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Effect of light and feeding management on sexual maturity and productivity of broiler breeder hens

Abbaker Ali Idris

To the Graduate Council:

I am submitting herewith a dissertation written by Abbaker Ali Idris entitled "Effect of light and feeding management on sexual maturity and productivity of broiler breeder hens." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Kelly R. Robbins, Major Professor

We have read this dissertation and recommend its acceptance:

J.P. Hitchcock, R.R. Shrode, M.O. Smith, S.D. Mundy

Accepted for the Council:

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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

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S. Darrell Mundy

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Vice Provost and Dean of the Graduate School

EFFECT OF LIGHT AND FEEDING MANAGEMENT ON SEXUAL MATURITY AND PRODUCTIVITY OF BROILER BREEDER HENS

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ABSTRACT

Six experiments were conducted utilizing broiler breeder females in both windowed and windowless houses to assess or determine: 1) the effect on sexual maturity and subsequent egg production produced by light intensity changes during photostimulation; 2) "black-out" versus natural daylength rearing programs; 3) effect on productivity of broiler breeder pullets caused by rearing and stimulating photoperiods; 4) effect on egg production resulting from light intensity changes and feed allowance during lay; 5) optimum age and body weight at sexual maturity in broiler breeders; and 6) daily ME requirement of the broiler breeder hen.

Traits measured included growth rate, average age and body weight at first egg, peak % hen-day production and age at peak production, rate of decline in % hen-day production, average number of eggs per hen, feed consumed through first egg or per dozen eggs, egg quality and mortality rate.

The results obtained indicated that light intensity changes during photostimulation or peak egg production did not affect any of the measured traits. However, birds maintained under high light intensity from hatching (HH) produced more eggs and achieved a significantly higher peak % egg production than birds housed under low light intensity. Rearing photoperiod on the other hand, significantly affect the age at sexual maturity and subsequent performance of the birds. Optimum age (172 d) or body weight (3.4 kg) at sexual maturity were determined from either feeding management or combination of light and feeding management.

Hens provided with 540 vs. 435 kcal ME/d commenced laying 14 days earlier with a significant improvement in growth and egg production rates. Neither livability nor egg quality was affected by treatment; however, feed efficiency was significantly depressed by the high energy level.

The results indicated also that birds responded significantly better to a higher amount of daily feed intake. Daily dietary energy of 425 kcal ME/bird with 0.0565

g/kcal ME protein:energy ratio was found to support performance adequately through 35 weeks of age but not thereafter, as shown by other diets of either similar protein:energy ratio but higher energy level (500 kcal ME) or lower protein:energy ratios (0.048-0.0533 g/kcal ME) but higher energy levels (450-500 kcal ME).

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INTRODUCTION

The effects of light environment and feeding practices on poultry management have generated much interest among researchers and poultry producers. There is circumstantial evidence that lighting and feeding patterns are two key environmental factors which induce and regulate domestic hen reproduction. The literature revealed that modification of various aspects of light (duration, intensity, color, wavelength and/or frequency of light-dark cycles) and feeding management (*ad libitum* vs. restricted) could affect sexual maturity, rate of lay, egg quality and feed efficiency of poultry.

The results of lighting recommendations for commercial layers were reviewed and summarized by Ernst et al. (1987). They concluded: 1) step-down lighting programs during rearing can significantly delay onset of sexual maturity; 2) decreases in daylength at any age before photostimulation will delay sexual maturity; 3) red light should not be used for developing pullets because it sometimes results in reduced performance during the laying cycle; 4) later onset of sexual maturity results in larger egg size and may result in production of fewer eggs in the subsequent laying cycle; 5) younger birds are slower to mature sexually than are older birds when they are exposed to stimulatory photoperiods; 6) earlier sexual maturity results when larger increases in daylength are given to photosensitive pullets; 7) step-up lighting programs from 6L:18D can be used during the laying phase to shift the production curve to the right (lower peak; greater egg size); 8) step-up lighting programs can be used during the first half of the laying cycle to reduce energy use; 9) intermittent light (15 min L: 45 min D during the light phase) can save electricity and improve feed conversion, but the program is not recommended between the start of a stimulatory photoschedule and 36 weeks of age because reduced egg production will result; 10) in light-controlled housing, interrupted lighting programs (i.e., 8L:10D:1/2L:51/2D) can save electricity during the laying cycle; 11) in open housing, one-hour light phases can be used to define subjective dawn and dusk with a resultant saving in electricity; 12) and ahemeral lighting programs (28 hr photoperiods) at the end of the laying cycle can be used to improve shell quality without reduction of egg numbers.

From a practical point of view, turkey breeders are customarily reared on a short daylength (8 hr to circumvent or dissipate juvenile photorefactoriness) until 30 weeks of age then transferred to 14 hours of light. Similarly, commercial leghorn layers are known to be positively responsive to weekly increments of 15 minutes photolength. As far as broiler breeders are concerned, there are still relatively little data published on what are the most appropriate photoperiod programs to be adopted during rearing and/or breeding phases for optimum performance; and, most of the attempts made to evaluate the influence of light intensity, if not all, failed to establish any effective practical role in curbing or boosting one of the measured reproduction-production parameters.

The concept of restricted quantitative (various levels of feed supply) or qualitative (altered calorie-protein ratios or limited specific essential amino acids) feeding programs is another area which has received considerable attention. In fact, poultry producers commonly regarded as an effective tool for maintaining fecundity and offsetting the negative correlation between body size, productivity and livability of heavy breeds. On the other hand, the role and importance of maternal feed supply which is not just a question merely of quantity of food required but food quality also merits further research on daily nutrient allowances for broiler breeders during the pullet-layer transition and during lay. Thus, even though much has been written about the effects of lighting and feeding regimes in developing broiler breeders, the results obtained are still inconsistent within and among studies, and there is much to be learned or re-evaluated with respect to the immense advances in genetics and natural environmental phenomena such as "cloudy syndrome", humidity and suspended dust.

The objective of these experiments reported here was to evaluate the effects of different lighting and management practices on productivity of broiler breeder females.

Six experiments were conducted using female broiler breeder chicks to determine the following:

1) effect of light intensity changes during photostimulation on subsequent egg production; 2) effect on sexual maturity and egg production of an 8L:16D "black-out" rearing program versus natural daylength rearing programs; 3) effect on productivity of broiler breeder pullets caused by rearing and stimulating photoperiods; 4) effect of light intensity changes and feed allowance during lay on egg production; 5) optimum age and body weight at sexual maturity in broiler breeders; and 6) the daily metabolizable energy (ME) requirement of broiler breeder hens.

PART I

LITERATURE REVIEW

EFFECT OF LIGHT AND FEEDING MANAGEMENT ON SEXUAL MATURITY AND PRODUCTIVITY OF BROILER BREEDER HENS

Reproductive physiologists have contributed enormously and in several ways to enhancing the management of poultry under intensive farming, particularly in relation to lighting and feeding patterns. The greatest impetus for the discovery of the beneficial effects of artificial lighting on egg production has come from the natural observations that egg production falls before the autumn equinox but increases to the seasonal maximum in early spring before daylength increases to 12 hours. This seasonality in egg production, as well as the rate of egg production within a season, suggests that the domestic hen is essentially a photoperiodic species. Morris (1962 and 1967) and Harrison et al. (1969) observed that when domestic hens were reared on short days, the onset of lay was advanced after transfer to long days. Other experimental studies (Morris and Fox, 1958; Bowman et al., 1964) established that exposure to long days during the first weeks after hatching exerts a major delaying effect on sexual maturity, irrespective of the subsequent lighting pattern. Sharp (1981) found that when laying hens were held on short photoperiods and transferred to long days, plasma concentrations of LH increased. However, when the procedure was reversed, the LH concentrations decreased. In 1984, Sharp studied seasonal breeding and sexual maturation of domestic hens and reported that sexual maturity was delayed in hens reared on long days because of the development of juvenile photorefractoriness. He concluded that the responses of the domestic hen reproductive system to a given daylength are not only the function of that daylength but also of previous photoperiodic history. Van Tienhoven and Planck (1973) found that seasonal breeders have a changing sensitivity to light during the year and thus do not respond to photostimulation in the same way at all times of the year. The reduction in photosensitivity is presumably due to development of photorefractoriness which is one of nature's ways to enable breeders to anticipate and react to the forthcoming breeding season in order to insure protection and survival of offspring.

The possible mechanisms of photoperiodic induction have been the subject of many studies. Theoretical considerations as well as much experimental data indicate that daylight acts as a prophetic agent, merely allowing birds to prophase reliably when favorable conditions are on way. The ancient dispute that the effects of increasing daylength on gonadotrophin release are indirect and depend directly on promoting food consumption and the consequent accumulation of energy reserves in the muscle can be refuted by findings of Follett et al. (1977) and Wingfield (1980). The justification of the former group was based on an observation that gonadotrophin secretion in quail increases steeply within the first day of exposure to long days which cannot logically be mediated by change in food intake. Phillips et al. (1985) reported in an extensive review that changes in daylength appear to regulate the release of gonadotrophins by acting directly on the brain to cause the hypothalamic drive to wax or wane. Similarly, North and Bell (1990) stated that the light stimulus will be initiated when light falls in the eye of the chicken and causes the release of LH and FSH hormones from the pituitary which in turn cause increased growth of the ova. Urbanski and Follett (1982) used castrated Japanese quail as a model to demonstrate the stimulatory effect of daylength on gonadotrophin secretion while at the same time preventing any modification in the response by the inhibitory feedback actions of gonadal steroids. Japanese quail were reared from hatch on short (8 hr) or long days (23 hr). When they were full grown but sexually immature they were castrated and transferred to a wide range of fixed daylengths (8, 10, 11, 12, 13, 14, 15, 16, 20 and 23 hr). The workers found that daylengths of about 11 hr or more stimulated LH release; shorter daylengths had no stimulatory effect; and a 13-hour day was stimulatory in birds previously exposed to 8 hr but inhibitory in birds grown under 23 hr. They termed the minimum daylength required to stimulate LH secretion as "critical daylength"; the range in which there was a direct relationship between photoperiod and the concentration of plasma LH was named "marginal daylength"; and the daylength that triggered the maximum release of LH was denoted as "saturated daylength". Photoperiods beyond the saturated daylength were found to be equally stimulatory. For instance, Morris (1962) demonstrated that an increase in daylength from 6 to 14 hr advanced sexual maturity, but an increase from 14 to 22 hr did not. Likewise, Morris et al. (1964) illustrated that increases or decreases in daylength between 14 and 22 hr have minor effects on the rate of lay, whereas, a reduction in light hours from 14 to 6 drastically reduces the rate of production. Regardless of the preceding findings which are mostly results from studies with egg-type chickens, Lofts and Murton (1968) emphasized that critical daylength might show both intra- and inter-specific differences which have not yet been precisely defined in domestic hens; consequently, further studies are required.

There are very few reports of interactions between the effects of light and of feed management as they alter the reproductive performance of birds. The potential of both factors when they are restricted during the growing periods of broiler breeders to delay sexual maturity is expected to be synergistic or additive if the two factors are combined in a trial or antagonistic when they oppose each other. Most studies conducted thus far indicate that this is not the case. Wingfield (1980) studied the effect of chronic food restriction on concentrations of LH during photostimulation in white-crowned sparrows. He explained that gonadal activity cannot be supported when feed is severely limited; at the same time, short periods of food control do not block photostimulation. Sharp and Moss (1981) found that the number and quality of eggs laid by red grouse were reduced by feeding a poor diet but that the date of the first egg under a natural lighting system was not affected. North and Bell (1990) reported that both light and feed restriction during the growing period of broiler breeders delayed sexual maturity. The maximum time of delay for each factor was about three weeks. When both factors were administered simultaneously, the maximum delay did not exceed four weeks. They concluded that the effect of concurrent application of light and feed restriction was not cumulative.

The concept of light "threshold" was reported by North and Bell (1990). They recommended that to develop any satisfactory growing program, light intensity during the growing period should be maintained at 5 lux and daylength at 11 to 12 hours. Conversely, Morris et al. (1964) concluded that there is no "threshold" daylength above which pullets can necessarily be expected to give maximum egg production. They assumed that maximum annual egg yield incorporates the principles of increasing daylengths and does not rely on any estimate of "the optimum daylength" for egg production.

The emphasis in this review to this point has been on the physiological and theoretical perceptions of light and feeding management. It is worth considering the reproductive and biological responses within the practical limits of light intensity, daily light period and the pattern of feed change that are associated with sexual maturity, egg production and subsequent performance of broiler breeders.

