THE EFFECT OF VARIOUS LIGHT REGIMES ON CHICKEN PULLETS TO 25 WEEKS OF AGE

By

PAUL ROBERT WALTHER

Bachelor of Science

Iowa State University

Ames, Iowa

1955

Submitted to the faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1962

THE EFFECT OF VARIOUS LIGHT REGIMES

ON CHICKEN PULLETS

TO

25 WEEKS OF AGE

Thesis Approved:

George W. Newell

Thesis Adviser

John W. West

Head of Department

Robert MacVicar

Dean of the Graduate School

ACKNOWLEDGEMENTS

The writer wishes to express gratitude and sincere thanks to Dr. George W. Newell, Associate Professor of Poultry Science, for his valuable guidance, criticism, suggestions and encouragement in conducting this research and in writing this manuscript. Gratitude is expressed to Dr. John W. West, Professor and Head of the Poultry Science Department, for supplying the necessary materials and facilities needed for the experimental portion of this study. The sincerity and the friendly and cooperative spirit of these and other members of the Department have been invaluable.

Recognition is also extended to Dr. Robert D. Morrison of the Department of Mathematics and Statistics for his patient assistance in the statistical analysis.

The writer also wishes to acknowledge the assistance of Mrs. Jane Hughes, office assistant, in the typing of manuscripts and Mr. Paul Minton, Mr. Paul McClure and other farm workers for help in collecting data used in this study.

TABLE OF CONTENTS

LIST OF TABLES OF EXPERIMENTAL PROCEDURE

TABLE

LIST OF FIGURES

Figure

LIST OF TABLES OF RESULTS

Table

Table

Table

INTRODUCTION

The purpose of this study was threefold. Inasmuch as few authors have ever made a comprehensive search of the literature concerning the effects of irradiation on the female chicken, it seemed desirable to record the results of such studies in one paper. The completeness of such a review is only relative as many known papers were unavailable in either complete form or even as abstracts.

Secondly, it was considered desirable to add to the many studies of the effect of light irradiation on the female chicken so that some greater understanding of the phenomenon might be brought about.

And thirdly, this study was used as the media for practicing new scientific methods of studying problems in zoology, physiology and statistics. At least, many of the methods were new to the author.

REVIEW OF LITERATURE

Direct and Indirect Responses of Chickens to Irradiation

IRRADIATION

The word "irradiation" is defined by the Webster's New Collegiate Dictionary (1960) as the state of being irradiated, illuminated or exposed to any type of ray or radiation. This is in contrast to "radiation", a word which is often confused with "irradiation." Radiation is the act or process of radiating, or the combined process of emission, transmission and absorption of radiant energy. We are interested primarily in the direct and indirect, reactions or responses, physically and physiologically, of female chickens to the state of being exposed to radiation from solar and incandescent light sources.

EARLY INVESTIGATIONS AND OBSERVATIONS

Castello (1924) found evidence that the practice of modifying winter egg production by supplementary illumination has been known for over 100 years. At the Second World's Poultry Congress in Barcelona, Spain, he quoted from "a book" of recommendations to Spanish peasants by Francisco Dieste y Buil of Madrid written in 1803.

"Chickens should be fed 7 a.m., 2 p.m., and 10 p.m. by lights or torches of wood or material so that the birds may see the food. One of the principal reasons why the hens do not lay eggs with such vigor in the winter is the lack of food."

The "feeding effect" of light was assumed by most early poultrymen producing eggs. According to Atkinson (1918), Dr. E. C. Waldorf of Buffalo, New York, claimed in 1889 and 1890 that by lengthening the feeding and digestive day of the ordinary hen, she can readily be induced to average more than one egg a day.

Banta (1918) states that Professor Halpin at the Michigan Agricultural College examined the crops of chickens at midnight in midwinter and found them in all cases nearly or quite empty. Halpin concluded that supplementary light was needed in the winter to allow the birds greater eating time. He used artificial lights to increase winter egg production as early as 1907. Lewis (1921), Dougherty (1922), Fairbanks (1924), Martin (1925), Tomhave and Mumford (1927) and Bartsch (1937) concluded from their observations that increased winter egg production can be attributed to extra consumption of feed when the hen's working day is lengthened.

Lewis (1921) recommended that artificial lights should be located so that the roosts as well as the floor be lighted but gave no reason for his suggestion.

The use of supplementary light during the winter to stimulate egg production began to be accepted by commercial poultrymen after 1910. Banta (1918) stated that a Western Washington poultryman started using kerosene lanterns to light birds as early as 1911. Atkinson (1918) cited the example of J. B. Roe of Pasadena, California, who in 1915 installed a lighting system for his birds. One 25-w Mazda bulb lighted each 12-by 16-foot pen from 4:30 a.m. to 8 p.m., with an increase of 300 percent in egg production during the fall and winter.

Atkinson subjected his flock of 6,000 birds to supplementary lights in 1916 (Atkinson and Emerson, 1918). Lights went on at 5 a.m., off at 7 a.m., on at dusk and off again at 7 p.m. Egg production was increased during the winter months but "probably not for the year." Bants (1918) stated that by 1918 poultrymen in 21 states, in 4 provinces of Canada and in England were using supplementary lights for laying hens with success.

Curtis (1920) reported that J. E. Rice of Cornell University found that a 30-minute "lunch" of supplemental light and feed from 8:30 to 9 p.m. stimulated pullets so that winter egg production exceeded that of daylight controls and those receiving a total of 14 hours of solar plus supplemental artificial light.

Kable, et al. (1928) challenged the principal of the "feeding effect" of light in stimulating egg production. They found that feed consumption was higher during periods of heavy production, but that annual egg production and feed consumption were not increased by the use of supplementary light. They concluded that the increase in egg production in winter was not due to the birds eating more feed, but rather feed consumption was increased because of higher production. Rider (1938), Callenbach et al. (1943), and Dakan (1934 a,b) concluded from their work that hens can eat and drink all they require for high production in 10 hours each day.

Dobie *et al.* (1946) demonstrated that the greatest rate of production was obtained when a two-hour "lunch" of feed and light was given in the midst of the long dark period. As a supplement to an 8-hour day (7:30 a.m. to 3:30 p.m.), the 2-hour period produced production superior to other regimes where the 2-hour period was given from 5:30 a.m. to 7:30 a.m., from 3:30 a.m. to 5:30 a.m., or from 7:30 p.m. to 9:30 p.m.

Two experiments were conducted by Temperton and Dudley (1947) to obtain information on whether additional feed is required when production is stimulated by artificial lighting. Lighting alone did not appear to have any effect on egg production. Access to feed during the hours of artificial light resulted in an increase in egg production over that obtained when feed was available only during daylight hours. When the feed consumption of the lighted group was limited to that of the unlighted group, egg production of the two groups was similar. They concluded that ovulation is stimulated through artificial lighting and that additional feed is required for increased egg production.

Darkness, *per se*, does not limit the feeding time of birds. Wilson and Abplanalp (1956), Kirkpatrick and Leopold (1952) and Wilson (1958), working with caged chickens and quail, observed that during long dark periods or with regimes with extremely short light periods, the birds would eat in the dark. It is not known if birds in a floor management system would follow this pattern.

To test the limits on feeding time, Burmester and Card (1939) submitted some layers to a 5-month test of 12 hours of light but to restricted feeding time. With an all-mash ration, body weight and egg production declined rapidly when hens were restricted to less than six hours of feeding time each day. The mash-fed hens, when restricted to short feeding periods (to 10 minutes out of each 12 hours), would eat continuously when feed was offered, in an effort to get sufficient total amounts of feed. Hens fed pellets could eat a given quantity of feed in a much shorter time, and hence, were able to maintain their weight and continued to lay while on feeding schedules as short as 2 hours daily in one continuous period, or 2 minutes every 12 hours.

The desirability of providing light for the first few days in the brooders is well known. Nutt et al. (1955) stated that light helps the chicks to find the source of warmth and to locate feed. Hammond and Titus (1941) and Barott and Pringle (1951) experienced that chicks started in pens illuminated with very low-intensity light or with red, blue or green lights exhibited a high mortality during the first two weeks due to starve-outs.

EGG PRODUCTION FACTORS

Since egg production is the result of gonadostimulation, some consideration of the factors determining egg production and how irradiation alters these factors must be made. The first-year egg production of a bird is determined by five characteristics: (1) age in days that laying commences, or sexual maturity, (2) intensity of production, or rate during a given period, (3) the amount of broodiness, (4) pause in production and (5) persistency of production determined by the length of time that laying continues prior to the first complete annual molt (Goodale, 1918; Goodale and Sanborn, 1922; Hays, 1944.)

AGE AT SEXUAL MATURITY

Age at first egg has a very significant effect on the first-year egg production. Early sexual maturity has long been considered to be an important fecundity trait. Its chief value seems to lie in its association with high production intensity and because it generally is associated with a longer laying year (Hays and Bennett, 1923; Kempster, 1925; Buster, 1927; Hays and Sanborn, 1929; Hays, 1944; Byerly and Knox, 1946; Hays, 1951).

Sexual maturity is usually measured in females by the mean age at which the first egg is laid (Hutt, 1949). Lerner and Taylor (1940) determined that the use of the median age at first egg may be more practical because it eliminates the difficulties often arising from the fact that one or two hens may begin to lay many months after their more precocious pen mates. Sexual maturity is sometimes measured by the age at first egg for the bird laying the first egg in the pen. Age at 10, 25, or 50 percent production is also used, especially when individual trap nest records are unavailable.

Several problems are immediately recognized upon examination of the results of experiments conducted to determine the effect of light on sexual maturity. The first is that of the lack of uniformity in the expression of measurement of sexual maturity, discussed previously. The second is the lack of information on the length of photo-period, and intensity and wave length of the artificial light source. The age of the birds and the time of application and the duration of that application is often not discussed. There is also a lack of information concerning the season during which the birds were exposed to solar irradiation and the latitude of the experiment station which might reflect the length of days for any particular date and change of daily light. The absolute day length changes are greater for high latitudes than for lower latitudes. The day length extremes are also greater at high latitudes than at low latitudes.

Kable _et al._ (1928), Kennard and Chamberlin (1931) found supplementary artificial light useful for hastening the development of normally slow-maturing or late-hatched pullets.

There is some agreement among investigators that photoperiods of 9 hours or less per day when administered during the latter part of the growing period tend to retard the expression of sexual maturity when compared to daylight, 12, 14, or 16 hour photoperiods (Mueller _et al._, 1951; Platt, 1955; Wilson and Abplanalp, 1956; Skoglund, 1959; Biellier, 1960; Lanatsch _et al._, 1960a; Lowe and Heywang, 1960;

Ostrander, 1960; Lert, 1961). One study disagrees with the premise that 9 hours or less was less stimulating than daylight (Sykes, 1956).

Decreasing artificial photoperiods tend to delay maturity when compared with daylight even though they are 22 or 24 hours in length at the hatch date of the chicks, and decreased 30 or 35 minutes each week (McClary, 1960a, b; Morris and Fox, 1960). A photoperiod of 6 hours plus 18 minutes increase each week delays maturity as compared with constant 14 hour periods (Powell, 1958) and a photo-period of 8 hours plus 40 minutes increase each week, when started at 8 weeks, stimulates earlier maturity than regimes of 16 hours or 16 hours decreasing 40 minutes per week (Berg *et al.*, 1960).

Fifteen hours of daily light was superior in stimulating maturity in several studies (Heywang, 1944; Byerly and Knox, 1946; Adolph, 1955), but 16 hours was inferior to either daylight or 10½ hours (Lowe and Heywang, 1960, 1961). Retardation of sexual maturity of all-night lighted pullets has been observed (Ringrose and Potter, 1953; Wilson *et al.*, 1956), as compared to daylight or 14-hour controls, although continuous light has been known to stimulate maturity (Karapetjan, 1950; Carson *et al.*, 1958) and to have no effect (Heywang, 1944; Hutchinson and Taylor, 1957) when compared with daylight or 12-hour controls.

Morris and Fox (1958a) have postulated that daylight changes are more important in determining sexual maturity than absolute quantities of light. In their work with

Rhode Island Red X Light Sussex pullets, the regression of age at maturity on day length change was $y = 166 - 1.64 (d_m - d_h)$ where y is age at sexual maturity in days, d_m is daylength at maturity in hours and d_h is daylength at hatching in hours. Their study showed a correlation of r = --0.9115 of daylength change on age at maturity.

BODY WEIGHT AND MATURITY

Sexual maturity occurs at heavier weights for fast-growing chickens than for slow-growing chickens of the same hatch and strain, but fed and managed differently (Prentice *et al.*, 1930; Hazel and Lamoreux, 1947). However, Upp and Thompson (1927), Hays (1933) considered body weight at maturity of positive linear relationship to age for birds of a flock under one management program.

Morris and Fox (1960, 1961) found that lighting birds increased both weight gains and age at maturity, but Morris and Fox (1958b) and Skoglund (1959) noted that restricting light increased age at maturity and decreased weight gains. Platt (1955) and Hutchinson and Taylor (1957) found that the photoperiodic effect on body weight is different than the effect on maturity. Although there was no difference in body weight, maturity was accelerated by a long light regime. Sykes (1956) found that, although maturity rate was not changed, a long light regime accelerated growth.

Hays (1951) and Morris and Fox (1960) found that the onset of sexual maturity tends to retard subsequent rate of growth in pullets.

AGE AT MATURITY AND EGG SIZE

Artificial light reduces egg weight during the laying year as compared to natural lighting (Thompson et al., 1931; Whetham, 1933; Warren et al., 1950). Once mature egg size is reached, flashing light regimes reduce egg size as compared with 14 hours of light per 24 administered in one or two cycles, and with an increasing light regime (Lanson, 1960).

Parkhurst (1933) found nonsignificant differences in egg weights for pullets subjected to natural lighting as compared to egg weights for birds subjected to all-night light, morning light, morning and evening light, and lights from 9 p.m. to 10 p.m.

Smaller birds tend to lay small eggs and pullets that begin to lay at an early age start off with smaller eggs than those which begin at a later age and at a larger body size (Curtis, 1914; Atwood, 1923; Jull, 1924; Lippincott et al., 1925; Axelsson, 1934). The question arises whether the first eggs are small because the pullet began laying at an early age or because she was small at the time. When the influence of age at first egg is eliminated by measuring partial correlation, a highly significant relationship is found between egg weight and body weight (Funk, 1935).

While age at first egg and body weight at that time have a marked effect on the size of the first egg laid, they have much less to do with the final egg size attained by the birds when full grown or with average size of all eggs laid (Marble, 1931; Hays, 1939; Funk and Kempster, 1934).

Hutchinson and Taylor (1957) noted that egg size during the production year followed body size at maturity.

However, other workers have claimed that the mean egg weight for the first year of laying is significantly related to the age at first egg, the earlier layers producing smaller eggs for the year than later ones (Maw and Maw, 1932; Upp and Thompson, 1927; Hays, 1952; Ringrose and Potter, 1953; Wilson et al., 1956; Morris and Fox, 1958b; Bowman and Archibald, 1959; Morris and Fox, 1960).

While average weight of all eggs laid by a hen is important, a more practical consideration is the length of time required by a pullet to get her eggs from a modest initial weight up to 23 or 24 ounces per dozen in weight. It seems that the younger the age at first egg the longer the time required to attain an egg weight of 24 ounces per dozen (Maw and Maw, 1932; Hays, 1934).

