AN ABSTRACT OF THE THESIS OF

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Title: SEXUAL MATURITY AND PERFORMANCE OF WHITE LEGHORN PULLETS SUBJECTED TO INTERMITTENT WATERING, LIGHTING REGIMES, AND NUTRIENT RESTRICTIONS

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A series of 8 experiments was conducted to investigate various methods of delaying the sexual maturity of developing White Leghorn (W. L.) pullets grown during a period of increasing daylength and to control the feed intake of W. L. layers. In the first five experiments W. L. pullets were fed low-lysine (0.54%) and low-protein (10.36%) developer rations from 8 to 20, and 8 to 20 or 12 to 20 weeks of age, respectively. Other groups were subjected to watering regimes in which water was cycling on 24 hr.--off 24 hr. and on 24 hr.--off 48 hr. from 8 to 20, and 8 to 20, 12 to 20, or 14 to 20 weeks of age, respectively. Additional groups were reared using two lighting programs; the first featured a gradual decline of 15 min./week in the daylength from 0 to 22 weeks of age. The second provided a constant amount of light from 0 to 12 weeks of age, a sudden 5-hr. drop at 12 weeks, and then a constant level from 12 to 20 weeks of age. In Exp. 6 to 8, W. L. layers were provided water concurrent with light

(15.0--16.25 hr./day), 15 min. each hour, three or five 15-min. periods/day or two 2-hr. periods per day. An additional group had access to feed for two 2-hr. periods per day.

The low-lysine developer had no effect on body weights, sexual maturity, or feed intake during the growing period. These pullets tended to lay fewer, but heavier, eggs during 40 weeks of lay. Cannibalism tended to be higher in the pullets fed low lysine. Feeding the low-protein developer from 8 or 12 to 20 weeks of age resulted in significantly lower body weights and feed consumption in the developing period. Fed from 8 to 20 weeks of age, this diet led to 14 and 11-day delays in reaching 25 and 50% production, respectively. Lay house performance was satisfactory in three of four comparisons, but brooder house mortality was slightly higher in pullets fed the low-protein diets.

Providing water every other day after 8 weeks of age did not significantly alter feed intake, body weights, or sexual maturity. Feed intake in the subsequent lay period was significantly lower for dwarf W. L. pullets, but unaffected in normal W. L. pullets. Hen-day production tended to be slightly lower and lay house mortality slightly higher for these pullets. Providing water every third day from 8, 12, or 14 to 20 weeks of age significantly reduced body weights and feed intake, and delayed 25 and 50% production. The degree of growth retardation was proportional to the duration of the water restriction regime. These pullets tended to lay at a higher rate, require less feed per egg, and lay larger eggs.

Pullets subjected to either of the lighting programs ate more and were heavier in the first 12 weeks of life, but consumed less from

12 to 20 weeks and weighed less than the control group at 20 weeks of age. Both lighting programs increased average egg weights in the laying period. A 5-hr. light reduction at 12 weeks of age delayed 25 and 50% production as much as 11 and 14 days, respectively. There were no significant differences in egg production, feed per hen-day, per egg, or per gram of egg.

Providing hens two 2-hr. or three 15-min. waterings after 5 months of lay significantly reduced egg production, reduced feed intake and weight gain, but had no effect on average egg weights. When the three 15-minute regime was initiated prior to lay, egg production was not altered, but feed per hen-day, per egg and per gram of egg, and average egg weight were reduced by 3.0, 11.0, 0.1, and 2.6 g., respectively. The number of large eggs was significantly reduced.

Egg production tended to be higher when pullets were provided five 15-min. waterings each day. No adverse effects were observed on average egg weights or mortality. In two comparisons, feed per hen-day, per egg, and per gram of egg were reduced by 0.3 and 3.0, 7.7 and 9.0, and 0.14 and 0.17 g., respectively. Providing layers water 15 min. each hour had no effect on egg production, feed intake, or weight gain during lay. In one comparison egg size was significantly increased and the number of medium eggs significantly reduced. These hens required slightly less feed to produce a gram of egg.

Providing laying hens two 2-hr. feedings significantly reduced egg production and weight gain during lay, reduced egg mass per hen-day, increased mortality, but had no effect on average egg weights. Feed per hen-day was decreased by 4.7 g., but feed per egg and per gram of egg were increased by 3.9 and 0.07 g., respectively.

Sexual Maturity and Performance of White Leghorn Pullets Subjected to Intermittent Watering, Lighting Regimes, and Nutrient Restrictions

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I. INTRODUCTION

The Single Comb White Leghorn Chicken has long been accepted as the egg production bird of choice wherever white eggs are preferred. Its phenotypic characteristics of relatively early precocity and small body size coupled with its genetic potential for very high egg production have made the White Leghorn (W. L.) the most economical egg production bird. At peak production, these chickens are capable of producing a dozen large eggs, 24 ounces of egg, with as little as 3 pounds of feed. Adding this amount to the feed consumed in the brooder house, they are able to produce 1 pound of a high-quality animal product with as little as 2 2/3 pounds of feed.

Because these birds have demonstrated such great potential for providing high-quality protein to the world's people, more research is justified to make them even more efficient. There are still many advances to be made in the nutrition, genetics, and management of these birds.

Three basic factors which influence age at sexual maturity are: (1) genetic makeup; (2) nutrition during the brooding and growing periods, and (3) photoperiod. White Leghorn breeders have selected birds that will mature at an age which will bring about optimum egg production and egg size. Light, whether it be natural or artificial, may alter the date of first egg as much as 4 or more weeks among birds bred to reach sexual maturity at the same age. The absolute amount of light is not as critical as the change in light and dark periods. Replacement pullets grown during a period of increasing daylength, from December to June, start laying earlier than the same strain of birds grown during a period of decreasing daylength, from June to December. This problem is accentuated in high latitudes where changes in daylength are greater. The changing daylengths exert their greatest influence upon the birds between 8 and 20 weeks of age. Hastening sexual maturity by an increasing daylength generally results in more peewee and small eggs during the early laying period. Peewee and small eggs have very little economic value except at Easter time. Very early sexual maturity may also reduce the total number of eggs a hen will lay during her production cycle.

During the last 30 to 40 years, the importance of photoperiod has become widely recognized. The production of eggs changed from multi-enterprised farms to a highly-integrated industry during this time. The multi-enterprised farmer normally brooded his chicks in late spring; therefore, most of the growing period occurred during a time of decreasing daylength. The commercial poultryman of today must brood replacements year-round to insure that he will have a relatively stable supply of all sizes of eggs to deliver to accounts which he supplies. Because of the year-round brooding, a management tool to offset the effects of increasing daylength became essential. Researchers have developed a number of lighting programs to solve the problem of increasing daylength. By using combinations of artificial and natural light, the light supplied to the bird is either held constant (e.g. 12 hours per day) or decreased at weekly intervals, even though the natural light may be increasing.

There has been a recent philosophical reconsideration on the part of researchers and commercial egg producers regarding the nutrition of the developing replacement pullet. It was once thought that pullets should receive all nutrients at levels that would promote rapid growth and heavy body weight prior to the onset of lay. The objective was to produce pullets weighing a minimum of 3 pounds at 20 weeks of age. Optimum 20-week body weight is now considered by many to be approximately 2.80 pounds. It is generally assumed that poultry consume feed to meet energy needs; however, many breeds of chickens, including Leghorns, tend to over-consume and become slightly-to-severely obese prior to sexual maturity. Many research projects in the last 20 years have dealt with restricting volume of feed or a specific nutrient in order to control body weight. These practices may also result in delayed sexual maturity, thus substituting for or complementing lighting programs.

Once the replacement pullets reach the lay house, another management problem arises. Here, too, the birds have a tendency to consume more feed than is necessary for maintenance and egg production. When over-consumption occurs, it generally results in obesity, increased mortality, reduced hen-housed egg production, and poorer feed efficiency. Because this problem is more critical with broiler breeders than with White Leghorns, many researchers have attempted to isolate management practices that would control obesity of broiler breeder stock. A limited amount of research has been conducted with White Leghorns attempting to more efficiently convert feed to eggs by regulating body weight. This is an area that needs attention if we are to achieve more efficient production of animal protein.

At this time, commercial poultrymen are paying in excess of 120 dollars per ton for their layer feeds. Since feed accounts for more than 70% of the cost of production, any practices that reduce the amount and/or cost of feed necessary to rear replacement pullets or to produce a dozen eggs would be of great economic benefit to the commercial egg producer.

This dissertation is a report of research conducted from 1971 to 1974 investigating various methods of delaying the sexual maturity of W. L. pullets during a time when natural daylength was increasing. Methods were explored that would both retard sexual development and control body weight. The major goal of these experiments was to produce pullets that would lay more eggs, lay fewer small and peewee eggs, and produce a dozen eggs with less feed.

During production limited-time feeding and intermittent watering experiments were conducted with W. L. layers. The major goal of these trials was to counteract the hen's tendency to overconsume.

II. REVIEW OF LITERATURE

Relationships Between Body Weight, Sexual Maturity, and Subsequent Performance

Skoglund *et al*. (1951) hatched New Hampshire (N. H.) chicks in each of the 12 months of 1946 and again in 1948. Pullets were reared under natural light. Those birds hatched in December were early to mature, while those hatched in June were late to mature. Eggs were classed by size as follows: (1) over 24 ounces; (2) 23 and 24 ounces; (3) 22 ounces; and (4) under 22 ounces per dozen. Eighty percent of the total eggs laid by April, May, June, August, and September-hatched chicks were classed as over 24 ounces per dozen. The December-hatched birds laid the fewest eggs in this category, 59.2%, followed by October, November, and February hatches with fewer than 70%, and March, January, and July under 75%. December-hatched pullets laid 84 and 47% smalls in the first and second months of lay, respectively, while May-hatched pullets laid only 46 and 22%, respectively.

Hays (1952) classified Rhode Island Red (R. I. R.) pullets by age at sexual maturity: Group 1, 140 to 189 days; Group 2, 190 to 219 days; and Group 3, 220 to 279 days. Egg weights were increased by 0.89 and 2.75 g. per egg for the delayed birds in Groups 2 and 3, respectively, in comparison with the earliest maturing birds. Group 2 began laying eggs averaging 24 ounces per dozen 3 weeks prior to Group 1. Annual egg production was 219.9, 215.5, and 182.4 eggs per hen for Groups 1, 2, and 3, respectively.

A highly significant correlation (r=0.887) between age at maturity and number of total and settable eggs was reported by Fuller et al. (1970). They also showed a high correlation between average egg weight and age at maturity. They concluded that heavy breed pullets should not be brought into production before 26 weeks of age.

Up to 2.04 kg., body weights of W. L. hens were inversely proportional to the number of eggs produced in the first lay year (Du Plessis and Erasmus, 1972). Above 2.04 kg., egg production declined rapidly as body weight increased, 14 eggs for each increase of 0.23 kg. Of the 212 eggs laid by birds weighing 1.36 kg., 162 weighed at least 56.75 g.; for each weight increase of 0.45 kg. up to 2.04 kg., there were 25 additional eggs above 56.75 g. When body weight exceeded 2.04 kg., the number of large eggs declined.

The Effects of Various Lighting Programs on Sexual Maturity and Subsequent Reproductive Performance

Tomhave (1954), in an effort to delay the sexual maturity of October-hatched N. H. pullets, compared the natural daylength with an artificial lighting schedule which simulated the natural daylength of birds hatched in March. At 20 weeks of age, all birds received 14 hours of light. Birds reared under the simulated program reached 25 and 50% production 7 and 14 days later, respectively. The artificial lighting program increased early egg size and significantly increased the number of eggs weighing in excess of 23 ounces during the 164-day lay cycle.

Platt (1955) demonstrated that the sexual development of January-hatched W. L. pullets could be retarded by holding light constant at 8 hours after 13 weeks of age, as compared with the natural daylength. A subsequent increase in daylength from 8 to 14 hours caused a marked increase in egg production to a higher level than the other group.

A study of the effect of changing from short to long daylengths was undertaken by Sykes (1956) using birds which had been held at 6 hours of light since 12 weeks of age. When daylength was increased to approximately 12 hours, a general increase in egg production was observed within 1 to 2 weeks. If birds were returned to the shorter daylength of 6 hours, production fell appreciably and incidence of molt increased.

Marr _et al_. (1957) exposed White Rock and W. L. chicks to either 8 or 14 hours of constant light starting at either 6 or 10 weeks of age. Birds reared under 8 hours of light were less mature and weighed less at housing, and demonstrated significantly better egg production and feed efficiency in the lay house.

Hutchinson and Taylor (1957) observed no differences in the sexual maturity of replacement pullets reared with a constant 12 or 23.5 hours of light. When a portion of the group receiving 23.5 hours of light was gradually reduced to 12 hours after 2 months of lay, molting was observed in many of the birds and low production persisted for several months. When a second group of birds that had received 23.5 hours of light was exposed to an artificial thermal autumn and winter, no deleterious effects were observed.

King (1958) reared W. L. pullets on 6 hours of light per day up to 5 months of age, after which the amount of light was increased 18 minutes per day each week up to 1 year of lay. These birds laid 4.5 dozen more eggs in the first year of lay than did a second group receiving a constant 12 and 14 hours of light in the brooder and lay houses, respectively.

Morris and Fox (1958a, b) brooded chicks weekly from June 2, 1954, to February 8, 1956, and reared them under natural light to 16 weeks of age. Those pullets hatched in December were the earliest and those hatched in June were the latest to reach sexual maturity. These experiments demonstrated that the summation of all changes of daylength occurring during the growing period--the net increase between hatch and maturity--is highly negatively correlated (r=-0.9115) with age at sexual maturity. Morris and Fox developed a regression equation for the R. I. R. X Sussex pullets used in this experiment: y=166-1.64 (dm-dH) where y=first egg, dm=natural daylength at maturity and dH= natural daylength at hatch.

Bowman and Archibald (1959) provided pullets either increasing light or a program which declined from 24 to 6 hours of light. The decreasing light program delayed the date the flock reached 25% production by 6 days. These birds peaked higher and laid at a higher rate of hen-housed production.

Shutze *et al*. (1959) provided either 12 or 24 hours of daily light to N. H. pullets from 0 to 8 weeks of age, after which pullets were placed on range. Pullets receiving 24 hours of light were retarded sexually and laid at the rate of 59.2%, as compared to 73.2% for those birds receiving 12 hours of light.

December-hatched White Rock and February-hatched W. L. pullets were provided either natural light or a constant 8 hours of daily light from 10 to 22 weeks of age by Marr et al. (1960). Egg production and feed efficiency were improved substantially by holding birds at 8 hours of light. When lay house light was increased gradually, 15 minutes per day each week, egg production of White Leghorns was boosted.

Shutze et al. (1960) reared late spring-hatched pullets with natural daylength or with 24 or 8 hours of light. Birds receiving 8 hours of light reached 50% production 1.5 to 2.0 weeks earlier and laid smaller eggs than the other two groups. Birds receiving light 24 hours per day reached a peak production of 67.0%, compared with 86.9% for those with the natural daylength. Pullets with 8 hours of light laid at a rate slightly lower than the naturally-lighted birds.

Lert et al. (1960) reported a significant improvement in egg production of White Leghorns when birds received 8 and 6 hours of daily light for the periods 8 to 12 weeks and 12 to 20 weeks of age, respectively. Peak production for control-lighted pullets was 85%, compared with 78% for those reared with increasing natural daylength.

McClary (1960) observed an 18-day delay in reaching 50% egg production when W. L. pullets were started on 22 hours of light daily and were decreased by 0.5 hours of daily light each week to 18 weeks of age, as compared with naturally-lighted controls. Egg weights at 7, 8, and 11 months of lay were higher for the sexually-delayed birds.

December-hatched R. I. R. X Sussex pullets were delayed 24.1 days in reaching sexual maturity when Morris and Fox (1960) exposed them to a daylength artificially reduced 35 minutes weekly to 20 weeks of age, as compared with naturally-lighted controls. Artificially-lighted birds were 8% heavier at 4 weeks of age; controls were significantly heavier (0.33 pounds) at 20 weeks of age. Artificially-lighted birds were again heavier at 24 weeks of age and laid more and heavier eggs during the production period, with 43.3% large and 1.5% small eggs, compared with 29.2% large and 6.3% small eggs for the controls (English sizes).

Siegel et al. (1961, 1963a, b) reared replacement pullets with 6 hours daily light to 20 weeks of age followed by 3% weekly increases thereafter, or with 14 hours daily light to 30 weeks of age followed by a 3% increase thereafter. The 6-hour pullets were significantly heavier at 8 weeks, but were lighter at 20, 52, and 72 weeks of age. Feed conversions to 8 weeks of age were 2.99 pounds of feed per pound of gain for those with 6 hours vs. 3.2 for the 14-hour pullets. The 14-hour birds reached 25 and 50% egg production 11 and 9 days earlier, respectively, than the 6-hour group. The 6-hour group required significantly less feed to produce a dozen eggs, but laid smaller eggs at 26 and 54 weeks of age.

Shutze et al. (1961a) brought W. L. pullets into production at 18 weeks of age by increasing the daily light from 9 to 16 hours during rearing. Birds on a fixed level or decreasing light program took 1 to 5 weeks longer to reach maturity. Birds grown with decreasing light laid at a higher rate than other groups.

Shutze et al. (1961b) hastened first egg and 50% production by 22 and 14 days, respectively, by increasing light from 8 to 24 hours daily at 8 weeks of age, as compared with light decreasing from 24 to 8 hours at 8 weeks of age. Egg production was highest for the pullets reared on decreasing light or 8 hours of daily light from 0 to 20 weeks of age. Blindness, bulging eyeballs, and the poorest egg production were observed with pullets receiving 24 hours of light daily from 0 to 20 weeks of age.

Average age at first egg from October-hatched W. L. pullets was delayed an average of 10 days when Lowe and Heywang (1961) held the light constant at 16 hours per day. The naturally-lighted birds averaged 11.5 more eggs during 51 weeks of lay (21 to 71 weeks of age); however, both groups started the lay period at the same chronological age.

King (1961) reported no detectable relationship between body weight at 22 or 24 weeks of age and increasing or decreasing daylength. Pullets receiving their daily light in 2, 4, or 6 periods were significantly heavier than pullets receiving only one light period. He observed a direct decrease in age at maturity as the amount of light was increased; each 2-hour increment of light decreased age at sexual maturity by about 2 days. Pullets receiving decreasing light matured later than all other treatments, including those grown in dark houses. Multiple light periods during the day (2, 4, or 6 periods) resulted in earlier sexual maturity; 2 hours of light in two periods had the same effect as 8 hours in one period.

Noles *et al*. (1962) delayed the sexual maturity of late fall-hatched W. L. pullets by holding their daily light constant at 6 hours from 8 to 20 weeks of age. Birds on 6 hours of light weighed less at 20 weeks of age, ate less feed during the developing period, and laid at a significantly higher rate than naturally-lighted pullets.

Lowe and Heywang (1961) provided October-hatched W. L. pullets three lighting programs: (1) natural light; (2) 8 hours daily to 14 weeks and 16 hours daily to 20 weeks of age; or (3) 16 hours daily to 14 weeks and 8 hours daily to 20 weeks of age. Birds on the decreasing light regime weighed less at 20 weeks of age, matured later, and laid heavier eggs than birds on the other two treatments.

Shutze et al. (1963a, b) observed that pullets laid their first egg and reached 10 and 25% egg production earlier when they were reared with an increasing lighting regime, beginning with 9 hours and increasing to 16 hours of light at 20 weeks of age, as compared to two decreasing lighting programs. Birds grown under either of the two decreasing lighting programs, 15.5 hours declining to 9.3 hours or 16 hours declining to 9.0 hours, laid at a higher rate of production than those receiving increasing light or a constant 8 hours of daily light. A third decreasing light program, starting with 22 hours and declining to 16 hours of light at 20 weeks of age, was not effective in delaying sexual maturity. Some pullets in this group laid their first eggs as early as 18.5 weeks of age; this group, as a whole, laid at a lower rate than other treatment groups. Increasing the photoperiod gradually or in one sudden increase at 22 weeks of age did not alter the lay house performance.

Erasmus (1963) observed significantly earlier sexual maturity, 8.6 days, and significantly smaller initial egg weights when W. L. pullets were reared during a period of increasing natural daylength compared with similar pullets reared during a period of decreasing daylength.

McGinnis et al. (1964) compared three step down-step up lighting regimes with a program providing 16 hours of daily light for the rearing of replacement pullets. Programs 1, 2, and 3, respectively, began with 22, 22, and 16 hours of light; gradually decreased to 16, 9, and 9 hours at 20 to 22 weeks of age; and subsequently increased gradually to 22, 22, and 16 hours of light per day for the lay period. Slightly larger egg size for the 22-9-22 group was the only difference reported. In a second trial, pullets reared with the 16-9-16 step down-step up regime laid at a higher rate. Increasing daylength at 18 or 20 weeks of age did not influence egg production.

Noles and Smith (1964) delayed date of first egg by 6 days with a constant 6 hours of daily light for rearing December-hatched W. L. pullets. Naturally-lighted pullets were significantly heavier at 145 days of age and consumed approximately 454 g. more feed up to that time. The 6-hour group laid 226 eggs and the naturally-lighted birds laid 225 eggs even though the 6-hour group initiated production 6 days later.

Lillie and Denton (1965) utilized several lighting programs for rearing March-hatched W. L. pullets. Light was held constant at 6 or 14 hours from 0 to 22 weeks or was decreased at 12, 14, or 16 weeks of age from 14 to 6 hours. Pullets receiving a constant 14 hours of light per day were heaviest at 22 weeks of age. Those receiving a constant 6 hours of daily light weighed significantly less and consumed less feed than those reduced to 6 hours of light at 12, 16, or 18 weeks. Decreasing light at 12, 16, and 18 weeks delayed sexual maturity by 15, 10, and 30 days, respectively, as compared to pullets receiving a constant 6 or 14 hours of light.

Harrison et al. (1965) reared W. L. pullets under four step down-step up lighting programs. All treatments started with 14 hours of light daily and decreased to 6 hours at 16 weeks. The 8-hour light decrease in Groups 1 to 4 was made in 1, 2, 4, and 8 decrements, respectively.

Light for Group 1 was returned to 14 hours at 16 weeks of age. Light for Group 2 was increased to 14 hours by means of one 4-hour and sixteen 15-minute increments. Groups 3 and 4 were also increased to 14 hours of light by means of one 2-hour and twenty-four 15-minute increments, and thirty-two 15-minute increments, respectively. The rate of light decrease had little effect on sexual maturity. The groups receiving abrupt increases at 16 weeks, Groups 1 and 2, reached 50% egg production at 26 and 29 weeks, respectively. Groups 3 and 4 with gradual light increases reached 50% production at 32 weeks, peaked later, and laid at a higher rate throughout the experiment.

Proudfoot and Gowe (1967) grew W. L. pullets using various lighting programs. All groups were compared with the controls which received a constant 14 hours of light to 21 weeks of age. Step-down and 6-hour constant lighting programs delayed sexual maturity and significantly reduced egg production; however, egg production data was collected on the same chronological period for all groups regardless of sexual maturity. Light treatments significantly reduced body weights at 21 weeks of age. Decreasing daylength significantly increased egg size. Birds receiving 6 hours of light to 21 weeks of age laid significantly smaller eggs.

Harrison et al. (1969) exposed W.L. pullets to various lighting regimes. All groups received 6 hours of light daily until they were switched to one of three different laying period light treatments at 14, 16, 18, or 20 weeks of age. Lay house light treatments were as follows: (1) 14 hours of daily light throughout the lay period; (2) 12 hours of light per day to 20 weeks of age and then increased 15 minutes per day at weekly intervals up to 14 hours of light; and (3) 8 hours of light to 20 weeks and then increased 15 minutes per day at weekly intervals to 14 hours per day. Average age at first egg was increased by 20 days when light was increased gradually from 6 to 8 hours in one increment and then to 14 hours in 15-minute increments. Age at sexual maturity was directly related to age (14, 16, 18, or 20 weeks) at the time the light was increased from 6 to 8, 12, or 14 hours. Increasing the light abruptly at 14 weeks tended to reduce egg production. Those birds gradually given added light reached sexual maturity later, reached a higher peak production, and maintained a higher rate of lay over a longer period of time. The age at the time of the initial light increase was proportional to the duration of hen-day egg production in excess of 80%. Early sexual maturity and early exposure to increasing light reduced egg size.

Bornstein and Lev (1969a, b) compared the effect of an increasing natural daylength with decreasing daylength for growing W. L. pullets. Groups 2, 3, and 4 were exposed to decreasing daylength at 0, 7, and 14 weeks of age, respectively. Light treatments terminated at 23 weeks of age. Pullets receiving decreasing daylength at 7 weeks required significantly longer to reach 10 and 50% production at 159 and 180 days, respectively, as compared with 140 and 150 days for the birds grown with increasing daylength. Delayed birds were significantly heavier at 161 days and laid significantly heavier eggs at 174 days of age, at 50% production, and throughout the experiment. These birds also laid the most eggs per hen housed. Bornstein and Lev concluded that improvement in egg size may be due to combined effects of age and body weight.

Proudfoot and Gowe (1974) compared three lighting regimes for W. L. replacement pullets: (1) controls, 14 hours daily from 0 to 21 weeks of age; (2) starting with 8 hours and 20 minutes and increasing by 17-minute weekly increments to 14 hours at 21 weeks; and (3) starting with 13 hours and increasing to 15 hours and 20 minutes at 12 weeks of age, then decreasing 16 minutes weekly to 13 hours at 21 weeks of age. The increasing photoperiod resulted in significant decreases in egg size, the number of eggs laid after hens reached 50% production, shell strength, egg quality, and monetary returns over the cost of chicks and feed. The program in which light was increased weekly, up to 12 weeks of age, and then decreased weekly to 21 weeks of age brought about significantly smaller eggs in one of the two trials in which it was utilized.

Withholding Water from Growing Chickens

Ross (1960) found that N. H. chicks which were given water for three 30-minute periods a day from 0 to 6 weeks of age consumed 88.9% as much feed and 103.3% as much water as controls with water *ad lib.*;

they had lower body weights but there was very little effect on feed conversion. Feces excreted by intermittently-watered chicks were significantly higher in moisture content. Their water-to-feed consumption ratio was 2.32 in comparison to 2.00 for the controls.

Lepkovsky et al. (1960) reported that feed intake and proteolytic activity of the intestinal contents remained the same with or without concurrent watering during a daily 2-hour feeding period. Delayed passage of food from the crop and reduced levels of liver and leg muscle glycogen indicated slower digestion in birds consuming feed without concurrent water intake.

Kellerup et al. (1965) initiated water restriction with broiler chicks 1-week old. Six groups received water ad lib. or 90, 80, 70, 60, or 50%, respectively, of the amount of water consumed by the ad lib. controls the previous day. In general, weekly feed consumption and water:feed ratios decreased with each increment of water restriction. Each increment of water restriction resulted in significantly lower body weights; however, all groups gained weight. Chicks drank less water per gram of body weight with each increment of restriction and with increasing age.

