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THE EFFECTS OF TIMING OF PHOTOSTIMULATION ON THE CARCASS COMPOSITION AND REPRODUCTIVE EFFICIENCY OF COMMERCIAL EGG-TYPE AND MEAT-TYPE FEMALE CHICKENS

BY

TRACI A. WAUTIER 

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **The Effects of Timing of Photostimulation on the Carcass Composition and Reproductive Efficiency in Commercial Egg-type and Meat-type Female Chickens** submitted by Traci A. Wautier in partial fulfillment for the degree of Master of Science in Avian Reproductive Physiology.

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ABSTRACT

Photoperiod management is widely used to manipulate the onset of sexual maturity in egg (SCWL) and meat-type (broiler breeder) chickens. Typically, SCWL pullets are reared under conditions of short days (8L:16D) until 126 days of age whereas, broiler breeders are kept under short days until 140 days of age. The effect of age at photostimulation on carcass composition at photostimulation and sexual maturity as well as its effect on subsequent reproductive performance in broiler breeders and SCWL hens was investigated. Six hundred broiler breeder pullets (Shaver Starbro) were obtained and reared in light-tight facilities. Some birds were selected for study and moved to laying cages at 120, 130, 140, 150, or 160 days of age (40 birds per treatment group). Skip-a-day feeding was used after 2 wks of age to control body weight to that level suggested by the breeder. Limited daily feeding was initiated at the time of caging (time of photostimulation). The photoperiods during rearing and lay were 8L:16D and 14L:10D, respectively. Individual egg production records were kept to 58 wks of age. A flock of 1600 SCWL pullets (Shaver 288 Strain) were housed in floor pens in light-tight facilities (8L:16D). All birds were provided with ad-libitum access to both feed and water. At 112 days, 126 days, and 140 days, 50 birds per treatment were moved to laying cages and subjected to a photoperiod of 14L:10D. Also at these times, 288 birds per treatment group were doubly caged and group production and feed consumption records kept. Data were collected to 64 wks of age.

The broiler breeder experiment showed significant differences in carcass composition at the time of photostimulation for body weight, dry matter, water, lipid, and ash content. As the age at photostimulation increased, body weight and lipid content of the carcass increased while water and ash content decreased. No significant differences were found between treatment groups at photostimulation for protein content. At sexual maturity, body weight differences between treatment groups were lessened due to feed restriction practices employed to limit body weight gains. No significant differences were found in dry matter, water, protein, lipid, or ash content. All groups showed an increased in lipid content from photostimulation to sexual maturity with the 120 d treatment group showing the largest increase. As age at photostimulation increased

the time required to reach sexual maturity (after photostimulation) decreased. Total egg production, first egg weight, average egg weight, total egg mass produced, average fertility, average hatchability, and average hatch of fertile did not differ significantly between treatment groups. However, chick production was significantly higher in the 140, 150, and 160 d treatment groups as compared to the 120 and 130 d treatment groups. Birds responded to delayed sexual maturity by increasing prime sequence length and decreasing the number of pause days.

Signficant differences were found in dry matter, water, lipid, and ash content between treatment groups at the time of photostimulation for SCWL pullets. No significant differences were found in carcass protein content between groups at the time of photostimulation. At sexual maturity, carcass lipid content was significantly different between treatment groups. Lipid content increased for all groups between photostimulation and sexual maturity with the 16 wk treatment groups showing the largest increase. The time required to reach sexual maturity from the time of photostimulation decreased as the age at photostimulation increased for the SCWL hens. No significant differences were found in total egg production, first egg weight, average egg weight, and total egg mass produced between treatment groups. Delaying sexual maturity resulted in increased prime sequence length and fewer pause days to produce approximately the same number of eggs.

For the hatching egg producer whose primary concern is chick production photostimulating at 140 d of age would produce hens with better fertility and hatchability and also better chick production. However, the results of the broiler breeder do suggest that photostimulating at 140, 150, or 160 d of age is better than photostimulating at 120 or 130 d of age in terms of chick production. The results of the SCWL trial suggest that 18 or 20 wks of age are perhaps better times to photostimulate than 16 wks of age because the birds seem to have better body reserves to attain peak production and persistency of lay.

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Introduction

The modern hen (*Gallus domesticus)* can be divided into two types: the egg-type laying hen versus the meat-type hen. While the egg-type hen is a high producing, easily managed bird the meat-type hen requires strict body weight management procedures to maximize production. Genetic progress has increased the growth performance of broilers (offspring of these meat-type hens) and obviously the parents also demonstrate this propensity for high weight gain. It has been demonstrated that large body weight gains in broiler breeder hens are detrimental to the reproductive performance of these birds (Robinson *et al.*, 1993). In order to offset these weight gains, feed restriction practices are used to limit body weight gain and therefore maximize reproductive output.

Photoperiod management is widely used to determine the onset of sexual maturity in egg and meat-type pullets. Typically, SCWL pullets are reared under conditions of short days (8L:16D) until 126 d of age, whereas broiler breeders are kept under short days until 140 d of age. A typical production curve for a flock of laying hens shows that egg production increases rapidly during the first 5-8 wks after the first egg is laid, reaches a maximum, and then declines until the end of the production period. A SCWL hen may lay as many as 300 eggs per production period. Robinson *et al.* (1990) obtained 184 eggs per hen with restricted fed broiler breeders. Thus there is a large difference in the reproductive performance of these two types of hens.

Sexual maturity in female chickens is signalled by the onset of lay. The attainment of sexual maturity is the result of a complex series of physical developmental and physiological processes (Eitan and Soller, 1991a). Photoperiod manipulation is used to regulate the age at which hens reach sexual maturity as they are very dependant upon environmental stimuli, particularly appropriate photoperiod. Manipulation of the photoperiod has provided evidence of weight and age thresholds for onset of sexual maturity in both types of female chickens (Eitan and Soller, 1991a). However, the suggestion that there may be a prerequisite body mass or endogenous biological clock for onset of sexual maturity is still under study (Bornstein *et al.*, 1984).

Reproductive Organ Morphology

Ovary Morphology

In the chicken, the left ovary is the only functional ovary and it is situated in the left, cranial region of the abdominal cavity adjacent to the vena cava and aorta (Gilbert, 1971; 1979; 1984). The ovary is a heterogeneous organ containing cell types in various stages of maturation and involution that are capable of producing, in various stages of their development, estrogens, androgens, progestagens, and prostaglandins (Etches, 1990). The ovary of a SCWL hen contains several thousand small white follicles (SWF)(< 1mm), 10-20 large white follicles (LWF) (2-3mm), 5-10 small yellow follicles (SYF), and 7-10 large yellow follicles (LYF) (> 10mm) (Robinson and Etches, 1986). The major difference between the two stages of yellow follicles is their content of yellow yolk. Immature follicles contain several layers of granulosa cells that subsequently become a monolayer in a large, yolky follicle. The thecal tissue and its vascular supply are less well developed in an immature follicle (Etches, 1990).

There are five portions of the oviduct (Aitken, 1971). The first is the infundibulum which is a thin, lightly muscularized tissue, and acts as a funnel which engulfs the ovum as it is released by the ovary. The infundibulum is also the site of fertilization. Next is the magnum which is the longest portion of the oviduct. It is lined with albumen secreting glands. Albumen deposition takes 2-3 hrs. The isthmus follows the magnum and it is here that membrane formation around albumen takes place. Following the isthmus is the shell gland or uterus in which calcium carbonate deposition takes place in a protein matrix to form a hard shell and any pigmentation is also added. Shell deposition takes approximately 20 hrs. The egg then passes through the last portion of the oviduct the vagina, where the cuticle is added, which opens into the cloaca and the egg is expelled. This process is called oviposition.

Ovarian Development

During the first 14 to 15 wks of life, the ovary grows slowly and contains only follicles less than 3mm in diameter (Etches, 1990). After 15 wks of age, a small amount of estrogen production is present in the hen (Peterson and Webster, 1974). It is assumed

that the source of this estrogen is the ovary since it is known that small follicles contain aromatase (Armstrong, 1984; 1985), are a rich source of estrogens (Etches *et al.*, 1984), and produce large amounts of estradiol in vitro in both the presence and absence of luteinizing hormone (LH) (Robinson and Etches, 1986; Lupicki *et al.*, 1993).

When the hen is photostimulated by an increasing photoperiod, for example from short (8L:16D) to long (14L:10D) days, the plasma concentration of LH rises rapidly from a base of < 1.5 ng/ml to a plateau of 6 ng/ml (Wilson and Cunningham, 1980). This change in the plasma level of LH accompanies the appearance of secondary sexual characteristics such as reddening of the comb, oviduct development, formation of medullary bone, and vitellogenin production by the liver (Etches, 1990).

The physiological mechanism that regulates growth and order of the ovarian hierarchy is not well understood. However, each follicle in the hierarchy, regardless of size, is subjected to each preovulatory surge of LH (Etches *et al.*, 1981). Therefore, some follicles may experience several hundred surges of LH before they ovulate. The acquisition of the ability to ovulate appears to take place in the cycle preceding ovulation.

Atresia is a common fate in the pool of small follicles, but once follicles enter the yolk-filled hierarchy, atresia is a rare event that can only be initiated by metabolic disturbances such as hormone injection, disease, or starvation (Gilbert *et al.*, 1981; 1983; Etches et al., 1984).

Neuroendocrine control of ovulation

The hypothalamus is an essential component of the neuroendocrine system controlling ovulation (Follett and Davies, 1979). A rising or high concentration of progesterone causes gonadotrophin-releasing hormone (GnRH) to be released into the hypothalamic/anterior pituitary portal system (Etches, 1990). The pituitary gland produces follicle-stimulating hormone (FSH) and LH which are gonadotrophins, i.e. they act directly on the gonads. In hens, the functions of LH are to cause follicular rupture and ovulation (Fraps, 1965; Lang *et al.*, 1984) and to promote steroidogenesis (Etches *et al.*, 1983; 1984; Robinson and Etches, 1986; Robinson *et al.*, 1988). Plasma levels

of LH reach a nadir 11 hrs prior to ovulation, a peak 4 to 6 before ovulation, decrease during the periovulatory period, and are maintained at relatively high concentrations during the middle of the ovulatory cycle (Etches, 1990). The preovulatory rise in the plasma concentration of LH has been associated with the preovulatory production of ornithine decarboxylase (Armstrong, 1986), progesterone, androgens, and estrogen and is the stimulus for follicular rupture (Etches, 1984). Progesterone is produced by the granulosa cells of the five largest preovulatory follicles, and its production is stimulated by the addition of LH in vitro and in vivo (Etches *et al.*, 1983). Due to the paracrine control of follicular steroidogenesis, the theca restricts progesterone production by the granulosa, only the largest preovulatory follicle (F1) secretes progesterone into the systemic circulation during the preovulatory LH surge (Etches *et al.*, 1981; Johnson *et al.*, 1988). This increase in the plasma concentration of progesterone initiates a positive feedback response from the hypothalamus to increase the secretion of GnRH into the hypothalmic pituitary portal system. Increased GnRH causes an increase in LH secretion from the adenohypophysis that, in turn, augments the production of progesterone from the F1 follicle. Androgens are produced by the small ovarian follicles and all but the largest of the large yolky follicles (Robinson and Etches, 1986). The majority of estrogens produced by the ovary of the laying hen are from the small follicles (Senior and Furr, 1975; Robinson and Etches, 1986). The theca cells of the large yolky follicles are capable of producing small quantities of estrogens, but this capability declines to undetectable levels as the follicles move from the fifth to the first position in the hierarchy. The granulosa tissue does not contain or produce detectable levels of estradiol (Bahr *et al.*, 1983; Wang and Bahr, 1983; Etches and Duke, 1984). High concentrations of estrogens, either alone or in combination with androgens, are required to sensitize the hypothalmic-pituitary axis to the positive feedback effects of progesterone (Wilson and Sharp, 1976), to stimulate vitellogenin formation in the liver (McIndoe, 1971), to regulate calcium metabolism (Etches, 1987), to stimulate and maintain a functional oviduct, and to maintain secondary sexual characteristics.

Control of ovulation

The onset of reproduction is stimulated by increasing daylength. The current understanding of this process is that light stimulates deep encephalic photoreceptors in the ventral forebrain, possibly the medial basal hypothalmus (Kuenzel, 1993). Photostimulation initiates two signals to GnRH-1 neurons in the hypothalmus (Sharp, 1993). One input is positive, causing a release of GnRH and the other a negative input, is slower to develop. GnRH causes a release of gonadotropin from the adenohypophysis, gonadotropin stimulates the production of LH which initiates the production of dehydroepiandrosterone (DHEA), androstenedione and estradiol in the small follicles (Robinson and Etches, 1986). Gonadotropins also stimulate the production of prostaglandins (PGs) in the granulosa cells of the SWF, the conversion of progesterone to testosterone in the thecal cells, and the production of estrogens in thecal cells and to a small extent in granulosa cells (Etches and Duke, 1984). Follicle recruitment may be the result of either hormonal or direct nervous stimulation of small follicles in the ovary. The exact mechanism of recruitment is unknown, but it is reasonable to say the combination of the events stimulated by the increased photoperiod results in the recruitment of follicles into a rapid growth period when yolk is deposited at an accelerated rate. The result of the successive recruitment of follicles into the rapid growth phase is the formation of the preovulatory follicular hierarchy.

Photostimulation results in increased steroidogenesis. In response to increased plasma estrogen levels, the liver produces vitellogenin (McIndoe, 1971). Following follicular recruitment, yolk is manufactured from these precursors, and deposited around the outside of the follicles rapidly for a period of 7-11 days in the chicken (Grau, 1976). When follicles mature, the theca cells lose their ability to metabolize progesterone to androstenedione (Robinson and Etches, 1986). The F1 acquires the ability to produce progesterone, while estradiol 17-B and androstenedione production is slowed. A mature follicle is an F1 follicle which has acquired the ability to ovulate in response to the preovulatory surge of LH. Progesterone levels increase because of the increased progesterone production in the F3-F1 follicles, and the lost ability to convert progesterone to androstenedione (Robinson and Etches, 1986, Yu *et al.*, 1991; 1992b).

When a mature follicle is present, positive feedback by progesterone and GnRH continues until the mature follicle responds to the LH surge by ovulating (Shimada and Satio, 1989; Etches, 1990). Oviposition is restricted to a 6-8 hr period of the lighting regime, provided that at least 1.25 hrs of darkness is included in each cycle (Etches, 1990). A sequence begins when an egg is laid at the beginning of the distribution that is characteristic of the current photoperiod. Subsequent eggs in the sequence are laid on consecutive days, and each egg is laid slightly later during the day. After the last egg in the sequence is laid, an interval of 40-44 hrs elapses before a new sequence is initiated. This has been called the "pause day".

Regardless of the photoschedule, oviposition precedes ovulation of the next egg in the sequence by 0.5 to 1.0 hrs. The exception to this occurs with the final egg of the sequence when oviposition is uncoupled from ovulation. Under 24-hr photoschedules the first ovulation of a sequence precedes oviposition by 27 hrs (Fraps, 1947). The "open period" for LH release constrains the release of gonadotropins to an approximately 8 hr period of the day.

Follicular Maturation Rate

Ovulation rate in the hen depends on the rate of follicular maturation and the duration of the 'open period' for luteinizing hormone (LH) release (Fraps, 1955; Etches and Schoch, 1984). Therefore, ovulation rate, and oviposition rate, may be reduced as a consequence of a decreased rate of follicular maturation or recruitment (Williams and Sharp, 1978a; Joyner *et al.*, 1987), by a shortening of the duration of the 'open period' or both. Ovulation is restricted to a certain portion of the day and this restriction is the result of a circadian rhythm in some component of the physiological system controlling ovulation (Etches, 1990). This hypothesis is based on the assumption that ovulation occurs when a 'mature' follicle is present in the ovary during the part of the day when ovulation is possible. The 'open period' for ovulation lasts about 8 h in the chicken (Etches, 1990). In the chicken, the final stage of maturation of the second largest preovulatory follicle begins when the largest preovulatory follicle is ovulated and this takes 24 to 28 h. Sequential ovulations are separated by 24 to 28 h. It is assumed that

all follicles except for the largest are nonovulable, when the largest follicle has ovulated and the second largest has taken its position a physiological maturation process begins, this process takes 24 to 28 h, and maturation can therefore be defined as the ability of the largest preovulatory follicle to ovulate in response to the preovulatory surge of LH (Etches, 1990).

Oviposition precedes ovulation of the next egg in the sequence by 0.5 to 1.0 h, except following oviposition of the last egg in the sequence when oviposition and ovulation are disconnected. The timing of ovulation is the result of a changing threshold and not the a specific 'on/off' signal (Etches, 1990). This statement is supported by the observation that the shortest interval between successive eggs occurs at the middle of sequences and the largest intervals occur at the beginning and end. If it were an 'on/off' signal then each successive oviposition would be equally spaced throughout the 8 h open period.

Egg Production and Sequence Length

A typical production curve for a flock of laying hens shows that egg production increases rapidly during the first 5 to 8 wks after the first egg is laid, reaching a maximum, and then declining until the end of the production period. Producers, in general, aim to maintain perisistency of lay, i.e. lessen the rate of decline after peak production is reached. Production parameters commonly measured are age at 50% production, peak rate of lay expressed as a percentage, and average cumulative egg production per hen. The peak rate of lay is a measure of the maximum number of hens laying at a maximum rate (Etches, 1990). Egg production declines after peak because some hens stop laying and because the rate of lay of individuals begins to decline. The rate of decline varies due to strain, nutrition, and environmental conditions also (Robinson *et al.*, 1990). The term 'prime sequence' refers to the highest number of consecutive days on which an egg is laid before there is a pause day. Robinson *et al.* (1990) found a strong correlation between length of the prime sequence and total egg output, $r=0.399$. This is understandable because the longer the prime sequence the fewer the pause days and the more eggs produced. In SCWL birds the average prime

sequence length is approximately 80, whereas with broiler breeders the average prime sequence length is approximately 40 (Robinson *et al.*, 1990). The high rate of egg production in laying hens is the result of the high degree of synchronization of the ovarian cycle; which controls the maturation of follicles, and the circadian control, which limits the open period for the release of LH from the anterior pituitary (Etches, 1990). Compared with egg-type laying hens, broiler breeders lay approximately half as many eggs yet they have more yellow ovarian follicles in rapid development (Jaap and Clancy, 1968; Hocking *et al.*, 1987). A Leghorn hen may lay as many as 300 eggs per production period, with a prime sequence length of 120 days. Robinson *et al.* (1990) obtained, with restricted fed broiler breeders, 184 eggs per hen with a peak mean sequence length of 19 eggs at 32 weeks of age. The hens averaged 48 sequences with a mean sequence length of 4.1 d. Leghorn hens lay more eggs than broiler breeder hens because of their longer prime sequence length, longer sequence lengths, and therefore there are fewer pause days.

Factors Affecting Egg size

Leeson *et al.* (1990) found a significant linear relationship between a proportion of small, medium, large, and extra-large egg sizes and increasing mature body size. The percentage of small, medium, and large size eggs decreased with increasing body weight at maturity, whereas the percentage of over-size eggs increased with increasing body size. Therefore, total egg mass increased significantly as mature body weight increased. Leeson and Summers (1981) indicated that reduction in egg size was the major problem resulting from early maturity of Leghorn pullets. Fuller *et al.* (1968) found that early maturing birds while laying more small eggs, also laid more oversize eggs during the early part of the laying period. A relationship may also exist between early maturity and the production of soft and thin-shelled eggs. Berg *et al.* (1963) reported that with Leghorns, increased photoperiod and full feeding, both of which were associated with early maturity, resulted in more double-yolked eggs at the onset of production.

Effect of Body Weight on Egg Production

In broiler breeders, low egg production results from *ad libitum* feeding which causes the development of a double follicular hierarchy (Hocking *et al.*, 1987; Yu *et al.*, 1992b; Lupicki *et al.*, 1993). Also when given *ad libitum* access to feed broiler breeders develop more large follicles than do egg-type hens (Jaap and Clancy, 1968; Hocking *et al.*, 1987). Restricted feeding, in broiler breeders, during rearing limits the number of large follicles in the ovary (Hocking *et al.*, 1989; Robinson, 1990) and may decrease the incidence of double hierarchies and the production of defective eggs (Whitehead and Hocking, 1988; Robinson, 1990). Hocking *et al.* (1986) found that atretic yellow follicles were common among broiler breeders, but not in Leghorns or restricted dwarf broiler breeders when the first egg was laid. They found poor egg production in older broiler breeders was caused by birds with few or no developing yellow follicles, atresia in yellow follicles and the continued occurrence of multiple ovulations. Atresia of yellow follicles is unusual in egg-type hens except at older ages (Gilbert *et al.*, 1981; 1983) but was very common in young *ad libitum*-fed dwarfs and normals (breeders). Johnson and van Tienhoven (1984) showed that more defective shells were produced initially by layers reared on *ad libitum* feeding rather than a restricted rearing regimen, suggesting a common cause of improved egg production in restricted layers and broilers. Gilbert et al. (1983) proposed two mechanisms for generating the yellow hierarchy; one initiating growth and a second controlling atresia. They concluded that the major mechanism governing egg production in the fowl is the control of atresia among white follicles, or its converse, the rate of recruitment to the yellow hierarchy. Atresia of yellow follicles may be related to relatively low food intake. Body fat is probably not the cause of low egg production in broiler breeders or aged layers (Chaney and Fuller, 1974; Hocking *et al.*, 1985). The physiological control of atresia among small white follicles appears to be the most likely reason for low egg production in both types of birds. As birds age, low egg numbers are associated with high rates of atresia among the white follicles and low numbers of ovulable yellow follicles (Hocking *et al.*, 1987).

Other Causes of Low Egg Production

Reductions in egg laying towards the end of the year have been associated with the increasing incidence of follicular atresia (Williams and Sharp, 1978a; Waddington *et al.*, 1985). Egg output can also be lost due to a condition known as erratic oviposition and defective egg syndrome (EODES) (van Middelkoop, 1972). In general, losses in egg production result from one or more of the following occurring: losses prior to ovulation (altered rate of follicular maturation, follicular atresia and/or increased incidence of inter-sequence pauses of greater than 1 d duration), losses at ovulation (altered incidence of internal laying) or losses post-ovulation (retrograde transport in oviduct or shell deposition impairment) (Robinson *et al.*, 1990).

Effect of Time of Photostimulation on Age at Sexual Maturity

In chickens, sexual maturity is signalled by the onset of lay (Eitan and Soller, 1991a). Recently, poultry breeders have been selecting for earlier sexual maturity (Arthur, 1985) and this has resulted in an advance in the optimum age at which to light stimulate pullets. It is advantageous to have pullets begin laying earlier because research indicates that the age at sexual maturity can influence egg size and the number of eggs produced in the subsequent laying period (Shanaway, 1983). In a trial with SCWL birds, Leeson *et al.* (1990) found that with increasing age at light stimulation birds were larger at the end of the trial, laid larger eggs, and consumed more feed. They also found that age at lighting had no effect on total number of eggs laid or total egg mass produced. There was also no indication of increased growth when birds were exposed to 14 hrs light at 15 wks of age vs. control birds maintained on 8 hrs light to 21 wks. This coincides with another experiment by Leeson and Summers (1987) whereby they found that pullets that were underweight at the time of photostimulation did not exhibit compensatory growth. These experiments suggest that as long as adequate weight for age is achieved, then age at light stimulation may by less important. Also because birds that are underweight at light stimulation do not show compensatory growth, we can assume that the onset of sexual development predominates over growth in terms of nutrient use.

Effects of Age at Photostimulation on Egg Size and Production

Early attainment of mature body size and composition resulted in early onset of egg production (Leeson and Summers, 1982). Some controvery does exist on the effect of age at maturity on egg characteristics. Fuller *et al.* (1969) observed that early maturity not only caused more small eggs but also more oversize eggs. Harms et al. (1979) also found that early maturity resulted in a reduced number of "normal grade eggs". However, Abbott and Couch (1971) indicated a significant decrease in double-yolk eggs with early sexual maturity. Egg-strain birds showed no loss in egg number contrary to the results of Leeson and Summers (1982) with broiler breeders. Greater weight for age with broiler breeder pullets suggests the potential for earlier induced maturity. With a 20% increase in feed allocation in the growing period, egg production started 4 wks after light and diet stimulation were introduced, peaking within a 4-week period. However, these birds failed to maintain egg production, with a 10% decline to 60% production by 28 wks of age. A similar pattern was observed for birds fed either 5 or 10% extra feed during rearing. With the control group, production started at 23 wks of age, peaked at 28-30 wks, and showed no sign of reduced production to the end of the trial. Up to peak production, comparable weights were seen because feed intake and egg production were similar. After peak, the early maturing birds gained more weight than the control birds, even though feed intake was identical, giving evidence of hens putting feed energy into body mass rather than egg production. Reduced egg size for the Leghorn birds was attributed to reduced body size as well as immmature body composition. With the broiler breeder pullet, both mature body size (2.1kg) and body composition were attained but persistency of production was not. Brody *et al.* (1980) concluded that a minimum body weight must be reached before broiler breeders begin laying. However, from the study of Leeson and Summers (1982), it is evident that broiler breeders can attain this weight by 14 to 15 wks of age and show signs of reproductive development, but sexual maturity does not occur until 21 to 25 wks which suggests the possibility of a minimum age requirement as well. These experiments also suggest a difference in the factors affecting sexual maturity in broiler breeders and Leghorn pullets.