If egg size is related to age, then early maturing birds are handicapped when average egg size for a production year or to given date is measured from age of maturity. Average egg size for any given age would give a more accurate evaluation of egg size. Most workers find that photoperiods, although influencing sexual maturity, have little effect on egg size for any given age of birds hatched the same time (Platt, 1955; Ostrander, 1960; Lawatsch et al., 1960; Lert et al., 1960; Morris and Fox, 1961). Exceptions to these observations were found by Bowman and Archibald (1959), Skoglund (1959), McClary (1960a) and Morris and Fox (1960). They noted that a delay in maturity increased egg size at any date early in the production year. Skoglund found that during the middle of the laying year the situation reversed itself, the late maturing birds producing smaller eggs than the early maturing birds the second half of the laying year.

MATURITY AND ANNUAL PRODUCTION

It is clear that age at first egg is not related to peak production rate after laying has begun. The correlation coefficients are insignificant (Kempster, 1925; Knox et al., 1935; Lerner and Taylor, 1937). However, pullets genetically able to lay at early ages are better layers than those starting later. Age at maturity and annual production are highly negatively correlated (Hays and Bennett, 1923; Jull, 1924; Kempster, 1925; Lippincott et al., 1925; Buster, 1927; Knox, 1930; Hays, 1944, 1951, 1952). Birds of a given strain but hatched at different seasons, also show the negative correlation of these traits (Berry and Walker, 1927; Upp and Thompson, 1927; Byerly and Knox, 1946; Morris and Fox, 1958a). Where artificial light and natural light are involved as maturity stimuli for birds of a given strain and hatched at one time, the negative correlation still exists (Ringrose, 1952; Tomhave, 1954; Carson et al., 1958; Skoglund, 1959; Lowe and Heywang, 1960).

Pullets, subjected to short photoperiods lighted before they reached 16 weeks of age, mature later, but lay at greater intensity to overcome the handicap if given adequate levels of light during the laying period, (Marr et al., 1957; Powell, 1958; Bowman and Archibald, 1959; Biellier, 1960;

Lawatsch et al., 1960a; Lert et al., 1960; McClary, 1960a,b; Morris and Fox, 1960; King, 1961; Lert, 1961; Morris and Fox, 1961).

Growing pullets, when exposed to long photoperiods, may not only be delayed in maturity but may become refractory or less sensitive to light stimulation during the laying period. Ringrose (1951, 1952), Tomhave (1954), and Lowe and Heywang (1960, 1961) noted that pullets raised under a regime of daily light of 14 hours or more matured later and laid at a lower rate than those reared under daylight conditions.

Bowman and Archibald (1959) observed that pullets, exposed to natural light to 16 weeks and then placed on a 14 hour photoperiod, matured later and laid at a lower rate than birds placed on a photoperiod increasing from 6 hours at 16 weeks.

Pullets exposed to 15 hours of light at 2½ or 3½ months (Adolph, 1955) or exposed to 14 hours at 16 weeks (Morris and Fox, 1958a) matured earlier but laid at a lower rate than birds raised in daylight. Pullets reared in 24 hours of continuous light matured earlier but laid at a lower rate than birds receiving continuous 24-hours of light to 4 months of age and then allowed only daylight (Callenbach, et al., 1944).

PERSISTENCY AND INTENSITY

Persistency is a production trait known to be important to annual yield of eggs (Hays, 1949) but is often ignored during short-term studies or observations. Persistency tends to be inversely related to intensity (Hays, 1949; Ryan *et al.*, 1959; Bray *et al.*, 1960). Birds or flocks exhibiting high intensity egg production may have a tendency to decline in production at a greater rate than those of lower intensity.

Byerly (1957) states that persistency is associated with vernal molt or pause. RIR pullets selected for their high incidence of pause exhibited greater declination of production than the non-pause group, indicating their relative lack of persistence.

Under constant environment and presumably optimal conditions of temperature, humidity, nutrition and light (14 hours daily), pullets approaching sexual maturity reach a maximum rate of egg production quickly. This maximum is not sustained, but is followed by a steady decline in rate in proportion to the elapsed time after first egg (Byerly 1948, 1957). As hens age, production decreases regardless of light treatment (Wilson and Abplanalp, 1956).

It is obvious that intensity and persistency are both desirable for high annual production. The closer the annual average rate (intensity) approaches 365 eggs, the more integrated the trait becomes with persistency.

MOLT AND WINTER PAUSE

Supplementary light in the fall and winter proves to be effective for preventing premature fall or winter molt and the recovery of egg production from birds which have started to molt (Kennard and Chamberlin, 1931; Jordan, 1934;

Bartsch, 1937; Warren *et al.*, 1950). While increased light periods are capable of stimulating reproductive activity in yearling hens which have not finished molting, the progress of the molt is not affected (Jordan, 1934; Riley and Byerly, 1943).

LIGHT INTENSITY

The fact that success in stimulating egg production has so frequently been achieved using a variety of arbitrarily chosen light sources indicated to Yeates (1954) that, within limits, intensity of light and wavelength are relatively unimportant. Luminaries have been devised using wood torches (Castello, 1924), kerosene lanterns (Banta, 1918; Shoup, 1918), gasoline lanterns (Lewis, 1921), natural gas (Waldorf, 1915; Kennard and Chamberlin, 1931), acetylene gas burners (Lewis, 1921), carbon arc (Kable and Fox, 1928; Titus and Nestler, 1935), fluorescent tubes (Wilson and Abplanalp, 1956; Ostrander *et al.*, 1960), incandescent bulbs (Platt, 1953; Wilson and Abplanalp, 1956; Ostrander *et al.*, 1960, and others) and infrared (Rider, 1938).

Light intensities as low as .5 to 1 foot candle at the bird level have been found to be adequate to stimulate egg production (Fairbanks, 1924; Roberts and Carver, 1941; Nicholas *et al.*, 1944; Dobie *et al.*, 1946; Skaller *et al.*, 1954; Ostrander, 1960). Longhouse (1955) was unable to increase the rate of egg production by augmenting light intensity on birds already in production. Whetham (1933) indicated that the amount of light per day is more important than intensity of light in stimulating egg production. Lower production rate was observed by Dakan (1934a, b) when light intensity was reduced to a level that still allowed the birds to see to eat and drink.

There was no increase in egg production from using a photo-electric cell to turn on lights during dark, overcast days for laying hens according to studies by Ostrander (1960). The cost of the photo-electric cell, the installation and the cost of the extra electricity used could not be justified.

Nicholas et al. (1944) found that there was no relationship between light intensity and egg weight.

Light intensity does affect age at maturity. Pinches and Scott (1942) noted that although lights of low intensity may keep hens laying, it will not bring pullets into production. Although the influence of light intensity on maturity is operative over a considerable period of early development, Wilson et al. (1956) found that its influence becomes more pronounced after 90 days of age. Birds receiving the highest light intensity matured the earliest. Lawatsch et al. (1960a) also noted that an environment of subdued light delays maturity.

HEALTH

The early investigators were concerned about the health of hens or pullets forced into unseasonal production through the stimulus of light. Lewis (1921) announced that the results of his experiences implied no ill effects and the hens showed greater resistance to disease. Dougherty (1922) was more cautious in his announcement that light was not harmful, but he did not recommend its use for breeders. Most workers have agreed that there is no difference in mortality among lighted and unlighted birds (Tomhave and Mumford, 1927; Penquite and Thompson, 1933; Payne and Simmons, 1934; Bartsch, 1937; Roberts and Carver, 1941; Callenbach et al., 1944; Nicholas et al., 1944; King, 1958a; Lowe and Heywang, 1961).

A small percent of female chickens in some flocks are incapable of gonadal response to light stimulus. Cole and Hutt (1953) found that from 0.3 to 2.9 percent of the birds of a group studied were apparently normal non-layers. They stated that among pullets over 9 months of age, it is normal to find from 2 to 5 percent that either do not lay at all or lay so sporadically that the accuracy of their records is doubtful.

In another group of birds Hutt et al. (1956) observed that ovarian regression was 8 times more frequent in flocks of the same breeding where artificial lighting of immature pullets was practiced. Of the caged, lighted pullets, 46.1 per cent exhibited ovarian regression compared to 5.5 percent for the unlighted, floor birds.

Continuous light of 2 to 3 fc intensity may adversely affect the eyes of growing chickens (Jensen and Matson, 1957 a,b; Shutze et al., 1959; Shutze et al., 1960, 1961; Lauber et al., 1961). The eyeballs of chickens receiving

24 hours of light from 60-w incandescent lamps from day of hatch developed enlarged eyeballs that were 33 to 38 percent larger than the 12-hour per day controls. The increase in size is the result of greater accumulation of fluid in the vitreous body of the eyes. The lenses are distorted and elongation of the eyeballs occurs, giving a peculiar "slant-eyed" condition. This condition is noted at 8, 10, and 20 weeks of age.

LIGHT AND GROWTH

Young chickens, day-old to 3 or 4 weeks of age need more light than older birds for maximum growth according to Moore (1957a, b) and Wilson *et al.* (1956). They noted that continuous light added to natural illumination favors early growth of chicks up to about 7 weeks of age; however, as they approach 20 weeks, the effects are just the opposite.

There has been some concern about the feeding effect of light on chicks. Jordan (1920) found that if feeding periods were too close, chicks did not feed fully each period. He concluded that feed periods should be timed so that the crop is emptied between each successive period and the feed periods need to be only long enough for the bird to fill the crop again. The dark period should not be so long that the chick becomes excessively hungry between feedings.

Moore (1957b) commented that young birds, given only 6 to 12 hours of light daily, either do not have long enough feeding time or have periods too lengthy between feeding to allow maximum growth. Barott and Pringle (1951) noted that among 13 light regimes, only when one hour of light was followed by as little as two hours of darkness did the young broilers voluntarily fail to eat during each period.

Tuckey *et al*. (1958) determined that for 4-week old New Hampshire pullets the rate of food passage ranges from 1 hour and 18 minutes to 2 hours and 48 minutes. Ewing (1951) reported that as the birds mature, the food passage rate decreases.

Darkness, *per se*, does not adversely affect chickens and pigeons according to Oltramare as quoted by Laurens (1928). The birds kept in total darkness as long as 3 months increased in weight more rapidly than those in light, though receiving the same amount of food.

It has been generally noted that chicks require a great deal of light for maximum growth. When lighted from day-old, 24 hours of artificial light provided greater growth stimulation than exposure to natural daylight (Le-Masurier and Branion, 1939; Heywang, 1944, 1946; Callenbach *et al*., 1944; Kleinpeter and Mixner, 1947; Karapetjan, 1950). Daily artificial photoperiods of 23½ or 24 hours were superior to 12 hours of artificial light in growth stimulation (Hutchinson and Taylor, 1947; Kleinpeter and Mixner, 1947; Jensen and Matson, 1957a; Moore, 1957a,b) and natural daylight was superior to 6, 8, or 12 hours of artificial light (Mueller *et al*., 1951; Sykes, 1956; Marr *et al*., 1957; Skoglund, 1959; Ostrander, 1960).

The reported deviations from the above observations are that growth was not affected differently by artificial photoperiods of 6 hours (Skoglund, 1959), 8 hours (Marr et al., 1960), 16 hours (Lowe and Heywang, 1961) or 17 hours (Morris and Fox, 1961) than by natural daylight. King (1958b) and Fangauf (1959) noted that 6 hours of artificial light effected greater growth than 14 hours of artificial light.

Morris and Fox (1960) noted that change in light may be more important than absolute amounts of light in its effect on growth. Birds grew at a greater rate when exposed to a regime of increasing daylight (7 hr. 44 min. to 14 hr. 20 min.) than a regime of decreasing artificial light (24 hr. to 14 hr. 5 min.).

When chicks were exposed to intermittent light regimes, growth rate progressively increased as photoperiods were shortened, even though daily length of light or ratio of light to dark generally remained the same (Barott and Pringle, 1951; Clegg and Sanford, 1951; Moore, 1957b; Guasco, 1958; Miller and Sanford, 1960; Shutze et al., 1961). Moore (1957b) noted that birds receiving 24, 18 or 12 hours of daily light in one period were retarded in growth. However, Shutze et al. (1961) found that continuous (24-hour) light was superior to intermittent light regimes. Moore found that cycles of 4½ hours or 3 hours of light administered 6 or 4 times daily were superior to other regimes tested. Barott and Pringle (1951) favored one hour of light each 5 hour period.

GROWTH RATE AND REPRODUCTIVE CAPACITY

Fast growth is desirable in broilers to be marketed at

8 to 12 weeks of age, but it does not necessarily follow that pullets for laying flocks should be similarly forced to maximum growth (Lamoreaux, 1958). Hays and Sanborn (1929) studied the question and found that the rate of growth within a flock had no effect on pullet-year egg production. Miller and Sanford (1960) found that when photoperiods effected a difference in growth rate within a flock, the heaviest groups of birds at housing performed the poorest in subsequent production when subjected to uniform photoperiods after housing.

LIGHT AND GLANDULAR STIMULATION

Thyroid

Cruickshank (1929), Galpin (1938) and Reineke and Turner (1945) noted that the thyroid gland weights showed marked seasonal variation, being the greatest in the fall and winter, decreasing in the spring and summer. Reineke and Turner also observed that the thyroid weight and its correlated secretory level were influenced to a great degree by seasonal variations in intensity and duration of sunlight. They concluded that this seasonal rhythm must be mediated by way of the anterior pituitary.

The thyroid weight increases as there are increases in body weight, according to investigations by Cruickshank (1929), Schultze and Turner (1945) and Kleinpeter and Mixner (1947). Schultze and Turner determined that there is an exponential relationship between the thyroid weight and body weight for birds ranging in age from 5 to 26 weeks.

The parameters were different for White Leghorns and White Plymouth Rocks. Odell (1952) and Glazener et al. (1949) observed that the greatest increase in thyroid secretion rate usually occurs during the period of greatest growth (4 to 12 weeks). The studies of Cruickshank (1929) indicate that the thyroid weight is greatest previous to the period of maximum egg production and it decreases during this period.

Galpin's data (1938) indicated a significant difference between thyroid weights of laying and non-laying hens, strongly suggesting an inverse relationship between thyroid size and reproductive activity, irrespective of any dependence upon seasonal temperature and light variations.

The size of the thyroid glands varies considerably depending upon a number of factors, such as season, environmental temperature, diet, age, and functional state. The differences in thyroid weights can normally be assumed to reflect differences in thyrotrophin released from the pituitary (Sturkie, 1954).

The effects of different quantities and qualities of light on thyroid weight and activity have been studied by Kleinpeter and Mixner (1947). Thyroxin secretion rate was not affected appreciably by the quality of light, but was influenced by the amount of light. Birds receiving 24 hours of light had heavier thyroids and higher secretion rates than those receiving 12 hours.

Moreng et al. (1956) observed no difference in thyroid weights for male and female chickens brooded in abundant or limited light regimes.

Nikolaiczuk and Maw (1942) noted that Leghorn cockerels had smaller thyroids and adrenal glands when exposed to direct sunlight than when exposed to subdued window light. There was an age-gland weight interaction. The glands regressed in weight in the age interval between 23 and 30 weeks.

Anterior Pituitary

Domm (1931) and Hill and Parks (1934) were among the first to study the relationship between the hypophysis and the gonadal activity in chickens. That the anterior pituitary plays a dominant role in the gonadal response to light is now well established, but the exact manner in which light affects this gland is still uncertain. The most widely supported theory is that light entering the eye, which acts as a receptor, starts nerve impulses, or stimuli, in the optic system. These impulses are then transmitted via the optic nerve to the brain which in turn sends impulses to the vicinity of the hypothalmus. The transmission to the pituitary is then completed by humoral relay involving the hypophyseal-portal blood vessels. Following stimulation, the anterior pituitary secretes the gonadotropic hormones which regulate the activity of the gonads. (Bissonnette, 1931a, b; Rowan, 1938; Benoit, 1935a, b, and 1938; Benoit *et al.*, 1950).