Role of Light Intensity in Broiler Breeder Production

Regarding the managerial impact of light intensity on poultry production, there is evidence that, besides its effect on feed consumption and energy expenditure, higher levels of illumination intensity can alter the behavior of the birds and provoke increased mortality from picking feathers or cannibalism. Most recently, North and Bell (1990) reported that illumination greater than 5 lux would induce cannibalistic characteristics and keep the birds nervous. Morris (1967a) stated that light intensity affected cannibalism and costs as well as yields and working conditions. Bressler and Maw (1966) showed that greater mortality, mainly due to connibalism, occurred in a house with windows than in a windowless house. In contrast to these reports, the findings of Skoglund (1958) revealed no mortality as a result of cannibalism among broilers subjected to light intensities up to 1200 lux. Moreover, Newberry et al. (1986) used light intensities as high as 30 lux in one experiment and 100 lux in another to investigate their effects on body weight, incidence of leg disorders, total mortality and mortality from sudden-death syndrome of roaster chickens. These workers found that none of the measured parameters was significantly affected by light intensity. They concluded that light intensity equal to or less than one lux had performance results equal to or superior to those obtained with lighting equal to or greater than 10 lux. Skoglund (1962) and Morris (1967b) also determined that as light intensity decreased below 100 lux, there would be an improvement in growth performance. Siopes et al. (1989) demonstrated that variations in light intensity ranging from 10.8 to 108 lux had no significant effect on growth of turkeys.

The impact of light intensity on growing and laying pullets was summarized by Morris (1967a). In (1966a) he illustrated that chick growth was slightly but consistently improved as the intensity of light declined from about 1200 lux to one or less. In another experiment (1966b) he showed that pullets raised under very dim lights and transferred to laying houses with the same light intensity were 12 days later maturing than were birds reared and held under more nearly normal lighting of 5 lux. Regardless of these findings, he concluded in his summary that light intensity was not as important for growing pullets as for laying ones because of its minor effects on growth and sexual maturity. Skoglund et al. (1975) compared a series of light intensities and recorded highest egg production under a light intensity of 5.38 lux. These results confirmed to some extent the observation of Morris (1967a) who noticed that birds responded positively to the increased light intensity up to a level of 5.38 lux, with little or no response to higher intensities.

There is little experimental information about the effect of light intensity on development of broiler breeder pullets and on egg production. Baughman and Brake (1987) found that low light intensity (10 lux) for broiler breeders in a "black-out" pullet house with birth housed in August at the age of 20 weeks resulted in 12-14 more eggs per hen than in birds raised under 100 lux. Contrary to this, when the same lighting programs were applied to broiler pullets housed in the spring (March), the workers did not observe any effect on egg production. They concluded that broiler breeders respond to natural daylight in preference to artificially lengthened days during lay. Brake (1987) on another occasion, emphasized that the use of artificial low intensity light during the growing period resulted in 12-14 more eggs per bird with a slightly lower egg specific gravity and shell weight. He concluded that preconditioning pullets with a light intensity lower than those expected in the breeder house appears to be valid. More evidence was later submitted by Brake and Baughman (1989). They showed that broiler breeders, when grown in incandescent light (8 hours of 20 lux) and exposed to autumn conditions (16 hours of 20-80 lux) during early lay had higher % hen-day production (51 vs. 47) and produced more eggs during 64 weeks (141 vs. 129) than did those grown under daylight (8 hours of 800 lux) even though both groups experienced the same photoperiods during both phases. However, when the same procedure was adopted for birds who became sexually mature during early spring, the results were opposite which was attributed to the reduction in light intensity from as much as 800 lux during the growing period to as little as 20 lux during lay.

Thus, it was suggested that the use of low intensity (20 lux) incandescent light during rearing increases the sensitivity of broiler breeders to fall and winter laying environments. These findings are in agreement with work of Morris and Owen (1966) who reported a decreased rate of lay in commercial layers grown at 50 lux and transferred to less than 16 lux during lay. Similarly, Robbins et al. (1988) coincidentally observed a sharp decline in the laying rate of broiler breeders during cloudy days of a fall season. They were able to offset the phenomenon and restimulate production by artificial elevation of the light intensity. This incident suggests that the adverse effects of the so called "cloudy syndrome" may be related to light intensity.

Some results contradictory to the preceding findings were reported by Morris (1967b). He contended that the minimum light intensity during lay cannot be influenced by growing house light intensity as long as a mixture of natural and artificial lighting was used during lay. The results of Proudfoot et al. (1984) also indicated that increased light intensity during the growing period had no significant effect on broiler breeder performance. Merat and Bordas (1989) compared light intensities of 10 and 400 lux on hens of different genotypes and found that neither body weight, sexual maturity, egg weight, the number of abnormal and cracked eggs, efficiency of feed utilization nor mortality was affected by light intensity.

Role of Photoperiodism in Broiler Breeder Production

In order to delineate and characterize the influential effects of changing photoperiod during the life cycle of broiler breeders, photoperiodism may be categorized under the following programs or subheadings:

Impact of constant daylength on broiler pullets

Payne (1975) reported that a 15-hour rearing photoperiod resulted in delayed maturity, increased mature body weight, and decreased egg numbers and incidence of smaller eggs, when compared to a 6-hour photoperiod. Moreover, he found that continuous lighting to 56 days and 15 hours daily thereafter resulted in a satisfactory egg production despite its association with a high incidence of subsequent blindness. These findings are in agreement with the result of Proudfoot (1980) who studied the effects of several lighting programs and concluded that a constant 12.5 hours versus 8 hours rearing daylength significantly delayed sexual maturity and reduced egg production.

Andrews et al. (1987) found no significant difference in hen-house production, feed per dozen eggs, hatch of fertile eggs and hatch of all eggs when comparing broiler pullets reared in a dark-house environment to 20 weeks of age compared to pullets reared under natural daylength. The only significant differences recorded were with respect to mortality and egg weight. Pullets under natural daylength had the heaviest egg weights and the lowest death rate.

Rearing under step-up or step-down photoperiods

Payne (1975) demonstrated that an abrupt reduction in daylength from 15 to 6 hours for the period 112 to 167 days of posthatching resulted in unsatisfactory subsequent performance, especially when the daylength was slowly elevated to 16 hours during the breeding period. He concluded that for maximization of egg yield, age at sexual maturity should be regulated in meat-type pullets by providing short photoperiods during rearing and by increasing the daylength after 18 weeks of age. Timmons et al. (1983) exposed broiler breeder pullets to a short daylength of 8 hr/d immediately prior to photostimulating the birds into egg production. After 8 weeks of short days the photoperiod was increased abruptly to 15 hr/d and then 1 hr more after a week to keep the birds under 16 hr of light throughout the laying period. In two experiments the workers observed that egg laying was consistently started 3-4 days after photostimulation causing them to comment that a darkout system can result in an earlier onset of egg production and more eggs per hen with less feed consumption than in hens accommodated under a conventional system. The results of Wilson et al.(1989) revealed that broiler breeder pullets, subjected to a restricted feeding plan at the age of 2 wks and reared under natural daylengths to the age of 20 wk and thereafter to 17 hr light, reached sexual maturity at ages of 204 days if reared during the summer and 218 days if reared during the winter. Birds treated similarly except started on a restricted feeding plan at 8 wk of age, matured at 215 and 255 days, respectively, in the winter and summer rearing photoperiods. Renden and Oates (1989) determined the age of 178 d and body weight of 2.8 kg at sexual maturity in broiler breeder pullets reared under 8 hr photoperiod to 17 weeks of age then 9 hr to 20 weeks and finally 15 hr to the end of the experiment. Proudfoot et al. (1980) studied the effect of increasing photoperiod on broiler breeders from 8 to 12 hr at 16 and 20 weeks of age. They determined that delayed photostimulation significantly reduced the number of double-yolked eggs and retarded sexual maturity, particularly in a dwarf genotype. They observed also an increase in egg weight (0.5 g) in the late maturing group. Some of these findings were reported again by the same team (1985) substantiating the belief that delaying the increase in photoperiod change (142 vs. 154 days of age) would suppress sexual maturity and increase egg weight and specific gravity. Brake et al. (1989) compared a decreasing natural daylength with constant incandescent light during rearing of broiler breeders. They projected that short photoperiods (8 or 9 hr) provided by increased light produced significantly higher fertility (95 vs. 90) and hatchability (93 vs. 91) percentages, and significantly lowered egg specific gravity (1.0823 vs. 1.0830) and egg weight (65 vs. 66 g). The advantage of incandescent light versus natural daylength in improving fertility rate was reported also by Brake (1989) who researched the impact of lengthening a short 8 hr rearing photoperiod by 6 hr light or as a sum of two (2+4) increases on photosensitive 20 wk old broiler breeder pullets, preconditioned under 8 hr/d of natural or artificial light.

Proudfoot (1979) compared the impact of a constant 14 hr daylength, a gradual step down and subsequent step-up of 17- to 9- to 14-hr daylength at ages 1,20 and 30 weeks, and a modified natural daylength of 12:40 to 15 to 13 to 15 hr at ages of 1,7,19 and 28 weeks. He stated that performance of birds on the 17 to 9 to 14 hr light pattern was equal or superior to that of birds under either the constant 14 hr daylength or increasing rearing photoperiod. Siopes (1989) inspected the relationships among duration of short daylengths (4,8 or 10 hr) during prelay light control, the length of time (6, 8 or 12 wk) that turkey hens were exposed to during light restriction and the subsequent photoinduced reproductive performance. He found that light restrictions of 4, 8 or 10 hr/d were equally effective in preconditioning hens.

In contrast to the preceding findings, Whitehead et al. (1987) studied two lighting regimes for broiler breeders. The first one entailed weekly increments of 0.5 hr light per day up to a maximum of 18 hr at 38 weeks of age. In the second one the daylength was increased 1 hr per day from 19 to 26 weeks and then 0.5 hr/d onwards to give a total of a 17-hr photoperiod at 30 weeks of age. The researchers found no influence on performance as a result of the two patterns. The results of this study indicate that broiler breeders either do not or do equally respond to gradual increases of light irrespective of the dose.

Grow et al. (1986) stated that the effect of genetic selection on plasma LH concentrations is a function of the lighting condition to which the hens are exposed. Grow et al. (1987) reported that light conditions had no effect on plasma concentrations of LH before and at the pre-ovulatory LH peak in first, mid-sequence or terminal ovulatory cycles.

Effect of ahemeral and intermittent or biomittent photoperiod systems

Phillips et al. (1985) reported as advantages increased egg size, improved shell quality and decreased feed and electrical costs as benefits, whereas reduced number of eggs and inconvenient working conditions are disadvantages of various lighting patterns (ahemeral, intermittent and biomittent) used to manipulate egg production and quality. Proudfoot (1980) reported that although an ahemeral light treatment (14 L : 13 D) had a depressing effect on egg production and feed efficiency in comparison to the conventional 24-hr day cycle (14 L : 10 D), it did result in increased egg size and improved shell strength. Similarly, Leeson and Clunies (1987) recommended the adoption of the ahemeral system of 28 hr.(14 L : 14 D) for older birds because they found that the system increased egg size (6% more yolk and 3% more albumin), enhanced shell quality by 7% and did not decrease the total number of eggs as it did when applied to young, active birds.

Siopes et al. (1986) contrasted intermittent with continuous lighting regimes and found that body weight of white tom turkeys was significantly greater under the former regime, whereas, feed conversion, mortality and leg disorders were not affected by either of the lighting schedules. Proudfoot (1980) found that a 24-hr intermittent-light program (10L:9D:2L:3D) promoted performance which was equal to or better than the 27-hr ahemeral day cycles. The 27 hr regime tended to depress fertility. Most recently Nickolas and Nam (1989) made an attempt to utilize a temporary ahemeral lighting program to increase the size of initial eggs in maturing pullets. They found that egg weight is permanently increased by this system in comparison with the conventional, 24-hemeral lighting. The system reduced % hen-day production in the short run, but in the long-term this negative effect was abolished.

Role of Feeding Management in Broiler Breeder Production

Theoretically, the nutritional objective of restricting feed or caloric intake is to develop pullets that are smaller and older at first egg. The older the birds are, supposedly the larger the egg size. In a review of published studies, there was general agreement among researchers and reviewers (Proudfoot and Lamoureux, 1973; Proudfoot, 1979; McDaniel et al., 1981; North and Bell, 1990) that the restriction of feed of broiler breeders during the rearing period modifies the response of the birds in various aspects and resulted in reduced body weight, delayed onset of lay, increased initial egg size, enhanced egg production and improved fertility, hatchability and livability of broiler chicks. In addition to the reproductive responses, the administration of restricted feeding was found also to alter the birds anatomically (relative weights and lengths of the digestive organs and skeletal muscles, Katanbaf et al., 1988), physiologically through modulation of blood metabolites (plasma glucose, liver lipids, xanthophyll levels and surface and cloacal temperatures, Katanbaf et al., 1989a), and activities of digestive enzymes (Nir et al., 1987).

Restricted feeding programs are routine in broiler breeder production. However, due to the diversity of issues such as age at which restriction should be commenced or terminated, the degree and length of feed restriction which affect age at onset of sexual maturity and subsequent egg production, and other environmental and genetic factors, there is less consensus among published reports.

