INFLUENCE OF FEEDING METHODS DURING EARLY LAY IN

BROILER BREEDER HENS

by

LUCY CLAIBOURNE GIBSON

(Under the direction of Jeanna L. Wilson)

ABSTRACT

The large-scale production of hatching eggs is the primary goal of the broiler breeder industry. Therefore, improving egg production is of great importance. Various feeding methods have been reported in the literature, and when compared to *ad libitum* feeding, restricted feeding during rearing and lay has been determined to be the most economical. Also, the effects of feeding methods have been determined to cause differences in reproductive and thyroid hormones. Finally, the present work evaluated the effects of a skip-a-day (SAD) feeding program and everyday (ED) feeding program during early lay following photostimulation until 8% egg production. The hens fed ED after photostimulation resulted in a 17 egg increase per hen suggesting SAD feeding during early lay is detrimental to future reproductive function. Therefore, ED feeding beginning at photostimulation is recommended to improve egg production in the broiler breeder industry.

KEYWORDS: Broiler breeder hens, skip-a-day feeding, everyday feeding

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DEDICATION

I dedicate this thesis to my parents. Bud and Lisa Gibson have been an amazingly supportive through my entire life. I appreciate your eternal love and care for me. I will never be able to hand you anything great enough that truly shows my appreciation, but I hope that by receiving this thesis I have made you proud. Thank you.

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CHAPTER 1

LITERATURE REVIEW OF FEEDING METHODS

Feeding Methods for Broiler Breeder Pullets

With poultry meat making up 35% of the total animal protein consumed in a North American diet (Reddy, 1999) one can understand the industry demand for a high yielding broiler. The parents, broiler breeders, have been genetically selected for fast growth traits so their progeny can reach a market weight in as little as 35 days. In addition to high body weights, many pathological problems are associated with these fast growth traits including ascites, lameness, and mortality. However, broiler breeders do not reach sexual maturity until 20 to 25 weeks of age, and if allowed free access to feed until sexual maturity, the birds will be grossly overweight and reproductively unfit. Therefore, feed restriction is commonly used during rearing and continued through the lay period to maximize hatching egg production.

The feeding programs of broiler breeder pullets changes in accordance with age. Depending on the strain, all broiler breeder chicks are allowed unrestricted access to feed during the first 7-28 days of their life which allows for a relatively rapid rate of gain. After the initial *ad libitum* feeding, the feeding program typically changes to restricted feeding in order to control body weight and manipulate sexual maturity. Feed amounts are 60-80% less than what would be consumed freely by the birds in order to delay growth and prevent obesity (Leeson and Summers, 2004). The method of feeding during the rearing period has been a highly debated

topic. *Ad libitum* feeding, restricting feeding time, nutrient dilution, and limiting the amount of feed are all feeding methods that have been evaluated in recent years for feeding broiler breeder pullets.

Ad libitum Feeding

The effects of *ad libitum* feeding are initially seen in the body weights and carcass characteristics. Several researchers have reported higher body weights in *ad libitum* fed hens than in restricted fed hens (Richards *et al*., 2003; Robbins *et al*., 1986). Robinson *et al*. (1991) reported that the *ad libitum* hens where 700 g heavier than feed restricted hens at 25 wk of age. Also, Renema *et al*. (1999a) reported a greater increase in weight gain following photostimulation in *ad libitum* fed hens. Renema *et al.* (1999a) examined the carcass characteristics at sexual maturity of *ad libitum* hens compared with feed restricted hens. Although the absolute weights of breast muscle, abdominal fat pad and liver were greater in *ad libitum* birds, the relative weights were also significantly different. The relative weight of the breast muscle in restricted birds was significantly greater than in the *ad libitum* birds (16.26% vs. 14.6%). The abdominal fat pad weight and the relative weight were significantly larger in the *ad libitum* birds than the restricted birds (124 g vs. 55 g and 3.7% vs. 2.0%). The weight of the liver was greater in the *ad libitum* fed birds than the restricted fed birds (78.9 g vs. 42.4 g), and the relative liver weight was also greater in the *ad libitum* fed birds (2.34% vs. 1.54%) (Renema *et al*., 1999a). The livers of the *ad libitum* fed birds contained 16.1 g of lipid compared to 3.0 g of lipid in the livers of the restricted birds. *Ad libitum* fed birds had a greater total weight of carcass protein, lipid, ash, and water than the restricted birds; however, these differences correlated with the significantly higher body weight of the *ad libitum* fed birds (Renema *et al*., 1999a). The

proportion of protein, ash, and water was greater in the restricted birds, but the carcass lipid was 100% greater in the *ad libitum* fed birds (740 g vs. 370 g). An average chicken egg yolk is composed of approximately 30% lipid (Nielsen, 1998), therefore, a laying hen has a high demand for lipids. The lipids are typically produced from hepatic lipogenesis, but broiler breeders given *ad libitum* access to feed have an excessive accumulation of lipid in adipose tissue which reduces feed efficiency, and it is hypothesized that this process takes away the necessary energy needed for egg production (Richards *et al*., 2003).