Jaap (1935) stated that the main differences between the high production layers and poor producers was due to either a difference in gonad-stimulating power of their pituitaries or differences in the ability of their ovaries to respond to equal amounts of pituitary stimulation.

Nikolaiczuk and Maw (1942) noted that the mean pituitary and testes weights of Leghorn cockerels were increased when exposed to direct sunlight on sun porches in contrast to birds confined in pens exposed to subdued window light.

Winchester (1940) has shown that the thyrotrophic secretion of the pituitary of hens is higher in winter than in summer and that the seasonal change in thyroid activity is not wholly a matter of change in environmental temperature, but of light change.

The anterior lobe of the pituitary of chickens is small. Kumaran and Turner (1949) found the anterior lobe of White Plymouth Rock Cockerels to range from 2.6 milligrams at six weeks of age to 9.9 milligrams at 20 weeks of age. Pituitary weights of White Leghorn cockerels at different ages increases steadily with age to about 9 milligrams at 120 days where it levels off (Breneman, 1950). There appears to be no difference in gland weights in normal males and females of comparable body weight at least up to 120 days of age (Oakberg, 1951). He found that at 120 days, White Leghorn females of a mean body weight of 1226 grams had a mean pituitary weight of 8.4 milligrams.

Ovary

Fronda and Marcello (1938) and Bennett (1947) described the relationship between size and age of the gonads in the fowl from the hatching date through sexual maturity. The studies by Fronda and Marcello showed that growth of both the testes and the ovary was gradual from one day of age to four months of age, but from four to eight months of age the growth was very rapid. The mean date of maturity for the birds they described was about six months and peak production occurred at eight months. Bennett noted that the increase in size of left ovaries in White Leghorn pullets proceeded at an increasing rate from one day through 131 days. The mean ovary size at 156 days was only slightly larger than that at 131 days.

Oviduct

The female fowl possesses two oviducts, but normally only the left one is functional (Allen, 1939). During the first four or five months of age, the development of the oviduct is in proportion to that of the body (Kaupp, 1918). However, with the approach of the laying period it undergoes a tremendous hypertrophy, resulting in a considerable increase in size (Domm, 1927). Considerable evidence is available to show that the cyclic growth changes of oviduct are controlled by secretions from the ovary (Goodale, 1916; Domm, 1929).

PERIODIC REGIMES AND PRODUCTION

The use of supplemental light to stimulate winter egg production has been reported by many investigators, but no one has developed a method of lighting that will consistently improve egg production for the entire year over that produced in a natural light environment, (Dougherty, 1917, 1922; Fairbanks, 1924; Kistler, 1924; Brown, 1925; Martin, 1925; Tomhave and Mumford, 1927; Cray, 1929; Kable _et al_., 1928; Parkhurst, 1930; Kennard and Chamberlin, 1931; Penquite and Thompson, 1933; Payne and Simmons, 1934; Ebbell, 1940; Penquite and Thompson, 1940; Roberts and Carver, 1941; Smith, 1942; Callenbach _et al_., 1943; Gutteridge _et al_., 1944; Nicholas _et al_., 1944; Heywang, 1945; Moore and Mehrhof, 1946; Avery, 1950; Warren _et al_., 1950; Fronda, 1951; Eramus, 1955; Moffatt, 1957). The major effect of changing the light environment appears to be the alteration of the time of response.

The use of artificial illumination to supplement the natural hours of light is customarily used by poultrymen during the late fall, winter and early spring so as to provide 13 to 14 hours per day for chickens in production. More than 12 or 13 hours or even 24 hours of light per day do not consistently improve the rate of egg production (Smith, 1930; Kennard and Chamberlin, 1931; Penquite and Thompson, 1940; Weinmiller and Mantel, 1940; Byerly and Moore, 1941; Smith, 1942; Dobie _et al_., 1946; Moore and Mehrhof, 1946; Warren _et al_., 1950; Byerly, 1948, 1957; Hutchinson and Taylor, 1957; Larionov, 1957; Skoglund, 1959; Byan _et al_., 1959; Lanson, 1960).

In an effort to increase the gonadotrophic effect of light over extended periods, poultrymen have resorted to various systems or regimes of light treatments. Intermittent lighting often gives higher egg production than the same amount of continuous light. In 4-week tests, Wilson and Abplanalp (1956) found that intermittent lighting was more effective than continuous lighting in maintaining egg production. Roberts *et al.* (1941) noted that a series of three 1-hour periods of light daily was superior to 7, 9, or 10 hours of uninterrupted daily light in a 28-week test. Wilcox *et al.*, (1960) exposed layers to four light periods per 24 hours, two of 1 hour duration during the daytime and two of 15 minutes each night and compared the egg production results of this regime with a 14-10 hour light-dark cycle. Pullets receiving intermittent light averaged significantly higher production than those receiving 14 hours continuous light. The rate of lay after the initial egg was identical in both systems during the 36-week study.

Results with Juncos and White Throated Sparrows confirm that a long dark period is not inhibitory *per se* and that it may even enhance the effect of a given photoperiod in gonadal stimulation. When responses were compared in photocycles of 12 hours of light, 12 dark to 12 hours of light, 16 dark in different experiments, a more rapid gonadal response occurred with a longer dark period (Wolfson and Winchester, 1959 a, b; Wolfson, 1960). Chickens show greater gonadal responses to photocycles of 14 hours of light and 12 dark than to 14 hours of light and 10 dark (Byerly and Moore, 1941; Biellier, 1960; Biellier and Ostmann, 1960). It appears that darkness enhances the gonadotrophic value of light for chickens (Abplanalp and Wilson, 1960).

Whetham (1933) in her famous paper noted that birds reached their peak in production before the greatest seasonal photoperiod occurs. She theorized that the action of light stimulates, not while held at a constant level but, when the light ration was "stepped up" above that to which the birds had already been conditioned. Birds tend to reach peak production at the time that the greatest positive rate of change in photoperiod occurs. She documented her theory by citing statistics from England, Denmark, Ireland, and Scotland in the period 1911-1931 that chicken egg production peaked in March and April and slacked in November. She also described refractoriness (not by name) in her observations that layers peak in production before the maximum seasonal light is received. Parker and McSpadden (1943) noted a similar refractory phenomenon in male chickens. Spermatogenesis is related to changes in length in day, since the peak in spermatozoa production is reached in April and May and fertility is lower during the period June to November than during December to May.

However, other workers have maintained that absolute length of photoperiods is important. Lamoreaux (1943b) noted that for male chickens, the threshold of response lies between 9 and 12 hours of light and that the maximum response resulted from exposure for 12 hours or more. Dobie _et al._ (1946) found that although ten hours of light was not sufficient to hold high production once it was attained, eleven hours or more was sufficient. Platt (1955) found eight hours of light retarded maturity and egg production and when the light period was changed to 14 hours, the birds reached 80% production within two weeks. Studies by Larionov (1957) indicated that high rates of fecundity can be stimulated with 12 to 14 hour photoperiods. Byerly (1948, 1957) calculated the daily light requirements for Rhode Island Red pullets to be from 7 to 9 hours and the optimum to be 13-14 hours. He noted that there are wide individual differences with respect to minimal daily light periods required for egg production and individual response to change in photoperiod. Sykes (1956) reported that birds given but 6 hours of light matured sexually and laid at the 30 percent level. However, birds reared on 12 hours of light until they were in production, and then given 6 hours of light per day, laid at a still lower rate.

Roberts and Carver (1941) noted that three 1-hour periods of light per day was superior to 10 hours of uninterrupted light of the same intensity (7.5 foot candles) in stimulating egg production in a 28-week test. A 24-hour light period was inferior to 13-, 15-, 17- or 19-hour periods. They found that 13 hours of artificial light per day was the minimum requirement for high producing hens, but 8 hours was below the threshold.

It is difficult to separate the gonadotropic effects of absolute length of photoperiod, change in photoperiod and rate of change. An abrupt change may be infinite in rate and instantaneous. The change can be positive or negative and may be brought about in a decreasing, constant or increasing rate.

As Whetham (1933) pointed out, the rate of egg production of birds, naturally lighted, increases during seasons of increasing daylight in widely separated latitudes. The decline in rate of production begins before maximum daylight is reached and as the photoperiod continues to increase, but at a decreasing rate. It does take several months of the exposure to natural photoperiods that are increasing at increasing rates to stimulate maximum gonadal activity, thereby suggesting the possibility of a threshold response that might be described in absolute photoperiodic terms.

As one goes north from the temperate latitudes there is a general tendency for birds of all kinds to come into production later at a rate of some 20 to 30 days per 10 degrees of latitude (Burger, 1949). At the time of the spring equinox or March 23, the absolute daylength is about the same at sea level at all latitudes but the rate of increase is greater at the higher latitudes than those latitudes closer to the equator. If rate of change were the only factor, then birds at higher latitudes would show a greater and earlier gonadophototrophic response than those at lower latitudes. This is not the common observation for wild birds (Burger, 1949) and it has not been shown to be true for chickens (Whetham, 1933). Whetham noted a slight tendency for peak chicken egg production to occur later in the spring at higher latitudes in both southern and northern hemispheres. This would imply that a threshold response does occur and this threshold is at a level less than the daily photoperiod observed at the spring equinox which is slightly more than 12 hours (sunrise to sunset) in duration at all latitudes.

Any time hens are exposed to reduced photoperiods, production rate decreases, (Hansson, 1930; Fairbanks and Heuser, 1939; Byerly and Moore, 1941; Larionov, 1941b, Hutchinson, 1956; Sykes, 1956; Wilson and Abplanalp, 1956; Hutchinson and Taylor, 1957; Larionov, 1957. When Wilson and Abplanalp (1956) reduced the daily photoperiod to 9 hours or less from 24 hours, reduced egg production resulted regardless of the lighting method, intermittent or continuous. As the production year progresses, the effect of reducing the photoperiods becomes more marked (Sykes, 1956). Hutchinson (1956), Hutchinson and Taylor (1957), gradually reduced the exposure photoperiod over an eight-week period from 23½ hours until 12 hours of light was reached. Production fell and remained lower for several months than for the control group exposed to a stable photoperiod of 12 hours. Fairbanks and Heuser (1939) noted that decreasing photoperiods for layers, whether natural or otherwise, gradual or abrupt, caused slumps in production. These workers concluded that both absolute length and change in length of photoperiods have an effect on egg production but that change is the more important.

Yeats (1954) discusses the general effect of daylight changes on egg production. He recommends that supplementary winter lighting should be increased gradually to augment the day-length rather than to keep it constant, with the idea that an increasing day-length would stimulate highest production. He considers it a poor practice to switch on the winter lighting system at 4 a.m. and allow the photoperiod to decline as dusk occours earlier in the day.

Several intensive studies show that naturally lighted pullets hatched during the late winter or the spring exhibit greater fecundity than those hatched during the other times of the year (Berry and Walker, 1927; Upp and Thompson, 1927; Jeffery and Platt, 1941). These studies also show that pullets hatched in July, August and September were inferior in fecundity. Birds reared under increasing photoperiods will exceed those birds reared under decreasing photoperiods in egg production. Under natural conditions, then, it is advantageous to have the photoperiod decreasing at the time of or soon after sexual maturity takes place.

Under artificial lighting there is evidence that pullets reared under decreasing photoperiods generally outlay their counterparts raised under increasing or stable regimes. Thus it seems to be important that the decreasing regime continues to the time of maturity. If not increasing, it should be stabilized at a level quite below that to be received during the laying period (Sykes, 1956; Marr et al., 1957; King, 1959; McClary, 1960a, b; Morris and Fox, 1960; Lert, 1961). The dissenting evidence is not very strong (Skoglund, 1959; Lowe and Heywang, 1960, 1961; Ostrander, 1960).

Both stepwise and abrupt changes in photoperiod during the growing period have been studied. There seems to be little difference in the laying period effects as to whether the decrease in photoperiod during the growing period takes place gradually or stepwise (McClary, 1960a; Morris and Fox, 1960) or all at once (Marr et al., 1957; Skoglund, 1959; Biellier, 1960; Lert, 1961) during an age range of 8 to 16 weeks.

There seems to be an upper limit of 14 hours or less in absolute length of photoperiod during the later stages of the rearing period for maximum future fecundity (Tomhave, 1954; Ringrose, 1951, 1952; Ringrose and Potter, 1953; Adolph, 1955; Morris and Fox, 1958a; Powell, 1958; Bowman and Archibald, 1959; Lowe and Heywang, 1960, 1961). Several studies indicate that even photoperiods of 12 hours during the growing period may be detrimental (Fanghauf, 1959; King, 1959).

There seems to be an upper limit of 13 or 14 hours for maximum gonadostimulation of the laying hen. In fact, 24-hours of lights early in the laying period may be detrimental (Callenbach et al., 1944; Byan et al., 1959). This maximum tends to limit the amount of light change possible between the growing period and the laying period. Very short photoperiods are required to induce initial egg production and there seems to be a requirement of about 11 to 13 hours to maintain maximum levels of production.

It seems that it is important that the photoperiods be increased, either gradually or abruptly soon after maturity occurs. The magnitude of this change seems to be important, also. The greater the change, the greater the gonadostimulation, within limits. The gonadostimulatory effect of light becomes less as the laying period progresses and the bird becomes less sensitive to the photostimulation (Sykes, 1956; Lowatsch et al., 1960; King, 1958a; Powell, 1958; Fangauf, 1959; King, 1959; Biellier, 1960; Boyce, 1960; Marr et al., 1960; McClary, 1960b; Morris and Fox, 1961).

If the rate of change in photoperiod from the growing period to the laying period is important, is it most advantageous to change it gradually, stepwise, or abruptly, all at once? This comparison was made in several studies. Most of the evidence indicates that gradual increases produce greater fecundity than abrupt increases (King, 1959; Morris and Fox, 1961). However, the dissenting study found considerable advantage to an abrupt increase to 14 hours of daily light over a regime of 6 hours per day plus 15 minutes per day increase each week (Ostander, 1960).

It seems that for the best results, the stepwise increase is best started at about 20 weeks, if 16 or 24 weeks are considered as alternative ages (King, 1959; Skoglund, 1959). Starting with a 6 hour photoperiod, a weekly increase of 18 minutes a day or a weekly increase of 3 percent of the prior week's photoperiod produces greater production than weekly increases of 8 or 28 minutes (King, 1959).

EXPERIMENTAL PROCEDURE

General

The study which is reported in this thesis involved one trial with egg-type pullets conducted at the Oklahoma State University Poultry Farm. A group of 408 sexed, day-old, Hy-Line 934-H pullets was obtained March 17, 1961, for use in this study. The hatchery sexed, dubbed and severely debeaked the chicks before they were delivered. Upon delivery, the birds were individually intranasally vaccinated with Newcastle disease vaccine (B_1 Strain) and infectious bronchitis vaccine.

Upon their arrival, the chicks were placed in a 32 feet square, straw loft brooder house. Litter consisted of about 4 inches of cane bagasse. A disposable cardboard draft shield limited the floor area to that around a natural gas hover brooder for several days. The draft shield was expanded until the fifth day, at which time the chicks were allowed free access to the entire floor area. A second brooder was provided at one week of age to relieve crowding. All artificial heat was discontinued at 6 weeks of age.