With reference to the current broiler breeder's management guides, recommended feed restrictions vary with age from severe to moderate, ranges of 29-32 wk, 82-85%, 78-89%, 93-104 and 167-183 for age at peak egg production, peak hen-day egg production, hatchability, number of eggs per 45-week-old hen and number of eggs per 64-week-old hen. Furthermore, the guides indicate that 5- to 10-% hen-day egg production should occur at 24 to 25 weeks of age. It has been recommended (anonymous, 1985-86) that commencement of egg production at ages of 24 to 25 weeks will help to minimize the number of small eggs and will eventually increase the number of settable eggs per broiler breeder hen.

Waldroup and Hazen (1976) reported that a gradual increase, similar to breeder company recommendations, in the amount of feed offered gave highest egg production. In a more recent study, Katanbaf et al. (1989b) concluded that controlling feed intake during rearing and laying periods enhances reproductive potential and subsequently leads to a larger total number of chicks produced per hen. Thomas et al. (1989) contended that severe feed restriction (24% below the standard or recommended) during the rearing period of broiler breeders significantly delayed sexual maturity and reduced the % hen-day production but not the total number of settable eggs, egg weight, fertility, hatchability, shell quality or livability of birds during 65 weeks of production. The advantages of restriction over *ad libitum* feeding were addressed also by Pearson and Herron (1981) and McDaniel et al. (1981).

Bornstein and Lev (1982) indicated that best performance in broiler breeders can be obtained with a high-energy allowance beginning 2 to 3 weeks prior to the start of egg production. Similarly, Pym and Dillon (1974) stated that severe restriction during rearing followed by *ad libitum* feeding during lay may be the best feeding program for broilers. Their results showed that *ad libitum* feeding during lay yielded more eggs per hen (168 vs. 144) than did modest restriction during lay. The findings of Wilson and Harms (1986) were similar. They reported that an average daily intake of 500 kcal ME/bird during lay resulted in significantly better performance than a "standard" feeding program of 400 kcal ME/d. The results of Robbins et al. (1986) revealed that feed restriction during rearing followed by *ad libitum* feeding during lay is superior in terms of higher % peak production (71 vs.

59), feed efficiency and more eggs per hen (159 vs. 106) to 68 weeks of age when compared to the *ad libitum* feeding throughout the experimental period. Whitehead et al. (1987) reported that egg production of broiler breeders fed *ad libitum* during the breeding period increased with the degree of food restriction during rearing. The superiority of *ad libitum* feeding during lay was again reported by Robbins et al. (1988). The most interesting treatments in this study involved birds fed *ad libitum* during lay and others restricted-fed in accord with the breeder's management guide. The measured traits depicted that the *ad libitum*-fed group reached sexual maturity at an earlier age (202 vs. 215 d) and at higher % peak egg production (87 vs. 71) and total number of eggs per hen (158 vs. 125). With reference to their results and others (Pym and Dillon, 1974; Bornstein et al., 1984; and Wilson and Harms, 1986). The workers concluded that when broiler breeders were reared under a restricted feeding regime, they reached sexual maturity at approximately 3400g body weight and required 500 kcal ME/d/bird for maximum production.

In contradiction to the preceding theme, McDaniel et al. (1981) stressed that pullets may become overweight on an *ad libitum* feeding program during lay which would cause a reduction in egg production, fertility and hatchability. Katanbaf et al. (1989b) studied the effect of four feeding regimes on performance of broiler breeder pullets. They reported that for most of the variables measured, differences among the restricted-feeding regimes were minor, whereas, considerable differences were noticed between them and the *ad libitum* regime. Birds on the latter program reached sexual maturity at age of 144 d, 60 days earlier, with body weight 4100g, 1200g greater than that of the restricted birds. In terms of productivity, however, % hen-day production, normal egg production and duration of fertility were all less while incidence of defective eggs was greater in the *ad libitum* group than in the restricted birds. Robinson et al. (1989a) compared the impact of full versus restricted feeding on Indian River Broiler Breeder pullets and found that the restricted hens had significantly more laying days (177 vs. 136), a greater number of 4 or 5 clutches, lower body weight (-700g) and smaller number of pause days (58 vs. 75). Likewise, in another study, Robinson et al. (1989b) studied the same breed and on the basis of their 21-wk body weight. The birds were divided into three groups, lighter, medium, and heavier which were then equally fed to 62 wk of age. The ages and body weights at sexual maturity in the groups were found to be (199, 186 and 184 d) and (3360, 3586 and 4132 g) respectively. The performance of the medium birds was the best, followed by the heavier group.

The poorest feeding practice was reported by Bornstein and Lev (1982). They attributed the worst performance obtained to slow gradual increases in feeding level in relation to rising average flock production.

Another controversial area in feeding management is its role in timing the onset of lay. Katanbaf et al. (1989b) emphasized that age at sexual maturity is a function of *ad libitum* feeding whereas the minimum body weight and composition at onset of lay are functions of restricted feeding.

Brody et al. (1980) stated that a minimum age is a prerequisite factor for initiation of sexual maturity. Their hypothesis was in agreement with the findings of Bornstein et al. (1984) who illustrated further that beyond the minimum threshold age the onset of lay is body weight- and/or fat pool-dependent. They reported an age of 24 to 25 weeks as minimum for *ad libitum*-fed birds to become sexually mature, whereas, the limits for those under conventional food restriction were 3.3 to 3.7 kg body weight and 203 to 250 days age. Brody et al. (1984) demonstrated difference between lines in meeting a body weight or a body composition requirement, or both, for the onset of sexual maturity. The results of Bartov et al. (1988) also indicated that there exists a minimum threshold body weight requirement for broiler breeders to start laying. They suggested a range of 2.3 to 2.7 kg body weight and an age of 20.5 wk as minima for birds first to become somatically mature and, hence, capable of the ensuing reproduction. Soller et al. (1984) on the other hand, endorsed the concept of minimum lean body mass as a chief factor controlling onset of lay. On the contrary, Renden and Oates (1989) refuted the notion of a threshold body weight or composition for puberty determination and most recently Renden et al. (1990) confirmed the denial of threshold body weight, composition or both to determine sexual maturity.

Egg characteristics and their relation to the feeding management is another important area. A recent study by Hurwitz and Plavnik (1989) indicated that egg weight is a function of both age and body weight at onset of production. The results of Katanbaf et al. (1989b), however, indicate that although *ad libitum*-fed birds reached sexual maturity at a heavier body weight (4.6 vs. 3.3 kg), they produced smaller eggs (37 vs. 46 g) when they started laying in comparison to the restricted group. The apparent discrepancy between these results and the preceding concept (egg weight is a function of body weight and age at first egg) may indicate two things: a negative correlation between body and egg weights at first egg or that the effect of age overrides the role of body weight. The results of Wilson and Harms (1986) support the first possibility. They found that while egg specific gravity decreased significantly, egg weight increased proportionally with increased body weight or energy intake . The results of Pym and Dillon (1974) and Robbins et al. (1988) on the other hand, conform to the second possibility. The view of the latter group indicated significant positive correlation of egg weight and specific gravity with age. Other reports noted that the major disadvantage of *ad libitum* feeding to achieve minimum age at sexual maturity is the sacrifice (trade off) of egg size (Bornstein et al., 1984; North and Bell, 1990). Scott et al. (1982) enumerated many factors, including genetics, stage of sexual maturity, age, some drugs and some dietary nutrients as determinants of egg size.

Metabolizable Energy Allowance forBroiler Breeder Hens

Although most of the basic nutritional requirements of chicks and laying hens are well established, information available on broiler breeder ME allowance during lay is still lacking. For example, Waldroup and Hazen (1976) recommended maximum daily requirements of 422 kcal ME, 418 mg lysine and 380 mg methionine per bird for normal-sized broiler breeders. Bornstein and Lev (1982) obtained the best performance when birds were provided with a daily ME intake of 440 kcal/bird, beginning 2 to 3 weeks prior to onset of lay. Wilson and Harms (1984) concluded that the typical nutritional recommendations of broiler breeders during lay were excessive and thus wasteful. They proposed daily nutrient specifications of 20.6 g protein, 754 mg sulfur amino acids, 400 mg methionine, 938 mg lysine, 1379 mg arginine, 256 mg tryptophan, 4.07 g calcium, 683 mg total phosphorus and 170 mg sodium. Later the same workers (Wilson and Harms,

1986) and most recently, Robbins et al. (1988) specified that a ME intake of 500 kcal/d/bird for broiler breeders during lay resulted in higher production than did the conventional feeding regimes of 400-449 kcal ME/d. Spratt and Leeson (1987) conducted an experiment for 41 weeks and concluded that 19 g protein and 385 kcal ME/d/bird are sufficient for maintaining normal performance through peak production of broiler breeders.

In terms of protein : energy ratio, Pearson and Herron (1981) concluded that if the protein : energy ratio is increased above 0.0628 g/kcal ME, hatchability will be reduced. In another study (Wilson and Hazen, 1982) they reported that a level of 0.0745 g/kcal ME from 26 to 36 weeks of age increased embryonic death, and a level of 0.0837 g/kcal ME depressed egg production. Their results indicate that as the protein-to-energy ratio increases, hatchability and egg production will be reduced in respective order.

The wide variations in ME recommendations for broiler breeders during lay (385-500 kcal/d/bird) could possibly be due to the marked tendency and capability of broiler breeders of consuming feed far in excess of their energy requirements for maintenance and egg production or can be justified on the basis of discrepancies in genetic and environmental factors.

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PART II

EFFECTS OF LIGHT ON BROILER BREEDER DEVELOPMENT

INTRODUCTION

To most biologists light means "visible light" of 4000-7700 Å wavelength. This is probably because of the minor physiological effects of invisible light (wavelength < 4000 or > 7700 Å). The biological effects of light phenomenon consist of three major facets: 1) action due to quality of light (wavelength or color); 2) the intensity (actual energy measured in gram-calories or foot-candles); 3) the duration (length of daylight). With respect to the type of action, light has four direct effects upon mammals: first, it harms or stimulates all exposed or weakly protected cells; second, it stimulates photoreceptors; third, it governs 24-hours (circadian) rhythms; and fourth, it is responsible for photoperiodism (Edgar, 1966).

Most of the experimental work has focused on the latter effect (photoperiodism). A biological phenomenon demonstrates photoperiodicity if it changes systematically with intensity of illumination or either an increase or a decrease in the daily duration of light. The periodic effects on avian species include: 1) the inducing of reproductive conditions; 2) migration; and 3) seasonal changes in feathers. Although many researchers have been concerned with the effect of light on reproduction only, relatively, few favorable outcomes have been achieved.

The objective of the studies presented herein was to take functional measurements of two of the three facets of light effects that might be incorporated into management of commercial broiler breeders. Studies chosen to perform were: 1) effect of changes in light intensity during photostimulation on subsequent egg production; 2) effect of an 8L:16D "black-out" rearing program as compared to those of natural daylength rearing programs on sexual maturity and egg production; and 3) effect of rearing and stimulating photoperiods on productivity of broiler breeder pullets.

MATERIALS AND METHODS

Stock, General Management and Experiment Design

During a three-year study (1987-1990), six experiments using March-hatched commercial broiler breeders were conducted. This section describes only three of the six. The other three will be described in the next part. Breeds employed in these experiments included Shaver Color-Pac (exp. 1), Indian River (exp. 2) and Hubbard (exp. 3).

The three experiments were begun at hatching and ended when the experimental birds were 45 weeks of age. Each experiment was conducted in light-proof floor pens with three replicate pens of 30 birds each. Treatments were designed to evaluate the impacts of various lighting programs on performance of broiler breeder pullets with particular emphasis on body weight and age at sexual maturity and subsequent performance. Feed allocations during the growing period were based on mean pen body weight using restricted every-other-day schedules specified by the primary breeders for in-season flocks. Restricted feeding was imposed through 23 weeks of age of birds in experiments 1 and 2, 17 weeks of age in experiment 3; thereafter, birds were fed ca. 178 g feed/bird/d (500 kcal ME).

Birds in all experiments were vaccinated against Newcastle-Bronchitis when they were 7 days, 5 wk and 18 wk of age. Fowl pox and Avian encephalomyelitis vaccines were administered at ages 12 and 16 weeks, respectively. Access of birds to water was unlimited in all experiments. Trapnests in both the light-proof darkrooms and the conventional-type broiler house were installed when the birds were 16 weeks of age and kept closed, thus allowing birds access to the nest perches. The operation of the trapnests began 1 to 2 weeks prior to onset of lay.

Data collected in all experiments included individual body weight and egg production, feed intake, mortality and egg quality measures (experiment 3) from which the following data were determined; age, body weight and feed consumption at first egg; body weight changes from 21 wk of age to first egg or from first egg to the end of the experiments; total egg production (total eggs per hen; % peak hen-day production; % hen-day production; age at peak production; and rate of decline in % hen-day production from age at peak production to 45 weeks of age); egg weight; egg specific gravity; and fertility.