Ad libitum access to feed significantly effected follicular development in broiler breeder hens. Yu *et al.* (1992a) found that at 18 weeks of age broiler breeder hens given *ad libitum* access to feed during the growing phase have a higher oviduct weight (8.74 g vs. 3.56 g) and a higher ovary weight (5.35 g vs. 0.63 g) compared to feed restricted birds. At sexual maturity, Renema *et al.* (1999b) reported that *ad libitum* birds have a higher relative ovary weight than restricted-fed birds due to the increased number of large yellow follicles. The greater number of large yellow follicles results in a poorly defined follicular hierarchy with a higher number of follicles being paired by similar size and weight. The greater amount of pairing can interfere with optimum ovarian function by increasing the number of abnormal eggs. The *ad libitum* birds had an average of 1.7 hierarchies of large yellow follicles on the ovary compared to 1.2 follicular hierarchies in a feed restricted hen. The increased number of large yellow follicular hierarchies suggests the average number of follicles that could be ovulated on a certain day is increased in *ad libitum* fed birds, creating a double hierarchy (Renema *et al*., 1999b; Whitehead and Hocking, 1988). However, restricted feeding during rearing and lay reduces the number of large yellow follicles on the ovary of the broiler breeder hen (Hocking *et al*., 1989). Hocking and Robertson (2000) determined the number of normal and atretic follicles was decreased with feed restriction.

The number of small yellow follicles, large white follicles, and medium white follicles were similar between the *ad libitum* and restricted fed groups (Renema *et al*., 1999b), and these authors concluded that the *ad libitum* fed birds had less small follicle atresia which may be associated with the shorter sexual maturation period compared to the fed restricted birds.

In addition to increased folliculogenesis, follicular development and sexual maturity are achieved quicker in *ad libitum* fed birds when compared with feed restricted birds. Renema *et al*. (1999b) found that *ad libitum* fed birds reached sexual maturity at 25.3 days following photostimulation compared to the feed restricted birds who reached sexual maturity at 38.9 days following photostimulation, which agrees with Robbins *et al.* (1988) who stated that birds fed *ad libitum* during rearing reached sexual maturity 14 days prior to restricted birds. Heck *et al*. (2004) also reported feed restriction delayed sexual maturity by six weeks when compared to *ad libitum* fed hens, and Melnychuk *et al*. (2004) reported sexual maturity was delayed by 15 days in restricted fed hens.

Although Yu *et al*. (1992a) found that feed restricted and *ad libitum* fed birds came into egg production at the same time; these authors reported that birds fed *ad libitum* produce a significantly lower number of eggs with a higher incidence of erratic ovipositions and soft-shelled or abnormal eggs. In agreement, Fattori *et al*. (1991) stated restricted fed hens persisted in lay longer, laid fewer defective eggs, and had few occurrences of multiple ovulations. Robinson *et al*. (1991) also reported that *ad libitum* fed birds have lower egg production with a lower prime sequence and more pause days. Intersequence pause days were greater (11 d) in *ad libitum* fed hens than in restricted fed hens (Robinson *et al*., 1991). In another study that collected eggs for only 10 days between 28 and 29 weeks of age, *ad libitum* birds reached an earlier peak egg production; however, there was no difference in egg production during this short

data collection period, except the *ad libitum* birds had a higher incidence of unsettable eggs (Liu *et al*., 2004). In addition, these authors suggested that the lower egg production recorded in other studies for *ad libitum* birds may be due to broiler breeder hens being housed on the floor which resulted in the loss of floor eggs, and therefore not all eggs were accounted in production records (Liu *et al*. 2004). Fertility, hatchability, and viability were also found to be significantly lower in *ad libitum* birds than in the feed restricted birds (Yu *et al*., 1992a).

In conclusion, the production problems associated with *ad libitum* feeding have resulted in restricted feeding becoming the standard industry practice. Previous research has shown that restricted feeding during rearing compared to *ad libitum* feeding improves the reproductive performance during the lay period. Broiler breeder hens that are allowed *ad libitum* access to feed reached sexual maturity at an earlier age (Robbins *et al.*, 1988; Heck *et al.*, 2004), produce a significantly lower number of eggs (Robinson *et al*., 1991; Yu *et al*., 1992a; Heck *et al*., 2004), have a shorter lay sequence (Robinson *et al*., 1991) and persist in lay for a shorter amount of time (Yu *et al.*, 1992a). In addition, Yu *et al*. (1992a) found that *ad libitum* feeding during rearing and lay increased the amount of unsettable eggs, erratic ovipositions, and multiple ovulations. Heck *et al*. (2004) also found a higher proportion of defective eggs in birds provided *ad libitum* feed access. Another complication associated with *ad libitum* feeding is that the hen becomes obese, and Goerzen *et al*. (1996) reported that overweight hens have a reduced duration of fertility. Since there is a negative relationship between body weight and reproductive performance (Robinson *et al*., 1993), the generally accepted practice of the broiler breeder industry is to limit feed intake in order to control obesity and the associated problems.