Feed was fed in six 4-feet long troughs, open from both sides. Water was offered from gallon fountains for two weeks, then was given in one 8-feet long automatic, float-valve trough and one float-valve, round pan. A series of rations was designed by the nutrition section of the Oklahoma State University Poultry Department for use in this project. The rations were designed to incorporate some of the latest available nutritional information, yet holding cost within a reasonable range. The ration formulii are found in tables I, II, III, and IV. One-thousand pounds of ration number 1 was fed followed by 4,000 pounds of ration number 2. Ration number 3 was fed until the birds were about 21 weeks of age and then followed by ration number 4.

The coccidiostat Trithiadol was fed at the 0.1 percent level until July 19, when Glycamide was substituted at the same level in the feed.

The birds were exposed to daylight entering the windows of the house plus supplementary 24-hours of light from one 60-watt incandescent light suspended 7 feet from the floor at the center of the house. The daily period from sunrise to sunset increased from about 12 hours, March 17, to 13 hours 35 minutes at the time the birds were 8 weeks of age.

This initial period was concluded when the birds were eight weeks old. All pullets were then weighed, wingbanded, wing-web vaccinated for fowl pox and Newcastle disease and placed at random in 12 pens. Each 6' x 16' pen housed 32 or 33 pullets. Light was excluded from 10 of the pens with opaque plastic film. The windows of the two remaining pens were covered with transparent plastic, allowing daylight illumination.

TABLE I

Pullet Starter No. 1

	Pounds
Ground Corn	26
Ground Milo	22
Oat Mill Feed	6
Alfalfa Meal (17% protein)	2.5
Blood Meal	3
Fish Meal (70% protein)	10
Soybean Meal (50% protein)	10
Dried Fish Solubles	3
Live Yeast Culture	3
Distillers Solubles (C.F.S. #3)	3
Fluidized Pex	2
Di Calcium Phosphate	2
Vitamin Concentrate VMC-60	1
Vitamin Concentrate VC-60-A	0.25
Salt	0.5
Fat (Tallow)	5
Lecithin	0.5
Trithiadol	0.1
DL Methionine	0.25
	100.10

TABLE II

Pullet Starter No. 2

	Pounds
Ground Corn	20
Ground Milo	22
Oat Mill Feed	12
Alfalfa Meal (17% protein)	2.5
Blood Meal	3
Fish Meal (70% protein)	10
Soybean Meal (50% protein)	10
Dried Fish Solubles	3
Live Yeast Culture	3
Distillers Solubles (C.F.S. #3)	3
Fluidized Fex	2
Di Calcium Carbonate	2
Vitamin Concentrate VMC-60	1
Vitamin Concentrate VC-60-A	0.25
Salt	0.5
Fat (Tallow)	5
Lecithin	0.5
Trithiadol	0.1
DL Methionine	0.25
	100.10

TABLE III

Pullet Grower No. 1

	Pounds
Ground Corn	23
Ground Milo	22
Oat Mill Feed	12
Alfalfa Meal (17% protein)	2.5
Fish Meal (70% protein)	10
Soybean Meal (50% protein)	10
Dried Fish Solubles	3
Live Yeast Culture	3
Distillers Solubles (C.F.S. #3)	3
Fluidized Pex	2
Di Calcium Phosphate	2
Vitamin Concentrate VMC-60	0.5
Salt	0.5
Fat (Tallow)	5
Lecithin	0.25
DL Methionine	0.25
TM-10	0.5
Baciferm	0.5
Vitamin A (30,000)	(60 gm.)
Vitamin D (30,000)	(6.8 gm.)
Trithiadol*	0.1
	101.08

*Changed to Glycamide, 0.1 lb., August 19, 1961

TABLE IV

Pullet Grower No. 2

	Pounds
Ground Corn	29
Ground Milo	22
Oat Hulls	8
Alfalfa Meal (17% protein)	2.5
Fish Meal (74% protein)	4
Soybean Meal (50% protein)	10
Dried Fish Solubles	3
Fluidized Pex	2
Dried Brewers Yeast	3
CFS #3	3
Calcium Carbonate	4
Di-Cal, Phos.	3
Vitamin Mineral Conc. (VMC-60)	1
Salt	.5
Lecithin	0.25
dl-Methionine	0.25
Fat (tallow)	5
	100.6

Each pen was ventilated by forced draft. Six squirrel-cage blowers provided the movement of air into the pens, each blower forcing air through a system of ducts into two pens. The air was then exhausted through the straw loft and out the louvered ends of the building. Ventilation was provided continuously except during brief periods of power failure, motor failure or during motor or blower maintenance and repair.

Each pen was provided with about 4 inches litter composed of cane bagasse. The equipment in each pen consisted of two, 50-pound capacity, tube feeders suspended at a height so that the pan edges were level with the birds' backs. Fresh water flowed continuously through one, 4-inch cup waterer in each pen. At night birds roosted on the jump boards of the 15-hole, trap nests and the screened stand by the water fountain.

The six light treatments, replicated twice, were assigned completely at random to the 12 pens. All artificial light was controlled by electric time clocks and switches. Each of the artificially lighted pens had one 40-watt incandescent bulb and 8-inch shallow aluminum reflector suspended about 7 feet above the litter in the center of the pen. No supplementary artificial light was provided for the pens receiving daylight treatments at any time during the period from 8 to 25 weeks.

There seems to be no accurate way to describe the intensity of artificial light in the pens that would be meaningful. The light striking the bird is a combination of incident and reflected light radiated from the light source. Intensities vary depending on bird posture, direction faced, distance from the lamp, etc. The intensity at any given point in the pen changes as dust and dirt collect on the bulb surface, reflector, walls, ceiling and floor or as the dust or dirt is disturbed. Bulbs age and decrease their emission energy as they burn. Unless the lamps are all on the same circuit, they will vary in intensities due to differentials in input energy (Weitz, 1956; Staley, 1960).

Photometers are usually designed to measure light relative to the sensitivity of the human eye for wavelengths in the visual range. The generally accepted or standard light source is a tungsten filament lamp operating at 2,700-3,400° K. The meters read high in sunlight so a multiplying correction factor of .8 or .7 must be applied to obtain a correct fc figure for daylight measurements (Staley, 1960). The visual sensitivity spectrum for humans and similarly for chickens differs from the gonadotrophic spectrum for chickens (Farner, 1961) so it can be expected that these same photometers are biased in their measurements of light relative to requirements of poultry for gonad stimulation. Until these gonadotrophic requirements are determined, no meaningful correction factors can be applied. Carson et al., (1958) commented that the best means at hand for evaluating the amount of light available during an experiment is to merely describe the lighting units, the pen size and the character of the surfaces.

The two pens receiving daylight treatments were exposed to natural solar radiation. When the birds were housed at 8 weeks, the day length from sunrise to sunset was about 13 hours and 35 minutes and was increasing. At the time of the June solstice the day-length had increased to about 14 hours and 31 minutes. By the time the birds were 25 weeks old, the length of day had decreased to about 12 hours and 40 minutes. The following Table V cites the day lengths of selected days during the experimental period. All times are given for sea level at 35° north latitude. Dawn and twilight are defined as that time when the brightest stars are visible and the horizon is clearly defined (U. S. Naval Observatory, 1959).

TABLE V

Approximate daylight exposure (hours and minutes) on selected days for birds receiving the natural daylight treatment

Age of pullets (wks.)	Date (1961)	Day length-- sunrise to sunset		Day length-- dawn to twilight	
		hrs.	min.	hrs.	min.
0	March 17	12	01	13	11
8	May 12	13	35	14	51
Summer solstice	June 22	14	31	15	30
20	August 4	13	48	14	24
25	Sept. 8	12	40	13	31

During the period from 8 to 20 weeks of age, six treatments with two replications per treatment were made:

1. 6 hours of artificial light and 18 hours darkness
2. 8 hours of artificial light and 18 hours darkness
3. 10 hours of artificial light and 18 hours darkness
4. 12 hours of artificial light and 18 hours darkness
5. 24 hours of artificial light and 18 hours darkness
6. Natural light with no artificial lighting

During the period, 8 to 20 weeks of age, the following measurements and observations were made:

1. Individual body weight in ounces at weekly intervals.
2. Feed consumption per pen at weekly intervals
3. Mortality, recorded as it occurred
4. Eggs, identified by bird and pen, and individual egg weight in grams
5. Pituitary, thyroid, oviduct, ovary and eyeball weights on a sample of birds at the end of 20 weeks of age.

At the end of the twentieth week all birds were weighed as usual. Of the birds still living in each pen, 2 birds were randomly assigned to and placed in each of the 12 pens. Those not so assigned were removed and sacrificed as sample birds for measurements of pituitary, thyroid, ovary, oviduct and eyeball weights.

Birds were killed by breaking the necks and were not allowed to bleed freely. When reflexive movements stopped, heads were severed, placed in a locker at 0° F.

Thyroids, ovaries and left oviducts were removed, cleaned of fat and extraneous tissue and weighed. Within a week, the eyeballs and pituitaries were removed from the heads and also weighed. Ovary, thyroid and eyeball weights were taken as the sum of the weight of those found in individual birds.

A total of 288 pullets in the 12 pens (24 birds per pen) were exposed to the second treatment period. The light regimes from 20 to 25 weeks of age involved the following treatments with two replications per treatment:

1. 6 hours of artificial light per day during the twenty-first week with an increase of 18 minutes each week thereafter
2. 7 hours of artificial light followed by 5 hours of darkness with each period being repeated twice each 24 hour period
3. 14 hours of artificial light followed by 10 hours of darkness
4. 18 hours of artificial light followed by 6 hours of darkness
5. 24 hours of artificial light with no dark period
6. Natural daylight and darkness with no supplementary artificial light

The following measurements were taken during the period from 20 to 25 weeks of age:

1. Individual daily egg production and egg weight
2. Mortality as it occurred
3. Feed consumption per pen per week

4. Individual body weight per week

Statistical analysis of the experimental data was made according to the methods described by Steele and Torrie (1960). Most of the data was transferred to IBM cards and computations were then made utilizing the IBM equipment of the Oklahoma State University Statistical Laboratory.

RESULTS

GROWTH

The effect of several light regimes on growth during the period of age from 8 to 20 weeks is shown in Table I. Observations for all treatments during the 12 weeks period were made on the same group of birds. The 20-week weights were greater for treatments receiving 10 and 24 hours of artificial light per day, the 6-hour and 8-hour photoperiods showed the lowest 20-week weights and the 12-hour and daylight treatments were intermediate in growth effect. An analysis of variance of the weekly body weights showed significant differences in weeks, treatments and weeks by treatment interactions. All were significant at the .005 confidence level (Table II). A Student-Newman-Keul's multiple range test at the .01 confidence level showed that unless a one-in-a-hundred chance had occurred, the mean body weights for treatments of 6 hours and 8 hours were different than 10 and 24 hours. Treatments of 10 hours, 12 hours, 24 hours and daylight effected no difference in body weights, and the response to 6 hours, 8 hours, 12 hours and natural daylight were also shown not to be different (Table III).

In order to remove the effect of variations due to differences in initial weights, mean gains for the 12-week period were computed. No week-to-week carryover effects are possible with this analytical approach, giving strength to

TABLE I

Mean Body Weight (oz.), Treatment by Week, 8 to 20 Weeks

Weeks	Treatments					
	6-hr.	8-hr.	10-hr.	12-hr.	24-hr.	daylight
8	25.5	25.6	25.1	25.5	25.2	25.3
9	28.1	28.1	29.1	28.4	28.9	28.7
10	31.9	32.1	32.7	32.3	32.6	32.3
11	34.9	35.4	35.1	35.5	35.3	34.9
12	38.1	38.2	38.4	37.6	38.3	37.7
13	40.3	40.0	40.0	39.3	40.7	40.2
14	40.7	39.2	41.2	40.8	40.1	40.6
15	42.4	41.3	43.7	43.0	43.4	42.7
16	42.5	42.7	43.5	43.0	44.1	42.7
17	44.1	45.0	45.8	45.5	46.2	45.2
18	45.3	45.5	48.1	46.3	47.8	46.8
19	46.1	46.1	50.2	47.5	50.1	48.6
20	46.2	46.4	51.5	48.4	51.8	50.4

TABLE II

Analysis of Variance on Weekly Body Weight Means
8 to 20 Weeks

Source of Variation	d.f.	M.S.	F	
Weeks	12	668.13	761.4	P .005
Treatments	5	11.15	12.71	P .005
Weeks X Treatments	60	1.365	6.50	P .005
Pens in Treatments	6	0.8775		
Pens by Weeks in Treatments	72	0.2101		

TABLE III

Student-Newman-Keul's multiple range test,
.01 confidence level, of mean of weekly body weights,
8 to 20 weeks

Treatment	8-hr.	6-hr.	12-hr.	daylight	24-hr.	10-hr.
Ranked means*	38.88	38.92	39.45	39.70	40.35	40.37

* Any two means underscored by the same line are not significantly different

the validity of the analysis. Using pens in treatments as the error mean square, the analysis of variance showed treatment differences at the .005 confidence level (Table IV). A Student-Newman-Keul's multiple range test at the .01 confidence level indicated that the treatments of 10 hours, 24 hours, and daylight, although not different from each other, were superior in stimulating gains in body weight to the other treatments. The treatments of 6 hours and 8 hours were inferior in stimulating gains to all other treatments and 12 hours was intermediate in its effects. (Table V).