Ernst and Mather (1992) found that SCWL pullets exposed to lighting at 126 d of age peaked in production first and began to decline slightly before those exposed to lighting at 136 d or 146 d of age. When pullets reached 66 weeks of age, there were no significant differences in eggs per hen housed or percent hen-day production. The significant negative linear relationship between the age at which birds were light stimulated and the number of eggs produced suggests that as the days to 50% egg production increased, the number of eggs per hen housed decreased. The mean egg weight and egg mass were not influenced significantly by the date at which the birds were housed. Lighting pullets at 136 or 146 d of age resulted in a significant decrease in the percentage of small eggs but no significant improvement in egg value per hen housed. Body weight was not affected by age at which light stimulation occurred. Specific gravity of eggs was significantly lower for pullets lighted at 136d of age, but this was a very small difference and is not judged important from a practical standpoint. Ernst and Mather (1992) concluded that there is no advantage in delaying light stimulation beyond 18 wks of age with the Hy-line W-36 strain of commercial Leghorns. Earlier lighting and moving resulted in the production of more small eggs, but the value of eggs produced to 66 wks of age did not differ with lighting treatment, and egg production and egg value were negatively correlated with age at 50% production, suggesting that earlier light stimulation was more profitable with regard to these variables with the conditions used in this study.

A reduced capacity to respond to hormone signals is involved in decreasing egg production rates with time. Johnson *et al.* (1986) found that the response of the largest follicles to LH decreased with age. Williams and Sharp (1978b) found that the hypothalamus was not as responsive to progesterone feedback in older hens. Decreased estrogen production observed in old hens may be responsible for decreases in follicular recruitment and growth (Bahr and Palmer, 1989), as yolk and albumen precursors would be negatively affected (Gruber, 1972).

Prerequisites for sexual maturity

It has been speculated that there may be a minimum requirement for age, body

weight, body composition, body length, or growth rate for sexual maturity to occur in the female (Frisch, 1974; Brody *et al.*, 1980; ; Soller *et al.*, 1984a). Pullets are reared on 8-10 hr constant daylengths because this usually delays maturity and improves egg size. Success with earlier maturing pullets depends on attainment of adequate body weight gain according to Leeson and Summers (1981). Eitan and Soller (1991a, b) concluded that age at onset of lay differed markedly for broiler breeds, but not for Leghorn hens, as a function of light treatment. Particularly the modern broiler showed greater sensitivity to light blackout than the Leghorn birds. Their conclusion was that the rate of development of the reproductive tract from onset of responsiveness of the hormonal system to light stimulation, is strongly dependent on the degree of light stimulation in broiler breeds, but much less so in layers. This suggests a negative correlation between responsiveness to light stimulation and growth-rate. Different genetic stocks mature at different ages under the same photoschedule (Bowman and Jones, 1963; Proudfoot and Gowe, 1967; 1974).

Fertility, Hatchability, and Hatch of Fertile

Fertilization is defined as the union of sperm from the male with the egg or ovum of the female. Hatch of fertile is the term used to describe embryonic viability. This term is the inverse of the rate of embryonic mortality. In order for an egg to hatch it must be fertile, and the term hatchability is defined as the interaction between fertility and hatch of fertile. In hatching egg production, these three parameters are very important to the producer because it is the production of viable offspring that determines the profitability of the business.

Effect of Age on fertility and hatchability

As mentioned previously, a decrease in egg production occurs with all strains of birds with increasing age but in broiler breeders there is a larger drop than in Leghorns. Along with this decreased production there is also a decline in fertility and hatchability (Atwood 1929; Kirk *et al.*, 1980; Bahr and Palmer, 1989; Etches, 1990; Robinson *et al.*, 1990). The effect of age on fertility and hatchability may be caused by increased

incidence of atresia and internal laying, decreased follicular recruitment into the hierarchy, decreased shell quality, or a reduced ovulation rate (Bahr and Palmer, 1989). When ovulation rate is reduced the hen consequently has shorter sequences and an increase in the incidence of 'first of sequence' eggs (Atwood, 1929; Robinson *et al.*, 1990). For the first egg of a sequence, it takes approximately 40 h for that egg to be laid from the time of oviposition of the last egg compared with 24 h for the other eggs in a sequence (Etches, 1990). Therefore, the mature F1 follicle from the first of sequence eggs is in the ovary for about 16 h longer than the F1 follicles of the next eggs. This may be related to the decreased fertility and hatchability seen in first of sequence eggs. In broiler breeders, which have shorter sequences early and late in their production periods, there are more first of sequence eggs and lower fertility, hatchability, and viability values have been shown to correspond with these times (Robinson *et al.*, 1990). Robinson *et al.* (1991b) found that in broiler breeders there were no significant differences in fertility or viability at 7 d of incubation between the eggs in a sequence. However, they did find that the number of viable embryos per 100 eggs set (fertility by viability) was significantly reduced in the first of sequence eggs when compared with the rest of the eggs in the sequence. Fasenko *et al.* (1992) also found that the embryos of first of sequence eggs, while being developmentally advanced, were also less viable than embryos of subsequent eggs of a sequence. Hen age has been found to be significantly related to fertility and hatchability, it has been shown that both fertility and hatchability begin to decline at approximately 30 wks (Kirk *et al.*, 1980; Fasenko *et al.*, 1992). These decreases in fertility and hatchability as the hen ages may be due to older hens being less able to retain sperm in the uterovaginal sperm host gland which has been observed in turkeys (van Krey *et al.*, 1967; Christensen, 1981) and broiler breeders (Pierson *et al.*, 1988a), or a lower quality follicle.

Specific Gravity

Egg specific gravity has been used as a measure of shell quality (Godfrey and Jaap, 1949; Hamilton, 1982), and reductions in specific gravity have been associated with

increased bird age (Hamilton, 1978; McDaniel *et al.*, 1979; Roland, 1979) and depressed hatchability (Godfrey and Jaap, 1949; McDaniel *et al.*, 1979). The relationship of egg-shell quality to hatchability in aging birds is poorly understood. An egg must exchange adequate amounts of vital gases (carbon dioxide and oxygen) and lose 12 to 15% of its weight as water during incubation to insure successful hatching (Rahn *et al.*, 1979). McDaniel *et al.* (1981) found significant positive correlations among shell quality and fertility, and hen-day production and hatchability. Egg weight exhibited significant negative correlation coefficients with both hatchability and hen-day production. Body weight and its relation to decreasing fertility and hatchability may be due to accumulation of fat. Overall means for fertility, hatchability, and early and late dead embryos were significantly different between high and low specific gravity groups.

Effects of increasing egg weight

The weight of the ovum at ovulation increases steadily throughout the laying cycle, which is a reflection of the increased time needed to reach maturity (Bacon and Cherms, 1968; Sharp, 1989). The increase in yolk size directly relates to an increase in egg size (Bacon *et al.*, 1972), which results in a larger poult size (Shanaway, 1984). The yolk:albumen ratio increases in broiler breeder eggs with age (O'Sullivan *et al.*, 1991). Fasenko *et al.* (1992) found that fertility decreased as egg weight increased from a range of 55 to 65 g to a range of 65 to 75 g. One explanation for this effect is that the hen lays fewer but larger eggs as she ages due to decreased follicular maturation rate which means that the follicle could be subjected to preovulatory aging which may reduce oocyte quality and negatively affect its ability to be fertilized. Or, the reduced follicular maturation rate caused a reduced sequence length and therefore increased the number of first of sequence eggs and this may have also contributed to the decline in fertility seen with increasing egg weight. It has been shown that first of sequence eggs are heavier than the rest of the eggs in the sequence and may be more susceptible to preovulatory aging (Atwood, 1929; Robinson *et al.*, 1990). Shell weight increases with time (Rahn *et al.*, 1981), but shell quality declines slightly late in lay, as reflected in lower levels

of plasma calcium and phosphorus at this time (Strong and Nestor, 1978).

Effect of body weight on fertility and hatchability

In overweight broiler breeders, an infiltration of fat in the sperm storage glands at the uterovaginal junction can reduce sperm storage efficiency (McDaniel *et al.*, 1981), and reduced infundibular motility, both of which can lead to the production of fewer settable, fertile eggs. Liver lipids reflect the energy state of the bird, with higher lipid levels reflecting a more positive energy balance. It has been found that plasma low density lipoprotein concentrations in broiler breeders are closely related to body fat (Whitehead and Griffin, 1984).

Small differences in body weight do not influence fertility or hatchability to a great extent (Wilson and Harms, 1986; Fattori *et al.*, 1991; Robinson and Robinson, 1991), partly due to the fact that when hens are inseminated frequently, sperm storage problems are not encountered. However, there is evidence that embryo viability is affected by body weight. Most of the problems with embryo viability associated with body weight are related to the production of unsettable eggs which exhibit poor hatchability. Full-fed hens exhibit significantly reduced fertility and hatchability compared to hens that are feed restricted (Yu *et al.*, 1992a). It is noted that full-fed hens tend to lay erratically, i.e. outside of the normal period for ovipositon (late in the day or during the dark cycle). Erratic laying has been shown to result in reduced egg shell quality (due to a loss of coordination of ovulation and shell deposition) (Jaap and Muir, 1968; van Middelkoop, 1972; Katanbaf *et al.*, 1989b) and therefore exhibit increased moisture loss during incubation and an increased incidence of embryonic mortality (McDaniel *et al.*, 1981a).

Natural Mating Effects

When hens are artificially inseminated fertility remains high late in lay (O'Sullivan *et al.*, 1991). However, in naturally mating flocks there is a normal decline

in fertility with age (Kirk *et al.*, 1980), and most of this decline is attributed to males. Excessive weight gain during the rearing period and the resulting heavy body weight has a negative impact on breeder male fertility (Ingram and Wilson, 1987). As body weight increases, males are more susceptible to mechanical disorders involving feet and leg problems, and such problems interfere with normal mating activity (Burke and Mauldin, 1985).

Carcass Composition

Body Size

Body size bears a relationship to sexual maturity and egg weight. Selection for increased body size has also resulted in delaying sexual maturity and increasing the beginning egg weight (Lerner, 1945). It is not clear whether the beginning egg weight difference is due to the larger body size or to the later maturity of the size line. They concluded that early maturity depresses initial egg weight only in the smaller birds. In birds with greater body size, egg weight becomes a function of body size. Soller *et al.* (1984b) found that regardless of the degree of feed restriction during rearing, birds entered lay at the same lean body weight, ash, and protein content but at different age, carcass weight, dry matter and fat content. Bornstein *et al.* (1984) concluded that a high degree of fatness is associated with the onset of ovulation. Brody *et al.* (1980) found that hens maintained at a low mean body weight by feed restriction did not mature sexually. Restricted feeding results in both delayed maturity and a leaner carcass. Restricted birds matured later, had a much lower carcass fat content at maturity, laid more eggs and significantly larger eggs than full-fed, high energy controls which were not delayed. The decrease in fat was accompanied by a corresponding increase in water content and, to a lesser extent, ash and protein content of the carcass (Fuller *et al.*, 1968).

Frame Size

"Frame size" or skeletal dimension has been used with increasing frequency in describing the physical characteristics of pullets. The two most common measures of

frame size are shank (tarsometatarsus) length and keel length. However, although two pullets may be of similar weight, their skeletal dimensions may differ. With Leghorn pullets there is interest in early rapid development in order to accomodate early maturity. Lerner (1945) suggested that skeletal size to be the limiting factor in increasing body size, hence, the recent interest in trying to increase early skeleton size. The converse may apply with broiler breeder pullets in that adequate mature (20 wks) weight coupled with small frame size could be advantageous in limiting subsequent growth during the breeding period. Renden and Marple (1985) found age at sexual maturity inversely related to body weight, i.e. highest body weight matured earliest, in SCWL birds. Shank length reached a maximum length 8 wks after sexual maturity. Percentage fat was greatest in heavy birds; fat increased from sexual maturity to 8 wks after sexual maturity, decreased from 8-12 wks (peak production) and increased after 12 wks in their experiment. In the low-weight birds, percentage fat decreased from sexual maturity to 8 wks and increased thereafter. Percentage of protein was lowest in the high body weight birds and these birds consistently lost body protein after sexual maturity. Low body weight birds and control birds showed an increase in percentage protein from sexual maturity to 8 wks after sexual maturity. All groups showed a decrease in protein during 8-12 wks (peak production). The Low body weight group increased protein slightly after peak production, and control and High body weight groups exhibited continuous protein loss to 16 wks after sexual maturity. Percentage body ash increased from sexual maturity to 8 wks after maturity, dropped during peak production and increased thereafter. It is important to note that there were no significant relationships between body weight and age at sexual maturity in low body weight hens, also no significant relationships between lean weight and age at sexual maturity. A significant although small correlation existed between shank length and age at sexual maturity, in control hens, the association was negative i.e. age at sexual maturity decreased as shank length increased. Brody *et al.* (1984) showed the same relationship. These data did not support the hypothesis that there are strict compositional requirements for sexual maturity to occur in the hen.

Effect of age on determining sexual maturity

Dunnington *et al.* (1983) postulated that age, not body weight, is the limiting factor for sexual maturity in heavy chickens and that body weight or composition are limiting factors for sexual maturity in light chickens. Falconer (1984) stated that body weight and age are equal determinants of puberty in mice across weight classes and that, within a weight class, body size is more important than age. Results of this study demonstrate that the influences of body weight, composition, and other physical parameters on age at sexual maturity are dependant on the size of the bird, and that none of the above variables by themselves are adequate to predict age at sexual maturity.

Effects of restricted feeding on body composition

Robinson *et al.* (1991a) found that the major difference, between full-fed and restricted broiler breeders, in body composition at 62 wks of age was in the content of fat, although age at sexual maturity was not affected by level of feeding. At 26 wks of age the growth curve levelled out which indicates that the limits to rapid growth were reached by this time. The *ad libitum* fed birds gained significantly more fat and protein during the 40 wk laying period than did the restricted birds. It has been reported previously that *ad lib* feeding hastens sexual maturity, due to the fact that such birds attain this prerequisite body mass and body composition sooner than restricted birds (Brody *et al.*, 1980; Robbins *et al.*, 1986; Ingram and Wilson, 1987; Hocking *et al.*, 1989; Katanbaf *et al.*, 1989b; Yu *et al.*, 1992b). In this study, restricted and full-fed hens, photostimulated at 18 wks of age, did not differ significantly in age at sexual maturity. Therefore, those hens which differed significantly in body weight at first egg may not have been limited as much by attainment of critical body mass or body composition values as by meeting the requirement for chronological age and the development of the ovary and oviduct.

Robinson and Robinson (1991) found that low weight pullets had less fat on both absolute and relative percentage terms. The medium and high weight groups were not different from each other in fat content. The low weight group had significantly more

water on a percentage basis than the other two groups. Low weight groups also had significantly less protein on both an absolute and percentage basis than the high weight birds.

Minimum body weight for the onset of sexual maturity is controlled by the absolute rate of energy intake relative to body weight (Kennedy and Mitra, 1963). However, lean body mass (Brody *et al.*, 1980) and body composition requirements (Frisch and McArthur, 1974) are also evident. Each of these is related, as cause and/or effect, to endocrinological or neuro-endocrine influences. Pullets that reached sexual maturity had significantly longer shanks and greater total ash content. Pullets which had begun laying had larger livers on an absolute and percentage basis than those which had which may be attributed to the role of the liver in synthesis of egg contents.

Summary

The minimum body requirements necessary for the onset of sexual maturity in the hen are still not fully understood. The literature supports the view that there are different factors to be considered when considering attainment of sexual maturity in meat-type versus egg-type hens. With meat-type hens attainment of a prerequisite body weight is not the problem because this can be accomplished at a very young age. However, what is yet to be determined is the body composition and age requirements necessary for sexual maturity to occur and if these factors can be manipulated to improve the production efficiency of these birds. The same situation occurs in egg-type hens but with these pullets the problem is not an age requirement but the problem of attaining adequate frame size and body weight to support this early sexual maturity.

This research project was designed to determine if carcass composition varies with photostimulation and sexual maturity for birds photostimulated at different ages, the factors which influence reproductive function, and if age at photostimulation can be used to alter the production efficiency of both broiler breeder and SCWL pullets.

Research Projects

Objectives

The purpose of this research was to examine the carcass composition of hens prior to sexual maturity as well as at sexual maturity. In order to achieve different times of sexual maturity the birds were photostimulated at different ages. The effects of altering the age at photostimulation, in terms of altering the production efficiency of the birds, was also examined.

Project Descriptions

Project 1. This project was designed to examine if variability in pre-pubertal carcass composition of broiler breeder hens is related to variability in reproductive form and function. Factors which influence egg production and sequence length in broiler breeders were also examined along with production efficiency of birds delayed in reaching sexual maturity.

Project 2. This project was designed to examine carcass composition at photostimulation and sexual maturity for SCWL birds photostimulated at different ages. The possibility of increasing the efficiency of production of modern commercial SCWL hens by altering the age at photostimulation was also examined.

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II. THE EFFECT OF AGE AT PHOTOSTIMULATION ON CARCASS COMPOSITION, AGE AT SEXUAL MATURITY AND REPRODUCTIVE FUNCTION IN BROILER BREEDER HENS

Introduction

The beneficial effects of feed restriction and body weight control of broiler breeders in order to maximize reproductive output are well known. Excessive body weight in broiler breeder females is negatively correlated with hen-day production, fertility, hatchability, and egg shell quality (Yu *et al.*, 1992a, b; Robinson *et al.*, 1993). However, the development of "ideal" growth curves has been a trial and error experience for breeding companies. It is also becoming more evident that there is very little relationship between body weight and carcass composition in feed restricted broiler breeders.

One way to obtain variability in pre-pubertal carcass composition is to induce pullets to reach sexual maturity at different ages. Photostimulation is a basic management procedure for regulation of sexual maturity of pullets. Pullets that are photo-stimulated early begin to lay early and would still be undergoing skeletal growth, however, pullets that are photo-stimulated later would demonstrate more growth in the form of tissue (fat and protein) growth alone on an already established mature frame size.

Studies have shown that underfeeding can delay sexual maturity until about the same weight is attained as seen in a comparable group of well-fed animals at sexual maturity (Lister *et al.*, 1966; Brody *et al.*, 1980). Hence, a minimum weight for onset of sexual maturity has been proposed (Brody *et al.*, 1980). The results of the study by Brody *et al.* (1980) and work by Zelenka *et al.* (1982) found that broiler breeders could reach the minimum body weight requirement suggested by Brody *et al.* (1980) by 14 to 15 wks of age but not reach sexual maturity until 21 to 25 wks of age. This finding suggests the possibility of a minimum age requirement for sexual maturity.

The objectives of this experiment were to determine: if carcass composition varies at time of photostimulation and at sexual maturity in birds photostimulated at different

ages; the relative importance of any differences seen in carcass composition at sexual maturity on subsequent reproductive function; the effects of altering the age at photostimulation on subsequent reproductive performance.

Materials and Methods

Stocks and Management

Six hundred day-old Starbro broiler breeder pullets were acquired from Shaver Breeding Farms Ltd. (Cambridge, Ontario). The pullets were housed in a light-tight facility during rearing and were divided, 100 birds per pen, into six floor pens (4.75 x 5.85 m). Water and feed (replacement starter ration) was provided *ad libitum* until 2 wks of age. After 2 wks of age the birds were feed restricted to maintain body weight at the target recommended by the breeder. A photoperiod of 23L:1D was used for the first two wks of age, at which time the photoperiod was changed to 8L:16D. Beak trimming was performed at 7 d of age.

At 4 wks of age each pullet was wing-banded for identification purposes. At 6 wks of age the starter diet was replaced with a grower ration. The pullets were weighed at 12 wks of age and a total of 450 birds (based on being closest to the target weight for 12 wks of age) were chosen to participate in the experiment. The birds were randomly assigned to one of five treatment groups designated 120, 130, 140, 150, or 160 d. Within each treatment group the birds were further subdivided into one of three groups designated A, B, or C (Table II-1). Group A birds were killed at the time of photostimulation for carcass composition and ovary morphology analysis (n=20 birds per treatment group). Group B was killed at the time of sexual maturity (first egg) for carcass composition and ovary morphology analysis (n=20 birds per treatment group). Group C was housed in individual laying cages at the time of photostimulation for recording of: body weight at sexual maturity and weekly until 34 wks of age and every 2 wks until 60 wks of age. Also recorded on the Group C birds was individual egg production rate, sequence length, inter-sequence pause length, egg weight and specific gravity, and 60 wk carcass analysis (n=40 birds per treatment group).

Table II-1. Experimental design: time of photostimulation and study period for broiler breeder experiment.

	Time of Photostimulation (days of age)				
Study Period	120d	130d	140d	150d	160d
Group A (killed at PS)	n=20	n=20	n=20	n=20	n=20
Group B (killed at SM)	n=20	n=20	n=20	n=20	n=20
Group C (killed at 60 wks of age)	n=40	n=40	n=40	n=40	n=40

At the time of photostimulation, the pullets were changed to a 14L:10D program and were individually caged. At photostimulation the birds were provided with a layer ration. All diets were wheat based and formulated following NRC (1984) requirements.

Body Weight and External Morphometrics

Birds were weighed individually at 4, 8, 12, and 16 wks of age and also at the time of photostimulation of each treatment group. From 24 to 34 wks of age they were weighed on a weekly basis. After this time they were weighed every 2 wks until 60 wks of age. Body weights were measured frequently in order to monitor body weight gain and adjust feed intake accordingly.

At 24 and 28 wks of age, as well as at the time of kill, external measures including shank length, keel length, head width, and girth were measured. Shank length and head width were measured with hand-held calipers. Shank (tarsometatarsus) length was measured, on the left leg, as the distance from the middle of the foot pad to the hock joint (or joint of tarsometatarsus to the tibia). Head width was measured by placing the calipers over the head of the bird and placing both end of the calipers on either ear. Keel length and girth were measured

keel at the bottom of the v-joint on the keel straight along the top of the keel to the point at the end of the keel. Girth was measured by placing by a measuring tape under the birds wings at the point of attachment of the wings to the body and then around the body and using the notch on the keel as the reference point.

Body Composition Analysis

At the time of kill carcasses were weighed and the external morphometrics recorded. The breast muscles (pectoralis major and minor), abdominal fat pad, liver, right and left tibiae, ovary, oviduct, number of large follicles, large follicle weight and diameter were also recorded. "Large follicle" number was recorded as the number of follicles whose diameter was 10mm or greater. The abdominal fat pad included fat surrounding the gizzard. With the exception of the right and left tibiae, which were burned to determine total ash content, all organs and body parts were returned to the carcass which was then frozen. The frozen carcasses were pressure cooked for 4 hrs in order to soften them and then ground in an industrial blender until homogenous. A sample taken from each carcass was freeze-dried for further analysis. Chemical analysis following standard procedures (Association of Official Analytical Chemists, 1980) was performed, in duplicate, on the freeze-dried samples for determination of total dry matter, total protein, total lipid, and total ash.

Groups A and B for each treatment were processed as described above. Group C birds were not analyzed for total body composition analysis, in this group organ weights and external morphometrics were recorded only.

Egg Collection and Incubation

For the birds that were killed at first egg (Group B) egg weight and bird weight at this time were recorded. Eggs were collected daily for the Group C birds in each treatment and individual production was recorded. The eggs were further recorded as to shell integrity (normal, soft-shelled, double-yolked, broken, abnormal shape, or pecked). Weight of one egg was taken weekly from each hen and recorded, if no egg was present on this day then the next egg was weighed. Specific gravity

was measured on one egg for each hen every 28 days.

Sequence length was measured by counting the number of consecutive days on which an egg was laid before there was a pause day. Egg production was also subdivided into two wk periods and the number of eggs produced in each of these periods tallied. Mean sequence length, for each two wk period, was calculated by dividing the number of eggs produced in that period by the number of sequences.

Beginning at wk 27 each hen was artificially inseminated with 50 uL of fresh undiluted semen. Inseminations were conducted once per week. Semen was collected by abdominal massage from Shaver Starbro broiler breeder males and pooled. Insemination followed semen collection by less than 10 min.

The eggs were incubated and hatched at a commercial hatchery in lots according to treatment. There were two lots (20 hens per lot) per treatment group. Upon removal from the hatcher, all the unhatched eggs were broken open and the fertility status and stage of embryo development was determined and recorded. Fertility was calculated as the number of fertile eggs per 100 eggs set. Hatchability equalled the number of eggs hatched per 100 eggs set and hatch of fertile was calculated as the number of eggs hatched divided by the number of fertile eggs. Chick production was calculated as settable egg production multiplied by hatchability.

Statistical Analysis

Data were evaluated by analysis of variance using the General Linear Models (GLM) procedures (SAS Institute, 1985). Carcass composition analysis, organ weights, and external morphometrics were analyzed both within study period and within treatment. Differences between treatments in a study period were examined. Production data were compared within periods of the production cycle using birds within treatment as the source of variation. Differences between means were evaluated with the TTEST procedure (SAS Institute, 1985). Several body components and production parameters were compared across all treatments with Pearson correlation analysis (Steel and Torrie, 1980). Unless otherwise stated, all statements of significance were based on testing at the 0.05 level.