Feed Restriction Programs of Broiler Breeder Pullets

Skip-A-Day feeding vs. Daily Feeding

Skip-a-day feeding (SAD) is a common feed restriction management practice in the poultry industry. When birds are on SAD feeding, birds are provided two days worth of feed every other day which is continued from approximately 2 wk of age through 5% egg production (North, 1972). SAD feeding has been used in the poultry industry since the 1970s. Pym and Dillon (1974) compared SAD feed restriction of 80, 60, or 40% with *ad libitum* feeding and found hatching egg production was higher in birds restricted during rearing and provided *ad libitum* feeding during lay. These authors found the most economical feeding method to be 40% feed restriction during rearing and *ad libitum* feeding during lay. Later, it was also reported that SAD feeding compared to *ad libitum* feeding reduced pullet body weight gains, delayed sexual maturity, increased the number of settable eggs, and decreased feed consumption (Harms *et al*., 1979 and Wilson *et al*., 1989).

SAD feeding is commonly used to assist bird management by improving flock uniformity and efficient nutrient utilization (Bartov *et al*., 1988). SAD feeding provides a larger amount of feed than everyday (ED) or daily feeding and therefore, reduces the competition among the birds because there is more of an opportunity for all birds to have a meal. Body weight uniformity within a flock is very important. Petitte *et al.* (1982) reported a more uniform group of birds achieves a higher level of egg production during the first 10 weeks of lay and begins laying at an earlier age than a less uniform group of birds. Similarly, Hudson *et al*. (2001) reported increased egg production with a highly uniform flock. Also, flocks that are uniform are easier to manage because the nutrient requirements among birds are similar. Flocks of hens with uniform body

weights come into lay at the same time and produce uniform weight eggs which results in more uniform chicks.

One alternative to SAD feed restriction is feeding everyday (ED). ED feeding provides a restricted amount of feed on a daily basis, but is generally thought to decrease flock body weight uniformity because a smaller amount of feed is distributed during the daily feeding period increasing feeding competition among the birds for feed. Bennett and Leeson (1989) found that birds fed daily from 5 to 20 weeks of age were significantly heavier than SAD fed birds. They noted "one disadvantage of daily feeding was that the birds tended to eat their feed faster that then skip-a-day birds, making it more difficult to maintain uniformity under commercial type conditions." However, Bennett and Leeson (1989) reported body weight uniformity measures were not significantly different between the two treatments. Using dwarf broiler breeders, Lesson and Summers (1985) compared SAD feeding with ED feeding during rearing. Again, ED fed birds were significantly heavier during rearing and this relationship was maintained through lay. In contrast to Bennett and Lesson (1989), Brooks (1995) found that pullets fed on a SAD basis were significantly heavier than ED fed pullets. The difference in findings is attributed to the intensity of feed activity in ED fed pens compared to the SAD fed pens and the extra expenditure of energy associated with increased feeding intensity. Brooks (1995) also reported no differences in total or settable egg production and no difference in the coefficient of variation of body weight which agrees with Bennett and Leeson (1989).

Although ED feeding during rearing appears to have positive effects on flock uniformity and performance under research conditions, SAD feeding is still the generally accepted practice by the United States poultry industry. This acceptance of SAD feeding is based primarily on the best method of mechanically feeding a large flock size (excess of 10,000 birds) from a single

automated feeding system. However, another topic of interest is the best time to use feed restriction. There are conflicting reports on the optimum timing and duration of feed restriction. Again, Pym and Dillion (1974) reported severe restriction during the rearing period followed by *ad libitum* feeding during the lay period to be the best method to optimize production in broiler breeder hens. McDaniel *et al*. (1981) and Yu *et al*. (1992a,b) suggested that feed restriction occur during both the rearing and breeder periods for optimum performance. Robbins *et al*. (1986, 1988) reported that restricting feed intake during the rearing period followed by *ad libitum* feeding during part or all of the laying period, increased egg production compared to birds which were fed restricted amounts during both periods. However, Robinson *et al*. (1991) reported *ad libitum* feeding during the breeding period resulted in lower egg production. Bruggeman *et al*. (1999) determined feed restriction from 7 to 15 weeks followed by either *ad libitum* or restricted feeding led to improved reproductive performance. The birds that were feed restricted from 7 to 15 weeks had higher proportional ovary and oviduct weights at sexual maturity, but also had the highest cumulative egg production (124.38 eggs/bird). Birds provided a*d libitum* feeding during rearing and laying had similar proportional ovary and oviduct weight, but significantly lower cumulative egg production (83.07 eggs/bird) (Bruggeman *et al*., 1999). Regardless of conflicting reports, the more accepted practice is to use restricted feeding beginning at two weeks and continue throughout the rearing and laying periods (Yu *et al*., 1992b).