There were little treatment differences in weights and gains during the period from 8 to 12 weeks, but by 18 weeks the superior weights for the 10-hour, 24-hour and daylight treatments started to show up. The gains for the increasing 6-hour and the 8-hour treatments decreased at an increasing rate during the 18 to 20 week period. (Figure I)

When the birds were rerandomized at 20 weeks, it was apparent that the smaller birds were designated for slaughter and the larger birds of the experiment were placed in the laying pens (Figures I and II). It is also apparent that there were treatment differences at 20 weeks after the birds were reassigned (Table VI and Figure II). Therefore, it was considered very pertinent to analyze the gains due to treatments during 20 to 25 weeks. The gains in body weight proved to be significant at the .01 confidence level for that period (Table VII). A Student-Newman-Keul's multiple range test indicated that the 18-hour treatment was

TABLE IV

Analysis of Variance on Total Body Weight gain, 8 to 20 Weeks

Source of Variation	d.f.	M.S.	F	
Treatments	5	14.390	77.78	P .005
Pens in Treatments	6	0.185		

TABLE V

Student-Newman-Keul's multiple range test, .01 confidence level, of mean body weight gain, 8 to 20 weeks

Treatment	6-hr.	8-hr.	12-hr.	daylight	10-hr.	24-hr.
Ranked Means* (oz.)	20.66	20.81	22.97	25.06	26.44	26.63

*Any two means underscored by the same line are not significantly different

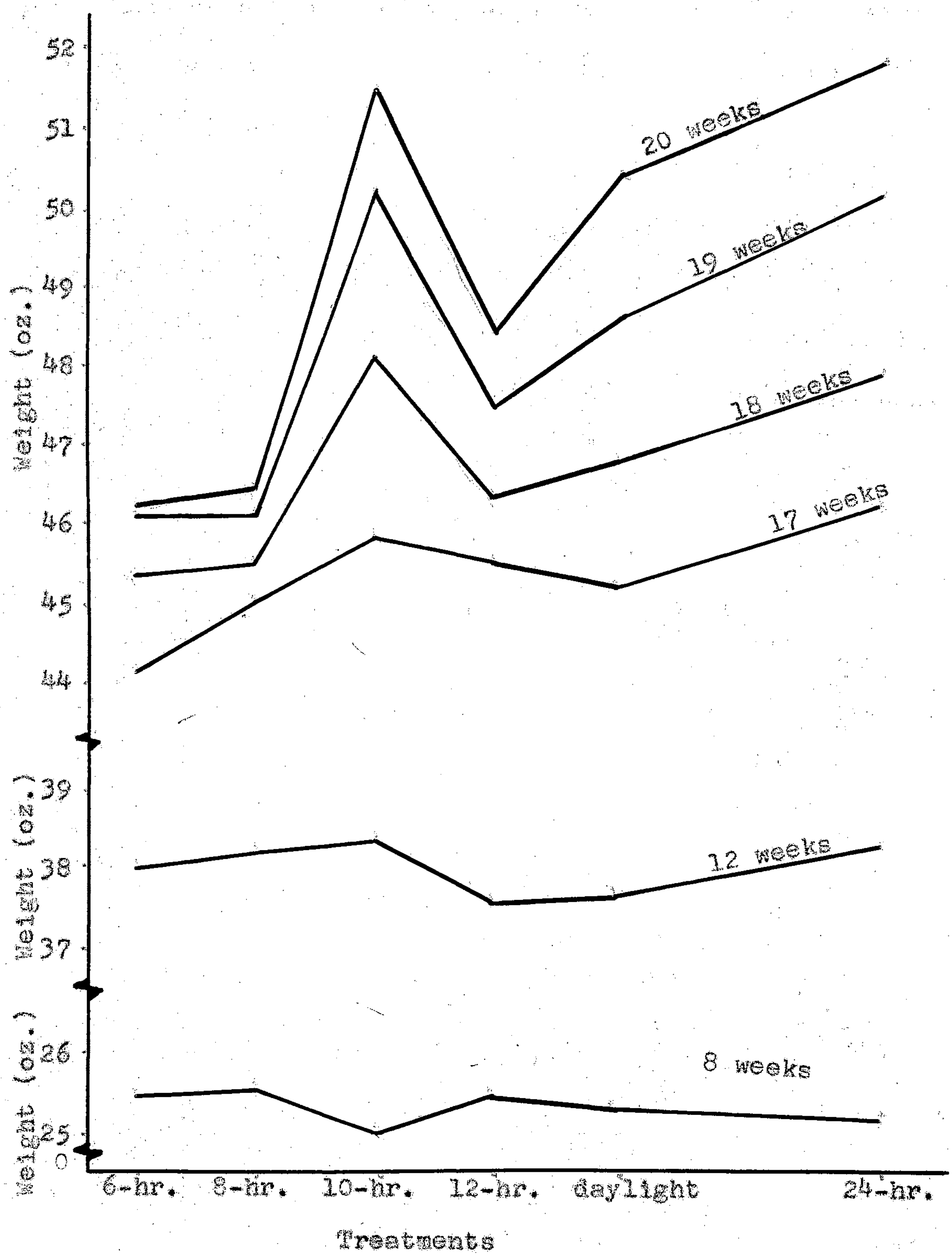

FIGURE I. Mean Body Weight By Treatment For Selected Weeks

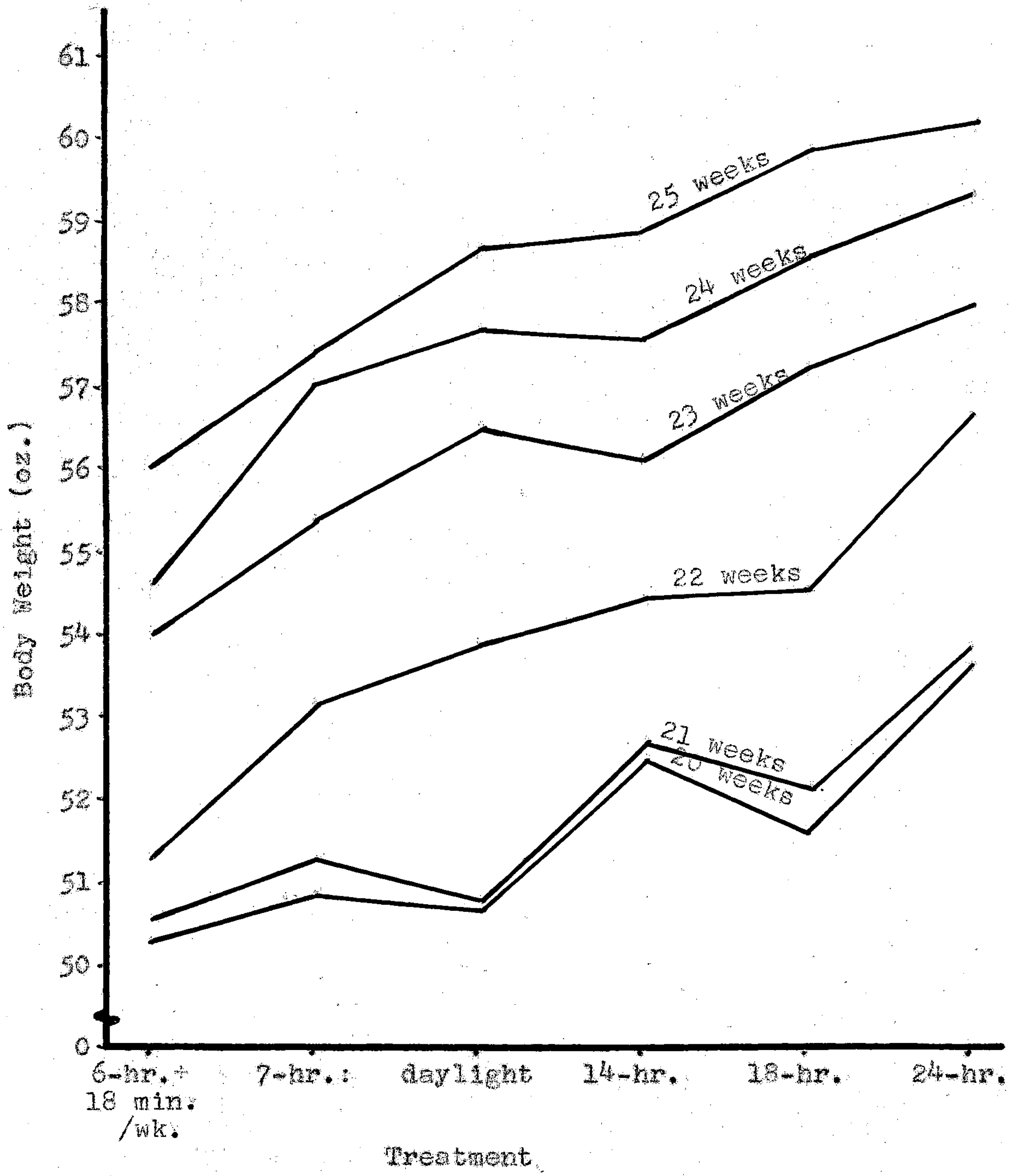

FIGURE II. Mean Body Weight By Treatment, 21 to 25 Weeks

TABLE VI

Mean Body Weight (oz.),
Treatments by Week,
20 to 25 Weeks

Week	Treatments					
	6-hr.+ 18 min./wk.	7-hr: 5-hr	14-hr.	18-hr.	24-hr.	daylight
20	50.4	50.9	52.5	51.6	53.7	50.7
21	50.6	51.4	52.7	52.2	54.0	50.8
22	51.4	53.2	54.5	55.0	56.7	53.9
23	54.1	55.6	56.2	57.5	58.0	56.5
24	54.6	57.1	57.7	58.5	59.5	57.7
25	56.1	57.6	58.9	59.9	60.2	58.8
overall mean	53.4	55.0	56.0	56.6	57.7	55.5

TABLE VII

Analysis of Variance on Mean Body Weight Gain,
20 to 25 Weeks

Source of Variation	d.f.	M.S.	F	
Treatment	5	12.031	12.43	P .01
Pens in treatment	6	0.968		

significantly superior to all other treatments except the 7-hour: 5-hour treatment. The 7-hour: 5-hour treatment effect was not different than any other treatment (Table VIII).

Growth rate was greatly affected by the process of re-randomizing and moving the birds at 20 weeks. The gains made during the 21st weeks were a great deal less than those made during the 22nd and 25th weeks (Table VI and Figure II). No such diminution of gains was observed when the birds were placed under the 8 to 20 week treatments (Table I and Figure I). It appears that these birds were affected more by the process of moving them from one pen or house to another at 20 weeks than at 8 weeks, as reflected by gains in body weight the following week.

The overall mean henday feed consumption was calculated for each week during the 9th through the 20th week (Table IX). It was also determined by treatment for the period (Table X). An analysis of variance indicated no significant variations due to weeks, treatments or interactions of weeks and treatments (Table XI).

To determine the relationship, if any, of the body weight gains to feed consumption, overall feed efficiency was calculated by treatments (Table XII) and by weeks (Table XIII) for the 9th through the 20th week. There was a significant variation among weeks at the .05 confidence level, tending to decrease with time, and a significant variation among treatments at the .10 confidence level (Table XIV). The treatments of 6 hours, 8 hours and 12 hours effected

TABLE VIII

Student-Newman-Keul's Multiple Range Test, .01 Confidence Level, of Mean Body Weight Gain, 20 to 25 Weeks

Treatment	14-hr.	6-hr. + 18 min. /wk.	24-hr.	day-light	7-hr. : 5-hr.	18-hr.
Ranked Means* (oz.)	7.38	7.67	8.39	8.45	11.10	13.67

* Any two means underscored by the same line are not significantly different

TABLE IX

Overall Mean Henday Feed Consumption By Week, 9 to 20 Weeks

Week	Feed Consumption (lb.)	Week	Feed Consumption (lb.)
9	0.1058	15	0.1351
10	0.1296	16	0.1222
11	0.1334	17	0.1432
12	0.1327	18	0.1410
13	0.1341	19	0.1438
14	0.1340	20	0.1308

TABLE X

Overall Mean Henday Feed Consumption By Treatment, 9 to 20 Weeks

Treatment	Feed Consumption (lb.)	Treatment	Feed Consumption (lb.)
6-hr.	0.1214	12-hr.	0.1348
10-hr.	0.1278	8-hr.	0.1353
Daylight	0.1319	24-hr.	0.1416

TABLE XI

Analysis of Variance on Weekly Feed Consumption Means, 9 to 20 Weeks

Source of Variation	d.f.	M.S.	F
Weeks	11	0.1257	0.9549
Treatments	5	0.1161	0.8818
Weeks X Treatments	55	0.2226	0.0016
Pens in Treatments	6	0.1316	
Pens by Weeks in Treatments	66	0.1424	

TABLE XII

Overall Mean Feed Efficiency* By Treatment
9 to 20 Weeks

Treatment	Feed Efficiency	Treatment	Feed Efficiency
8-hr.	0.1265	daylight	0.1428
12-hr.	0.1315	24-hr.	0.1444
6-hr.	0.1328	10-hr.	0.1638

*Pounds of gain per pound of eed onsumed

TABLE XIII

Overall Mean Feed Efficiency* By Week,
9 to 20 Weeks

Week	Feed Efficiency	Week	Feed Efficiency
9	0.2761	15	0.1519
10	0.2628	16	0.0403
11	0.1927	17	0.1373
12	0.1956	18	0.0862
13	0.1398	19	0.0915
14	0.0358	20	0.0732

* Pounds of gain per pound of eed onsumed

lower feed efficiency than 10 hours, 24 hours and daylight.

Feed consumption and feed efficiency data were obtained for the twenty-first through the twenty-fifth weeks by treatments (Table XV) and by weeks (Table XVI). The variations due to treatments were not statistically significant for feed consumption (Table XVII) but were significant at the .10 confidence level for feed efficiency (Table XVIII). There were significant weekly increases in feed consumption during the twenty-first through the twenty-fifth weeks, at the .10 confidence level. Variations due to weeks were highly significant for feed efficiency during the same period. Feed efficiency decreased steadily from 0.1698 to 0.0464, the change being significant at the .005 confidence level.

TABLE XIV

Analysis of Variance on Weekly Feed Efficiency, 9 to 20 Weeks

Source of Variation	d.f.	M.S.	F	
Week	11	0.07647	6.01	P .05
Treatment	5	0.00430	3.38	P .10
Week X Treatment	55	0.00239	1.24	
Pens in Treatment	6	0.00127		
Pen X Week in Treatment	66	0.00194		

TABLE XV

Overall Mean Feed Consumption and Feed Efficiency* By Treatment, 21 to 25 Weeks

Treatment	Henday Feed Consumption (lb.)	Feed Efficiency
6-hr.+18 min./wk.	0.1846	0.0710
7-hr.: 5 hr.	0.1886	0.1288
14-hr.	0.1704	0.0743
18-hr.	0.1787	0.1450
24-hr.	0.1986	0.0830
Daylight	0.1527	0.1035

*Pounds of gain per pound of feed consumed

TABLE XVI

Overall Mean Henday Feed Consumption And
Feed Efficiency* By Week, 21 to 25 Weeks

Week	Feed Consumption (lb.)	Feed Efficiency
21	0.1501	0.1698
22	0.1684	0.1189
23	0.1796	0.1125
24	0.1943	0.0570
25	0.2024	0.0464

* Pounds of gain per pounds of feed consumed

TABLE XVII

Analysis of Variance on Weekly Feed Consumption,
21 to 25 Weeks

Source of Variation	d.f.	M.S.	F	
Week	4	0.5182	4.216	P .10
Treatment	5	0.2550	2.075	
Weeks by treatment	20	.4111	0.765	
Pens in treatment	6	.1229		
Pens by weeks in treatment	24	.536998		

TABLE XVIII

Analysis of Variance on Weekly Feed Efficiency, 21 to 25 Weeks

Source of Variation	d.f.	M.S.	F	
Week	4	0.03032	12.44	P .005
Treatment	5	0.00930	3.82	P .10
Week X Treatment	20	0.00929	5.03	P .005
Pens in Treatment	6	0.00244		
Pens X Weeks in Treatment	24	0.00185		

GLANDULAR WEIGHTS

At 20 weeks of age all but 24 birds per pen or treatment replicate were slaughtered and the thyroid and pituitary glands, the oviduct, ovaries and the eyeballs were weighed (Table XIX). The variations due to treatments were analyzed with no significance being observed for any of the glands or organs (Table XX). An attempt was made to remove the effect of body size, and the treatment means of glandular weights were adjusted for the body sizes (Table XXI). It became apparent that because body weights were not independent of the treatments, an analysis of covariance was not valid.

EGG PRODUCTION

Because so many of the eggs could not be identified by individual bird, several different measures of treatment effect on maturity were made. Before the birds were placed in the laying pens, 5 eggs were laid, 2 eggs in each of the pens receiving 24 hours of artificial light and one in a pen receiving daylight.

Maturity was measured during the 21-to 25-week period by days of age to 10 percent, 25 percent, 50 percent, and 75 percent production, calculated from the first day of the first two consecutive days that had a mean equal to or greater than the production level in question. (Table XXII).