Water was withheld from broilers for a period of 24, 48, or 72 hours during the first, third, fifth, or seventh week of life by Arscott (1969). The only significant reduction of body weight was observed in birds without water for 72 hours in the third week. The broilers tended to overconsume in the 5 succeeding days following restriction compared to the controls. No differences in mortality were observed. It was observed that feed consumption decreased during water restriction.

Kirkland and Fuller (1971), in an effort to delay sexual maturity and to control body weights of broiler breeders, withheld water completely for 24 hours every other day; on alternate days water was available ad lib. In addition, pullets received either high or low-energy diets of 2700 or 1800 kcal. of M. E. per kg. Sexual maturity was significantly delayed by 1.6 to 2.3 weeks due to the lower energy diet. A greater delay of 4.0 to 4.5 weeks was observed with a combination of a low-energy diet and water restriction. Up to 1 year of age, the birds that received a combination of a low-energy diet and water restriction laid significantly more eggs with a greater percentage of settable eggs. These positive results were obtained even though these birds had reached sexual maturity 4.0 to 4.5 weeks later than the controls. In eight 28-day production periods, the low energy-water restriction group laid significantly more settable eggs, 131 vs. 102 eggs, and required less feed per egg than the high energy-water ad lib. controls. All water-restricted birds, regardless of the energy content of the diet, had lower carcass fat content at maturity. In addition, they laid significantly fewer small eggs resulting in a significantly higher average egg weight. Mortality in the growing period was not related to water deprivation. Lay house mortality was directly related to both body weight and carcass fat content at maturity.

Feed Restriction of White Leghorn Replacement Pullets

Sherwood and Milby (1954) restricted the feed intake of range and confinement-reared pullets to 70 and 85% of ad lib., respectively. Feed restriction delayed sexual maturity 15 to 26 days and increased the cost of feed prior to the first egg. Egg weights in the early lay cycle favored restriction. There was no difference in egg production.

MacIntyre and Aitken (1959) restricted feed intake of 8-week-old White Leghorns to 63, 72, or 76% of the feed intake of controls. Restriction reduced 20-week body weights, delayed the onset of lay, increased the rate of egg production, decreased the total amount of feed consumed, improved feed efficiency, and improved albumen quality. The controls laid three times as many peewee eggs in the first 3 weeks of production and had heavier body weights at the end of the lay period.

Fuller et al. (1959) limited the feed intake of W. L. pullets to 9 pounds per 100 birds per day. The four groups had their intake restricted from 6 to 16, 6 to 18, 6 to 24, or 12 to 24 weeks of age, respectively. Degree of growth depression was proportional to length of feed restriction. Restricting feed to 24 weeks of age delayed sexual maturity by 5 weeks. Body weights of all groups were equal at 30 weeks of age. Mortality was slightly higher in the severely restricted groups. Restricting feed from 6 to 18, 6 to 24, and 12 to 24 weeks of age significantly increased egg production. Birds restricted from 6 to 24 weeks of age reached an average egg weight of 53 g. 4 weeks earlier than controls; in addition, they required significantly less feed to produce a dozen eggs.

Mortality was increased threefold when Thomas and Albritton (1960) restricted the feed intake of 8-week-old W. L. pullets to 50 or 75% of ad lib. The 75 and 50% restricted birds weighed 227 and 454 g. less at 20 weeks of age, respectively. Five and 50% production were delayed 15 and 23 days, respectively, by 50% restriction. This group also laid fewer small and peewee eggs.

Gowe et al. (1960a, b) restricted feed intake of range-reared pullets to 70% of that of controls during the previous week beginning at 7 weeks of age. Restriction delayed maturity by 12 days, decreased 147-day body weights by 288 g., increased the rate of lay, decreased lay house mortality, increased the number of large and extra large eggs, decreased the number of small and peewee eggs, and improved income per bird by $0.19.

MacIntyre and Gardiner (1961) and Gardiner and MacIntyre (1962) restricted the feed intake of W. L. pullets to 70% ad lib. for 5 to 22, 9 to 22, 13 to 22, or 17 to 22 weeks of age. In a second experiment feed intake was restricted to 60% ad lib. for 9 to 17, 13 to 17, 13 to 21, or 17 to 21 weeks of age, or 50% ad lib. for 17 to 21 weeks of age. Feed restriction reduced feed intake and 21 or 22-week body weights and delayed the attainment of 50% production (4 to 19 days) in direct relationship to the degree and duration of restriction. Feed restriction in Experiment 1 lowered the feed requirement per dozen eggs and significantly increased egg production. Restriction decreased the number of peewee and small eggs laid in the early lay cycle, but had no effect on average egg weights, mortality, body weights at the end of lay, and internal or external egg quality as measured by specific gravity and Haugh unit values.

Berg and Bearse (1961) restricted the feed intake of 8-week-old W. L. pullets by 17%, which reduced 21-week body weights by 20 and 42 g. for the corn and barley-base diets, respectively. Restriction did not delay sexual maturity; however, birds were grown during a period of decreasing daylength. Berg and Bearse reported that unpublished data from the Western Washington Experiment Station show a sexual delay due to feed restriction when light was held constant at 16 hours per day. Restriction of the corn diet increased egg size by 0.7 g. while restriction of the barley diet decreased egg size by 0.2 g.

Walter and Aitken (1961) restricted feed intake of 8-week-old W. L. pullets to 75% ad lib. A second group was limited to 6 pounds of mash and 6 pounds of whole grain per 100 birds per day from 8 to 21 weeks of age. In all comparisons, restricted birds ate less feed in the lay period. Restriction decreased body weights at housing, increased early egg size, and improved feed efficiency in two of three comparisons. Body weights at maturity were unaffected.

Hollands and Gowe (1961) restricted the feed intake of W. L. pullets to 90, 80, and 70% ad lib. for the age periods 22 to 28, 29 to 35, and 36 to 147 days of age, respectively. Restriction reduced 21-week body weights by 382 g., delayed maturity by 15 days, increased rearing mortaltiy, decreased lay house mortality, and increased hen-day egg production by 2.1 and 8.2% for the first and second cycles, respectively.

Gerry (1962) restricted 8-week-old W. L. and White Plymouth Rock pullets to 80% of the ad lib. intake of a diet containing two-thirds mash and one-third oats. A second group ate mash free choice for 2 hours in the morning and oats for 2 hours in the afternoon. Restriction resulted in lower feed cost during rearing and reduced 20-week body weights. Body weights were approximately equal following the lay period.

Fuller (1962) provided 5 pounds of mash per 100 pullets per day for 5 days a week beginning at 8 weeks of age. In addition, these pullets received 5 pounds of oats for the first 4 weeks and 10 pounds thereafter per 100 birds per day. Feed restriction resulted in lower average body weights at 21 weeks of age, significantly improved egg production, increased egg weights, and improved feed efficiency.

Deaton and Quisenberry (1963) reported that W. L. pullets were delayed 9 days in reaching 50% production when feed intake was held constant at 10 pounds per 100 birds per day from 8 to 21 weeks of age. Berg et al. (1963) fed 8-week-old W. L. pullets diets with 3106 or 2396 kcal. of M. E. per kg. Intake of the high-energy diet for a third group was held to 80% ad lib. Restricted feeding decreased 20-week body weights by 20 g., delayed sexual maturity, slightly reduced lay house mortality, and increased egg weights when pullets were reared with increasing or decreasing daylength. Restricted birds reached 50% production 10 days earlier than the birds on full feed and increasing light.

Luckham et al.(1963) reported superior performance with pullets having feed available 6 of 7 days from 8 weeks of age to maturity. Skip-a-day, skip-2-days, and 30% feed restriction all resulted in reduced body weights at maturity and delayed sexual maturity.

MacIntyre and Gardiner (1964) restricted the feed intake of W. L. pullets to 70% ad lib. for 5 to 21, 5 to 23, 5 to 25, 5 to 27, or 5 to 29 weeks of age. Restriction resulted in a 26 to 32-day delay in sexual maturity, higher peak production, and higher rearing and lay house mortality. The first 2,000 eggs laid by each pen were sized on a commercial grader. The percentage of large and medium eggs increased as the duration of restriction increased. Restricted groups laid less than 10% peewee eggs in comparison with 45% for the controls. The full-fed birds laid more small eggs throughout the experiment. Birds restricted from 5 to 25 weeks of age laid most efficiently.

Strain et al. (1965), Gowe et al. (1965), and Hollands and Gowe (1965) restricted feed intake of several strains of W. L. pullets to 90% ad lib. from 21 to 27 days, 80% ad lib. from 28 to 34 days, and 70% ad lib. from 35 to 147 days of age. In a second experiment, the 10 and 20% restrictions began at 8 and 28 days of age, respectively. All amounts were based on the control group's consumption of the previous week. Feed restriction increased age at first egg by an average of 15 days. Restricted birds weighed 310 g. less at 147 days and 40 g. less at 365 days of age. Restricted birds, on the average, laid five more eggs than the full-fed birds. In 16 out of 25 comparisons, the full-fed birds laid larger eggs. When feed was restricted to 70% ad lib., feed cost was $0.23 less per bird in the rearing period. The 80% restriction resulted in a savings of $0.17 per bird. Restricted birds ate more feed in the lay house, but not enough to negate brooder house feed savings. The net income per bird was $0.31 higher for the restricted birds. For strains laying smaller eggs, feed restriction decreased the number of peewee and extra large eggs and increased the number of large and medium eggs.

Lillie and Denton (1966) fed a control developer or one diluted with 25% oat hulls to W. L. pullets from 8 to 20 weeks of age; in addition they restricted feed intake of some pullets to 80, 75, or 70% of the amount of feed the control group had eaten the previous day. Birds receiving the fiber-diluted diet consumed 12% more feed. Feed restriction resulted in significantly lower feed intake and 20-week body weights. Thirty percent restriction led to higher brooder house mortality. Weight gain during lay was significantly greater for restricted birds.

Proudfoot and Gowe (1967) initiated several feed restriction programs with W. L. pullets. One group received feed _ad lib_. from 1 to 21 days of age, then 90, 80, and 70% of a control group's _ad lib_. feed intake from 22 to 28, 29 to 35, and 36 to 147 days of age, respectively. A second group received 70% _ad lib_. from 22 to 147 days of age. A third group consumed 90% _ad lib_. from 22 to 28 days of age followed by 80% _ad lib_. to maturity. A fourth group was restricted to 75% _ad lib_. intake from 56 to 154 days of age. All amounts were based on consumption of the controls from the previous week. Feed restriction resulted in a 9 to 19-day delay in reaching 50% production, reduced body weights, increased rate of lay, larger eggs, and better internal egg quality. Feed efficiency favored the full-fed birds.

Bolton and Blair (1970) fed control W. L. pullets diets containing 3090, 2990, and 2960 kcal. of M. E. per kg. from 0 to 6, 6 to 16, and

16 to 22 weeks of age, respectively, while a restricted group received for the same time periods diets containing 2775, 2630, and 2595 kcal. per kg. The birds fed the higher energy levels were significantly heavier at 16 weeks of age and at the end of the lay period. Diets did not have any effect on sexual maturity. The lower energy diets led to significantly more eggs. Total volume of egg produced was greatest when pullets received the low-energy starter and a high-energy developer.

Fuller and Chaney (1974) utilized two developers, 1800 and 2700 kcal. of M. E. per kg. of diet, for rearing replacement pullets from 6 to 20 weeks of age. Feeding the lower energy diet delayed sexual maturity an average of 4.3 weeks, increased the total number and number of settable eggs per bird by 11 to 17 and 17 to 26 eggs, respectively, and lowered the feed requirement per egg.

Proudfoot and Gowe (1974) restricted feed intake of two groups of W. L. pullets to 90% ad lib. from 6 to 21 weeks of age, or to 75% ad lib. from 6 to 21 weeks of age. Amounts were based on the ad lib. consumption of the controls from the previous week. Restricted feeding resulted in a 14 to 19-day delay in sexual maturity, a significant increase in egg size, a significant decrease in average body weights at 147 and 351 days of age, and an increase in monetary returns. In two of three trials, eggs from feed-restricted birds had higher specific gravity values. Restriction led to significantly higher Haugh unit values and egg weights in all tests. Lay house mortality was lower for restricted birds.

Low-Protein Diets

Range-reared pullets were delayed 1 week in reaching sexual maturity when Platt and Stover (1945) excluded all protein concentrates from their ration after 12 weeks of age. Providing only whole grain after 12 weeks of age resulted in an 8-week delay in maturity. After reaching sexual maturity these birds laid at a higher rate than did the controls.

Berg and Bearse (1958) reported that W. L. pullets performed equally well when consuming developer rations containing 2420 kcal. of M. E. per kg. with 15% protein or 2860 kcal. with 18% protein. A second experiment demonstrated that pullets receiving 16, 14, and 12% protein from 8 to 12, 12 to 16, and 16 to 20 weeks of age, respectively, grew as well as pullets receiving 16% protein from 8 to 20 weeks of age.

Denton and Lillie (1959) fed W. L. pullets from 0 to 26 weeks of age starter and developer diets containing various protein levels. The regimes were: (1) 21% from 0 to 8 weeks, 16% from 8 to 26 weeks; (2) 16% from 0 to 26 weeks; (3) 16% from 0 to 8 weeks, 12% from 8 to 26 weeks; and (4) 12% from 0 to 26 weeks. Body weights at 8 and 16 weeks reflected dietary protein content--the higher the protein, the heavier the birds. Growing treatments had no effect on egg production or feed conversion in the lay house.

Sunde and Bird (1959) observed optimum growth of W. L. pullets when they fed as little as 15% protein from 10 to 15 weeks of age and

12% from 15 to 20 weeks of age. Maximum weight gains were observed when pullets were fed 13.2 or 14.1% protein from 10 to 20 weeks of age. Feeding an 11.4% protein developer to pullets from 10 to 20 weeks of age resulted in a slight reduction in egg production.

Berg (1959) fed W. L. pullets growing rations containing 3135 kcal. M. E. per kg. and 12.7, 15.8, or 18.8% protein. Three other groups received diets containing 2420 kcal. of M. E. per kg. and 13.2, 15.9, or 18.9% protein. Increased protein resulted in increased body weights at 21 weeks of age. The protein levels of the 2420 kcal. diet had no effect on sexual maturity. Lowering the protein content of the 3135 kcal. diet increased the number of days necessary to reach 50% production.

Turk _et al_. (1961) fed replacement pullets starter rations containing 20.5% protein and 1518, 1760, 1958, 2123, 2299, 2475, or 2660 kcal. of productive energy (P. E.) per kg. Increasing the energy content of the diet had no effect on sexual maturity up to 2475 kcal. per kg. At this level, protein became the limiting nutrient and sexual maturity was delayed. Intake of the high-energy diets led to consumption of loose feathers and to high mortality.

Waldroup and Harms (1962) and Harms (1963) fed W. L. pullets from 8 to 21 weeks of age various developer diets containing 9 to 25% protein and 1540 to 2596 kcal. of M. E. per kg. At all energy levels, body weights at 21 weeks of age were increased by increasing protein increments up to 20%. Increasing the energy level when the protein level was held constant at 9% decreased body weights. Birds fed a diet containing 9% protein and 2068 kcal. of energy consumed less feed than other groups fed this same energy level with greater percentages of protein. Average age at first egg was increased by 19.4 days and egg production was lowered by 3.5% when feeding a diet containing 9% protein and 2068 kcal. of energy as compared to feeding a diet with 20% protein and 2596 kcal. of energy. From the third to the eleventh month of production, pullets which had been provided developer diets containing 9% protein and 1540 or 2068 kcal. of energy laid at a higher rate than all other groups.

Bullock et al. (1963) fed three groups of 8-week-old W. L. pullets developer rations containing 2585 kcal. of M. E. per kg. and 10.5, 15.0, or 17.5% crude protein. Two other groups of pullets were fed diets containing 1808 kcal. of energy and 10.5 or 15.0% protein. Birds consuming the diet with 10.5% protein and 2585 kcal. of energy did not eat as much feed as the group receiving 15.0% protein and 2585 kcal. energy. Fifty percent production was delayed 4.5, 7.0, and 10.0 days for the groups consuming the low-protein, low-energy, and the combination low energy-low protein diets, respectively. Egg production was not altered by developer diets.

Waldroup et al. (1966) and Waldroup (1970) observed a 23.6-day delay in sexual maturity when 8-week-old broiler breeder pullets were fed developer rations containing 10% protein. Birds consuming the low-protein diet weighed 654 g. less at 24 weeks of age than did those receiving the standard 16% developer. Protein level had no effect on lay house performance. The low-protein pullets laid a lesser number of medium and a greater number of extra large eggs.

Petersen et al. (1966) observed that growth rates of W. L. pullets were directly related to protein content of the starter diet. Pullets received diets containing 14, 16, 18, or 20% protein from 0 to 7 weeks of age. Pullets receiving chick starters containing 16, 18, or 20% protein showed no difference in 20-week body weights, age at first egg, age at 25 and 50% production, egg weights, and egg production. The 14% chick starter markedly depressed performance in the lay house. Petersen and Sauter (1967) found that feeding starter rations containing 16, 18, and 20% protein to W. L. from 0 to 8 weeks of age resulted in 8-week body weights that were in direct proportion with the protein content of the ration. Protein content of the starter ration did not affect 20-week body weights, age at first egg, age at 50% production, egg weights, or annual egg production.

Lillie and Denton (1966) concluded that the protein level for egg-type pullets may be reduced from 21 to 16% and 16 to 12% for the periods 0 to 8 and 8 to 20 weeks of age, respectively, without observing adverse effects. Lillie and Denton (1967) fed W. L. pullets diets varying in protein content in the brooding and developing periods. Groups 1, 2, and 3 received starter diets containing 21, 16, and 16% protein, respectively, from 0 to 8 weeks of age. These same groups, from age 8 to 20 weeks, received developer rations containing 16, 16, and 12% protein, respectively. Pullets consuming the 16% protein starter ration weighed 31 g. less at 8 weeks than those fed 21% protein. Feeding a 12% protein developer further depressed 20-week body weights by 7 g. In Trial 1, hen-day egg production was significantly higher for those pullets consuming the 21% protein starter. In Trial 2, no differences in production were observed.

Smith (1967) reported a significant drop in daily feed consumption when W. L. pullets were fed developer diets containing 11 or 15% protein from 12 to 20 weeks of age. The control group received a 19% protein ration. Birds consuming the 11 and 15% diets weighed 13 and 9 g. less, respectively, than the controls at 20 weeks of age. Flock age at 50% production was increased by 3 and 6 days, respectively, by feeding the 15 and 11% protein diets.

Wright et al. (1968) fed W. L. pullets from 8 to 18 weeks of age a developer diet that contained either 10 or 16% protein and 2068 kcal. of M. E. per kg. In a second trial, the low-protein developer was fed from 9 to 18 weeks of age. Feeding the lower protein level increased average age at first egg by 5 and 18 days in Trials 1 and 2, respectively. Birds consuming the low-protein developer outlaid the controls in Trial 1, but not in Trial 2. Protein restriction delayed peak production in Trial 2. Protein restriction resulted in improved feed efficiency in Trial 1 and inferior efficiency in Trial 2.

Santana and Quisenberry (1968) reared W. L. pullets from 8 to 24 weeks of age utilizing developer rations containing 2083 or 2207 kcal. of M. E. per kg. and protein levels of 12, 14, 16, or 18%. Twenty-four week body weights were lowest and lay house gain highest for the 12% protein group. Birds were continued on the developer diets in the lay house, except that methionine, lysine, and tryptophan were supplemented to meet National Research Council levels for all deficient diets. The 12% protein group demonstrated the poorest egg production, egg size, and feed efficiency.

Summers et al. (1969) fed chick starters with 14 or 20% crude protein to caged and floor-reared W. L. pullets from 0 to 8 weeks of age. All birds received a 13% protein developer from 8 to 25 weeks of age. Feeding the lower protein level retarded 8-week body weights by an average of 127 g. At 25 weeks of age, caged pullets fed the low-protein starter were significantly heavier than the controls, but there was no significant difference in the body weights of floor-reared pullets. Protein level did not affect subsequent reproductive performance.

Blair et al. (1970) fed W. L. pullets from 6 to 16 weeks of age developer rations containing various protein levels and different protein supplements. The rations contained: (1) 16.3% protein with 5.1% meat and bone meal, and 10.2% soybean meal; (2) 13.7% protein with 5.1% meat and bone meal, and 5.1% soybean meal; (3) 13.6% protein with 10.2% soybean meal, and no meat and bone meal; and (4) 11.5% protein with 5.1% soybean, and no meat and bone meal. Pullets fed the 13.6 and 11.5% protein diets consumed significantly less feed from 6 to 16 weeks of age and weighed significantly less at 16 weeks. A slight reduction in egg size was observed in birds fed the lowest protein level. There was no significant effect on egg production, feed efficiency, or mortality.

Armas et al. (1970), using a 3x2x2 factorial arrangement of treatments, reared Babcock B-300 pullets from 8 to 21 weeks of age on protein levels of 10, 14, or 18% with fiber levels of 4 or 11% and P. E. levels of 1500 or 2200 kcal./kg. Birds consuming the 10% diet required an average of 5.5 and 7.0 days longer to reach first egg and 50% production, respectively, and weighed 147 g. less than the controls at 21 weeks of age. The 10, 14, and 18% protein groups laid an average of 237.0, 235.3, and 235.5 eggs per bird, respectively.

Foster (1971) fed W. L. chicks from 6 to 19 weeks of age 15.9, 14.6, or 12.3% protein, or whole wheat only. Birds consuming 12.3% protein or whole wheat took significantly longer to reach sexual maturity. The 12.3% protein group was significantly lighter at 89, 134, and 196 days of age. Egg production and egg weights were not affected.

Wells (1971) reared medium weight hybrid pullets using two feeding regimes: (1) 18.5% protein from 0 to 8 weeks, and 15.5% protein from 8 to 18 weeks; (2) 18.5% protein from 0 to 6 weeks, 15.5% protein from 6 to 12 weeks, and 12.5% protein from 12 to 18 weeks. At 15 weeks of age, birds fed the high-protein regime were significantly heavier. There was no difference in feed intake. Poor feathering was observed in pullets consuming the low-protein diets. A slight increase in mortality resulting from the lower protein diet was the only difference observed in lay house performance.

Holmquist and Carlson (1972) fed 8 to 20-week-old White Leghorns three developer diets. Diet 1 was low protein-low energy with 10% protein and 1950 kcal. of M. E. per kg.; Diet 2 was low protein-high energy with 12% protein and 2900 kcal. energy per kg.; and Diet 3 was high protein-high energy with 16% protein and 2900 kcal. per kg. The low protein-low energy diet reduced body weights and lay house mortality. After 8 weeks of lay, the low protein-low energy group required less feed to produce a dozen eggs.

Auckland and Fulton (1973) reported that feeding developer diets containing 11.3 and 9.1% protein to W. L. pullets from 12 to 18 weeks depressed 18-week body weights by 5 and 9% and delayed sexual maturity by 2.4 and 2.8 days, respectively, as compared to controls receiving a 14.6% developer. Hen-day egg production and egg weights decreased slightly as the protein level declined.

Owings _et al_. (1973) fed replacement pullets 18 or 14.7% protein from 3 to 12 weeks of age, then 15 and 13% protein, respectively, from 12 to 20 weeks of age. Body weights at 20 weeks were 1317 and 1298 g. for the high and low-protein groups, respectively. Low-protein pullets suffered greater mortality in the lay house.

Goan _et al_. (1973) reported that pullets fed a 10.2% protein developer returned a greater income than pullets fed a 17.6% protein diet. Birds were fed the developers from 10 to 20 or 24 weeks of age. Feeding the low-protein diet to pullets up to 20 and 24 weeks of age resulted in a reduction of feed intake of 227 and 681 g. per pullet, respectively. Low-protein pullets reached 50% production 9 days later than the control group, but they still laid an average of 4 more eggs per bird. Income per bird was increased by $0.10 to $0.24 per bird by feeding the low-protein diet. This financial gain was basically due to feed savings in the rearing period. The plumage of the low-protein birds was very ragged; loose feathers were consumed rapidly.

Stockland and Blaylock (1974) fed caged and floor-reared W. L. replacement pullets various levels of protein during the following stages of development: 0 to 6, 6 to 10, 10 to 14, and 14 to 20 weeks of age. Levels fed were 12, 14, 16, 18, and 20% protein. Birds on a 20-14-12-12 nutritional regime were significantly lighter at 20 weeks of age and required longer to reach 50% production. Growth was maximized in the 6 to 10, 10 to 14, and 14 to 20-week age periods by 14, 14, and 12% protein, respectively. Egg production, egg weights, feed efficiency, and 62-week body weights were not altered by protein levels. In a second trial birds required 16, 12, and 12% protein for maximum growth in periods 6 to 10, 10 to 14, and 14 to 20 weeks of age, respectively.

Low-Lysine Diets

Enos and Moreng (1964) substantiated a hypothesis that genetic variability exists among domestic fowl for the utilization of lysine. When comparing the growth response of birds fed a control and a low-lysine (0.50% lysine) starter, a good deal of variability was observed. Growth of the various female lines ranged from 30.47 to 46.57% of the control group. Male lines fed the low-lysine diet weighed 20.19 to 41.79% as much as the controls. When the low-lysine diet was fed to chicks for the first 4 weeks only, egg production was not inhibited.

Singsen et al. (1964, 1965) fed meat-type chicks low-lysine starter and developer rations containing 0.47 and 0.59% lysine, respectively. Pullets received the deficient starter and developer diets for varying lengths of time starting at 0, 4, 8, 12, or 16 weeks of age, and terminating at 4, 8, 12, 16, or 21 weeks of age. Birds on the low-lysine developer for 12 weeks or longer required 20.0 days longer to reach 25% production and 17.7 days longer to reach 50% production. Birds consuming the control diet for the first 4 to 8 weeks and then changing to the deficient diet later were not delayed in sexual maturity or restricted in body weight at 21 weeks in comparison to the control birds. Singsen concluded that it was necessary to start and continue chicks for 12 weeks on the low-lysine diet to get maximum growth retardation and delay in sexual maturity. Birds started on a low-lysine diet laid at a slightly higher rate than those starting on a normal diet; egg sizes were slightly increased by the low-lysine diets.

Fisher (1966) fed 16 various diets to pullets from 10 to 20 weeks of age that contained 0.4, 0.5, 0.6, or 0.7% lysine with 0.20, 0.24, 0.28, or 0.32% methionine. Maximum growth occurred with 0.5% lysine and 0.2% methionine. Feed intake was not altered by treatment. The rate of lay after peak production was significantly higher for birds fed the lowest levels of amino acids.