Percentage hen-day production was calculated for each day of the laying period. Peak production was estimated as the average of the 5 consecutive days of highest % of hen-day production. For egg quality measures, eggs were collected for three successive days; egg size and specific gravity were determined the morning of the fourth day. A series of saline solutions adjusted to a range of 1.068 to 1.100 g/mL in 0.004 g/mL increments were used to measure specific gravity. Eggs were rinsed, set in an incubator and kept under standard conditions for 7 d, then candled. Eggs with definite embryonic development were deemed fertile, all remaining eggs were broken out; those showing clear allantoic development (i.e., presence of veins) were considered fertile, all others infertile.

Statistical analyses of the data were done using the SAS (1982) General Linear model (GLM). All experiments were conducted using a completely randomized design. Treatments differences were tested for significance using ANOVA with orthogonal and nonorthogonal single-degree-of-freedom contrasts. Unless otherwise specified, a confidence of .05 was used.

Experiment 1

This experiment was conducted to determine the extent to which light intensity changes during photostimulation affect reproductive traits of broiler breeder pullets. A total of 300 spring-hatched Shaver Color-Pac Broiler Breeder females were used. Day-old chicks were raised in a growing house through 10 weeks of age under similar light schedules (continuous lighting through day 3 followed by natural daylength (lights on at sunrise; off at sunset)) of low light intensities (ca. 20 lux). At 10 weeks of age, pullets were weighed; all underweight, overweight and morbid birds were discarded. The remaining birds were randomly distributed to nine light-proof darkrooms (30 pullets/room) after being individually banded.

Each of the three light treatments was randomly assigned to three light-proof floorpens (3.2x2.2 m each). The rooms were covered with a deep litter system and equipped with Plasson automatic waterers and 60" trough feeders. The light treatments are described in Table 1. The average light intensity at bird level in each room was measured by an electronic light meter.

Experiment 2

This experiment was designed to compare three different types of light rearing programs: 1) a simulated winter hatch natural lighting program; 2) a simulated summer hatch natural lighting program; and 3) a "black-out" (8L:16D) lighting program. The specific treatment protocols are shown in Table 2.

Chicks were brooded through 7 days of age in a growing house and moved to the light-proof darkrooms on day 8 posthatching. In the darkrooms, birds were randomly distributed and assigned to the 3 light rearing treatments in a manner similar to procedure in experiment 1. Light intensity of ca. 20 lux (i.e., a 40 watt incandescent light bulb) was used throughout the experimental period.

Experiment 3

Experiment 3 was undertaken to clarify the relationship between rearing photoperiods and subsequent egg production. The light management regimes are described in detail in Table 3. One day-old female broiler breeder chicks (Hubbard) were managed similar to the management of those in experiment 2 during the first week of life. On day 8 posthatching triplicate light-proof darkrooms containing 30 chicks each were randomly assigned to each of the 3 light management regimes.

The feeding schedules recommended by the breeder were adopted for all birds through 17 weeks of age; then all birds were fed 178 g feed/bird/d (500 kcal ME/bird/d) at the beginning of the 18 week of age. Egg quality measures (size and specific gravity) were monitored at 27, 33, 37, 41 and 45 weeks of age.

TABLE 1. Descriptions of treatments in experiment 1 on the effect of light intensity changes during photostimulation on performance of broiler breeder pullets

		Light Intensity Treatment		
Age	Daylength	1	2	3
(wk)	(hr)		(lux)	
10-17	14:30	20.8	20.8	65.3
18-19	15:00	20.8	20.8	65.3
20-21	15:30	20.8	48.2	59.5
22-25	16:00	20.8	59.5	48.2
26-45	17:00	20.8	65.3	20.8

TABLE 2. Descriptions of treatments in experiment 2 on the effect of simulated winter and summer hatches versus black-out housing on sexual maturity and performance of broiler breeder pullets

Treatment	Age	Daylength
	(wk)	(hr)
1- Simulated natural winter hatch (SNWH)	18-19	14:24
	19-20	14:37
	20-24	15:00
	24-26	16:00
	26-45	17:00
2- Simulated natural summer hatch (SNSH)	18-19	13:30
	19-20	13:30
	20-24	14:00
	24-26	15:00
	26-45	16:00
3- Black-out housing (BOH)	1-17	8:00
	17-20	10:00
	20-24	14:00
	24-26	15:00
	26-45	16:00

TABLE 3. Descriptions of treatments in experiment 3 on the effect of rearing and prebreeding photoperiods on sexual maturity and subsequent performance of broiler breeder pullets

Treatment	Age	Daylength
	(wk)	(hr)
1- Black-out housing (BOH)	1-17	8:00
	18-20	10:00
	21-23	14:00
	24-25	15:00
	26-45	16:00
2- Simulated natural lighting hatch with a 2 + 4 hr photostimulation schedule at 18 and 21 weeks of age (SNLH)	1-17	13:30
	18-20	15:30
	21–25	19:30
	26-45	20:00
3- Modified black-out housing schedule with an advanced photostimulation schedule (MBOH).	1-15	8:00
	16-18	10:00
	19-21	14:00
	22-23	15:00
	24-45	16:00

RESULTS

Experiment 1

Table 4 illustrates the effects of light intensity changes (20.8 to 65.3 lux) during photostimulation on body weight gain of broiler breeder pullets. Through 45 wks of age body weight gain was similar among the three light intensity treatments.

The effects of the light intensity treatment on performance of broiler breeder pullets through 45 wks of age are presented in Table 5. No significant treatment effects in any of the measured reproduction traits were observed.

Experiment 2

Effects of black-out (BOH), simulated natural winter (SNWH) or summer (SNSH) light treatments on body weight gain are presented in Table 6. Although the birds in all treatments exhibited negative body weight balance following the onset of lay, the body weights differences among treatments were not statistically significant.

Treatment effects on sexual maturity and egg production are shown in Table 7. In comparison to SNWH and SNSH systems, the BOH program significantly advanced onset of lay with least body weight and feed intake. Body weight change of BOH birds from 21 wks to first egg was significantly less while the change from the first egg to 45 wks of age was significantly larger. Moreover, egg production of BOH birds peaked at a younger age and they produced more eggs than did the birds under either SNWH or SNSH regimes. Percent peak hen-day production and mortality rate were the only traits not significantly affected by the experimental treatments.

TABLE 4. Effect of light intensity changes during photostimulation on average body weight of broiler breeder pullets (Exp. 1) [1,2]

Age	1	2	3
(wk)		(g)	
21	2155	2162	2167
24	2205	2208	2227
29	3340	3319	3372
33	3458	3524	3681
37	3580	3668	3619
45	3952	3967	3961

[1] Data are means of triplicate groups of 30 hens each.

[2] Treatments were: 1 = constant 20.8 (lux); 2 = (20.8 - 65.3 lux); 3 = (65.3 - 20.8 lux).

TABLE 5. Effect of light intensity changes during photostimulation on broiler breeder pullets performance through 45 weeks (Exp. 1) [1]

Variable	Treatment [2]			
	T_1	T_2	T_3	SEM[3]
Age at 1st egg, d	213	213	211	.88
Bw at 1st egg, g	3749	3748	3779	26.29
ΔBw from 21 weeks to 1st egg, g	1549	1585	1613	24.51
ΔBw from 1st egg to 45 weeks, g	203	219	182	42.24
Peak egg production, % hen-day	85	85	85	1.31
Age at peak production, d	244	252	242	1.98
Eggs per hen	76	76	77	1.10
Weekly rate of decline in hen-day production from peak, %	2	3	2	.16
Mortality, %	.33	.22	.33	.98

[1] Data are means of triplicate groups of 30 hens each.

[2] Treatments were: T_1 = constant low light intensity; T_2 = low-high light intensity; T_3 = high-low light intensity.

[3] Standard Error of Means from ANOVA, 6 df.

TABLE 6. Effect of three common broiler breeder lighting programs (SNWH, SNSH, & BOH) on average body weight (Exp. 2)[1,2]

Age[3]	1	2	3
(wk)		(g)	
15	1708	1699	1678
18	2072	2091	2067
21	2340	2397	2380
24	2472	2531	2562
27	3469	3508	3271
30	3451	3487	3218
33	3446	3402	3299
36	3546	3589	3374
39	3581	3647	3453
42	3649	3714	3558
45	3690	3784	3593

[1]Data are means of triplicate pens of 30 hens each.

[2]Treatments were: 1 = simulated natural winter hatch; 2 = simulated natural summer hatch; 3 = black-out housing system.

[3]Feed intake was elevated to 178 g/bird/d (500 kcal) for all groups at age 24 weeks.

TABLE 7. Effect of simulated natural winter and summer hatches versus black-out housing on sexual maturity and subsequent performance of broiler breeder pullets through 45 weeks (Exp. 2) [1]

Variable	Treatment [2]			SEM[3]
	T_1 SNWH	T_2 SNSH	T_3 BOH	
Age at 1st egg, d[4]	191	193	173	1.01
Bw at 1st egg, g [4]	3495	3528	2991	16.24
Feed consumed until 1st egg, kg[4, 5]	14.3	14	11.3	.02
ΔBw from 21 wks to 1st egg, g[4]	1098	1188	611	16.24
ΔBw from 1st egg to 45 wks, g[4, 5]	289	162	602	16.24
Peak egg production, % hen-day	83	84	86	.90
Age at peak production, d[4]	224	230	196	1.19
Eggs per hen[4]	78	84	110	2.15
Weekly rate of decline in hen-day				
production from peak, % [4]	2.20	2.07	1.10	.16
Mortality, %	7	2	12	1.94

[1] Data are means of triplicate groups of 30 hens each.

[2] Treatments were: T_1 = simulated natural winter hatch (SNWH); T_2 = simulated natural summer hatch (SNSH); T_3 = black-out housing (BOH).

[3] Standard Error of Means from ANOVA, 6 df.

[4] T_3 vs. $T_1 + T_2$ is significant ($P < .05$).

[5] T_1 vs. T_2 is significant ($P < .05$).

The only differences encountered between SNWH and SNSH birds were that feed consumption rate from hatching to first egg and body weight changes from first egg to 45 wks of age of the former group (SNWH) were significantly greater than those of the latter group.

Experiment 3

Mean body weights through 45 wks of age as affected by rearing and prebreeding photoperiods are shown in Table 8. Feed restriction (per the breeder's recommendations) through 17 wks of age followed by an abrupt increase to 500 kcal ME/bird/d promoted steady growth of all birds during the experimental period. Until the onset of oviposition, both BOH and advanced photostimulated black-out housing (modified BOH, MBOH) birds gained slightly more body weight than contemporaries that differ only in rearing photoperiod (simulated natural lighting hatch, SNLH). After 24 wks of age (1st egg), the BOH and MBOH birds continued to grow but at a slower rate. At 45 wks of age they attained body weight approximately equal to that of the SNLH birds.

Data at first egg (age, body weight and feed consumption) and the subsequent reproductive performance are shown in Table 9. Both BOH and MBOH birds reached sexual maturity an average of 18 days earlier, at 364 g lower body weight and with 3.2 kg less feed than did SNLH birds. Moreover, during the 45-wk experimental period, birds subjected to an 8 hour rearing photoperiod (BOH and MBOH) produced significantly more eggs, achieved higher % peak egg production at a younger age, grew more uniformly during pre- and post-sexual phases, and exhibited a slower decline in % hen-day production from peak to 45 wks of age in comparison to SNLH birds. There was no treatment effect on mortality rate.

Treatment effects on egg quality characteristics at 27, 33, 37, 41 and 45 wks of age are shown in Table 10. Egg weights at 33 wks of age and specific gravity at ages 27, 33 and 37 wks of the BOH and MBOH birds were significantly smaller in comparison to those of the SNLH birds.

TABLE 8. Effect of rearing and prebreeding photoperiods on average body weight of broiler breeder pullets (Exp. 3) [1,2]

Age[3]	1	2	3
(wk)		(g)	
12	1214	1240	1263
21	2789	2728	2867
24	3261	3105	3295
27	3625	3717	3607
31	3671	3826	3694
38	3824	4036	3898
45	3972	4069	3999

[1]Data are means of triplicate pens of 30 hens each.

[2]Treatments were: 1 = black-out housing system; 2 = simulated summer-winter hatch; 3 = modified black-out housing system.

[3]Feed intake was elevated to 178 g/bird/day (500 kcal) in all groups at age of 18 weeks.

TABLE 9. Effect of rearing and prebreeding photoperiods on sexual maturity and subsequent performance of broiler breeder pullets through 45 weeks (Exp. 3) [1]

Variable	Treatment[2]			SEM[3]
	T_1 BOH	T_2 SNLH	T_3 MBOH	
Age at 1st egg, days[4]	172	189	170	.69
Bw at 1st egg, g [4]	3427	3758	3362	26.67
Feed consumed until 1st egg, kg[4, 5]	14.4	17.4	14.00	.12
ΔBw from 21 wks to 1st egg, g[4]	638	1030	526	22.38
ΔBw from 1st egg to 45 wks, g[4, 5]	545	310	636	10.33
Peak egg production, % hen-day [4]	83	75.7	80	.94
Age at peak production, days[4]	196	237	202	2.57
Eggs per hen[4]	94	78	88	1.70
Weekly rate of decline in hen-day				
Production from peak to 45 weeks, % [4]	1.57	2.63	1.70	.17
Mortality, %	7	9	4	1.46

[1] Data are means of triplicate groups of 30 hens each.

[2] Treatments were: T_1= black-out system; T_2= simulated natural lighting hatch; T_3 = modified black-out system.

[3] Standard Error of Means from ANOVA, 6 df.

[4] T_2 vs. T_1 + T_3 was significant ($P < .05$).

[5] T_1 vs. T_3 was significant ($P < .05$).

TABLE 10. Effect of broiler breeder reaing and prebreeding photoperiods on egg quality characteristics at ages 27 to 45 weeks (Exp. 3)[1]

Variable	Treatment[2]	Age (wk) 27	33	37	41	45	$\bar{X} \pm SD$
Egg weight, g[3]	1	55	59	60	64	66	61 ± 1.08
	2	55	61	64	66	67	63 ± 1.57
	3	54	59	62	65	66	61 ± 1.32
Egg specific gravity, g/mL[4]	1	1.081	1.082	1.081	1.080	1.083	1.081 ± .001
	2	1.086	1.084	1.082	1.081	1.082	1.083 ± .002
	3	1.082	1.082	1.080	1.080	1.082	1.081 ± .001

[1] Data are means of triplicate groups of 30 hens each of 3 consecutive days.

[2] Treatments were: T_1 = black-out housing system; T_2 = simulated natural lighting hatch; T_3 = modified black-out housing system.

[3] T_2 vs. $T_1 + T_3$ was significant ($P < 0.05$) at 33 and 37 weeks.

[4] T_2 vs. $T_1 + T_3$ was significant ($P < 0.05$) at 27, 33 and 37 weeks.

DISCUSSION

The results of experiment 1 indicate that the range of light intensities used during photostimulation had no effect on age or body weight at sexual maturity nor on egg production through 45 weeks of age, which was surprising. The results suggest that the bird's perception of light intensity is different from that of daylength. The results also support the findings of other workers (Morris, 1967a; Proudfoot et al., 1984; Merat et al., 1986; and Merat and Bordas, 1989), but differ from the conclusions of others (Morris and Owen, 1966; and Brake, 1987; Brake and Baughman, 1989). This contradiction in results may be attributed to the variation in genetic responses of the breeds utilized (Merat and Bordas, 1989).

Unlike effects of light intensity, the effects of rearing photoperiod on the traits of sexual maturity and performance were very marked. Differences due to type of rearing photoperiod were detected for all characteristics studied (age, body weight and feed consumption at first egg; body weight changes during prebreeding and breeding phases; total egg production) except % hen-day peak egg production and mortality rate. The results obviously indicate the substantial beneficial effect of a black-out housing system (BOH) in comparison to natural winter (SNWH) or summer (SNSH) lighting regimes. Besides the improvement in the various production traits, the BOH lighting program significantly reduced age, body weight and amount of feed consumed through sexual maturity. It was revealed that as the rearing photoperiod became longer (> 10 hr), there was a depression in sexual maturity and total number of eggs. Thus, the effects of the SNWH or SNSH treatments were similar to those obtained by Payne (1975), Proudfoot et al. (1980, 1985) and Sharp (1984). Similar effects of the BOH regime have been reported in several other studies (Morris, 1962, 1967; Harrison et al., 1969; Timmons et al., 1983; Renden et al., 1990). In contrast to results observed in this study, Andrews et al. (1987) reported no significant differences in hen-house production, feed per dozen eggs or hatchability of broiler pullets reared in a dark-house environment to 20 weeks of age when compared to pullets reared under natural day length. The major difference between the two experiments is that the latter workers reared the birds under complete darkness (0L:24D).

Experiment 3 was designed to investigate further the effects of rearing and prebreeding photoperiods. As mentioned earlier, it resembles experiment 2 with slight modifications.

Taken together, the results of both trials confirm that the BOH program is the most successful regime among all treatments studied. The response of the BOH birds in both trials was particularly surprising. Regardless of the variations in breed and duration of feed restriction during the rearing period, the birds entered lay at almost the same age (172-173 days) but at different body weights and feed consumption rates. Average body weight and feed consumption at first egg were 2.991 and 11.3 kg, respectively, for the BOH birds of trial 2 and 3.427 and 14.4 kg, respectively, for their counterparts in trial 3. When the birds of experiment 2 were increased to 500 kcal ME/bird/d at 24 weeks of age, some of the BOH birds had already started laying, which is consistent with the conclusion of Wingfield (1980) that short periods of feed restriction do not block the effect of photostimulation. In other words, feed restriction does delay sexual maturity but does not affect the sensitivity of birds to photostimulation; the data support also the notion that minimum lean body mass is a chief factor controlling onset of lay (Soller at al., 1984) and thus the difference in body weight between the two groups (.436 kg) is likely due to body fat deposition; likewise, the results can be interpreted as corresponding to the view of North and Bell (1990) viz., that the effect of concurrent application of light and feed management are not additive, or, alternatively, that the age (18 wk) or the time (6 wk) prior to the onset of lay at which the birds were increased to high-energy allowance is inappropriate to accelerate sexual maturity. This latter trend warrants further study for determination of the lower limit of genetic potential of age at first egg and its commercial desirability.

Another striking feature of the birds under BOH system was that the flocks were very homogeneous. Within two weeks post photostimulation, more than 90% of the flock commenced laying. Thus, with respect to age and % hen-day production at peak (Tables 7 and 9), the data agreed with the observation of North and Bell (1990) that uniform flocks reportedly reach peak egg production at an earlier age and attain higher levels of peak egg production than do heterogeneous flocks. Similarly, the egg production data indicate that the BOH birds produced an average of 110 (trial 2) or 94 (trial 3) eggs/hen in 45 weeks. This is the only group that produced within or even beyond the limits (93-104) of the currently available commercial broiler breeder management guides. The extra eggs produced by trial 2 birds demonstrates either breed effect or the superiority of lean versus obese birds at this age in terms of higher peak (86 vs. 83) and/or lower weekly rate of decline from peak egg production (1.1 vs. 1.57). Nevertheless, the number of eggs/hen for birds under all simulated natural lighting systems (SNWH, SNSH and SNLH) ranged between 78 and 84, which is below the breeders recommendations. The poor performance of these birds is likely due to late sexual maturity and successive decline from peak egg production. Moreover, the results of experiment 3 indicate that advanced photostimulation (MBOH) was without advantage over the BOH system.

The relationships among egg size, body weight and age in the early production period are of great significance in cost effective breeder management. Indices of egg quality were not measured in trial 2. The birds in this trial entered lay at a light body weight (2.991 kg); therefore, it is likely that this light body weight might have had a negative impact on egg size (Wilson and Harms, 1986). In trial 3, BOH birds produced significantly lighter eggs of lower specific gravity during the first week of production (Table 10). However, from a practical point of view, if eggs in the weight range of 50 to 72 g (Bornstein and Lev, 1982) and specific gravity of 1.076 to 1.084 g/mL (Robert and John, 1985) are considered as most suitable for hatching; then all eggs laid by the BOH birds at 27 to 45 weeks of age were satisfactory for setting and hatching. Furthermore, the age at which these birds entered lay also is optimum for producing settable eggs. Commencement of egg production at 24-25 weeks of age will reduce the number of small eggs and increase the number of settable eggs per broiler breeder hen (Anonymous, 1985, 1986). As far as the effect of body weight at first egg (3.427 kg) is concerned, the results are in accord with the conclusion of Robbins et al. (1988) that broiler breeder hens reared on a restriction feeding program will reach sexual maturity at approximately 3.4 kg body weight, which is optimum for maximum production (with 500 kcal ME/bird/d) without any detrimental effect on egg quality.

In summary, the results of this study indicate that light intensity changes during photostimulation have no effect on age or body weight at sexual maturity nor on egg production through 45 weeks of age.

As far as the rearing photoperiod is concerned, the results indicate that it is a key factor in light management. The data strongly supported the conclusions that: 1) the responses of the reproductive system of broiler breeder pullets to a given daylength are not the function of that day length but mainly of the previous photoperiodic history; 2) photoperiodic management does improve broiler breeder performance as reflected by feed utilization to the first egg and enhanced egg production. The data presented herein suggested that optimum age (172 d) or body weight (3.43 kg) at sexual maturity, egg size or weight and flock uniformity would occur if broiler breeder pullets were reared under restricted light (8-10 h) and restricted feed (per the breeder's recommendations) to 17 weeks of age then simultaneously photostimulated and increased to 500 kcal ME/bird/d at 18 weeks of age. However, the minimum age at sexual maturity which may be of importance from genetic point of view and expected to be a function of a cumulative effect of light and feeding management warrants further investigation.

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PART III

FEED MANAGEMENT OF BROILER BREEDER HENS

INTRODUCTION

Obesity which results from overfeeding appeared to be a major constraint on the new strains of broiler breeders from thriving or performing optimumly (Costa, 1981). Accordingly, in recent years the need for feed restriction and body weight control has gained popularity and acceptance among researchers and producers. Various systems of feed restriction have been devised and broadly applied in poultry science and production; yet the degree of restriction, age at beginning of restriction and feed allowances are extremely variable. The most common industry practice consists of severe to moderate feed restriction during rearing, a period of gradual increase in daily feed allocation (adolescent phase) and modest feed control during the laying period. Recent recommendations (Wilson and Harms, 1986; Robbins et al., 1988) proposed abrupt instead of stepwise increases in daily feed allowance during the pullet-layer transitional period. Other workers (Pym and Dillon, 1974) emphasized the preference of *ad libitum* feeding during the laying phase over the modest feed restriction.

The program of choice can be defined as any feeding regime that promotes early egg production without necessarily affecting the well-being or subsequent reproductive performance. Bearing this in mind, currently the industry does not possess a consistent feeding programs to be adopted; also there is no clear-cut agreement as to any distinct advantage or superiority of one of the preceding feeding plans over another. The key factor behind the lack of consensus could be the interaction of the layer management program with the rearing and/or growing management programs. There is substantial evidence that the degree and duration of feed restriction during the rearing period affect the birds' characteristics at sexual maturity and their subsequent performance. Similarly, the nutrient allowance (particularily ME) during the pullet-layer transitional period (i.e., from the final stages of the adolescent phase to the peak of egg production) is another factor well known to have decisive effects on feeding management and reproductive performance. Yet, little information is available on specific ME needs of broiler breeders during the adolescent and laying phases. Moreover, little data have been reported comparing ages at which dietary energy elevation should be initiated.

The experiments reported here were undertaken to determine: 1) effect of light intensity changes and feed allowance during lay on egg production; 2) optimum age and body weight at sexual maturity in broiler breeders; and 3) daily ME requirement of broiler breeder hens.

MATERIALS AND METHODS

Stock, General Management and Experimental Design

With the exception of the following managerial modifications, the breeding stocks and the adopted management procedures (vaccination, watering and nesting) used in this study were the same as those described in part I. Three experiments were conducted through 64-65 wks of age of birds in a conventional-type broiler breeder house to assess the effects of feeding practices on production. Accordingly, if light intensity was excluded in experiment 1, lighting schedules were similar within experiments 1-3 with slight modifications among them. Feeding management, on the other hand, varied within and among experiments 1,2 and 3, especially during the pullet-layer transition and laying phases.

Data collected or calculated from the independent variables also were identical with those measured before (part I) except that in this study, the criterion of rate of decline in % hen-day production from age at peak production to 45 wks of age was replaced by feed consumption per dozen eggs.

Independent experimental variables of experiment 1 were light intensity and feeding level; the experimental design was a randomized block with feeding level constituting a block. Experiments 2 and 3, on the other hand, were conducted using a completely randomized design. Statistical analyses of the data were done using the SAS (1982) General Linear Model (GLM). Treatment differences were tested for significance using ANOVA with orthogonal and nonorthogonal single-degree-of-freedom contrasts. To assess the relationships among the dietary energy concentrations of experiment 3 (T1-T4), a stepwise regression procedures were used. Unless otherwise stated, a confidence of .05 was used.

Experiment 1

Seven hundred sixty female and 135 male Shaver Color-Pac Breeders were utilized to assess the effects of light intensity changes at peak hen-day production, and the effects of daily energy allowance during lay.

The treatment variables were light intensity and feeding level (Table 1). Changes in light intensity were effected by changing wattage of pen light bulbs. The recorded light intensities were measured as an average in each pen (replicate group) at floor level directly below the light bulb and in the corners of the pen every two weeks so that the effect of changes in natural sunlight intensity might be included. In order to prevent confounding effects of light from contiguous pens and from pens directly across the hallway, the wire partition between pens was covered with opaque plastic, and replicates were arranged such that each pen faced a pen in which the opposite light intensity (bulb size) was used. This restriction of randomness was unavoidable.

At one day of age the female chicks were randomly distributed (38/pen) and assigned to one of the experimental treatments in a conventional-type broiler breeder house. At 18 weeks of age birds were culled and redistributed within treatments so that each pen contained 34 pullets (i.e., 20 extra birds per treatment at one day of age to allow for mortality and culling). Males were grown in a separate house through 18 weeks of age. At 18 weeks all underweight and overweight males were culled; the remaining males were randomly mingled with the females (3/pen). Thus, each of the 4 light intensity treatments was replicated 5 times with a replicate group consisting of one pen containing 34 hens and 3 cocks. Two feeding levels were adopted. There were 10 replicate pens per feeding level. All birds were fed with accord with the breeder's recommendations through 23 weeks of age. At 24 wks of age and thereafter, half of the birds (10 pens) were randomly assigned to restricted feeding (i.e., per the breeders recommendations). The other half were increased to full feeding. Daylight did not differ among treatments. All birds were subjected to constant light during the first 3 days of life; natural daylength (lights on at sunrise; off at sunset) during the period 3 days through 17 wks of age; 15 hrs during the period 18 through 19 wks of age; 15.5 hrs during the period 20 through 21 wks of age; 16 hrs during the period 22 through 25 wks of age; and 17 hrs for the remainder of the experiment.

In addition to egg quality measures (weight, specific gravity, and fertility) the treatment effects on % hatchability were measured at 65 wks of age.

TABLE 1. Descriptions of treatments with 2 feeding levels and 4 light intensity programs for broiler breeder pullets (Exp. 1)

Total pens #	20							
Feeding Treatments[1]:								
Designation	Ad libitum				Restricted			
Pens #	10				10			
Light Treatments:								
Hatching to 30 wks (Lux)	22.6	9.8	22.6	9.8	22.6	9.8	22.6	9.8
31 wks to 65 wks (Lux)	22.6	9.8	9.8	22.6	22.6	9.8	9.8	22.6
Designation	HH	LL	HL	LH	HH	LL	HL	LH
Pens #	2	2	3	3	3	3	2	2

[1] The average daily intake of the ad libitum group from 24 to 65 weeks of age was 540 kcal ME/bird, whereas, the restricted group consumed approximately 80% of the ad libitum group consumption (435 kcal ME/bird/d).

Experiment 2

The (non-destructive) project was executed in an attempt to determine the minimum age and body weight at which sexual maturity occurs in broiler breeder hens. Four feeding treatments were implemented. The treatments are depicted in Table 2.

Four hundred fifty female and sixty male 1-day-old broiler chicks were reared separately in a growing house per the breeder's recommendations through 15 wks of age. At 15 wks of age the birds were transferred to a conventional-type broiler breeder house where they were weighed and distributed to 12 pens (34 females and 3 males/pen) on the basis of approximately similar body weight. The 15-wk-old birds were then randomly assigned to the four feeding treatments in 3 replicate pens,. All birds were maintained under natural (spring-summer) daylength to 12 wks of age and then subjected to 14.5 hrs of daily light (14.5L:9.5D).

At subsequent 3-wk intervals daylength was increased by half an hour until a maximum of 17 hr of light per day was reached at 27 wks of age and continued for the remainder of the experiment. Birds were weighed at 3-wk intervals from 21 wks of age to the end of the experiment. At 63 wks of age treatment effects on egg characteristics were determined.

Experiment 3

This experiment was conducted to determine the metabolizable energy requirement of broiler breeder hens.

Seven hundred fifty Hubbard breeder pullets were allocated (50 chicks/pen) to 15 pens in a growing house and reared through 16 wks of age per the breeder's specifications. At 16 wks of age pullets were weighed, and all morbid and unthrifty birds were culled. The remaining pullets were moved and randomly allotted (34 pullets/pen) to 20 pens in a conventional-type broiler breeder house.

TABLE 2. Descriptions of treatments in the experiment on the effect of 4 feeding programs on sexual maturity and subsequent performance of broiler breeder pullets (Exp. 2)[1,2]

Age	T_1	T_2	T_3	T_4
(wk)		(g/bird/d)		
1-8	41	41	41	41
8-15	51	51	51	51
15-18	178	67	67	67
18-21	178	178	79	79
21-24	178	178	178	97
24-64	178	178	178	178

[1] 178 gram feed = 500 kcal ME.

[2] Treatments were: T_1, T_2, T_3, and T_4 = respectively increased at 15, 18, 21, and 24 weeks of age to 500 kcal ME/bird/d.

The 16-wk-old pullets were exposed to a 14:30L:9:30D photoperiod. At 20 wks of age the photophase was lengthened by two hrs (16:30L:7:30D), and at 24 wks lengthened by one hr (17:30L:6:30D).

The experiment began when the birds were 21 weeks of age. There were 5 treatments, each replicated 4 times; a pen of 34 pullets plus 4 separately grown cockerels constituted a replicate group. The four experimental diets and five treatments are presented in Tables 3 and 4, respectively.

Diets A, B, C and D (Treatments 1-4, respectively) were fed at the rate of 150 g/bird/d from 21 to 65 wks of age. Treatment 5 consisted of feeding diet A at the rate of 177 g/bird/d.

Treatment effects on egg characteristics were determined at ages of 33, 41, 58 and 65 wks. A comparison of treatment 1 to treatment 4 revealed the effects of dietary energy concentrations, whereas, treatment 4 versus 5 revealed the impact of total amounts of daily feed intake.

TABLE 3. Composition of experimental diets, % (Exp. 3)

Ingredient	A	B	C	D
Corn	64.52	58.73	52.94	52.22
Soybean meal (48.5 % CP)	15.73	16.57	17.42	18.86
Fishmeal (60 % CP)	2.50	2.50	2.50	2.50
Alfalfa meal (17 % CP)	6.50	6.50	6.50	6.50
Vitamin premix [1]	.65	.65	.65	.65
Dicalcium Phosphate	1.62	1.62	1.62	1.62
Limestone	6.20	6.20	6.20	6.20
Salt (trace mineralized)	.35	.35	.35	.35
DL-methionine	.10	.10	.10	.10
Manganese Sulfate	.25	.25	.25	.25
Fat [2]	1.81	6.75	11.69	14.98
Calculated Analysis:				
ME, kcal/kg	2833	3000	3166	3349
CP, %	16	16	16	16
Ca, %	2.98	2.98	2.98	2.98
Available P, %	.49	.49	.48	.48
Lysine, %	.82	.84	.85	.86
Sulfur amino acids, %	.64	.63	.62	.63
Tryptophan, %	.20	.20	.20	.20
Threonine, %	.66	.65	.65	.64

[1] Contained per kilogram: vitamin D_3, 125,000 ICU; vitamin A, 700,000 IU; riboflavin, 790 mg; vitamin B_{12}, 1.83 mg; niacin, 6.94 g; D-Ca panthothenate, 1.22 g; choline, 78 g.

[2] Dry fat product which contained 85% fat of 7020 kcal ME/kg.

TABLE 4. Descriptions of treatments for determination of daily metabolizable energy requirement of broiler breeder hens (Exp. 3)

Variable	Treatment 1	2	3	4	5	NRC[1] Reqts
Diet #	A	B	C	D	A	—
Feed, g/bird/d*	150	150	150	150	177	—
ME, Kcal/bird/d	425	450	475	500	500	—
CP, g/bird/d	24	24	24	24	28.3	22
Ca, g/bird/d	4.47	4.47	4.47	4.47	5.27	4.125
P, mg/bird/d	735	735	720	720	867	375
Lys, mg/bird/d	1230	1260	1318	1290	1451	765
SAA, mg/bird/d	960	945	930	945	1133	820
Trp, mg/bird/d	300	300	300	300	354	190
Thr, mg/bird/d	990	975	975	960	1168	720

[1] NRC (1984) Nutrient Requirements of poultry. All diets formulated to provide excesses of all limiting nutrients except energy.

* Daily treatment allocation started from 21 to 65 weeks of age.

RESULTS

Experiment 1

Feed intake and body weight data through 65 wks of age are given in Tables 5 and 6. *Ad libitum* fed hens consumed approximately 240 g/bird/d during 24-30 wks of age and then plateaued at an average daily intake of 180-183 g/bird for the remainder of the experimental period. The restricted group on the other hand, consumed ca. 155 g/bird/d during the laying period which was equivalent to 80 % of the *ad libitum* group's intake.

The growth rate among the various light intensity treatments followed the same pattern. For instance, all birds experienced body weight gains at ages of 33, 45 and 57 wks and body weight loses at 37, 49 and 61 wks of age. Although the differences in body weight gain were minor and non significant among the four light intensity treatments, birds housed under low light intensity (LL) consistently had the lowest body weight gain during the laying period. Nevertheless, the effect of feeding level on body weight gain was more prominent than was the light treatment effect. As compared to *ad libitum* feeding, restricted feeding reduced body weight gain significantly during the laying period.

A significant interaction between light intensity changes at peak production and the daily energy allowance during lay did not occur with respect to any of the performance traits studied. Thus, results in Table 7 show the mean values for each trait as affected by the main factors (light intensity x feeding level). Birds maintained under high intensity light fron hatching (HH) produced more eggs, and achieved significantly better feed efficiency and higher % peak production at a younger age than did birds housed under low light intensity. However, no other measure of performance was affected by these two treatments, nor did light intensity changes at 30 wks (LH or HL) affect production characteristics.

Hens fed *ad libitum* (540 kcal ME/bird/d) commenced production 14 days earlier and at a higher body weight than did restricted fed birds (435 kcal

TABLE 5. Feed consumption by broiler breeders subjected to ad libitum and restricted feeding programs (Exp. 1)[1]

Age		Ad libitum	Restricted
(wk)		——— (g /bird/d)	———
24-26		240	116
27-30		241	138
31-34		178	153
35-38		180	160
39-42		180	160
43-46		180	160
47-50		180	160
51-54		183	160
55-58		183	165
59-62		183	165
63-65		183	165
	Mean	193	155

[1] Ad libitum feeding began at 24 weeks of age.

TABLE 6. Effect of 4 light intensity programs and 2 feeding levels on average body weight of broiler breeder pullets (Exp. 1)

	Light Intensity Treatment [1,2]				Feed Treatment [3,4]	
Age	LL	HH	LH	HL	Ad libitum	Restricted
(wk)	(g)					
21	1973	1928	1920	1925	1933	1940
24	2260	2227	2217	2221	2243	2000
29	3383	3371	3477	3529	3785	3094
33	3568	3624	3626	3659	3832	3407
37	2918	3422	3421	3488	3631	2993
42	3336	3411	3468	3562	3598	3241
45	3419	3519	3598	3561	3674	3374
49	3278	3366	3542	3476	3545	3286
53	3404	3477	3535	3460	3603	3335
57	3449	3564	3590	3517	3672	3388
61	3415	3528	3695	3470	3741	3313
65	3425	3579	3505	3508	3645	3364

[1] Data are means of 5 replicate groups of 34 hens each.

[2] Light treatments were: HH = high light intensity throughout the experiment (22.6 Lux); LL = low light intensity throughout the experiment (9.8 Lux); LH = low light intensity (9.8 Lux) for the first 30 weeks then increased to high level (22.8 Lux); HL = opposite of LH.

[3] Data are means of 10 replicate groups of 34 hens each.

[4] Ad libitum feeding began at 24 wks of age.

TABLE 7. Effect of light intensity and feeding level on sexual maturity and subsequent performance of broiler breeder pullets through 65 weeks of age (Exp. 1)

	Light Intensity Treatment [1, 2]				Feed Treatment[3]		
Variable	HH	LL	LH	HL	Ad libitum	Restricted	SEM[4]
Age at 1st egg, d[6]	208	210	207	206	201	215	.50
Bw at 1st egg, g[6]	3411	3462	3490	3523	3693	3250	17.40
ΔBw from 21 wk to 1st egg, g[6]	1438	1534	1570	1473	1760	1310	28.77
ΔBw from 1st egg to 65 wks, g[6]	7.3	58.9	8	-7.6	-47.8	114.3	34.15
Feed consumed/hen from hatching, kg[6]	58.6	57.8	60.5	60.7	63.8	55.0	.34
Total feed consumed/dozen eggs, kg[6]	4.4	4.5	4.5	4.5	4.6	4.3	.10
Eggs/hen[6]	161	155	162	158	165	153	1.35
Hen-day production, %[6]	60	57	60	59	61	57	.62
Peak egg production, % hen-day[5, 6]	88	77	82	83	82	80	.38
Age at peak production, d[5, 6]	228	236	240	238	230	240	1.96
Mortality, %	4.7	5.9	4.1	2.4	4.4	4.1	.00
At 65 wk age:							
Egg weight, g	69	68	69	70	69	69	.50
Egg specific gravity, g/mL	1.075	1.067	1.078	1.076	1.075	1.076	.07
Egg fertility, %	80	79	81	80	82	77	1.44
Egg hatchability, %	71	68	71	77	71	73	2.68

[1] Data are means of 5 replicate groups of 34 hens each.