TABLE XIX

Mean Weight of Selected Glands and Organs of Birds
Sacrificed At 20 Weeks

Treatment	Glands				
	Thyroid* (mgm.)	Ovary** (gm.)	Oviduct (gm.)	Pituitary (mgm.)	Eyeball* (gm.)
6-hr.	57.01	0.63	0.75	7.29	2.14
8-hr.	61.82	0.57	1.20	7.28	2.09
10-hr.	59.80	3.61	8.95	8.05	2.02
12-hr.	59.05	0.78	5.02	7.20	2.04
daylight	64.87	2.89	12.01	8.54	1.99
24-hr.	62.64	9.09	10.32	9.38	2.04

* Mean weight of left and right thyroids and eyeballs

** Total weight of left and right ovaries per bird

TABLE XX

Analysis of Variance on Body Weights
and Selected Glands and Organs of Birds Sacrificed
At 20 Weeks of Age

Source of variation	d.f.	Body wt.	Thyroids	Ovaries	Oviduct	Pituitary	Eyeballs
				(Mean Squares)			
Treatments	5	69.15	390.17	144.81	261.58	10.081	0.1466
Pens in treatments	6	22.90	536.43	38.47	173.82	6.769	0.0415
Birds in pens		21.46	722.02	44.02	53.02	2.790	0.0678
Birds in pens d.f.		62	59	62	62	62	61

TABLE XXI

Mean Weight of Selected Glands and Organs, Adjusted for Body Weight, of Birds Sacrificed at 20 Weeks

	Glands				
Treatment	Thyroid (mgm.)	Ovary (gm.)	Oviduct (gm.)	Pituitary (mgm.)	Eyeball (gm.)
6-hr.	61.20	0.85	0.75	8.32	2.18
8-hr.	64.98	0.77	1.21	8.31	2.12
10-hr.	55.68	2.49	8.94	9.14	1.99
12-hr.	59.48	0.86	5.03	8.25	2.06
daylight	63.04	2.79	12.01	9.61	1.98
24-hr.	60.12	8.95	10.32	10.46	2.02

TABLE XXII

Age in Days at Selected Levels of Production

Treatment and Replication	Level of Production			
	10%	25%	50%	75%
Daylight				
1	151	155	162	170
2	154	158	163	172
6-hr.+18 min./wk.				
1	153	162	---*	---*
2	155	163	---*	---*
14-hr.				
1	149	151	166	171
2	149	156	166	170
18-hr.				
1	152	156	159	172
2	148	154	164	173
24-hr.				
1	147	157	169	---*
2	152	155	167	171
7-hr:5-hr.				
1	151	157	164	171
2	151	159	165	---*

*The Indicated production rate was not achieved by 175 days of age.

For instance, if a pen of 24 birds laid 2 eggs at 151 days of age and 3 eggs at 152 days, the mean production for the 2 days would be 2.4 eggs or slightly greater than 10 percent production. Assuming that this was the first time that the mean of the production of 2 consecutive days reached this level, then the pen in question was considered to have reached 10 percent production at 151 days of age.

No significant variation between pens was noted at age of 10 percent production (Table XXIII), but a .05 confidence level of significance was noted at 25 percent production (Table XXIV). A Student-Newman-Keul's multiple range test showed that the 14-hour treatment stimulated earlier age at 25 percent production than the increasing 6-hour regime, but not significantly earlier than the other treatments (Table XXV). No further comparisons could be made because both replications of the increasing 6-hour regime had not reached 50 or 75 percent production at the end of the 25th week and one replication each of the 7-hour: 5-hour and the 24-hour treatments failed to reach 75 percent production.

Another measure of maturity was made by considering the overall egg production. Only one bird had died among all treatments and she died the first day of the 21st week, so the egg production for that one pen was corrected by the factor 24/23. The overall egg production was calculated by weeks (Table XXVI) and by treatments (Table XXVII). Significant variations were observed among weeks and by treatment-week interactions at the .005 confidence level.

TABLE XXIII

Analysis of Variance on Age at 10 Percent Production

Source of Variation	d.f.	M.S.	F
Treatment	5	7.4	1.64
Pens in treatment	6	4.5	

TABLE XXIV

Analysis of Variance on Age at 25 Percent Production

Source of Variation	d.f.	M.S.	F	
Treatment	5	19.50	5.45	P .05
Pens in treatment	6	3.58		

TABLE XXV

Student-Newman-Keul's Multiple Range Test, .05 Confidence Level, Age at 25 Percent Production

Treatment	14-hr.	18-hr.	24-hr.	day-light	7-hr.: 5-hr.	6-hr.+ 18 min./wk.
Ranked means	153.5	155.0	156.0	156.5	158.0	162.5

*Any two means underscored by the same line are not significantly different.

TABLE XXVI

Overall Egg Production By Weeks, 21 to 25 Weeks

Week	Eggs	Week	Eggs
21	2.78	24	82.02
22	17.16	25	105.68
23	46.91		

TABLE XXVII

Student-Newman-Keul's Multiple Range Test on Weekly Egg Production Mean, 21 to 25 Weeks, at .01 Confidence Level

Treatment	6-hr.+ 18 min. /wk.	7-hr.: 5-hr.	14-hr.	24-hr.	day-light	18-hr.
Ranked means* (eggs)	29.0	50.7	53.8	54.0	56.0	62.0

* Any two means underscored by the same line are not significantly different.

Treatment variations were significant at the .01 level (Table XXVIII). Student-Newman-Keul's multiple range test indicated that the increasing 6-hour regime was inferior to all other treatments in stimulating total production to 25 weeks.

When an analysis of variance was made on the total egg production at the 25th week, the confidence level of .01 on significant treatment variation was also observed (Table XXIX). Student-Newman-Keul's multiple range test showed the same relationship as before, that the increasing 6-hour regime was inferior in stimulating egg production as compared with the other treatments the 25th week (Table XXX).

Mean egg weights were obtained per treatment for the 25th week and it appeared that daylight and increasing 6-hour regimes had depressing effects on egg size (Table XXXI). However, when an analysis of variance was made, no significant treatment differences were found to exist. (Table XXXII). No double-yolk eggs were included when mean egg weights were calculated, but their numbers were included in egg production analysis.

It was observed that during the period ending with the 25th week, all eggs weighing 57 grams or more were double-yolk eggs. It was desirable to determine the relationship, if any, between treatments and the percent of double-yolk eggs produced. A steady increase in production of double-yolk eggs was observed as the treatments were considered in the order, 18-hours, increasing 6 hours,

TABLE XXVIII

Analysis of Variance on Mean Egg Production Per Week, 21 to 25 Weeks

Source of Variation	d.f.	M.S.	F		
Week	4	22,321.3	185.24	P	.005
Treatment	5	1,293.3	10.73	P	.01
Week X Treatment	20	221.8	4.20	P	.005
Pens in Treatment	6	120.5			
Pens X Weeks in Treatment	24	52.9			

TABLE XXIX

Analysis of Variance on Total Egg Production, 25th Week

Source of Variation	d.f.	M.S.	F		
Treatment	5	1,128.90	11.10	P	.01
Pens in treatment	6	101.72			

TABLE XXX

Student-Newman-Keul's Multiple Range Test, .01 Confidence Level of Total Egg Production, 25th Week

Treatment	6-hr.+ 18 min. /wk.	7-hr.: 5-hr.	14-hr.	24-hr.	day light	18-hr.
Ranked Means*	59.0	108.5	109.1	114.0	120.0	124.5

* Any two means underscored by the same lines are not significantly different

TABLE XXXI

Mean Egg Weight* 25th Week

Treatment	Mean Egg Weight (gm.)	Treatment	Mean Egg Weight (gm.)
Daylight	44.64	14-hr.	46.30
6-hr.+18 min. /wk.	45.50	7-hr.:5-hr.	46.36
18-hr.	46.16	24-hr.	46.98

* Double-yolk eggs removed

TABLE XXXII

Analysis of Variance on Mean Egg Weights*, 25th Week

Source of Variation	d.f.	M.S.	F
Treatment	5	845.37	1.00
Pens in treatment	6	844.53	

* Double-yolk eggs removed

7 hours: 5 hours, daylight, 24 hours and 14 hours (Table XXXIII). But because of the high variation among pens in treatments, the relationship was not significant (Table XXXIV).

Commercially, the incidence of floor-laid eggs is important because of the labor involved. Floor-laid eggs were undesirable in this experiment in that the producers of the eggs could be identified by pen only and not by birds. The percentage of unidentified eggs produced per pen, in terms of percent of the number of eggs produced in those pens the 25th week, was calculated (Table XXXV). There was a great increase in the production of these eggs as the treatments were considered in the order, 18 hours, daylight, 7 hours: 5 hours, 14 hours, 24 hours and increasing 6 hours. However, these relationships did not prove to be significant (Table XXXVI).

TABLE XXXIII

Double-Yolk Eggs as Percent of Treatment Production, 21 to 25 Weeks

Treatment	Percent production Double-yolk eggs
18-hr.	0.97
6-hr.+18 min./wk.	1.03
7-hr.:5-hr.	1.38
daylight	1.45
24-hr.	1.85
14-hr.	2.28

TABLE XXXIV

Analysis of Variance on Percent of Double-Yolk Eggs Laid, 21 to 25 Weeks

Source of Variation	d.f.	M.S.	F
Treatment	5	0.4997	0.619
Pens in treatment	6	0.8071	

TABLE XXXV

Percent Unidentified Eggs Produced Per Pen and Overall Weighted Mean by Treatments, 25th Week

	Treatment					
	18-hr.	day light	7-hr.: 5-hr.	14-hr.	24-hr.	6-hr.+ 18 min. /wk.
Replication 1	0.9	8.0	15.8	11.2	28.3	18.2
Replication 2	12.0	4.2	17.5	28.6	17.3	36.4
Weighted Mean	5.9	6.0	16.6	19.7	21.3	27.3

TABLE XXXVI

Analysis of Variance of Percent Unidentified Eggs Produced, 25th Week

Source of Variation	d.f.	M.S.	F
Treatment	5	150.83	2.020
Pens in treatment	6	74.66	

MORTALITY

A total of 33 birds died during the period from the eighth through the twentiety week (Table XXXVII). After an early epidemic of deaths during the 8- to 20-week period, a diagnosis of Fowl Cholera was made by the Oklahoma State University Veterinary Diagnostic Clinic. Sulfaquinoxaline was used and the epidemic was brought under control. Later an outbreak of Blackhead was diagnosed and the disease was brought under control with the administration of Enheptin.

During the period from the twenty-first through the twenty-fifth week, only one bird died. She died the first day of the first week of the period. Her death was considered to be due to injuries.

Although the variation in mortality due to treatment is significant at the .025 level, it is not reasonable to accept the results of this test. It is not considered realistic to assume equal exposure to the diseases for all pens at any one time during the test.

TABLE XXXVII

Mortality by Treatment, 8 to 20 Weeks

Treatment	Number of birds lost	Treatment	Number of birds lost
6-hr.	5	12-hr.	2
8-hr.	10	Daylight	8
10-hr.	4	24-hr.	4

DISCUSSION

GROWTH

From the standpoint of growth weights and gains by Leghorn-type pullets, it might be concluded that 6- and 8-hour light regimes do not provide an environment which would stimulate maximum response (Table III and V). It would appear that the response became significantly more inferior for these regimes late in the 8- to 20- week period (Figure I). It would be expected, according to the studies by Moore (1957a,b) and Wilson *et al*. (1956), that the birds would require less light as they grew older and respond positively to static, short light regimes as they approached 20 weeks.

Exposure to 12 hours of artificial light and to natural daylight produced body weights not different from either the 6- and 8-hour regimes or the 10- and 24-hour regimes. Natural daylight, 10- and 24-hour light regimes were superior in body weight gains, though. It is difficult to postulate a reason why 10 hours should produce gains superior to 12 hours, when the other regimes show a trend to greater response to longer photoperiods.

No meaningful interactions between the 8- to 20- week treatments and the 21- to 25- week treatments could be found. They were observed to be too complex and disarrayed to suggest any reasonable pattern.

Although there were significant differences in gains during the 21- to 25-week period, no general trend was observed except that the daily regime of increasing 6 hours of light was in the inferior response group as were the 6- and 8-hour regimes during the earlier period (Tables V and VIII). The change in light was not more important than absolute amounts in its effect on growth, as Morris and Fox (1960) reported.

Apparently the birds adjusted well to all of the regimes at 8 weeks of age but had trouble adjusting to new environments at 21 weeks of age regardless of treatments (Table I and VI, Figures I and II). It would be desirable to investigate this phenomenon further, as it may have great pertinence in the reduction of physiological stress in growing replacement pullets.

It was expected that feed efficiency would follow closely the gains in body weights. The closeness of the relationships was striking for the 8- to 20-week period (Table V and XII) and also for the 21- to 25-week period Table VIII and XV). Generally small gains were accompanied by greater feed requirements per pound of gain.

GLANDULAR WEIGHTS

No significant variation due to treatment was observed for any of the organs or glands selected for sampling at 20 weeks. There were some strong trends, though, and some interesting relationships. No differences in response were noted in the size of the eyeballs exposed to the various light regimes prior to 20 weeks of age. It should be noted that the fc intensity in this study was lower than that reported in studies where continuous light appeared to be harmful to the eyes (Jensen and Matson, 1957 a,b; Shutze *et al.*, 1959; Shutze *et al.*,1960, 1961; Lauber *et al.*, 1961). It may be that light intensity is a factor in causing enlarged eyeballs in growing birds exposed to continuous light.

It is interesting to note that the ovary and oviduct mean weights at 20 weeks tended to increase with longer light regimes. A major exception was the relationship between the 10- and 12-hour regimes. To accord a general statement as that immediately stated, the responses of the 10- and 12-hour regimes should have been reversed (Table XIX). The 10- and 12- hour regimes had peculiar effects upon body weights, too (Figure I).

EGG PRODUCTION

Because of the loss of egg identification due to floor egg laying, no period interactions could be studied. A great deal of information otherwise available from the experiment was lost. The random and factorial placement of the birds into the pens and treatments of the 21- to 25-week period was considered a random population similar to that with which a commercial poultryman would work if he were to obtain started pullets from various farms and place them under his management.

It is quite conclusive that the increasing 6-hour regime was inferior to the other regimes when considering weekly egg production means (Table XXVII) or total egg production for the 5 weeks (Table XXX). There were no significant egg size differences (Table XXXII). The regimes other than the increasing 6-hour regime provided income considerably greater than the increasing 6-hour regime during the 21- to 25-week period.

It becomes apparent that, as the degree of retardation of maturity increases, increased production intensity and persistency must follow to provide overall production to a given age equal to that of regimes that facilitate early maturity.

The greater the overall production rate during the laying year, the greater is the importance of early maturity. If however, late maturity brought about by a light regime such as the increasing 6-hour one described will also permit greater persistency, then it would have the advantage of providing fewer small eggs and more extra large and jumbo eggs than rival regimes. This study has not touched on the relationship of these light regimes to persistency.

The degree of retardation of maturity may also become an important factor. It would seem that retardation could be carried to an extreme and lose any or all advantages.

SUMMARY

March-hatched Leghorn-type hybrid pullets were brooded under usual floor conditions to 8 weeks of age, after which 32 pullets were randomly assigned to each of 12 pens. Duplicate pens of pullets were maintained to 20 weeks of age on six light treatments, as follows: natural daylight; daily artificial photoperiods of 6, 8, 10, 12 and 24 hours. The artificial light was provided by one 40-watt bulb and reflector per pen.

Body weight gains during the period from 8 to 20 weeks reflected highly significant treatment effects. The effects of lighting treatment upon growth, ranked in ascending order, were: 6 hours, 8 hours, 12 hours, natural daylight, 10 hours, and 24 hours.

At 20 weeks of age, only the birds receiving daylight and 24 hours of artificial illumination had started to lay. The oviduct weights of sacrificed birds from these treatments tended to be greater, confirming the observations of advanced maturity. No significant treatment differences were observed for weights of thyroids, ovary or pituitary glands at age 20 weeks. Birds exposed to 6 hours daily light treatment tended to have larger eyeballs than those exposed to other treatments, daylight birds having the smallest.