Peacock (1967) and Peacock and Combs (1967) fed an imbalanced protein developer to White Rock pullets starting at 8, 12, or 16 weeks of age and continuing up to maturity. The imbalanced diet contained 8% hydrolyzed feather meal and 87% corn; it provided 14.5% protein, including 0.29% lysine, 0.19% methionine, and 0.11% tryptophan. Controls received an 18.4% protein developer. Feeding of the imbalanced diet, when started at 8 weeks of age, resulted in a 450 g. depression in body weight at maturity and a 5-day delay in sexual maturity. Initiated at 12 or 16 weeks, the imbalanced diet did not alter the growing period performance other than delaying maturity by 4 days.

Couch et al. (1967) fed Pilch heavy breed pullets a diet containing only 0.62% lysine from 0 to 12 weeks and a control developer after 12 weeks of age. The low-lysine diet resulted in reduced body weights, delayed sexual maturity, increased peak egg production, and increased egg production over the entire laying cycle.

Trammell et al. (1967, 1968) fed a low-lysine starter for periods of 4, 8, or 12 weeks and a low-lysine developer during the developmental period. Pullets fed the low-lysine starter for 4, 8, or 12 weeks weighed only 25% of the control group's weight. When these birds were fed a complete diet, recovery was dramatic. When birds that had been fed normally for the first 6 weeks were given a low-lysine diet up to 22 weeks of age, body weights were reduced and average egg weights were increased. When pullets were restricted early in life, egg weights were depressed throughout the lay period.

Trammell et al. (1969) fed diets containing 0.32 to 0.64% lysine to broiler breeder pullets from 7 to 26 weeks of age. The lysine restriction during the developing period decreased the average body weight, delayed sexual maturity, increased egg production, and increased the number of settable eggs. Another trial showed that feeding pullets starter diets containing 0.52 to 0.53% lysine for the first 4, 8, or 12 weeks decreased body weight and increased the number of small eggs.

Sherwood et al. (1969) fed meat and egg strain pullets starter diets that contained 1.08 or 0.58% lysine and developer diets that contained 0.67 or 0.42% lysine; all other amino acid levels met the accepted requirements. Performance of these pullets was compared with control and restricted-fed groups. Performance of the pullets fed the low-lysine diets was equal to the controls, but inferior to the performance of pullets limited in their intake of a conventional feed. The low-lysine starter reduced 24-week body weights and increased by

3 days the length of time required to reach 10% production. Feeding the low-lysine developer did not reduce 24-week body weights, and retarded sexual maturity only 2 days. Sherwood concluded that the lysine requirement during the developer period from 8 weeks to maturity does not exceed 0.30% lysine/1000 kcal. M. E.

Abbott et al. (1969) reported significant increases in growth in pullets fed diets containing a low level of lysine (0.4%) when arginine levels were 0.55, 0.71, and 0.90% as compared to 0.40% lysine and 0.47% arginine. Pullets fed a diet containing 0.50% lysine and 1.08% arginine exhibited no retardation of growth or sexual maturity when compared with a diet containing 0.77% lysine and 0.90% arginine.

Summers et al. (1969) fed W. L. pullet chicks starter diets containing 20% crude protein with soybean meal, hydrolyzed feather meal, or rapeseed meal as the protein supplements. All groups received a 13% protein corn-soy diet from 8 weeks of age to maturity. Body weights at 8 weeks were 703, 684, and 158 g. for the chicks fed the soybean meal, rapeseed meal, and feather meal diets, respectively. Birds started with the feather meal diet laid at a lower rate, consumed less feed per hen-day, suffered greater lay house mortality, and laid smaller eggs. Pullets fed the rapeseed meal starter performed as well as the controls fed soybean meal.

Hooper et al. (1969) fed broiler breeder pullets developer diets containing 0.72% lysine from 7 to 18 weeks of age, or 0.43% lysine from 7 to 18, 7 to 20, or 7 to 22 weeks of age. The low-lysine developer resulted in lower average body weights, delayed sexual maturity, and higher egg production.

Abbott and Couch (1970) reported that heavy breed pullets produced a greater number of viable chicks when fed a diet containing 0.40% lysine and 0.60 to 0.70% arginine than did groups receiving low lysine-low arginine (comparable to a low-protein diet) or conventional diets. When both amino acids were restricted, retardation was too severe and a significant increase in lay house mortality was observed.

Couch and Trammell (1970) fed low-lysine starters to three groups of broiler breeder pullets up to 4, 8, or 12 weeks of age. Control and low-lysine starters contained 1.12 and 0.53% lysine, respectively. A fourth group that had been fed the control starter was fed a low-lysine developer (0.42% lysine) from 6 to 22 weeks of age. Pullets consuming the low-lysine starter had lower body weights at 4, 8, 12, 18, and 22 weeks of age. Feeding the low-lysine developer resulted in an 885 g. reduction in body weight at 22 weeks of age. Feeding a low-lysine starter or developer resulted in decreased feed intake and delayed sexual maturity. Birds consuming a low-lysine developer laid 3% more eggs than the control group. Feeding the low-lysine starter resulted in smaller eggs; feeding the low-lysine developer resulted in fewer small eggs. Pullets fed a low-lysine starter or developer weighed significantly less after 8 and 12 months of lay.

Bonds _et al_. (1971) fed dwarf and normal W. L. pullets starter diets containing 1.10, 0.87, or 0.63% lysine up to 7 weeks of age. The dwarf White Leghorns performed equally well with 1.10 and 0.87% lysine in the diet. The diet containing only 0.63% lysine retarded the growth of the dwarf and normal White Leghorns by 25.7 and 40.1%, respectively.

Luther et al. (1972) reported that broiler breeder pullets were delayed in reaching 25 and 50% egg production by feeding low-lysine diets from 8 to 22 weeks of age. At maturity the control groups weighed an average of 357 g. more than the low-lysine pullets. Hen-day egg production for the pullets consuming the low-lysine developer was 6.15% lower than the level reached by the control group.

Luther and Couch (1973) reported that the lysine levels for maximum growth of replacement pullets are 1.10, 0.90, and 0.66% for the age periods 0 to 6, 6 to 14, and 14 to 20 weeks, respectively. Based on their research, the authors concluded that broiler breeder pullets should be fed developer diets containing 0.27 to 0.30% or 0.31 to 0.35% lysine in the winter and summer, respectively. Levels above 0.35% will not satisfactorily control body weight and sexual maturity regardless of temperature and light. The arginine level should be kept below 0.70%.

Intermittent Watering of Caged Layers

Maxwell and Lyle (1957) provided 5-month-old laying hens access to water for three 15-minute periods daily (8:00 A.M., 1:00 P.M., and 4:45 P.M.). Control birds had water available at all times. After 6 weeks the two groups of hens were exposed to the opposite treatment and the experiment continued for another 6 weeks. Egg production and feed efficiency favored the intermittent-watered birds. When droppings were scored from one to five, with five being the wettest, the droppings from the controls were higher in moisture in comparison with the water-restricted birds (3.8 vs. 1.75). Restricted and control groups consumed 0.39 and 0.72 pounds of water per bird per day, respectively.

Salverson (1959) reported results of water-restriction programs in commercial use in Southern California. There was no reduction in egg production when water was flowing 15 minutes in a 60-minute period or 30 minutes in a 120-minute period. Beneficial results obtained were reduced water runoff, financial savings on monthly water bills, and cleaner water troughs.

Wilson et al. (1965) reported the results of three trials with intermittent watering of W.L. layers. In Trial 1, the birds with in-mittent water received two 2-hour periods of water availability (8:00 to 10:00 A.M. and 4:30 to 6:30 P.M.). Egg production favored the restricted birds, 62.3% for the restricted birds vs. 58.7% for controls in four 28-day production periods. In Trial 2, the intermittently-watered birds had water available for only one 2-hour period (12:00 noon to 2:00 P.M.). Egg production favored the controls, 60.5% vs. 57.5% for the restricted birds, during five 28-day production periods. Fecal moisture was reduced by water restriction, 64.1 vs. 68.6%. When feces were collected during the period of water availability, moisture content was lower for the controls, 68.2 vs. 69.9%. Haugh units were 5.4 units higher for the restricted group. In Trial 3, egg production for birds receiving two 2-hour water periods equalled controls, except for a slightly lower peak production. No differences were observed in egg weights. Feed consumed per hen per 28-day period was 2.756 and 2.660 kg. for the controls and restricted groups, respectively. Visual observations suggested an improvement in the condition of the feces.

Hill (1969) provided pullets and hens five 15-minute periods of water availability per day. The first year of water restriction began at 41 and 93 weeks of age for the pullets and hens, respectively. The only difference was an improvement in feed efficiency by water restriction. The second year, tests began when the pullets and hens were 21 and 73 weeks old, respectively. Hen-day egg production was slightly reduced by watering time limitations in the pullet group. However, both pullet and hen feed efficiency was improved by this treatment. It was noted that the water troughs of birds on water limitation were definitely easier to keep clean.

Hill and Richards (1969) reported the results of limiting water availability to W. L. pullets and hens to five 25-minute periods daily. When the water restriction began on the 169th day of lay, the only result was an improvement in feed efficiency for the water-limited hens. When the watering time was restricted from the first day of lay, pullet egg production was reduced. There was no adverse effect on the hens. Hill concluded that restriction of water to five 25-minute periods per day was too severe when initiated with the onset of egg production.

Knight (1970) reported no adverse effects when 6,000 hens were provided six 30-minute watering periods per day. The water traveled a distance of 450' to reach the last cage in each row. Cleaner water troughs was one benefit of this intermittent watering regime.

Feed Restriction of Laying Hens

Heywang (1940) restricted the feed intake of two groups of W. L. hens to 75 or 87.5% of the control group's ad lib. consumption. These restrictions proved to be too severe. Egg production for the control, 87.5% ad lib., and 75% ad lib. groups was 193, 127, and 90 eggs, respectively.

Singsen et al. (1958) reported high egg production in a flock of White Plymouth Rock hens with controlled feeding. The controlled feeding group received only the amount of feed calculated to be necessary for actual needs. Egg production, body weight, environmental temperature, and energy content of the ration were considered in making this calculation. These birds consumed 22 to 29% less feed than those fed ad lib. on a low-energy diet. Controlled feeding reduced mortality and degree of obesity.

Walter and Aitken (1961) observed a reduction in body weight and egg production when W. L. hens were restricted in their feed intake by 12%. The drop in egg production was more severe in hens that had been fed on a restricted basis in the developing period.

Combs et al. (1961) observed a non-significant reduction in egg production by restricting the feed intake of Columbian Plymouth Rocks to 90% ad lib. Feed per hen-day and feed per dozen eggs favored the restricted birds. Body weight gains averaged 558 and 341 g. for the controls and restricted birds, respectively. Metabolizable energy per unit of egg produced was decreased by 11.6% due to feed restriction.

Donaldson and Miller (1962) restricted feed intake of White Plymouth Rocks and a White Rock X Wyandotte layers to 80% of free choice. The amount fed was based on the control group's consumption from the previous week. Control and restricted rations contained 2075 and 1890 kcal. of P.E./kg. Hen-day egg production and egg weights were significantly increased by feed restriction. Restricted hens were significantly lighter and required less feed to produce a dozen eggs. Mortality was not affected.

Jackson (1970) fed a high-energy diet, 2690 kcal. of M. E. per kg. and 16.3% protein or a concentrated diet, 3550 kcal. per kg. and 21.8% protein, to light and medium weight egg production hens. Limiting the feed intake of both the high-energy and the concentrated diets to 85 g. per bird per day reduced egg production. Restriction of the high-energy diet led to a significant decline in egg weights. Feed restriction improved feed efficiency in all instances, except when medium weight layers were restricted in the consumption of the high-energy diet. Regardless of the diet, restriction caused a loss of body weight.

Two strains of brown egg laying hens were restricted to 90% *ad lib.* by Gerry and Muir (1972). Feed restriction resulted in lower average body weights, 318 and 272 g. for Strains 1 and 2, respectively. Feed restriction decreased egg production by 3.03%, but improved feed efficiency. Restricted birds required an average of 141 g. less feed to produce a dozen eggs.

Hannagan and Wills (1973) restricted layers to 113 g. of feed per day from peak production, 40 to 45 weeks of age, until the end of the lay cycle. Hens were consuming this amount of feed free choice at peak production. Limiting feed intake reduced carcass fat deposition and improved feed-to-egg conversion by 10%. Egg size was reduced; restricted hens laid 15% fewer eggs weighing in excess of 65 g. than did the *ad lib.* fed controls.

White Leghorn X Australorp hens were restricted to 88, 94, or 97%

of ad lib. by McMahon et al. (1974). Those restricted to 88% laid 4% more eggs, but egg size was greatly decreased. Profit up to 62 weeks of age was $2.03 for birds receiving 94% ad lib. as compared with $1.57 for the controls. A 3% restriction of feed intake resulted in 5% more eggs.

Cherry (1959) limited the eating time of three groups of light Sussex hens to 6, 8, or 10 hours per day. The control group had feed available ad lib. Feed intake was significantly reduced by limiting the eating period to either 6 or 8 hours. Birds with feed available 6 hours per day ate 23% less feed than the control group. In addition, egg production was significantly reduced and birds lost an average of approximately 227 g. In the second trial, Cherry provided a pelleted feed for periods of 2, 4, 6, or 8 hours per day. Following an adaptation period, normal egg production was obtained with as little as 2 or 4 hours of feeding time with a pelleted diet.

Sherwood and Milby (1961) reported that meat birds having feed available 3 hours per day were able to consume as much feed as the ad lib. fed controls. In a second trial, White Leghorns were fed 90% ad lib. Egg production favored controls, but restricted birds were more efficient in feed conversion.

Patel and McGinnis (1970) provided feed to W. L. pullets for 4 or 14 hours per day. The 4 hours of feeding were provided in two 2-hour meals or one 4-hour meal which reduced feed intake by 15 and 10%, respectively. Egg size was decreased in both instances. Those birds receiving two 2-hour meals gained an average of 95 g. less than the controls in the 16-week experimental period. In addition, these pullets laid better than those birds receiving one 4-hour meal, and equally as well as those provided feed 14 hours per day.

McGinnis and Patel (1971) allowed W. L. laying hens two 2-hour feeding periods per day. These birds consumed 9 to 16% less feed, laid as well as the controls, and had less internal fat when slaughtered at the end of the experiment. Broiler breeds on the time-limit feeding ate 9% less and showed a 14% increase in fertility.

Polin and Wolford (1972) provided feed to six groups of W. L. hens in the following manner: (1) controls, feed ad lib.; (2) 80% of the control group's feed intake; (3) two 2-hour meals; (4) one 4-hour meal; (5) two 1.5-hour meals; and (6) two 2.5-hour meals. With the exception of 80% ad lib. feeding, feed restriction reduced egg production. All feed restrictions reduced feed consumed per hen-day, total weight of eggs laid, and average egg weights. With the exception of the two 2-hour meals regime, feed restriction reduced the kilograms of feed necessary to produce a kilogram of egg.

Harrison (1972) restricted the feeding periods of W. L. hens to one 4-hour feeding or two 2-hour feedings per day. Two 2-hour feedings reduced feed intake, but had little effect on egg production and egg weight. Providing only one 4-hour meal decreased egg production, egg weights, and body weights.

Bell and Moreng (1973) conducted a 2x2x2 factorial experiment with W. L. laying hens. Birds were provided 17 hours of light or six 10-minute light periods daily. Feed was available round the clock or during six 10-minute periods. Hens received diets containing 18 or 20% protein. Limiting hens to six 10-minute feedings significantly decreased feed per hen-day, grams of protein consumed per hen-day, grams of feed consumed per gram of egg, feed cost per dozen eggs, and body weight gain. Slight reductions in egg production and egg weights were also observed. In Trial 2, where protein level was held constant and two energy levels served as the third variable, limited-time feeding significantly reduced egg production and reduced feed intake by 20.6%. Feed restricted birds produced eggs with higher Haugh unit values. In a third experiment, hens had feed available for 10, 20, 30, or 45 minutes each 4-hour period. Birds having feed for 10 or 20 minutes each 4 hours consumed significantly less feed per day.

Andrews (1973) allowed three groups of hens the following feeding periods: (1) one 2-hour and one 4-hour period; (2) two 2-hour and one 1-hour period; and (3) three 1.25-hour periods. Limited-time feeding increased the number of large eggs and decreased the number of extra large and jumbo eggs. Improved shell quality was also observed by limiting feeding time.

Johnson _et al_. as quoted by Coates (1974) allowed hens free access to feed, made feed available for two 2-hour periods during the day, or alternated the two programs monthly. Limited-time feeding decreased egg production by 2.5% and slightly decreased egg size. Limited-time feeding reduced feed intake by 1.044 kg. per 100 birds per day, resulting in a $0.17 improvement in egg income over feed cost.

III. EXPERIMENTAL PROCEDURE

General Procedure

The following procedures apply to all experiments unless otherwise indicated. All experiments were conducted at the Oregon State University Poultry Research facilities, Corvallis, Oregon. Corvallis is located at the latitude of 44°38' North. All rations used for this research were formulated and milled on the University campus.

Single Comb W. L. pullets were used in all experiments. The normal size Oregon State University (O. S. U.) strain of W. L. used were the progeny of a rotational strain cross involving three lines maintained at O. S. U. The O. S. U. strain of W. L. dwarfs were the progeny of sex-linked dwarf males from a line selected at the Oregon Agricultural Experiment Station (Bernier and Arscott, 1972) mated to normal females from the O. S. U. rotational strain cross. To obtain the O. S. U. normal or dwarf chicks, eggs were saved and set in Jamesway incubators, Model 252B (James Mfg. Co., Los Angeles, California). The day-old chicks were vent-sexed by a professional sexor. Babcock B-300 strain W. L. pullets were utilized in some experiments. These were obtained as sexed day-old chicks from Skylane Hatchery, Woodburn, Oregon.

Experiments 1 through 5 involved studies of delaying the sexual maturity of normal and dwarf W. L. pullets grown during a period of increasing natural daylength. Low-lysine and low-protein developer rations, water restriction, and lighting programs were investigated.

Subsequent lay house performance of these pullets was also evaluated. Experiments 6, 7, and 8 involved studies of intermittent watering in the lay house. Experiment 7 included the study of a limited-time feeding program.

Electric cool room brooders manufactured by A. R. Wood Co. were used to supply heat for the 8-week brooding period. Brooders operated at 35°C. (95°F.) for the first week; temperatures were decreased with the aging of the chicks. Douglas fir shavings were used for litter in all floor-house experiments.

Body weights were routinely measured in all brooding experiments. For group weights, a Fairbanks-Morse 500-pound capacity platform scale was utilized. Pullets were placed in tared crates; crates were then weighed to the nearest one-quarter or one-sixteenth pound, depending on the accuracy of the specific scale. Individual body weights of pullets and hens were measured to the nearest five-hundreths of a pound on a milk scale. Pounds were converted to grams by multiplying by a factor of 453.6.

Feed intake was measured for each 4-week period during all experiments. Each replicate was fed from its own galvanized can. Storage cans were tared in accordance with the platform scale. A one-quarter pound unit scale was used in Exp. 1, 2, and 3. Feed cans for Exp. 4, 5, 6, 7, and 8 were weighed with a one-sixteenth pound unit scale. At the end of each 28-day period, feed troughs were emptied into storage cans prior to their being weighed. Pounds were converted to grams as noted previously.

Egg weights were measured in all lay house experiments. Average egg weights for Exp. 1, 2, 3, 4, and 5 were determined by weighing each lot of eggs from a replicate on a Toledo gram scale, Model 4030 (Toledo Scale Co., Toledo, Ohio) and dividing that value by the number of eggs per lot. In Exp. 6, 7, and 8, eggs were weighed individually to the nearest tenth of a gram on a Mettler gram scale, Model P-1000 (Mettler Scale Co., San Francisco, California). Averages were then determined from individual egg weights. Grams of egg produced per replicate was calculated by multiplying the 3-day sample average egg weight times the number of eggs laid for the 28-day period.

Egg sizes for Exp. 1, 2, 4, 5, 6, 7, and 8 were determined by individually weighing each egg collected during the sampling period on the Mettler gram scale and classifying them according to the following categories: (1) jumbo, 70.9 g. and up; (2) extra large, 63.8 to 70.8 g.; (3) large, 56.7 to 63.7 g.; (4) medium, 49.6 to 56.6 g.; (5) small, 42.5 to 49.5 g.; and (6) peewee, 42.4 g. and below. Percentages determined were multiplied times the number of eggs laid for the 28-day period. The numbers of each size for each 28-day period were totaled for the year and a yearly percentage for each size was calculated. In Exp. 3, egg sizes were determined by the use of a five case per hour capacity Eggo-Matic washer-grader (Otto Niederer Sons, Inc., Titusville, New Jersey).

Albumen quality studies were conducted in Exp. 1, 2, 6, and 7. Eggs were individually weighed and broken on an egg quality table. The height of the thick albumen was measured midway between the yolk and the outer edge of the thick albumen by means of a specially designed micrometer (B. C. Ames Co., Waltham, Massachusetts). Haugh units were calculated using micrometer readings and egg weights on an Egg Quality Slide Rule designed by A. W. Brant and K. H. Norris. Prior to breaking, these eggs were subjected to specific gravity determination. Using the procedure described by Arscott and Bernier (1961), the specific gravity was measured in aqueous salt solutions scaled from 1.052 to 1.104 in increments of 0.004.

A limited number of fecal samples was collected in Exp. 2 and 8 for dry matter determination. Circular pans, 31.8 cm. in diameter, were suspended beneath cages for a 24-hour period. The pans were then placed in a drying oven (Scientific Supplies, Seattle, Washington) at 102°C. for 36 hours. All weighings were done on the previously mentioned Mettler gram scale.

Sangamo time switches or Inter-Matic time switches were used to regulate artificial lights in all experiments. Dayton or Paragon clocks were used to control the water solenoids in Exp. 1, 2, 6, 7, and 8. These clocks are so designed that each pin on the dial represents 15 minutes. A Paragon 7-day clock, Model 7007-0, was used to control solenoid valves for the water restriction treatments in Exp. 4 and 5. On this clock each pin represents a 30-minute period.

Data collected from all experiments were analyzed by analysis of variance and Duncan's New Multiple-Range Test (Steel and Torrie, 1960). When pullets were subjected to various treatments in the brooder house and a second variable in the lay house, lay house data was analyzed by means of a three factor analysis of variance.

Experiment 1. Various Methods of Delaying the Sexual Maturity of Normal White Leghorn Pullets and Their Subsequent Lay House Performance

Approximately 600 O. S. U. strain W. L. pullets were utilized in this experiment. The birds were hatched February 3, 1972. At 1 day of age, the pullets were randomly assigned to six 4.88x4.88m. (16x16') pens, each pen receiving approximately 100 birds.

All pens were fed a 20.9% crude protein chick starter from 0 to 4 weeks of age and a 14.73% crude protein pullet developer from 4 to 8 weeks of age. The composition of experimental rations is shown in Table 1.

All birds, with the exception of Treatment 6, were reared with natural daylength, which increased from 9 hours and 55 minutes at time of hatch to 15 hours and 33 minutes at 20 weeks of age. Group 6 was reared with a lighting program recommended by DeKalb Agriculture Research, Inc. (1971). These birds received 20.5 hours of natural plus incandescent (one 60-watt bulb per pen) artificial light daily for the first 12 weeks. At 12 weeks of age, the daily light was decreased to 15.5 hours, which was maintained up to 20 weeks of age. All groups were given 16.25 hours of light daily when they were moved to the lay house at 20 weeks of age.

At 8 weeks of age, each pen of pullets was randomly distributed into two pens, resulting in two replicates of approximately 50 birds each per treatment. At this time the low-protein, low-lysine, and water restriction programs were initiated. Birds were group weighed and sexing errors were removed. The control group, the lighting program group, and the water restriction groups continued on the 14.73%

Table 1. Composition of pullet rations for Experiments 1, 2, and 3

Ingredients	Type of ration			
	Chick starter[1]	Control developer	Low lysine developer	Low protein developer
	%	%	%	%
Corn, ground yellow	68.40	79.50	78.25	89.25
Cottonseed meal (41% prot.)			6.25	
Soybean meal (44% prot.)	17.00	10.00		2.50
Corn gluten meal (42% prot.)			5.00	
Fish meal (70% prot.)	5.00	2.00	2.00	0.50
Meat and bone meal (50% prot.)	6.00	2.00	2.00	0.50
Alfalfa meal (20% prot.)	2.00	3.00	3.00	3.00
Limestone flour	1.00	1.00	1.00	1.25
Dicalcium phosphate		2.00	2.00	2.50
Salt, iodized	0.30	0.30	0.30	0.30
DL-Methionine (98%)	0.05			
PM-1-65[2]	0.25			
PM-2-65[3]		0.20	0.20	0.20
Sulfaquinoxaline (40%)	0.0375	0.0375	0.0375	0.0375
Calculated analysis				
Crude protein (%)	20.87	14.73	14.78	10.36
Methionine (%)	0.44	0.28	0.31	0.22
Lysine (%)	1.22	0.70	0.54	0.55
Arginine (%)	1.34	0.90	0.92	0.59
M. E. (kcal./kg.)	3022.00	3104.00	3157.00	3203.00
Kcal./kg.:% prot.	144.80	210.70	213.60	309.20

[1]This starter was fed to chicks in Exp. 1, 2, and 4 from 0 to 4 weeks of age and in Exp. 3 from 0 to 8 weeks of age.

(Continued on next page)

Table 1. (Continued)

[2]The trace mineral and vitamin mix contributes per kilogram of ration the following amounts: manganese, 59.9 mg.; iron, 19.8 mg.; copper, 2.0 mg.; cobalt, 0.1 mg.; iodine, 1.2 mg.; zinc, 27.5 mg.; vitamin A, 3,300 I.U.; vitamin D, 1,100 I.C.U.; riboflavin, 3.3 mg.; d-pantothenic acid, 5.5 mg.; niacin, 19.4 mg.; choline, 190.9 mg.; vitamin B_{12}, 5.5 mg.; vitamin E, 1.1 I.U.; vitamin K, 0.25 mg.; zinc bacitracin, 4.4 mg.; BHT, 125 mg.

[3]The trace mineral and vitamin mix contributes per kilogram of ration the following amounts: manganese, 47.9 mg.; iron, 16.1 mg.; copper, 1.58 mg.; cobalt, 0.08 mg.; iodine, 1.0 mg.; zinc, 22 mg.; vitamin A, 2640 I.U.; vitamin D, 880 I.C.U.; riboflavin, 1.8 mg.; d-pantothenic acid, 4.4 mg.; niacin, 13.2 mg.; choline, 76.3 mg.; vitamin B_{12}, 3.5 mg.; vitamin E, 0.88 I.U.; vitamin K, 0.20 mg.; BHT, 100 mg.

protein developer up to 20 weeks of age. Treatments 2 and 3 received the low-lysine and low-protein diets, respectively. Group 4 was given alternating 24-hour periods of water and no water. Group 5 was given a repeating schedule of 24 hours of water and 48 hours of no water. Water valves for the pens on restricted water were turned off and on manually at 8:00 A.M. as prescribed by the respective schedules. Each pen was provided with one free flow water trough 132 cm. (52") in length. The complete experimental design is shown in Table 2.