Timed Feed Restriction

Another method of feed restriction that has been evaluated is limiting the amount of time the feed is available. One study by Powell and Gehle (1976) compared a timed feeding program

(3 daily feeding periods of 15 minutes each from 0 to 14 days followed by 2 daily feeding periods of 15 minutes), skip-a-day feeding a high energy diet, and everyday feeding of a high energy diet during rearing; however, these treatments did not provide the same total amount of feed to the birds. Timed feeding proved to be similar to *ad libitum* feeding due to the timed fed birds consumed the largest amount of feed and had the heaviest body weights. Also, timed birds reached 25 and 50% total egg production significantly faster than the SAD and ED group. Powell and Gehle (1976) determined that SAD feed restriction is the optimum feeding program for limiting body weight of pullets.

Qualitative Feed Restriction

Qualitative feed restriction or modifying the quality of the diet is one possible feeding program that could be more satisfying to animal welfare concerns because a larger amount of feed can be provided, and qualitative restriction is considered a logical solution to the problem of stress that is associated with feed restriction (Duncan, 1990). Two ways of applying qualitative feed restriction are to add an inert ingredient, such as sand, that adds volume to the feed without adding nutritional value. Or adding volume with a lower quality feed ingredient, such as oat hulls. Zuidhof *et al*. (1995) examined the effects of adding 15 – 30% ground oat hulls to a standard broiler breeder grower and laying diet from 0 to 56 weeks of age. With 15% dilution, there was improved flock body weight uniformity, lowered bird stress, increased egg production, and increased feed consumption time from 264 to 349 minutes. Although 30% dilution of the diet reduced stress even more since feed consumption time increased, egg production was not improved. Sand has also been evaluated as a filler for diets. Hogsette *et al*. (1976) added 5% sand to broiler breeder diets and did not find any significant differences in egg production, egg

weights, fertility, hatchability or body weight uniformity. However, in two of the three experiments the birds provided sand in the diet were more feed efficient resulting in energy and nutrient savings.

Another study compared the effects of feeding a lower quality feed ingredient, cottonseed meal, to feeding the standard dietary protein source, soybean meal, by using SAD feeding until 18 weeks of age (Lordelo *et al*., 2004). The birds that received the cottonseed meal (CSM) diet had improved body weight uniformity because a greater amount of feed had to be provided in order to compensate for the lower quality of the CSM and the larger amount of feed provided more uniform access to the feeding system for all birds. In addition to improved body weight uniformity, no significant differences in egg production were found through 32 weeks of age. In fact, birds provided CSM diet reached peak egg production a few days sooner and laid approximately 1 egg more per hen than the control hens through 32 weeks of age when the experiment was completed (Lordelo *et al.*, 2004).

Recently, Tolkamp *et al*. (2005) performed an analysis of qualitative feed restriction during rearing by adding ground oat hulls and calcium propionate (an appetite suppressant). Comparing the experimental treatment to the control treatment (a standard mash fed once per day), Tolkamp *et al*. (2005) found no difference in body weight uniformity, while body weight means were similar. Also, Tolkamp *et al*. (2005) found no difference in subsequent egg production, egg weight, or egg shell quality. These results and the results of others suggest that feeding a qualitative restriction diet does not have a negative impact on bird performance and therefore, may be an alternative to a strict feed restriction program.

Feeding Methods for Broiler Breeder Laying Hens

Feeding methods for broiler breeder laying hens have not been as extensively investigated as the feeding methods of pullets; however, limited research has been conducted on the effects of *ad libitum* feeding and restricted feeding during the lay period. Typically, after pullets are moved into the laying house, the feeding program changes in order to support egg production. Some poultry companies change from a SAD feeding program to a restricted ED feeding program at the time of placement into the laying house, while others will wait to start ED feeding until 5% egg production is achieved before switching from SAD to ED (North, 1972). For either method the total amount of feed provided to the birds is increased as egg production increases. When egg production begins to decline, the feed allocation is gradually decreased since energy demands are also decreasing.

In a study that examined the rearing and laying feeding methods (Pym and Dillon, 1974), *ad libitum* feeding resulted in higher hatching egg production, but also higher hen mortality when compared with birds that were feed restricted during lay. In another study that examined the feeding treatments during rearing and lay (Robbins *et al*., 1986), peak egg production was highest in hens that were fed restricted during rearing and allowed *ad libitum* feeding during lay when compared with birds that were allowed *ad libitum* feeding or birds that were restricted fed throughout. Although peak egg production was greatest in hens that were provided restricted feeding during rearing and *ad libitum* during lay, mortality from 24-68 weeks was lowest in birds provided restricted feeding throughout the study (Robbins *et al*., 1986).