[2] HH = high light intensity throughout the experiment (22.6 Lux).

LL = low light intensity throughout the experiment (9.8 Lux).

LH = low light intensity (9.8 Lux) for the first 30 weeks then increased to high level (22.8 Lux).

HL = high light intensity (22.8 Lux) for the first 30 weeks then decreased to low level (9.8 Lux).

[3] Data are means of 10 replicate groups of 34 hens each.

[4] Standard error of means from ANOVA, df 12.

[5] HH vs. LL (light treatment was significant ($P < .05$).

[6] High vs. low (feed treatment) was significant ($P < .05$).

ME/bird/d). Moreover, birds fed the higher daily energy allowance consumed more feed during lay and produced significantly more eggs but at lower feed efficiency (total feed consumed/dozen eggs). Body weight change during prebreeding and breeding stages, % peak egg production and age at peak production also were affected by feeding treatments. The *ad libitum* fed birds peaked at a higher level and at a younger age. Neither mortality nor egg quality was affected by feed treatment.

Experiment 2

Effects of feeding management on body weight gain are summarized in Table 8. All birds were restricted-fed per the breeder's specifications then subsequently increased to a daily allowance of 500 kcal ME/bird at either 15, 18, 21 or 24 wks of age. Growth rates of the 15- and 18-wk groups were identical during 48 to 63 wks of age. The two groups achieved significantly higher body weights than did 21- or 24-wk birds. The latter two groups attained similar body weights during 55 to 63 wks of age.

The data in Table 9 illustrate the effect of the four feeding regimes on performance of broiler breeders during the growing and laying periods. The 15-wk birds entered lay and achieved peak production at average ages of 172 and 218 days, respectively, which were significantly earlier than the 18-, 21- and 24-wk birds by, 17, 34 and 51 days, respectively, in onset of lay and by 22, 23 and 26 days in age at peak production. Total feed consumption for the 15 wk birds was significantly greater, but they produced more eggs and had better feed efficiency in comparison to the other groups. Although the 15-wk birds exhibited the lowest body weight change during the prebreeding stage, they were the only group that did not show negative body weight balance during the production cycle. Body weight at 1st egg, body weight change from 1st egg to 45 wks of age, % peak egg production, mortality rate and egg quality measures were not significantly affected by treatment.

TABLE 8. Effect of 4 broiler breeder feeding programs on average body weight (Exp. 2)[1,2]

Age	1	2	3	4
(wk)		(g)		
15	1469	1502	1501	1516
18	2298	1682	1671	1655
21	2832	2440	1956	1980
24	3171	2856	2499	2059
27	3460	2304	3088	2935
30	3371	3249	3125	3057
33	3387	3264	3248	3192
36	3391	3289	3221	3197
39	3492	3381	3295	3207
42	3503	3369	3303	3231
45	3513	3427	3370	3300
48	3596	3605	3383	3329
52	3671	3658	3453	3358
55	3702	3668	3527	3482
57	3742	3710	3541	3548
60	3825	3806	3570	3565
63	3889	3894	3637	3644

[1] Data are means of triplicate pens of 34 hens each.

[2] Treatments are: 1, 2, 3, and 4 = respectively increased at 15, 18, 21, and 24 weeks of age to 500 kcal/bird/d until the end of the trial.

TABLE 9. Effect of feeding level on sexual maturity, subsequent performance and egg characteristics of broiler breeder pullets through 64 weeks (Exp. 2)[1]

Variable	Treatment[2]				SEM[3]
	T_1 15-wk	T_2 18-wk	T_3 21-wk	T_4 24-wk	
Age at 1st egg, d[4,5,6]	172	189	206	213	.85
Bw at 1st egg, g	3409	3451	3415	3371	20.04
ΔBw from 21 wks to 1st egg, g[4,5,6]	577	1002	1458	1391	19.92
ΔBw from 1st egg to 45 wks, g	104	-24	-45	-71	20.04
ΔBw from 1st egg to 63 wks, g[5,6]	480	443	217	273	18.04
Peak egg production, % hen-day	72	72	75	73	1.04
Age at peak production, d[4]	218	240	241	244	2.56
hen-day production, %[4]	57	54	55	55	.54
Eggs per hen[4,5,6]	178	163	157	153	1.33
Feed consumed until 1st egg, kg[5,6]	16.4	16.9	18.1	17.7	.07
Feed consumed/hen from hatching, kg[4,5,6]	65.7	63.3	61.3	59.7	.05
Total feed consumed/dozen eggs, kg[4]	4.4	4.7	4.7	4.7	.03
Mortality, %	7	4	2	5	.75
At 63-week age:					
Egg weight, g	68.7	68.7	68.2	68.7	.40
Egg specific gravity, g/mL	1.079	1.079	1.080	1.079	.00
Egg fertility, %	87.7	90.7	87.7	93	2.27

[1] Data are means of triplicate groups of 34 hens each.

[2] Treatments are: T_1 = increased at 15 weeks to 500 kcal/bird/d; T_2 = increased at 18 weeks to 500 kcal/bird/d; T_3 = increased at 21 weeks to 500 kcal/bird/d; and T_4 = increased at 24 weeks to 500 kcal ME/bird/d.

[3] Standard Error of Means from ANOVA, 8 df.

[4] T_1 vs. T_2 was significant ($P < .05$).

[5] T_3 vs. $T_1 + T_2$ was significant ($P < .05$).

[6] T_4 vs. $T_1 + T_2 + T_3$ was significant ($P < .05$).

Experiment 3

Table 10 show the effects of daily energy concentrations (T1-T4) and the amount of daily feed consumption (T4 vs. T5) on body weight gain of broiler breeders during prebreeding and laying phases. To 35 wks of age dietary energy allowance of 425 kcal ME/bird/d (T1) effectively supported growth rate of the breeder pullets when compared to higher dietary energy concentrations (450-500 kcal ME). The highest body weight gain during this time was achieved by the birds under diluted 500 kcal ME (T5). After 35 wks of age, however, the T1 birds gained significantly less body weight than did other groups. The highest body weight gain was attained by T4 birds followed by T3 and T2 birds, respectively.

The data in Table 11 illustrate the effects of dietary energy concentration and the total amount of daily feed intake on sexual maturity and subsequent performance of broiler breeder pullets. Regardless of the equality in dietary energy levels (T4 & T5), the total amount of daily feed intake significantly affected age and amount of feed consumption at sexual maturity. The higher amount of daily feed intake (T5) advanced the onset of lay by 9 days and reduced feed consumption by 1.3 kg/hen in comparison to the T4 birds. Moreover, during the laying period, the T5 birds achieved significantly higher % hen-day production and produced more eggs; however, they consumed significantly more feed and maintained lower body weight gain than did contemporaries (T4) that received equal dietary energy. Body weight gain at 1st egg also was improved by improved daily feed intake (T5) but the difference was not significant nor were body weight change during the prebreeding stage, % peak egg production, age at peak production and mortality rate.

The effect of dietary energy concentration T1-T4 (425-500 kcal ME/bird/d) on the other hand, had no significant effect on age at 1st egg, peak production, feed consumption/hen to 1st egg or during laying, body weight change during the prebreeding phase or mortality rate; however, a linear effect on body weight change during laying, % peak hen-day production, number of eggs per hen and feed efficiency was observed. There was a quadratic effect on body weight at 1st egg (i.e., a curvilinear relationship among T1-T4).

Egg quality characteristics as affected by dietary energy level and amount of daily feed intake are summarized in Table 12. With the exception of egg specific gravity, which was linearly affected by dietary energy concentration at ages of 33 and 65 wks, and quadratically at age of 41 wk, no treatment effect on any of the other egg quality measures (egg weight and % fertility) during 33, 41, 58 and 65 wks of age was detected.

TABLE 10. Effect of ME energy level and total amount of feed consumption on average body weight of broiler breeder pullets (Exp. 3) [1, 2]

Age	1	2	3	4	5
(wk)			(g)		
20	1853	1961	1883	1911	1901
28	3043	3057	2980	3023	3120
35	3427	3411	3427	3482	3507
40	3471	3574	3600	3669	3577
49	3765	3849	3949	3910	3862
65	3785	3999	4129	4274	3929

[1] Data are means of 4 replicate pens of 34 hens each.

[2] Treatments were starting daily-basis ME feeding at 21 wk of age and they are: 1 = 425 kcal ME/bird; 2 = 450 kcal ME/bird; 3 = 475 kcal ME/bird; 4 & 5 = 500 kcal ME/bird, but they differ in total amount of feed/d.

TABLE 11. Effect of ME level and total amount of daily feed consumption on sexual maturity and subsequent performance of broiler breeder pullets (Exp. 3)[1]

Variable	Treatment					
	kcal ME/hen/d					
	425 T_1	450 T_2	475 T_3	500 T_4	500 T_5	SEM[2]
Age at 1st egg, d[3]	211	212	213	215	206	1.06
Bw at 1st egg, g[4]	3491	3408	3440	3529	3519	11.79
ΔBw from 20 wks to 1st egg, g	1619	1472	1557	1623	1618	24.77
ΔBw from 1st egg to 65 wks, g[3,5]	295	591	689	740	407	30.65
Peak egg production, % hen-day[5]	73	82	81	81	78	.78
Age at peak production, d	320	310	322	313	304	2.83
Hen-day production, %[3,5]	52	54	54	54	62	.37
Eggs per hen[3,5]	145	152	157	158	172	1.13
Feed consumed/hen until 1st egg, kg[3]	17.9	17.9	18.2	18.4	17.1	.16
Feed consumed/hen from hatching, kg[3]	54.3	54.4	54.4	54.3	62.4	.04
Total feed consumption/dozen eggs, kg[5]	4.5	4.3	4.2	4.2	4.4	.03
mortality, %	6.8	6.8	4.5	5.3	8.3	1.15

[1] Data are means of 4 replicate pens of 34 hens each.

[2] Standard Error of Means from ANOVA, 15 df.

[3] The effect of total daily feed consumption with equal energy concentration (T_4 vs. T_5) was significant ($P < .05$).

[4] The Quadratic effect of dietary energy concentration (T_1 - T_4) was significant ($P < .05$).

[5] The linear effect of dietary energy concentration (T_1 - T_4) was significant ($P < .05$).

TABLE 12. Effect of ME level and total amount of daily feed consumption on egg quality characteristics of broiler breeder pullets of ages 33 to 65 weeks (Exp. 3)[1]

Variable	Treatment, kcal ME/hen/d	Age, wk				
		33	41	58	65	X ± SD
Egg weight, g	T_1 425	60	67	68	70	66 ± 1.33
	T_2 450	60	67	69	70	67 ± .73
	T_3 475	59	67	69	70	66 ± 1.34
	T_4 500	60	67	69	70	67 ± 1.23
	T_5 500	59	67	68	69	66 ± 1.56
Egg specific gravity, g/ml[2, 3]	T_1 425	1.084	1.082	1.079	1.079	1.081 ± .001
	T_2 450	1.083	1.083	1.079	1.078	1.081 ± .001
	T_3 475	1.082	1.082	1.080	1.078	1.081 ± .001
	T_4 500	1.082	1.081	1.077	1.077	1.079± .001
	T_5 500	1.082	1.082	1.078	1.078	1.081± .001
Fertility, %						
	T_1 425	93	91	87	90	90 ± 5.90
	T_2 450	87	91	86	77	85 ± 9.25
	T_3 475	93	94	94	85	92 ± 5.29
	T_4 500	85	91	93	82	88 ± 7.63
	T_5 500	92	91	93	83	90 ± 5.21

[1] Data are means of 4 replicate pens of 30 hens each.

[2] The linear effect of dietary energy concentration (T_1 - T_4) was significant ($P < .05$) at ages of 33 and 65 weeks.

[3] The Quadratic effect of dietary energy concentration (T_1 - T_4) was significant ($P < .05$) at 41 weeks of age.

DISCUSSION

Experiment 1

Light intensity has been shown to have only minor effects on growth rate or sexual maturity of pullets (Morris, 1966b; Proudfoot et al., 1984; Merat and Bordas, 1989). These findings are consistent with the results obtained in this experiment. However, the most interesting aspect of the study is that birds maintained under high light intensity from hatch (HH) produced more eggs and achieved a significantly higher % peak production at a younger age than did birds accommodated under low light intensity (LL).