Light regimes were changed when the pullets were 20

weeks of age. At this time the birds in each pen were randomly and factorially assigned to the 6 light regimes as distributed among the 12 pens. The daily light regimes were 14, 18, 24, 6 hours increased 18 minutes each week, 7 hours of light followed by 5 hours of darkness and natural daylight. During the period from 20 to 25 weeks, body weight gains showed highly significant treatment effects, and ranked in ascending order of growth stimulating value as follows: 14 hours, 6 hours + 18 minutes per week, 24 hours, daylight, 7 hours light-5 hours dark and 18 hours. The 18-hour photoperiod was significantly superior to all other treatments except the 7-hour light: 5-hours dark.

There were no significant differences in egg weights at 25 weeks, but egg production was significantly inhibited for birds exposed to the increasing 6-hour regime. The increasing 6-hour regime tended to increase the percentage of floor eggs produced.

SELECTED BIBLIOGRAPHY

Abplanalp, H., and W. O. Wilson, 1960. After effects of light in chickens. Ecology 41: 580-583.

Adolph, R. H., 1955. Don't light pullets too early. Pacific Poultryman, February, 1955.

Allen, Edgar, 1939. <u>Sex and Internal Secretions</u>. The Williams & Wilkins Co., Baltimore.

Atkinson, M. E., 1918. Lighting system for increased egg production. Reliable Poultry J. 25: 187-188, 231.

Atkinson, M. E., and E. E. Emerson, 1918. More evidence of egg yield value of lighting system. Reliable Poultry J. 25: 541-572.

Atwood, H., 1923. Certain correlations in the weight and number of eggs and the weight of fowls. West Virginia Agr. Exp. Sta. Bul. 182: 1-16.

Avery, T. B., 1950. How hens perform in an ideal environment. Kansas Acad. Sci. 52: 468-469.

Axelsson, J., 1934. Continued research upon variation and heredity of some characters in White Leghorns, Rhode Island Reds and Barnevelders. Lantbruks - Hogskol. Ann. (Uppsala) 1: 69-207.

Banta, Luther, 1918. Use of artificial lighting to increase winter egg yield. Reliable Poultry J., 25: 765-766, 800.

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

Bartsch, O., 1937. The influence of illumination upon laying activity of hens. Arch. Geflugelk. 11: 369-382.

Benoit, J., 1935 a. Stimulation par la lumiere artificielle du developpement testiculaire chez des canards avenglos par section due nerf optique. Compt. Rend. Soc. Biol. 120: 133-136.

Benoit, J., 1935b. Stimulation par la lumiere artificielle du developpement testiculaire chez des canards avengles par enucleation des globes oculaires. Compt. Rend. Soc. Biol. 120: 136-139.

Benoit, J., 1938. Role des yeux et de la voie nerveuse oculohypophysaire dars la gonadostimulation par la lumiere artificielle chez le canard domestique. Compt. Rend. Soc. Biol. 129: 231-234.

Benoit, J., F. X. Walter and I. Assenmacher, 1950. Nouvelles recherches relatives à l'action de lumiéres de différentes d'onde sur la gonadostimulation du conard mâle impubère. Compt. Soc. Biol. 144: 1206-1211.

Bennett, C. H., 1947. Relation between size and age of the gonads in the fowl from hatching date to sexual maturity. Poultry Sci. 26: 99-104.

Berg, L. R., R. S. Hansen, G. E. Bearse and L. Merrill, 1960. Influence of light periodocity on the response of developing White Leghorn pullets to varying nutritional regiments. Poultry Sci. 39: 1234. Abstract.

Berry, L. N. and Walker, 1927. The influence of the time of hatch on the laying ability of Single Comb White Leghorn pullets. New Mexico Agr. Exp. Sta. Bul. 158: 3-18.

Biellier, H. V., 1960. The effect of age of restricting light during the adolescent period on reproductive performance of chickens subjected to various day-lengths. Poultry Sci. 39: 1235. Abstract.

Biellier, H. V. and O. W. Ostmann, 1960. Effect of varying day-length on time of ovaposition in domestic fowl. Missouri Agr. Exp. Sta. Res. Bul. 747: 51.

Bissonnette, T. H., 1931a. Studies on the sexual cycle in males of the European starling (Sturnus vulgaris) by changes in the daily period of illumination and of muscular work. J. Exp. Zool. 58: 281-319.

Bissonnette, T. H., 1931b. Studies on the sexual cycles in birds v. Effects of light of different intensities upon the tesis activity of the European Starling (Sturmus vulgaris). Physiol. Zool. 4: 542-574.

Bowman, J. C. and J. D. H. Archibald, 1959. Effect of Controlled lighting on production characters in the fowl. Nature 183: 1138, 1159.

Boyce, John, 1960. Controlled lighting affects egg production "naturally". Poultry Tribune, April, 1960.

Bray, D. F., S. C. King and V. L. Anderson, 1960. Sexual maturity and the measurement of egg production. Poultry Sci. 39: 590-601.

Breneman, W. R., 1950. A study of the pituitary-gonad-comb relationship in normal, unilateral-castrated, and caponized chicks. J. Exp. Zool. 114: 115.

Brown, E. T., 1925. Artificial lighting of poultry housing. J. Ministry Agr. (G. Brit.) 32: 710-720.

Burger, J. W., 1949. A review of experimental investigations on seasonal reporduction in birds. The Wilson Bulletin 64: 211-230.

Burmester, B. R. and L. E. Card, 1939. The effect of restricted feeding time on food intake, body weight and egg production. Poultry Sci. 18: 402-403. Abstract.

Buster, M. W., 1927. The relation of rate of maturity to egg production. California Agr. Exp. Sta. Bul. 424.

Byerly, T. C., 1948. Light and egg production. Poultry Sci. 27: 656.

Byerly, T. C., 1957. Light and egg production. Poultry Sci. 36: 465-468.

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

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

Callenbach, E. W., J. E. Nicholas and R. R. Murphy, 1943. The effect of light and availability of feed on egg production. Pennsylvania Agr. Exp. Sta. Bul. 455.

Callenbach, E. W., J. E. Nicholas and R. R. Murphy, 1944. Influence of light on age at sexual maturity and ovulation rate of pullets. Pennsylvania Agr. Exp. Sta. Bul. 461: 12.

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

Castello, Salvador, 1924. Regarding the rules of lighting of poultry houses and the distribution of food to the fowls during the long winter nights. Proc. 2nd World's Poultry Congr. (Barcelona) 278-280.

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

Cole, R. K., and F. B. Hutt, 1953. Normal ovulation in non-laying hens. Poultry Sci. 32: 481-492.

Cray, R. E., 1929. Artificial lighting for poultry houses. Ohio Ext. Bul. 26: 16.

Cruickshank, E. M., 1929. Observations on the iodine content of the thyroid of the fowl during the growth, laying and moulting periods. Biochem. J. 23: 1044-1049.

Curtis, Grant M., 1920. Reliable Poultry J. monograph 26: 1002-1109.

Curtis, M. R., 1914. A biometric study of egg production in the domestic fowl. Arch. Entwicklungsmech. Organ. 39: 217-327.

Dakan, E. L., 1934a. Light absorption, feed consumption, and the urge to lay. Poultry Sci. 13: 317-318. Abstract.

Dakan, E. L., 1934b. Ohio experiment gives new views on lighting. Poultry Tribune (Western Ed.) October, 1934.

Dobie, John B., J. S. Carver and June Roberts, 1946. Poultry lighting for egg production. Washington Exp. Sta. Bul. 271: 1-27.

Domm, L. V., 1927. New experiments on ovariotomy and the problem of sex inversion in the fowl. J. Exp. Zool. 48: 31.

Domm, L. V., 1929. Spermatogenesis following early ovariotomy in the Brown Leghorn fowl. Arch. Entwicklungsmech. 119: 171.

Domm, L. V., 1931. Precocious development of sexual characters in the fowl by homeoplastic hypophyseal implants. II. Female. Proc. Soc. Exp. Biol. Med. 29: 309-312.

Dougherty, F. E., 1917. Artificial lighting of laying hens. J. Am. Assn. of Inst. and Invest. of Poultry Husb.

Dougherty, F. E., 1922. The use of light to increase winter egg production. California Exp. Sta. Cir. 254: 1-8.

Ebbell, H., 1940. Stallbeleuchtung wahrend der ganzen Nacht. Archiv. fur Geflugelk. 14: 77-79.

Eramus, J. E., 1955. Artificial lighting of laying hens. Farming in South Africa 335: 445-446.

Ewing, W. Ray, 1951. Poultry Nutrition, 4th Ed., W. Ray Ewing, South Pasadena, California

Fairbanks, F. L., 1924. Artificial illumination of poultry houses for winter egg production. Cornell (N. Y.) Ext. Bul. 90: 1-39.

Fairbanks, F. L. and G. H. Heuser, 1939. Artificial illumination of poultry laying houses for winter egg production. Cornell (N. Y.) Ext. Bul. 411.

Fangauf, K. W., 1959. Progressive lighting. Dtsch. Wirtsch. Geflugeiz. 11: 660.

Farner, D. S., 1961. Comparitive Physiology: Photoperiodicity. Annual Review of Physiology. Ed. Victor E. Hall. Annual Reviews, Inc., Palo Alto, California. 23: 71-96.

Fronda, R. E., 1951. The influence of artificial illumination on the egg production of New Hampshire yearling hens. Phillippine Agriculturalist 34: 213-218.

Fronda, F. M. and A. S. Marcello, 1938. Sexual differentiation in the organs of the viscera of male and female Los Banos Cantonese fowls. Phillippine Agriculturalist 27: 548-557.

Funk, E. M., 1935. Relation of body weight and egg weight in the domestic fowl. Poultry Sci. 14: 232-236.

Funk, E. M. and Kempster, 1934. Egg weight in the domestic fowl. Missouri Agr. Exp. Sta. Bul. 332: 1-15.

Galpin, P. N., 1938. Factors affecting weight of Brown Leghorn chickens. Proc. Roy. Soc. Edin. 58: 98-113.

Glazener, E. W., C. S. Shaffner and M. A. Jull, 1949 . Thyroid activity as related to strain differences on growing chickens. Poultry Sci. 28: 834-849.

Goodale, H. D. 1916. Further developments in ovariotomized fowl. Biol. Bul. 30: 286.

Goodale, H. D., 1918. Internal factors influencing egg production in the Rhode Island Red breed of domestic fowl. Am. Naturalist. 52: 65-321.

Goodale, H. D. and R. Sanborn, 1922. Changes in egg production in the station flock. Massachusetts Agr. Exp. Sta. Bul. 211.

Guaseo, G., 1958. Intermittent illumination in broiler breeding. Zootec. e Vet. 13: 169-178. Animal Breeding Abstract 26: 434.

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

Hammond, J. C. and H. W. Titus, 1941. Effect of colored lights and colored walls on the growth and mortality of chickens. Poultry Sci. 20: 507-513.

Hansson, N., 1930. The nutrition of egg-laying hens. Proc. 4th World's Poultry Cong. (London) 291-300.

Hays, F. A., 1933. Relation between body weight and age at sexual maturity. Poultry Sci. 12: 23-25.

Hays, F. A., 1934. Time interval from first egg to standard egg weight in Rhode Island Red pullets. Massachusetts Agr. Exp. Sta. Bul. 313: 1-11.

Hays, F. A., 1939. The significance of body weight in breeding for egg production. Massachusetts Agr. Exp. Sta. Bul. 364: 1-16.

Hays, F. A., 1944. The significance of inherited characters affecting egg production. Poultry Sci. 23: 310-320.

Hays, F. A., 1949. High fecundity in poultry. Poultry Sci. 28: 921-928.

Hays, F. A., 1951. The relation of age at sexual maturity to some developmental characters. Poultry Sci. 30: 723-726.

Hays, F. A., 1952. Effects of age at sexual maturity on body weight, egg weight and egg production. Poultry Sci. 31: 1050-1054.

Hays, F. A. and J. S. Bennett, 1923. Correlation of sexual maturity to annual egg record. Poultry Sci. 2: 205-206.

Hays, F. A. and R. Sanborn, 1929. Rate of growth in Rhode Island Reds. Massachusetts Agr. Exp. Sta. Bul. 259.

Hazel, L. N. and W. F. Lamoreux, 1947. Heritability, maternal effects and nicking in relation to sexual maturity and body weight in White Leghorns. Poultry Sci. 26: 508-514.

Heywang, B. W., 1944. The effect of artificial light on chicks brooded during hot weather. Poultry Sci. 23: 481.

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

Heywang, B. W., 1946. Growth of chickens fed only during the cooler part of the day. Poultry Sci. 28: 492-497.

Hill, R. T. and A. S. Parks, 1934. Hypophysectomy of birds. III. Effect on gonads, accessory organs and head furnighings. Proc. Roy. Soc. of London, Series B. 116: 221-236.

Hutchinson, J. C. D., 1956. Control of seasonal variation in the egg production of hens. Nature 177: 795.

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

Hutt, F. B., 1949. Genetics of the Fowl. McGraw-Hill Book Co., Inc., N. Y.

Hutt, F. B., W. F. Lamoreux and K. Goodwin, 1955. Don't light growing pullets! The Kimberchick News, Ser. Publ. Kimber Farms, Inc., Niles, California, April, 1955.

Hutt, F. B., K. Goodwin and W. D. Urban, 1956. Investigations of non-laying hens. Cornell Vet. 46: 257-273.

Jaap, R. G., 1935. Gonad-stimulating potency of individual pituitaries. Poultry Sci. 14: 237-246.

Jeffrey, F. P. and C. S. Platt, 1941. A 3-year study of out-of-season hatching. New Jersey Agr. Exp. Sta. Bul. 687: 23.

Jensen, L. S. and W. E. Matson, 1957a. Enlargement of the avian eye by subjecting chicks to continuous incandescent light. Science 125: 741.

Jensen, L. and W. Matson, 1957b. Continuous light causes bigger eyeballs. Science News Letters 72: 6.

Jordan, J. P., 1920. Use of Artificial Light to Increase Winter Egg Production. Reliable Poultry J. 9.

Jordan, W., 1934. All-night, poultry house lighting. Archiv. Geflugelk. 8: 322-325.

Jull, M. A., 1924. Egg weight in relation to production. II. The nature and causes of changes in egg weight in relation to annual production in pullets. Poultry Sci. 3: 153-172.

Kable, G. E. and F. E. Fox, 1928. Carbon arc lamps for lighting and irradiating laying pullets. Agr. Eng. 9: 191.

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

Karapetjan, S. K., 1950. The role of lighting in the development of domestic poultry. Agribiologija 1950: 65-78. Animal Breeding Abstract 19: 65-78.

Kaupp, B. G., 1918. The Anatomy of the Domestic Fowl. W.B. Saunders Co.

Kempster, H. L., 1925. Correlation between sexual maturity and egg production. Missouri Agr. Exp. Sta. Res. Bul. 78.

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

King, Dale F., 1958a. Brand new way to light your layers. Farm Journal, February, 1958.

King, Dale F., 1958b. Get more eggs with new lighting plan. Poultry Tribune, February, 1958.

King, D. F., 1959. Artificial light for growing and laying birds. Alabama Agr. Exp. Sta. Progress Report 72.

King, D. F., 1961. Effects of increasing, decreasing and constant lighting treatments on growing pullets. Poultry Sci. 40: 479-484.

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

Kistler, P. T., 1924. The effect of artificial illumination on Single Comb White Leghorn pullets. Pennsylvania Agr. Exp. Sta. Annual Report of Director. 24.