Other management practices were similar for all treatments. The pullets were weighed by replicate at 12 and 16 weeks of age. All birds were debeaked and vaccinated for fowl pox at 10 and 16 weeks of age, respectively. Starter and developer rations contained the equivalent of 0.015% Sulfaquinoxaline for the control of coccidiosis. Feed intake was determined for each 4-week period.

All pullets were individually weighed, legbanded, moved to the lay house, and changed to a layer feed (Table 3) at 19 weeks and 6 days of age. Forty-four birds from each of the 12 replicates were randomly assigned to two different lay houses--32 birds to cages in Lay House 1, and 12 birds to cages in Lay House 2. The 32 birds transferred to House 1 were distributed between two 16-bird replicates, each composed of four 30.5x45.7 cm. (12 x 18") cages with four birds per cage. All pullets were provided 16 hours and 15 minutes of light in the lay house (4:15 A.M. to 8:30 P.M.). These 16-bird groups were assigned to two lay house treatments, water _ad lib._ or water available for five 15-minute periods daily. The time clock was set to open the solenoid valves at 5:30 A.M., 9:30 A.M., 1:15 P.M., 5:00 P.M., and 9:00 P.M.

Table 2. Experimental design for Experiments 1 and 2

Group	Treatment	Ration fed 8-20 weeks of age	Water program used 8-20 weeks of age	Type of Lighting program
1	Control	14.73% protein developer	*ad lib.*	Natural light
2	Low lysine	0.54% lysine developer	*ad lib.*	Natural light
3	Low protein	10.36% protein developer	*ad lib.*	Natural light
4	Water restriction 1	14.73% protein developer	Repeating cycle water on 24 hours off 24 hours	Natural light
5	Water restriction 2	14.73% protein developer	Repeating cycle water on 24 hours off 48 hours	Natural light
6	Lighting program [1]	14.73% protein developer	*ad lib.*	Natural plus artificial light

[1]Total light was 20.5 hours daily 0 to 12 weeks of age, then 15.5 hours daily 12 to 20 weeks of age.

Table 3. Composition of layer diets for Experiments 1 and 2

Ingredients	Experiment 1	Experiment 2 (caged birds)	Experiment 2 (floor birds)
	%	%	%
Corn, ground yellow	72.00	71.95	71.94
Soybean meal (44% prot.)	13.75	13.75	13.75
Fish meal (70% prot.)	3.00	3.00	3.00
Alfalfa meal (20% prot.)	3.00	3.00	3.00
Limestone flour	2.50	2.50	2.50
Oyster shell	3.00	3.00	3.00
Dicalcium phosphate	2.00	2.00	2.00
Salt, iodized	0.50	0.50	0.50
PM-2-65[1]	0.25	0.25	0.25
DL-Methionine (98%)		0.05	0.05
Amprolium (25%)			0.0165
Calculated analysis			
Crude protein (%)	15.47	15.47	15.47
M.E. (kcal./kg.)	2924.00	2922.00	2922.00
Methionine (%)	0.29	0.34	0.34
Kcal./kg.: % prot.	189.00	188.90	188.90

[1]The trace mineral and vitamin mix contributes per kilogram of ration the following amounts: manganese, 59.9 mg.; iron, 20.1 mg.; copper, 1.98 mg.; cobalt, 0.10 mg.; iodine, 1.2 mg.; zinc, 27.5 mg.; vitamin A, 3,300 I.U.; vitamin D, 1,100 I.C.U.; riboflavin, 2.2 mg.; d-pantothenic acid, 5.5 mg; niacin, 16.5 mg; choline, 95.4 mg; vitamin B_{12}, 4.4 mg; vitamin E, 1.10 I.U.; vitamin K, 0.25 mg.; BHT, 125 mg.

Water was provided by means of free flow V-troughs placed between 4.88 m. (16') rows of back-to-back cages. The 12 birds from each replicate transferred to Lay House 2 were equally divided among four lay house treatments. Procedures for these treatments are presented in Experiment 7--Intermittent Watering and Limited-time Feeding of White Leghorn Pullets.

Egg production, mortality and feed consumption data were collected for ten 28-day periods, beginning for each group when they reached 25% production. Prior to this stage, all eggs were weighed and sized. As treatment groups reached 25% production, eggs were weighed and sized for a 3-day preliminary period. In addition 3-days' eggs were weighed at the end of each 28-day production period. Eggs weighed during the preliminary, first, fifth, and ninth 3-day periods were subjected to specific gravity determinations. Four randomly-selected eggs from each of the 16-bird replicates were broken daily following specific gravity tests to determine albumen quality as measured by Haugh units.

Experiment 2. Methods of Delaying the Sexual Maturity of Dwarf White Leghorn Pullets and Their Subsequent Lay House Performance

Approximately 800 O. S. U. dwarf W. L. pullets were utilized in this experiment. The pullets were hatched February 3, 1972. At 1 day of age, the pullets were randomly assigned approximately 130 per pen to six 4.88x4.88 m. (16x16') pens. With the following exceptions, the procedures for Exp. 2 are identical to Exp. 1.

At 8 weeks of age each 4.88x4.88 m. (16x16') pen was divided into two 4.88x2.44 (16x8') pens. The pullets were distributed equally, forming 12 pens of approximately 65 birds each. Two replicate pens were assigned to each of the six treatments described in Exp. 1.

When the pullets reached 20 weeks of age, 60 birds were selected at random from each replicate to be used for lay house studies. Forty birds from each replicate remained on the floor in their respective brooder house pens. Egg production and feed intake data were collected for eleven 28-day periods. Eggs were weighed according to the procedures described in Exp. 1. The other 20 birds from each replicate were transferred to Lay House 1 and assigned 10 pullets to a 61x61 cm. (24x 24") cage. Each 10-bird cage served as a replicate for the two lay house treatments described in Exp. 1. Procedures for egg weight, specific gravity and albumen quality studies were the same as Exp. 1 except that only three randomly-chosen eggs were broken per replicate, rather than four.

After 20 weeks of age, pullets were fed a lay mash similar to that used in Exp. 1. The diets fed to the dwarf W. L. pullets contained 0.5 g. of dl-methionine/kg. of feed. In addition, pullets maintained on the floor had Amprolium added to the diet for the prevention of coccidiosis. Refer to Table 3 for the specifics of these diets.

Experiment 3. Feeding a Low-Protein Developer to Dwarf White Leghorn Pullets

One thousand forty-four O. S. U. dwarf W. L. pullets were utilized in this experiment. The birds were hatched February 25, 1972. At 1 day of age, the pullets were randomly distributed among four 4.88x4.88 m. (16x16') brooder house pens, each pen receiving 261 birds.

All pens were fed a 20.87% crude protein chick starter from 0 to 8 weeks of age (Table 1). All pens were subjected to natural light during the brooding and growing periods, which increased from 10 hours and 58 minutes at the time of hatch to 15 hours and 33 minutes at 16 weeks of age, and then decreased to 15 hours and 15 minutes at 20 weeks of age.

At 8 weeks of age, the pullets were group weighed and sexing errors were removed. The doors separating the experimental pens and empty adjacent pens were opened, doubling the available floor space. From 8 weeks of age to sexual maturity, two groups of pullets were fed the control 14.73% protein developer and two groups were fed the low-protein developer containing 10.36% protein (Table 1).

Other management practices were the same for the two treatments. The pullets were group weighed at 12, 16, and 18 weeks of age. All birds were debeaked and vaccinated for fowl pox at 9 and 12 weeks of age, respectively. Feed consumed per bird was determined for the periods 0 to 8, 8 to 12, 12 to 16, and 16 to 18 weeks of age.

The first egg was laid on June 29, 1972, when the pullets were 17 weeks and 6 days of age. On June 30, 1972, both treatment groups were changed to a lay mash (Table 4).

Subsequently, 220 pullets from each of the four grow house pens were randomly distributed 55 per pen in four lay house pens, resulting in 16 lay house pens. The overall experimental design was a 2x4 factorial arrangement (2 grow house treatments x 4 lay house treatments), with two replicates for each of the eight treatment combinations. Composition of the four lay house diets, which used barley, corn, milo,

Table 4. Composition of lay rations for Experiment 3

Ingredients	1 Lay mash[1]	2 Barley base	3 Corn base	4 Milo base	5 Wheat base
	%	%	%	%	%
Barley, ground		67.27			
Corn, ground yellow	67.65		67.27		
Milo, ground				67.27	
Wheat, ground					67.27
Fat, animal[2]	1.00	2.00	2.00	2.00	2.00
Soybean meal (44% prot.)	20.00	18.73	18.73	18.73	18.73
Alfalfa meal (20% prot.)	3.00	3.00	3.00	3.00	3.00
Limestone flour	5.60	6.15	6.15	6.15	6.15
Dicalcium phosphate	2.00	2.00	2.00	2.00	2.00
Salt, iodized	0.50	0.50	0.50	0.50	0.50
DL-Methionine (98%)		0.10	0.10	0.10	0.10
PM-2-65[3]	0.25	0.25	0.25	0.25	0.25
Calculated analysis					
Crude protein (%)	15.83	15.62	15.21	15.15	15.48
Methionine (%)	0.27	0.36	0.36	0.29	0.36
M. E. (kcal./kg.)	2895.00	2396.00	2923.00	2841.00	2693.00
Kcal./kg.:% prot.	182.90	153.40	192.20	187.50	174.00

[1]This diet was fed to pullets after the first egg was laid and prior to the initiation of the lay house treatments.

[2]Fancy tallow stabilized with G-16 (Griffith Lab., Chicago, Ill.) which is composed of butylated hydroxytoluene, 14%; propyl gallate, 5%; proplyene glycol, 2%; monoglyceride citrate, 35%; and vegetable oil, 36%.

[3]Refer to footnote 1 in Table 3.

or wheat as the grain component, is shown in Table 4.

On August 8, 1972, when the egg production for the entire group of pullets averaged 25%, the lay house treatments were initiated. Egg production, feed consumption, and mortality records were maintained for ten 28-day periods. Three days' eggs at the start of the experiment and at the end of each 28-day period were bulk weighed and sized for each pen on a commercial egg grader.

Experiment 4. Second Year Studies with Various Methods of Delaying Sexual Maturity

Approximately 720 Babcock B-300 W. L. pullets were utilized in this experiment. The birds were hatched December 18, 1972. At 1 day of age, the pullets were wingbanded and randomly assigned to six 4.88x4.88 m. (16x16') brooder house pens, each pen receiving approximately 120 birds.

All pens were fed the 20.87% crude protein chick starter from 0 to 4 weeks of age (Table 1) and the 14.73% crude protein developer from 4 to 8 weeks of age (Table 1).

All pullets, with the exception of Treatments 5 and 6, were reared with increasing natural daylength which increased from 8 hours and 50 minutes at the time of hatch to 14 hours and 36 minutes at 20 weeks of age. Sixty-watt incandescent bulbs provided 9 hours of light per day (8:00 A.M.--5:00 P.M.) until weather permitted the houses to be opened to natural daylength. Ten-watt hover lights operated 24 hours per day until the chicks were 2 weeks of age. One week later windows to the indoor hallway were opened. At the end of the fifth week, windows on the outsides of the brooder house were opened; therefore, these pullets were subjected to natural daylength from January 29, 1972, when the daylength was 9 hours and 42 minutes, to sexual maturity.

Group 5 was reared using Lighting Program 1. This program called for 20.5 hours of light for the first week of the chicks' lives. On Monday of each succeeding week, the amount of light was decreased by 15-minute decrements down to 15 hours of light per day. On May 28, 1972, when the birds were 22 weeks old, the amount of daily light was increased 15 minutes weekly to a maximum of 16.25 hours. Treatment 6 was subjected to Lighting Program 2. This program was recommended by DeKalb Agriculture Research, Inc. (1971). This group of pullets received 20.0 hours of light daily for the first 12 weeks. At 12 weeks of age, the amount of light was decreased to 15.0 hours daily. This level was maintained up to 22 weeks of age. At that age, the amount of light was increased to 16.25 hours daily. Brooder house pens being used for the light programs were made impregnable to light from adjacent pens. Also, black plastic curtains were hung in the hallway between treatments to insure that the artificial light did not affect naturally-lighted birds. All treatment groups were provided 16.25 hours of light daily in the lay house.

At 8 weeks of age, sexing errors were removed and each group of pullets was randomly distributed into two 4.88x4.88 m. (16x16') pens, resulting in two replicates containing 60 birds each. At this time, the low-protein and the first of two water restriction programs were initiated. The control group, the lighting program groups, and the water restriction groups continued on the 14.73% protein developer up to 20 weeks of age. Group 2 received the diet containing 10.36% protein from 8 to 20 weeks of age. Group 3 (Water Restriction 1) was given a repeating schedule of 24 hours of water and 48 hours of no water from 8 to 20 weeks of age. Starting at 14 weeks of age, Group 4 (Water Restriction 2) was given the repeating schedule of 24 hours of water and 48 hours of no water. Solenoid valves were controlled by a 7-day time clock. The clock was set to open or close the solenoid valves at 8:00 A.M., as prescribed by the water restriction programs. Each pen contained one free flow water trough, 132 cm. in length (52"). Daily maximum and minimum ambient temperatures were measured in all pens subjected to water restriction. The complete experimental design is shown in Table 5.

Other management practices were the same for all treatments. Each pen of pullets was bulk weighed at 4, 8, 12, and 16 weeks of age. All birds were debeaked and vaccinated for fowl pox at 10 and 15 weeks of age, respectively.

Treatment Groups 1 and 3 (controls and Water Restriction Program 1) were weighed every 2 weeks starting at 10 weeks of age. Treatment 4 (Water Restriction Program 2) was weighed every 2 weeks starting at 12 weeks of age.

During the tenth, fourteenth, and eighteenth weeks of age, daily feed intake for the control group and Water Restriction 1 Group was determined for 3 consecutive days--the day prior to, the day of, and the day following water availability. During this same period, water intake for the day of water availability was determined for each pen by measuring the grams of water consumed from two 5-gallon watering

Table 5. Experimental design for Experiment 4

Group	Treatment	Ration fed 8-20 weeks of age[1]	Water program used: 8-14 weeks of age	Water program used: 14-20 weeks of age	Type of lighting program
1	Controls	14.73% protein developer	*ad lib*.	*ad lib*.	Natural light
2	Low protein	10.36% protein developer	*ad lib*.	*ad lib*.	Natural light
3	Water restriction 1	14.73% protein developer	Repeating cycle water on 24 hours off 48 hours	Repeating cycle water on 24 hours off 48 hours	Natural light
4	Water restriction 2	14.73% protein developer	*ad lib*.	Repeating cycle water on 24 hours off 48 hours	Natural light
5	Lighting program 1[2]	14.73% protein developer	*ad lib*.	*ad lib*.	Natural plus artificial light
6	Lighting program 2[3]	14.73% protein developer	*ad lib*.	*ad lib*.	Natural plus artificial light

[1]Composition of these diets is shown in Table 1.

[2]Total light was 20.5 hours for the first week and then declined 15 minutes each week to 15 hours daily when the pullets were 22 weeks old.

[3]Total light was 20 hours daily 0 to 12 weeks of age, then 15 hours daily 12 to 20 weeks of age.

cans placed in each pen. Values were corrected for evaporation by measuring the amount of water evaporated from identical 5-gallon cans placed in the hallway. In the same manner, the daily feed and water intake was measured for the controls and Water Restriction 2 Group during the sixteenth and twentieth weeks of development. On May 1, 1973, when the pullets were 141 days old, they were individually weighed and 56 birds were selected at random to be used for the lay house studies. They were changed to a layer mash at 20 weeks of age which contained 15.32% protein and 2912 kcal. M. E./kg. (Table 6).

On May 3, 1973, when the pullets were 19 weeks and 3 days of age, two typical birds from the control, the Water Restriction 1, and the Water Restriction 2 groups were selected for kidney, ovary, and oviduct weights. Organs were weighed on a Precision Balance (Roller Smith Company, Bethlehem, Pennsylvania).

Four samples of the 15% protein developer were taken during May, 1973. These samples were dried in a Cenco Drying Oven (Central Scientific Company, Chicago, Illinois) to determine moisture content of the ration being fed to the water-restricted birds.

By mid-May, the control group had reached 25% production. All other treatments were delayed in reaching sexual maturity, laying only a few eggs by this time. At this point, what appeared to be a nutritional or infectious disease caused all pullets to discontinue production. For this reason, it was not possible to weigh eggs from the initial production period. Subsequently, it was determined that vitamin D had been excluded from the vitamin premix used in the milling of rations fed to these pullets.

Table 6. Composition of rations for Experiment 5

Ingredients	Starter[1]	Developer 1[2]	Developer 2[3]	Lay mash
	%	%	%	%
Corn, ground yellow	64.05	76.35	81.35	72.65
Soybean meal (44% prot.)	26.00	17.00	12.00	12.62
Meat and bone meal (50%)	5.00			5.00
Alfalfa meal (20%)	2.00	2.50	2.50	2.50
Limestone flour	0.50	1.00	1.00	3.08
Oyster shell flour				2.50
Dicalcium phosphate	1.25	2.50	2.50	1.00
Salt, iodized	0.40	0.50	0.50	0.40
DL-Methionine (98%)	0.05			
PM-1-65[4]	0.25			
PM-2-65		0.15[5]	0.15	0.25[6]
Calculated analysis				
Crude protein (%)	20.68	15.12	13.28	15.32
Methionine (%)	0.37	0.37	0.24	0.26
M. E. (kcal./kg.)	2917.00	3049.00	3108.00	2912.00
Kcal./kg.:% prot.	141.00	201.60	234.00	190.10

[1]Fed from 0 to 32 days of age.

[2]Fed from 33 to 78 days of age.

[3]Fed from 79 days to 20 weeks of age.

[4]Refer to footnote 1 in Table 1.

[5]The trace mineral and vitamin mix contributes per kilogram of ration the following amounts: manganese, 35.9 mg.; iron, 12.1 mg.; copper, 1.19 mg.; cobalt, 6 mg.; iodine, 0.72 mg.; zinc, 16.5 mg; vitamin A, 1980 I. U.; vitamin D, 660 I. C. U.; riboflavin, 1.32 mg.; d-pantothenic acid, 3.3 mg.; niacin, 9.9 mg.; choline, 57.2 mg.; vitamin B_{12}, 2.64 mg.; vitamin K, 0.15 mg.; vitamin E, 0.66 I. U.; BHT, 75 mg.

[6]Refer to footnote 1 in Table 3.

By July 23, 1973, when the birds were 31 weeks of age, they had returned to full production. Beginning on this date, egg production records were maintained for nine 28-day periods. Eggs laid on the last 3 days of each period were bulk weighed and average egg weights were determined.

Experiment 5. Further Studies of Delaying Sexual Maturity by a Low-Protein Diet, Water Restriction, and the DeKalb Lighting Program

Approximately 400 Babcock B-300 W. L. pullets were used in this study, which was designed to duplicate as much as possible the work begun and lost in Exp. 4. The birds hatched March 12, 1973. At 1 day of age, the pullets were randomly assigned to two 4.88x4.88 m. (16x16') brooder house pens, each pen receiving approximately 200 birds.

All birds received a chick starter containing 20.68% crude protein for the first 32 days of their lives. From 33 to 78 days of age, the pullets were fed a developer which provided 15.12% crude protein. At this stage of growth, the pullets were changed to a developer containing 13.28% crude protein. Table 6 gives the composition of these diets and of the laying feed used.

When the pullets were 8 weeks of age doors joining the experimental pens and vacant adjacent pens were opened, doubling the floor space per pullet. Pullets were also debeaked during the eighth week.

On June 5, 1973, at the age of 12 weeks, 240 of the pullets were moved to a second light-proof brooding facility. They were randomly assigned to eight 3.05x4.57 m. (10x15') pens with 30 pullets to a pen. The eight pens were randomly assigned to four treatments.

All pens, with the exception of the two replicate pens in Treatment 4, received an artificially-increasing daylength. This increasing light program was designed to duplicate the naturally occurring increases in photoperiod taking place at the time Exp. 4 was conducted. For example, from the twelfth to the thirteenth week of the developing period of Exp. 4. the daylength increased 22 minutes; therefore, the lighting program in Exp. 5 provided for the same increase in daylength for the respective period of the pullets' lives. However, the total daily light period was longer than that used in Exp. 4 since the daylength when the experiment was initiated on June 5 was 15 hours and 25 minutes. From the twelfth to the twenty-fourth week, the amount of daily light increased 4 hours and 26 minutes to a total of 20 hours. At 26 weeks the amount of light was increased to 21 hours and held at that level throughout the laying period.

Treatment 4 was subjected to increasing natural light as were pullets in the other treatments until they were moved to new quarters on June 5, 1973. At 10 weeks of age, they were receiving 15 hours of light. At 12 weeks of age, the amount of daily light provided to these birds was decreased to 10 hours and held constant at this level until the birds were 21 weeks old. At 22 weeks of age, the amount of daily light was increased by 1 hour to 11 hours. From 22 to 26 weeks of age, the amount of light was increased to 12 hours by means of 15-minute weekly increments. It was then increased up to 21 hours by four 2-hour and one 1-hour bi-weekly increases.

Group 2 was fed the low-protein diet (10.36% protein) used in Exp. 1, 2, 3, and 4 beginning at 12 weeks of age. Groups 1, 3, and 4 continued on the 13.28% developer up to 20 weeks of age. Group 3, starting at 12.5 weeks of age, was subjected to a repeating schedule of 24 hours of water and 48 hours of no water. Group 1 served as controls for the experiment. Daily ambient temperatures were recorded in the water restriction pens. At 20 weeks of age, all treatments were changed to a lay mash (Table 5) and all were provided water ad lib.

All birds were individually weighed at 20 weeks of age and at the end of the laying period. Replicates were group weighed at 16 and 25 weeks of age.

Egg production, mortality, and feed consumption data were collected for eleven 28-day periods, beginning for each treatment as it reached 25% production. Prior to this stage, all eggs were weighed and sized. As treatment groups reached 25% production, eggs were weighed and sized for a 3-day preliminary period. In addition, 3 days' eggs were weighed at the middle of each 28-day production period.

Experiment 6. Intermittent Watering of White Leghorn Laying Hens

One hundred and twenty-six O. S. U. strain W. L. laying hens were utilized in this experiment. These hens had been in lay for 5 months prior to the initiation of the experiment in December, 1971. They were housed three birds to a 43.2x43.2 cm. (17x17") cage. The cage facility was enclosed; all light was provided by 100-watt incandescent bulbs. Hen-day egg production was calculated for a 28-day preliminary period. Based on these results, 14 cages (seven cages in each of two rows) were assigned to three treatments so that average egg production for the replicates was approximately equal for all treatments. The hens had been previously legbanded; they were individually weighed prior to the initiation of the experiment. All treatment groups were exposed to 15 hours of daily light during the experiment.

The amount of time the hens had access to water was the variable investigated in this experiment. The solenoid valve providing water to the control group was regulated by the same time clock operating the light; therefore, the controls had free access to water while the lights were on (7:30 A.M.--10:30 P.M.). Group 2 had free access to water from 8:30 A.M. to 9:30 A.M. and 5:30 P.M. to 6:30 P.M., while Group 3 had water flowing for three 15-minute periods each day at 8:00 A.M., 1:30 P.M., and 6:30 P.M. Water troughs for this experiment were made from 4.88 m. (16') lengths of 2.54 cm. (1") PVC plastic pipe which had been cut lengthwise. Solenoid valves and time clocks were used to regulate water flow. All three treatments received the same ration (Table 7).

Egg production, feed consumption, and mortality records were kept for five 28-day periods. The facilities were not designed to determine feed intake for each cage; therefore, feed consumption data was determined for each of the two rows of seven cages for each treatment. Three days' eggs were weighed and sized at the end of each 28-day period. These eggs were also subjected to specific gravity and albumen quality determinations. Birds were individually weighed at the end of the experiment to determine weight gain or loss.

Table 7. Composition of diets for Experiments 6,7, and 8

Ingredients	Exp. 6	Exp. 7	Exp. 8
	%	%	%
Corn, ground yellow	67.65	72.00	72.65
Fat, animal[1]	1.00		
Fish meal (70% prot.)		3.00	
Meat and bone meal (50% prot.)			5.00
Soybean meal (44% prot.)	20.00	13.75	12.62
Alfalfa meal (20% prot.)	3.00	3.00	2.50
Limestone flour	5.60	2.50	3.08
Oyster shell		3.00	2.50
Dicalcium phosphate	2.00	2.00	1.00
Salt, iodized	0.50	0.50	0.40
PM-2-65[2]	0.25	0.25	0.25
<u>Calculated analysis</u>			
Crude protein (%)	15.83	15.47	15.32
Methionine (%)	0.27	0.29	0.26
M. E. (kcal./kg.)	2895.00	2924.00	2912.00
Kcal./kg.: % prot.	182.90	189.00	190.10

[1]Refer to footnote 2 in Table 4.

[2]Refer to footnote 1 in Table 3.

Experiment 7. Intermittent Watering and Limited-time Feeding of White Leghorn Pullets

One hundred and forty-four O. S. U. strain W. L. pullets were involved in this experiment. These pullets were subjected to six different management treatments in the brooder house (Exp. 1, Table 2). Pullets were moved to the lay house at 20 weeks of age. The lay house facility and cage density were the same as in Exp. 6. In the brooder house, 12 birds from each of the 12 replicates were selected at random for use in Exp. 7. Three birds from each of these 12-bird groups were randomly assigned to four lay house treatments, so that every replicate from the brooder house was represented by one three-bird replicate in each lay house treatment.

Management practices other than feeding and watering times were the same for all treatments. Lights were on from 7:45 A.M. to 12:00 midnight. All birds were fed a diet containing 15.47% protein and 2924 kcal. of M. E. per kg. (Table 7). Pullets were legbanded and individually weighed prior to the start of, and at the termination of, the experiment.

The treatments were as follows: (1) controls, feed _ad lib_. and the solenoid valve open while the lights were on; (2) feed _ad lib_. and water flowing 15 minutes each hour from 8:00 A.M. to 11:00 P.M.; (3) feed _ad lib_. and water flowing five 15-minute periods daily at 8:00 A.M., 11:30 A.M., 3:00 P.M., 6:30 P.M., and 10:00 P.M.; (4) water as per Treatment 1 with access to feed from 8:00 A.M. to 10:00 A.M. and from 3:00 P.M. to 5:00 P.M. Limited-time feeding was accomplished by manually removing the plywood lids covering the feed troughs.

Birds were allowed to adapt to their surroundings for 3 days prior to the start of the limited-time feeding and intermittent watering.