Hocking *et al*. (2002a) compared several feeding methods after peak egg production. When birds reared on restricted feeding were provided *ad libitum* feeding following peak egg production, there was a rapid increase of body weight and at 60 weeks bird body weight was

similar to those provided *ad libitum* feeding through the entire study. In contrast, when birds were reared on *ad libitum* feeding and then changed to restricted feeding following peak egg production, there was a decrease in body weight, but at 65 weeks these hens were 1 kg heavier than birds provided restricted feeding throughout the entire study (Hocking *et al*., 2002a). Initially, restricting the feed intake of the *ad libitum* reared hens resulted in a weight loss; however, these hens compensated and became more feed efficient. Another study by Hocking *et al*. (2002b), examined the effects of restricted feeding on egg production. The experiment determined that restricted feeding post-peak improved total and settable egg production by 8-10%. Hocking *et al*. (2002a,b) concluded that post-peak restricted feeding resulted in improved egg production and hen livability. Currently, the effects of SAD feeding after photostimulation have not been thoroughly investigated.

Animal Welfare Issues Concerning Feeding Methods

In recent times, there has been increased public pressure on the poultry industry to improve animal welfare policies. One concern for major animal welfare organizations is the feeding methods of broiler breeders, in particular, the fasting period associated with SAD feeding. In this section, the current research on the animal welfare aspect of feeding methods for broiler breeders will be examined.

There are many aspects of feed restriction that are considered to be beneficial to the bird. Broiler breeder males that are feed restricted compared to males that are provided *ad libitum* feeding have fewer bone, joint, and foot problems (Hocking and Duff, 1989) and fewer age-related decreases in tendon elasticity (Iqubal *et al*., 2000). Also, broiler breeders fed restricted

amounts have a lower mortality rate (Hocking *et al*., 2002b; Pym and Dillon 1974; Robbins *et al*., 1986) than those provided *ad libitum* feeding.

Although there are many aspects that are considered benefits, there are also aspects that are considered problematic. Feed deprivation is known as a physiological stressor in broiler breeders. SAD feeding in broiler breeder males has been reported to elevate plasma levels of corticosterone. These elevated levels persisted for at least ten weeks following the start of feed restriction (Mench, 1991). Birds fed a restricted diet show more signs of boredom and frustration than those provided a larger quantity of feed. Specifically, Sandilands *et al*. (2005) found birds fed a standard restricted diet spent more time pecking at objects than birds provided a quantitatively restricted diet. Also, Hocking *et al.* (2002a) found that feed restricted birds spent more time drinking and spot-pecking and less time resting and eating than the birds provided *ad libitum* feeding. Skip-a-day feeding has already been banned in the United Kingdom. The law states:

> "All animals shall have access to feed at intervals appropriate to their physiological needs (and, in any case, at least once a day), except where a veterinary surgeon acting in the exercise of his profession otherwise directs."
>
> UK. Schedule 1 (para 24) of the Regulations (DEFRA, 2002)

With animal welfare being a contemporary issue in the poultry industry in the U.S., preparation must be made to meet the possibility that SAD feeding may be banned in the United States as it has been in the United Kingdom. If SAD feeding was banned in the United Sates, qualitative feed restriction or ED feeding are two feeding methods that could become more commonly used.

Hormonal control of ovarian development

In order to fully understand ovarian development in broiler breeder hens and to find the most effective feeding method, we must understand how feeding influences a bird's reproductive hormone profile. Regretfully, there is a scarcity of research relating to the hormonal control of follicular maturation and egg production in the broiler breeder hen. The effects of estrogen, progesterone, luteinizing hormone (LH), and follicle stimulating hormone (FSH) will be discussed as it relates to follicular maturation based on results obtained from research with commercial laying hen.

Functions of reproductive hormones

Estrogen is primarily produced by the theca cells of small follicles and has many functions. Estrogen and progesterone are responsible for priming the hypothalamus and pituitary for progesterone to induce the LH peak (Wilson and Sharp, 1976). Estrogen plays a large role in the development of the egg. It is involved with vitamin D metabolism and calcium homeostasis, and this is required for egg shell formation (Etches, 1987). Estrogen is also involved with the synthesis of the albumin proteins: ovalbumin, conalbumin, ovomucoid and lysozyme (Palmiter, 1972). Estrogen also induces the hepatic synthesis of vitellogenin, a precursor of the egg yolk phosphoproteins (Deely *et al*., 1975). Besides egg formation, estrogen participates in the development of secondary sex characteristics, such as shape of feathers, size of comb and wattles, and sexual behavior.