Results

Body Composition

Body weight at the time of photostimulation (Group A birds) increased steadily as the age at photostimulation was increased (Table II-2). The 160 d group was the heaviest among the five treatment groups weighing 2216.85g while the 120 d group was the lightest at 1525.45g. The percentage dry matter per bird was shown to be greatest (39.04%) in the 160 d group while the 120 d group had the lowest dry matter (35.45%). The 150 and 160 d groups were not significantly different from each other and neither were the 120, 130, or 140 d groups. The carcasses of the 160 d group also had the lowest water content (60.96%) while the 120 d group had the highest water content (64.55%). Protein content on a percentage basis was not significantly different among the five treatments, an average of 22.88%. However, lipid content (as a percentage) was significantly greater in the 150 and 160 d groups (12.24% and 12.35%, respectively) versus the 120, 130, and 140 d groups (8.82%, 10.14%, and 10.23%, respectively). The 120 d group had the lowest fat content (8.8%). Percentage of ash per bird was numerically lowest in the 160 d group, but was not significantly different among the 120, 150, or 160 d groups (average of 3.28%).

Body weight at sexual maturity (Group B) increased proportionally across the treatments with the 160 d group weighing 2702.14g and the 120 d group 2497.75g (Table II-3). An exception was the 130 d group wchih was the lightest (2419.13g) at sexual maturity. No significant differences were found between treatments for the percentage of dry matter per bird. Percentage water was numerically the largest, 59.38%, in the 130 d group although there was no significant differences between treatment groups. Protein as a percentage of body weight was not significantly different among treatments as was the case with percent ash per bird. Protein content averaged approximately 22% for all birds whereas ash content averaged 3.20%. Lipid content although not significantly different between treatments, was highest in the 150 d (16.32%) and 160 d groups (15.67%). The 120, 130, and 140 d groups averaged 14.5% for lipid content.

Organ Weights

As a percentage of body weight (Table II-4) liver weight was significantly highest (2.82%) in the 160 d group at photostimulation. Groups 120, 130, and 140 were not significantly different from each other; the 120 and 150 d groups were also not significantly different. The 150 d group was lowest (1.91%) for liver weight as a percentage of body weight at photostimulation. At sexual maturity there were no significant differences among treatments for liver weight as a percentage of body weight with the average for all treatments being approximately 1.8%. At 60 wks of age, although there were no significant differences between treatment groups, liver weight was higher and averaged 1.95% for all treatments. Liver weight as a percentage of body weight increased for all treatments from sexual maturity to 60 wks of age.

Table II-5 shows the fat pad weight on an absolute and percentage basis. The 120 d group had the smallest fat pad (as a percentage of body weight; 0.72%) at photostimulation which was significantly different from the 150 and 160 d groups (1.69% and 1.53%, respectively). At sexual maturity and 60 wks of age there were no significant differences among the treatment groups. However, at sexual maturity the average fat pad weight as a percentage of body weight was 2.24% and at 60 wks of age the average was 6.31%. This represents an approximate 4% gain in fat pad weight. Fat pad weight was not found to be highly correlated with carcass fat content at photostimulation or sexual maturity ($r=0.14$ and $r=0.10$, respectively). However, fat pad weight and body weight at photostimulation and sexual maturity were found to be highly correlated ($r=0.75$ and $r=0.50$, respectively).

At the time of photostimulation, the 160 d group had the highest breast muscle weight (as a percentage of body weight; 14.36%) but was not significantly different from the 140 and 150 d groups (Table II-6). The 120 d group had the lowest (12.23%) breast muscle content at this time but was not significantly different from the 130 d group. There were no significant differences in breast muscle weight among the five treatments at sexual maturity or 60 wks of age. However, at 60 wks of age all groups had a lower, average of 13.15%, breast muscle weight (as a

percentage of body weight) than they did at sexual maturity (average of 13.9%). Correlation analysis showed that breast muscle weight was the most highly correlated with body weight at photostimulation and sexual maturity ($r=0.93$ and $r=0.81$, respectively). At photostimulation, girth and keel length were most highly correlated with breast muscle weight ($r=0.81$ and $r=0.81$, respectively).

Table II-7 shows ovary weight on an absolute and percentage basis. At photostimulation the 120 d group had the lowest (0.445%) ovary weight (on an relative basis) but was not significantly different from the 140 d group (0.61%). The 130, 150, and 160 d groups were not significantly different from each other at this time. The 160 d group had the highest ovary weight (0.91%) at photostimulation. At sexual maturity and 60 wks of age the treatments did not differ significantly from each other. For all five treatments the ovary represented a smaller proportion of body weight at 60 wks of age (on average 1.25%) than at sexual maturity (on average 1.88%).

As a percentage of body weight, oviduct weight was significantly greatest in the 120 (0.111%) and 130 d (0.104%) groups when compared with the 140, 150, and 160 d groups, which averaged 0.08%, at photostimulation (Table II-8). No significant differences were found between treatments at sexual maturity or at 60 wks of age. All treatments exhibited a decrease in oviduct weight as a percentage of body weight between sexual maturity, (with an average among treatments of 2.29%), and 60 wks of age (with an average among treatments of 1.88%).

Table II-9 shows that no large follicles were present at time of photostimulation for any of the treatment groups. Large follicle weight (Table II-9) was significantly greater in the 140, 150, and 160 d groups versus the 120 and 130 d groups at sexual maturity. The average of the three groups with the largest follicle weights was 10.67g versus 9.43 for the other two groups. However, there was no significant difference in the number of large follicles at sexual maturity between treatments. The average for all treatment groups at sexual maturity was 7.04 large follicles. At 60 wks of age there was also no significant difference among treatment groups for large follicle weight, averaging 17.55g, and follicle number, averaging

4.36, for all groups. Between sexual maturity and 60 wks of age, large follicle weight increased and follicle number decreased for all treatment groups.

External Morphometrics

Shank length did not differ significantly among treatments at any of the times measured (Table II-10). Head width was not significantly different among treatments at 24 wks of age (Table II-11). At 28 wks of age the 120, 130, and 160 d groups were not significantly different from each other, nor were the 140 and 150 d groups. At photostimulation, head width for the 120 d group was significantly smaller (30.66 mm) and the 160 d group was significantly the largest (34.04 mm). At sexual maturity and 60 wks of age there were no significant differences among treatment groups for head width.

Keel length was not significantly different among treatments at 24 or 28 wks of age (Table II-12). At photostimulation, the 160 d group had the longest keel (17.60 cm) but these birds were not significantly different from the 140 d or 150 d, (17.15 cm and 17.47 cm, respectively) groups. The 120 d group had the shortest keel (16.30 cm) at photostimulation but this was not significantly different from the 130 d group (16.58 cm). At sexual maturity and 60 wks of age there were no significant differences in keel length among the five treatments. Girth at 24 and 28 wks of age was not significantly different among treatments (Table II-13). The average for all treatments for girth at 24 wks of age was 33.73 cm, and 33.8 cm at 28 wks. At photostimulation, the 160 d group was significantly larger, 33.30 cm, than the other treatments. Also at this time, the 140 and 150 d groups were not significantly different, whereas the 120 and 130 d groups were both significantly different from the other treatments. The 120 d group had the smallest girth measurement (29.15 cm) at this time. At sexual maturity there were no significant differences among the treatment groups. The 160 d group remained the group with the largest girth throughout the trial with values of 34.16 cm at sexual maturity and 38.31 cm at 60 wks of age. At 60 wks of age, the 150 and 160 d groups were not significantly different from each other, as were the 140 and 150 d groups and the 130

and 140 d groups. The 120 d group had the significantly smallest, 36.38 cm, girth at 60 wks of age.

Correlation analysis showed that the external measures, taken at 24 and 28 wks of age, were not good predictors of future egg production. At 28 wks of age shank length, keel length, head width, and girth all showed negative correlations ($r=-0.09$, $r=-0.15$, $r=-0.12$, and $r=-0.22$, respectively) with egg production.

Production summary

Table II-14 summarizes the production records of all treatment groups for the entire production period. Days prior to first egg was significantly greatest (181.51 d) for the 160 d group. However, the 160 d group had the significantly lowest number of days from photostimulation to sexual maturity (24.16 d) while the 120 d group had the highest (50.55 d). Days from photostimulation to sexual maturity decreased as the age at photostimulation increased (Figure II-1). No significant differences were found in first egg weight between treatments. For all treatment groups overall egg production, average egg weight, total egg mass produced, specific gravity, and unsettable eggs did not differ significantly among groups. Figure II-2 shows the egg production (%) of all the treatment groups from 22 to 58 wks of age. Overall egg production was numerically greatest (162.8) in the 140 d group with this group producing approximately seven more eggs per hen than the worst group (155.16). Prime sequence length although not significantly different was greatest in the 150 d group (13.18 d) followed by the 140, 160, 130, and 120 d groups. The 120 d group had the greatest number of sequences (63.18) followed by the 130, 150, 140, and 160 d groups. Number of pause days was greatest in the 130 d group (91 d) followed by the 120, 150, 140, and 160 d groups. Figure II-3 shows the average sequence length for all five treatment groups from 24 to 58 wks of age.

Fertility, Hatchability, and Hatch of Fertile

Table II-15 shows the average fertility, hatchability, hatch of fertile, and chick production values for all treatment groups over the production period. There were no

significant differences among treatments for fertility, hatchability, or hatch of fertile over the production cycle. Figures II-4, II-5, and II-6 show fertility, hatchability, and hatch of fertile divided into four-week periods for the different treatment groups. The 140 d group had the largest values for all three parameters but when compared to the other treatments these differences were not significant. The 140, 150 , and 160 d groups all showed consistently higher values when compared to the 120 and 130 d groups for these three parameters. Chick production was significantly greatest in the 140 (132.51 chicks/hen), 150 (129.80 chicks/hen), and 160 d (127.37 chicks/hen) groups. The 120 and 130 d groups (118.89 and 116.56, respectively) were not significantly different from each other but were significantly lower than the other three groups. Correlation analysis also proved that egg production was the best indicator of fertility ($r=0.72$).

Mortality in this trial was very low and there were no mortality by treatment interactions. The 120 and 150 d treatment groups had two mortalities each, while the 160 d treatment group had one mortality. The 130 and 140 d treatment groups had no mortalities for either group.

Discussion

Body weight was significantly greater in the 150 and 160 d groups than the 120, 130, and 140 d groups at the time of photostimulation. The difference at this time may be attributed to age difference. Increasing body weights were seen as age increased and as feed allocation had been increased to account for some body weight gains as per the Shaver Breeder Manual. This finding is reflected in carcass dry matter content which represents body weight minus water content. Water content of the carcass, on a percentage basis, at photostimulation was shown to be significantly higher in the 120 and 130 d groups which may again be attributed to age differences. Lipid content of the carcass at photostimulation was significantly greater in the 150 and 160 d groups versus the other treatments. Together these two observations support the findings of Fuller *et al.* (1968) who found that decreased fat content was

accompanied by an increase in water content of the carcass.

At sexual maturity the 160 d group remained significantly heavier than the other treatments. However, due to feed restriction practices employed to limit body weight gains during this period, there were no longer direct age related differences in body weight at this time (Figure II-1). No significant differences were found in water, protein, lipid, or ash content at sexual maturity between treatments. The lack of significance between these measures at this time is indicative of the similarity in body weights.

When comparing body composition between the time of photostimulation and sexual maturity, it is evident that all hens showed an increase in lipid content with attainment of sexual maturity. However, the greatest increase in fat content relative to body weight was seen in the 120 d treatment group. This group lost approximately 6% in carcass water content and gained the same amount in fat content between photostimulation and sexual maturity. This increase in lipid content reflects the importance of fat content relative to the onset of sexual maturity and is supported by the findings of Bornstein *et al.* (1984). These findings may indicate the effect of estrogens on fat accumulation. A high degree of fatness is considered counter-productive. However, in this case the effect seems to be heightened which resulted in the rapid increase in lipid content in the 120 d group as compared to the other treatments. These results support the hypothesis that a certain level of fatness is required for the onset of ovulation (Bornstein *et al.*, 1983).

Protein content of the carcass did not change greatly between photostimulation and sexual maturity. There are two possible explanations for this finding. One is that any prerequisite lean mass requirement for sexual maturity was reached at an early age. Alternatively, crude protein levels may remain constant due to a highly regulated balance between protein deposition and degradation. The results of the body composition analysis show that although the birds entered lay at different body weights and ages their carcass content of dry matter, water, protein, lipid and ash are relatively constant. These findings support the hypothesis of others (Frisch, 1974; Brody *et al.*, 1980; Soller *et al.*, 1984) that there may be a minimum body

composition requirement for sexual maturity to occur in the female.

Abdominal fat pad weight in full-fed birds has been found to be highly correlated with body fat content (Becker *et al.*, 1979). In the present study, fat pad weight was not found to be not highly correlated with carcass fat content at photostimulation or sexual maturity however, this finding may be due to the degree of feed restriction used. Abdominal fat pad weight as a percentage of body weight increased as the birds aged for all treatments. Correlation analysis showed a high correlation between fat pad weight and body weight at photostimulation and sexual maturity. The greatest increase in fat pad weight on a percentage basis was seen in the 120 d group from photostimulation to sexual maturity. However, at sexual maturity and 60 wks of age there were no significant differences between treatments for fat pad weight on a percentage basis (Table II-5). There was also no significant differences in percent lipid per bird at sexual maturity (Table II-3).

In the present study breast muscle weight at photostimulation and sexual maturity showed the greatest correlation with body weight. The decrease in correlation between photostimulation and sexual maturity can be attributed to increasing fat content of the carcass seen at this time. The high correlations of girth and keel length with breast muscle weight at photostimulation indicates that breast muscle weight is highly dependant on keel length and together these two factors correspond to girth.

Relative liver weight showed significant differences between treatments at photostimulation but these differences were not significant at sexual maturity. All groups showed a decrease in liver weight relative to body weight at sexual maturity. The majority of the yolk components are synthesized in the liver (Leveille *et al.*, 1975). At 60 wks of age, the liver represented a larger proportion of body weight than at sexual maturity for all treatments. This observation was consistent with the increase in large follicle weight which occurred over time. Abdominal fat pad weight also increased over time, and both of these parameters reflect the increased fat metabolism and synthesis by the liver.

Significant differences were found in ovary weight as a percentage of body

weight (Table II-7) at photostimulation. The 120 d group had the significantly smallest ovary (as a percentage of body weight) compared to all other treatments and the 160 d group had the largest ovary (150 and 160 d groups were not significantly different). This indicates that ovary growth occurs with increasing age and body weight. Although these differences were relatively small they also demonstrate that some ovarian development does occur without photostimulation. At sexual maturity and 60 wks of age there were no significant differences between treatments. The ovary represented a smaller proportion of body weight at 60 wks of age than at sexual maturity in all treatments. This finding is also reflected in the number of large follicles, with more large follicles present at sexual maturity than at 60 wks of age (Table II-9). Hocking *et al.* (1987) also found that follicle number declines with age due to reduced follicular recruitment and maturation. Although follicle number decreased with age, the weight of the largest follicle increased with age which agrees with the results of previous studies (Roland, 1978; 1979). After sexual maturity, there was a continued increase in liver weight and large follicle weight.

At sexual maturity large follicle weight was found to be significantly greater in the 140, 150, and 160 d groups versus the 120 and 130 d groups. This difference was not apparent when first egg weights were compared (Table II-14) as no significant differences were found in first egg weight.

At all times during this study, the oviduct represented a larger proportion of body weight than did the ovary. At photostimulation the oviduct was already developing and represented a larger proportion of body weight than did the ovary (Table II-8). This suggests that the bird does not need photostimulation to begin oviductal development. The oviduct reached its maximum proportion of body weight at sexual maturity for all groups except the 130 d group, which was underweight at sexual maturity. Oviduct weight on a percentage basis was significantly greater in the 120 d and 130 d groups compared to the other treatments. However, at sexual maturity and 60 wks of age there were no significant differences among treatments.

In order to estimate 'frame size' external measures such as keel length, head width, girth, and shank length were measured. Shank length was not significantly

different among treatments at any of the times measured. Keel length showed significant differences at photostimulation with the 120 and 130 d groups being significantly shorter than the 140, 150, and 160 d groups. This observation could be explained by age differences. At sexual maturity this difference disappeared, with no significant differences between treatments. However, the 120 and 130 d groups did show a greater increase in keel length than did the other three treatments. This suggests that the younger pullets were still increasing frame size after photostimulation. This may indicate that 120 and 130 d is too soon to photostimulate pullets as the birds have not yet reached mature frame size.

Head width is important in sex separate feeding as it is the basis for feeding males and females seperately and thereby controlling body weight gain more effectively. No significant differences were found between treatments at 24 wks of age, sexual maturity, and 60 wks of age. However, it is difficult to ascertain from these data when mature head width is reached.

Girth has been used to estimate the degree of 'fleshing'. At 24 and 28 wks of age no significant differences were found between treatments. At photostimulation the 160 d group was significantly larger and the 120 d group significantly smaller than the other groups. This indicates that the 160 d group had reached mature frame size at this time and was putting energy into tissue accretion. The 120 d group was most likely still undergoing skeletal growth at this time which agrees with the shorter keel length at this time also. At sexual maturity no significant differences were seen between treatments indicating that the 120 d group had stopped increasing in frame size and was putting energy into tissue deposition. The 160 d group maintained the largest girth throughout the study and at 60 wks of age was significantly larger than the 120 and 130 d groups. This increased girth was reflected by the higher fat pad weight seen in the 160 d group at 60 wks of age. Breast muscle weight as a percentage of body weight was not significantly different at sexual maturity or 60 wks of age, but at photostimulation the 160 d group was significantly heavier than the 120 and 130 d groups. Fat pad weight followed the same trend as breast muscle weight.

No significant differences were found in egg production among treatment groups. Numerically, the 140 d group produced the most eggs, producing almost seven more eggs per hen that the worst, 130 d, group. This may be of significance to hatching egg producers. Prime sequence length is known to be correlated with total egg production (Robinson *et al.*, 1993). In this study no significant differences were found for prime sequence length, number of pause days, average egg weight, specific gravity, or non-settable egg production. However, the 140, 150, and 160 d groups did have numerically longer prime sequences, fewer pause days and fewer sequences than the 120 and 130 d groups. Thus, birds coming into lay later reacted to delayed sexual maturity by having a longer prime sequence, fewer pause days, and therefore fewer sequences in order to produce approximately the same number of eggs as the earlier maturing groups.

Average egg weight was not significantly different among treatments but, was shown to increase over time for all treatment groups (Figure II-2). This observation is consistent with previous studies (Bacon *et al.*, 1972; O'Sullivan *et al.*, 1991) which show that increasing yolk size directly relates to an increase in egg size. Supporting this observation also is the increased large follicle weight seen at 60 wks of age.

Average sequence length over the production period is illustrated in Figure II-3. The 120 d group had the lowest peak in sequence length whereas the 140 d group peaked highest and was followed closely by the 150 d group. These peaks were reflected in the higher egg numbers produced by the 140 and 150 d groups. However, although the 120 d group did not peak as high as the other groups they did show better persistency of lay than the other treatments although they had poor overall production. The 130 d group had the largest drop in production after peak was reached. These observations reflect the overall poor persistency of lay seen with broiler breeder hens and is of concern to producers because of the loss in production that it represents. Bahr and Palmer (1989) suggested that egg production may decrease with age due to increased incidence of follicular atresia and internal laying, decreased follicular recruitment, decreased shell quality, or a reduced ovulation rate. The drop in egg production over time, along with the reduced follicle numbers,

support this observation.

O'Sullivan *et al.* (1991) have reported that fertility remains high late in lay when hens are artificially inseminated and the findings presented here agree with this observation. Although no significant differences were found in average fertility, hatchability, or hatch of fertile among the different treatments, the 140 d group was numerically the highest in all categories (Table II-15). These differences may be significant to hatching egg producers as the 140 d group is approximately 6% higher for hatch of fertile and hatchability than the 120 and 130 d groups. The reason for these differences could be related to the greater number of sequences seen for the 120 and 130 d groups compared to the 140 d group. Robinson *et al.* (1991) and Fasenko (1992) showed that first of sequence eggs have lower fertility, hatchability, and viability values, and the 120 and 130 d groups would have produced more first of sequence eggs due to a greater number of sequences. Correlation analysis proved that the best indicator of fertility is egg production. Perhaps of most significance to the producer were the significant differences found in chick production. The 140 d treatment group had the highest chick production (132.51) but was not significantly different from the 150 and 160 d treatment groups (129.8 and 127.37, respectively). The 120 and 130 d treatment groups had the lowest chick production (118.89 and 116.56, respectively), but were not statistically different from each other.

Overall, this experiment demonstrated that broiler breeder pullets can be delayed in reaching sexual maturity by delaying the age at photostimulation. However, this trial also showed that delaying the age at photostimulation significantly reduces the number of days required to reach sexual maturity from the time of photostimulation. Egg production was not significantly affected by delayed age at sexual maturity, the birds responded to delaying age at sexual maturity by having longer prime sequence lengths and fewer pause days. For the producer who is interested in chick production, greater chick production from hens photostimulated at 140 d could be the most advantageous.

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TABLE II-2. Effect of age at photostimulation on body composition on an absolute and percentage basis at the time of photostimulation in broiler breeder hens.

Time of Photostimulation[1] (days of age) (SEM)					
Variable	120	130	140	150	160
% Dry Matter of Bird	35.45^{c} (3.84)	36.63^{c} (2.07)	37.14^{bc} (1.91)	38.88^{ab} (3.00)	39.04^{a} (3.70)
% Water	64.55^{a} (3.84)	63.37^{a} (2.06)	62.86^{ab} (1.91)	61.12^{bc} (3.00)	60.96^{c} (3.70)
% Protein of Bird	22.78^{a} (2.73)	22.64^{a} (0.88)	23.55^{a} (0.98)	22.75^{a} (1.05)	22.70^{a} (1.00)
% Lipid of Bird	8.82^{b} (2.34)	10.14^{b} (2.91)	10.23^{b} (1.83)	12.24^{a} (3.18)	12.35^{a} (4.01)
% Ash of Bird	3.36^{ab} (0.40)	3.42^{a} (0.21)	3.45^{a} (0.21)	3.29^{ab} (0.19)	3.20^{b} (0.25)
Body Weight (g)	1525.45^{d} (42.40)	1713.47^{c} (43.50)	1933.43^{b} (41.37)	2104.95^{a} (43.50)	2216.85^{a} (42.40)
Weight of Water (g)	980.90^{d} (121.74)	1083.62^{c} (85.55)	1214.55^{b} (103.94)	1283.65^{a} (97.49)	1345.75^{a} (121.13)
Weight of Protein (g)	344.47^{d} (46.46)	387.09^{c} (31.24)	455.46^{b} (46.85)	479.49^{ab} (54.24)	502.30^{a} (53.36)
Weight of Lipid (g)	135.49^{c} (44.54)	177.48^{bc} (65.65)	199.04^{b} (48.07)	260.92^{a} (80.34)	280.36^{a} (111.73)
Weight of Ash (g)	50.73^{d} (6.42)	58.51^{c} (5.27)	66.59^{b} (6.60)	69.13^{ab} (5.86)	70.67^{a} (7.64)

$^{a-d}$Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-3. Effect of age at photostimulation on body composition on an absolute and percentage basis at the time of sexual maturity in broiler breeder hens.