Collection of data started on July 19, 1972, when the house collectively was laying at the rate of 45%. Egg production, feed consumption, and mortality records were maintained for ten 28-day periods. Three days' eggs at the start of the experiment and at the end of each 28-day period were weighed and sized. The eggs weighed at the end of the first, fifth, and ninth periods were subjected to specific gravity and albumen quality studies. Feed intake data was taken for each of the two rows of six cages for each treatment.

Experiment 8. Intermittent Watering of Babcock B-300 White Leghorn Layers

Experiment 8 involved 144 W. L. pullets which had all been reared under optimum conditions. On July 17, 1973, at the age of 18 weeks, the pullets were housed in the same laying facility used for Exp. 6 and 7. All pullets were randomly placed three to a cage. Pullets were legbanded and individually weighed at housing time. Throughout the experiment lights were on from 8:00 A.M. to 12:15 A.M.

The variable studied in this experiment was the amount of time the birds had access to water in a free-flow trough. Treatments were as follows: (1) controls, water available 16.25 hours per day concurrent with the lights; (2) water flowing 15 minutes each hour from 8:15 A.M. to 11:15 P.M.; (3) five 15-minute watering periods per day at 3.5 hour intervals (8:15 A.M., 11:45 A.M., 3:15 P.M., 6:45 P.M., and 10:15 P.M.); and (4) three 15-minute watering periods daily at 5.5

hour intervals (8:15 A.M., 1:45 A.M., and 6:45 P.M.). All treatments had free access to a lay ration containing 15.32% protein and 2912 kcal. M. E./kg. (Table 7). For the first month after housing all birds had water available as per Treatment 1. On August 15, 1973, when the birds were 22 weeks of age and laying at a rate of 9%, water accessibility to Treatments 2, 3, and 4 was reduced to 15 minutes each hour. For Treatments 3 and 4, it was further decreased on August 17, 1973, to five 15-minute periods. Three days later Treatment 4 was limited to three 15-minute periods.

Collection of data began on August 28, 1973, when the pullets were 24 weeks old and were laying at the rate of 38%. Egg production, feed consumption, and mortality records were maintained for nine 28-day periods. At the middle of each period, 3 days' eggs were weighed and sized. Minimum and maximum daily temperatures were recorded during the experimental period. Pullets were individually weighed at the end of the 36-week experiment.

IV. RESULTS AND DISCUSSION

Experiment 1. Various Methods of Delaying the Sexual Maturity of Normal White Leghorn Pullets and Their Subsequent Lay House Performance

Results of this study are summarized in Table 8. The first egg was laid by a pullet from the low-lysine group at 18 weeks of age. This is the expected date of first egg for pullets grown at this latitude during a period of increasing natural daylength.

Sixteen weeks after the lay house phase of the experiment was initiated, the power supply to the time clocks controlling the solenoid valves for the lay house treatments was inadvertently cut off. The pullets being subjected to intermittent watering were without water for 3.5 days. This brought about a molt in many of the pullets. Therefore, the lay house performance data represents two, rather than four, replicates per treatment.

Feeding a pullet developer containing 0.54% lysine and 0.92% arginine from 8 to 20 weeks of age did not reduce weight gains. Flock age at 25 and 50% production was increased 2 and 3 days, respectively. These findings differ from the results of Trammell and Creger (1967), Trammell *et al*. (1968), and Hooper *et al*. (1969), which showed reduced body weights in broiler breeder pullets fed developer diets containing 0.32 to 0.64% lysine. However, Abbott *et al*. (1969) observed no growth retardation or delay in sexual maturity when feeding a diet containing 0.50% lysine and 1.08% arginine. They observed significantly greater gains when the arginine content of diets was increased and the diet contained 0.4% lysine. Sherwood *et al*. (1969) concluded that the lys-

Table 8. Performance of White Leghorn pullets subjected to various nutritional and management treatments in the brooder house--Experiment1[1]

Group	Body weights 8 weeks	12 weeks	16 weeks	20 weeks	Flock age at 25% prod.	Flock age at 50% prod.
	g.	g.	g.	g.	days	days
1[2]	598	1001[a]	1277[a]	1457[a]	154.75[cd]	161.75[c]
2[3]	579	958[ab]	1237[a]	1450[a]	157.25[bcd]	165.00[bc]
3[4]	591	831[c]	1075[b]	1261[c]	168.25[a]	172.00[a]
4[5]	607	1009[a]	1259[a]	1424[ab]	155.50[c]	163.00[bc]
5[6]	620	913[b]	1216[a]	1374[b]	160.75[b]	168.25[ab]
6[7]	599	1006[a]	1231[a]	1441[ab]	159.50[bc]	170.50[a]

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Group 1 served as the controls.

[3]Group 2 received a low-lysine developer from 8 to 20 weeks of age (Table 1).

[4]Group 3 received a low-protein developer from 8 to 20 weeks of age (Table 1).

[5]After 8 weeks of age Group 4 had water cycling on 24 hours, off 24 hours.

[6]After 8 weeks of age Group 5 had water cycling on 24 hours, off 48 hours.

[7]Group 6 was reared with a DeKalb lighting program which provided 20.5 hours of light daily from 0 to 12 weeks of age and 15.5 hours of light daily from 12 to 20 weeks of age.

(Continued on next page)

Table 8. (Continued)

Group	Feed intake per bird						Brooder house mortality[9]
	0-8 weeks	8-12 weeks	12-16 weeks	16-19 weeks	19 weeks-25% prod.	0 weeks to 25% prod.[8]	
	kg.	kg.	kg.	kg.	kg.	kg.	%
1	1.892	1.884[a]	2.077	1.440	1.829	9.122	3.06
2	1.879	1.802[ab]	2.091	1.469	1.878	9.119	3.09
3	1.812	1.591[c]	1.897	1.434	2.583	9.317	3.85
4	1.870	1.696[bc]	1.993	1.471	1.943	8.973	3.00
5	1.877	1.656[bc]	1.887	1.369	2.706	9.495	3.92
6	1.925	1.914[a]	1.976	1.518	2.232	9.565	7.92[10]

[8]Feed consumed per pullet from 1 day of age until the flock reached sexual maturity, defined as 25% production.

[9]Mortality from 0 to 20 weeks of age.

[10]Higher mortality due to piling in one replicate accounting for 3% mortality.

ine requirement in the developing period did not exceed 0.30%/1000 kcal. of M. E. Luther and Couch (1973) concluded that the lysine and arginine levels should not exceed 0.35 and 0.7%, respectively, to effectively retard growth and sexual maturity of broiler breeder pullets. These findings suggest that both the lysine and arginine levels of the low-lysine diet in the current study were too high to cause growth retardation and delayed sexual maturity.

Providing water to pullets only every other day after 8 weeks of age caused a significant reduction in feed intake between 8 and 12 weeks of age. The pullets, however, were able to adapt their feed consumption patterns in order to consume more feed than the controls from 16 to 19 weeks of age. Sixteen and 20-week body weights of these pullets were only slightly lower than the controls. This group required 1 and 2 days more than the controls to attain 25 and 50% production, respectively. These results are in agreement with the findings of Kirkland and Fuller (1971), which showed that broiler breeder pullets were not retarded by an every-other-day watering schedule due to increased consumption on the days water was available. The results of Kirkland's study and this experiment indicate that withholding water every other day is not severe enough to retard growth or sexual development.

When water availability was limited at 8 weeks of age to every third day, feed consumption was markedly reduced, and 12 and 20-week body weights were significantly lower. Between 8 and 19 weeks of age these pullets consumed 91% as much feed as the controls. These pullets required 6 days longer than the controls to reach both 25 and 50% production. The delayed sexual maturity and retarded growth agrees with the findings of Gowe et al. (1960a), Walter and Aitken (1961), Hollands and Gowe (1961,1965), Hollands et al. (1965), and Strain et al. (1965) when they physically limited feed intake to a percentage of the control group's ad lib. intake.

Feeding pullets from 8 to 20 weeks of age a developer diet containing 10.36% crude protein resulted in a significant reduction in 12, 16, and 20-week body weights. In addition, between 12 and 16 weeks of age, pullets fed this ration consumed significantly less feed than any other group, including those limited in access to water. In comparison with the controls these birds were delayed 14 and 11 days in attaining 25 and 50% production, respectively. Similar reductions in weight gains and feed intake were observed by Bullock et al. (1963), Smith (1967), and Blair et al. (1970). Waldroup and Harms (1962), Bullock et al. (1963), Lillie and Denton (1967), Smith (1967), and Blair et al. (1970) also observed a delay in the onset of sexual maturity by lowering the protein content of the developer diet. Poorer feathering was observed in the pullets fed the low-protein developer. Wells (1971) and Goan et al. (1973) have reported similar findings. Nitrogen determinations in the O. S. U. poultry nutrition lab demonstrated the protein content of the low-protein diet to be 10.85% (N.x6.25).

Eight and 12-week body weights were slightly increased by subjecting pullets to the DeKalb lighting program. Feed consumption of this group also exceeded that of the controls for the first 12 weeks of life. The increased intake is easily explained by the greater amount of light and thus feeding time these pullets received during the brooding period. By 16 weeks of age, these pullets were slightly lighter and were consuming less feed than the control group. Morris and Fox (1960) reported a similar reversal in body weights and feed intake. Apparently, increasing daylength promotes greater feed intake than does a decreasing light regime.

When comparing feed intake per pullet of all six treatments up to 25% production, no significant differences were observed. However, those pullets having water available every other day tended to consume slightly less feed than did the control pullets. Pullets fed the low-protein developer and those limited to water every third day required as much feed per pullet up to 25% production as did the controls. The volume of feed saved from 8 to 20 weeks of age was equalized by greater consumption between 20 weeks of age and 25% production. The pullets subjected to the lighting program consumed slightly more feed than did the controls due to greater consumption during the brooding period and a delay in reaching 25% production.

Differences in brooder house mortality were very slight. Mortality for the pullets on the lighting program was higher due to a piling incident in the eighth week that accounted for 3% mortality. Prior to debeaking, the low-protein fed pullets suffered 1% mortality due to cannibalism. Limiting access to water to every other day or every third day had no effect on mortality. Gowe et al. (1960a), Walter and Aitken (1961), Hollands and Gowe (1961, 1965), Hollands et al.(1965), and Strain et al. (1965) have reported increased mortality in the brooder house when feed intake was restricted from 70 to 90% of the controls' intake. Limiting access to water has a definite advantage over limiting feed intake per se. There is less social stress and competition for the feed. When the solenoid valves open in the morning, there is some initial competition around the water trough. However, it was observed that all birds (approximately 50 per replicate) had satisfied their thirst within 30 minutes when only 132 linear cm. (52") of trough space were provided. As soon as pullets satisfy their thirst they move immediately to the feed trough. Even those birds that are on the lower end of the peck order and have to wait in line to drink and eat have all the feed they want. There was no problem of lack of uniformity in this experiment, a problem which may arise when restricting the volume of feed fed to a group of pullets. The experimental aides soon found that they needed to provide more feed on the days that pullets had access to water.

Lay house performance is summarized in Table 9. All treatment groups, with the exception of the low-lysine pullets, gained significantly more weight in the 40-week lay period than did the control group. Balnave (1973) in summarizing the effects of restricted feeding on growing pullets reported that the retardation of body growth in the developing period, regardless of method, results in increased weight gain during the laying period. Those pullets most severely retarded in growth, low-protein and water every third day, tended to consume more feed per hen-day. Conversion of feed to eggs favored the control pullets. The low-protein and low-lysine groups laid at a markedly lower rate. The lower egg production for the low-lysine group agrees with the findings of Luther et al. (1972), but differs from the findings of Hooper (1969) and Couch and Trammell (1970), who reported

Table 9. Performance during a 40-week lay period as affected by brooder house treatments--Experiment 1[1]

Group[2]	Wt. gain[3]	Hen-day egg prod.	Feed per hen-day	Feed per egg	Early egg weights[4]	Avg. egg weights[5]	Lay house mortality
	g.	%	g.	g.	g.	g.	%
1	478[b]	69.4	118.4	170.8	43.6[bc]	61.3	9.38
2	521[b]	58.7	117.6	200.8	41.8[c]	63.2	12.50
3	762[a]	58.3	124.0	212.5	45.2[ab]	62.7	12.50
4	604[ab]	66.5	115.5	179.4	44.0[bc]	61.7	21.88
5	749[a]	65.4	123.5	191.6	45.2[ab]	63.2	28.13
6	588[ab]	61.6	117.5	191.0	47.3[a]	63.5	18.75

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Refer to Table 8 for group treatment explanations.

[3]Average weight gained per bird during the 40-week laying period.

[4]Average weight of all eggs laid prior to the time each treatment reached 25% production.

[5]Average weight of eggs laid during the 40-week laying period.

improved egg production in broiler breeder females fed low-lysine developer diets. The reduction in hen-day egg production due to feeding the low-protein developer is not consistent with the findings of Waldroup and Harms (1962), Bullock _et al_. (1963), Lillie and Denton (1966), Wright _et al_. (1968), and Blair _et al_. (1970) who found that feeding 10 to 12% protein from 8 weeks of age produced satisfactory results. The lower egg production of the pullets reared with the decreasing light program can not be explained by results reported in the literature. Both groups of pullets limited in their access to water in the brooder house laid at rates just slightly lower than the controls.

When comparing average egg weights prior to each treatment's attaining 25% production, it was found that the groups fed the low-protein developer or provided water every third day, or reared with decreasing light laid significantly heavier eggs (Table 9). These three groups, and the low-lysine group, laid slightly heavier eggs throughout the experiment. The control, low-protein, and lighting program groups laid 29.5, 7.5, and 8.5% peewee eggs, respectively, during the period prior to 25% production (Table 10). During the 40-week laying period, the water every third day and the lighting program groups tended to lay fewer small and medium eggs and more extra large and jumbo eggs. These results agree with previous studies utilizing stepdown lighting programs and feed restriction of pullets.

Mortality tended to be higher in pullets reared with decreasing light and/or limited access to water. Balnave (1973) reported that restricted feeding normally reduces lay house mortality, while decreasing light programs usually have no effect. There is no explanation

Table 10. Egg size as affected by brooder house treatments--Experiment 1[1]

Group[2]	Egg sizes					
	Peewee	Small	Medium	Large	X-large	Jumbo
	%	%	%	%	%	%
Prior to 25% production[3]						
1	29.5[ab]	55.7[ab]	14.9			
2	58.4[a]	31.2[b]	10.5			
3	7.5[b]	74.3[a]	18.3			
4	27.1[ab]	66.7[a]	6.3			
5	24.9[ab]	60.7[a]	14.4			
6	8.5[b]	55.5[ab]	34.9	1.2		
During 40 weeks of lay						
1	0.2	6.5	22.7	35.4	30.8	4.5[b]
2	0.1	2.8	19.4	37.3	26.4	14.0[a]
3	0.0	3.3	20.1	34.6	35.1	7.0[ab]
4	0.4	6.4	23.7	27.8	31.3	10.4[ab]
5	0.2	2.2	15.8	33.2	38.0	10.6[ab]
6	0.0	2.2	15.1	35.7	33.0	14.1[a]

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Refer to Table 8 for group treatment explanations.

[3]All eggs laid by a specific treatment prior to their reaching 25% production.

for the higher mortality observed in this experiment.

Results of intermittent watering in the lay house are summarized in Table 11. The results shown represent the first 16 weeks of lay. The pullets receiving five 15-minute periods per day, as noted previously, were without water for 3.5 days after the 16th week due to a power outage to the time clocks operating the solenoid valves. There was no significant difference in hen-day egg production between the control and intermittently-watered pullets. The intermittently-watered pullets consumed significantly less feed per hen-day and required 3.6 g. less feed to produce an egg. A slight difference in egg size, 0.4 g., favored the control group. Hill (1969) reported a slight reduction in hen-day egg production of pullets when he initiated the same intermittent watering schedule with pullets 21 weeks of age. This difference was not observed in the current study. There were no significant differences observed in Haugh units or specific gravity determinations in this experiment. Wilson et al. (1965) observed a 5.4 Haugh unit improvement in albumen quality when hens received one 2-hour watering period. The difference in watering regimes probably accounts for the difference in results.

Experiment 2. Methods of Delaying the Sexual Maturity of Dwarf White Leghorn Pullets and Their Subsequent Lay House Performance

The performance of dwarf W. L. pullets is shown in Tables 12-16. As was the case in Exp. 1, half of these pullets were without water for 3.5 days after 16 weeks of lay. Therefore, results given are based on only two replicates in the lay house. Effects of intermittent

Table 11. Performance of intermittently-watered dwarf and normal White Leghorn pullets[1]

Treatment	Hen-day egg prod.	Feed per hen-day	Feed per egg	Avg. egg weights
	%	g.	g.	g.
Normal White Leghorns[2]				
Controls[3]	71.2	108.0[a]	152.2	57.5
Intermittent watering[4]	70.6	104.2[b]	148.6	57.1
Dwarf White Leghorns[5]				
Controls	63.1	76.5	121.5	53.6
Intermittent watering	59.6	74.2	126.0	53.0

[1]Values with differing lowercase superscripts are significantly different at the 5% level. The data included within this table is a summary of four 28-day periods.

[2]Pullets used in this study were subjected to six brooder house treatments in Exp. 1 (Table 2).

[3]The control group had water available at all times.

[4]The intermittently-watered group had access to water five 15-minute periods each day during the 16-week lay house study.

[5]Pullets used in this study were subjected to six brooder house treatments in Exp. 2 (Table 2).

watering on the first 16 weeks of lay are summarized in Table 11.

Feeding the low-lysine developer to dwarf replacement pullets from 8 to 20 weeks of age did not reduce weight gains or delay sexual maturity (Table 12). The pullets fed the low-lysine developer were 42 and 33 g. heavier than the control pullets at 16 and 20 weeks of age, respectively. In addition, they attained 25% production prior to any other group. Feed intake was approximately equal to that of the controls. The inability of the low-lysine diet to retard growth and sexual maturity is apparently due to the fact that neither the arginine nor the lysine levels were low enough.

Pullets fed the low-protein developer weighed significantly less than all other groups at 12 and 16 weeks of age, and weighed less than all except the water every third day group at 20 weeks of age. Feed intake for these pullets from 8 to 12 weeks was significantly less than the other five groups (Table 12). These results agree with the findings in Exp. 1 and with the findings of others as previously discussed in Exp. 1. When the protein content of the developer ration is lowered, the feed intake declines, thus compounding the retardation in growth. The low-protein pullets were 2 and 10 days slower than the controls in reaching 25 and 50% production, respectively.

Pullets having access to water every other day consumed 95% as much feed as the controls from 8 to 19 weeks of age; however, they weighed 98.6% as much as the controls at 20 weeks of age. Their sexual maturity was not delayed. These results agree with the findings in Exp. 1. The pullets consumed additional feed on the days the water was on to compensate for lower consumption on the days that the water

Table 12. Performance of dwarf White Leghorn pullets subjected to various nutritional and management treatments in the brooder house[1]

Group	Body weights 8 weeks	12 weeks	16 weeks	20 weeks	Flock age at 25% prod.	Flock age at 50% prod.
	g.	g.	g.	g.	days	days
1[2]	415	669^{b}	836^{a}	1012^{ab}	165.50	172.00
2[3]	415	668^{b}	879^{a}	1045^{a}	163.00	171.75
3[4]	433	586^{c}	730^{c}	893^{d}	167.25	182.75
4[5]	421	662^{b}	838^{a}	997^{bc}	164.25	171.75
5[6]	419	594^{c}	782^{b}	932^{cd}	166.50	175.25
6[7]	444	720^{a}	855^{a}	1038^{ab}	164.75	171.75

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Group 1 served as the controls.

[3]Group 2 was fed a low-lysine developer from 8 to 20 weeks of age.

[4]Group 3 was fed a low-protein developer from 8 to 20 weeks of age.

[5]After 8 weeks of age Group 4 had water cycling on 24 hours, off 24 hours.

[6]After 8 weeks of age Group 5 had water cycling on 24 hours, off 48 hours.

[7]Group 6 was reared with a DeKalb lighting program which provided 20.5 hours of light daily from 0 to 12 weeks of age and 15.5 hours of light daily from 12 to 20 weeks of age.

(Continued on next page)

Table 12. (Continued)

Group	Feed intake per bird: 0-8 weeks	8-12 weeks	12-16 weeks	16-19 weeks	19 weeks-25% prod.	0 weeks to 25% prod.[8]	Brooder house mortality[9]
	kg.	kg.	kg.	kg.	kg.	kg.	%
1	1.212	1.074[b]	1.359	1.078	2.063	6.786	4.98
2	1.220	1.142[b]	1.406	1.012	1.485	6.265	7.85
3	1.206	0.949[c]	1.189	0.958	1.852	6.154	5.27
4	1.206	1.044[bc]	1.298	0.977	1.761	6.286	2.19
5	1.240	1.034[bc]	1.240	0.936	1.834	6.284	4.22
6	1.346	1.253[a]	1.372	1.055	1.911	6.937	1.53

[8] Feed consumed per pullet from 1 day of age until the flock reached 25% production.

[9] Mortality from 0 to 20 weeks of age.

was off. Those pullets having access to water every third day consumed 91% of the controls' 8 to 20-week feed intake and weighed 92% as much as the controls at 20 weeks of age. These birds were only retarded 1 and 3 days in reaching 25 and 50% production, respectively. Pullets reared with the DeKalb lighting program were significantly heavier than all other groups at 12 weeks of age and consumed significantly more feed from 8 to 12 weeks of age. These results are parallel with the findings in Exp. 1. For unknown reasons the decreasing light did not retard sexual maturity. In comparison with the controls, all groups except the lighting program group consumed less feed per pullet up to 25% production. Due to their greater feed consumption during the first 12 weeks of life, the lighting program group consumed 0.2 kg. more feed than the controls up to 25% production.

Brooder house mortality tended to be higher in the low-protein and low-lysine groups because of a high incidence of cannibalism prior to debeaking. It appeared that the pullets sensed the need for more protein. Birds which died in both treatments were found completely stripped of flesh.

Performance of those pullets housed in cages in the lay house is summarized in Table 13. These pullets fed a low-protein developer or limited to water every other day gained significantly more weight in the lay house than did the controls. The other treatments resulted in nonsignificant increases in weight gains. There were no significant differences in hen-day egg production. The poorest production was observed in pullets given water every other day and the best production was found in pullets reared with decreasing light.

Table 13. Performance of caged dwarf pullets during a 40-week lay period as affected by brooder house treatments[1]

Group[2]	Wt. gain[3]	Hen-day egg prod.	Feed per hen-day	Feed per egg	Early egg weights[4]	Avg. egg weights[5]	Lay house mortality
	g.	%	g.	g.	g.	g.	%
1	256[b]	56.1	92.9[a]	165.5	40.2	56.6	25.0
2	439[ab]	53.1	83.2[b]	156.8	42.9	57.0	10.0
3	529[a]	56.1	84.8[b]	151.0	41.4	56.7	15.0
4	514[a]	49.1	78.3[c]	159.3	41.3	58.0	35.0
5	342[ab]	53.3	82.4[bc]	154.8	43.4	56.6	5.0
6	364[ab]	56.9	86.8[b]	153.3	43.6	58.4	10.0

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Refer to Table 12 for group treatment explanations.

[3]Average weight gained per bird during the 40-week lay period.

[4]Average weight of all eggs laid prior to the time each treatment reached 25% production.

[5]Average weight of all eggs laid during the 40-week lay period.

The pullets receiving water every other day consumed significantly less and the control group consumed significantly more feed per hen-day than any other treatment. The controls required more feed to produce an egg than did the other groups. These results indicate that the lower body weights due to the various nutrient restrictions resulted in decreased feed intake and improved feed efficiency in the lay house in this experiment. There were no significant differences in egg weights; however all groups tended to lay heavier eggs than the controls in the period prior to sexual maturity, and pullets reared with decreasing light tended to lay heavier eggs throughout the experiment (Table 13). These results agree with the findings of McClary (1960) who observed greater egg weights in pullets reared with a gradual stepdown-stepup lighting program.

The control, water every third day, and decreasing light groups laid 53.9, 41.6, and 31.3% peewee eggs, respectively, in the period prior to 25% production (Table 14). This tendency is consistent with the findings in Exp. 1 (Table 10). The pullets on the decreasing light program tended to lay fewer peewee and small eggs, and more large and extra large eggs throughout the 40-week laying period. There was a good deal of variability in lay house mortality, but differences were not statistically significant (Table 13).

Table 15 summarizes the performance of the dwarf W. L. pullets that remained on the floor during the laying period. Performance of the pullets subjected to water every other day or the decreasing light program and those fed the low-protein developer is not available. Performance of the low-lysine and water every third day groups is

Table 14. Egg size as affected by brooder house treatments--Experiment 2[1]

Group[2]	Egg sizes					
	Peewee	Small	Medium	Large	X-large	Jumbo
	%	%	%	%	%	%
Prior to 25% production[3]						
1	53.9	46.1				
2	60.3	39.7				
3	66.9	33.1				
4	59.1	40.9				
5	41.6	44.1	14.3			
6	31.3	63.1	5.6			
During 40 weeks of lay						
1	0.3	10.7	47.0	33.8	8.2	0.0
2	1.2	11.6	33.7	42.8	10.3	0.4
3	1.1	11.4	44.5	35.4	13.0	0.4
4	1.2	12.5	32.7	36.9	14.9	1.8
5	0.0	14.7	36.8	35.9	11.2	1.5
6	0.5	5.8	31.4	45.4	15.0	1.9

[1] Egg size summary of dwarf pullets reared on the floor and moved to cages at 20 weeks of age.

[2] Refer to Table 12 for group treatment explanations.

[3] All eggs laid by a specific treatment prior to their reaching 25% production.

Table 15. Performance of floor-housed dwarf pullets during a 44-week lay period as affected by brooder house treatments

Treatment	Hen-day egg prod.	Avg. egg weights	Feed per hen-day	Feed per egg	Lay house mortality
	%	g.	g.	g.	%
Controls	58.3	58.6	109.8	188.2	16.3
Low-lysine developer	59.3	58.2	110.7	186.4	13.0
Water restriction[1]	60.4	58.0	103.4	171.6	13.8

[1]After 8 weeks of age these pullets had water cycling on 24 hours, off 48 hours.

compared with the controls in this section. Hen-day egg production for 44 weeks of lay was greatest for the water every third day group and lowest for the controls. The control and water every third day groups consumed 109.8 and 103.4 g. per hen-day and 188.2 and 171.6 g. per egg, respectively. Regardless of whether the dwarf pullets subjected to water every third day were placed in cages or left on the floor, they consumed less feed and were more efficient in their conversion of feed to eggs than were the controls. Perhaps the reduced body weight at sexual maturity as a result of the water restriction lowered the maintainence requirement in the lay house. No definite trends in egg sizes were observed among treatments of floor-housed layers (Table 16).