Kleinpeter, M. E. and J. P. Mixner, 1947. The effect of the quantity and quality of light on the thyroid activity of the baby chick. Poultry Sci. 494-498.

Knox, C. W., 1930. Factors influencing egg production. I. The influence of maturity upon egg production in Single Comb White Leghorns. Iowa Agr. Exp. Sta. Res. Bul. 119: 309-332.

Knox, C. W., M. A. Jull and J. P. Quinn, 1935. Correlation studies of egg production and possible genetic interpretations. J. Agr. Res. 50: 573-589.

Kumaran, J. D. and C. W. Turner, 1949. The normal development of the testes in the White Plymouth Rock. Poultry Sci. 28: 511-520.

Lamoreaux, W. F., 1943. The influence of different amounts of illumination upon the production of semen in the fowl. J. Exp. Zool. 94: 73-95.

Lamoreaux, W. F., 1958. Lighting programs for poultry. Mimo. Publ. Kimber Farms, Inc., Niles, California.

Lanson, Raino K., 1960. A study of the influence of light and darkness upon the reproductive performance of the fowl. Unpublished Ph. D. Thesis. Rutgers University, New Brunswick, New Jersey.

Larionov, W. T. 1941. Shortening of the moulting period in birds by a change in the daily amount of illumination. C. R. Acad. Sci., U. R. S. S., N. S., 32: 227-229. Animal Breeding Abstract 11: 127.

Larionov, V. F., 1957. The specific effect of light on the proliferation of birds. Doklady Akad. Novk. S. S. S. R. 112: 160-162.

Lauber, J. K., J. V. Shutze and J. McGinnis, 1961. Effects of exposure to continuous light on the eye of the growing chick. Proc. Soc. Exp. Biol. Med. 106: 871-872.

Laurens, H., 1928. The physiological effects of radiation. Physiol. Rev. 8: 1-91.

Lawatsch, M. F., C. B. Knodt and J. W. Nelson, 1960. Effect of controlled light upon weight gains, feed consumption, egg production and mortality of caged layers. Mimo. Publ. Cargill-Nutrena Research Farm, Elk River, Minnesota.

Le Masurier, H. E. and H. D. Branion, 1939. Some observations on the skeletal development of the fowl to six weeks of age. Poultry Sci. 18: 114-122.

Lerner, I. M. and L. W. Taylor, 1937. Interrelationships of egg production factors as determined for White Leghorn pullets. J. Agr. Research 55: 703-712.

Lerner, I. M. and L. W. Taylor, 1940. The use of the median as a measure of sexual maturity in White Leghorn pullets. Poultry Sci. 19: 216-218.

Lert, P. J., 1961. Restricted pullet lighting. Pacific Poultryman, June, 1961.

Lert, P. J., W. O. Wilson and S. A. Hart, 1960. Effect of restricted lighting of pullets on subsequent egg production. Poultry Sci. 39: 1270. Abstract.

Lewis, H. R., 1921. American methods of lighting and the associated feeding problems. Proc. 1st World's Poultry Cong. (Hague). 77-82.

Lippincott, W. A., S. L. Parker and L. M. Schaumburg, 1925. The correlation between age at the laying of the first egg and the weight of eggs during the first laying year in White Leghorn. Poultry Sci. 4: 127-140.

Longhouse, A. D., 1955. Length of daylight hours and intensity of light on a windowless house. Memorandum to Members of Technical Committee. NE-8, Poultry Housing.

Lowe, R. W. and B. W. Heywang, 1960. Hens can get too much light too soon. U.S.D.A. Agr. Res. October, 1960.

Lowe, R. W. and B. W. Heywang, 1961. Effect of additional light during growing period on egg production of October hatched White Leghorn pullets. Poultry Sci. 40: 177-180.

Marble, D. R., 1931. A statistical study of factors affecting egg weight in the domestic fowl. Poultry Sci. 10: 84-92.

Marr, J. E., J. L. Milligan, R. C. Eaton and H. L. Wilcke, 1957. Effect of controlled light during the growing period upon subsequent laying performance of chickens. Poultry Sci. 36: 1128. Abstract.

Marr, J. E., F. W. Garland, C. W. Pope, H. L. Wilcke and R. M. Bethke, 1960. Further studies on controlled light during the growing and laying periods of chickens. Poultry Sci. 39: 1272. Abstract.

Martin, J. H., 1925. Feeding for egg production. Kentucky Ext. Cir. 186: 15.

Maw, A. J. G. and W. A. Maw, 1932. A method of estimating the mean annual egg weight. Poultry Sci. 13: 131-134.

McClary, C. F., 1960a. Genetic behavior and photoperiodism in laying chickens. Poultry Sci. 39: 1273. Abstract.

McClary, C. F., 1960b. Step down step-up lighting plan. Poultry Tribune, February, 1960.

Miller, B. F. and P. E. Sanford, 1960. The effect of various lighting techniques on growth, egg production and shell quality of chickens. Poultry Sci. 39: 1276. Abstract.

Moffatt, B. W., 1957. Lights for layers. Queensland Agr. J. 83: 90-95.

Moore, Claude H., 1957a. The effect of light on growth of broiler chickens. Poultry Sci. 36: 1142-1143. Abstract.

Moore, Claude H., 1957b. How much light do broilers need? Poultry Tribune, January, 1957.

Moore, O. K. and N. R. Mehrhof, 1946. Periodic increase in lighting versus continuous lighting for layers. Florida Agr. Exp. Sta. Tech. Bul. 420.

Moreng, R. E., R. L. Bryant and D. G. Gosslee, 1956. Physiological reaction of chicks to limited light. Poultry Sci. 35: 977-983.

Morris, T. R. and S. Fox, 1958a. Light and sexual maturity in the domestic fowl. Nature 181: 1453-1454.

Morris, T. R. and S. Fox, 1958b. Artificial light and sexual maturity in the fowl. Nature 182: 1522.

Morris, T. R. and S. Fox, 1960. The use of light to delay sexual maturity in pullets. Brit. Poultry Sci. 1: 25-36.

Morris, T. R. and S. Fox, 1961. Increasing versus constant daylight for laying pullets. Brit. Poultry Sci. 2: 59-67.

Mueller, C. D., T. B. Avery, H. D. Smith and R. E. Clegg, 1951. Effects of controlled light and temperature for laying hens. Poultry Sci. 30: 679-686.

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

Nikolaiczuk, N. and W. A. Maw, 1942. A preliminary study of the effect of sunlight, dubbing, and fractionated anterior pituitary extract upon growth, endocrine glands and sexual capacity of Single Comb White Leghorn cockerels. Poultry Sci. 21: 483-496.

Oakberg, E. F., 1951. Genetic differences in quantitative histology of the adrenal, organ weights, and interorgan correlations in White Leghorn chickens. Growth 15: 57.

Odell. T. T., 1952. Secretion rate of thyroid hormone in White Leghorn castrates. Endocrinol. 51: 265.

Ostrander, Charles E., 1960. The effect of various light intensities on egg production of Single Comb White Leghorn pullets. Unpublished M.S. Thesis. Michigan State University, East Lansing, Michigan.

Ostrander, C. E., R. K. Ringer, H. C. Zindel and C. W. Turner, 1960. The effects of various light intensities on egg production of Single Comb White Leghorn pullets. Quart. Bul. Michigan Agr. Exp. Sta. 43: 292-297.

Parker, Jesse E. and B. J. McSpadden, 1943. Seasonal variation in semen production in domestic fowls. Poultry Sci. 22: 142-147.

Parkhurst, R. I., 1930. Artificial illumination to increase winter egg production. J. Ministry of Agr. 36: 960-961.

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

Payne, L. F. and L. J. Simmons, 1934. Management of Leghorn hens and pullets with and without artificial lights. Poultry Sci. 13: 323-332.

Penquite, R. and R. B. Thompson, 1933. Influence of continuous light on Leghorns. Poultry Sci. 12: 201-205.

Penquite, R. and R. B. Thompson, 1940. Results of a ten-year study of the influence of artificial light on egg production. Poultry Sci. 19: 358. Abstract.

Pinches, H. E. and H. M. Scott, 1942. Low-intensity lighting of hens with special reference to blackout regulations. Proc. Am. Soc. Agr. Eng. (Chicago) December 9, 1942.

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

Platt, C. 1955. A study of the effect of restricted light on January hatched pullets. Poultry Sci. 34: 1045-1047.

Powell, C. D., 1958. The Doane "Stimulight" system of egg production. Mimo. Publ. Doane Agr. Serv., Inc. St. Louis, Missouri.

Prentice, J. H., R. G. Baskett and G. S. Robertson, 1930. The nutrition of the chick and its effect on growth, maturity, egg production and mortality. Proc. 4th World's Poultry Congr. (London) Paper No. 37: 242-254.

Reineke, E. P. and C. W. Turner. 1945. Seasonal rhythm in the thyroid hormone secretion of the chick. Poultry Sci. 24: 499-504.

Rider, Percy L., 1938. The influence of light on growth and reproduction of the domestic fowl. Unpublished M.S. Thesis. Ohio State University, Columbus, Ohio.

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

Ringrose, R. C., 1951. Fall hatches and maturity--a progress report. Combings, Mimo. Publ. Poultry Dept. U. New Hampshire, Sept. 20, 1951.

Ringrose, R. C., 1952. Fall hatches and maturity--a progress report. Combings, Mimo. Publ. Poultry Dept. U. New Hampshire, June 16, 1952.

Ringrose, R. C. and L. M. Potter, 1953. Artificial light delays pullet maturity. New Hampshire Agr. Exp. Sta. Bul. 402: 42-43.

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

Rowan, W., 1938. Light and seasonal reproduction in animals. Biol. Rev. 13: 374-402.

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

Schultze, A. B. and C. W. Turner, 1945. Determination of rate of thyroxine secretion of certain domestic animals. Missouri Agr. Exp. Sta. Res. Bul. 392.

Shoup, Mrs. G. R., 1918. Artificial lighting of poultry houses in Western Washington. J. Am. Assn. of Inst. and Invest. in Poultry Husb. 4: 44-47.

Shutze, J. V., L. S. Jensen, J. S. Carver and W. E. Matson, 1961. Influence of various lighting regimes on the performance of growing chickens. Washington State University Agr. Exp. Sta. Bul.

Shutze, J. V., L. S. Jensen and W. E. Matson, 1959. Effect of lighting regimes on growth and subsequent egg production of chicks. Poultry Sci. 38: 1246. Abstract.

Shutze, J. V., W. E. Matson and J. McGinnis, 1960. Influence of photoperiod for pullets to maturity on growth, subsequent egg production and egg weight. Poultry Sci. 39: 1294. Abstract.

Skaller, F., T. E. Allen and B. L. Sheldon, 1954. The effect of intensity of daylight on egg production of fowls in cages. Australian J. Agr. Res. 5: 578-583.

Skoglund, W. C., 1959. University of New Hampshire complete first year of lighting schedule experiment for layers. Combings, Mimeo. Publ. U. New Hampshire Coop. Ext. Serv. October 14, 1959.

Smith, C. W., 1930. The relation of environmental conditions in poultry houses to winter egg production. Nebraska Agr. Exp. Sta. Bul. 247: 29-30.

Smith, L. J., 1942. Poultry lighting studies. 52nd Ann. Report Washington Agr. Exp. Sta. 425: 9.

Staley, K. A., 1960. Fundamentals of light and lighting. GE Bul LD-2.

Steel, R. G. D. and J. H. Torrie, 1960. Principles and Procedures of Statistics. McGraw-Hill Book Company, Inc., New York.

Sturkie, Paul D., 1954. Avian Physiology. Comstock Publishing Associates, Ithaca, New York.

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

Temperton, H. and F. J. Dudley, 1947. The relative importance of light and food on winter egg production. Harper Adams Utility Poultry J. 32: 35-41.

Thompson, W. C., D. Philpott and H. C. Page, 1931. The significance of measurements of quantity and quality of egg yield. New Jersey Agr. Exp. Sta. Bul. 528.

Titus, H. W. and R. B. Nestler, 1935. Effect of vitamin D on production and some properties of eggs. Poultry Sci. 14: 90-98.

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

Tomhave, A. E. and C. W. Mumford, 1927. The use of artificial lights on White Leghorn pullets to increase winter egg production. Delaware Agr. Exp. Sta. Bul. 151: 1-5.

Tuckey, R., B. E. March and J. Biely, 1958. Diet and the rate of food passage in the growing chick. Poultry Sci. 37: 786-792.

Upp, C. W. and R. B. Thompson, 1927. Influence of time of hatch on hatchability of the eggs, rate of growth of the chicks, and characteristics of the adult females. Oklahoma Agr. Exp. Sta. Bul. 167: 36.

U. S. Naval Observatory, 1959. The Nautical Almanac of the year 1961. U. S. Government Printing Office.

Waldorf, E. C., 1915. Ten eggs per week per hen and how it was done. Reliable Poultry J. 21: 1356.

Warren, D. C., R. Conrad, A. E. Schumacher and T. B. Avery, 1950. Effects of fluctuating environment on laying hens. Kansas Agr. Exp. Sta. Tech. Bul. 68: 43.

Webster's New Collegiate Dictionary, 1960. G. & C. Merriam Co., Springfield, Massachusetts.

Weinmiller, V. L. and K. Mantel, 1940. Dauerbeleuchtung fur lege und Zuchthenner. Arch. Kleintiersucht 6: 129-139.

Weitz, C. E., 1956. General Electric Lamps. G. E. Application Engineering Bul. LD-1.

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

Wilcox, T. W., G. T. Davis and A. F. Beeckler, 1960. Effects of intermittent light on egg production. Poultry Sci. 39: 1306. Abstract.

Wilson, W. O., 1958. Light for egg production and growth. Poultry Sci. 37: 1253. Abstract.

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

Wilson, W., A. E. Woodward and H. Abplanalp, 1956. The effect and aftereffect of varied exposure to light on chicken development. Biol. Bul. 111: 415-422.

Winchester, C. F., 1940. Growth and development: LI Seasonal metabolic and endocrine rhythms in the domestic fowl. Missouri Agr. Exp. Sta. Res. Bul. 315.

Wolfson, A., 1960. Role of light and darkness in the regulation of the annual stimulus for spring migration and reproductive cycle. Proc. 7th International Ornithological Cong. (Helsinki) 1958. 758-789.

Wolfson, A. and D. P. Winchester, 1959a. Role of light in the photoperiodic responses of migratory birds. Science 129: 1425-1426.

Wolfson, A. and D. P. Winchester, 1959b. Role of light in the progressive phase of the photoperiodic response of migratory birds. Biol. Bul. 117: 601-610.

Yeates, N. T. M., 1954. Progress in the Physiology of Farm Animals. Ed. John Hammond. Butterworths Scientific Publications, London. 373-374.

VITA

Paul Robert Walther

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF VARIOUS LIGHT REGIMES ON CHICKEN PULLETS TO 25 WEEKS OF AGE

Major Field: Poultry Production

Biographical:

Personal data: Born: Butler County, Iowa, April 8, 1929.

Education: Undergraduate study: Illinois Institute of Technology, Chicago, Illinois; Iowa State University, Ames, Iowa; Bachelor of Science degree in Poultry Husbandry from Iowa State University, August 1955.

Experiences: Active duty in the United States Navy, November, 1950--October, 1954; Iowa State University Extension Poultryman, October, 1955--January, 1961; Research Assistant, Poultry Science Department, Oklahoma State University, January, 1961--January, 1962.

Organizations: Poultry Science Association

Date of Final Examination: