and Carver, 1941; Dobie, et al., 1946). Hartman and King (1956) stated that although it seems more than necessary, the recommended intensity of light for the chicken is one foot candle. Intensities of illumination from 0.5 to 38.0 foot candles at the feeders and from 0.0 to 27.0 on the roosts showed no difference in degree of reproductive response (Nicholas, et al., 1944). Platt (1953) reported that eight hours of exposure to a dim red lamp and natural daylight is equivalent to 14 hours of artificial light per day. The dim bulbs were placed within three feet of the birds on the roosts.

Artificial lights have affected turkeys in two ways. They have stimulated the earlier production of hatching eggs (Albright and Thompson, 1933, 1934; Asmundson, et al., 1946; Milby and Thompson, 1941b; Scott and Payne, 1937; Wilcke, 1939). Greater annual egg production was also accomplished by lighting turkey breeders (Albright and Thompson, 1934; Milby and Thompson, 1941b; Wilcke, 1939). The use of lights to stimulate egg production had no adverse effect on fertility (Wilcke, 1939) or hatchability (Albright and Thompson, 1934; Wilcke, 1939). Asmundson and Moses (1950) stated that lights up to 15 hours did not have any consistent effect on hatchability when compared with unlighted birds. Milby and Thompson (1941b) reported that fertility and hatchability might be slightly decreased. A light intensity of 2 foot candles produced maximum results for turkeys (Asmundson, et al., 1946). Asmundson and Moses (1950) reported that length of day of 13 hours or more gave no significant difference in total egg production; however, shorter lengths of day resulted in later maturity and decreased egg production. The use of incandescent lights (200 watts, 4 feet from the birds) stimulated the reproductivity of male and female quail (Baldini, et al., 1954). The hens produced considerably more eggs under light than would have been produced under natural lighting.

Geese respond to light stimulation outside of the normal production season (Kinney, et al., 1959). Sixteen hours of light in November and December resulted in approximately normal production. A 38-day lag between the application of long-light days and onset of production is consistent with that noted in chickens and turkeys. A prior period of restricted light, six hours of light, caused egg production to occur 5-7 days after the long-light day treatment began.

Until 1924, the reproductive rhythm in birds was attributed to the rising temperatures of spring, yet in the practice of "yogai" in Japan, many centuries ago, and the induction of "muit" in Holland, light has been applied practically to induce winter singing (Rowan, 1936). Increased egg production through the use of artificial light, first practiced a century ago in Spain, is shown to be essentially different from the principle dealt with here. Days increased to spring duration by means of artificial light in mid-winter induced development of sex organs. Spring days artificially curtailed to winter length induced sexual regression.

If increasing light is excluded from the ocular region, testicular development is inhibited in the English sparrow, therefore the ocular region probably is the receptor area for light stimulus (Ringoen and Kirshbaum, 1939). Burger and coworkers (1942) concluded that light is the primary stimulus for testicular activation in the male starling. Light is the primary factor in inducing sexual activity in pheasant, quail and grouse through the mediation of the hypophysis (Clark, et al., 1937).

Benoit and Ott (1944) achieved spectacular results in a long series of experiments with immature ducks. They found that light induced spermatogenesis when: 1) the optic nerve was cut but the eyeball remained in the socket; 2) the eyeball was removed and the orbit illuminated; 3) the hypophysis was illuminated directly by a narrow beam of light; and 4) parts of the rhinencephalon and hypothalmus were illuminated by a narrow beam of light. Gonadal response was slight when blue light was used and the eye kept intact, but when the eye was removed and the hypophysis was illuminated directly with blue light, marked gonadal response occurred. Benoit considered the hypophysis to be stimulated by a dual system: 1) an oculo-hypophyseal system; and 2) an encephalo-hypophyseal system. He believed that both systems are able to function at the same time; for example, light could stimulate the eye proper and, by penetration of the head, stimulate deeper areas. By illuminating with strong light, half a duck's head, placed on photographic paper, Benoit found that light could penetrate to the pituitary. The penetration was best with red rays, the rays that in the normal duck are the best activators of spermatogenesis.

Increasing light brought about gonadal development in male European starlings (Bissonnette, 1931a, 1933a,b, 1936). Stimulation of egg production may be brought about by changes in the light "ration" rather than by the quantitative amount of light (Whetham, 1933). Burger (1940) observed that spermatogenesis is not induced by an increase in day-length but because the day-length is reached which is sufficient to be completely stimulating with 12.5 hours of light being more than the minimum and sufficient for optimum spermatogenesis in the starling. The gonad stimulating effect of increasing light is modified by low temperature or limited feeding in that size and number of eggs laid, which requires much energy, depends on environmental factors such as temperature (Kendeigh, 1941). Working with juncos, Rowan (1936) observed that the gonads could be increased to breeding season size by increased light even in a cold environment. Nesting behavior, however, did not occur in canaries until the temperature was increased. Large increases of light, five to six hours per day, caused some of the birds to succumb and die while small increases did not cause this (Bissonnette, 1931a; Rowan, 1936). Burrows and Byerly (1938) pointed out that increased daily light periods had an inhibitory influence on broodiness.

With chickens, the use of lights in many laying flocks indicated that it is not the amount of light received by the hen in a 24-hour period, but whether it is increasing or decreasing that influences egg production (Hartman and King, 1956). King (1958a,b) reported that pullets raised on six hours of light to maturity, then given an 18 minute per day increase every week, will produce four to five dozen more eggs per year. This increasing light caused the pullets to maintain a high rate of production throughout the 12-month laying year. It had no detrimental effect on egg size or mortality.

Winn (1951) reported that comparable results were evoked under both fixed and lengthening photoperiods in slate-colored juncos. He concluded that change in day-length is not essential for either spermatogenic activity or successive testes cycles. Furthermore, fixed photoperiods did not prevent full testicular development.

Moore and Mehrhof (1946) reported that birds receiving all-night light laid 2.44 per cent more eggs than birds receiving increasing light increased two hours a day every 14 days. Increasing light produced a greater initial response in increased egg production, but after a period it caused a greater refractoriness to light stimulation. Birds on all-night lights consumed less feed per dozen eggs than birds receiving increasing light. Continuous lighting appeared to inhibit expression of sexual maturity in some pullets and prevented high intensity during the entire laying period, according to Callenbach and coworkers (1944). Growth, feed consumption and mortality were either not affected or only slightly. Continuous lighting (Callenbach, et al., 1944) is of no value in the management of late-hatched pullets and is detrimental to sexual maturity. Continuous lighting delayed sexual maturity of pullets (Wilson, et al., 1956), and growth in both sexes was retarded until they reached 20 weeks of age. Continuous lights did not increase or decrease total egg production to a significant degree (Penquite and Thompson, 1932, 1940). Hens and pullets exposed to all-night lights laid fewer eggs in March, April and May than controls without lights (Penquite and Thompson, 1940). All-night lights did not have a deleterious effect on hatchability or adult viability (Penquite and Thompson, 1940). No significant difference in feed consumption was evident.

Eggs from birds receiving continuous light had a significantly higher blood spot incidence than eggs from birds receiving 14 hours of light per day (Stiles and Dawson, 1959). Eggs laid by birds given 15-minute intermittent light and dark had a slight increase in blood spot incidence. Both continuous and intermittent light increased albumen height, egg weight and Haugh score.

Byerly (1957) stated that maximum rate of lay is reached with a daily period of illumination of about 13 to 14 hours. He also reported there are wide individual differences with respect to minimal daily light periods required for egg production and individual response to increase in length of daily light periods. Continuous light has brought about premature egg laying in pheasants, quail and grouse in the spring months (Clark, et al., 1937).

Red light was found to be more stimulating to spermatogenesis in the European starling than white light (Bissonnette and Wadlund, 1931; Bissonnette, 1932, 1933b). Green light was found to be inhibitory (Bissonnette, 1932, 1933b). By using more intense light and doubling the red rays, Bissonnette and Wadlund (1932) speeded up sexual activity over light of lower intensity and about the same concentration of green rays. Red rays have greater penetrating power than green (Bissonnette, 1932). Violet light of low intensity was slightly inhibitory (Bissonnette, 1933b).

In the ferret, heat waves and near infrared were comparatively inactive in accelerating the recurrence of estrous (Marshall and Bowden, 1934). This effect began with red rays and continued through the visible rays to near ultraviolet. Intensity seemed more important than wave-length. The color of the light in the environment of growing chickens is less important than the intensity of the light (Hammond and Titus, 1941). Neither the color nor the intensity of the light to which pullets are subjected during the first 16 weeks of their life affected the live weight subsequently attained by the pullets, their egg production during the pullet year, the fertility of their eggs, or the hatchability of their fertile eggs (Hammond and Titus, 1941). Female turkeys subjected to unfiltered white light or the longer wave-lengths of red light only were stimulated to sexual maturity (Scott and Payne, 1937). The shorter wave-lengths failed to exert any influence on age at sexual maturity. When poults had a choice between red, orange, yellow or green neon light over the feeder, they preferred green much more than the other colors (Smith and Phillips, 1959). Female sparrows subjected to 33 days of green light showed no gonadal response; whereas, those treated with red light over the same period manifested follicular development and hypertrophy of the oviduct (Ringoen, 1942). Red light is vastly more effective than green in accelerating gonadal development in sparrows (Ringoen, 1942). Only wave-lengths of light between

0.58 microns and 0.68 microns were able to stimulate the starling to produce sperm (Burger, 1944). Hall (1946) stated that in a system to control summer egg production by restricted light and feeding, one must eliminate all stimulating rays from sunlight or electric lights by filters to properly restrict light. The use of white or red incandescent, or red fluorescent bulbs produced no significant difference in egg production (Roberts and Carver, 1941). In work with two strains of chickens, one strain produced equally well under red, green, cool white, soft white fluorescent and white incandescent lamps (Carson, et al., 1957). The other strain was more sensitive to light environment. Egg production was adversely affected by red light, but significantly enhanced by cool white illumination. According to Carson and coworkers (1957) egg production can be stimulated by green or cool white light as well as by light with a higher percentage of red and yellow wave-lengths. The use of red colored incandescent, red fluorescent, or incandescent with ultraviolet did not improve egg production (Dobie, et al., 1946). White, red, blue and green fluorescent lights gave practically the same growth in a house with white enamel inside walls (Barott and Pringle, 1951). In all cases over 50 per cent of the radiation of these lights had a wave-length over 7,600 angstroms (Barott and Pringle, 1951). Continuous lighting with red, yellow, green or blue lights was compared with incandescent light and no light (Carson, et al., 1956). All pens reached 50 per cent production at about the same time. Lighted pens laid significantly more eggs than the unlighted pens. Birds raised with red, gold, green, blue, soft white or cool white fluorescent lamps from 15 weeks of age under 24 hours of light showed no difference in egg production from lighted pullets getting 60-watt incandescent light (Carson, et al., 1958). These were colored lights and not filtered to remove yellow and red rays.

The use of incandescent light in conjunction with fluorescent light improved sperm production over fluorescent light alone (Carson, et al., 1958). A 15-watt fluorescent tube compared favorably with a 60-watt incandescent light to stimulate the onset of egg production among Broad Breasted Bronze turkeys in January, but it was not adequate to maintain a high level of production for a period of 10 weeks (Payne and McDaniels, 1958). When the fluorescent light was supplemented with direct sunlight during the daylight hours, both fertility and hatchability were quite satisfactory. When used as the only source of illumination for a 14-hour period daily, a 15-watt fluorescent tube was inadequate as indicated by low production, fertility and hatchability (Payne and McDaniels, 1958). Egg production in laying hens was significantly greater in pens which received direct sunlight than in confined pens adequately supplied with cod liver oil (Byerly, et al., 1937). Fluorescent lighting has an antirachitic influence where ordinary incandescent lights do not have this effect (Willgeroth and Fritz, 1944). According to Willgeroth and Fritz (1944), a 14-watt white fluorescent tube produced calcification equal to that of feeding 20 A.O.A.C. units of vitamin D (13.3 I.C.U.) per 100 grams of diet. Turkey hens given 14 hours of ultraviolet irradiation gave significantly greater egg production than turkey hens under the same conditions without the 14 hours of ultraviolet light (Carson and Junnila, 1953).

For five consecutive years hens exposed to the radiation from a bactericidal ultraviolet lamp laid from 10 to 19 per cent more eggs than a control group with no ultraviolet radiation or daylight but in an artificially lighted room (Barott, et al., 1951) where all hens received ample dietary vitamin D. Exposure to rays longer than the bactericidal, but still shorter than the visible spectrum, gave results comparable to those of the controls. It is concluded that bactericidal radiation peaking at 2587 angstrom units of wave-length exerted a stimulatory effect upon egg production which has not been described previously and that vitamin D was not involved in this effect (Barott, et al., 1950).

Ultraviolet radiation may be of some benefit to chicks between hatching and four weeks of age (Barott and Pringle, 1951). Ultraviolet light was not necessary to stimulate increase in gonad size in juncos (Rowan, 1936). Ultraviolet light has little direct effect on comb growth of White Leghorn cockerels (Lamoreux, 1943b).

In studies with different sources of light, Milby and Thompson (1945) reported that turkey breeding females gave no response to kerosene lanterns and differed little from hens exposed to natural lighting. Comparable turkey hens lighted with gasoline lanterns or natural gas lights gave essentially the same egg production characteristics as hens lighted with electric lights. No significant difference could be shown in fertility and hatchability.

In a study of the effect of light intensity on the testis activity of European starlings, Bissonnette (1931b) reported that all birds subjected to 10-, 15-, 25-, 40-, 50- and 60-watt incandescent bulbs showed increased sexual activity. However, he pointed out that the rate of increased sexual activity increased with light intensity up to the 40-watt level and then it tended to level off. Decrease in intensity or length of light period brought about a regression of testes in the starling (Bissonnette, 1932). By using more intense light and doubling the red rays, Bissonnette and Wadlund (1932) speeded up sexual activity in the starling over light of lower intensity. Bissonette (1933b) concluded the degree of stimulation varies with the intensity of the illumination and it along with daily light period and wave-length of light are the primary factors in controlling seasonal sexual cycles in starlings when diet is adequate and constant. In work with juncos, Rowan (1936) found some of the birds did not respond to low intensity. When the intensity is very high it showed no effect by increasing gonadal development.

In work with growing pullets, Wilson and coworkers (1956) found that under suboptimal light intensities, rate of sexual development was increased by larger daily exposures to light. Growth was not affected by lower light intensities, but sexual maturity was delayed (Wilson, et al., 1956). Chicks raised in an environment of low light intensity, once they learn to eat, grew as rapidly and used their feed as efficiently as those raised in an environment of higher light intensity (Hammond and Titus, 1941). This was true even when the light was of extremely low intensity (Hammond and Titus, 1941). Light intensity for growing chickens need only to supply sufficient light for the birds to feed (Barott and Pringle, 1951). One foot candle is the lowest intensity for the efficient operation by the attendant and any extra intensity is a waste of energy (Barott and Pringle, 1951). There was no great difference in the growth of chicks under different intensities of light or different colors of lights (Rider, 1938). Intensities of incandescent light varying from 1.0 to 31.3 foot candles produced no significant difference in egg production, provided the hens received 13 hours of light per day (Roberts and Carver, 1941; Dobie, et al., 1946). Intensity of illumination from 0.3 to 38.0 foot candles at the feeders and from 0.0 to 27.0 on the roosts had no effect on degree of reproductive response (Nicholas, et al., 1944). There was no relationship between experimental light treatment and egg weight or mortality (Nicholas, et al., 1944). Turkeys failed to respond to light that was administered four hours each day during the normal period of daylight (Scott and Payne, 1937). Turkey hens did not respond to all-night dim (0.04 to 0.1 foot candle) light (Asmundson, et al., 1951). Turkey hens started and kept on bright all-night lights laid a higher percentage of waste eggs than hens on a 14-hour day

(Asmundson, et al., 1951). A light intensity of 2 foot candles produced maximum results (Asmundson, et al., 1946). Less than 0.1 foot candle had no effect on stimulating egg production. The earlier eggs from the brightly lighted pens were smaller. The maximum body weight attained by birds in the brightly lighted pens was less than that attained by the dimly lighted birds (Asmundson, et al., 1946).

Turkeys preconditioned by restriction to six hours of light during the adolescent period produced more eggs than turkeys not preconditioned (Ogasawara, et al., 1959). Fourteen hours of light per day exerts more influence on egg production than 12 hours of light or preconditioning. Best results are obtained when the turkeys are given 14 hours of light after being preconditioned. Preconditioning also has a beneficial effect on semen production. McCartney (1960) reported similar beneficial results with restricted light treatment prior to egg production.

Increasing light brought about gonadal development in European starling males (Bissonnette, 1931a). The shortening daily period of exposure to light was thought to cause the regression of testes activity between May and November in the male starling (Bissonnette, 1930). The testes undergo a rapid regression in June long before the high summer temperatures hit (Bissonnette, 1930). Bissonnette and Cseck (1938) found that pheasants, started with one hour of light per night and increased one hour each week up to six hours of light per night came into production in about six weeks with good fertility. Reduction to natural light on April 1 resulted in some slack in egg production with the more productive birds being least affected (Bissonnette and Cseck, 1938). Rowan (1936) reported that increasing light stimulated increase in gonad size in male juncos while decreasing length of day caused a regression in gonad size. Female English sparrows responded less readily and not as fully to light stimulation as the males (Ringoen and Kirschbaum, 1939). Riley (1940) reported that neither increased light nor activity were effective in stimulating ovarian development of the house sparrow. The gonad stimulating effect of increasing light was restricted on male and female sparrows by low temperature or limited feeding (Kendeigh, 1941). The rate of testicular growth was related to the magnitude of the photoperiod in juncos exposed to daily photoperiods of 24, 20, 15½, 12 and 9 hours (Winn, 1951).

Birds raised on six hours of light matured at about the same age as controls, but at a lower body weight (Sykes, 1956) and the birds on a short day produced fewer eggs than the controls. Moultrie and coworkers (1954) reported that variations in amount of daily light up to six weeks of age had no effect on feathering in New Hampshire-White Rock crossbred chicks, but chicks reared from 6 to 10 weeks or 6 to 12 weeks under continuous light had fewer undesirable body feathers than birds reared during that time under 5, 10 and 15 hours of light daily. Growth was somewhat retarded when the pullets were restricted to eight hours of light, but at maturity it approached that of birds with natural light (Platt, 1955b). At housing, pullets exposed to 8 hours of light were lighter in body weight and appeared to be less sexually mature than those that received 14 hours of light or the natural lighted day (Marr, et al., 1957). Egg production and feed efficiency were significantly increased by controlling the daily light during the growing period (Marr, et al., 1957), but there was no significant difference in egg size. Sykes (1956) concluded that age at sexual maturity is not affected by the absolute length of the day and that egg production is affected by both the absolute length and by the change in length of day. Limited light was not detrimental to body weight in growing chicks (Moreng, et al., 1956). Comb size was increased, thyroid decreased, testes size increased, adrenal slightly increased and liver size slightly decreased by limited light during a seven-week experiment with growing chicks (Moreng, et al., 1956). Lamoreux (1943b) reported that exposure to a short period of artificial light daily did not induce greater comb growth than exposure to long periods of similar light. White Leghorn cockerels made greater gains when exposed to 9 hours of light compared to exposure to 12 hours of light (Lamoreux, 1943a) and males exposed to 4 hours of light gained more than males exposed to 14 hours of light. Gains in body weight of domestic fowl are greater when the daily period of light is inadequate for the maximum stimulation of reproduction (Lamoreux, 1943a).

In Arizona, Heywang (1944) found that artificial lights during hot weather stimulated feed consumption and increased body weight of growing birds. However, continuous light (all-night) had no advantage over light from midnight to dawn. When the pullets began to lay, they weighed a little more and came into production a few days earlier. Here again, all-night lights had no advantage over midnight to dawn lighting. Egg size of the first 10 eggs was not affected (Heywang, 1944). In work with laying hens artificial light did not appreciably affect the feed consumption, egg production, or live weights of the pullets during hot weather (Heywang, 1945). No stimulation of feed consumption or egg production, and no great difference in live weight, resulted from using artificial light all-night instead of from midnight to dawn (Heywang, 1945). All-night lights showed only slight advantage over a 14-hour day in increased egg production (Ryan, et al., 1959). There was evidence of a variation in response to the two light treatments among strains and breeds.

Eight hours of exposure to a (10-watt) dim red light bulb and natural daylight was equivalent to 14 hours of standard light per day where the dim bulbs were within three feet of the birds while on the roost (Platt, 1953). Egg production was immediately increased when light was increased from 8 to 14 hours per day, with the rate of lay exceeding that of birds receiving 14 hours of light (Platt, 1955a). Parkhurst (1933) reported that by using evening lunch, morning lights and evening lights to give at least a 14-hour day or a dim light all night, no significant difference in egg weight was produced. The time of adding supplemental light during the day did not affect egg production provided 13 hours of light was given per day (Dobie, et al., 1946). Pullets or hens subjected to all-night light laid a considerably greater number of winter eggs than those without light or with morning light at 4:00 a.m. (Kennard and Chamberlin, 1931). Sykes (1956) reported that an increase in day-length between December and August always increased production, and a decrease in day-length between February and August always decreased production. Using a schedule of 14 hours of light and 12 hours of dark, Byerly and Moore (1941) found that this lighting practice increased clutch length and increased per cent production for a period of a month to six weeks; however, total production for the period was not measured. The use of 14 hours of light and 12 hours of dark increased clutch length but did not increase total egg production (Van Albada, 1958).

Working with turkeys, Mueller and coworkers (1951) found that restricting light to 12 hours daily from 4 to 16 weeks of age, and to 10 hours daily from 17 to 28 weeks of age resulted in reduced molting of the first post-juvenile plumage when compared with turkeys reared under natural light or those provided with 15 hours of light daily. Poults receiving all-night lights did not grow better or consume more feed than poults receiving only normal daylight (Milby and Thompson, 1941a); however, lights may aid in preventing crowding and piling up. Light limited to 8 hours daily from 16 to 30 weeks of age resulted in considerable increase in egg production of January and March hatched breeder turkeys, but showed no difference over controls for May and September hatched birds (Marr, et al., 1956). Turkey hens given 9 to 15 hours of light per day showed that a longer daily light period caused earlier egg production (Asmundson and Moses, 1950). Length of day of 13 hours or more gave no significant difference in total egg production. The use of artificial lights to lengthen the day up to 15 hours did not have any consistent effect on hatchability when compared with unlighted birds (Asmundson and Moses, 1950), but egg weight after March 1 was slightly reduced by the use of artificial lights.

A night feeding, given at 9:00 p.m. with artificial light, gave appreciable benefit to growing birds after seven weeks of age resulting in more rapid growth, improved feather development and less mortality (Zaratan, 1929). Broiler chicks grew best with continuous light up to 3-4 weeks of age (Moore, 1957). Better growth was obtained with four to six light periods per day instead of one light period (Barott and Pringle, 1951; Clegg and Sanford, 1951; Moore, 1957).

Chicks exposed to continuous light gained better than birds on other lighting regimes except two hours of light and two hours of dark gave comparable results (Shutze, et al., 1959). Continuous light caused some stress signs to appear. Pullets exposed to continuous light came into production slower and did not peak as high. Continuous light during the rearing period depressed subsequent egg production. Feed efficiency was a little better for the birds under restricted light (Moore, 1957). By breaking the dark period with a short period of light, spermatogenesis can be stimulated in juncos and sparrows with 10 hours of light which is insufficient when given as one daily light period (Jenner and

Engels, 1952; Farner, et al., 1953a,b). Kirkpatrick and Leopold (1952) reported a similar response to the broken dark period in the bob-white quail. Some dark is beneficial to growth (Kirkpatrick, 1957). When the 10 hours of light was broken into nine periods of equal length, sparrows responded similarly to birds receiving 18 hours of continuous light (Farner, et al., 1953a,b). Breaking the dark period with a short period of light brought about estrous in female ferrets similar to artificially increased light and much faster than natural increasing light (Hart, 1951).

Sparrows subjected to 5 hours of light and 1 hour of dark showed a strong gonadal and fat response similar to birds exposed to 20 hours of light except with a greater reproductive response (Wolfson, 1953). Birds with intermittent lighting fell a little behind in egg production in the autumn, when compared with other artificially lighted groups (Van Albada, 1958). For the rest of the year there was no great difference between these groups. From work with intermittent light on White Leghorn pullets and hens, Wilson and Abplanalp (1956) drew the following conclusions: 1. Intermittent lighting generally gave higher egg production than the same amount of continuous lighting. 2. Egg production obtained under short photoperiods was not proportionate to the amount of light given. 3. The minimum amount of light needed for an all-or-none response for maintaining egg production in pullets is probably less than six evenly spaced one-minute photoperiods in 24 hours. 4. Hens were more susceptible than pullets to light changes and possibly to other environmental factors. 5. Good layers were more resistant to shocks from light changes than poor layers. 6. The time of oviposition was influenced by light and management factors. Pullets kept in total darkness between five days and seven and one-half months of age came into production at about the same time as the control group and produced almost as well during a 21-day laying period (Rider, 1938).

Flashing light, added to a photoperiod that was too short to stimulate spermatogenesis in the starling, caused a stimulation of spermatogenesis (Burger, et al., 1952). Matthews (1957) reported that flash lighting using 1500-watt bulbs appeared to be as satisfactory as continuous night lighting for stimulating pullets or hens housed intensively for winter egg production.

Limited and unlimited feeding periods had no effect on gonadal development in starlings (Bissonnette, 1931a). The increased light ration rather than the lengthening of the feeding day appeared to stimulate the early ovarian activity of the turkey (Scott and Payne, 1937). Riley (1940) reported that gradually increasing daily periods of activity did not result in gonadal development in the male house sparrow while both increasing light and increasing activity and light stimulated gonadal activity. Increased daily periods of wakefulness or exercise without added light did not induce gonad development in male or female sparrows (Kendeigh, 1941). Callenbach and coworkers (1943) reported that the availability of feed within time limits is not a factor affecting egg production, but light exerts a strong influence. Light rather than the increase in feeding time was the factor affecting growth and egg production (Wilson, 1958). Wilson (1958) reported that light response, in addition to genetic differences, was dependent on four primary variables: 1. Age and previous light treatment, 2. Intensity of light, 3. Frequency of light periods, 4. Hours of light per 24 hours. Hens with a low level egg production were most affected by variations in light period (Whetham, 1933; Kennard and Chamberlin, 1931; Kable, et al., 1928; Bissonnette and Cseck, 1938).

Based on date of first egg, pullets hatched late in spring were slower in reaching sexual maturity than early hatched pullets. According to Byerly and Knox (1946) this is associated with length of day. Supplementary artificial light for October-hatched pullets slowed sexual maturity (Tomhave, 1954). Morris (1958) reported that light slowed maturity on December-hatched chicks by three weeks. In work with pigeons and doves, Riddle (1931) stated that birds from eggs of September to January matured earlier than those from other months of the year. Platt (1955b) reported that January-hatched pullets reared under 8 hours of artificial light were slower to mature than birds given natural light. When the birds on restricted light were given 14 hours of light at 30 weeks of age, egg production increased rapidly to a level higher than the control group on 14 hours of light (Platt, 1955b). Pullets reared with 12 hours of light and with 23½ hours of light came into production at about the same age, but the group on the longer day grew more rapidly (Hutchinson and Taylor, 1957).

All-night light proved effective for prevention of a premature fall or winter molt (Kennard and Chamberlin, 1931). However, Riley and Byerly (1943) reported that lighting had no effect on the progress of molting, even though reproductive activity was stimulated. Reduction in day-length from 23½ hours to 12 hours resulted in low production and molting (Hutchinson and Taylor, 1957). Lerner and Taylor (1941) reported that 88 per cent of the birds began their annual rest in the period during which length of day decreases by 0.2 or more per cent daily.

The onset of darkness was a factor in determining oviposition and terminating a clutch of eggs (Warren and Scott, 1936). Periodic increase in lighting did not noticeably affect either time of laying or rhythm of laying (Moore and Mehrhof, 1946). Fraps and coworkers (1947) concluded that photoperiodicity is not a necessary factor in the regulation of time of lay or of the diurnal temperature cycle, but is associated with factors that determine bodily activity. Days less than 24 hours in length decreased average clutch length and hen-day production while days longer than 24 hours increased clutch length and treatment hen-day production (Ostmann and Biellier, 1958).

MATERIALS AND METHODS

Growing Phase

The chicks used in this experiment were a commercial[1] strain of single comb White Leghorn pullets. They were hatched on April 30, 1958 at the Kansas State University poultry farm. The day-old chicks were vaccinated ocularly for Newcastle and bronchitis. They were then placed in battery brooders for two weeks and given 24 hours of light during this time. The chicks were started on scratch grain and chick starter granules which were placed on egg flats for the first four days. Fresh water was supplied during the first four days with one-quart glass fountains. The chick starter granules fed during this period was the K. S. U. chick starter diet prepared by the K. S. U. feed technology mill. This was true for all diets used in this experiment. When the chicks were two weeks of age, 600 were randomized into eight lots of 75 chicks each, wing-banded and placed in a brooder house with the light treatments shown in Table 1.

All pens were darkened with heavy kraft paper impregnated with asphalt (Sisalkraft) except for the control lot (lot 8). Each pen was 10 feet by 20 feet and contained an electric brooder and two automatic water fountains. All lots were supplied with two one-gallon glass water fountains until the chicks learned to use the automatic waterers. Two four-foot feeders were placed in each lot and adjusted and changed to larger feeders as the birds

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[1] Ghostly strain--second generation removed from commercial breeding farm.

Table 1. Light treatments.

Lot No.	Growing phase	Laying phase
1	6 hours of light per 24 hours 40-watt incandescent light	Increased light period 15 minutes per day every week[1]
2	1 hour of light and 3 hours of dark, 6 cycles per 24 hours 40-watt incandescent light	Increased one light period by 15 minutes every week[2]
3	6 hours of light per 24 hours 15-watt incandescent light	Increased light period 15 minutes per day every week[1]
4	6 hours of light per 24 hours 40-watt incandescent light	Increased light period 15 minutes per day every two weeks
5	6 hours of light per 24 hours 15-watt fluorescent light	Increased light period 15 minutes per day every week[1]
6	5 hours of light, 9 hours of dark, 1 hour of light, 9 hours of dark per 24 hours 40-watt incandescent light	Increased light period 15 minutes per day every week[3]
7	6 hours of light per 24 hours 40-watt fluorescent light	Increased light period 15 minutes per day every week[1]
8	Natural light April 30, 1958 to Oct. 1, 1958	Natural light supplemented with 40-watt incandescent to give at least 14 hours of light per day.
9	Range reared	Natural light supplemented with 40-watt incandescent to give at least 14 hours of light per day
10	Range reared	12 hours of light with 15 minutes per day increase in light period every week. 40-watt incandescent. Exposed to natural light

[1] During the last six weeks of the experiment the time clock would not adjust to less than one and one-half hour of darkness per day. The time clock was left this way for three weeks, then switched to continuous lighting for the last three weeks.

[2] The increase in light period was added to a different light period every week so intermittent light was continued until near the end of the experiment.

[3] The increase in light period was added to both ends of the light period so both dark periods were kept approximately equal in length. The one-hour light period was not altered.

grew. At eight weeks of age, the chicks were switched to K. S. U. chick grower granules.

During the first three weeks, mortality was excessively high due to a reaction of the chicks to the bronchitis vaccine. All birds that died between two and three weeks of age were replaced by similar birds at the beginning of the fourth week. The attraction lights on the brooders were used during the first week in the brooder house so the chicks could find the heat and become acquainted with their new surroundings. After that, the attraction lights were not used.

When the chicks were four weeks of age, ammonia accumulated in some of the pens so that it became necessary to supply additional ventilation. Two 10-inch exhaust fans arranged so they would draw air from all eight pens provided adequate ventilation during the rest of the growing period.

At 16 weeks of age, the birds were vaccinated in the wing web with Newcastle and fowl pox vaccine. The vaccines were mixed and administered simultaneously. All birds were debeaked with an electric debeaker. Chicks were weighed and feed consumption data collected at four weeks of age and every four-week period up to 22 weeks of age when the birds were housed for laying.

Laying Phase

Fifty pullets from each lot were selected on the basis of sexual maturity and body weight and were placed in the laying house at 22 weeks of age. The pullets in lots 9 and 10 were of the same breeding and age as the birds in the other eight lots. They were reared on the K. S. U. poultry range as most replacement pullets are reared at Kansas State University. Lot 9 started with only 45 birds and lot 10 with 48 birds because the pens were smaller than the other eight pens. Four square feet were allowed per bird in all pens. Refer to Table 1 for treatments during the laying phase of this experiment. The various light treatments except for lots 9 and 10 were randomly arranged in a 20 x 80 foot laying house in which all openings were covered with heavy kraft paper impregnated with asphalt to exclude light except the control group (lot 8) which was left with an open front. Ventilation was provided by two 12-inch exhaust fans installed above the loft. The air entered the pens through two 3 foot by 4 inch ducts at the front of each pen which opened about one foot from the floor. Each pen was 10 by 20 feet. The K. S. U. layer breeder granules were fed throughout the laying phase of the experiment. The feed was placed in three hanging feeders in each pen. Each waterer had an electric heating unit built into the base to prevent freezing of the water. Adequate roosting space over dropping pits was provided at the rear of each pen. Each pen was provided with 15 commercial metal nests. Each nest was equipped with a commercial trap front which was locked open except during days when the birds were trap-nested.

Lots 9 and 10 (range reared) were housed in another house. Each pen was equipped the same as the other pens except the house was left with the open front, and natural ventilation was used.

Automatic waterers were used except during cold weather, when the birds were watered in buckets. The pens with the open fronts (lots 8, 9, and 10) were equipped with muslin windows that could be closed wholly or partly during inclement weather.

The pullets were weighed at the time of housing and every 84 days after that during the experiment. Feed consumption was measured every 56 days and egg weight and per cent shell were determined at the end of each 28-day period. The birds were trapnested three consecutive days every week throughout the experiment. Hatchability was measured two times during the experiment, July 11, 1959 and November 10, 1959. Four White Leghorn males were added to each lot on December 24, 1958. The laying phase of this experiment entailed 18 28-day periods between October 1, 1958 and February 16, 1960.

RESULTS

The analysis of variance and Chi square tests applied are described by Snedecor (1956). Duncan's tests are described by Duncan (1955). All of Duncan's tests are at the 0.05 level of significance.

Growing Phase

Feed Conversion. Analysis of the feed conversion data showed there was no significant difference between the various treatments in confinement rearing. Feed conversion was determined and calculated at 8 and 12 weeks of age (Tables 2 and 3).

Table 2. A comparison of feed conversions during the growing period.

Age (weeks)	Lot No. 1	2	3	4	5	6	7	8
8	3.06	3.05	2.96	3.02	3.02	2.96	3.18	3.06
12	4.03	3.84	4.71	4.16	4.31	3.93	4.55	4.33

Table 3. Analysis of variance of feed conversion during the growing period.

Sources	d.f.	M.S.	F.
Lots	7	0.0514	1.16 n.s.
Weeks	1	5.7002	
Residual	7	0.0444	

n.s. - Not significant at the 0.05 level.

Body Weight. There was no significant difference in body weight of the birds under the various treatments between 2 and 12 weeks of age (Table 4). Lot 2 (intermittent light) showed a significantly greater body weight (Tables 5 and 6) between 2 and 20 weeks of age except for lot 6 ("midnight lunch"). The "midnight lunch" group was intermediate between the intermittent light and the natural light controls (lot 8). The birds in lot 7 (40-watt fluorescent) were significantly smaller than those in the natural lighting group (lot 8) and 40-watt incandescent groups (lots 1 and 4). Birds in the 15-watt incandescent and fluorescent groups (lots 3 and 5, respectively) were not significantly different in body weight from those in lot 7 or lots 1 and 4.

Table 4. Analysis of variance of body weight during the growing period between 2 and 12 weeks of age.

Sources	d.f.	M.S.	F.
Lots	7	1180.0050	1.23 n.s.
Weeks	3	1174727.4325	
Residual	21	958.2515	

n.s. - Not significant at the 0.05 level.

Table 5. Analysis of variance of body weight during the growing period between 2 and 20 weeks of age.

Sources	d.f.	M.S.	F.
Lots	7	6588.5804	4.10 **
Weeks	5	1931208.5347	
Residual	35	1606.9457	

** - Significant at the 0.01 level.

Table 6. Ranked lots for mean body weight between 2 and 20 weeks of age (gms.) based on Duncan's (1955) method.[1] Lots ranked from high to low in weight.

	Lot No.							
	2	6	8	1	4	3	5	7
$\bar{x}$	772.4	735.8	714.1	705.1	699.6	693.3	682.0	653.7
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			———	———	———	———	———	
						———	———	———

[1] Any two lots not underscored by the same line are significantly different, and any two lots underscored by the same line are not significantly different.

Laying Phase

Body Weight. The birds with intermittent light (lot 2) and "midnight lunch" (lot 6) were heavier at housing time than those in other lots that were reared in confinement. The range-reared birds at housing weighed approximately the same as birds in lots 2 and 6 (Table 7).

Table 7. Comparison of average body weight (pounds) at housing.

	Lot No.									
	1	2	3	4	5	6	7	8	9	10
Average weight	2.92	3.48	2.97	2.98	2.95	3.20	2.94	3.03	3.21	3.30

Intermittent light and the "midnight lunch" (lots 2 and 6) techniques produced hens that were significantly heavier throughout the experiment than all other lots. Forty-watt fluorescent light caused the hens to be significantly lighter in weight than all other treatments. There was no significant difference in body weight of birds given 15-watt incandescent, 15-watt fluorescent, 40-watt incandescent or supplemented natural light. Increasing the length of light (lots 1, 4 and 10 versus lots 8 and 9) revealed no significant difference in body weight (Tables 8 and 9).

Per Cent Production. Birds in lot 8 (natural light, confinement reared) laid at a higher average rate than all other treatments tested for a 12-month or longer period (Table 10). Per cent production was significantly better for lot 8 than all other treatments except lots 9 and 10 (both range reared) which were

Table 8. Analysis of variance of body weight during the laying phase of the experiment.

Sources	d.f.	M.S.	F.
Lots	9	0.2451	12.38 ***
Dates	6	2.8601	
Residual	54	0.0198	

*** - Significant at the 0.005 level.

Table 9. Ranked lots based on Duncan's <u>op. cit.</u> method. Lots ranked from high to low in body weight during the laying phase of the experiment.

	Lot No.							
	2	6	3	10	4	1 & 9	5 & 8	7
$\bar{x}$	4.53	4.46	4.29	4.25	4.21	4.18	4.14	3.85

Table 10. Summary of per cent production.

Lot No.	Periods			
	Oct. 1,'58- Sept.29,'59	Oct.29,'58- Oct.27,'59	Oct. 1,'58- Feb.16,'60	Oct.29,'58- Feb.16,'60
1	52.07	54.31	44.96	47.80
2	43.89	46.36	36.85	39.06
3	53.60	56.53	45.61	48.41
4	56.71	60.56	50.22	53.46
5	56.18	59.38	49.35	52.34
6	52.45	56.30	47.02	50.06
7	51.92	55.48	47.42	50.56
8	66.99	70.27	58.25	60.82
9	59.91	62.69	53.54	56.17
10	62.61	66.12	56.50	59.68

intermediate in per cent production (Tables 11, 12, 13, and 14). Lot 2 (intermittent light) was significantly lower in production throughout the entire experiment as the data in the above-mentioned tables indicate with a wide difference separating it from the other lots. All other treatments showed no significant difference in egg production for either the entire laying phase or a 12-month period from October 1, 1958 to September 30, 1959 (Tables 11, 12, 13, and 14).

Table 11. Analysis of variance of per cent production for the 12-month period: October 1, 1958-September 30, 1959.

Sources	d.f.	M.S.	F.
Lots	9	532.1451	5.59 ***
Periods	12	3312.3776	
Residual	108	95.1516	

*** - Significant at the 0.005 level.

Table 12. Ranked lots based on Duncan's op. cit. method. Lots ranked from high to low for per cent production during the 12-month period: October 1, 1958-September 30, 1959.

	Lot No.									
	8	10	9	4	5	3	6	1	7	2
$\bar{x}$	66.99	62.61	59.91	56.71	56.18	53.60	52.45	52.07	51.92	43.89

Table 13. Analysis of variance of per cent production for entire laying phase of experiment.

Sources	d.f.	M.S.	F.
Lots	9	668.0877	8.64 ***
Periods	17	3938.2590	
Residual	153	77.3075	

*** - Significant at the 0.005 level.

Table 14. Ranked lots based on Duncan's op. cit. method. Lots ranked from high to low for per cent production during the entire laying phase of the experiment.

	Lot No.									
	8	10	9	4	5	7	6	3	1	2
$\bar{x}$	58.25	56.50	53.54	50.22	49.35	47.42	47.02	45.61	44.96	36.85

Feed Conversion. For a 12- and 14-month period following housing (Oct. 1, 1958-Sept. 30, 1959 and Oct. 1, 1958-Nov. 24, 1959, respectively) there was no significant difference in feed conversion between various light treatments (Tables 15 and 16). Statistical analysis of the data for a 12-month period from November 26, 1958 to November 24, 1959 indicated that birds in lot 2 (intermittent light) required significantly more feed per dozen eggs than all other treatments (Tables 17 and 18). Birds in lots 5 and 8 (15-watt fluorescent; natural light - confinement reared, respectively) gave the best feed conversion for a 12-month period

Table 15. Analysis of variance of feed conversion for the 12-month period: October 1, 1958 -September 29, 1959.

Sources	d.f.	M.S.	F.
Lots	9	15.1019	1.13 n.s.
Periods	6	211.0983	
Residual	54	13.3832	

n.s. - Not significant at the 0.05 level.

Table 16. Analysis of variance of feed conversion for 14-month period: October 1, 1958-November 24, 1959.

Sources	d.f.	M.S.	F.
Lots	9	16.6974	1.41 n.s.
Periods	7	193.4324	
Residual	63	11.8072	

n.s. - Not significant at the 0.05 level.

Table 17. Analysis of variance of feed conversion for 12-month period: November 26, 1958-November 24, 1959.

Sources	d.f.	M.S.	F.
Lots	9	3.2892	5.19 ***
Periods	6	35.1569	
Residual	54	0.6332	

*** - Significant at the 0.005 level.

Table 18. Ranked lots based on Duncan's op. cit. method. Lots ranked from high to low in pounds of feed consumed per dozen eggs produced during the 12-month period: November 26, 1958-November 24, 1959.

	Lot No.									
	2	1	9	6	3	4	10	7	5	8
$\bar{x}$	7.54	6.53	6.42	6.38	5.89	5.83	5.67	5.67	5.55	5.09

from November 26, 1958 to November 24, 1959. Birds in these two lots were significantly better than birds in lots 1, 6 or 9 (40-watt incandescent increased every week; "midnight lunch"; natural lighting - range reared, respectively). Birds in lots 3, 4, 7 and 10 (15-watt incandescent; 40-watt incandescent increased every two weeks; 40-watt fluorescent; 40-watt with increasing light-range reared, respectively) were intermediate in feed conversion (Tables 17 and 18). For the entire laying period, birds in lot 2 (intermittent light) required significantly more feed per dozen eggs than all other treatments except birds in lot 3 (15-watt fluorescent) which were intermediate in feed conversion. There was no significant difference between all other treatments for the entire laying phase (Tables 19 and 20). For the entire laying phase the birds in lots 8 and 10 (natural light-confinement reared; natural light with increasing light, respectively) gave the best feed conversion.

Table 19. Analysis of variance of feed conversion for the entire laying phase of the experiment.

Sources	d.f.	M.S.	F.
Lots	9	58.0100	2.79 **
Periods	9	320.4207	
Residual	81	20.8179	

** - Significant at the 0.01 level.

Table 20. Ranked lots based on Duncan's op. cit. method. Lots ranked from high to low in pounds of feed consumed per dozen eggs produced during the entire laying phase of the experiment.

	Lot No.									
	2	3	4	1	6	5	7	9	10	8
$\bar{x}$	14.74	11.46	10.45	9.84	9.22	8.61	8.45	7.56	6.95	6.93

<u>Egg Weight</u>. Birds in lot 2 (intermittent light) produced heavier eggs during this experiment. This egg weight was not significantly greater than that of the birds of other lots except lots 3, 4, 7 and 9 (15-watt incandescent; 40-watt incandescent increased every two weeks; 40-watt fluorescent; natural light-range reared, respectively) (Tables 21, 22, 23 and 24).

For the entire experiment, the birds in lot 4 (40-watt incandescent increased every two weeks) were not significantly different from the birds in lots 3, 7 and 9 (15-watt incandescent; 40-watt fluorescent and natural light - range reared, respectively). All other lots were significantly different from lot 4.

Table 21. Analysis of variance of egg weight for the 12-month period: October 29, 1958-October 28, 1959.

Sources	d.f.	M.S.	F.
Lots	9	25.128	30.96 ***
Dates	12	108.826	
Residual	108	0.812	

*** - Significant at the 0.005 level.

Table 22. Ranked lots for egg weight for the 12-month period: October 29, 1958-October 28, 1959, based on Duncan's op. cit. method. Ranked from high to low.

	Lot No.									
	2	8	10	6	5	1	9	3	4	7
$\bar{x}$	60.0	58.0	58.0	57.9	57.7	57.5	57.3	56.9	55.5	55.1

Table 23. Analysis of variance of egg weight for entire laying phase of the experiment.

Sources	d.f.	M.S.	F.
Lots	9	30.380	29.25 ***
Dates	16	150.412	
Residual	144	1.039	

*** - Significant at the 0.005 level.

Table 24. Ranked lots for egg weight for the entire laying phase of the experiment, based on Duncan's op. cit. method. Ranked from high to low.

	Lot No.							
	2	1 & 8	5 & 10	6	9	3	7	4
$\bar{x}$	61.3	59.4	59.2	59.1	58.7	58.3	56.9	56.6

<u>Per Cent Shell</u>. Statistical analysis of the data for a 12-month period from November 24, 1958 to November 25, 1959 revealed no significant difference in per cent shell between the various light treatments (Table 25). For the entire laying phase, lots 5 and 8 (15-watt incandescent; natural light - confinement reared, respectively) had the highest per cent shell for the experiment. These lots were only significantly different from lots 1, 3 and 4 (40-watt incandescent, light increased weekly; 15-watt incandescent; 40-watt incandescent with light increased every two weeks, respectively). All other treatments were intermediate in per cent shell with little difference among all groups (Tables 26 and 27).

Table 25. Analysis of variance of per cent shell for the 12-month period: November 24, 1958-November 25, 1959.

Sources	d.f.	M.S.	F.
Lots	9	0.2080	1.95 n.s.
Dates	12	2.6189	
Residual	108	0.1067	

n.s. - Not significant at the 0.05 level.

Table 26. Analysis of variance of per cent shell for the entire laying phase of the experiment.

Sources	d.f.	M.S.	F.
Lots	9	0.2619	2.47 *
Dates	15	2.1400	
Residual	135	0.1060	

* - Significant at the 0.05 level.

Table 27. Ranked lots for per cent shell for the entire laying phase of the experiment, based on Duncan's op. cit. method. Ranked from high to low.

	Lot No.									
	8	5	9	2	10	6	7	1	3	4
$\bar{x}$	8.65	8.64	8.62	8.46	8.46	8.45	8.45	8.37	8.33	8.30

Hatchability. Statistical analysis of the per cent of total eggs set and fertile eggs set showed there was no significant difference in hatchability due to the various light treatments (Tables 28 and 29).

Table 28. Analysis of variance of per cent hatchability of total eggs set.

Sources	d.f.	M.S.	F.
Lots	9	168.2147	0.74 n.s.
Dates	1	1591.3280	
Residual	9	227.1869	

n.s. - Not significant at the 0.05 level.

Table 29. Analysis of variance of per cent hatchability of fertile eggs set.

Sources	d.f.	M.S.	F.
Lots	9	162.2591	0.62 n.s.
Dates	1	749.0880	
Residual	9	260.1269	

n.s. - Not significant at the 0.05 level.

Mortality. Chi square test of the mortality showed no significant difference either for a 12-month period following housing (Oct. 1, 1958-Sept. 30, 1959) or for the entire laying period ($\underline{x}^2 = 16.459^{n.s.}$, 9 d.f. and $\underline{x}^2 = 9.321^{n.s.}$, 9 d.f., respectively). The mortality of the high light intensity groups (lots 7, 8, 9 and 10) was compared with the groups subjected to low light intensity (lots 1 through 6). A Chi square test of these data indicated a significant difference at the 0.01 level for the 12-month period following housing ($\underline{x}^2 = 7.3142$, 1 d.f.). There was no significant difference between the light intensity groups for the entire laying period ($\underline{x}^2 = 2.1445$, 1 d.f.). Light intensities are given in Table 30.

Table 30. Intensity of light in the different lots measured at the floor level nearest the light source.

Lot No.	Foot candles
1	1.0
2	1.0
3	0.3
4	1.0
5	5.5
6	1.0
7	14.0
8	90.0
9	90.0
10	90.0

DISCUSSION

The primary objective of this experiment was to test, under Kansas conditions, the results reported by King (1958a,b). Other lots were designed to study the effect of different sources of light and intensities of light upon the laying hen. Egg production, shell quality, feed conversion and mortality were used as criteria for measuring these effects. The results of this experiment do not entirely confirm the work of King (1958a,b). The control group (lot 8) produced at a significantly higher rate of production than the group receiving a 15-minute increase in 40-watt incandescent light every week (lot 1). In the range-reared groups (lots 9 and 10), the birds receiving increasing light (lot 10) did not significantly produce at a higher rate of production than the range-reared control group (lot 9). All groups that received increasing light were significantly below the confinement reared control group (lot 8) except for lot 10, which was not significantly different from either control group (lots 8 and 9).

One possible explanation for this difference in response to increasing light is the reported variation of various breeds and strains of chicken in their response to light stimulation. Wilson and Abplanalp (1956) reported that good layers were more resistant to changes in light than poor layers. Wilson (1958) stated that genetic differences influence the light response of laying hens in addition to other factors. Byerly (1957) reported there were wide individual differences among laying hens with respect to minimal daily light periods required for egg production and individual response to increase in length of daily light periods. In work with two strains of chickens, Carson and coworkers (1957) reported that one strain is more sensitive to light environment than the other strain.

In general, there was no significant difference in feed conversion between the control lots and lots receiving increasing light. This statement holds true also for hatchability, egg weight, body weight and mortality. These findings agree with the results reported by King (1958a,b). Intermittent lighting resulted in birds that were heavier than other treatments which agrees with the results obtained by other workers. The "midnight lunch" group resulted in heavier birds than the controls or birds given increasing light, but not as heavy as the intermittent lighting group. Those groups receiving high intensity of light, natural light and 40-watt fluorescent, showed a higher mortality than the groups receiving low intensity of light, 15-watt incandescent and fluorescent, during the first 12 months of this laying experiment. This tends to indicate that high intensity of light places an additional stress on laying hens. When the entire laying period of this experiment is taken into consideration, there was no significant difference in mortality between treatments. It was observed that birds exposed to the 15-watt incandescent light were not readily disturbed when the pen was entered, while the birds under the 40-watt fluorescent light were easily excited. Light intensity in the 15-watt incandescent pen was 0.3 foot candle on the floor directly under the source, while the light intensity in the 40-watt fluorescent pen was 14.0 foot candles in a similar position. During the growing period, the birds receiving high intensity of light (40-watt fluorescent and natural light) presented a cannibalism problem which was not observed in the other lots. Intensity of light for the 40-watt fluorescent group was 14.0 foot candles while the natural light intensity was 90 foot candles directly inside the window at floor level. The natural lighted group showed more severe cannibalism than the 40-watt fluorescent group.

SUMMARY AND CONCLUSIONS

This experiment was conducted to study the effects of increasing light and different levels of incandescent and fluorescent light upon an egg-laying strain of chickens and egg production. Body weight, feed conversion, egg production, egg weight, per cent

shell and mortality were criteria used to determine these effects along with general observations. This experiment was conducted in two parts, growing phase and laying phase.

During the first 12 weeks of the growing phase, there was no significant difference in body weight or feed conversion among the various light treatments. The birds given one hour of light and three hours of dark showed a significantly greater body weight between 2 and 20 weeks of age than the groups that were given six hours of continuous light per day. Birds that received the same total amount of light but received one hour of light during the dark period of the day had an average body weight that was greater than those that received six continuous hours of light and less than the birds on intermittent light. There was no significant difference between the other light treatments at 20 weeks of age.

It was observed that birds raised with a low light intensity (0.3 foot candle) were easier to handle while those with high intensity light (14.0 and 90.0 foot candles) were nervous and easily disturbed. The birds in the high light intensity pen were the only birds where cannibalism became a problem, with it being most severe in the 90.0 foot candle pen.

At housing time (22 weeks of age), the birds receiving intermittent light were more sexually developed than those receiving other treatments. Birds receiving only 0.3 foot candle of light showed the least sexual development.

Pullets receiving natural light supplemented to a minimum of 14 hours of light per day produced at a higher rate than any other group during the laying phase. The lowest rate of lay was demonstrated by the intermittent lighting treatment.

Intermittent lighting resulted in birds that were heavier than all other treatments. These birds also gave the least efficient feed conversion while the natural lighted birds gave the best. Birds given intermittent light produced the heaviest eggs with the natural lighted group close to it in egg weight.

Birds in lots receiving high intensity light (14.0 and 90.0 foot candles) showed a significantly higher mortality rate than the birds in lots receiving low intensity light (0.3 and 5.5 foot candles) during the first 12 months of the laying period. There was no significant difference in mortality over the entire laying period.

There was no great difference in egg weight and no significant difference in hatchability between treatments.

Birds receiving increasing light, as such, were not outstanding in any measurement observed. An increase in annual egg production did not result from its use as had been previously reported.

On the basis of these findings, one may draw the following conclusions:

1. Gradual increasing light did not cause an increase in annual egg production.
2. When the daily light was given in two or more periods, it caused an increase in body weight.

3. Birds given extremely high intensities of light showed more signs of stress, resulting in increased mortality.
4. Egg weight, hatchability and per cent shell are not necessarily dependent on light treatment.
5. No significant difference between incandescent and fluorescent light was observed.

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LITERATURE CITED

Albright, W. P., and R. B. Thompson.
Securing early turkeys by stimulating egg production.
Poul. Sci. 12:124-128. 1933.

__________.
Morning lights increase egg production in bronze turkeys.
Rpt. Okla. Agr. Exp. Sta. 1932-34:132-134. 1934.

Asmundson, V. S., F. H. Kratzer, and B. D. Moses.
Relation of all-night light to egg quality in turkeys.
Poul. Sci. 30:546-548. 1951.

Asmundson, V. S., F. W. Lorenz, and B. D. Moses.
Influence of light intensity on ovulation in turkeys.
Poul. Sci. 25:346-354. 1946.

Asmundson, V. S., and Ben D. Moses.
Influence of length of day on reproduction in turkey hens.
Poul. Sci. 29:34-41. 1950.

Baldini, J. T., R. E. Roberts, and C. M. Kirkpatrick.
The reproductive capacity of bobwhite quail under light stimulation. Poul. Sci. 33:1282-1283. 1954.

Barott, H. G., and Emma M. Pringle.
Effect of environment on growth and feed and water consumption of chickens. Jour. Nutr. 45:265-274. 1951.

Barott, H. G., L. Schoenleber, and L. E. Campbell.
The effect of ultraviolet irradiation at 2587 angstrom units on the egg production of hens. Poul. Sci. 29:747 (abst.). 1950.

__________.
The effect of ultraviolet radiation on egg production of hens.
Poul. Sci. 30:409-416. 1951.

Benoit, J., and I. Ott.
External and internal factors in sexual activity. Yale Jour. Biol. and Med. 17:27-46. 1944. (Original not available for examination, abstracted in Burger, J. Wendell, A review of experimental investigation on seasonal reproduction in birds. Wilson Bull. 61:211-230. 1949.)

Bissonnette, T. H.
Studies on the sexual cycle in birds: III. The normal regressive changes in the testis of the European starling (<u>Sturnus vulgaris</u>) from May to November. Am. Jour. Anat. 46:477-492. 1930.

Bissonnette, T. H.
Studies on the sexual cycle in birds: IV. Experimental modification of the sexual cycle in males of the European starling (*Sturnus vulgaris*) by changes in the daily period of illumination. Jour. Exptl. Zool. 58:281-320. 1931a.

__________.
Studies on the sexual cycle of birds: V. Effects of light of different intensities upon the testis activity of the European starling (*Sturnus vulgaris*). Physiol. Zool. 4:542-574. 1931b.

__________.
Studies on the sexual cycle in birds: VI. Effects of white, green and red lights of equal luminous intensity on the testis activity of the European starling (*Sturnus vulgaris*). Physiol. Zool. 5:92-123. 1932.

__________.
Does increased light absorption cause increased egg production in the fowl? Poul. Sci. 12:396-399. 1933a.

__________.
Light and sexual cycles in starlings and ferrets. Quart. Rev. Biol. 8:201-208. 1933b.

__________.
Sexual photoperiodism. Quart. Rev. Biol. 11:371-386. 1936.

Bissonnette, T. H., and A. G. Csech.
Interrupted night-lighting with pheasants. Ecology 19:181-187. 1938.

Bissonnette, T. H., and A. P. R. Wadlund.
Spermatogenesis in *Sturnus vulgaris*: Refractory period and acceleration in relation to wave length and rate of increase of light ration. Jour. Morph. 52:403-428. 1931.

__________.
Duration of testis activity of *Sturnus vulgaris* in relation to type of illumination. Jour. Expt. Biol. 9:339-350. 1932.

Burger, J. Wendell.
Further studies on the relation of the daily exposure to light to the sexual activation of the male starling (*Sturnus vulgaris*). Jour. Exptl. Zool. 84:351-362. 1940.

__________.
Some effects of colored illumination on the sexual activation of the male starling. Jour. Exptl. Zool. 94:161-168. 1944.

Burger, J. W., T. H. Bissonnette, and H. D. Doolittle.
Some effects of flashing light on testicular activation in the male starling (Sturnus vulgaris). Jour. Exptl. Zool. 90:73-82. 1942.

Burrows, W. H., and T. C. Byerly.
The effect of certain groups of environmental factors upon the expression of broodiness. Poul. Sci. 17:324-330. 1938.

Byerly, Theodore C.
Light and egg production. Poul. Sci. 36:465-468. 1957.

Byerly, T. C., and C. W. Knox.
Date of hatch and day length affect age at first egg. Poul. Sci. 25:587-592. 1946.

Byerly, T. C., and O. K. Moore.
Clutch length in relation to period of illumination in the domestic fowl. Poul. Sci. 20:387-390. 1941.

Byerly, T. C., H. W. Titus, N. R. Ellis, and R. B. Nestler.
Effects of light, soybean and other diet supplements on seasonal hatchability and egg production. Poul. Sci. 16:322-330. 1937.

Callenbach, E. W., J. E. Nicholas, and R. R. Murphy.
Effect of light and availability of feed on egg production. Pa. Agr. Expt. Sta. Bull. 455:1-14. 1943.

___________.
Influence of light on age at sexual maturity and ovulation rate of pullets. Pa. Agr. Expt. Sta. Bull. 461:1-12. 1944.

Card, L. E.
Poultry production. Eighth edition. Philadelphia: Lea & Febiger, p. 263, 1952.

Carson, J. R., B. F. Bacon, and W. A. Junnila.
Colored illumination during the rearing period and its effect on sexual maturity and productivity. Poul. Sci. 35:1136 (abst.). 1956.

___________.
Light quality and the stimulation of egg production. Poul. Sci. 36:1108 (abst.). 1957.

Carson, J. R., and W. A. Junnila.
Ultraviolet irradiation of the turkey hens. Poul. Sci. 32:871-873. 1953.

Carson, J. R., W. A. Junnila, and B. F. Bacon.
Sexual maturity and productivity in the chicken as affected by the quality of illumination during the growing period. Poul. Sci. 37:102-112. 1958.

Clark, L. B., S. L. Leonard, and Gardiner Bump.
Light and the sexual cycle of game birds. Science 85:339-340. 1937.

Clegg, Robert E., and Paul E. Sanford.
The influence of intermittent periods of light and dark on the rate of growth of chicks. Poul. Sci. 30:760-762. 1951.

Dobie, John B., J. S. Carver, and June Roberts.
Poultry lighting for egg production. Wash. Expt. Bull. 471: 1-27. 1946.

Duncan, D. B.
Multiple range and multiple F tests. Biometrics 11:1-42. 1955.

Farner, D. S., L. R. Mewaldt, and S. D. Irving.
The roles of darkness and light in the photoperiodic response of the testes of white-crowned sparrows. Biol. Bull. 105:434-441. 1953a.

____________.
The roles of darkness and light in the activation of avian gonads. Science 118:351-352. 1953.

Fraps, R. N., B. H. Neher, and I. Rothchild.
The imposition of diurnal ovulatory and temperature rhythms by periodic feeding of hens maintained under continuous light. Endocrin. 40:241-250. 1947.

Gutteridge, H. S., S. Bird, H. I. McGregor, and Jean M. Pratt.
The effect of heat, insulation, and artificial light on egg production and feed consumption of pullets. Sci. Agr. 25:31-42. 1944.

Hall, G. O.
The artificial control of egg production. Poul. Sci. 25:3-12. 1946.

Hammond, John C., and Harry W. Titus.
Effect of colored light and colored walls on the growth and mortality of chickens. Poul. Sci. 20:507-513. 1941.

Hart, D. S.
Photoperiodicity in the female ferret. Jour. Exptl. Biol. 28: 1-12. 1951.

Hartman, Roland C., and Dale F. King.
Keeping chickens in cages. Fourth edition. Redlands, California: Roland C. Hartman, pp. 149-151. 1956.

Heywang, Burt W.
The effect of artificial light on chicks brooded during hot weather. Poul. Sci. 23:481-485. 1944.

Heywang, Burt W.
The effect of artificial light on laying chickens during hot weather. Poul. Sci. 24:83-86. 1945.

Hutchinson, J. C. D., and W. W. Taylor.
Seasonal variation in the egg production of fowls: Effect of temperature and change of day length. Jour. Agr. Sci. 49:419-434. 1957.

Jenner, Charles E., and William L. Engels.
The significance of the dark period in the photoperiodic response of male juncos and white throated sparrows. Biol. Bull. 103:345-355. 1952.

Kable, G. W., F. E. Fox, and A. G. Lunn.
Electric lights for increasing egg production. Oregon Agr. Expt. Sta. Bull. 231:1-37. 1928.

Kendeigh, S. C.
Length of day and energy requirements for gonad development and egg-laying in birds. Ecology 22:237-248. 1941.

Kennard, D. C., and V. D. Chamberlin.
All-night light for layers. Ohio Agr. Expt. Sta. Bull. 476:1-22. 1931.

King, Dale F.
Brand new way to light your layers. Farm Journal 82(2):36-37. Feb. 1958a.

__________.
Get more eggs with new lighting plan. Poultry Tribune 64(2):15. Feb. 1958b.

Kinney, T., R. E. Burger, and R. N. Shoffner.
Response of Embden geese to light. Poul. Sci. 38:1469-1470. 1959.

Kirkpatrick, Charles M.
Bobwhite weight gains on different light-dark cycles. Poul. Sci. 36:989-993. 1957.

Kirkpatrick, C. M., and A. C. Leopold.
The role of darkness in sexual activity of the quail. Sci. 116: 280-281. 1952.

Lamoreux, W. F.
The influence of different amounts of illumination upon the body weights of birds. Ecology 24:79-84. 1943a.

Lamoreux, W. F.
Effect of differences in light and temperature upon the size of combs on White Leghorns. Endocrinology 32:497-507. 1943b.

Lerner, I. Michael, and Lewis W. Taylor.
Factors affecting the duration of the first annual rest. Poul. Sci. 20:490-495. 1941.

Marr, J. E., F. W. Garland, Jr., J. L. Mulligan, and H. L. Wilcke.
Effect of controlled light during the growing period upon subsequent performance of breeder turkeys. Poul. Sci. 35:1156 (abst.). 1956.

Marr, J. E., J. L. Mulligan, R. C. Eaton, and H. L. Wilcke.
Effect of controlled light during the growing period upon subsequent laying performance of chickens. Poul. Sci. 36:1138 (abst.). 1957.

Marshall, F. H. A., and F. P. Bowden.
The effect of irradiation with different wave-lengths on the oestrous cycle of the ferret, with remarks on the factors controlling sexual periodicity. Jour. Expt. Biol. 11:409-422. 1934.

Matthews, P.
The application of "flash lighting" to egg production on the deep litter system. World's Poultry Science Journal 13:303-305. 1957.

McCartney, M. G.
Controlled lighting for turkeys. Ohio Farm and Home Research 45(1):11, 14. Jan.-Feb., 1960.

Milby, T. T., and R. B. Thompson.
The use of all night light for growing turkeys. Poul. Sci. 20:332-336. 1941a.

__________.
The effect of artificial light on reproduction in poultry, with special reference to turkeys. Proc. Okla. Acad. Sci. 22:41-44. 1941b.

__________.
Sources of artificial light for turkey breeding females. Poul. Sci. 24:438-441. 1945.

Moore, Claude H.
The effect of light on growth of broiler chickens. Poul. Sci. 36:1142-1143 (abst.). 1957.