The results of intermittent watering of dwarf layers is shown in Table 11. Hen-day egg production for the controls was 3.5% higher than the intermittently-watered hens. The intermittently-watered layers consumed 2.3 g. less feed per hen-day, but required 4.5 g. more feed to produce an egg. The slight difference in egg weights, 0.60 g., favored the control group. It has not been determined why intermittent watering detrimentally affected the performance of the dwarf W. L. pullets but resulted in beneficial effects in the normal W. L. The dwarf pullets had 6.1 linear cm. (2.4") of water trough space per bird while the normals were provided 7.6 cm. (3"). A second possible explanation is that the dwarf pullets have shorter legs and did not obtain a sufficient amount of water in five 15-minute watering periods per day for optimum production. There were no significant differences in Haugh unit values or specific gravity determinations. Twenty-four fecal samples from each treatment were collected and dried. The dry

Table 16. Egg size of floor-housed dwarf pullets as affected by brooder house treatments

Treatment	Egg sizes					
	Peewee	Small	Medium	Large	X-large	Jumbo
	%	%	%	%	%	%
Prior to 25% production[1]						
Controls	34.8	59.4	5.8			
Low-lysine developer	33.2	54.8	12.4			
Water restriction[2]	42.4	54.8	1.9	0.9		
During 44 weeks of lay						
Controls	0.5	7.1	33.8	42.5	14.7	1.5
Low-lysine developer	0.2	8.4	31.6	43.9	13.4	2.6
Water restriction	0.1	8.1	34.3	42.8	13.6	1.2

[1] All eggs laid by a specific treatment prior to their reaching 25% production.

[2] After 8 weeks of age these pullets had water cycling on 24 hours, off 48 hours.

matter content of the feces was 21.1 and 20.9% for the control and intermittently-watered groups, respectively. The T-test analysis demonstrated that these means are not significantly different.

Experiment 3. Feeding a Low-Protein Developer to Dwarf White Leghorn Pullets

The results of feeding dwarf W. L. pullets diets containing 14.73 or 10.36% protein are shown in Tables 17 and 18. Feeding the low-protein ration resulted in significantly lower body weights at 12, 16, 19, and 64 weeks of age. These pullets also consumed significantly less feed from 0 to 19 weeks of age (Table 17). These results follow the same pattern observed in Exp. 1 and 2 (Tables 8 and 12). The low-protein developer reduced feed intake as well as body weight gain. The low-protein pullets consumed 93% of the control group's intake and weighed 87% as much as the controls at 19 weeks of age. Mortality in the brooder house was 1.89 and 1.28% for the control and low-protein groups, respectively. Bullock et al. (1963) and Blair et al. (1970) have observed increased mortality when feeding developer diets containing approximately 10% protein. The probable cause for the lower mortality in this experiment is that a 20.87% protein starter was fed to both groups from 0 to 8 weeks of age. In Exp. 1 and 2, pullets were fed the starter to 4 weeks of age and a 14.73% protein developer from 4 to 8 weeks of age. In those experiments, the pullets fed the 10.36% protein developer from 8 weeks of age did suffer slightly higher mortality (Tables 8 and 12).

There were no significant differences in hen-day egg production,

Table 17. Performance of dwarf White Leghorn pullets fed two protein levels from 8 to 19 weeks of age[1]

Treatment	Body weights (weeks of age)					Feed[4] intake
	12	16	19	28	64	
	g.	g.	g.	g.	g.	kg.
Controls[2]	729[a]	939[a]	1035[a]	1234[A]	1377[A]	4.751[a]
Low-protein[3]	628[b]	816[b]	901[b]	1140[B]	1277[B]	4.415[b]

[1]Values with differing uppercase superscripts are significantly different at the 1% level; different lowercase superscripts indicate significance at the 5% level.

[2]The control group was fed a 14.73% crude protein developer from 8 to 19 weeks of age.

[3]The low-protein group was fed a 10.36% crude protein developer from 8 to 19 weeks of age.

[4]Feed intake is the kilograms of feed consumed per pullet from 0 to 19 weeks of age.

average egg weights, feed consumed per hen-day, or feed required to produce an egg (Table 18). Lay house mortality for the control and low-protein groups was 9.98 and 14.77%, respectively. Although the mortality rate for the low-protein pullets was elevated, it was not unusually high. This rate approximated the usual death loss of 1.0 to 1.5% per month observed in the commercial egg industry.

No significant differences were observed in egg sizes determined on a commercial grader. The results of this experiment agree in general with the findings of Waldroup and Harms (1962), Bullock et al. (1963), Lillie and Denton (1966), Wright et al. (1968), and Blair et al. (1970) who concluded that satisfactory performance may be obtained with pullets fed 10 to 12% protein developer rations after 8 weeks of age.

Experiment 4. Second Year Studies with Various Methods of Delaying Sexual Maturity

Brooder house performance of the Babcock B-300 pullets is summarized in Table 19. In May, 1973, shortly after the control group had reached 25% production, a nutritional disease (vitamin D deficiency) caused a transient but drastic decline in the egg production of all treatments. Therefore, it was not possible to determine when each of the six treatments reached 25 and 50% production. The first egg was laid on April 24, 1973, by one of the control pullets, when they were 127 days of age. The control group reached 25% production when they were 141 days old. This early sexual maturity is normal with pullets brooded in December and raised during a period

Table 18. Performance of dwarf White Leghorn layers during a 40-week lay period as affected by protein content of the developer diet

Treatment	Hen-day egg prod.	Avg. egg weights	Feed per hen-day	Feed per egg	Mortality Brooder house	Mortality Lay house
	%	g.	g.	g.	%	%
Controls[1]	59.89	57.5	89.4	151.4	1.89	9.98
Low-protein[2]	58.05	57.0	88.6	155.6	1.28	14.77

Treatment	Egg sizes					
	Peewee	Small	Medium	Large	X-large	Jumbo
	%	%	%	%	%	%
Controls	0.4	6.4	33.1	40.1	15.7	4.2
Low-protein	0.7	7.0	34.2	39.4	16.4	2.4

[1]The control group was fed a 14.73% crude protein developer from 8 to 19 weeks of age.
[2]The low-protein group was fed a 10.36% crude protein developer from 8 to 19 weeks of age.

Table 19. Brooder house performance of pullets subjected to various management and nutritional treatments in the brooder house--Experiment 4[1]

Group[2]	Body weights				
	4 weeks	8 weeks	12 weeks	16 weeks	19 weeks
	g.	g.	g.	g.	g.
1[3]	262	612^{ab}	938^{b}	1219^{a}	1465^{a}
2[4]	252	580^{b}	773^{d}	1017^{c}	1184^{d}
3[5]	249	574^{b}	848^{c}	1031^{c}	1285^{c}
4[6]	260	601^{b}	932^{b}	1091^{b}	1369^{b}
5[7]	275	628^{a}	959^{ab}	1222^{a}	1396^{b}
6[8]	293	641^{a}	992^{a}	1249^{a}	1396^{b}

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Each group consisted of two 60-bird replicates.

[3]Group 1 served as the controls.

[4]Group 2 was fed a low-protein developer from 8 to 20 weeks of age.

[5]Group 3 was provided water in cycles of 24 hours on, 48 hours off from 8 to 20 weeks of age.

[6]Group 4 was provided water in cycles of 24 hours on, 48 hours off from 14 to 20 weeks of age.

[7]Group 5 was reared with a gradually declining lighting program from 20.5 hours at 0 to 15 hours of light at 22 weeks of age.

[8]Group 6 was reared with a lighting program that provided 20 hours of light daily from 0 to 12 weeks of age and 15 hours of light daily from 12 to 20 weeks of age.

(Continued on next page)

Table 19. (Continued)

Group	Feed intake per bird[9] 0-4 weeks	4-8 weeks	8-12 weeks	12-16 weeks	16-20 weeks	Brooder house mortality[10]
	g.	kg.	kg.	kg.	kg.	%
1	556.6	1.188	1.759[b]	1.975[a]	2.026[a]	2.44
2	568.4	1.207	1.564[c]	1.817[b]	1.831[b]	7.44
3	580.6	1.191	1.435[c]	1.685[c]	1.602[c]	4.46
4	575.6	1.229	1.712[b]	1.845[b]	1.657[c]	0.83
5	606.9	1.280	1.823[ab]	1.934[a]	1.955[ab]	1.65
6	619.6	1.293	1.907[a]	1.937[a]	1.921[ab]	0.00

[9]Feed intake data is given for each 4-week period in the development of the pullet.
[10]Mortality from 0 to 20 weeks of age.

of increasing daylength.

The pullets fed the low-protein developer (10.36% protein) after 8 weeks of age weighed significantly less than all other groups at 12 and 19 weeks of age. From 8 to 20 weeks of age, they consumed significantly less feed than the control pullets. At 19 weeks of age, they weighed only 83% as much as the controls and had consumed only 90.5% as much feed for the period of 8 to 20 weeks of age.

The pullets subjected to either of the lighting programs were heavier at 4, 8, 12, and 16 weeks of age, but were significantly lighter than the controls at 19 weeks of age. In addition, they consumed more feed than the controls for the first 12 weeks of their lives and less feed than the controls from 12 to 20 weeks of age. The greater feed consumption and heavier body weights up to 12 weeks of age are explained by more feeding time resulting from the greater amount of light provided the pullets on the lighting programs. The inferior body weights and reduced feed consumption after 12 weeks of age compared with the controls can only be explained by the increasing photoperiod of the control group and/or the decreasing photoperiod experienced by both lighting program groups.

The pullets provided water every third day starting at 8 weeks of age weighed significantly less than the control pullets at 12, 16, and 19 weeks of age. They weighed 84.5% as much as the controls at 19 weeks of age, and consumed 82% as much feed as the controls from 8 to 20 weeks of age. This same treatment group in Exp. 1 and 2 consumed 91% as much feed as the controls. This difference can be explained only by strain differences. The pullets provided water every third day starting at 14 weeks of age weighed significantly less than the controls at 16 and 19 weeks of age. They weighed 89.5% as much as the controls at 19 weeks of age and consumed 90.5% as much feed as the controls from 8 to 20 weeks of age.

The reduced feed intake by the water-restricted pullets is probably best explained by Lepkovsky et al. (1960), who observed that the digestion of feed is slowed when feed intake is not accompanied by water intake. Delayed passage of food from the crop and lower muscle glycogen level were indicative of the slower digestion. The slower passage of feed through the digestive tract discourages feed consumption. From 8 to 12 weeks of age, the pullets having water available every third day were more efficient in their conversion of feed than the controls. The grams of feed to gram of gain ratio was 5.39 and 5.24 for the controls and water every third day groups, respectively. It is quite well known that rapid rate of passage decreases the digestibility of the ration. Perhaps the water restriction led to a slower rate of passage and ultimately to more efficient digestion. The control group was more efficient after 12 weeks of age.

Figure 1 shows the growth curves of the control group and the two groups limited in their access to water. When the water restriction was initiated at 8 weeks of age, the pullets were initially slowed but then maintained a relatively normal growth curve. When the water restriction program was begun at 14 weeks of age, the pullets lost weight between 14 and 16 weeks of age. Figure 1 shows an unexpected change between 14 and 16 weeks of age in the growth pattern of both groups limited in their access to water. All pullets were innoculated

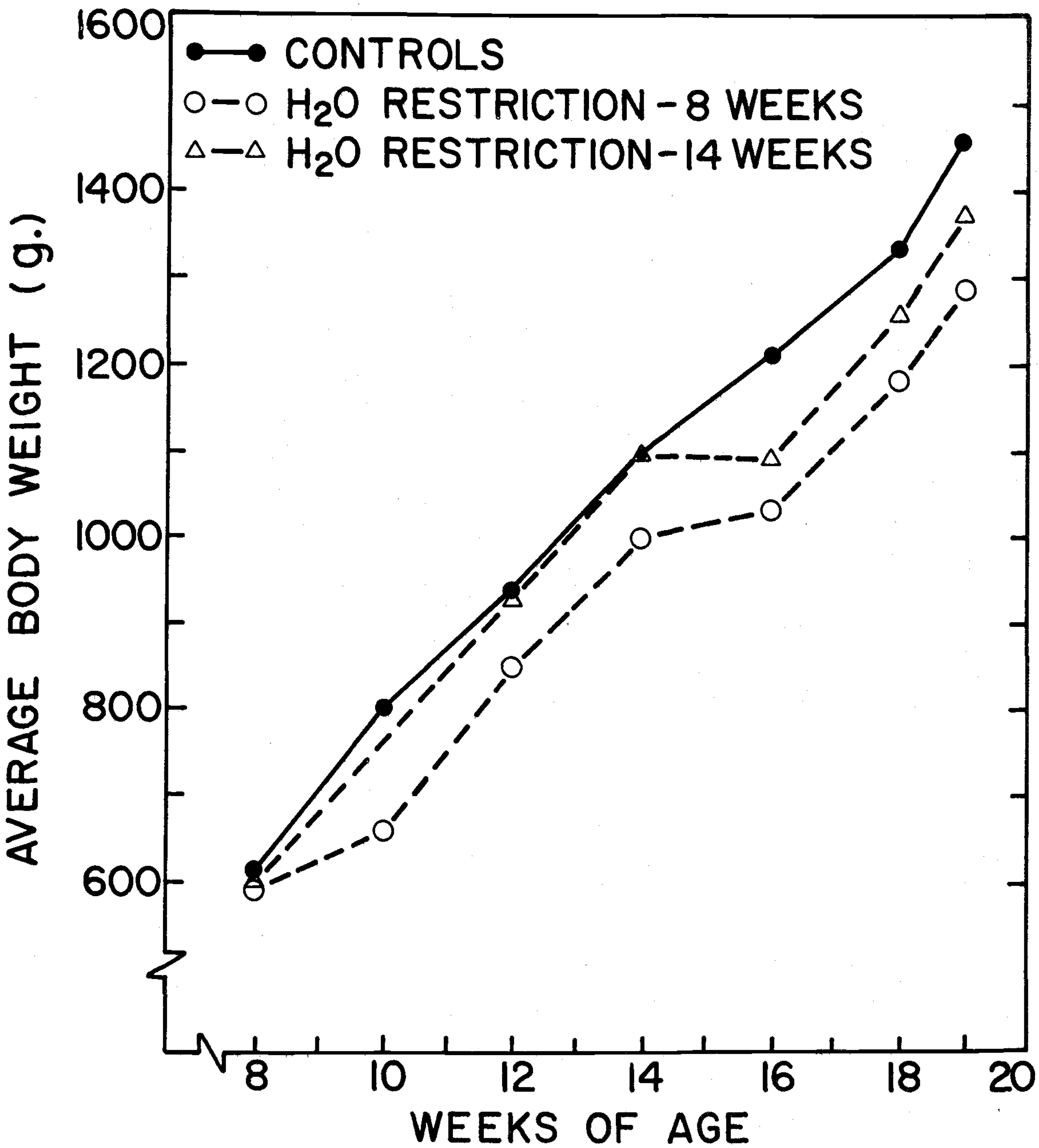

Figure 1. Body weights of birds subjected to water restriction at 8 or 14 weeks of age.

against fowl pox in the fifteenth week of their lives. The reaction of the vaccine, together with water available only every third day, probably accounted for the unusual reduction in growth. After 16 weeks of age, both of these groups maintained relatively normal growth curves.

Table 20 shows the daily feed and water consumption patterns of pullets provided water every third day after 8 weeks of age. Daily consumption was measured during the tenth, fourteenth, and eighteenth weeks of these pullets' lives. In the tenth week the control pullets consumed an average of 63.1 g. of feed per bird per day. On the days that water was available to the water-restricted pullets, they consumed 63.1 g. of feed. On the first and second days after the water was turned off, they consumed an average of 48.5 and 36.3 g. of feed, respectively. They maintained a similar consumption pattern throughout the experiment. They consumed approximately 75 and 50% as much feed on the first and second days without water, respectively, as they did on the day water was available. On the days water was available, the water-restricted group consumed 148, 203, and 281% as much water as the control group in the tenth, fourteenth, and eighteenth weeks, respectively. This pattern indicates that, as the experiment progressed the pullets were learning to drink more water on the days that it was available, but they were never observed to drink three times as much water as the controls.

Table 21 shows the daily feed and water consumption patterns of pullets having access to water every third day after 14 weeks of age. The control pullets consumed a daily average of 72 g. of feed per bird during the sixteenth week. The water-restricted pullets consumed 73 g.

Table 20. Daily feed and water intake of pullets restricted in their access to water after 8 weeks of age

Time period	Treatment	Feed intake day prior to water[1]	Feed intake day water is available[2]	Feed intake day following water[3]	Water intake on day water is available[4]
		g. per bird	g. per bird	g. per bird	g. per bird
10th week of age	Controls[5]	61.7	64.0	63.5	134.7
	Water restriction[6]	36.3	63.1	48.5	198.7
14th week of age	Controls	65.3	78.9	71.7	120.7
	Water restriction	39.0	80.7	60.8	244.9
18th week of age	Controls	71.2	81.7	81.7	98.9
	Water restriction	48.1	71.7	61.2	277.6

[1]In the repeating cycle of water for 24 hours and no water for 48 hours, this is the second consecutive day without water.

[2]The 1 day in 3 that the pullets had access to water.

[3]The first day that the pullets were without water following their day of watering.

[4]Water intake of the controls and the water-restricted pullets on the day that both groups had access to water.

[5]The controls had access to a free-flow water trough at all times.

[6]After 8 weeks of age these pullets had water cycling on 24 hours, off 48 hours.

Table 21. Daily feed and water intake of pullets restricted in their access to water after 14 weeks of age

Time period	Treatment	Feed intake day prior to water[1]	Feed intake day water is available[2]	Feed intake day following water[3]	Water intake on day water is available[4]
		g. per bird	g. per bird	g. per bird	g. per bird
16th week of age	Controls[5]	76.7	70.3	68.0	98.9
	Water restriction[6]	46.7	73.0	56.7	215.5
20th week of age	Controls	82.6	74.4	88.9	132.0
	Water restriction	42.6	81.7	62.6	261.3

[1]In the repeating cycle of water for 24 hours and no water for 48 hours, this is the second consecutive day without water.

[2]The 1 day in 3 that the restricted pullets had access to water.

[3]The first day that the pullets were without water following their day of watering.

[4]Water intake of the controls and the water-restricted pullets on the day that both groups had access to water.

[5]The control group had access to a free-flow water trough at all times.

[6]After 14 weeks of age these pullets had water cycling on 24 hours, off 48 hours.

on the day water was available, but only 56.7 and 46.7 g. on the first and second days after the water was turned off, respectively. These pullets drank 218 and 198% as much water as the controls during the sixteenth and twentieth weeks, respectively. Tables 20 and 21 demonstrate that the water-restricted pullets were not able to consume enough feed on the days the water was on to negate the reduced consumption on the days the water was off. Kirkland and Fuller (1971) and Exp. 1 and 2 demonstrated that pullets provided water every other day can consume enough feed when the water is on to maintain optimum growth.

The highest temperature recorded inside the water restriction pens on a day when the water was off was 22.5°C. (73°F.). At no time did the pullets show signs of heat stress. The developer ration fed to the water-restricted pullets contained 91.2% dry matter.

Table 22 summarizes the organ weights and the oviduct lengths of representative birds from the control group and water restriction groups at 19 weeks and 3 days of age. Water restriction did not affect kidney weight as a percentage of body weight. Ovary and oviduct weights were heavier and oviduct length was considerably longer in the control pullets. These results agree with the visual observations for comb development. At this age comb development on the control pullets was relatively advanced while in the water-restricted pullets the combs had just begun to grow.

Brooder house mortality was slightly higher for the low-protein group (Table 19). Most of the mortality was observed in one replicate. Cannibalism did not appear to be a contributing factor in this instance.

Table 22. Oviduct length and organ weights of pullets subjected to water restriction at 8 or 14 weeks of age

Group[1]	Organ weights[2]								Oviduct length
	Left kidney		Right kidney		Ovary		Oviduct		
	g.	%	g.	%	g.	%	g.	%	cm.
1[3]	4.8	0.367	4.8	0.367	13.1	1.00	42.1	3.21	47.6
2[4]	4.3	0.359	4.4	0.363	0.8	0.06	2.6	0.22	21.0
3[5]	4.0	0.326	3.9	0.318	0.8	0.06	11.4	0.93	36.8

[1]Each group consisted of two 60-bird replicates.

[2]At 19 weeks and 3 days of age one representative bird from each replicate was sacrificed for organ measurements. Organ weights are expressed as an average weight and as a percentage of body weight.

[3]Group 1 served as the controls.

[4]Group 2 was subjected to a repeating cycle of water on for 24 hours, off for 48 hours starting at 8 weeks of age.

[5]Group 3 was subjected to a repeating cycle of water on for 24 hours, off for 48 hours starting at 14 weeks of age.

Lay house performance of pullets from Exp. 4 from 31 to 67 weeks of age is summarized in Table 23. The pullets subjected to Lighting Program 2, which featured a sudden 5-hour drop in the amount of light at 12 weeks of age, and those provided water every third day after 8 weeks of age laid at a significantly higher rate then the control pullets and those fed a low-protein developer. Those pullets subjected to a gradually declining lighting program in the brooder house laid significantly heavier eggs than the control and water-every-third-day-at-eight-weeks groups. All treatments, with the exception of the low-protein group, produced significantly more grams of egg per hen-day than did the control group. The pullets subjected to the sudden light decrease in the brooder house produced the greatest mass of egg per hen-day.

There were significant differences in lay house mortality. Those pullets provided water every third day starting at 14 weeks of age suffered only 2.2% mortality which was significantly less than the 8.6% mortality observed in the control group. The lowest mortality rates were observed in the two water-restricted groups and in the group subjected to Lighting Program 2. Gowe _et al_. (1960), Walter and Aitken (1961), Hollands and Gowe (1961,1965), and Strain _et al_. (1965) have all observed reduced lay house mortality when they restricted feed intake. Water Restriction Programs 1 and 2 in this experiment resulted in 18 and 9.5% reductions in brooder house feed intake, respectively. Therefore, the water restriction actually led to a feed restriction that allowed the results of the current study to be compared with feed restriction findings. Improvement in egg production as a result of

Table 23. Lay house performance of pullets subjected to various management and nutritional treatments in the brooder house--Experiment 4[1]

Group	Hen-day egg prod.	Hen-housed egg prod.	Avg. egg weights	Grams egg per hen-day	Mortality
	%	%	g.	g.	%
1[2]	78.8[bc]	76.5[b]	60.5[b]	47.4[c]	8.60[a]
2[3]	79.7[ab]	78.0[ab]	61.1[ab]	48.6[bc]	6.40[ab]
3[4]	81.3[a]	80.3[a]	60.0[b]	49.2[b]	3.20[ab]
4[5]	81.0[ab]	80.1[a]	61.6[ab]	49.7[ab]	2.20[b]
5[6]	78.3[c]	76.7[b]	63.0[a]	49.2[b]	6.70[ab]
6[7]	81.6[a]	80.5[a]	62.4[ab]	50.7[a]	3.00[ab]

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Group 1 served as the controls.

[3]Group 2 was fed a low-protein developer from 8 to 20 weeks of age.

[4]Group 3 had water cycling on 24 hours, off 48 hours from 8 to 20 weeks of age.

[5]Group 4 had water cycling on 24 hours, off 48 hours from 14 to 20 weeks of age.

[6]Group 5 was reared with a gradually declining lighting program from 20.5 hours at 0 to 15.5 hours of light daily at 22 weeks of age.

[7]Group 6 was reared with a lighting program that provided 20 hours of daily light from 0 to 12 and 15 hours of daily light from 12 to 20 weeks of age.

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Table 23. (Continued)

Group	Feed per hen-day[8]		Feed per egg[9]		Feed per gram egg[10]	
	grams per bird	% of controls	grams per egg	% of controls	grams per gram egg	% of controls
1	120^{b}	100.0	153^{bc}	100.0	2.54^{ab}	100.0
2	125^{ab}	104.2	157^{ab}	102.6	2.57^{a}	101.2
3	122^{ab}	101.7	150^{c}	98.0	2.49^{b}	98.0
4	122^{ab}	101.7	151^{c}	98.7	2.47^{b}	97.2
5	124^{ab}	103.3	158^{a}	103.3	2.52^{ab}	99.2
6	126^{a}	105.0	154^{ab}	100.7	2.49^{b}	98.0

[8] Total feed consumed/total number of hen-days for the 36-week experimental period.

[9] Total feed consumed/total number of eggs laid during the 36-week experiment.

[10] Total feed consumed/total grams of egg for the 36-week experiment.

restricting water concurs with findings reported by the previously mentioned authors who restricted feed intake.

In the feed per hen-day comparison in the lay house, the pullets subjected to Lighting Program 2 (5-hour decline in daylength at 12 weeks) consumed significantly more feed than the control pullets; however, the former group laid at a significantly higher rate (Table 23). The two groups of pullets subjected to water restriction required the fewest grams of feed to produce an egg. These two groups, along with Lighting Program 2, required the least amount of feed to produce a gram of egg. The low-protein group required the greatest amount of feed to produce a gram of egg. The higher rate of lay for the water restriction groups and Lighting Program 2 is the primary reason for their being most efficient. Eggs were not sized in this experiment.

Experiment 5. Further Studies of Delaying Sexual Maturity by a Low-Protein Diet, Water Restriction, and the DeKalb Lighting Program

Brooder house performance is summarized in Table 24. Feeding a pullet developer containing 10.36% protein after 12 weeks of age resulted in significantly lower body weights at 16, 18, and 20 weeks of age. These pullets required 3 days longer than the control group to reach 25 and 50% production. As in Exp. 1, 2, 3, and 4, feeding the lower protein developer resulted in reduced feed intake, a reduction of 7.5% in this experiment. Lab analysis of the control and low-protein developers showed that they contained 13.44 and 10.85% crude protein (Nx6.25), respectively.

Table 24. Brooder house performance of pullets as affected by nutrition and management in the brooder house--Experiment 5[1]

Group[2]	Body weights					Age at 25% prod.	Age at 50% prod.	Feed to[3] 25% prod.
	14 weeks	16 weeks	18 weeks	20 weeks	25 weeks			
	g.	g.	g.	g.	g.	days	days	kg.
1[4]	849	966[a]	1078[a]	1085[a]	1413	162[c]	172[b]	4.398[B]
2[5]	830	905[b]	984[b]	981[b]	1366	165[c]	175[ab]	4.390[B]
3[6]	798	846[c]	995[b]	1006[b]	1382	169[b]	181[ab]	4.407[B]
4[7]	840	944[a]	1024[ab]	1033[ab]	1386	176[a]	183[a]	5.275[A]

[1]Values with differing uppercase superscripts are significantly different at the 1% level; different lowercase superscripts indicate significance at the 5% level.

[2]Each group consisted of two 30-bird replicates.

[3]Feed consumed per pullet from 12 weeks of age until the flock reached 25% production.

[4]Group 1 served as the controls.

[5]Group 2 was fed a low-protein developer ration from 12 to 20 weeks of age.

[6]Group 3 was provided water cycling on 24 hours, off 48 hours from 12 to 20 weeks of age.

[7]Group 4 was reared with a modified DeKalb lighting program which provided natural increasing daylength up to 15 hours of daily light at 12 weeks of age. Ten hours of daily light was provided from 12 to 22 weeks of age.

Providing water to pullets every third day after 12 weeks of age caused these pullets to be significantly lighter than the control group at 16, 18, and 20 weeks of age. Figure 2 shows the growth patterns of the control and water restricted groups. The water-restricted birds did not gain any weight between 12 and 14 weeks of age. The pullets were innoculated for fowl pox during the thirteenth week. The initiation of the water restriction, coupled with the reaction to the vaccine, could explain the lack of a weight gain. Figure 2 also shows very little gain for the controls or the water restricted group from 18 to 20 weeks of age. The cause for this is unknown. From 12 to 20 weeks of age, the water-restricted birds consumed 17.6% less feed than the control pullets and required 7 and 9 days longer to reach 25 and 50% production, respectively. These results are consistent with the findings of Exp. 1, 2, and 4 (Tables 8, 12, and 19).

The group subjected to a 5-hour light decrease at 12 weeks of age consumed 97% as much feed as the control group between 12 and 20 weeks of age. At 20 weeks of age, they weighed 2% less than the control pullets. This group demonstrated the greatest delay in reaching sexual maturity; they required 14 and 11 days longer than the controls to reach 25 and 50% production, respectively.

No mortality occurred between 12 and 20 weeks of age. This further demonstrates that water restriction and low-protein diets can be utilized without observing greater mortality in the brooder house. During the period from 12 to 20 weeks of age, the water-restricted pullets were subjected to 10 and 4 days when the temperature within their pens rose above 26.7°C. (80°F.) and 32.2°C. (90°F.),

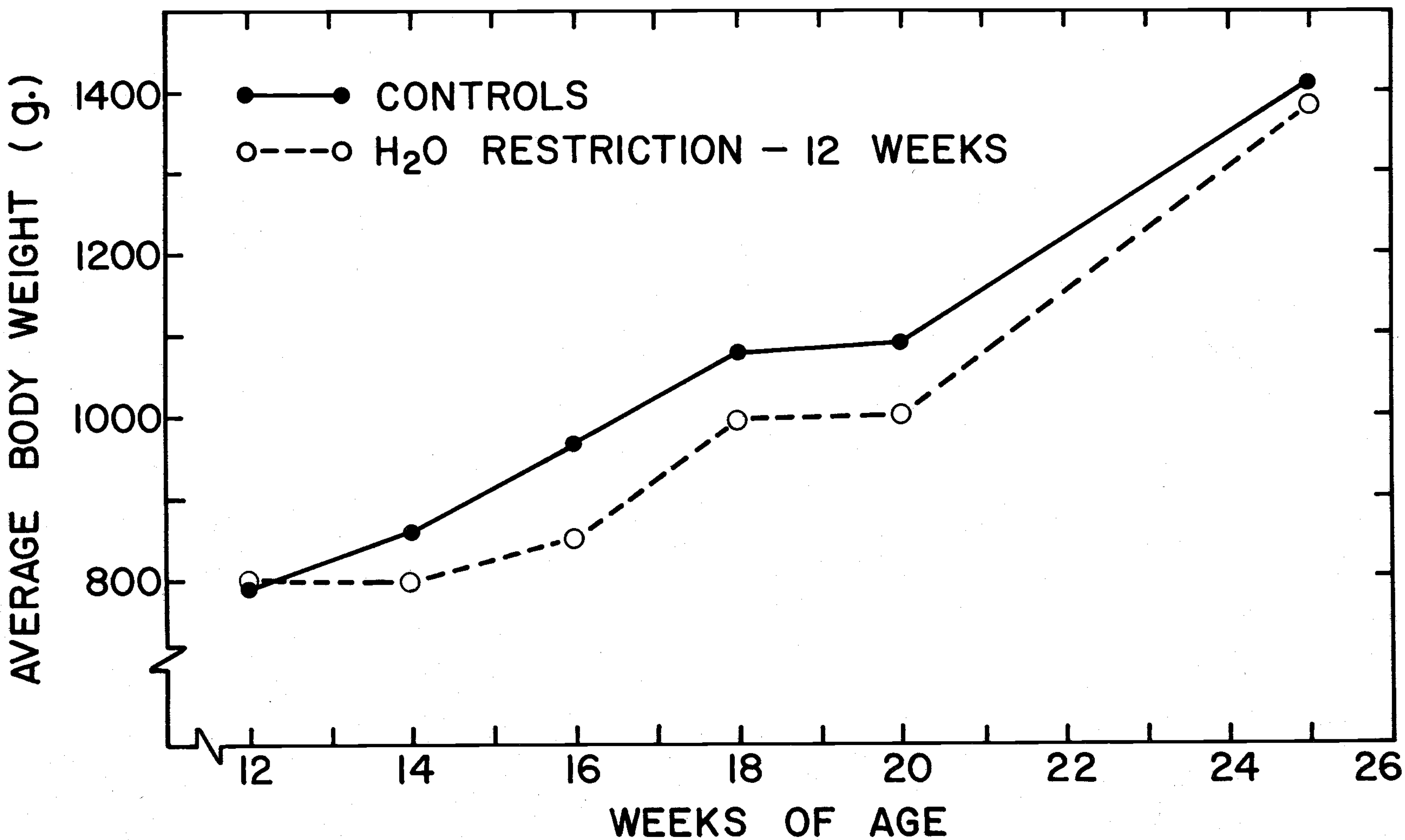

Figure 2. Body weights of birds subjected to water restriction at 12 weeks of age.

respectively. No water was available on these days. Birds did not appear to be heat stressed.

There were significant differences in the feed consumed per pullet up to 25% production. The pullets subjected to the light decrease required significantly more feed than the other treatments. This was due to their reaching 25% production 14 days after the control group. Body weights at 25 weeks of age were not significantly different. At this age, the low-protein, water restricted, and lighting program groups weighed 96.7, 97.8, and 98.1% as much as the controls, respectively.

There were no significant differences in hen-housed or hen-day egg production (Table 25); however, the control group had the poorest hen-day egg production. The water-restricted group laid at the highest rate both on a hen-day and hen-housed basis.

The water-restricted birds and the lighting program birds gained the most weight in the lay house. Surprisingly, the low-protein group only gained 11 g. more than the control group during the laying period. In Exp. 1, 2, 3, and 4, the pullets fed the low-protein developer gained considerably more weight than the controls during the laying period (Tables 8, 12, 17, and 19).

Although there was no statistical significance, slight differences in egg weights favored the water restricted and lighting program groups (Table 25). The control, low-protein, water restricted, and lighting program groups produced 44.6, 44.7, 47.6, and 46.9 g. of egg per hen-day, respectively. Again, the water-restricted and lighting program groups led in this important criteria.

Table 25. Performance of Babcock B-300 pullets during a 44-week lay period as affected by brooder house treatments.

Group[1]	Hen-day egg prod.[2]	Hen-housed egg prod.[3]	Weight gain[4]	Early egg weights[5]	Avg. egg weights[6]	Grams egg per hen-day[7]	Mortality
	%	%	g.	g.	g.	g.	%
1	75.8	73.4	683	42.9	58.8	44.6	5.00
2	76.2	72.5	694	42.3	58.7	44.7	6.67
3	80.1	78.8	794	44.7	59.5	47.6	8.45
4	78.9	72.8	758	45.6	59.4	46.9	16.67

[1]Refer to Table 24 for treatment group explanations.

[2]Total number of eggs laid/total number of hen-days for the 44-week experiment.

[3]Total number of eggs laid/total number of hen-housed days for the 44-week experiment.

[4]Average amount of weight gained during the 44-week laying period.

[5]Average weight of all eggs laid by each treatment prior to reaching 25% production.

[6]Total egg mass/total number of eggs laid during the 44-week experiment.

[7]Total egg mass/total number of hen-days.

(Continued on next page)

Table 25. (Continued)

Group	Feed per hen-day[8]		Feed per egg[9]		Feed per gram egg[10]	
	grams per bird	% of controls	grams per egg	% of controls	grams per gram egg	% of controls
1	110.9	100.0	146.4	100.0	2.49	100.0
2	112.6	101.5	147.8	100.9	2.52	101.2
3	115.3	104.0	144.0	98.4	2.42	97.4
4	116.1	104.7	147.1	100.5	2.48	99.5

[8] Total feed consumed/total number of hen-days for the 44-week experiment.

[9] Total feed consumed/total number of eggs laid during the 44-week experiment.

[10] Total feed consumed/total grams of egg for the 44-week experiment.

There were no significant differences in feed consumed per hen-day, feed consumed per egg, or feed consumed per gram of egg (Table 25). The low-protein, water restricted, and lighting program groups consumed 1.7, 4.4, and 5.2 g. more feed per hen-day than the controls, respectively; however, these groups laid at hen-day rates 0.36, 4.26, and 3.11% higher than the controls, respectively. The water-restricted birds required the least amount of feed to produce an egg and a gram of egg (Table 25). These results agree with the findings of Exp. 4 (Table 23) which showed the water-restricted birds to be the most efficient converters of feed to eggs.

In the period prior to 25% production, the water restricted and lighting program pullets tended to lay fewer peewee eggs and more small and medium eggs (Table 26). The controls, low-protein, water restricted, and lighting program pullets laid 41.5, 46.1, 20.3, and 15.9% peewee eggs, and 4.6, 4.3, 8.7, and 16.7% medium eggs, respectively. During the 44-week laying period, the water-restricted and lighting program pullets tended to lay fewer small and more extra large eggs.

The lighting program group suffered the greatest mortality during the 44-week experiment (Table 25). This was due to a high incidence of leukosis in one replicate which caused 30% mortality. The other replicate had only 3.3% mortality. This mortality also accounts for the relatively low hen-housed production of the lighting program treatment. Only the mortality observed in the lighting program group is in excess of the 1.0 to 1.5% per month expected under commercial conditions.

Table 26. Egg size of Babcock B-300 pullets as affected by brooder house treatments--Experiment 5

Group[1]	Egg sizes					
	Peewee	Small	Medium	Large	X-large	Jumbo
	%	%	%	%	%	%
Prior to 25% production[2]						
1	41.5	51.7	4.6	1.1	1.1	
2	46.1	46.5	4.3	1.7	1.3	
3	20.3	66.4	8.7	2.5	2.1	
4	15.9	67.4	16.7			
During 44 weeks of lay						
1	0.2	8.6	24.0	45.1	20.0	2.2
2	0.6	7.0	26.7	44.6	19.4	1.6
3	0.1	6.1	23.3	45.0	24.3	1.2
4	0.3	6.8	23.8	43.9	22.5	2.7

[1]Refer to Table 24 for treatment group explanations.

[2]All eggs laid by a specific treatment prior to their reaching 25% production.

Experiment 6. Intermittent Watering of White Leghorn Laying Hens

The response of the hens to the intermittent watering initiated after 5 months of lay was quite variable. Some three-bird replicates were not affected at all while others dropped to below 20% production, with many hens going into a molt. By the fourth period a good portion of them had returned to production.

The lay house performance of these hens is summarized in Table 27 and Figure 3. Both intermittent watering schedules resulted in a significant decline in hen-day egg production. Providing two 1-hour watering periods resulted in a decline in egg production during the first 28-day period; however, production climbed each succeeding period until it nearly equalled that of the controls during the fourth period. Limiting water to three 15-minute periods per day reduced production during the first two 28-day periods. Production of these hens nearly equalled the level of the controls during the fourth period.

The adverse effect on egg production observed due to reducing water availability to birds already in production was not observed by Maxwell and Lyle (1957). They provided layers water _ad lib_. or three 15-minute periods daily for 6 weeks after which treatments were reversed. Changing from water _ad lib_. to intermittent watering did not cause a drop in production. Perhaps strain difference could account for the dissimilarity in results. Differences in average weight gains during lay were not statistically significant; however, the control hens gained an average of 110 g. while the two intermittently-watered groups gained only 16.0 and 15.3 g.

Birds on control, the two 1-hour periods, and the three 15-

Table 27. Performance of hens subjected to intermittent watering--Experiment 6[1]

Group[2]	Hen-day egg prod.	Weight gain	Feed per hen-day	Avg. egg weights	Feed per egg	Feed per gram egg	Mortality
	%	g.	g.	g.	g.	g.	%
1[3]	58.4[a]	109.8	114.1	62.2	195.4	3.19	4.76
2[4]	51.8[b]	16.0	100.9	62.5	194.8	3.12	2.44
3[5]	48.7[b]	15.3	101.4	63.1	208.0	3.30	4.76

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Each group consisted of 14 replicates of three birds each.

[3]Group 1 served as the controls.

[4]Group 2 had access to water from 8:30-9:30 A.M. and 5:30-6:30 P.M.

[5]Group 3 had access to water for 15 minute periods at 8:00 A.M., 1:30 P.M., and 6:30 P.M.

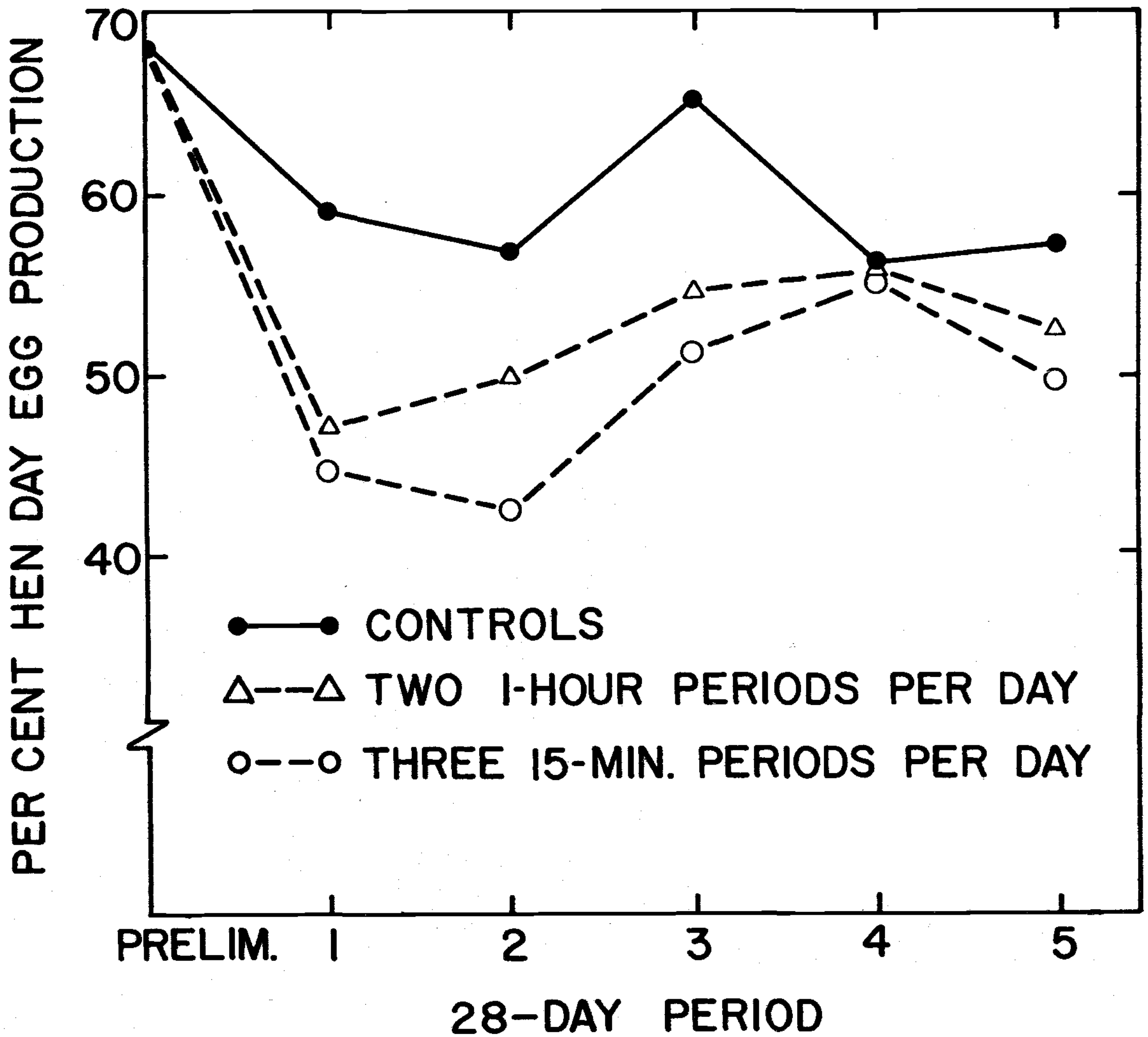

Figure 3. Egg production curve of hens subjected to intermittent watering--Experiment 6.

minute periods consumed 114.1, 100.9, and 101.4 g. feed per hen-day, respectively. Thus the two intermittent watering regimes resulted in feed savings of 11.6 and 11.1%, respectively. The group having water available two 1-hour periods daily consumed 0.6 g. less feed per egg and 0.07 g. less feed per gram of egg than the control group even though their egg production was 6.6% lower. This finding indicated that intermittent watering has some potential for feed savings.

No significant differences were observed in egg weights. The slight variance noted favored the intermittently-watered hens. Mortality was nearly equal for all three treatments.

Results of the specific gravity determinations are shown in Table 28. Both intermittently-watered groups had significantly higher values than the control group during period 2. The group provided three 15-minute watering periods daily laid eggs with the thickest shells (as indicated by specific gravity values) during the third and fourth 28-day periods. The results of albumen quality studies are summarized in Table 29. The three 15-minute-periods group laid eggs of significantly superior albumen quality during the third, fourth, and fifth 28-day periods.

Wilson _et al_. (1965) reported that limiting hens to one 2-hour watering period per day increased albumen quality 5.4 Haugh units. In the current study, improvements were observed in both shell thickness, as measured by specific gravity, and in albumen quality when hens were intermittently watered. However, it was not possible to determine if the increased albumen height and shell thickness were due only to the intermittent watering or the hens' molting and subsequently returning

Table 28. Specific gravity of eggs from intermittently-watered hens--Experiment 6[1]

Group[2]	Specific gravity					
	Prelim. period	Period 1	Period 2	Period 3	Period 4	Period 5
1[3]	1.0850	1.0806	1.0768[b]	1.0791[b]	1.0777[b]	1.0773
2[4]	1.0835	1.0810	1.0805[a]	1.0783[b]	1.0782[b]	1.0786
3[5]	1.0833	1.0808	1.0794[a]	1.0813[a]	1.0812[a]	1.0806

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Each group consisted of two replicates of 21 birds each.

[3]Group 1 served as the controls.

[4]Group 2 had access to water from 8:30-9:30 A.M. and 5:30-6:30 P.M.

[5]Group 3 had access to water for 15-minute periods at 8:00 A.M., 1:30 P.M., and 6:30 P.M.

Table 29. Albumen quality of eggs from intermittently-watered hens--Experiment 6[1]

Group[2]	Haugh units					
	Prelim. Period	Period 1	Period 2	Period 3	Period 4	Period 5
1[3]	83.4	81.9	81.0	81.0[B]	76.0[B]	74.4[b]
2[4]	82.7	81.5	81.1	83.4[AB]	78.5[AB]	78.2[ab]
3[5]	83.7	82.2	82.4	86.3[A]	81.0[A]	79.9[a]

[1]Values with differing uppercase superscripts are significantly different at the 1% level; different lowercase superscripts indicate significance at the 5% level.

[2]Each group consisted of 14 replicates of three birds each.

[3]Group 1 served as the controls.

[4]Group 2 had access to water from 8:30-9:30 A.M. and 5:30-6:30 P.M.

[5]Group 3 had access to water for 15-minute periods at 8:00 A.M., 1:30 P.M., and 6:30 P.M.

to production. One of the primary objectives of force molting, causing hens to molt by means of management practices, is to bring about an improvement in internal and external egg quality. Because the significantly higher Haugh unit and specific gravity values of eggs laid by intermittently-watered hens were observed concurrently with the period of time that molted hens were returning to production (third, fourth, and fifth 28-day periods), it is not possible to definitely attribute the improvements in quality to intermittent watering, *per se*.

Experiment 7. Intermittent Watering and Limited-time Feeding of White Leghorn Pullets

Performance of pullets subjected to intermittent watering or limited-time feeding is summarized in Table 30. Limiting feeding time of O. S. U. strain W. L. pullets to two 2-hour periods daily resulted in a significant decrease in hen-day egg production. This result disagrees with the finding of Patel and McGinnis (1970) who observed no decline in egg production when limiting feeding time in the same manner as used in this experiment. Polin and Wolford (1972), however, found that hens given two 2-hour meals daily laid 8% fewer eggs.

There was no significant difference in the hen-day egg production of the control and intermittent-watering groups; however, both intermittent-watering groups laid at a higher rate than the control pullets.

The group receiving 15 minutes of water each hour laid significantly heavier eggs than the control and two 2-hour feedings groups. Here again both intermittent watering groups outperformed the controls.

Table 30. Performance of White Leghorn pullets subjected to intermittent watering or limited-time feeding--Experiment 7[1]

Group[2]	Weight gain[3]	Hen-day egg prod.[4]	Avg. egg weights[5]	Grams egg per hen-day	Mortality
	g.	%	g.	g.	%
1[6]	699[a]	70.5[ab]	60.7[b]	42.29	11.1
2[7]	698[a]	74.6[a]	63.1[a]	46.78	11.1
3[8]	544[b]	73.4[ab]	61.5[ab]	44.80	13.9
4[9]	498[b]	66.7[b]	61.0[b]	40.27	19.5

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Each group consisted of 12 replicates of three birds each.

[3]Average weight gained per pullet during the 40-week experiment.

[4]Average of hen-day egg production for the ten 28-day periods.

[5]Average of egg weights for the ten 28-day periods.

[6]Group 1 served as the controls.

[7]Group 2 had access to water 15 minutes each hour that the lights were on.

[8]Group 3 had access to water five 15-minute periods each day.

[9]Group 4 had access to feed two 2-hour periods each day.

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Table 30. (Continued)

Group	Feed per hen-day[11]		Feed per egg[12]		Feed per gram egg[13]	
	grams per bird	% of controls	grams per egg	% of controls	grams per gram egg	% of controls
1	114.4^{a}	100.0	162.7^{ab}	100.0	2.69^{a}	100.0
2	124.0^{a}	108.4	167.4^{a}	102.9	2.67^{a}	99.3
3	114.1^{ab}	99.7	155.0^{b}	95.3	2.55^{b}	94.7
4	109.7^{b}	95.9	166.6^{a}	102.4	2.76^{a}	102.6

[11]Total feed consumed/total number of hen-days for the 40-week experiment.

[12]Total feed consumed/total number of eggs laid during the 40-week experiment.

[13]Total feed consumed/total grams of egg for the 40-week experiment.

In comparison with the control group, average egg weights were not reduced by limited-time feeding. This finding conflicts with the results of Patel and McGinnis (1970) and Polin and Wolford (1972) who observed lower egg weights when providing two 2-hour feedings per day; however, Harrison (1972), utilizing the same feeding regime, observed no difference in egg weights.

Layers provided two 2-hour feedings or five 15-minute waterings gained significantly less weight during the 40-week lay period than the control or 15-minutes-water-per-hour groups. This would indicate that a greater percentage of the feed consumed by the intermittently-watered (five 15-minute periods per day) pullets was being converted into eggs rather than weight gain.

Mortality for the four treatments was not significantly different. However, mortality for the limited-time feeding layers reached 19.5%. This level exceeds the commercially accepted rate of 1.5% per month. The high mortality for this group reduced the cumulative hen-housed production to 55.7%. The other three treatments laid in excess of 66% on a hen-housed basis.

The group provided 15 minutes of water each hour produced 110% as much egg mass per hen-day as the control group. The layers receiving five 15-minute water periods daily produced 5.9% more egg mass per hen-day than the control pullets. These increases in egg mass are due to the higher hen-day egg production and average egg weights observed in both intermittently-watered groups.

Intermittent watering did not result in a significant reduction in feed intake per hen-day in the experiment. On the contrary, those pullets having water 15 minutes each hour consumed 10 g. more feed per hen-day than the controls. However, these birds were laying heavier eggs and at a higher rate of production. Five 15-minute waterings and limited-time feeding resulted in feed savings per hen-day of 0.3 and 4.7 g., respectively. There was a significant difference in the amount of feed required to produce an egg in this experiment (Table 30). Layers having five 15-minute waterings per day required 7.7, 12.7, and 11.6 g. less feed to produce an egg than the control, 15-minutes-water-each-hour, and limited-time feeding groups, respectively. In comparison with these same groups, the layers provided five 15-minute waterings required 0.14, 0.12, and 0.21 g. less feed to produce a gram of egg. This difference was statistically significant. Hill (1969), utilizing a similar watering regime, also observed an improvement in feed efficiency.

The summary of egg sizes is shown in Table 31. Layers provided 15 minutes of water each hour tended to lay fewer medium and large eggs and more extra large and jumbo eggs. This corresponds with the finding that they laid significantly heavier eggs as compared to the control group. Increased egg size has not been reported in the literature as a possible benefit of intermittent watering. Upon periodic observation, it was noted that all intermittently-watered birds first satisfied their thirsts when the solenoid valve opened and then began to actively consume feed. One of the advertised advantages of automatic feeding is that the movement of the chain or auger promotes feed consumption. Perhaps in this experiment, the water activated each hour served the same function as the automatic feeder, causing an increased

Table 31. Effects of intermittent watering and limited-time feeding on egg size--Experiment 7[1]

Group[2]	Egg sizes				
	Peewees and smalls	Medium	Large	X-large	Jumbo
	%	%	%	%	%
1[3]	4.04	20.05[ab]	46.64	25.04	4.24
2[4]	1.33	15.04[b]	40.91	34.68	8.06
3[5]	1.33	20.70[ab]	45.38	30.53	2.07
4[6]	1.71	22.51[a]	46.24	26.75	2.80

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Each group consisted of 12 replicates of three birds each.

[3]Group 1 served as the controls.

[4]Group 2 had access to water 15 minutes each hour that the lights were on.

[5]Group 3 had access to water five 15-minute periods each day.

[6]Group 4 had access to feed two 2-hour periods each day.

feed intake and ultimately significantly heavier egg weights.

No significant differences were observed in specific gravity and albumen quality studies. This would suggest that the significant differences observed in Exp. 6 (Tables 28 and 29) were due to hens molting and subsequently returning to production rather than the intermittent-watering programs.

Experiment 8. Intermittent Watering of Babcock B-300 White Leghorn Layers

Performance of the Babcock B-300 pullets subjected to intermittent watering is summarized in Table 32. Laying pullets provided three 15-minute waterings each day gained significantly less body weight during 36 weeks of lay than the other three treatments. Providing 15 minutes of water each hour or five 15-minute periods daily did not reduce weight gain during lay in comparison with the control group. In Exp. 7, O. S. U. strain W. L. pullets watered five times daily gained significantly less weight than the controls. The difference in findings between the two experiments can only be explained by strain differences. Differences in hen-day and hen-housed egg production were not significant; however, all three groups of pullets subjected to intermittent watering programs laid at a higher hen-day rate than the control group. Those pullets provided three and five 15-minute water periods each day outproduced the controls by 3.11 and 2.88%, respectively, on a hen-housed basis. The higher hen-day egg production observed in this experiment agree with the results recorded in Exp. 7 (Table 30). In both experiments, pullets provided five

Table 32. Performance of White Leghorn pullets subjected to intermittent watering--Experiment 8[1]

Group[2]	Weight gain[3]	Hen-day egg prod.[4]	Hen-housed egg prod.[5]	Avg. egg weights	Grams egg hen-day[7]	Mortality
	g.	%	%	g.	g.	%
1[7]	623[a]	74.8	74.8	57.2[a]	42.8	0.0[b]
2[8]	663[a]	76.1	70.9	56.7[a]	43.1	11.1[a]
3[9]	628[a]	77.7	77.4	57.1[a]	44.4	2.8[b]
4[10]	524[b]	77.9	77.9	54.6[b]	42.6	0.0[b]

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Each group contained two replicates of 18 birds each.

[3]Average weight gained per hen during the 36-week experiment.

[4]Total number of eggs laid/total number of hen-days for the 36-week experiment.

[5]Total number of eggs laid/total number of hen-housed days for the 36-week experiment.

[6]Total grams of egg produced/total number of hen-days for the 36-week experiment.

[7]Group 1 served as the controls.

[8]Group 2 had access to water 15 minutes each hour (8:00 A.M. to 11:00 P.M.) that the lights were on.

[9]Group 3 had access to water five 15-minute periods each day.

[10]Group 4 had access to water three 15-minute periods each day.

(Continued on next page)

Table 32. (Continued)

Group	Feed per hen-day[11]		Feed per egg[12]		Feed per gram egg[13]	
	grams per bird	% of controls	grams per egg	% of controls	grams per gram egg	% of controls
1	111[a]	100.0	148	100.0	2.60	100.0
2	111[a]	100.0	146	98.6	2.57	98.8
3	108[ab]	97.3	139	93.9	2.43	93.5
4	106[b]	95.5	137	92.6	2.50	96.2

[11]Total feed consumed/total number of hen-days for the 36-week experiment.

[12]Total feed consumed/total number of eggs laid during the 36-week experiment.

[13]Total feed consumed/total grams of egg for the 36-week experiment.

15-minute water periods daily laid at a higher rate than the controls.

Hill (1969) observed a slight reduction in hen-day egg production when the layers were provided five 15-minute waterings each day beginning at 21 weeks of age. He concluded that this watering program was too severe for pullets in peak lay. The dissimilarity of results from Hill's work and the current experiment may be explained by strain differences. It might also be explained by water trough length. In the current study, the water needed to travel only 216 cm. (85") before reaching the last cage in each row. Under commercial conditions where troughs would be up to 91.4 m. (300') or more in length, the duration of the watering periods would have to be increased to insure that the last cage in each row received an ample supply of water.

The high hen-day egg production of pullets provided three 15-minute waterings constrasts with the significant reduction noted in Exp. 6 (Table 27 and Figure 3). Reducing water availability from _ad lib_. intake to three 15-minute periods per day after hens have been in lay may be too severe to maintain egg production. Initiating the program prior to the onset of lay may allow the pullets to adapt to the watering regime. O. S. U. and Babcock W. L. layers were used in Exp. 6 and 8, respectively. Strain differences may be a contributing factor to the dissimilarity of results in the two experiments.

The highest mortality, 11.1%, occurred in the group having water available 15 minutes each hour. Although this was significantly higher than the other treatments, it is not abnormally high. No mortality occurred in the controls or in those with water three 15-minute periods per day.

There were no significant differences in feed consumed per hen-day; however, groups provided five and three 15-minute water periods daily consumed 97.3 and 95.9%, respectively, as much feed as the group with water 15 minutes each hour, which consumed the same amount of feed per hen-day as did the controls. Statistical analysis showed no significant differences in feed consumed per egg; however, the intermittently-watered groups (15 minutes water each hour, five 15-minute periods, and three 15-minute periods, respectively) required 98.6, 93.9, and 92.6% as much feed as the controls to produce an egg. Respectively, these same groups required 98.8, 93.5, and 96.2% as much feed as the control group to produce a gram of egg. In this study the birds provided five 15-minute waterings daily were shown to be most efficient. These results concur with the findings of Exp. 7 (Table 30) and with those of Hill (1969).

There were significant differences in average egg weights (Table 32); pullets provided three 15-minute water periods per day laid significantly smaller eggs than the other treatments. This reduction in average egg weight was not observed in Exp. 6; however, those hens had been in lay 5 months prior to the initiation of the experiment, laid at a significantly lower rate than the control hens, and were of a different strain than used in this experiment. Figure 4 compares average egg weights of the control and intermittently-watered groups for each 28-day period. The reduction in average egg weight in the first five periods is undesirable because of the increased number of peewee, small, and medium eggs. However, the reduction in egg weights may be desirable after the sixth period when most

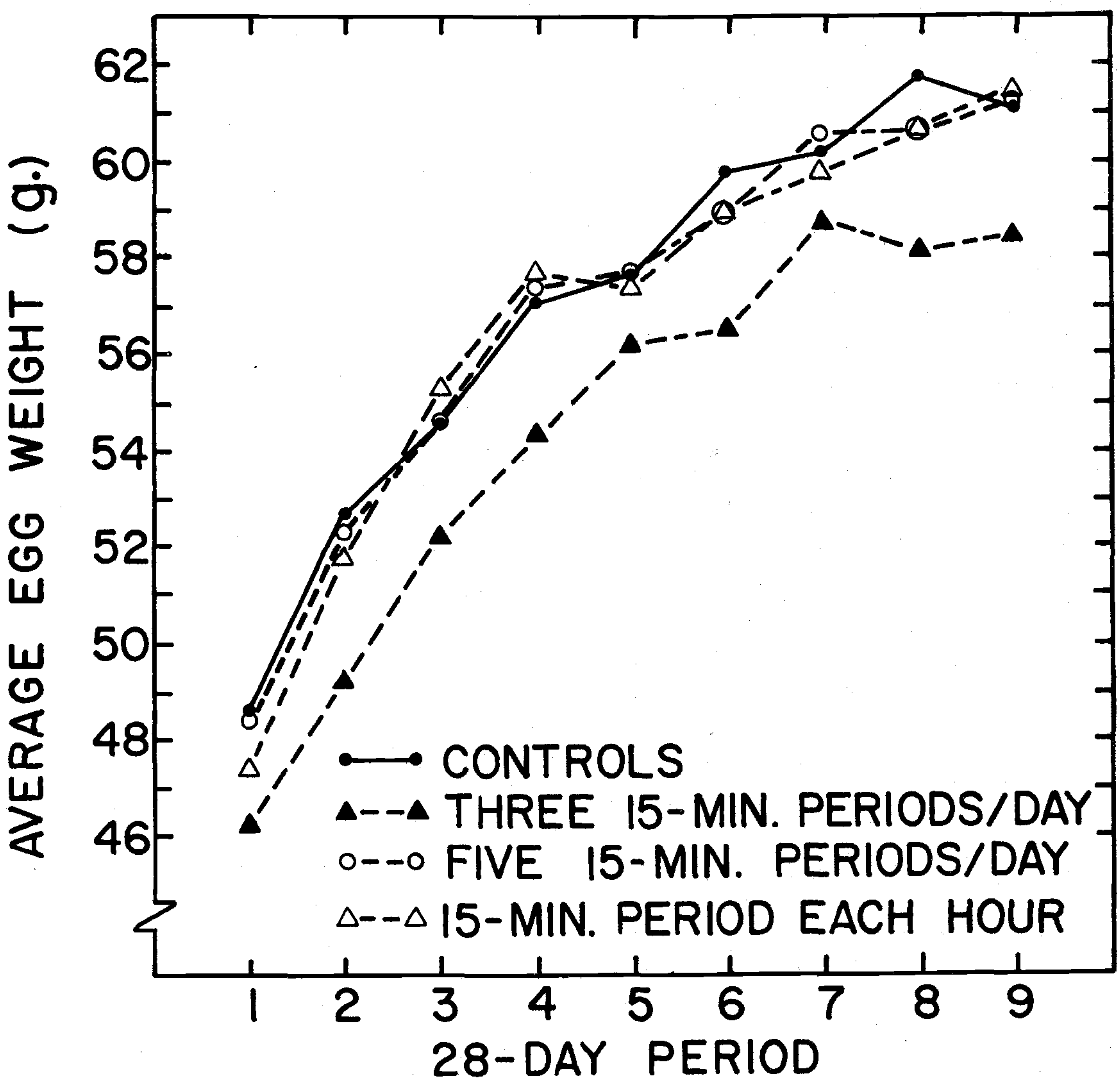

Figure 4. Egg weights of intermittently-watered hens--Experiment 8.

of the eggs laid are large, extra large, and jumbo. Producing a large percentage of extra large and jumbo eggs may not be profitable. The egg producer who sells to a wholesaler will receive the same price for his large and extra large eggs and not more than a one or two cent per dozen premium for his jumbo eggs. Therefore, the producer may profit more by producing fewer jumbo and extra large eggs as a result of this intermittent-watering regime and the feed savings incurred. Figure 4 also indicates that providing five 15-minute periods had little, if any, effect on average egg weights. A combination of five daily waterings for the first five or six months and three waterings thereafter may provide the optimum egg size for greatest profit.

The egg size summary is shown in Table 33. Pullets watered three times daily laid significantly fewer large eggs and tended to lay more peewee, small, and medium eggs and fewer extra large eggs. The other two intermittent-watering regimes did not significantly alter egg size.

There were no significant differences in the moisture content of the fecal samples. The average dry matter content of the feces from the control, three 15-minute, and five 15-minute groups was 28.5, 29.0, and 24.2%, respectively.

Since the laying facilities were not temperature controlled, the birds were exposed to temperatures in excess of 26.7°C. (80°F.) on many occasions. Periodically maximum ambient temperatures in excess of 32.2° C. (90°F.) were recorded. At no time did the intermittently-watered layers appear to be more heat stressed than the control group.

Table 33. Egg size of Babcock B-300 layers as affected by intermittent watering[1]

Group[2]	Egg sizes				
	Peewees and smalls	Medium	Large	X-large	Jumbo
	%	%	%	%	%
1[3]	8.61	38.49	42.70[a]	9.82	0.40
2[4]	12.55	31.63	48.44[a]	6.95	0.44
3[5]	9.46	36.44	42.48[a]	11.63	0.00
4[6]	20.26	41.46	31.25[b]	6.91	0.14

[1]Values with differing lowercase superscripts are significantly different at the 5% level.

[2]Each group consisted of two replicates of 18 birds each.

[3]Group 1 served as the controls.

[4]Group 2 had access to water 15 minutes each hour that the lights were on.

[5]Group 3 had access to water five 15-minute periods each day.

[6]Group 4 had access to water three 15-minute periods each day.

V. SUMMARY

There were two broad objectives of the research covered here. The first objective was to investigate various methods of delaying the sexual maturity of developing W. L. pullets and to compare these methods with lighting programs currently used by the commercial poultry industry to delay sexual maturity. The second objective was to investigate various methods of controlling the feed intake of W. L. layers in order to regulate weight gains and to improve feed efficiency. The following paragraphs summarize the results of these studies.

Methods of Delaying Sexual Maturity

Low-lysine developer rations

Feeding a pullet developer ration containing 0.54% lysine and 0.92% arginine did not retard the growth or sexual development of dwarf or normal W. L. pullets. In two of three comparisons the control group laid at a higher hen-day rate than the pullets fed the low-lysine developer. However, the low-lysine pullets tended to lay larger eggs in the 40-week experimental period in two of the three comparisons. No significant differences were observed in body weights or feed intake during the developing period, or flock age at 25 or 50% production. Fed to the dwarf W. L. pullets, the low-lysine developer resulted in greater cannibalism.

Low-protein developer rations

Feeding a pullet developer containing 10.36% crude protein from 8 to 20 weeks of age significantly reduced body weights and feed intake during the developing period. In two comparisons each with dwarf and normal W. L. pullets, the low-protein developer resulted in 11.8, 7.0, 9.11, and 9.5% reductions in feed intake, respectively. In one of two comparisons with the normal Leghorns, hen-day egg production was markedly reduced by feeding the low-protein developer; in the second comparison, hen-day egg production was higher for the low-protein group. In both comparisons with the dwarf White Leghorns, hen-day egg production was comparable in control and low-protein groups. The low-protein developer resulted in 14 and 11-day delays in reaching 25 and 50% production, respectively, in the normal Leghorns and delays of 2 and 11 days in the dwarf Leghorns. In three of four comparisons, feeding the low-protein developer resulted in slightly higher brooder house mortality. Normal White Leghorns fed the low-protein developer consumed more feed per hen-day in the lay house, but feed per hen-day for dwarfs in the lay house was reduced by feeding the low-protein developer.

Feeding the low-protein developer instead of a control developer (13.6% protein) from 12 to 20 weeks of age resulted in significant reductions in body weights and feed consumption, but only slight delays in reaching 25 and 50% production. There were no differences in egg production, weight gain during lay, average egg weights, grams egg produced per hen-day, and mortality. The pullets fed the lower protein developer consumed slightly more feed per hen-day, per egg, and per gram of egg.

Restricting water every other day

Providing water every other day to dwarf and normal W. L. pullets after 8 weeks of age had no significant effect on body weights or flock age at 25 or 50% production. Feed intake was significantly reduced only in the 8 to 12-week-old normal Leghorns. Dwarf pullets subjected to this watering regime consumed significantly less feed per hen-day in the lay house; no reduction was observed in the lay house for normal W. L. pullets. This watering regime had no significant effect on hen-day egg production, although production was lower in both normal and dwarf pullets subjected to this treatment. No significant differences were observed in feed per egg or average egg weights, but lay house mortality tended to be higher for pullets watered every other day. Because this watering regime did not succeed in retarding growth or sexual maturity, it was not further investigated in Exp. 3, 4, and 5.

Providing water every third day

When this watering regime was begun at 8 weeks of age, body weights and feed intake were significantly reduced. Feed intake from 8 to 20 weeks of age was reduced by 9, 9, and 18% in Exp. 1, 2, and 4, respectively. Hen-day egg production for these water-restricted pullets was slightly lower in Exp. 1 and 2, but significantly higher than the controls in Exp. 4. In three of four comparisons, they consumed less feed to produce an egg than did the control pullets. In two comparisons using normal White Leghorns these pullets consumed more feed per hen-day while in two comparisons using dwarf W. L. pullets, they consumed less feed per hen-day than the controls. Normal White Leghorns watered every third day were delayed 4 and 10 days in reaching 25 and 50% production, respectively. Dwarf pullets were delayed 1 and 3 days, respectively. In three of four comparisons, these birds produced eggs of higher average weight than the controls.

When this watering regime was begun at 12 weeks of age, body weights and feed intake in the developing period were significantly reduced. Flock age at 25 and 50% production was increased 7 and 9 days, respectively. In comparison with the control group these pullets laid at a higher hen-day and hen-housed rate, laid heavier eggs, and produced more grams of egg per hen-day. They consumed more feed per hen-day, but required less feed to produce an egg or a gram of egg.

When this watering regime was initiated at 14 weeks of age, pullets consumed significantly less feed from 14 to 20 weeks of age and were significantly lighter than the controls at 19 weeks of age. They laid at a slightly higher rate than the controls both on a hen-housed and hen-day basis. Average egg weight and grams of egg produced per hen-day tended to be higher for the water-restricted pullets. These pullets tended to consume more feed per hen-day but required less feed per egg or per gram of egg.

Gradually declining lighting program

Pullets subjected to a gradually declining lighting program were heavier than the controls for the first 16 weeks of their lives, but controls were significantly heavier at 19 weeks of age. Their feed consumption pattern paralleled their growth curve. These pullets laid at the same rate as the controls on a hen-housed and hen-day basis. They produced significantly heavier eggs and more grams of egg per hen-day than the control pullets. They tended to consume slightly more feed per hen-day and per egg, but less feed per gram of egg.

DeKalb lighting program

Pullets subjected to this lighting program were heavier at 4, 8, and 12 weeks of age, but lighter than the controls at 19 or 20 weeks of age. They consumed more feed than the controls for the first 12 weeks of development and less feed during the period 12 to 20 weeks of age. Normal W. L. pullets were delayed 5 and 9 days in reaching 25 and 50% production, respectively, in one comparison and 14 and 11 days in the second comparison. This lighting program did not retard the sexual development of dwarf W. L. pullets. In four comparisons this lighting program resulted in an increase in average egg weights, and in three of four comparisons, these pullets laid at a higher rate than the control birds. Normal W. L. pullets reared with this lighting program consumed more feed per hen-day than the control groups; however the dwarfs consumed significantly less than the controls. There was no significant difference in feed per egg or per gram of egg.

Methods of Controlling Feed Intake in the Lay House

Two 2-hour water periods per day

When this watering regime was begun with hens that had been in lay for 5 months, a significant decrease in hen-day egg production was observed. This watering regime resulted in 13 and 93 g. reductions in feed intake per hen-day and lay house weight gains, respectively. No differences were observed in average egg weights, mortality, or feed consumed per egg or gram of egg.

Three 15-minute water periods per day

When this watering regime was initiated with hens that had been in lay for 5 months, a significant decline in hen-day egg production occurred. In this instance feed per hen-day and average weight gain during 5 months of lay were decreased by 13 and 94 g., respectively. No differences were observed in average egg weights or mortality. Intermittent watering increased the amount of feed necessary to produce an egg and a gram of egg; this was due to the sharp decline in hen-day egg production.

In a subsequent experiment where this watering regime was begun prior to the onset of lay, hen-day and hen-housed egg production were 3.11% higher than the controls. There were no differences in mass of egg produced per hen-day or mortality, but average egg weights were significantly lower for the intermittently-watered pullets. This watering regime also resulted in significantly fewer large eggs. Intermittent watering resulted in 5, 11, and 0.1 g. reductions in feed consumed per hen-day, per egg, and per gram of egg, respectively.

Fifteen minutes of water each hour

In both comparisons of this watering regime and a control group, intermittently-watered pullets laid at a higher hen-day rate. In one comparison intermittent watering resulted in a significant increase in average egg weights and significantly fewer medium eggs; in the second comparison, there were no significant differences in average egg weights or egg sizes. In both comparisons the intermittently-watered pullets laid a greater mass of egg per hen-day, consumed as much feed per hen-day as the controls, but required slightly less feed per gram of egg.

Five 15-minute water periods per day

In two comparisons of this watering regime with control groups, intermittently-watered pullets laid at a higher hen-day rate, produced a greater mass of egg per hen-day, and consumed less feed per hen-day, per egg, and per gram of egg. There were no differences in mortality, average egg weights, or egg sizes. In one of two comparisons, the intermittently-watered pullets gained less weight than the controls. In a 16-week preliminary study, dwarf W. L. pullets did not perform satisfactorily when subjected to this watering regime, while intermittent watering had no effect on the normal W. L. layers.

Two 2-hour feedings per day

In comparison with a control and two intermittently-watered groups this feeding regime resulted in lower hen-day egg production, less egg mass produced per hen-day, and higher mortality. Pullets fed two meals per day consumed less feed per hen-day, but required more feed per egg and per gram of egg. No differences were observed in average egg weights or egg sizes.

VI. PRACTICAL APPLICATION

In this research low-lysine and low-protein developer diets, four water restriction programs, and two lighting programs were investigated to select the best management program for retarding the sexual maturity of W. L. pullets grown during a period of increasing natural daylength. Based on the results of this research, feeding a developer diet containing 0.54% lysine and 0.92% arginine will not retard sexual maturity. It is difficult to formulate diets low in lysine. Protein supplements that are low in lysine, such as corn gluten meal, cottonseed meal, or sesame meal, must be substituted for soybean meal and other protein supplements which are relatively high in this amino acid.

Providing water to pullets every other day after they have reached 8 weeks of age will not delay sexual maturity. Pullets are able to consume more feed on the days water is available, thus enabling them to grow as rapidly and mature as early as pullets having water at all times.

Reducing the protein content of developer diets is one way the commercial poultryman can reduce the cost of rearing replacement pullets as well as retarding their sexual maturity. Based on the findings of this research, satisfactory results may be obtained when the protein content of the diet fed from 8 to 20 weeks of age is reduced from 14.73 to 10.36%. Pullets fed the lower protein level, however, are more susceptible to stress and cannibalism. Therefore, the poultryman should make every effort to reduce stress conditions and cannibalism.

Pullets should be precision debeaked at 1 week of age or debeaked by conventional methods prior to 8 weeks of age.

Reducing the protein content of the diet fed to 12 to 20-week-old pullets from 13.28 to 10.36% protein is not an effective method of retarding sexual maturity. However, pullets reared on the lower protein level will perform as well as those fed the higher protein level. Formulation and milling of low-protein diets is very simple in comparison to low-lysine diets and certainly less expensive than rations containing higher protein levels. The commercial poultryman can reduce costs considerably by lowering the protein content of his developer diets.

Restricting water availability to every third day when W. L. replacement pullets are 8, 12, or 14 weeks old will successfully retard sexual maturity. In addition, pullets subjected to this treatment will lay slightly larger eggs. Increased mortality, sometimes a problem with feed restriction programs, is not observed in this program. This program may be utilized in areas where ambient temperatures reach 26.7 to 32.2°C. (80 to 90°F.) without adverse effects being observed. Pullets subjected to this watering regime will lay as well as, if not better than, pullets having water at all times.

This watering regime is accomplished by means of solenoid valves and a 7-day time clock. These items are rather inexpensive in cost in relation to the potential increased value of eggs laid by the flock. Pullets subjected to water restriction lay fewer peewee eggs which have little economic value.

Many commercial egg producers are now using more sophisticated watering systems in the brooder house. This watering regime has not been attempted with cup systems. Additional research work needs to be done before this program can be recommended for use in cup watering systems.

This watering regime should not be used in combination with feeding a low-protein developer ration until such a program can be experimented with. A combination of the water and protein restriction may prove to be too severe a treatment for replacement pullets.

The effect of the gradually declining lighting program on sexual maturity in Exp. 4 could not be determined because all groups went out of production due to a nutritional deficiency just as the earlier maturing groups were reaching sexual maturity. However, this treatment does improve average egg weight.

The DeKalb lighting program, which features a sudden 5-hour decline in the daily light at 12 weeks of age, will successfully delay sexual maturity and increase average egg size. This program is easily accomplished in conventional-style brooder houses by means of time clocks. This lighting program does increase the amount of feed required to raise a pullet from 1 day of age to 25% production. The long daylength during the first 12 weeks (e. g. 20.5 hours) encourages greater consumption of feed. In addition, these birds are delayed in reaching sexual maturity; therefore, they need to be fed a longer period of time before production is initiated. This additional feed cost increases the cost per dozen eggs.

Providing water every third day will result in delayed maturity and increased egg size, but does not increase the feed requirement prior to sexual maturity. In this regard the water every third day regime is superior to the lighting program.

The next step in this research needs to be the use of a combination of treatments. A combination of the DeKalb lighting program and water every third day may retard sexual maturity and save feed as well. Further studies are also needed on the use of low-protein developer diets in order to precisely determine what protein and amino acid levels should be fed during each phase of the developing period.

In this research with W. L. layers four intermittent watering regimes and one limited-time feed program were compared with a control program which featured feed ad lib. and water available concurrent with the time lights were on. Based on these studies the intermittent watering regime which provides the layer with five 15-minute periods per day offers the most promise for greater profits to the commercial egg producer. When this program is initiated prior to the onset of lay, no adverse effects are observed. Pullets subjected to this watering regime lay at the same or higher hen-day rate as the controls. This program does not alter mortality, average egg weights, or egg sizes.

The five 15-minute watering periods program does offer some potential for greater layer profits. Pullets watered in this manner consume less feed per hen-day, per egg, and per gram of egg. In the current studies feed savings per egg and per gram of egg reached as high as 6.1 and 6.5%, respectively. If lay mash is selling for $120 per ton, then intermittent watering reduced the cost of producing a dozen eggs by as much as $.0143 in O. S. U. experiments. Other financial savings include the lower volume of water used because valves are open only 75 minutes each day. For the poultryman utilizing free-flow troughs, this watering regime will require only 6% of the water normally used if no restraint on water flow is employed. Not only is the water bill reduced, but there is less water runoff with which to contend.

Frequent cleaning of V-troughs is a necessary task when using a free flow watering system. Intermittent watering reduced the need for manual or mechanical cleaning. When the water is not flowing the hens will pick the feed and organic matter out of the troughs.

Providing as few as three 15-minute watering periods per day may also have merit for commercial use. When this watering regime is initiated just prior to sexual maturity of Babcock B-300 pullets, there is no reduction in egg production, and feed efficiency is improved. However, this regime does have a deleterious effect on egg size, particularily in the first 5 months of lay. This regime may be beneficial in controlling egg size later. Pullets watered in this manner do not lay an excessive number of extra large and jumbo eggs. In many commodity markets the higher feed cost of producing extra large and jumbo eggs is not returned because these sizes receive little or no premium above the price of large eggs.

A combination of five 15-minute periods for the first 5 months and three 15-minute watering periods for the remaining months of the lay cycle may be the best management program for controlling egg size. Studies of this program are being conducted at the O. S. U. Agricultural Experiment Station.

The studies conducted here utilized relatively short water troughs in comparison with those found in commercial housing. Therefore, the duration of each water period should be extended to insure that layers in the last cage in each row will receive an ample amount of water. Thirty-minute periods should allow ample time for water to flow to the end of the troughs.

The costs of time clocks and plumbing supplies for the intermittent watering program are relatively small in comparison with the potential savings in feed and water. Solenoid valves can be purchased for as little as $15.00 each. The appropriate time clocks for intermittent watering have multiple pins on the face of the clock. Each pin represents a 15-minute period. These pins are easy to set and the clocks can be purchased for approximately $30.00 each.

Many commercial egg producers are now using cup rather than trough waterers. Intermittent watering with a cup watering system has not been thoroughly investigated. When the water supply to a cup system is interrupted, it is sometimes difficult to fill the water lines again. Spillage from the cups and air bubbles in the lines may occur. Cup manufacturing companies should be investigating intermittent watering considering the potential it has for feed savings.

Based on the studies at this station, limiting the feeding time of W. L. pullets to two 2-hour periods results in reduced feed intake, but also results in reduced egg production, higher mortality, and poorer feed efficiency. Additional studies with this and other limited time feeding regimes are necessary prior to discussing the merits of these programs for commercial production.

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