Since no other measure of performance had been affected by these two treatments (HH vs. LL), the results agree generally with observations of Merat and Bordas (1989) wherein one of the experimented genotypes produced significantly more eggs and had greater laying percentage and clutch length when subjected to high light intensity to than when subjected low light intensities. These results suggest a long-term effect of light intensity on egg production but do not explain its physiological role.

The results of the present study indicate also that none of the subsequent egg production traits was affected by light intensity changes (LH vs. HL). Wilson et al. (1976) concluded that birds sexually matured under less stimulatory environmental light exhibit resistance to subsequent changes in light environment experienced during lay. Morris (1967b) contended that the minimum light intensity during lay cannot be influenced by growing house light intensity as long as a mixture of natural and artificial lighting is used during lay.

Contrary to results of light treatments, the effects of feeding level on the performance of the experimental birds were very prominent. The results indicated that body weight changes of *ad libitum*-fed birds were associated with changes in feed consumption. A characteristic increase or decrease in body weight gain was observed during the early egg production or laying periods, respectively, which corresponds with daily feed intake 240 vs. 180 g. Similar relationships were reported by Robbins et al. (1986) and Katanbaf et al. (1989a) in broiler breeders and by Kruger (1982) in turkeys. The effects of *ad libitum* feeding study on sexual maturity and subsequent performance observed here confirm previous findings (Pym and Dillon, 1974; Robbins et al., 1986, 1988; Lilburn and Myers-Miller, 1990a) that there was an advantage of *ad libitum* feeding during the early stages of production with various controlled feeding regimes in terms of advancing sexual maturity and improving total egg production. However, the results do not agree with Pym and Dillon (1974) who reported that *ad libitum* feeding during lay versus modest restriction significantly improved feed efficiency and increased mortality rate nor with Robbins et al. (1988) who did not observe any significant effect on feed efficiency. These variations could be attributed to the use of different strains of chicks or to variations in daily ME intake. For instance, birds in this study consumed approximately 540 kcal ME/bird/d in comparison to the 497 kcal ME/bird/d of Robbins et al. (1988), which suggests that dietary ME of broiler breeders during lay should not exceed 500 kcal/d. This was supported by Wilson and Harms (1986) and later by Robbins et al. (1988).

The performance of birds under feed restriction, on the other hand, concur with observations of Thomas et al. (1989) in that feed restriction significantly delayed sexual maturity and reduced % hen-day production but did not affect egg quality or livability of birds. However, these findings differ from some other reports (Waldroup and Hazen, 1976; Katanbaf et al., 1989b) which indicated that restricted feeding during the rearing and laying periods enhances reproductive performance. These differences may result from the comparison of restricted feeding to *ad libitum* feeding throughout the experimental period instead of during the laying period only.

Experiment 2

The results of this experiment demonstrated that restricted broiler breeder females released to dietary 500 kcal ME/bird/d at 21 (T3) or 24 (T4) weeks of age did not show full compensatory growth during the 64-week experimental period, and remained at a body weight approximately 6.5% below that of groups released to the same amount of dietary ME at 15 (T1) or 18 (T2) weeks of age. These data vary from those of Robbins et al. (1986) and Pym and Dillon (1974) who observed equivalent body weights at 67-68 weeks of age regardless of rearing treatment. The results of this study however, suggest that there was a proportional relationship in the rate of gain of T1 birds versus T2 or T3 birds versus T4, but not between T1 and T2 birds versus T3 and T4 birds. Moreover, this disproportionate relationship in the growth rate of the two groups implies different physiological age responses.

The results also indicate that the longer the duration of feed restriction in broiler breeder is, the lower the body weight at the conclusion of the restriction period; consequently, the greater the delay in egg production when feed restriction ceases. Lee et al. (1971) used various degrees of feed restriction and obtained similar outcomes.

Another striking feature of this experiment is that all birds entered lay at similar body weight ca. 3.4 kg, which is optimum for subsequent performance (Robbins et al., 1988); however, most of the results obtained were highly variable within treatments. For example, birds released to full feeding at 15 weeks of age consumed significantly more feed from hatching to the end of the experiment when compared with either T2, T3, or T4 birds; however, they achieved significantly sexual maturity and peak egg production earlier. Conversely, prolonged feed restriction (T3 and T4) resulted in a reduced rate of growth, egg production and lower feed efficiency. This occurred despite the reduction in total feed consumption. Neither egg weight, specific gravity, fertility nor livability was affected by treatment, which indicates an advantage to advancing the initiation of full feeding of broiler breeder pullets. The results are in general compatible with the notion that high-versus medium-or-low-body-weight pullets exhibit significantly improved % hen-day production (Lilburn and Myers-Miller, 1990b).

Experiment 3

The results of this experiment revealed that the overall performance of broiler breeders is progressively improved by elevating the total amount of daily feed intake from 150 to 177 g while the dietary ME was held constant at 500 kcal (T4 vs. T5). The progressive improvement in growth, sexual stimulation and feed utilization was very marked during the first 35 weeks, then diminished. The positive effect of increased feed intake during the prelaying period on early egg production was reported by several workers (Cave, 1984; Brake et al., 1985; Lilburn et al., 1987). Lilburn and Myers-Miller (1990a) reported that a high protein treatment resulted in a significant improvement in % hen-day production from 24 to 28 and from 28 to 32 weeks of age without egg weight being affected. With respect to the protein: energy ratios of diets fed in T4 and T5 (0.048 vs. 0.0566 g/kcal ME) of this study, the response to increased total amount of daily feed intake may be attributed to the increased intake of protein and essential amino acids which stimulate tissue synthesis and enhance feed efficiency for growth. Moreover, the age dependent nature of the response may be due to decreased requirements for protein and essential amino acids with age (Boomgaardt and Baker, 1973; NRC, 1984). The results might suggest also some kind of inherent physical or physiological effects (i.e., gut fill, additional exercises for utilization of the extra feed and dense vs. diluted energy intake) mediated by total amount of daily feed intake.

Dietary treatment 1 (T1) supported satisfactory performance through 35 weeks of age despite its relatively low dietary energy (425 kcal ME); however, after 35 weeks of age the treatment did result in an early reductions in the rate of body weight gain, egg production and feed efficiency, which were significant. This poor performance indicates the inadequacy of 425 kcal ME at this stage of production to satisfy the increasing demand for productive energy as well as energy for maintenance which is body weight dependent. Nevertheless, the positive effect of the treatment through the early stages of production can be explained by the fact that the protein:energy ratio of T1 (0.0565 g/kcal ME) was equivalent to that of T5, which was apparently an optimum level for this stage. Pearson and Herron (1981) reported a detrimental effect of protein:energy ratio greater than 0.0628 g/kcal ME.

Treatments 2-4 (450-500 kcal ME) on the other hand, did not improve growth rate or performance prior to or during the early weeks of production as they did post 35 weeks of age. This was apparently due to the higher calorie:protein ratios of these treatments which could likely result in accumulation of excessive body fat instead of lean tissue which is capable of triggering sexual maturity. The overall performance of T2 (450 kcal ME) was equivalent to or better than those of T3 or T4; however, due to interactions of calorie-protein ratios prior to or during the early stages of production as well as thereafter, the results indicate the importance of subjective phase feeding and therefore suggesting further investigations.

Based upon results reported herein, one may conclude that light intensity changes at peak egg production had no significant effects on performance of broiler breeders under conventional-type housing; however, persistent high vs. low light intensity tended to advance and improve the age and % egg production at peak, respectively. This effect subsequently resulted in more eggs per hen.

Commencement of *ad libitum* (ca. 540 kcal ME/bird/d) feeding at 24 weeks of age improved most of the performance traits except feed utilization, which suggests the adoption of dietary energy greater than 435 and less than 540 kcal ME/bird/d for broiler breeders during lay. On the other hand, the results of the second experiment indicate that an abrupt increase of restricted broiler breeder pullets to a daily allowance of 500 kcal ME/bird as early as 15 weeks of age produced significantly better performance in terms of rate of production, feed efficiency and early sexual maturity than do similar programs initiated at 18 weeks of age or later.

The results provide evidence also that daily intake of 425 kcal ME/bird and a calorie:protein ration of 0.0565 g/kcal are sufficient for skeletal and lean body development during the early stages of the pullet-layer transition, but not adequate to satisfy the increased demand for net energy during peak egg production. The results apparently indicate also the disadvantage of feeding similar calorie:protein ratios throughout the entire laying period. And above all these indications, the results highlight also the importance of total energy consumption relative to that of protein to satisfy production requirements during the pullet-layer transitional period rather than amount of energy or percentage of protein per se in the diet .

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SUMMARY

Two studies, each consisting of 3 experiments were conducted during a 3-year period to assess the influence of light and feeding management on sexual maturity and subsequent performance of broiler breeder pullets. Study 1 was conducted in a windowless house through 45 weeks of age; study 2 was undertaken in a windowed house for 64-65 weeks. Study 1 experiments investigated: 1) the effects of light intensity changes during photostimulation on sexual maturity and subsequent egg production; 2) the effect of an 8L:16D "black-out" versus natural daylength rearing programs; and 3) effect of rearing and stimulating photoperiods on productivity of broiler breeder pullets. Investigated in the second study were: 1) effect of light intensity changes and feed allowance during lay on egg production; 2) optimum age and body weight of sexual maturity in broiler breeders; and 3) the daily ME requirement of broiler breeder hens.

Results obtained indicate that light intensity changes during photostimulation or lay have no effect on either age or body weight at sexual maturity or on egg production through 45 or 64 weeks of age in windowless or windowed houses. However, persistent high versus low light intensities from hatching tended to enhance egg production in a windowed house via achievement of earlier and higher % peak egg production. No significant interaction between light intensity and feed allowance was observed with respect to any of the measured traits.

The results provided also substantial evidence that rearing photoperiod is a key factor in light management. From data obtained one may conclude that: 1) the responses of the reproductive system of broiler breeder pullets to a given day length are not the function of that daylength but mainly of the previous photoperiodic history; 2) photoperiodic control does improve performance and feed utilization. Likewise, the results indicate that there indeed exists an optimum age (172 d) and/or body weight (3.4 kg) at sexual maturity. Increases in egg size and weight as well as flock uniformity would occur if broiler breeder pullets were reared under restricted light (8-10h) and restricted feed (per the breeder's recommendations) to

17 weeks of age then simultaneously photostimulated and increased to a daily energy allowance of 500 kcal ME/bird at 18 weeks of age. Similar results can be obtained also by increasing broiler breeder pullets (fed per the breeder's specifications) to 500 kcal ME/bird/d at 15 weeks of age in a conventional-type broiler house. A combination of light and feeding management at a younger age (i.e., less than 18 wks) is expected to determine the minimum age at sexual maturity which may be important from a genetic perspective. This effect, however, requires additional investigation.

The results described herein revealed also that *ad libitum* versus restricted feeding through the laying period significantly improved various aspects of performance but depressed efficiency of feed utilization. Similar results were obtained when birds were fed high versus low total amount of diet at equal energy intakes (500 kcal ME). The positive effect of a greater amount of daily feed intake was attributed to the relatively high (0.0566 vs. 0.048 g/kcal ME) protein:energy ratio which is apparently required during the pullet-layer transitional period.

Birds assigned to daily consumption of 425 kcal ME/bird exhibited the poorest performance during lay in comparison to those fed higher dietary energy concentrations (450-500 kcal ME/bird/d); however, the performance of these birds through 35 weeks of age was equivalent to or better than that of those on the higher dietary concentrations. The reason behind this improvement was concluded to be related to protein:energy ratio (0.0565 g/kcal ME) which was similar to that of the higher total amount of daily feed intake. Further, these results strongly suggest the importance of total energy consumption relative to protein to satisfy production requirements with respect to stage of production rather than the amount of energy per se in the diet.

VITA

Abbaker Ali Idris was born January Ist, 1955 in Kulbus, North Darfour Province, Sudan. He received his public education from Kulbus Elementary School, El Genaina Intermediate Secondary School and was graduated from High Secondary School of El Fasher in 1974. Following graduation, he worked for two years as a teacher in the same Elementary School where he started his journey of education. In 1976, he entered the Faculty of Veterinary Science, University of Khartoum, receiving a Bachelor's degree in Veterinary Science with honors as the best final year student of 1981. In the same year he was employed as a teaching assistant by the University of Khartoum, Institute of Animal Production. He enrolled in the Graduate School of the Khartoum University in 1982 where he obtained his M. V. Sci. degree in 1985 with concentration in Nutrition. In June 1986, he was awarded study leave from Khartoum University to study abroad. In Spring 1987, he entered the Graduate School of the University of Tennessee, Knoxville. That same year he was married. His Ist son was born in March 1989. He was granted the Ph. D. degree in Animal Science with emphasis on Poultry Management and Nutrition in December 1990.

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