Time of Photostimulation[1] (days of age) (SEM)					
Variable	120	130	140	150	160
Days prior to first egg	173.00^{bc} (1.21)	170.84^{c} (1.25)	175.23^{b} (1.20)	175.61^{b} (1.23)	181.51^{a} (1.21)
Days from PS to SM	50.55^{a} (1.48)	42.25^{b} (1.48)	34.20^{e} (1.48)	27.86^{d} (1.44)	24.16^{d} (1.52)
Body Weight (g)	2497.75^{bc} (37.11)	2419.13^{c} (45.45)	2543.00^{b} (40.65)	2585.76^{b} (39.67)	2702.14^{a} (179.61)
% Dry Matter of Bird	41.40^{a} (3.72)	40.63^{a} (4.24)	41.89^{a} (2.51)	42.96^{a} (2.29)	42.75^{a} (2.13)
% Water	58.60$^{[1]a}$ (3.72)	59.38^{a} (4.24)	58.11^{a} (2.51)	57.04^{a} (2.29)	57.25^{a} (2.13)
Weight of Water (g)	1465.40^{a} (174.27)	1434.63^{a} (138.57)	1475.91^{a} (75.62)	1474.59^{a} (97.84)	1547.74^{a} (127.99)
% Protein of Bird	22.57^{a} (1.99)	22.27^{a} (1.69)	22.89^{a} (0.87)	22.36^{a} (0.88)	22.78^{a} (0.67)
Weight of Protein (g)	561.90^{bc} (55.74)	538.62^{c} (59.11)	582.06^{b} (40.14)	577.84^{b} (34.75)	615.09^{a} (40.03)
% Lipid of Bird	14.48^{a} (2.43)	14.17^{a} (2.87)	14.88^{a} (2.79)	16.32^{a} (2.72)	15.67^{a} (1.98)
Weight of Lipid (g)	362.34^{b} (73.71)	344.75^{b} (84.45)	379.89^{ab} (83.14)	422.97^{a} (78.68)	423.65^{a} (62.90)
% Ash of Bird	3.34^{a} (0.39)	3.21^{a} (0.27)	3.40^{a} (0.27)	3.38^{a} (0.22)	3.29^{a} (0.24)
Weight of Ash (g)	82.87^{b} (8.00)	77.74^{c} (9.47)	86.33^{ab} (7.89)	87.33^{ab} (7.26)	88.68^{a} (6.96)

$^{a-d}$Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-4. Effect of age at photostimulation on liver weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
----------Liver weight (g) (SEM)--------					
Photostim.	34.04^{c} (1.76)	40.30^{b} (1.76)	44.26^{b} (1.76)	41.58^{b} (1.81)	65.48^{a} (1.76)
Sexual Maturity	50.99^{a} (1.85)	48.37^{a} (1.85)	45.92^{a} (1.85)	49.51^{a} (1.81)	53.64^{a} (1.90)
60 wk	75.09^{c} (2.45)	75.98^{bc} (2.51)	75.77^{bc} (2.42)	82.06^{ab} (2.48)	83.45^{a} (2.45)
--------Liver weight (% of BW) (SEM)-------					
Photostim.	2.08^{bc} (0.09)	2.25^{b} (0.09)	2.25^{b} (0.08)	1.91^{c} (0.09)	2.82^{a} (0.09)
Sexual Maturity	1.90^{a} (0.07)	1.85^{a} (0.07)	1.71^{a} (0.07)	1.81^{a} (0.07)	1.84^{a} (0.07)
60 wk	1.91^{a} (0.06)	1.92^{a} (0.06)	1.90^{a} (0.06)	2.05^{a} (0.06)	2.08^{a} (0.06)

$^{a-d}$Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-5. Effect of age at photostimulation on fat pad weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
-----Fat Pad weight (g) (SEM)-----					
Photostim.	11.79^{c} (3.41)	21.06^{bc} (3.41)	21.70^{b} (3.41)	36.70^{a} (3.49)	35.68^{a} (3.41)
Sexual Maturity	54.63^{b} (4.15)	56.20^{b} (4.15)	55.48^{b} (4.15)	62.49^{ab} (4.05)	71.23^{a} (4.26)
60 wk	245.88^{a} (9.20)	249.34^{a} (9.44)	248.62^{a} (9.08)	254.58^{a} (9.32)	255.14^{a} (9.20)
-----Fat Pad weight (% of BW) (SEM)-----					
Photostim.	0.72^{c} (0.16)	1.18^{bc} (0.16)	1.05^{c} (0.17)	1.69^{a} (0.17)	1.53^{ab} (0.16)
Sexual Maturity	2.04^{a} (0.15)	2.14^{a} (0.15)	2.06^{a} (0.15)	2.28^{a} (0.15)	2.44^{a} (0.16)
60 wk	6.26^{a} (0.23)	6.29^{a} (0.24)	6.23^{a} (0.23)	6.37^{a} (0.23)	6.36^{a} (0.23)

$^{a\text{-}d}$Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-6. Effect of age at photostimulation on breast muscle weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
	---------Breast Muscle Weight (g) (SEM)-----				
Photostim.	199.79[e] (8.22)	224.63[d] (8.22)	272.52[c] (8.22)	305.18[b] (8.44)	333.69[a] (8.22)
Sexual Maturity	369.24[b] (7.94)	368.10[b] (7.94)	366.33[b] (7.94)	386.39[ab] (7.75)	405.29[a] (8.14)
60 wk	510.82[a] (9.03)	524.25[a] (9.27)	526.68[a] (8.91)	529.32[a] (9.14)	534.71[a] (9.03)
	----Breast Muscle Weight (% of BW) (SEM)----				
Photostim.	12.23[b] (0.41)	12.57[b] (0.41)	13.87[a] (0.42)	14.06[a] (0.42)	14.36[a] (0.41)
Sexual Maturity	13.78[a] (0.29)	13.99[a] (0.29)	13.62[a] (0.29)	14.11[a] (0.29)	13.92[a] (0.30)
60 wk	13.00[a] (0.23)	13.22[a] (0.23)	13.20[a] (0.22)	13.23[a] (0.23)	13.33[a] (0.23)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-7. Effect of age at photostimulation on ovary weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
	-----Ovary weight (g) (SEM)-----				
Photostim.	0.45[d] (0.05)	0.63[bc] (0.05)	0.61[c] (0.05)	0.75[b] (0.05)	0.91[a] (0.05)
Sexual Maturity	47.78[a] (2.84)	49.31[a] (2.84)	53.39[a] (2.84)	49.43[a] (2.77)	56.58[a] (2.91)
60 wk	46.87[a] (2.31)	51.95[a] (2.40)	51.30[a] (2.28)	50.79[a] (2.33)	52.69[a] (2.30)
	-----Ovary Weight (% of BW) (SEM)-----				
Photostim.	0.00[c] (0.03)	0.04[ab] (0.00)	0.03[bc] (0.00)	0.04[ab] (0.00)	0.04[a] (0.00)
Sexual Maturity	1.78[a] (0.10)	1.87[a] (0.10)	1.98[a] (0.10)	1.80[a] (0.10)	1.94[a] (0.11)
60 wk	1.19[a] (0.06)	1.27[a] (0.06)	1.29[a] (0.06)	1.27[a] (0.06)	1.31[a] (0.06)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-8. Effect of age at photostimulation on oviduct weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
-----Oviduct weight (g) (SEM)-----					
Photostim.	1.82[a] (0.15)	1.86[a] (0.15)	1.66[a] (0.15)	1.58[a] (0.15)	1.90[a] (0.15)
Sexual Maturity	64.01[a] (1.56)	61.26[a] (1.56)	62.12[a] (1.56)	63.18[a] (1.53)	64.91[a] (1.60)
60 wk	63.12[a] (2.15)	63.99[a] (2.21)	60.53[a] (2.13)	59.66[a] (2.18)	62.56[a] (2.16)
-----Oviduct Weight (% of BW) (SEM)-----					
Photostim.	0.111[a] (0.008)	0.104[a] (0.008)	0.083[b] (0.008)	0.073[b] (0.008)	0.082[b] (0.008)
Sexual Maturity	2.34[a] (0.06)	2.33[a] (0.06)	2.31[a] (0.06)	2.31[a] (0.06)	2.23[a] (0.06)
60 wk	1.61[a] (0.05)	1.61[a] (0.05)	1.52[a] (0.05)	1.49[a] (0.05)	1.56[a] (0.05)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-9. Effect of age at photostimulation on large follicle weight and large follicle number[2] at photostimulation, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
	-----Large Follicle Weight (g) (SEM)-----				
Photostim.	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Sexual Maturity	9.25[b] (0.30)	9.60[b] (0.30)	10.61[a] (0.30)	10.50[a] (0.30)	10.90[a] (0.31)
60 wk	17.04[a] (0.53)	17.66[a] (0.55)	17.15[a] (0.51)	17.68[a] (0.54)	18.05[a] (0.54)
	-----Number of Large Follicles[2] (SEM)-----				
Photostim.	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Sexual Maturity	7.45[a] (1.39)	7.45[a] (2.01)	7.40[a] (1.79)	6.62[a] (1.69)	7.26[a] (1.48)
60 wk	4.24[a] (0.14)	4.43[a] (0.14)	4.45[a] (0.13)	4.42[a] (0.14)	4.47[a] (0.14)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).

[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

[2]Large follicle=follicles with diameter > 10mm.

TABLE II-10. Effect of age at photostimulation on shank length (mm) at photostimulation, 24 wks, 28 wks, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
	-----Shank Length (mm)(SEM)-----				
Photostim.	106.57[a] (0.86)	106.39[a] (0.86)	107.17[a] (0.86)	108.03[a] (0.88)	108.55[a] (0.86)
24 wk	110.28[a] (1.65)	108.34[a] (1.65)	110.42[a] (1.65)	110.80[a] (1.65)	107.58[a] (1.67)
28 wk	108.99[a] (0.51)	109.29[a] (0.51)	109.01[a] (0.51)	109.53[a] (0.51)	108.76[a] (0.52)
Sexual Maturity	110.36[a] (0.79)	110.16[a] (0.79)	110.58[a] (0.79)	108.72[a] (0.77)	110.38[a] (0.81)
60 wk	110.93[a] (0.59)	111.50[a] (0.61)	111.44[a] (0.58)	112.24[a] (0.60)	111.74[a] (0.59)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-11. Effect of age at photostimulation on head width (mm) at photostimulation, 24 wks, 28 wks, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
	-----Head Width (mm)(SEM)-----				
Photostim.	30.66[c] (0.25)	32.36[b] (0.25)	32.65[b] (0.25)	32.13[b] (0.25)	34.04[a] (0.25)
24 wk	35.54[a] (0.19)	35.44[a] (0.19)	35.24[a] (0.19)	35.48[a] (0.19)	35.40[a] (0.19)
28 wk	34.79[a] (0.17)	34.35[ab] (0.17)	34.26[b] (0.17)	33.93[a] (0.17)	34.73[a] (0.17)
Sexual Maturity	33.50[a] (0.27)	33.59[a] (0.27)	33.93[a] (0.27)	33.61[a] (0.27)	33.43[a] (0.28)
60 wk	33.63[a] (0.22)	34.10[a] (0.22)	33.92[a] (0.21)	33.59[a] (0.22)	34.28[a] (0.22)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-12. Effect of age at photostimulation on keel length (cm) at photostimulation, 24 wks, 28 wks, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
	-----Keel Length (cm)(SEM)-----				
Photostim.	16.30[b] (0.18)	16.58[b] (0.18)	17.15[a] (0.18)	17.47[a] (0.18)	17.60[a] (0.18)
24 wk	17.30[a] (0.10)	17.23[a] (0.10)	17.33[a] (0.10)	17.28[a] (0.10)	17.31[a] (0.10)
28 wk	17.40[a] (0.12)	17.63[a] (0.12)	17.43[a] (0.12)	17.60[a] (0.12)	17.62[a] (0.12)
Sexual Maturity	17.90[a] (0.17)	17.70[a] (0.17)	17.65[a] (0.17)	17.81[a] (0.17)	18.26[a] (0.18)
60 wk	17.69[a] (0.12)	17.76[a] (0.12)	17.73[a] (0.12)	17.82[a] (0.12)	17.74[a] (0.12)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-13. Effect of age at photostimulation on girth (cm) at photostimulation, 24 wks, 28 wks, sexual maturity, and 60 wks of age in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
	-----Girth (cm) (SEM)-----				
Photostim.	29.15[d] (0.25)	30.23[c] (0.25)	31.80[b] (0.25)	32.63[b] (0.26)	33.30[a] (0.25)
24 wk	34.23[a] (0.21)	33.78[a] (0.21)	33.48[a] (0.21)	33.63[a] (0.21)	33.64[a] (0.21)
28 wk	34.38[a] (0.18)	33.95[a] (0.18)	33.73[a] (0.18)	34.15[a] (0.18)	34.31[a] (0.19)
Sexual Maturity	33.90[a] (0.32)	33.55[a] (0.32)	33.85[a] (0.32)	33.81[a] (0.31)	34.16[a] (0.33)
60 wk	36.38[d] (0.25)	37.24[c] (0.25)	37.55[bc] (0.24)	38.16[ab] (0.25)	38.31[a] (0.25)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.

TABLE II-14. Effect of age at photostimulation on age at sexual maturity, egg production, first egg weight (g), average egg weight (g), total egg mass produced (g), specific gravity, prime sequence length (days), number of sequences, number of pause days in broiler breeder hens.

Variable	Time of Photostimulation[1] (days of age) 120	130	140	150	160
Days prior to first egg	173.00[bc] (1.21)[2]	170.84[c] (1.25)	175.23[b] (1.20)	175.61[b] (1.23)	181.51[a] (1.21)
Days from PS to sexual maturity	50.55[a] (1.48)	42.25[b] (1.48)	34.20[e] (1.48)	27.86[d] (1.44)	24.16[d] (1.52)
First egg wt. (g)	44.08[a] (1.28)	43.45[a] (1.25)	45.46[a] (1.28)	44.81[a] (1.25)	45.38[a] (1.28)
Avg. egg wt. (g)	56.64[a] (1.09)	55.69[a] (1.12)	54.98[a] (1.07)	56.38[a] (1.12)	56.45[a] (1.10)
Total egg mass produced (g) per hen	9096.85[a] (186.18)	8641.45[a] (191.14)	8950.11[a] (183.84)	9130.27[a] (191.14)	8764.21[a] (186.18)
Egg production	160.62[a] (3.89)	155.16[a] (3.99)	162.80[a] (3.84)	161.95[a] (3.95)	157.97[a] (3.89)
Specific gravity	1.078[a] (0.001)	1.079[a] (0.001)	1.082[a] (0.001)	1.081[a] (0.001)	1.079[a] (0.001)
Unsettable eggs	2.30[a] (0.34)	2.17[a] (0.35)	1.60[a] (0.33)	1.67[a] (0.34)	2.02[a] (0.34)
Prime sequence length	9.77[a] (1.15)	10.38[a] (1.18)	12.13[a] (1.14)	13.18[a] (1.17)	12.05[a] (1.15)
Number of sequences	63.18[a] (1.53)	63.11[a] (1.57)	59.28[ab] (1.51)	61.34[ab] (1.55)	57.67[b] (1.53)
Number of pause days	83.46[a] (3.61)	91.00[a] (3.71)	78.35[a] (3.57)	79.45[a] (3.66)	77.33[a] (3.61)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.
[2]SEM

TABLE II-15. Effect of age at photostimulation on average fertility (%), hatchability (%), and hatch of fertile (%) at photostimulation, sexual maturity, and 60 wks of age as well as overall chick production in broiler breeder hens.

Time of Photostimulation[1] (days of age)					
Variable	120	130	140	150	160
Fertility (%)	90.7[a] (1.8)[2]	86.3[a] (1.8)	91.1[a] (1.7)	90.3[a] (1.8)	90.9[a] (1.8)
Hatchability (%)	75.1[a] (2.7)	76.2[a] (2.9)	82.2[a] (2.7)	81.0[a] (2.7)	80.4[a] (2.7)
Hatch of fertile (%)	79.6[a] (2.6)	79.8[a] (2.7)	86.2[a] (2.5)	84.8[a] (2.6)	84.5[a] (2.6)
Chick production (chicks/hen)	118.89[b] (2.95)	116.56[b] (3.03)	132.51[a] (2.91)	129.80[a] (2.99)	127.37[a] (2.99)

[a-d]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 120=120d; 130=130d; 140=140d; 150=150d; 160=160d.
[2]SEM

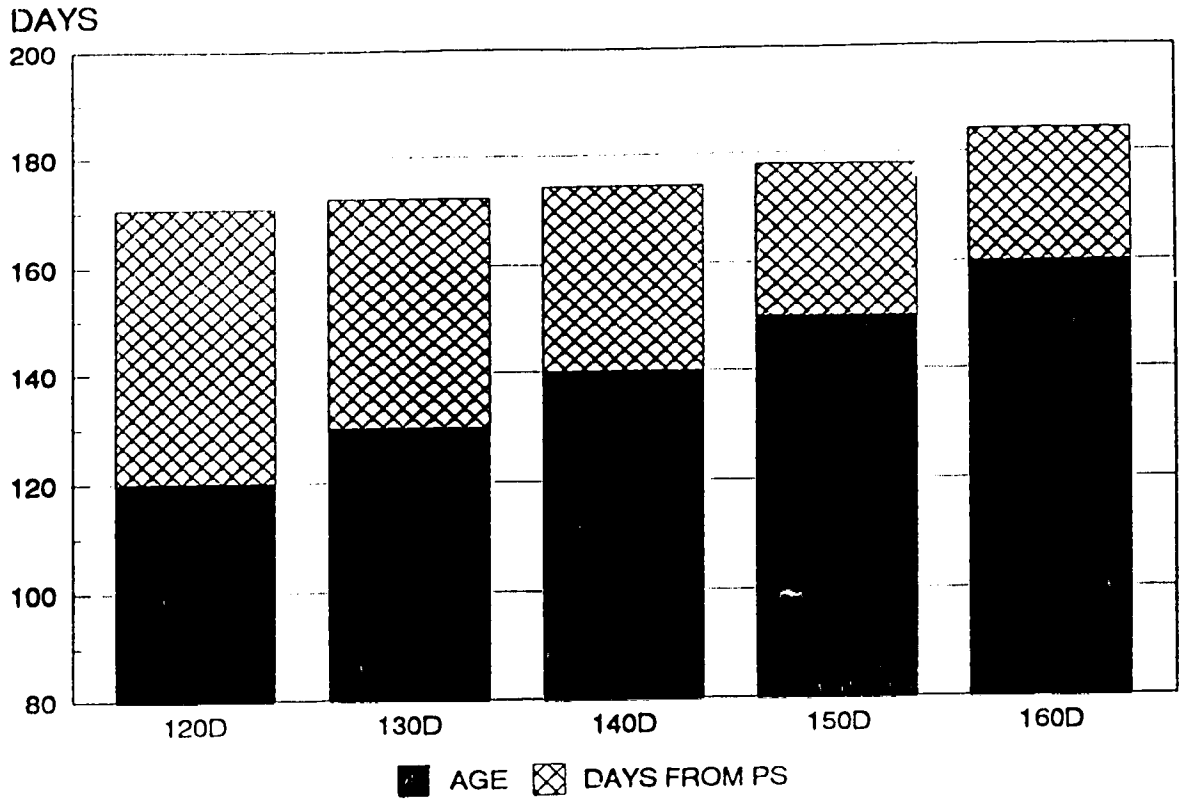

FIGURE II-1. Effect of age at photostimulation on days from photostimulation to sexual maturity and days of age at sexual maturity in broiler breeder hens photostimulated at different ages.

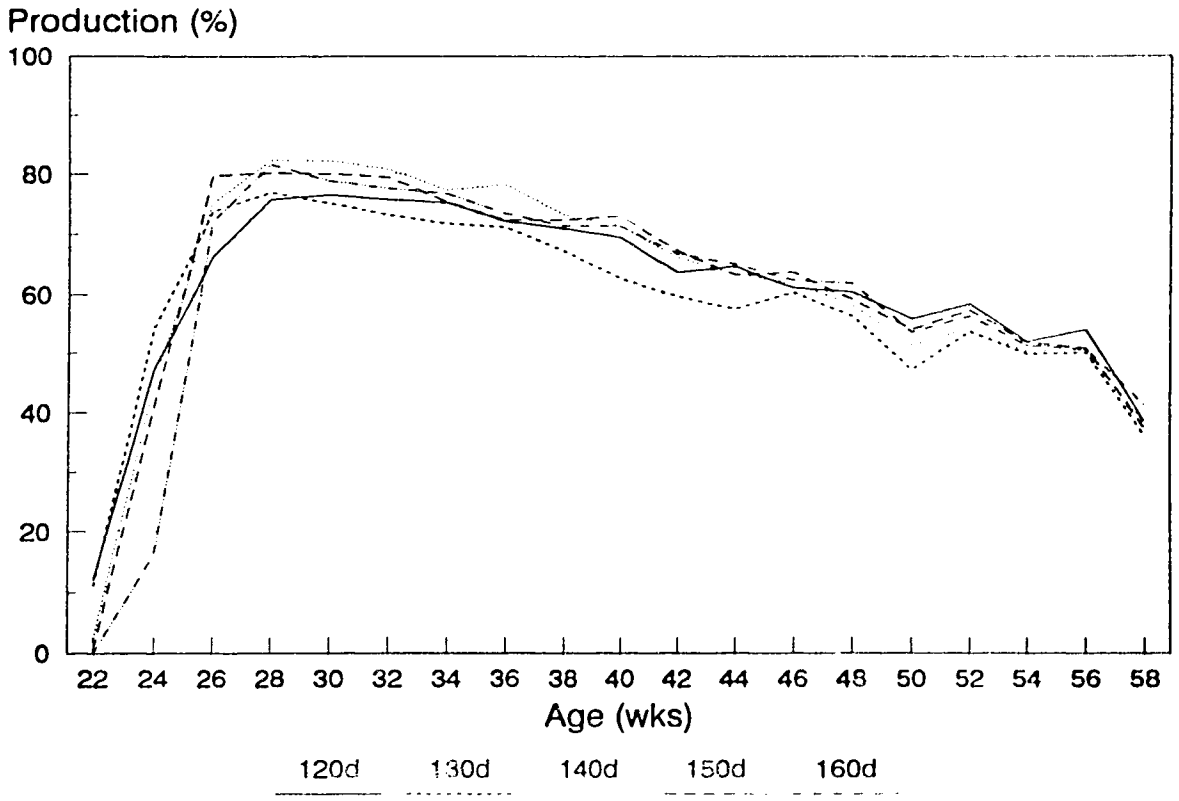

FIGURE II-2. Effect of age at photostimulation on egg production (%) in broiler breeder hens photostimulated at different ages.

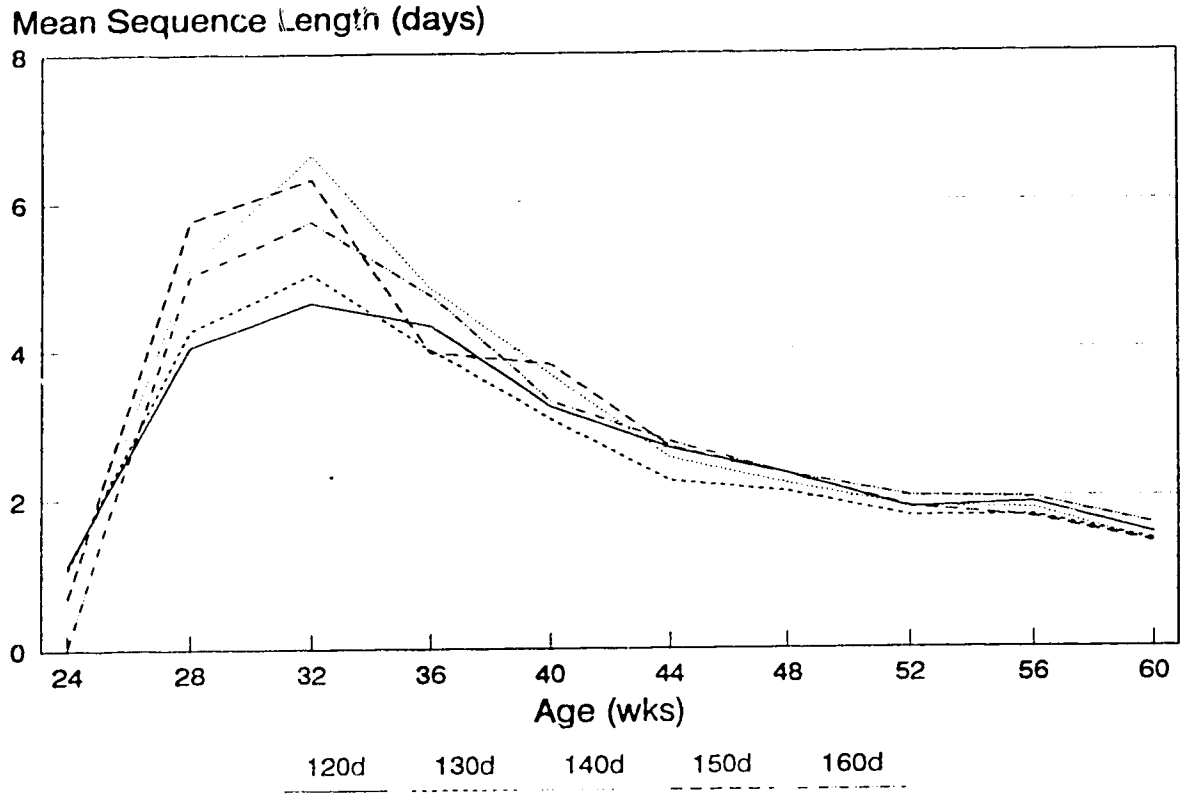

FIGURE II-3. **Effect of age at photostimulation on average sequence length in broiler breeder hens photostimulated at different ages.**

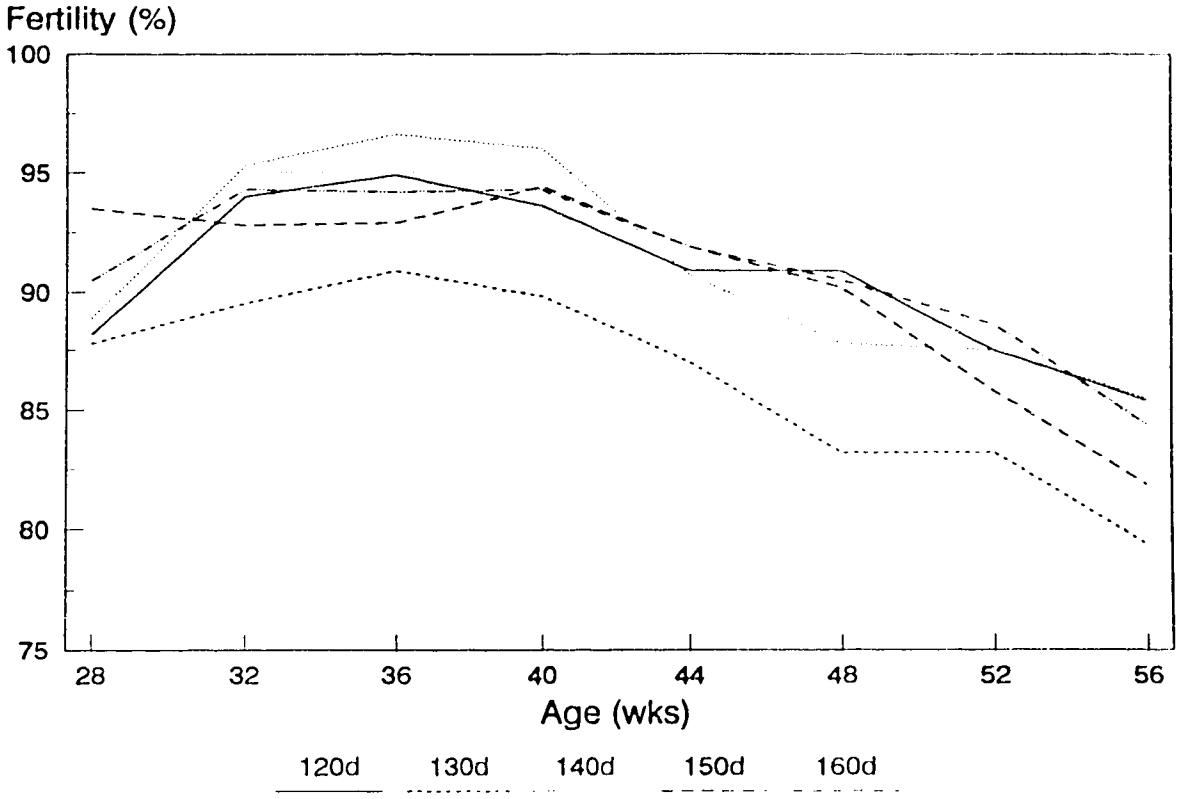

FIGURE II-4. **Effect of age at photostimulation on average fertility (%) from 28-56 wks of age divided into four-week intervals in broiler breeder hens photostimulated at different ages.**

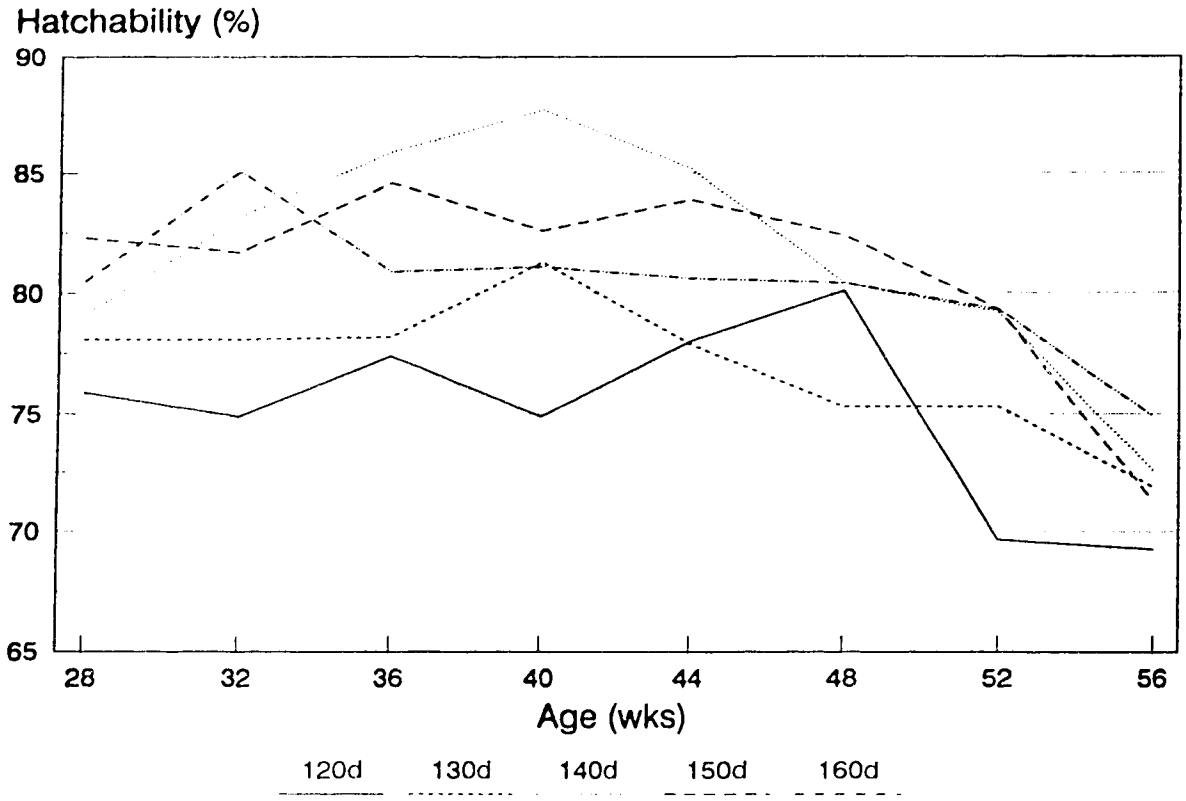

FIGURE II-5. **Effect of age at photostimulation on average hatchability (%) from 28-56 wks of age divided into four-week intervals in broiler breeder hens photostimulated at different ages.**

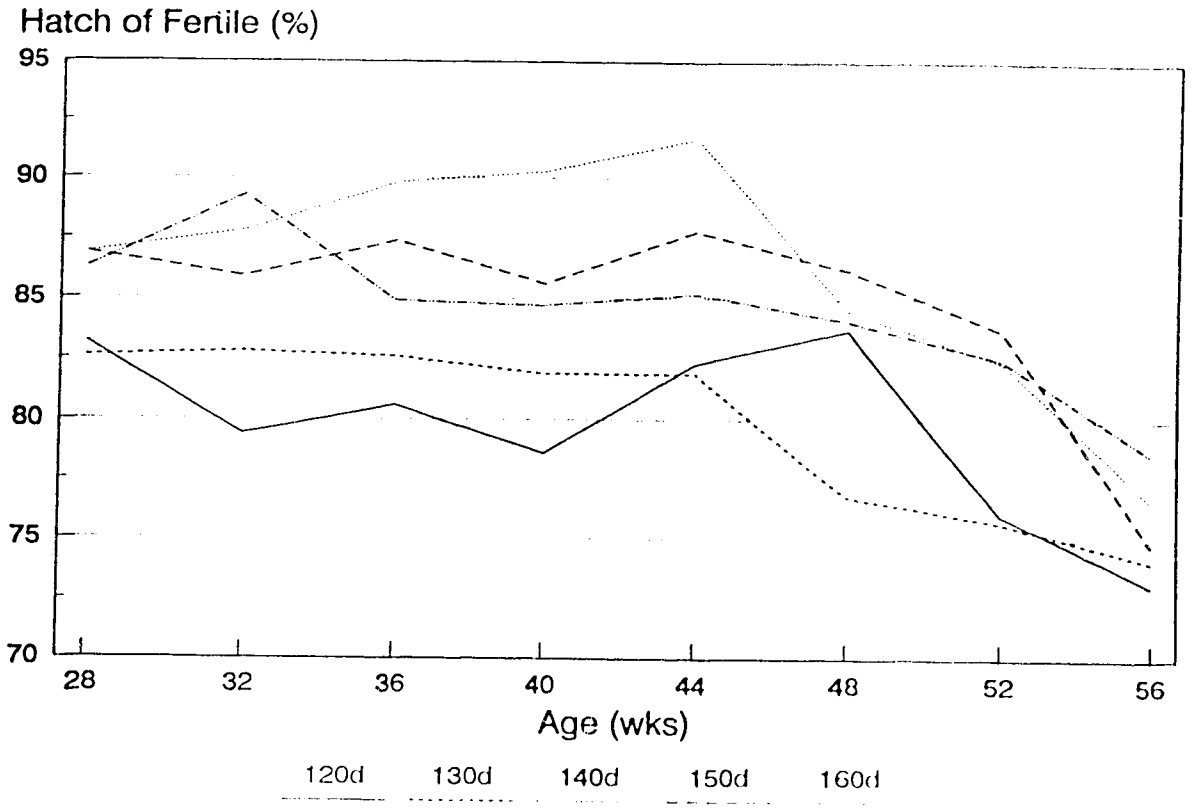

FIGURE II-6. **Effect of age at photostimulation on average hatch of fertile (%) from 28-56 wks of age divided into four-week intervals in broiler breeder hens photostimulated at different ages.**

III. THE EFFECT OF AGE AT PHOTOSTIMULATION ON AGE AT SEXUAL MATURITY, CARCASS COMPOSITION AND REPRODUCTIVE PERFORMANCE IN SINGLE COMB WHITE LEGHORN HENS

Introduction

Feeding strategies for egg-type hens have been based on determining minimum protein and energy requirements and formulating "least-cost" rations from these requirements. The majority of mortality seen in commercial SCWL flocks has been shown to be related to oviductal prolapse, internal laying, fatty liver haemorrhagic syndrome and secondary problems resulting from these reproductive disorders (Robinson, 1993). This study also showed that mean egg weight, which is positively correlated with body weight, was approximately 3 grams heavier in those flocks that have a high incidence of reproductive problems. Therefore, egg-type hens do exhibit body weight problems which impairs reproductive fitness.

It is assumed that body condition during the egg production period is influenced by age at sexual maturity. Photoperiod manipulation can be used to regulate age at sexual maturity simply by advancing, or delaying, the age at which pullets are exposed to an increased photoperiod. Carcass composition can be examined at the time of photostimulation and at sexual maturity. This approach can be used to differentiate between lean growth (protein deposition) and fat deposition during this period of reproductive organ development and significant body weight gain. There is no published comprehensive report of the carcass composition of hens at photostimulation and sexual maturity in modern SCWL hens.

It has been postulated (Dunnington *et al.*, 1983) that body weight or composition are the limiting factors for sexual maturity in light chickens. Results of a study by Falconer (1984) suggest that the influences of body weight, composition, and other physical parameters on age at sexual maturity are dependant on the size of the bird and that none of the above variables by themselves are adequate to predict age at sexual maturity.

With Leghorn pullets the problem is not attaining early sexual maturity but achieving adequate skeletal size to accomodate early maturity (Lerner, 1945). Studies reported by Leeson *et al.* (1990; 1981) have shown that total egg mass increases significantly as mature body weight increased. Therefore, it appears that the major problem associated with early maturing Leghorn pullets is reduced egg size. With delayed age at light stimulation SCWL birds have been shown to be larger at the end of the trial, laid larger eggs, and consumed more feed (Leeson *et al.*, 1990). However, they also found that age at lighting had no effect on total egg production or total egg mass produced. An experiment by Leeson and Summers (1987) showed that pullets which were underweight at the time of photostimulation did not exhibit compensatory gain. This finding indicates that the onset of sexual development predominates over growth in terms of nutrient use.

The objectives of this research project were to determine if carcass composition varies at photostimulation and sexual maturity in SCWL pullets photostimulated at different ages, and if there were differences to determine their relative influence on reproductive function. The third objective was to determine if there was any advantage in terms of reproductive performance by altering the age at photostimulation of SCWL pullets.

MATERIALS AND METHODS

Stocks and Management

Sixteen hundred SCWL pullets (Shaver Starcross 288 strain) were acquired from Shaver Breeding Farms Ltd. (Cambridge, Ontario). The pullets were housed, during rearing, in a light-tight facility, and divided (156 per pen) into floor pens (4.74 x 5.85). The birds were provided with feed (a chicken starter ration) and water *ad libitum*. A photoperiod of 23L:1D was used for the first two wks of age, at which time the photoperiod was changed to 8L:16D. The pullets were also provided with a grower ration at six wks of age. Beak trimming was performed at 7 d of age.

Each pullet was wing-banded and weighed at 12 wks of age and randomly assigned to one of three treatment groups designated 16, 18 , or 20 wks, based on the

age at which they were photostimulated. At the time of photostimulation the photoperiod was changed to 14L:10D. Diet was also changed from a grower ration to a standard laying ration. Birds from each of these treatment groups were sub-divided into one of four experimental groups according to their experimental fate (Table III-1). Group A birds were killed at the time of photostimulation for carcass composition and ovary morphology analysis (n=20 birds per treatment group). Group B was killed at the time of sexual maturity (first egg) for carcass composition and ovary morphology analysis (n=20 birds per treatment group). Group C was housed in individual laying cages at the time of photostimulation for recording of body weight at sexual maturity and at 2-week and monthly intervals to 64 wks of age, individual egg production rate, sequence length, inter-sequence pause length, egg weight and 64 wk carcass composition and ovary morphology analysis (n=50 birds per treatment group). Group D was housed at a stocking rate of two birds per cage at the time of photostimulation. Within each treatment, there were six blocks of 24 cages (48 hens). Therefore, n=288 hens per treatment. Data were recorded on a per block basis for: egg production, egg weight, feed consumption, feed conversion, and mortality.

Table III-1. Experimental design: time of photostimulation and study period for SCWL experiment.

Time of photostimulation (wks of age)			
Study period	16wks	18wks	20wks
Group A (killed at PS)	n=20	n=20	n=20
Group B (killed at SM)	n=20	n=20	n=20
Group C (individ. caged at PS; killed at 64 wks of age)	n=50	n=50	n=50
Group D (doubly caged at PS)	n=288	n=288	n=288

Feed Intake, BW, Body Composition

Group C and Group D birds were fed *ad libitum* throughout the laying period. For each replicate in Group D, feed intake was monitored on a weekly basis. Group C birds were weighed once every two weeks until 28 wks of age and then once 4 weeks until 64 wks of age. Group D birds were weighed every 10 wks.

Prior to carcass composition analysis, feed was deprived for 12 hours to facilitate gut clearance. At the time of kill the weight of the breast muscles (pectoralis major and minor), abdominal fat pad, liver, right and left tibiae, ovary, oviduct, and large follicle were recorded. As well, large follicle diameter, number of large follicles, and shank length were also recorded. "Large follicles" can be defined as those follicles whose diameter is 10 mm or greater. With the exception of the right and left tibiae, which were used to determine ash content, all body components were frozen, pressure-cooked for 2 hours to soften the carcass, and blended using an industrial blender until homogenous in order to obtain a sample for further analysis. Chemical analysis following standard procedures (Association of Official Analytical Chemists, 1980) was performed, in duplicate, on the freeze-dried samples for determination of total dry matter, total protein, total lipid, and total ash.

Groups A and B were processed as described above. Group C was not analyzed for total body composition analysis, organ weights, ovary morphology, and shank length were recorded. Group D organ weights, ovary morphology, and shank length, at 64 wks of age, were not recorded for this experiment.

Egg Collection

Individual production was monitored daily for Group C. Egg collection was also further sub-divided into the categories of normal, soft-shelled, double-yolked, abnormal shape, broken, or pecked. Group C eggs were individually weighed once per week starting at 20 wks of age. If there was no egg present on the day of weighing then the next day's egg was used. Specific gravity was measured once per month on the Group C eggs also. Group D production was measured on a per block basis, with production recorded daily, and a group egg weight being taken weekly.

Feed consumption was measured on a bi-weekly basis in order to determine feed conversion.

Sequence length was measured by counting the number of consecutive days on which an egg was laid before there was a pause day. Egg production was also subdivided into two wk periods and the number of eggs produced in each of these periods tallied. Mean sequence length, for each two wk period, was calculated by dividing the number of eggs produced in that period by the number of sequences.

Statistical Analysis

Data were evaluated by analysis of variance using the General Linear Models (GLM) procedures (SAS Institute, 1985). Carcass composition analysis, organ weights, and shank length were analyzed both within the study period and within treatment. Differences between treatments in a study period were examined. Production data was compared within periods of the production cycle using birds within treatment as the source of variation. Differences between means were evaluated with the TTEST procedure (SAS Institute, 1985). Several body components were compared across all treatments with Pearson correlation analysis (Steel and Torrie, 1980). Unless otherwise stated, all statements of significance were based on testing at the 0.05 level.

Results

Body Composition

Table III-2 shows the body composition of birds killed at the time of photostimulation (Group A) for all three treatment groups. Body weight was greatest in the 20 wk group (1197g) and lowest in the 16 wk group (1024.10g). Percentage dry matter was significantly greatest in the 20 wk group (39.85%) compared to the 16 and 18 wk groups (36.46% and 37.48%, respectively) which were not significantly different from each other. The 20 wk group was significantly lower (60.15%) than the other two treatments for percentage water. The percentage of protein and ash per bird did not differ significantly among treatments. Protein content for all treatment

groups averaged 26.20%, while ash content averaged 3.92%. Carcass lipid content was significantly greatest in the 20 wk group (8.22%) as compared to the 16 wk and 18 wk treatments (5.46% and 6.38%, respectively).

Body composition of the birds killed at sexual maturity (Group B) is shown in Table III-3. Body weight increased over time with the 20 wk birds being the heaviest (1348g) and the 16 wk group the lightest (1248.22g). There were no significant differences in percent dry matter content between treatments; the average for all groups was 44.23%. No significant differences were found in water and protein content between treatments; they averaged 55.77% and 25.21%, respectively. Ash content also showed no significant differences between treatment groups. However, the 16 wk treatment had the largest lipid content (15.18%) and was significantly different from the 18 wk group (12.83%). Groups 18 and 20 wk were not significantly different from each other.

Organ Weights

Table III-4 shows liver weight at photostimulation, sexual maturity, and 64 wks of age. No significant differences were found among the three groups at any time. At photostimulation, the 16 wk birds had the greatest relative liver weight (2.25%) versus the 20 wk group which had the lowest (1.8[illegible] 16 wk group also had the highest relative liver weight at sexual maturity (2.63%). At 64 wks of age there were no significant differences among treatments for liver weight; the average across all treatments was 1.98%.

Relative fat pad weight was lowest in the 16 wk group at photostimulation (0.37%) when compared to the other treatments, although the difference was not significant (Table III-4). However, at sexual maturity the 16 wk group had the significantly largest fat pad on both an absolute (33.65g) and relative (2.50%) basis. The 18 wk treatment group had the lowest fat pad weight among treatments with absolute and relative values of 23.11g and 1.66%, respectively. On a percentage basis, the 16 wk treatment maintained their larger fat pad weight (5.02%) although there were no significant differences among the treatments at 64 wks of age. The 20

wk treatment group, at 64 wks of age, had the lowest fat pad weight relative to body weight (4.57%). All groups showed an increase in fat pad weight from photostimulation to sexual maturity and from sexual maturity to 64 wks of age.

Table III-6 shows breast muscle weight and shows no significant difference between treatments on a percentage basis at photostimulation, sexual maturity, or 64 wks of age. Breast muscle weight, as a percentage of body weight, decreased for all groups across time. Although not statistically significant, the 16 wk treatment had the lowest breast muscle weight on a percentage basis, at photostimulation and sexual maturity (14.66% and 12.56%, respectively) but all groups were more similar by 64 wks of age. The average relative fat pad at 64 wks across all treatment groups was 10.65%.

Ovary weight, on both an absolute and relative basis (8.34g and 1.19%, respectively), was significantly largest in the 20 wk group at photostimulation (Table III-7). At sexual maturity and 64 wks of age there were no significant differences among treatments. However, at sexual maturity, the ovary represented a larger percentage of body weight than at 64 wks of age. Average ovary weight on a relative basis at sexual maturity and 64 wks of age for all treatment groups was 3.68% and 2.52%, respectively.

Oviduct weight is represented in Table III-8. At photostimulation, the 20 wk treatment group had a significantly heavier oviduct weight on both a percentage (0.68%) and absolute (14.66g) basis. No significant differences were found between treatments for oviduct weight on a relative basis at sexual maturity and 64 wks of age. However, the greatest increase in oviduct weight was seen in the 16 wk treatment group which increased from 2.87g at photostimulation to 52.07g at sexual maturity. At 64 wks of age the oviduct represents a larger proportion of body weight than at sexual maturity for all treatment groups therefore, the oviduct increased in mass from sexual maturity to 64 wks of age.

Table III-9 illustrates the effect of age at photostimulation on large follicle weight and follicle number. The 20 wk treatment group had a significantly heavier large follicle weight at photostimulation (2.60g) versus the other two treatments (0.00

and 0.14, respectively). This difference was no longer significant at sexual maturity or 64 wks of age. All treatments showed an increase in large follicle weight over time. Follicle number was also significantly greatest in the 20 wk group at photostimulation (1.85) versus the 16 and 18 wk treatments (0.00 for both treatments). All groups showed an increase in follicle number from photostimulation to sexual maturity and a decrease from sexual maturity to 64 wks of age. For all treatment groups combined, follicle number increased from 0.62 at photostimulation to 6.17 at sexual maturity and 4.98 at 64 wks of age. No significant differences were found in follicle number between treatments at sexual maturity or 64 wks of age.

Shank (tarsometatarsus) length from the time of photostimulation through to the end of the trial is illustrated in Table III-10. Overall, no significant differences between treatment group were found at any of the times measured in this study. The 16 wk treatment group had the longest shank length at photostimulation and 64 wks of age (101.21 and 101.57 cm, respectively).

Production Summary

Significant differences were found between treatment groups (Group C) for days prior to sexual maturity and days from photostimulation to sexual maturity (Table III-10). The 16 wk treatment group was found to have the significantly lowest days prior to sexual maturity (139.74d) but was also the greatest in days from photostimulation to sexual maturity (31.76d). The opposite occurred for the 20 wk group which was significantly greater for days prior to sexual maturity (152.89d) but lowest for days from photostimulation to sexual maturity (17.5d). These findings are illustrated in Figure III-1.

Although not statistically significant, the 20 wk group had a higher first egg weight (44.45g) than the other two treatment groups. Also, no significant differences were also found for average specific gravity, average egg weight, total egg mass, unsettable eggs, or total eggs produced between the different treatment groups. The 16 wk treatment group produced the greatest number of eggs (274.13). The 18 wk treatment group produced the most unsettable eggs and also had the highest average

egg weight and total egg mass produced (0.594, 50.65g, and 13878.69g, respectively).

Prime sequence length was greatest in the 20 wk treatment (82.53 d) although there was no overall significant differences between treatments. This finding was also true for mean sequence length. The 16 wk group had the greatest number of pause days (34.11 d) and sequences (27.65) but again these differences were not significant between treatments for these parameters. Figures III-2 and III-3 show egg production (%) and mean sequence length, respectively.

Table III-12 shows the Group D production parameters. No significant differences were found between treatment groups for hen-day production (%), number of eggs produced, feed consumed per egg, or feed consumed per dozen eggs produced. Hen-day production and number of eggs produced for the production period averaged 88% and 584.87, respectively for all three treatments. Feed consumed per egg and feed consumed per dozen eggs produced for all three treatments averaged 133.0g and 1590.0g, respectively.

Mortality in this trial was very low and not affected by treatment. The 16 wk treatment group had 1 mortality, the 18 wk group 3 mortalities, and the 20 wk treatment group 4 mortalities.

Discussion

Body weight increased for all groups from photostimulation to sexual maturity. These differences were maintained throughout the study with the exception of the 18 wk group which was heaviest at 60 wks of age (Figure III-4). These findings suggest that the 16 wk group was underweight at the time of photostimulation and agrees with previous studies (Leeson and Summers, 1987b; 1990) where pullets underweight at the time of photostimulation did not exhibit compensatory growth.

At photostimulation percent dry matter was found to be significantly lower in the 16 and 18 wk groups versus the 20 wk group (Table III-2), however, at sexual maturity no significant differences were found. The 16 wk group had the lowest value at photostimulation and the highest dry matter content at sexual maturity (Table

III-3). These differences in dry matter content are reflected in water content on a percentage basis. At photostimulation, the 16 and 18 wk groups had significantly greater water content than the 20 wk group but these differences were not significant at sexual maturity. All groups showed a decrease in water content from photostimulation to sexual maturity. Percentage lipid increased for all groups from photostimulation to sexual maturity with the 16 wk treatment showing the largest gain in lipid content (Table III-3). This supports the hypothesis that a high degree of fatness is associated with the onset of ovulation (Bornstein *et al.*, 1984). Photostimulation is known to induce ovarian development and with this development comes an increase in circulating hormone levels, particularly estrogen (Etches, 1990). One of the functions of estrogen is increased fat deposition. The large increase in lipid content for the 16 wk treatment suggests that this group did not have the necessary fat content at photostimulation to attain sexual maturity and responded to photostimulation by fat accumulation as did the other treatment groups. However, the 16 wk group surpassed all groups in lipid content on a percentage basis at sexual maturity and this suggests a increased response of this group to the effects of estrogen.

Differences in protein content as a percentage of body weight were found to be not significant between treatments at photostimulation or sexual maturity. At sexual maturity, protein represented less of the total body weight than at photostimulation for all groups. This suggests two possible explanations. One is that, after photostimulation, lean tissue deposition slows and fat deposition increases. Alternatively, protein levels remain constant due to a highly regulated balance between protein deposition and degradation. These observations also suggest that any prerequisite carcass protein requirement is reached by 16 wks of age.

The 16 wk group which was photostimulated earliest had the highest fat content on both an absolute and relative basis at sexual maturity. Although this indicates that photostimulation results in increased fat deposition it does not prove that fat content alone is the determinant for attainment of sexual maturity.

Breast muscle weight on a percentage basis decreased over time for all

treatment groups. This decrease was reflected in the lower protein content of the carcass between photostimulation and sexual maturity. This also supports the observation of Plotkin (1982) that breast muscle weight is a good indicator of lean tissue content. The increase in body weight over time and the decrease in relative breast muscle weight may be explained by the increase in fat pad weights seen over time.

The greatest increase in fat pad weight between photostimulation and sexual maturity occurred in the 16 wk group which coincides with the increase in lipid content also seen at this time. This indicates that these birds change their metabolism in response to photostimulation from skeletal and lean muscle growth to fat deposition and also that there may be a minimum fat requirement for sexual maturity to occur in SCWL hens. The 18 and 20 wk groups had higher body weights at photostimulation and sexual maturity but lower fat pad weights and a corresponding lower lipid content when compared to the 16 wk group at sexual maturity.

The liver is known to be the site where the majority of the products for yolk synthesis takes place (Leveille *et al.*, 1975). Although no significant differences were found in liver weight between treatments at any time throughout the study the liver represented a larger proportion of body weight at 64 wks of age than at sexual maturity. This finding is also reflected in the greater large follicle weights seen at 64 wks of age. At sexual maturity the liver represented the largest proportion of body weight in the 16 wk group which demonstrates a relationship between carcass fat and liver weight as this group also had the highest fat content at this time.

From photostimulation to sexual maturity the ovary increased rapidly in weight which is most likely due to the increased follicle number seen at this time also. The decrease in ovary weight on a percentage basis between sexual maturity and 64 wks of age is also reflected in the decreased follicle numbers at 64 wks of age.

Large follicle weight increased over time for all treatments. Previous studies (Bacon and Cherms, 1968; Sharp, 1989) have also shown that the weight of the ovum at ovulation increases throughout the laying cycle. Although large follicle weight increased from sexual maturity to 64 wks of age, follicle number decreased for all

groups from sexual maturity to 64 wks of age. A possible explanation for this result is a decreased follicular maturation rate or increased follicular atresia with increasing age (Gilbert *et al.*, 1981; 1983; Waddington *et al.*, 1985).

Oviduct weight increased over time for all treatment groups. However, at photostimulation and sexual maturity the oviduct represents a smaller proportion of body weight than the ovary. This indicates that ovarian development is less dependant on photostimulation in SCWL hens than in broiler breeders. In broiler breeder hens the oviduct represented a larger proportion of body weight at photostimulation than the ovary. These findings agree with those of Eitan and Soller (1991) who suggested that modern broiler breeder stocks have a greater sensitivity to light blackout than the egg-type laying hen.

Significant differences were found between all treatments for days prior to first egg, with the 16 wk group reaching sexual maturity earliest. However, as shown in Figure III-1, the 16 wk group also had the longest time interval between photostimulation and sexual maturity while the 20 wk group had the shortest interval. These results indicate that the 16 wk treatment was not physiologically ready to lay at this time and therefore required more time to reach the necessary physiological or neuro-endocrine requirements necessary for sexual maturitation.

Egg production (Group C) did not differ significantly between treatments although the 16 wk group produced approximately six more eggs per hen than the 20 wk group. However, although the 18 and 20 wk groups came into production later than the 16 wk group they responded to the delay in sexual maturity with longer prime sequence lengths, fewer pause days, and fewer sequences. This finding is also reflected in percent hen-day production (Figure III-5). The 18 and 20 wk groups appeared to reach a higher peak production rate and have a better persistency of lay when compared to the 16 wk group. A study by Ernst and Mather (1992) also found that those pullets exposed to lighting earlier peaked in production first and began to decline in production slightly before those exposed to lighting later. It can not be determined from this study if the 18 and 20 wk groups would have ever compensated for the decreased egg production due to delayed sexual maturity. However, it is

evident from these results that delayed sexual maturity results in longer prime sequences, and therefore fewer sequences and fewer pause days. Prime sequence length is known to be correlated with total egg output (Robinson *et al.*, 1990) and this correlation may have been better expressed if the hens were kept to 64 or 68 wks of age. Figure III-4 shows group egg production over time and all groups are very similar. Mean sequence length (Figure III-3) demonstrates that the 20 wk treatment had the longest prime sequence and the 16 wk group the shortest. It is apparent from Figure III-2 that there is a drop in production for the 16 wk treatment at approximately 28-30 wks of age. The 16 wk treatment may not have had the body reserves necessary to reach peak production and the reserves that they did possess may have been depleted by this time.

One of the problems associated with the onset of early sexual maturity in egg-type pullets is the production of more small eggs due to reduced body size (Fuller, 1969). In this study, although body weight was greatest in the 20 wk group at sexual maturity (Table III-3) no significant differences were found between treatments for first egg weight.

Correlation analysis showed that at photostimulation breast muscle weight is highly correlated ($r=0.89$) with body weight. At sexual maturity the best indicator of body weight is shank length ($r=0.51$. Thus shank length may be the best indicator of mature frame size in SCWL pullets.

No significant differences were found between treatments for average egg weight or total egg mass produced over the production period. The results presented here agree with a study by Leeson *et al.* (1990) who found that age at lighting had no effect on total egg production or total egg mass produced for SCWL hens. The birds photostimulated later in this trial, 18 and 20 wks, were also larger at the end of the trial. However, as shown in the Group D production data, there were no significant differences found between treatments for feed consumed per egg produced, feed consumed per dozen eggs produced, hen-day production (%), or number of eggs produced. These results are also illustrated in Figures III-6 and III-7.

In general, these results indicate that delaying the age at photostimulation

shortens the time between photostimulation and sexual maturity and that the carcass composition of the birds at sexual maturity differs significantly only in carcass fat content. More importantly for the producer, these results show that delaying the age at sexual maturity does not adversely affect egg production because the birds respond to the delay by increasing prime sequence length and decreasing the number of pause days. However, lighting too early may result in inadequate body reserves to achieve persistency of lay as demonstrated by the 16 wk treatment group. Overall, 18 or 20 wks of age seems to be the best time to photostimulate this particular strain of SCWL pullets.

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TABLE III-2. Effect of age at photostimulation on body composition on an absolute and percentage basis at the time of photostimulation in SCWL hens.

Time of Photostimulation[1] (wks of age) (SEM)			
Variable	16wk	18wk	20wk
% Dry Matter of Bird	36.46[b] (1.65)	37.48[b] (2.18)	39.85[a] (2.24)
% Water	63.55[a] (1.65)	62.53[a] (2.17)	60.15[b] (2.24)
% Protein of Bird	26.24[a] (0.91)	26.35[a] (1.13)	26.02[a] (1.99)
% Lipid of Bird	5.46[b] (1.77)	6.38[b] (2.01)	8.22[a] (2.34)
% Ash of Bird	3.85[a] (0.36)	3.95[a] (0.43)	3.96[a] (0.36)
Body Weight (g)	1024.10[b] (88.37)	1158.80[a] (118.67)	1197.00[a] (97.22)
Weight of Water (g)	647.4[b] (58.4)	723.89[a] (71.40)	719.58[a] (60.45)
Weight of Protein (g)	267.28[b] (24.48)	304.99[a] (29.35)	311.77[a] (35.53)
Weight of Lipid (g)	56.66[c] (19.29)	75.20[b] (30.75)	99.15[a] (30.60)
Weight of Ash (g)	39.16[b] (4.50)	45.64[a] (5.66)	47.53[a] (6.57)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-3. Effect of age at photostimulation on body composition on an absolute and percentage basis at the time of sexual maturity in SCWL hens.

Time of Photostimulation[1] (wks of age) (SEM)			
Variable	16wk	18wk	20wk
Days prior to first egg	139.74[a] (0.94)	146.33[b] (0.94)	152.89[c] (0.94)
Days from PS to sexual maturity	31.76[a] (1.22)	21.90[b] (1.25)	17.50[c] (1.25)
% Dry Matter of Bird	44.83[a] (0.85)	44.08[a] (0.78)	43.79[a] (0.78)
% Water	55.17[a] (0.85)	55.92[a] (0.78)	56.21[a] (0.78)
% Protein of Bird	24.24[a] (0.54)	25.84[a] (0.50)	25.55[a] (0.50)
% Lipid of Bird	15.18[a] (0.72)	12.83[b] (0.66)	13.27[ab] (0.66)
% Ash of Bird	3.73[a] (0.09)	3.82[a] (0.08)	3.70[a] (0.08)
Body Weight (g)	1284.22[a] (110.37)	1309.67[a] (154.40)	1348.00[a] (98.54)
Weight of Water (g)	706.84[a] (19.27)	736.10[a] (17.81)	757.13[a] (17.84)
Weight of Protein (g)	310.99[b] (6.70)	334.68[a] (6.20)	344.09[a] (6.20)
Weight of Lipid (g)	197.13[a] (11.34)	168.32[a] (10.50)	179.77[a] (10.50)
Weight of Ash (g)	47.85[a] (1.21)	49.54[a] (1.12)	49.81[a] (1.12)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-4. Effect of age at photostimulation on liver weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 64 wks of age in SCWL hens.

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
---Liver weight (g)(SEM)---			
Photostim.	23.86[a] (16.07)	22.70[a] (3.78)	22.24[a] (4.01)
Sexual Maturity	24.69[a] (3.90)	23.99[a] (3.13)	24.82[a] (3.79)
64 wk	35.44[a] (1.57)	35.62[a] (1.55)	35.57[a] (1.57)
---Liver Weight (% of BW) (SEM)---			
Photostim.	2.25[a] (0.20)	1.90[a] (0.20)	1.81[a] (0.20)
Sexual Maturity	1.83[a] (0.06)	1.73[a] (0.06)	1.77[a] (0.06)
64 wk	2.00[a] (0.09)	1.97[a] (0.09)	2.00[a] (0.09)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-5. Effect of age at photostimulation on fat pad weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 64 wks of age in SCWL hens.

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
---Fat Pad weight (g)(SEM)---			
Photostim.	3.97[a] (1.38)	8.24[b] (1.38)	13.11[c] (1.38)
Sexual Maturity	33.65[a] (2.27)	23.11[b] (2.27)	26.15[b] (2.27)
64 wk	88.86[a] (6.24)	88.71[a] (6.17)	82.78[a] (6.31)
---Fat Pad (% of BW) (SEM)---			
Photostim.	0.37[a] (0.12)	0.69[a] (0.12)	1.06[a] (0.12)
Sexual Maturity	2.50[a] (0.17)	1.66[b] (0.17)	1.87[b] (0.17)
64 wk	5.02[a] (0.35)	4.91[a] (0.35)	4.57[a] (0.35)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-6. Effect of age at photostimulation on breast muscle weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 64 wks of age in SCWL hens.

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
---Breast Muscle weight (g)(SEM)---			
Photostim.	155.15[a] (4.18)	181.72[b] (4.18)	189.16[b] (4.18)
Sexual Maturity	169.27[a] (4.95)	184.70[b] (4.95)	191.58[b] (4.95)
64 wk	188.62[a] (4.41)	192.60[a] (4.36)	189.35[a] (4.41)
---Breast Muscle Weight (% of BW) (SEM)---			
Photostim.	14.66[a] (0.36)	15.23[a] (0.36)	15.36[a] (0.36)
Sexual Maturity	12.56[a] (0.36)	13.30[a] (0.36)	13.68[a] (0.36)
64 wk	10.66[a] (0.25)	10.65[a] (0.24)	10.67[a] (0.25)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-7. Effect of age at photostimulation on ovary weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 64 wks of age in SCWL hens.

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
---Ovary weight (g)(SEM)---			
Photostim.	0.51[a] (1.56)	1.24[a] (1.56)	8.34[b] (1.56)
Sexual Maturity	33.97[a] (2.15)	37.06[a] (2.15)	34.64[a] (2.15)
64 wk	45.51[a] (2.08)	43.45[a] (2.06)	45.92[a] (2.08)
---Ovary (% of BW) (SEM)---			
Photostim.	0.27[b] (0.17)	0.68[a] (0.17)	1.19[a] (0.17)
Sexual Maturity	3.86[a] (0.12)	3.58[a] (0.12)	3.61[a] (0.12)
64 wk	2.57[a] (0.12)	2.40[a] (0.12)	2.59[a] (0.12)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-8. Effect of age at photostimulation on oviduct weight and weight as a percentage of body weight at photostimulation, sexual maturity, and 64 wks of age in SCWL hens.

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
---Oviduct weight (g)(SEM)---			
Photostim.	2.87[a] (2.04)	8.13[a] (2.04)	14.66[b] (2.04)
Sexual Maturity	52.07[a] (1.62)	49.68[a] (1.62)	50.56[a] (1.62)
64 wk	55.64[a] (2.24)	55.49[a] (2.22)	58.64[a] (2.24)
---Oviduct (% of BW) (SEM)---			
Photostim.	0.05[b] (0.13)	0.10[b] (0.13)	0.68[a] (0.13)
Sexual Maturity	2.52[a] (0.16)	2.67[a] (0.16)	2.47[a] (0.16)
64 wk	3.15[a] (0.13)	3.07[a] (0.12)	3.30[a] (0.13)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-9. Effect of age at photostimulation on large follicle weight and large follicle number[2] at photostimulation, sexual maturity, and 64 wks of age in SCWL hens.

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
---Large Follicle weight (g)(SEM)---			
Photostim.	0.00[a] (0.54)	0.14[a] (0.54)	2.60[b] (0.54)
Sexual Maturity	8.47[a] (0.92)	9.34[a] (0.92)	11.05[a] (0.92)
64 wk	15.63[a] (0.28)	15.27[a] (0.28)	15.66[a] (0.28)
---Follicle Number[2] (SEM)---			
Photostim.	0.00[a] (0.38)	0.00[a] (0.38)	1.85[b] (0.38)
Sexual Maturity	6.40[a] (0.41)	6.40[a] (0.41)	5.70[a] (0.41)
64 wk	5.05[a] (0.13)	4.95[a] (0.13)	4.93[a] (0.13)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.
[2]Large follicle=follicles with diameter > 10mm.

TABLE III-10. Effect of age at photostimulation on shank length (cm) at photostimulation, sexual maturity, and 64 wks of age in SCWL hens.

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
	---Shank Length (cm)(SEM)---		
Photostim.	101.21[a] (0.95)	99.26[a] (0.95)	98.67[a] (0.95)
Sexual Maturity	98.99[a] (0.86)	100.23[a] (0.86)	99.28[a] (0.86)
64 wk	101.57[a] (0.80)	100.80[a] (0.78)	99.50[a] (0.79)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

TABLE III-11. Effect of age at photostimulation on age at sexual maturity, egg production, first egg weight (g), average egg weight (g), total egg mass produced (g), specific gravity, prime sequence length (days), number of sequences, number of pause days in SCWL hens (Group C).

	Time of Photostimulation[1] (wks of age)		
Variable	16 wk	18 wk	20wk
Days prior to first Egg	139.74[a] (0.94)[2]	146.33[b] (0.94)	152.89[c] (0.94)
Days from PS to sexual maturity	31.76[a] (1.22)	21.90[b] (1.25)	17.50[c] (1.25)
First egg wt. (g)	42.60[a] (1.31)	42.26[a] (1.31)	44.45[a] (1.34)
Avg. egg wt. (g)	48.66[a] (0.77)	50.65[a] (0.77)	49.57[a] (0.77)
Total egg mass produced (g)	13599.06[a] (239.66)	13872.59[a] (239.66)	13228.17[a] (239.66)
Egg production	274.13[a] (2.99)	271.74[a] (2.99)	267.85[a] (2.99)
Specific gravity	1.084[a] (0.001)	1.084[a] (0.001)	1.083[a] (0.001)
Poor egg production	0.587[a] (0.098)	0.594[a] (0.098)	0.515[a] (0.098)
Prime sequence length	68.69[a] (5.49)	81.74[a] (5.49)	82.35[a] (5.49)
Number of sequences	27.65[a] (1.62)	25.63[a] (1.62)	22.39[a] (1.62)
Mean sequence length (days)	12.52[a] (1.31)	12.73[a] (1.31)	16.55[a] (1.31)
Number of pause days	34.11[a] (2.96)	29.48[a] (2.96)	27.33[a] (2.96)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.
[2]SEM

TABLE III-12. Effect of age at photostimulation on hen-day production (%), number of eggs produced, and feed conversion values of SCWL hens (Group D).

Time of Photostimulation[1] (wks of age)			
Variable	16wk	18wk	20wk
Number of eggs produced (2 hens)	584.39[a] (5.02)	585.05[a] (5.02)	585.18[a] (5.14)
Hen-day production (%)	88.10[a] (0.70)	87.90[a] (0.70)	89.30[a] (0.70)
Feed consumed per egg (kg)	0.133[a] (0.001)	0.134[a] (0.001)	0.133[a] (0.001)
Feed consumed (kg) per dozen eggs	1.59[a] (0.02)	1.60[a] (0.02)	1.59[a] (0.02)

[a-c]Means within a row with no common superscripts differ significantly ($P < .05$).
[1]Time of Photostimulation: 16=16wk; 18=18wk; 20=20wk.

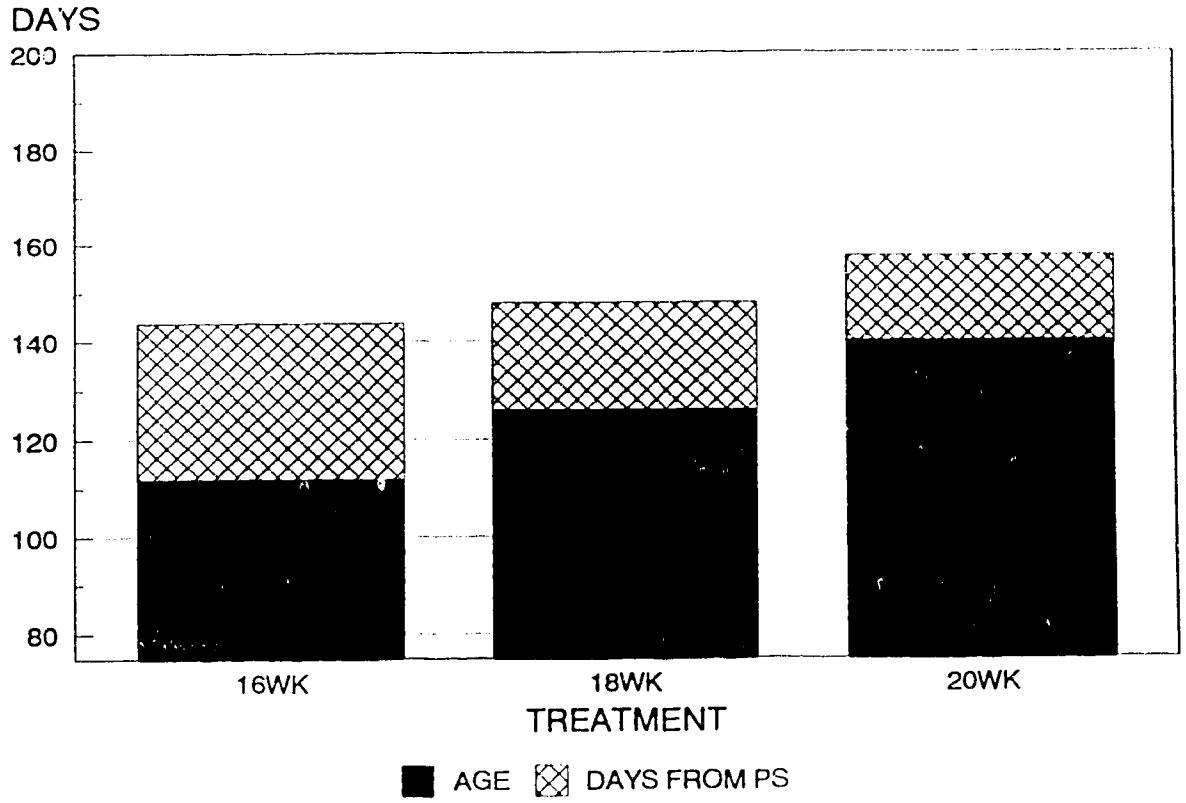

FIGURE III-1. Effect of age at photostimulation on days prior to sexual maturity and days from photostimulation to sexual maturity in SCWL hens photostimulated at different ages (Group C).

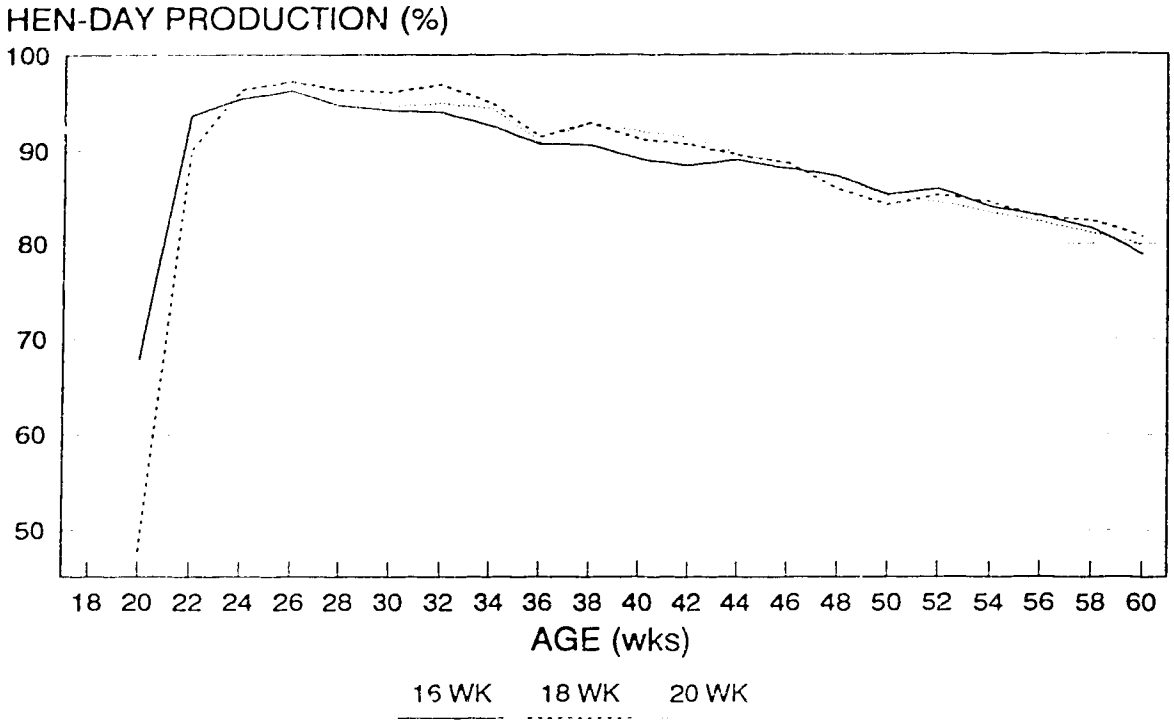

FIGURE III-2. Effect of age at photostimulation on egg production (%) in SCWL hens photostimulated at different ages (Group C).

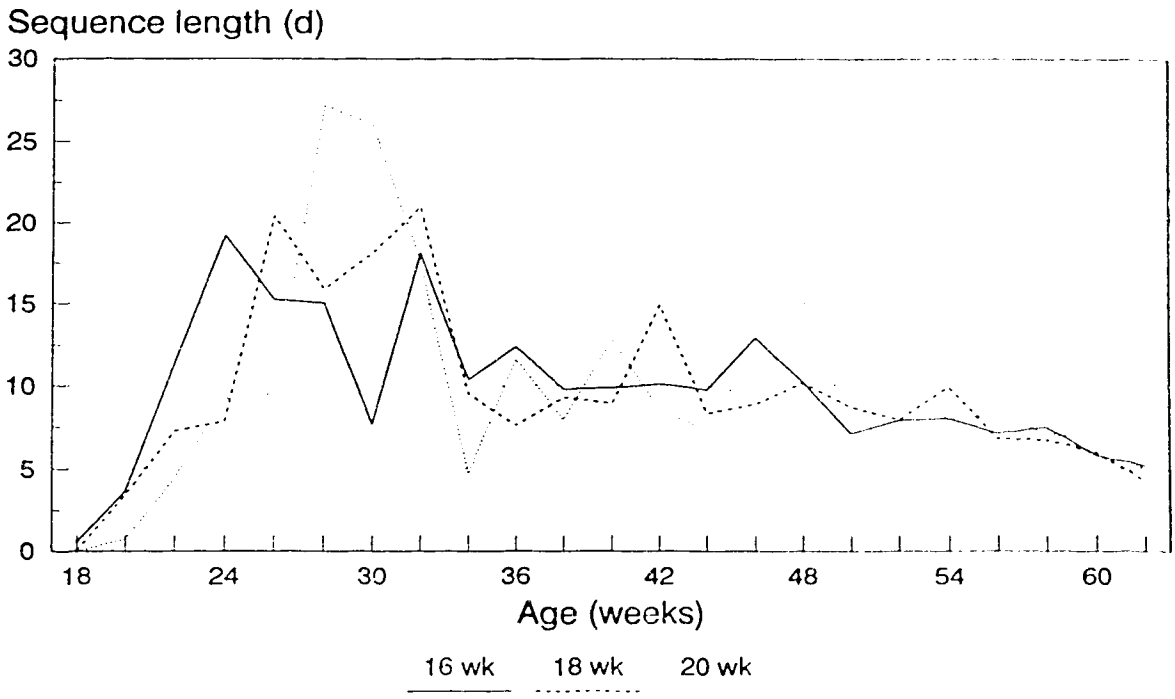

FIGURE III-3. Effect of age at photostimulation on mean sequence length (days) in SCWL hens photostimulated at different ages (Group C).

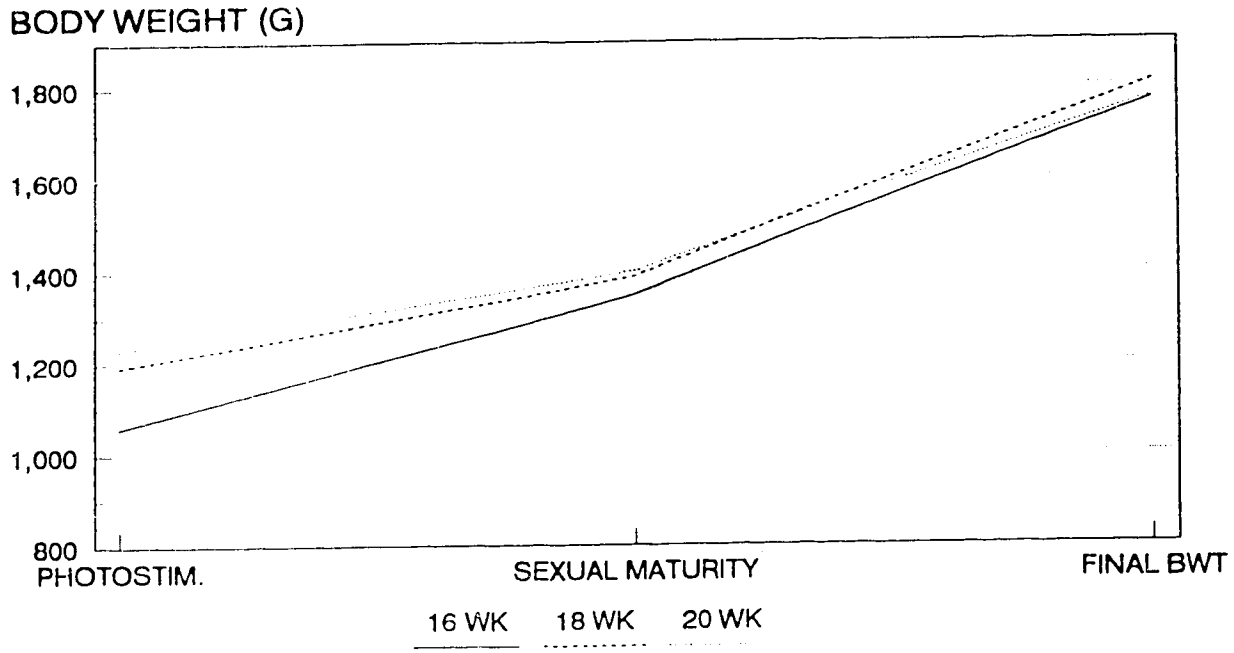

FIGURE III-4. **Effect of age at photostimulation on body weight (g) at photostimulation (PS), sexual maturity, and 62 wks of age in SCWL hens photostimulated at different ages (Group C).**

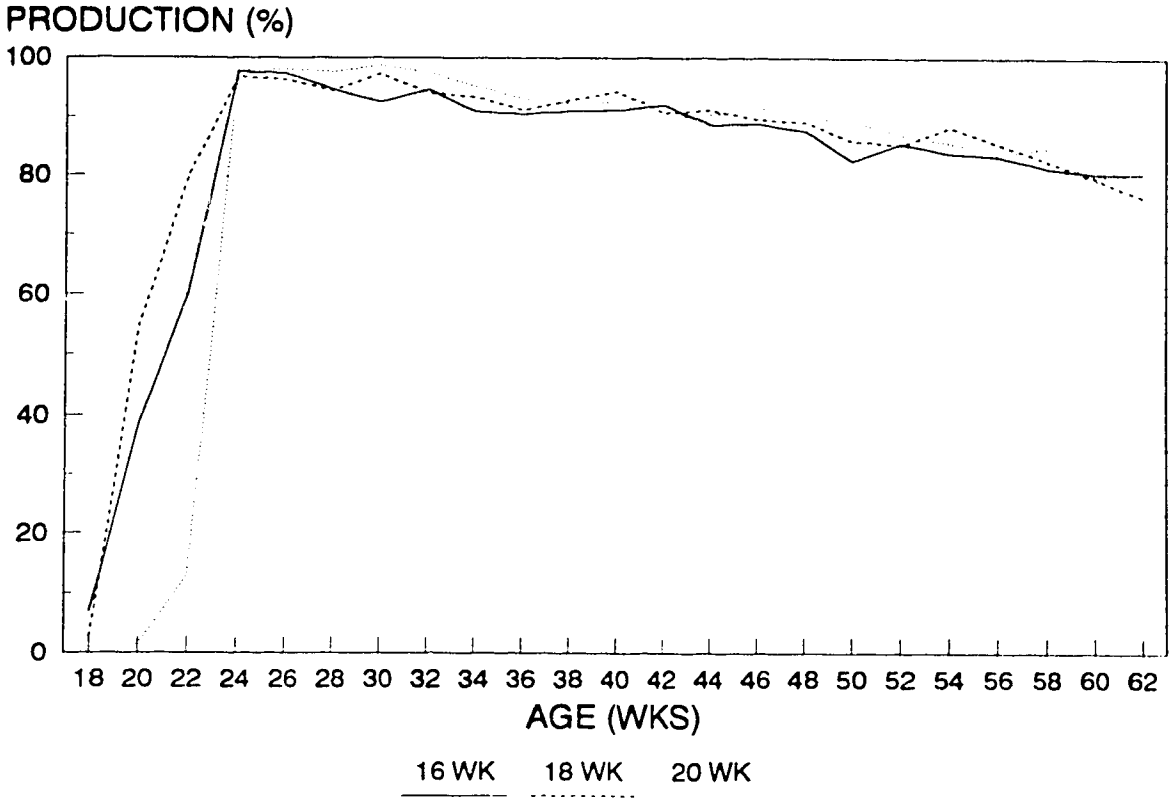

FIGURE III-5. **Effect of age at photostimulation on percent (%) hen-day production in SCWL hens photostimulated at different ages (Group D).**

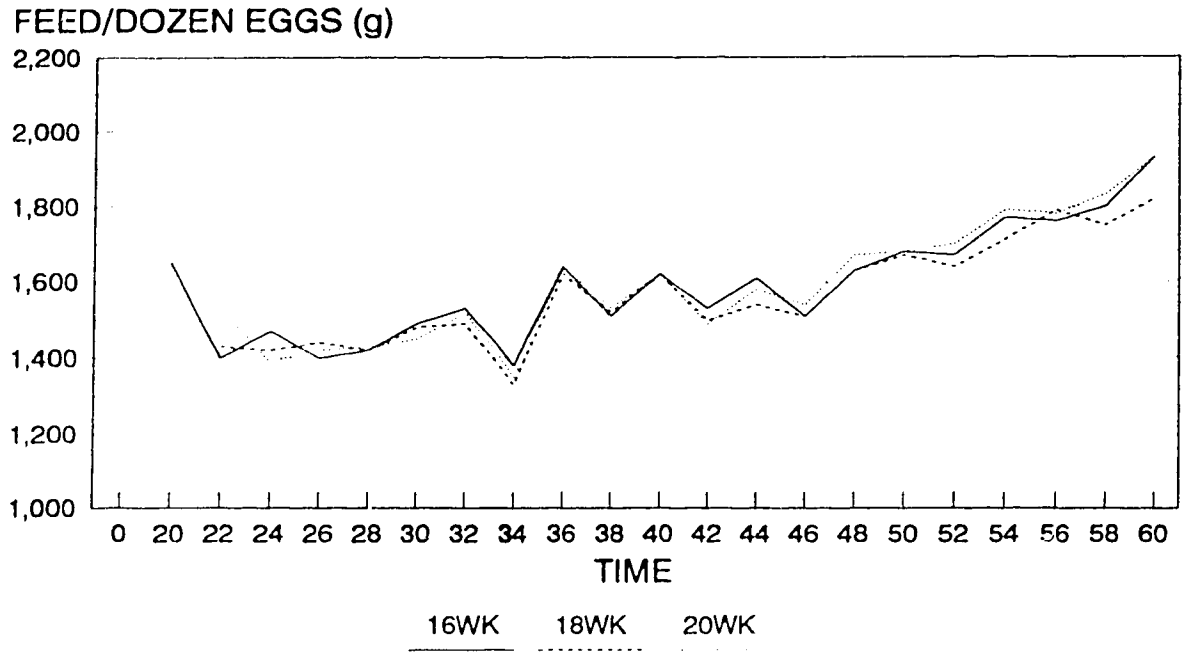

FIGURE III-6. **Effect of age at photostimulation on feed consumed (g) per dozen eggs produced in SCWL hens photostimulated at different ages (Group D).**

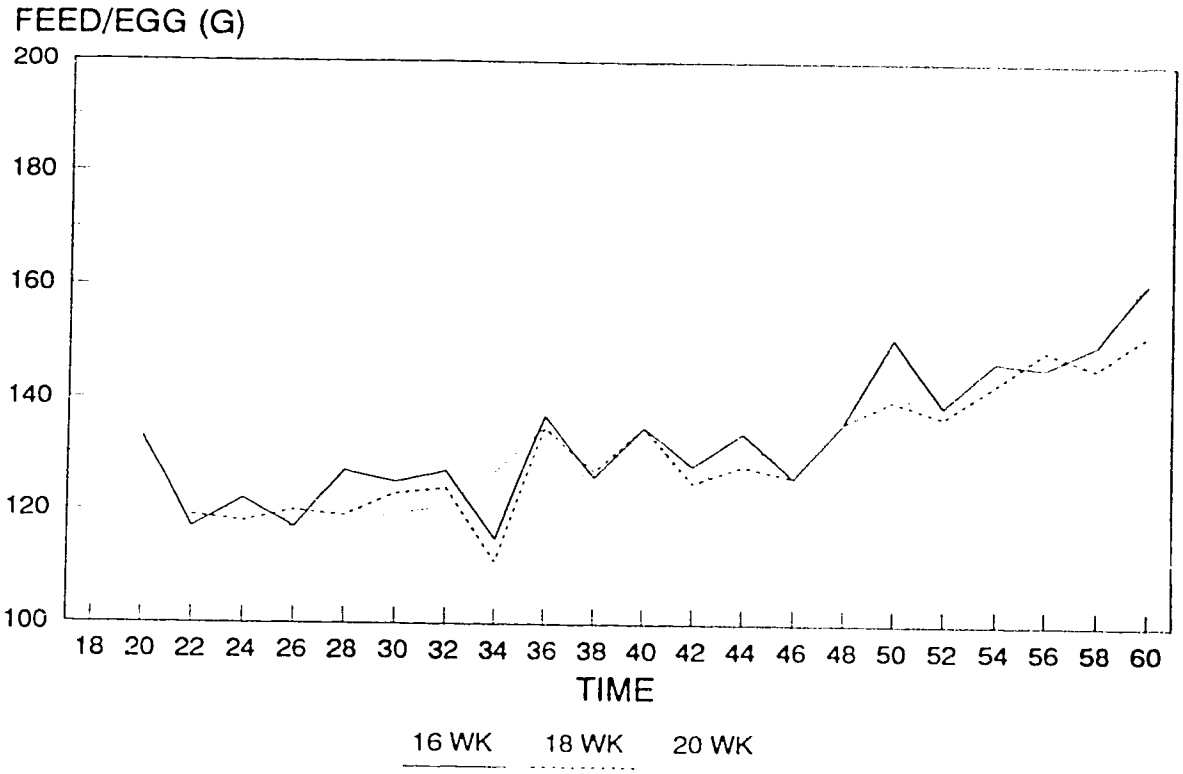

FIGURE III-7. Effect of age at photostimulation on feed consumed (g) per egg produced in SCWL hens photostimulated at different ages (Group D).

IV. General Discussion and Conclusions

Broiler Breeder Trial

One of the objectives of this study was to determine if carcass composition varied at time of photostimulation and at sexual maturity in birds photostimulated at different ages. The broiler breeder experiment showed that there was a difference in carcass composition in birds photostimulated at different ages at both photostimulation and sexual maturity. At photostimulation significant differences were found between treatment groups in body weight, dry matter content, water content, lipid content, and ash content. The differences found in carcass composition may be related to body weight and age differences. When birds were photostimulated at a later age, water content decreased, lipid content increased, and ash content decreased. These factors suggest that as the bird ages less skeletal growth occurs and there is more fat deposition. This explanation is supported by the lack of significant differences in protein content between treatment groups at photostimulation. These findings agree with previous studies (Bennett and Leeson, 1989) which found that lean tissue deposition occurs faster when the bird is young but also increases along with increasing body weight and age to remain at a relatively constant level. At sexual maturity, body weight differences between groups were lessened due to feed restriction practices employed to control body weight gain. Concurrent with the similarities in body weight, were a lack of significant differences found in dry matter content, water content, protein content, lipid content, and ash content. These findings suggest that carcass composition at sexual maturity varies little among birds photostimulated at different ages. It also agrees with the suggestion of Bornstein *et al.* (1984) that there may be a minimum fat requirement for sexual maturation in these birds, because all treatment groups showed an increase in lipid content from photostimulation to sexual maturity. The birds photostimulated earliest, 120 d, had the greatest increase in fat content from photostimulation to sexual maturity which also demonstrates that photostimulation results in rapid accumulation of fat in preparation for sexual maturity.

While these results support the role of fat in onset of sexual maturity they do

not rule out the possibility that there exists a minimum age requirement. Previous studies with broiler breeders (Leeson and Summers, 1982) have shown that attainment of mature body weight in full-fed broiler breeder pullets is not a problem as it can be achieved by 14-15 wks of age. Therefore, there must also be a minimum age requirement or body composition requirement for sexual maturation. The early maturing 120 d treatment group may have been the youngest at sexual maturity but they also took the longest amount of time from photostimulation to reach sexual maturity. This supports a possible minimum age requirement for sexual maturity.

This study also demonstrated, in agreement with previous studies (Eitan and Soller, 1991a, b), that broiler breeder pullets show greater sensitivity to light blackout than layer birds as evidenced by the lack of ovarian development at time of photostimulation regardless of age. Although large follicle weight at sexual maturity was increased by delayed sexual maturity, this did not translate into a significant increase in first egg weight. Average egg weight and total egg mass produced did not differ significantly between treatments which may be of significance to the producer. Delayed maturity is thought to result in larger eggs with poorer shell quality and therefore poorer hatchability. In the present study, as specific gravity and overall hatchability values were not significantly different for the different treatment groups.

Thus egg production is not adversely affected by delaying sexual maturity which may be of some significance to the hatching egg producer. Of greater importance to the hatching egg producer is chick production. The higher chick production seen in the 140 d treatment group and to a lesser extent 150 and 160 d treatment groups, versus the 120 and 130 d treatment groups, suggests that photostimulating later rather than earlier would be more beneficial to the producer. By altering the age at photostimulation savings may be had in feed costs or other areas. However, from these results it appears that beginning egg weight is not influenced by earlier or later photostimulation. However, meat-type birds may develop some problems with carcass composition if photostimulation is too early.

SCWL Trial

Although the differences were not significant body weight differences between treatments at the time of photostimulation were maintained at sexual maturity. The birds photostimulated earliest, 16 wk, were lightest at photostimulation and sexual maturity. At 64 wks of age, there was no longer any linear increase in body weight as age at photostimulation increased. These findings support previous work (Leeson and Summers, 1987) in which egg-type pullets did not exhibit compensatory gain. Significant differences were found in dry matter, water, lipid, and ash content between treatment groups at the time of photostimulation. These differences may be related to differences in body weight and age. Protein content was not significantly different between treatment groups. These findings indicate that any critical lean mass requirement is met at an early age and after this point tissue accretion is mainly fat. At sexual maturity, the only parameter which showed significant differences between treatments was lipid content. Lipid content increased for all groups between photostimulation and sexual maturity. This finding suggests the importance of fat content for the onset of sexual maturity (Frisch *et al.*, 1974) and also demonstrates the effect of photostimulation on body composition. In this study the group photostimulated earliest, 16 wk, showed the greatest increase in fat content from photostimulation to sexual maturity and also the largest fat content at sexual maturity. This suggests that there may have been a hyper-sensitive response to the effects of estradiol on fat accumulation. Relative liver weight increased the most during this time in the 16 wk treatment group, which indicates the role of the liver in lipogenesis and possible fat accumulation here. Overall, these results support the hypothesis of Bornstein *et al.* (1984) that there may be a minimum fat content necessary for the onset of sexual maturity.

These results do not rule out the possibility of their also being a minimum age and body requirement for sexual maturity. In the present study the group photostimulated earliest, 16 wk, reached sexual maturity at the earliest age but also had the longest time period between photostimulation and sexual maturity. The 20 wk treatment group, which was photostimulated latest, reached sexual maturity at the

oldest age but also had the fewest number of days between photostimulation and sexual maturity. Therefore, as age at photostimulation increased, days from photostimulation to sexual maturity decreased. These findings do not rule out the possibility that a minimum age requirement for sexual maturity exists in SCWL hens. All groups exhibited body weight gain from photostimulation to sexual maturity and therefore the possiblity of their also being a minimum body weight requirement for sexual maturity is not ruled out. It is difficult to separate age and body weight differences in this study to determine which is more important in determining the onset of sexual maturity. Previous results (Leeson and Summers, 1983; 1985) suggest that the early onset of sexual maturity in SCWL pullets is more dependant on achieving adequate body weight gain rather than an age requirement. Present results suggest that 16 wk of age is too early to photostimulate birds because persistency of lay may be compromised as the birds lack adequate body reserves to maintain high production rates. Delaying age at photostimulation may benefit the producer as these birds reach production faster and demonstrate persistency of lay. However, birds photostimulated at 18 wks of age are able to withstand the rigors of high egg production.

Egg production curves of the different treatment groups in this study demonstrate the importance of adequate body weight or body reserves for persistency of lay. The 16 wk treatment group showed a significant drop in production at approximately 28-30 wks of age and this may be attributed to the lack of adequate body reserves to reach peak production and sustain that production. This finding agrees with the results of Leeson and Summers (1982) with broiler breeder pullets who found that persistency of lay was not achieved by early maturing pullets. Reductions in egg size, first egg weight, and overall egg mass produced were not seen in this experiment for early maturing verus later maturing birds. Egg production was not significantly affected by increasing or decreasing the age at sexual maturity. However, delaying sexual maturity did result in longer prime sequence length and fewer pause days resulting in approximately the same number of eggs as the earlier maturing groups.

Egg-type birds are not thought to have body weight control problems and are thus fed *ad libitum* throughout the laying period in order to sustain their high production rates. In this study, fat content was seen to increase over time while breast muscle content, which is indicative of lean body mass, decreased on a percentage basis. This suggests that the birds may be consuming beyond their energy requirements for egg production and the result is increased fat deposition. Potential savings in feed costs are possible if laying hens can be feed restricted in order to match egg production with body weight and decrease fat deposition.

Ovary development at photostimulation was evident for all treatments, although the 16 wk group did not have any large follicle development at this time. These results are in agreement with those of Eitan and Soller (1991a, b) who suggested that layer birds were less sensitive to light restriction by short daylengths than broiler breeder pullets.

Further work is needed to separate body weight and age as potential determinants of sexual maturity. This could be accomplished by grouping birds according to body weight and sampling at different ages within body weight groupings. Also, in order to further understand reproductive organ development, estradiol and luteinizing hormone (LH) levels could be measured at regular intervals. Determining circulating hormone levels would help elucidate the effects of photostimulation on changing carcass composition and reproductive organ morphology.

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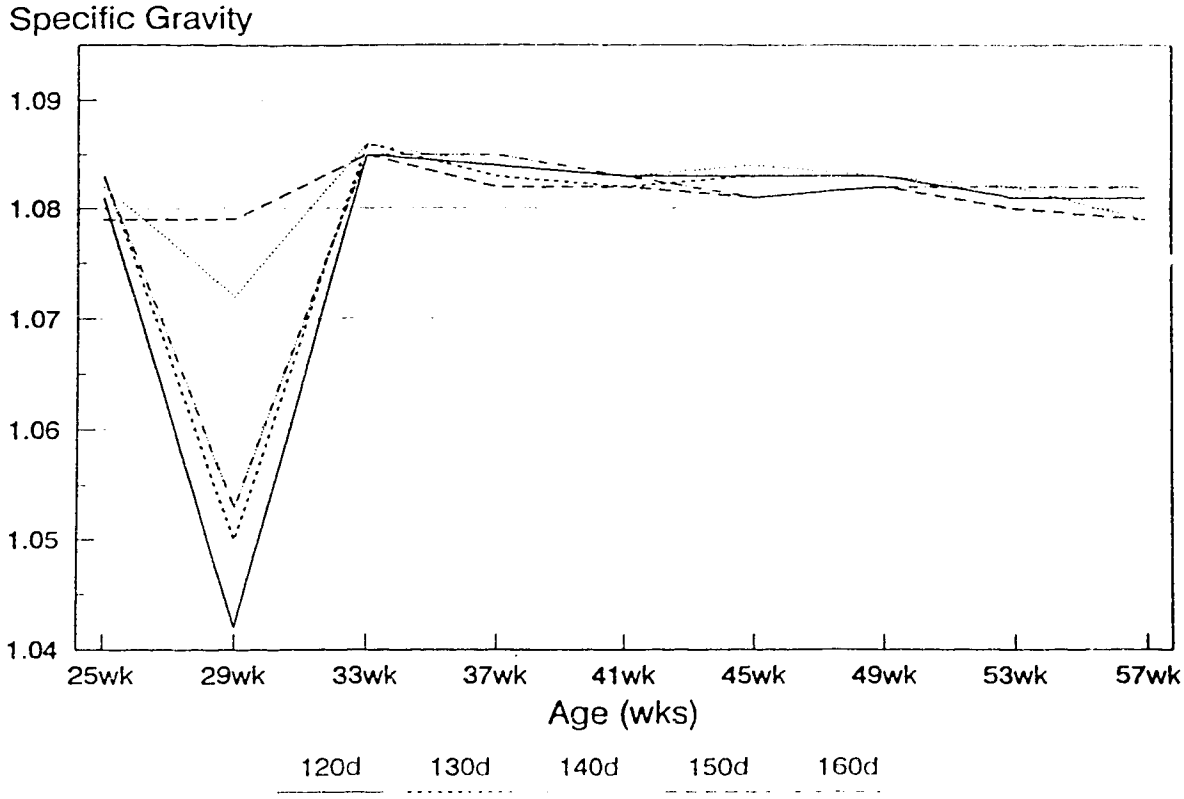

FIGURE V-1. Effect of age at photostimulation on the specific gravity of eggs produced from broiler breeder hens photostimulated at different ages.

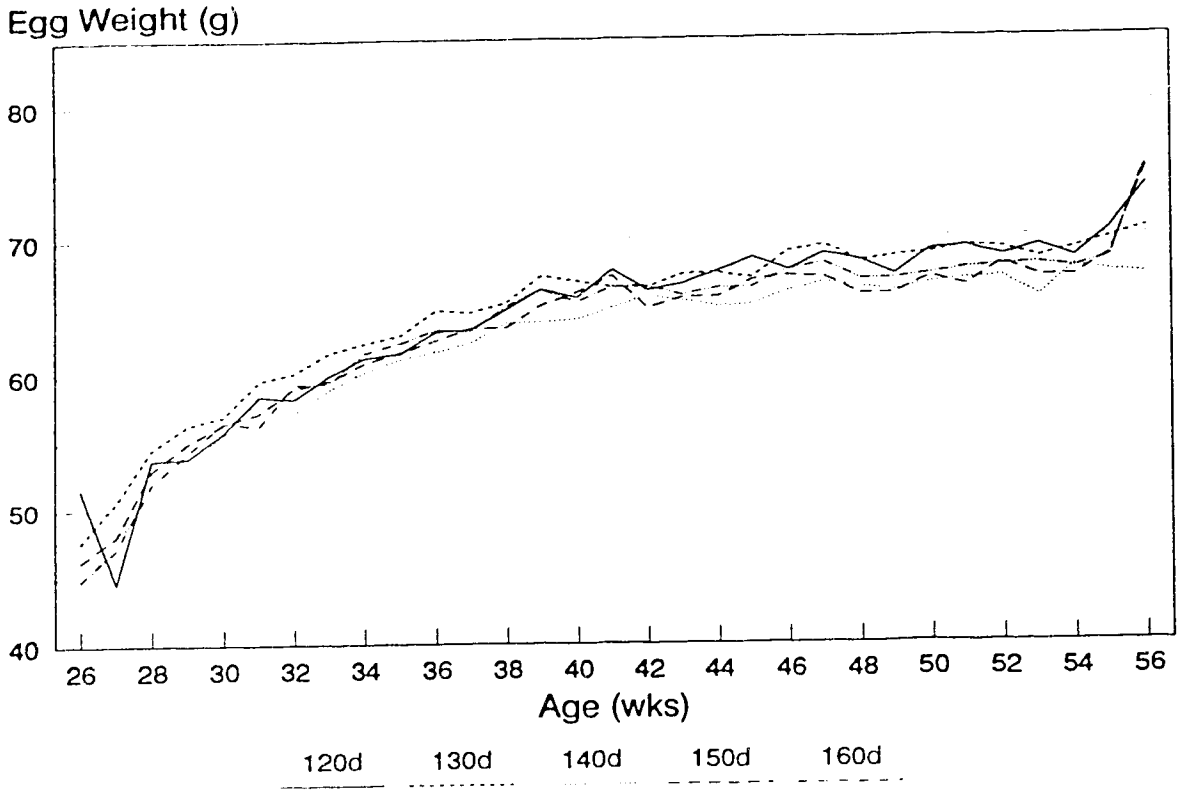

FIGURE V-2. Effect of age at photostimulation on the average egg weight (g) from 26 to 56 wks of age from broiler breeder hens photostimulated at different ages.

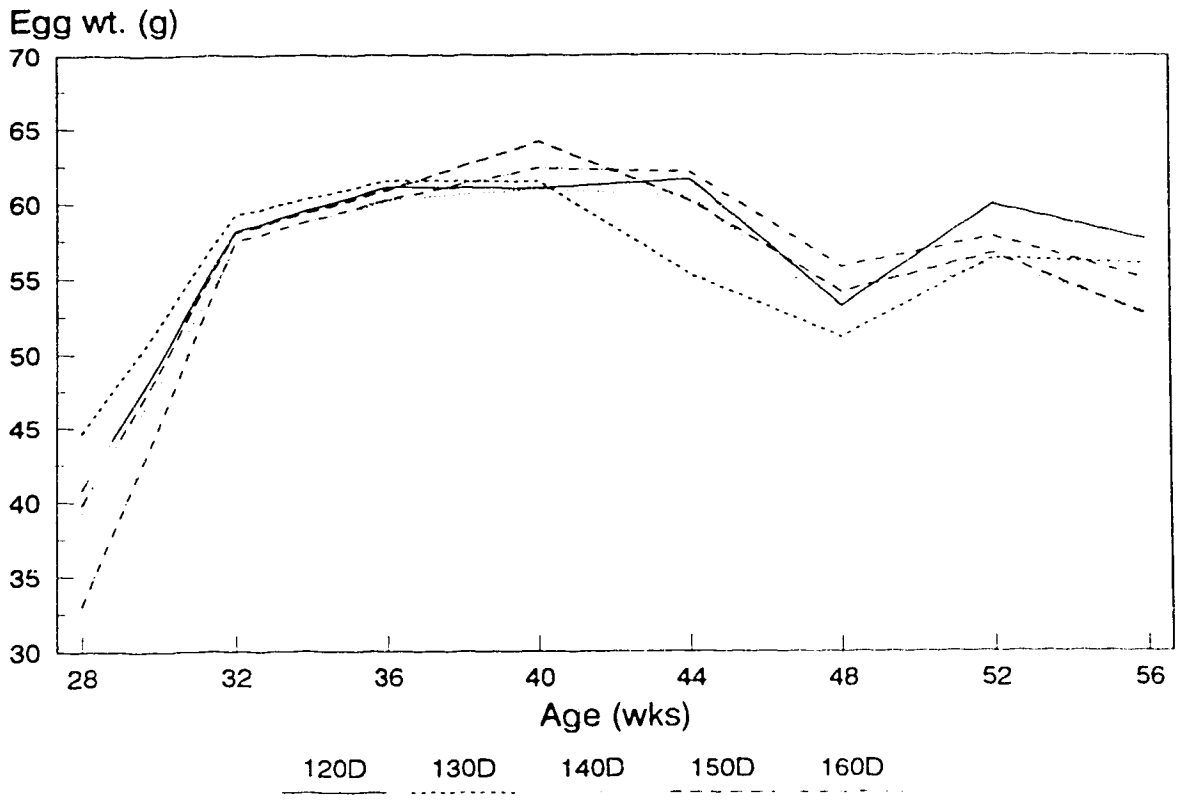

FIGURE V-3. Effect of age at photostimulation on the average egg weight (g), divided into four-week periods for the period of 28 to 56wks of age, in broiler breeder hens photostimulated at different ages.

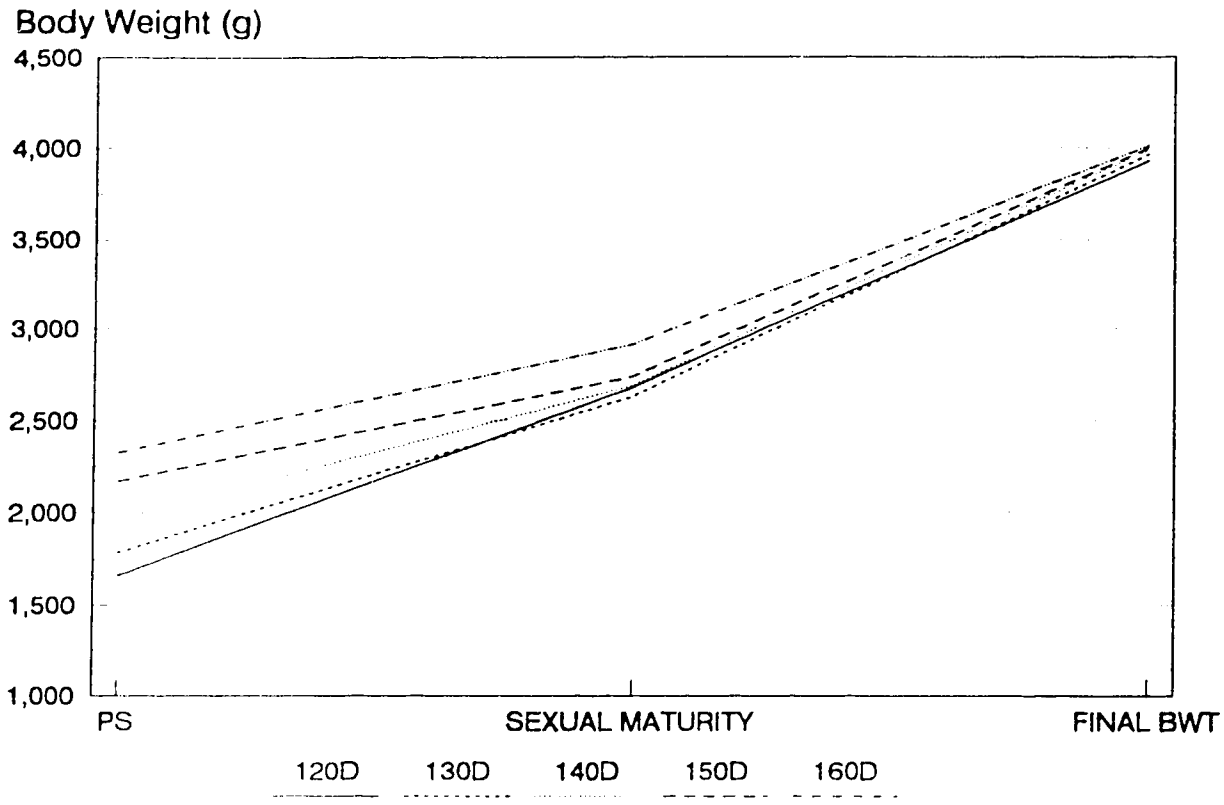

FIGURE V-4. **Effect of age at photostimulation on the body weight (g) at photostimulation (PS), sexual maturity, and 60 wks of age in broiler breeder hens photostimulated at different ages.**

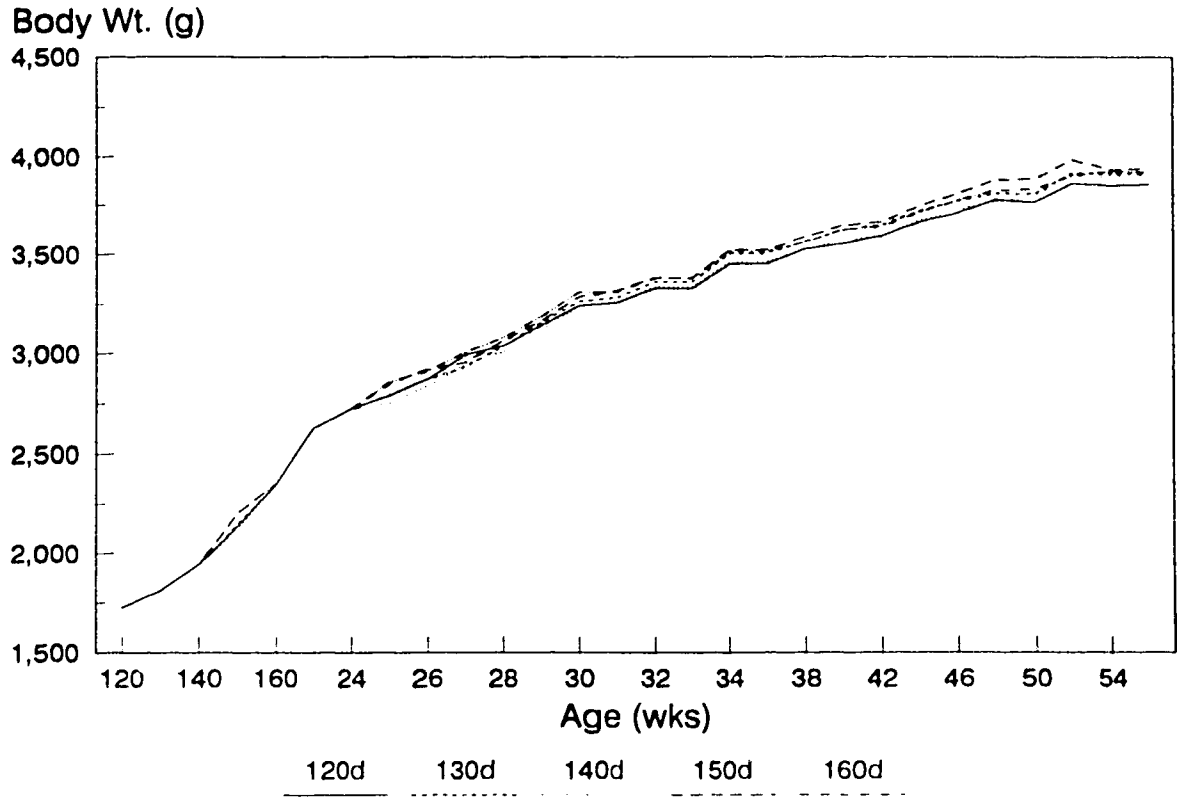

FIGURE V-5. Body weight over time from 120 d of age to 60 wks of age in broiler breeders photostimulated at different ages.

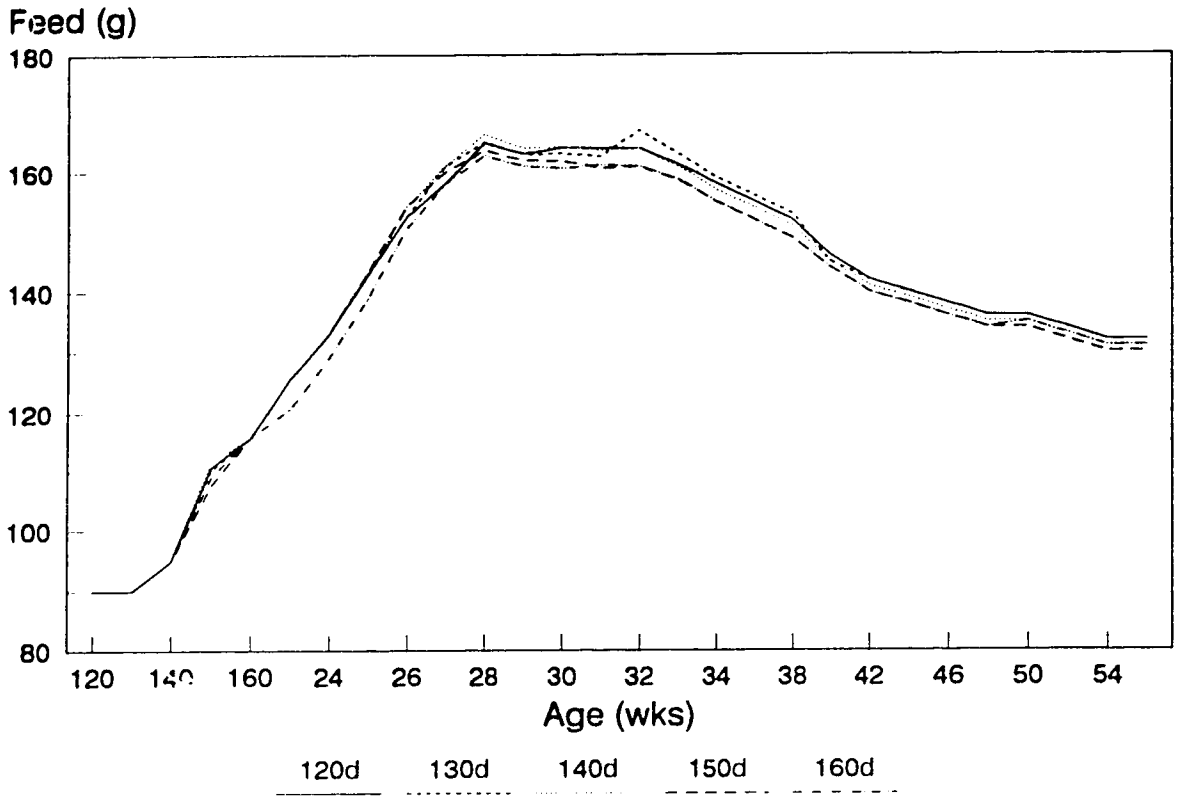

FIGURE V-6. Feed allocation over time from 120 d of age to 60 wks of age in broiler breeders photostimulated at different ages.

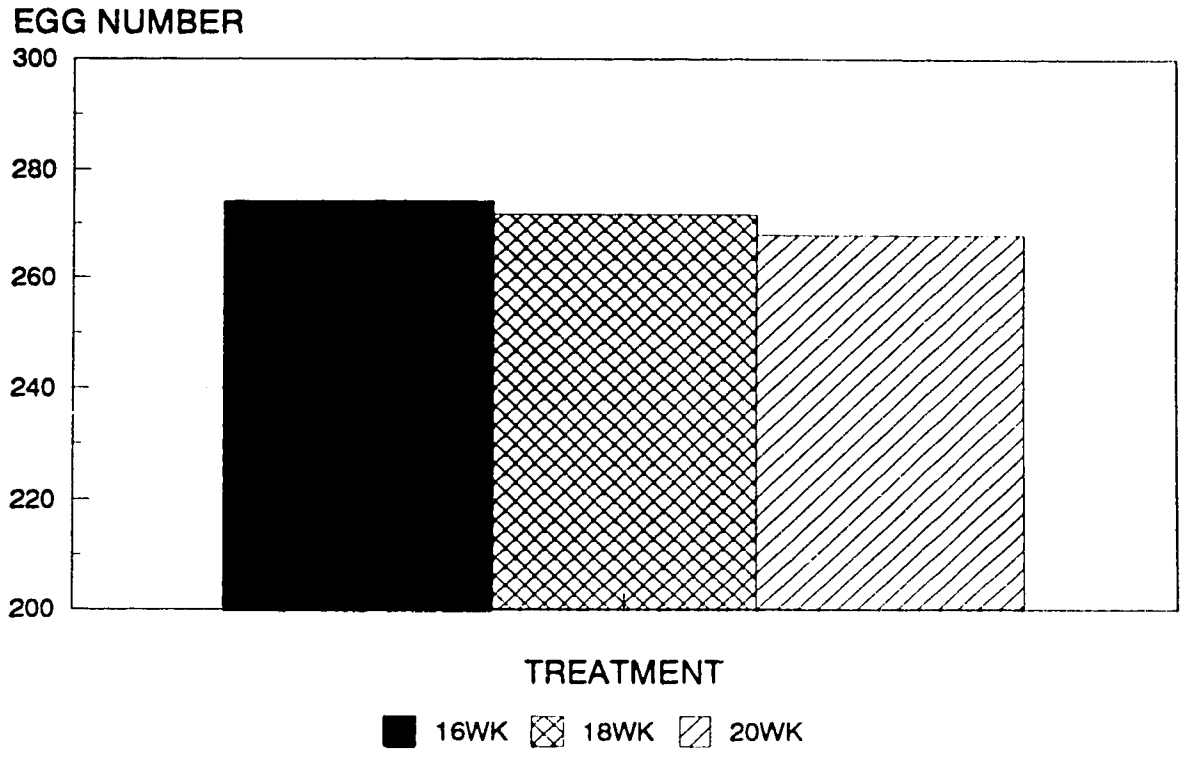

FIGURE V-7. Effect of age at photostimulation on total egg production in SCWL hens photostimulated at different ages (Group C).

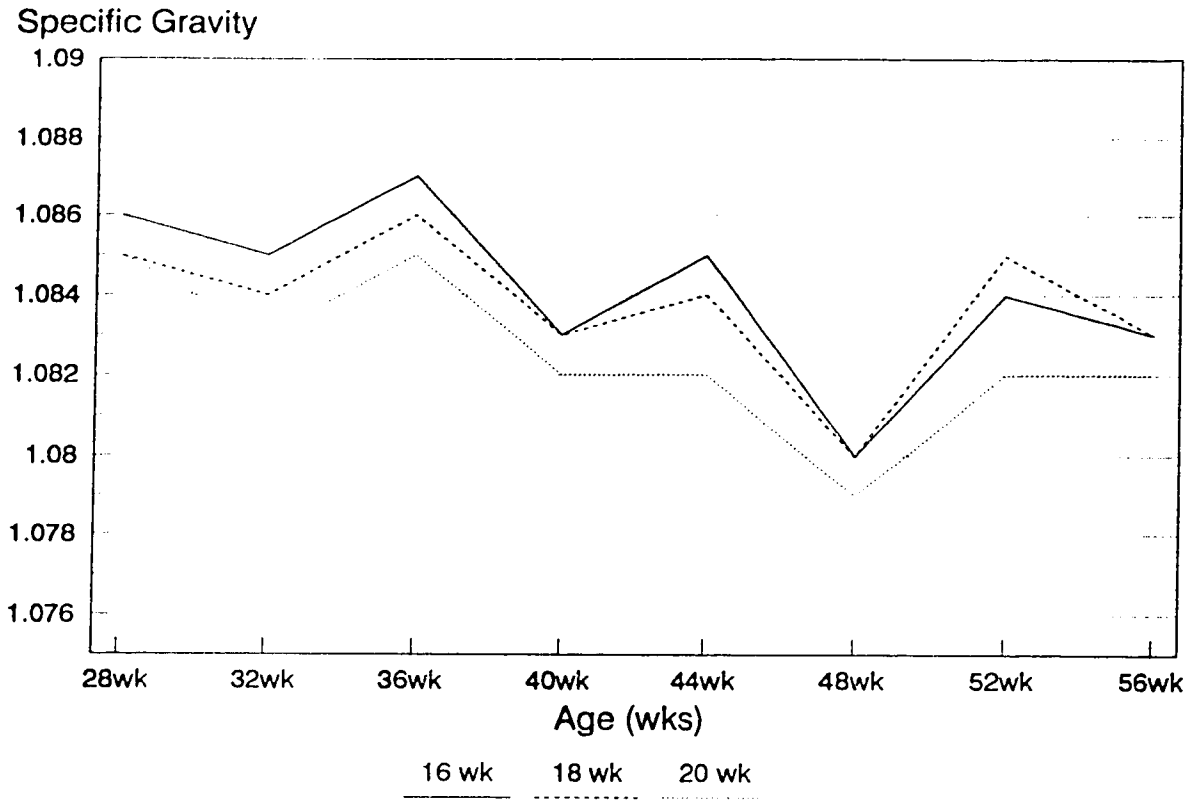

FIGURE V-8. Effect of age at photostimulation on the specific gravity of eggs produced from SCWL hens photostimulated at different ages.

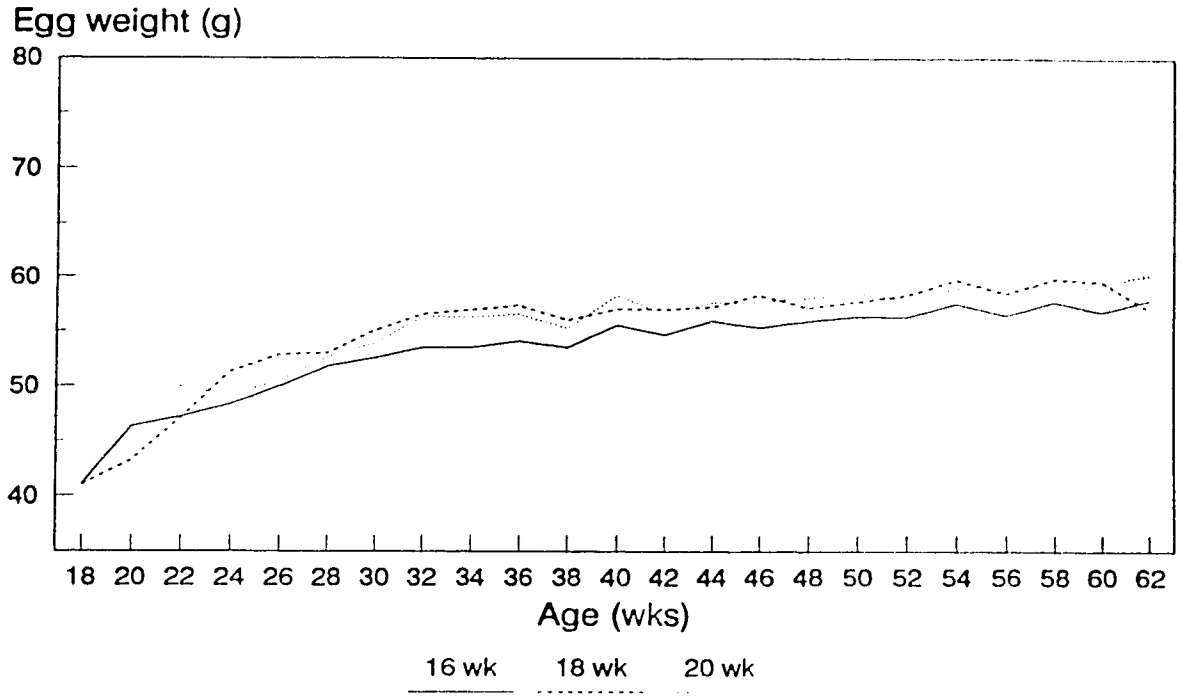

FIGURE V-9. **Effect of age at photostimulation on egg weight (g) for the period of 18 to 62 wks of age in SCWL hens photostimulated at different ages.**

TABLE V-1. Premix Formulations.

Nutrient	Layer Premix[1] (Amt. supplied in 1 kg of final ration)	Broiler Premix[1] (Amt. supplied in 1 kg of final ration)
Vitamin A	12000 I.U.	10000 I.U.
Vitamin D3	3000 I.U.	2500 I.U.
Vitamin K	2.0 mg	2.0 mg
Pantothenic Acid	14.0 mg	14.0 mg
Riboflavin	6.5 mg	5.0 mg
Folacin	1.0 mg	0.8 mg
Niacin	40.0 mg	65.0 mg
Thiamine	3.3 mg	2.0 mg
Pyridoxine	6.0 mg	4.0 mg
Vitamin B12	0.02 mg	0.015 mg
Biotin	0.2 mg	0.18 mg
Vitamin E	40 I.U.	35 I.U.
Iodine	0.5 mg	0.5 mg
Manganese	75.0 mg	70.0 mg
Copper	15.0 mg	8.5 mg
Zinc	80.0 mg	80.0 mg
Selenium	0.1 mg	0.1 mg
Iron	100.0 mg	100.0 mg

[1]Inclusion rate=0.5%.

TABLE V-2. Choline Premix.

Nutrient	Ingredients required to make 50 kg of Choline premix	Amount supplied in 1 kg of final ration
Choline chloride (60%)	1.667 kg	100 mg
Wheat shorts	48.333 kg	
Total	50.000 kg	

TABLE V-3. Ration Formulations.

Ingredient	Starter ration	Grower ration	Layer ration
Ground wheat[1]	64.55	54.85	74.8
Stabilized fat	0.0	0.0	1.0
Ground barley[1]	10.0	30.0	0.0
Soybean meal[1]	14.0	4.0	11.1
Canola meal[1]	5.0	5.0	0.0
Corn gluten meal[1]	2.0	2.0	2.0
Ground limestone[1]	1.5	1.5	8.25
Biofos[1]	1.5	1.25	1.5
Choline chloride premix[1]	0.5	0.5	0.5
HLR broiler premix[1]	0.5	0.5	0.5
DL methionine	0.05	0.00	0.00
Iodized salt[1]	0.35	0.35	0.35
Amprol[1]	0.05	0.05	0.00
ME (kcal/kg)	2739	2811	2738
Protein (%)	19.10	15.50	16.30
Calcium (%)	0.90	0.86	3.46

[1]As a percentage of final ration totalling 100%.