Moore, O. K., and N. R. Mehrhof.
Periodic increase in lighting versus continuous lighting for layers. Fla. Agr. Expt. Sta. Bull. 420:1-12. 1946.

Moreng, Robert E., Reece L. Bryant, and David G. Gosslee. Physiological reaction of chickens to limited light. Poul. Sci. 35:977-983. 1956.

Morris, T. R. Light treatment prevents too early maturity. Modern Poultry Keeping 79(13):5. Sept. 25, 1958.

Moultrie, Fred, Clyde D. Mueller, and Loyal F. Payne. The effect of light on feathering of broiler chicks. Poul. Sci. 33:784-790. 1954.

Mueller, Clyde D., Fred Moultrie, L. F. Payne, H. D. Smith, and R. E. Clegg. The effect of light and temperature on molting in turkeys. Poul. Sci. 30:829-837. 1951.

Nicholas, J. E., E. W. Callenbach, and R. R. Murphy. Light intensity as a factor in the artificial illumination of pullets. Pa. Agr. Expt. Sta. Bull. 462:1-24. 1944.

Ogasawara, F. X., V. S. Asmundson, and W. O. Wilson. The effect of restricting light during the adolescent period on reproductive performance in turkeys subsequently exposed to a 12- and 14-hour day. Poul. Sci. 38:1233 (abst.). 1956.

Ogle, R. C., and W. F. Lamoreux. Artificial light for poultry in war time. Cornell Ext. Bull. 544:1-4. 1942.

Ostmann, O. W., and H. V. Biellier. The effect of varying day-lengths on time of oviposition in the domestic fowl. Poul. Sci. 37:1231 (abst.). 1958.

Parkhurst, Raymond T. Some factors affecting egg weight in the domestic fowl. Poul. Sci. 12:97-111. 1933.

Payne, L. F., and G. R. McDaniel. Fluorescent lights for turkey breeders. Poul. Sci. 37:722-726. 1958.

Penquite, R., and R. B. Thompson. Influence of continuous light on Leghorns. Poul. Sci. 12:201-205. 1932.

__________. Results of a ten year study of the influence of artificial light on egg production. Poul. Sci. 19:358 (abst.). 1940.

Platt, Clarence. Maintaining winter egg production by the use of dim red light. Poul. Sci. 32:143-145. 1953.

Platt, C. S.
Restricting light delays sexual maturity of pullets. New Jersey Agri. 37(1):12-16. 1955a.

__________.
A study of the effect of restricted lighting on January hatched pullets. Poul. Sci. 34:1045-1047. 1955b.

Riddle, Oscar.
Studies on the physiology of reproduction in birds: XXIX. Season of origin as a determiner of age at which birds become sexually mature. Am. Jour. Physiol. 97:581-587. 1931.

Rider, P. L.
The influence of light on growth and reproduction of the domestic fowl. Ohio State University Master's Thesis.

Riley, G. M.
Light versus activity as a regulator of the sexual cycle in the house sparrow. Wilson Bull. 52:73-86. 1940.

Riley, Gardner M., and T. C. Byerly.
Influence of increased light on progress of molt and egg production in yearling Rhode Island Red hens. Poul. Sci. 22:301-306. 1943.

Ringoen, Adolph R.
Effects of continuous green and red light illumination on gonadal response in the English sparrow, Passer domesticus (Linnaeus). Am. Jour. Anat. 71:99-116. 1942.

Ringoen, A. R., and Arthur Kirschbaum.
Factors responsible for the sexual cycle in the English sparrow, Passer domesticus (Linnaeus). Ocular stimulation and spermatogenesis; Effect of increased light ration on ovarian development. Jour. Exptl. Zool. 80:173-186. 1939.

Roberts, June, and J. S. Carver.
Electric lights for egg production. Agri. Engin. 22:357-364. 1941.

Rowan, Wm.
The effect of controlled illumination on the reproductive activities of birds. Proc. World's Poul. Congress 6:142-152. 1936.

__________.
Light and seasonal reproduction in animals. Biol. Rev. 13:374-402. 1938.

Ryan, F. A., E. P. Singsen, J. R. Carson, L. M. Potter, and W. A. Junnila. Fourteen hour day versus all-night lights in poultry laying houses. Poul. Sci. 38:1243 (abst.). 1959.

Scott, H. M., and L. F. Payne. Light in relation to the experimental modification of the breeding season of turkeys. Poul. Sci. 16:90-96. 1937.

Shutze, J. V., L. S. Jensen, and W. E. Matson. Effect of lighting regimes on growth and subsequent egg production of chickens. Poul. Sci. 38:1246 (abst.). 1959.

Skoglund, W. C., and A. E. Tomhave. The influence of artificial light upon egg production, egg size, and value of eggs produced by White Leghorn pullets. Del. Agr. Expt. Sta. Bull. 273:468-479. 1948.

Smith, L. T., and R. E. Phillips. Influence of colored neon lights on feed consumption in poults. Poul. Sci. 38:1248. 1959.

Snedecor, George W. Statistical methods. Fifth edition. Ames, Iowa: The Iowa State College Press, 1956.

Souba, A. J., H. C. Knandel, and R. Adams Dutcher. Dried yeast products as a supplement to a good poultry laying ration as a means of increasing egg production. Poul. Sci. 31: 209. 1922.

Stiles, P. G., and L. E. Dawson. The effect of physical disturbance, sound and light on the incidence of blood and meat spots and other egg quality factors. Poul. Sci. 38:1250 (abst.). 1959.

Sykes, A. H. Short day-length and egg production in the fowl. Jour. Agr. Sci. 47:429-434. 1956.

Tomhave, A. E. Influence of artificial lights during rearing on the egg production of October hatched New Hampshires. Poul. Sci. 33: 725-729. 1954.

Tomhave, A. E., and C. W. Mumford. The use of artificial light on White Leghorn pullets to increase winter egg production. Del. Agr. Expt. Sta. Bull. 151: 1-15. 1927.

Van Albada, Ir. M. Seasonal and lighting influences on the laying rhythm of the fowl. Instituut Voor De Pluimveeteelt "Het Spelderholt," Mededeling No. 71, Beckbergen, Nederlands. 1958.

Warren, D. C., and H. M. Scott.
Influence of light on ovulation in the fowl. Jour. Exptl. Zool. 74:137-156. 1936.

Whetham, Elizabeth O.
Factors modifying egg production with special reference to seasonal changes. Jour. Agr. Sci. 23:383-411. 1933.

Wilcke, H. L.
The use of artificial lights for turkeys. Poul. Sci. 18:236-242. 1939.

Willgeroth, George B., and James C. Fritz.
Influence of incandescent and of fluorescent lights on calcification in the chick. Poul. Sci. 23:251-252. 1944.

Wilson, Wilbor O.
Light for egg production and growth. Poul. Sci. 37:1253 (abst.). 1958.

Wilson, W. O., and H. Abplanalp.
Intermittent light stimuli in egg production of chickens. Poul. Sci. 35:532-538. 1956.

Wilson, Wilbor, Allen E. Woodard, and Hans Abplanalp.
The effect and after-effect of varied exposure to light on chicken development. Biol. Bull. 111:415-422. 1956.

Winn, Hudson S.
Effects of different photoperiods on testicular growth in the slate-colored Junco. Anat. Rec. 111:525. 1951.

Wolfson, Albert.
Gonadal and fat response to a 5:1 ratio of light to darkness in the white-throated sparrow. Condor 55:187-192. 1953.

Zaratan, Ananias M.
Studies on the effects on the growth of chicks of night feeding with the aid of artificial illumination. Philippine Agr. 18: 387-396. 1929.

THE EFFECT OF VARIOUS LIGHTING TECHNIQUES ON AVIAN EGG PRODUCTION, SHELL QUALITY AND HATCHABILITY

by

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An experiment was conducted to study the influence of increasing light and different amounts of incandescent and fluorescent light on an egg laying strain of chickens. The chicks were battery brooded up to two weeks of age under continuous light. All diets used in this experiment were K.S.U. starter, grower and layer rations prepared by the K.S.U. feed technology mill. At two weeks of age, the chicks were randomized into eight lots and placed in a brooder house where the different light treatments were administered. The birds were moved to the laying house at 22 weeks of age, where the light treatments were continued. Except for the lighting, normal husbandry practices were followed during all parts of this experiment.

Feed consumption and body weights were taken at four-week intervals during the growing phase. There was no significant difference in feed conversion or body weight between 2 and 12 weeks of age. At 20 weeks of age the birds on intermittent light and those receiving a "midnight lunch" were significantly heavier than all other lots. Forty-watt fluorescent light and natural lighted birds were the most easily excited while those birds under 15-watt incandescent were not readily excited and were easier to handle. Cannibalism was a problem in the 40-watt fluorescent lot and the natural lighted lot, but not in the other lots.

Intermittent lighting produced hens with the heaviest body weight and the lowest egg production of all treatments. Egg weight also was highest in this lot, but it was not significantly different from the natural lighting control group.

Natural lighting produced the highest rate of lay and gave the best feed conversion. Next in egg production were the two range-reared lots; one received natural lighting with a 14-hour day and the other received natural light with a gradually increasing amount of light.

Those lots receiving natural light and 40-watt fluorescent light suffered significantly greater mortality than those receiving 15-watt incandescent and fluorescent during the first 12 months of the experiment.

There was no significant difference in mortality between treatments when the entire laying phase of 16 months was considered. Per cent shell was not greatly different between treatments.