FSH is primarily responsible for granulosa cell growth and maturation in developing preovulatory follicles (Johnson and Bridgham, 2001). In addition, sensitivity to FSH is critical in follicular recruitment into the preovulatory hierarchy. Only one follicle from the group of

small yellow follicles has an upregulated level of FSH receptors, and because of this upregulation of FSH receptors that one follicle continues to mature and enters the follicular hierarchy (Woods and Johnson, 2005). Daily injections of FSH have been shown to decrease the rate of atresia and increase the number of growing follicles in aging hens (Palmer and Bahr, 1992). Although FSH's role in steroidogenesis is not clearly defined, there is some evidence FSH does contribute to steroidogenesis in the ovary. Robinson *et al*. (1988) found that if plasma concentrations of FSH are 10 to 20 times greater than the concentrations of LH, it seems to play a role in stimulating the small follicles to produce estradiol. Also, FSH is known to promote production of progesterone by granulosa cells of the F5 follicle (Calvo and Bahr, 1983). In addition, granulosa cell cultures treated with highly purified ovine FSH (Davis *et al.,* 2001) or recombinant human FSH (Woods and Johnson, 2004) produced more progesterone than untreated controls.

Progesterone is the major steroid hormone secreted by the granulosa cells the F1 – F 3 follicles (Bahr *et al*., 1983; Huang *et al*., 1979). The plasma concentration is highest four to six hours prior to ovulation as it participates in a positive feedback loop to stimulate LH production resulting in an LH peak that induces ovulation (Johnson and van Tienhoven, 1980; Liu *et al.*, 2004). Specifically, plasma progesterone which is produced by the F1 follicle triggers secretion of luteinizing hormone releasing hormone (LHRH-1) from the hypothalamus (Etches, 1996). The LHRH-1 then travels to the anterior pituitary through the hypothalamus-pituitary portal vascular system and initiates the secretion of LH from the anterior pituitary. LH and progesterone create a positive feedback loop that is responsible for the preovulatory surge of LH and the progesterone surge four to six hours prior to ovulation (Johnson and van Tienhoven, 1980). Also, progesterone receptors have been located in cells along the stigma of the follicle

(Yoshimura and Bahr, 1991) and theca, stromal, and granulosa cells (Isola *et al*., 1987). These reports may indicate that progesterone is directly involved with ovulation.

Although large and small follicles can be stimulated by LH (Robinson and Etches, 1986), granulosa cells of a small follicle are selected into the hierarchy transition from being predominately FSH dependent to LH dependent (Calvo and Bahr, 1983). While both LH and FSH are involved in follicular growth and maintaining the hierarchy of follicles, once a follicle has been recruited, the expression of LH receptors in the granulosa cell layer of the preovulatory follicle quickly increases with follicular maturity (Li and Johnson, 1993). LH is the primary stimulus for steriodogenesis in the granulosa and theca cells of the largest follicles (Robinson *et al*., 1988) which, as already mentioned, results in the production of progesterone from these follicles. The progesterone stimulates LH production from the anterior pituitary. LH peaks four to six hours prior to ovulation (Robinson *et al*., 1988) and the binding of LH to its receptors on the cells along the stigma of the F1 follicle stimulate protease and collagenase activity that leads to the breakdown of the stigma and ovulation.

Effects of feeding methods on reproductive hormones

Differences in plasma concentrations of reproductive hormones in broiler breeder hens that are feed restricted or allowed *ad libitum* access to feed vary among research reports. In one study, plasma LH, progesterone, and estradiol concentrations of the *ad libitum* fed birds were similar to those of restricted fed birds (Liu *et al*., 2004). In contrast, Renema *et al*. (1999b) found some differences in plasma LH and FSH levels in broiler breeder hens that were on a standard restricted feeding program compared to birds allowed *ad libitum* access to feed. Although the plasma concentrations of LH and FSH were not different between the two feeding

groups at photostimulation and sexual maturity, the mean plasma LH was greater in the *ad libitum* birds than the restricted birds for the period from photostimulation to sexual maturity. The LH and FSH levels peaked three days following photostimulation and declined as sexual maturity neared, however, the LH and FSH levels remained higher for a longer period of time in the restricted birds following photostimulation than in *ad libitum* fed birds. Renema *et al*. (1999) attributed the longer period of a high LH and FSH levels in the restricted birds to the need to control ovarian development and the number of large follicles. Another study found that when blood samples were taken at 15 weeks of age, feed restriction up to 15 weeks of age significantly depressed pituitary LH and plasma LH (Bruggeman *et al*., 1999) compared to *ad libitum* fed birds. Subsequently, no difference between plasma LH concentrations was detected between these two groups of birds when measured at first egg. FSH levels were greater in *ad libitum* fed birds at 18 weeks, but there was no difference detected at 15 weeks or first egg (23 weeks). Although feed deprivation is known to depress LH in mammals (Cameron and Nosbisch, 1991; Nagatani *et al*., 2000), the role feed restriction of broiler breeders hens has on LH and FSH concentrations is unclear. Tanabe *et al*. (1981) found that food deprivation for seven days leads to decreased plasma LH concentrations and increased follicular atresia, but pituitary LH concentrations were not different between the laying hens and the food deprived hens.

The influence of feed restriction on plasma estradiol concentrations is also unclear based on several conflicting research reports. Renema *et al.* (1999b) reported the plasma estradiol-17B levels at sexual maturity were similar in the *ad libitum* fed birds and feed restricted birds (Renema *et al*., 1999b). Tanabe *et al*. (1981) found that along with decreased LH concentrations, estradiol and progesterone levels were significantly decreased in broiler breeder hens that were food deprived for seven days, but this would be expected since the feed deprivation was enough

that it caused ovarian regression. In contrast, birds provided *ad libitum* feeding did have a significantly higher mean plasma concentrations of estradiol, but the peak plasma concentration of estradiol in *ad libitum* fed birds was significantly lower than in the feed restricted birds (Renema *et al*., 1999b). However, plasma LH and FSH concentrations were higher in the *ad libitum* fed birds which could indicate lower levels of estrogen were available for negative feedback (Renema *et al*., 199b). At 28 weeks of bird age, Liu *et al*. (1999) reported there was no difference in the overall concentration of estradiol, which was relatively constant during the ovulatory cycles of *ad libitum* and feed restricted hens. There were also no differences in the concentrations of peripheral patterns of LH, progesterone, or estradiol during preovulatory surges between the *ad libitum* or restricted fed birds (Liu *et al*., 1999).

Thyroid Hormones in the Broiler Breeder Hen

Thyroid hormones are produced in and secreted from the thyroid gland. The thyroid gland requires iodine to synthesize thyroid hormones. Thyroxine or tetraiodothyronine (T4) has four iodine molecules, while triiodothyronine (T_3) contains three iodine molecules. The $T_3 - T_4$ relationship in the blood is either bound to protein or in free form. It is free T_3 which is capable of binding to its receptor on cells and eliciting a response. The secretion of these thyroid hormones is regulated by TSH (thyroid-stimulating hormone) which is regulated by the anterior pituitary.

Although thyroid hormone has many functions, most can be categorized as either metabolic or developmental. Thyroid hormones are considered the key regulator of the metabolic heat production required for the maintenance of body temperature in homoeothermic birds and mammals (Danforth and Burger, 1984). From a developmental stand-point, thyroid

hormones influence growth and maturation in birds. For example, thyroid hormone has been proven necessary for the development of normal brain architecture and neuronal connections in chicks (Bouvet *et al*., 1987). Also, muscle differentiation is controlled by T_3 during late embryonic development (Gardahaut *et al*., 1992).

Although the effects of thyroid hormones on metabolism and development are well known, the effects on reproduction are not well characterized in avian species. However, it has been demonstrated that thyroid hormones are involved in molting. Thyroid hormones are at an elevated state during molting, the loss and regeneration of feathers (Brake *et al*., 1979; Lien and Siopes, 1989). In turkeys, supplementing thyroid hormone, T_3, on the first day following the fasting period through the diet contributes to a relatively longer (10 days) molting period than the control group, which were provided a standard diet (Queen *et al*., 1997). However, supplementing T_4 reduces the number of days to first egg following a molt (Queen *et al*., 1997).

Changes in feed availability also effect plasma thyroid hormone concentrations. Food deprivation of 23.5 hours in five week old male broiler chicks decreased T_3 and insulin-like growth factor-I concentrations (Buyse *et al*., 2000). May (1978) found higher plasma T_3 concentration in birds provided *ad libitum* feeding and higher plasma T_4 concentrations in restricted fed birds. Bruggeman *et al*. (1997) reported similar results when comparing *ad libitum* feeding to restricted feeding in broiler breeder chickens. Feed restriction resulted in higher plasma concentrations of growth hormone (GH) and T_4, while T_3 was higher in *ad libitum* fed birds. Furthermore, in *ad libitum* and restricted groups, GH and T_3 concentrations decreased as the birds aged, but T_4 concentrations increased during the same time period.

Because of the effects of feed availability on thyroid hormone and the effects of thyroid hormone on molting are well known, the influence that thyroid hormone has on reproduction is

of great interest. There is some evidence of a connection between the thyroid and responses to an increased day length. Yoshimura *et al*. (2003) found that even when Japanese quail were kept under short day length, T_3 infusion increased testicular growth. Furthermore, the concentrations of T_3 and T_4 in the MPH region of the brain (nucleus hypothamuicus posterior medialis, infundibular nucleus, and the median eminence) were ten times greater in the quail subjected to long day length than those exposed to short day length. Also, Follet *et al*. (1988) proved that peripheral injections of T_3 and T_4 can mimic gonadotropin secretion and growth of gonads normally associated with an increased photostimulation. These reports of thyroid hormones playing a role in photostimulation suggest there is a hypothalamus-pituitary-ovarian axis that intersects with the thyroid hormone axis.

Summary

The benefits of restricted feed are well understood, and the broiler breeder industry has accepted the restricted feeding program of SAD feeding. Currently, SAD feeding is the optimum feeding regimen for improved reproductive performance and egg production; however, continued research could find an even more beneficial method of feed restriction. In addition, a deeper understanding of the effects that different feeding programs have on the hormonal control of ovarian development would further the industry's capability of meeting a broiler breeder hens specific needs for reproduction.

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CHAPTER 2

SKIP-A-DAY FEEDING VERSUS EVERYDAY FEEDING DURING EARLY LAY OF THE BROILER BREEDER HEN[1]

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Abstract

Skip-a-day (SAD) feed restriction is a common industry technique that is often used from 2 wk of age until 5% egg production in broiler breeders. Due to reproductive issues associated with fasting in mammals, the 24 h fast associated with SAD feeding is thought to be detrimental to reproduction in broiler breeders. The current study examines the effects of using an everyday (ED) feeding program to improve long term reproduction. Pullets were weighed weekly and fed on a SAD basis in rearing. At 20 weeks of age, pullets and cockerels were moved into laying facilities. From 21 to 26.5 wk, 15 of the 30 experimental pens (35 hens and 4 roosters per pen) were provided ED feeding while the remaining 15 pens continued on SAD feeding until 8% egg production. At 27 wk (8% egg production), all hens were placed on ED feeding until 65 wk. Blood samples were taken every four wk starting at 26 wk. Overall, the mean bird weights were significantly different; however, the coefficients of variation of bird weight were not significantly different between the two treatments. Estradiol was significantly elevated in SAD fed hens at 30 wk, progesterone was significantly depressed in the SAD hens at wk 30 and 34, and total T3 was depressed in SAD fed hens at 26 wk. Birds that were provided ED feeding have a hen-day egg production of 171 eggs versus 155 eggs from the SAD birds. These results suggest that SAD feeding after light stimulation reduces reproductive potential in broiler breeder hens.

(KEYWORDS: broiler breeders, skip-a-day feeding, everyday feeding)

Introduction

Feed restriction in broiler breeder hens improves reproductive performance by delaying sexual maturity and reducing body weight (Renema *et al*., 1999b; Robbins *et al*., 1988; Heck *et al*., 2004). Birds that are fed *ad libitum* produce a significantly lower number of eggs (Yu *et al*., 1992; Robinson *et al*., 1991; Robinson *et al*., 1993) than feed restricted birds. Also, birds provided *ad libitum* feeding during rearing and laying had a higher occurrence of unsettable eggs, erratic ovipositions, and multiple ovulations (Yu *et al*., 1992; Fattori *et al*., 1991). *Ad libitum* feeding was also found to have another detrimental impact on reproduction as reported by Goerzen *et al*. (1996), who observed that *ad libitum* fed broiler breeder hens had reduced duration of fertility in addition to poor persistency of lay.

Skip-a-day (SAD) feeding of pullets has become the primary means of feed restriction in the broiler breeder industry. It has been reported that SAD feeding, compared to *ad libitum* feeding reduced pullet body weight gains, delayed sexual maturity, increased the number of settable eggs, and decreased feed consumption (Harms *et al*., 1974; Wilson *et al*., 1989). Another reason SAD feed restriction has been utilized is because it reduces bird competition during feeding, improves flock body weight uniformity as well as feed efficiency (Bartov *et al*., 1988). Uniform flocks reach peak egg production at an earlier age and peak at a higher level (North, 1984; Petitte *et al*., 1982; Hudson *et al*., 2001).

With SAD feeding, the birds are provided two days worth of feed every other day. Since feed is consumed every other day, there is a fasting period that begins several hours after the feed is digested and lasts until the next feeding period. In mammalian species fasting has been associated with lower reproductive capability, specifically, reducing LH pulse frequency (Cameron and Nosbisch, 1991; Nagatani *et al*., 2000). These research findings suggest that SAD

feeding after light stimulation could have a negative impact on egg production. Therefore, this study will examine the effects of the fasting period associated with SAD feeding from photostimulation until 5% egg production and determine if the SAD feeding method is detrimental to future reproductive success in broiler breeder hens.

Materials and Methods

In January 2005, 1300 Cobb 500 slow-feathering pullets and 300 Cobb cockerels were full fed a standard corn/soybean meal based diet (Table 2.1) though 2 wk of age and were provided feed on a SAD basis from 2-20 wk of age at the University of Georgia Poultry Research Center. At 2 wk of age, chicks were switched from the starter diet to a developer diet (Table 2.1). Chicks were provided decreasing day length, starting with 24 h of light and decreasing to 8 h, from 2-14 d and then allowed 8 h of light per 24 h from 2-20 wk. A sample of pullets was weighed weekly, and the amount of feed provided was restricted in order to achieve primary breeder recommended body weights. Feed was distributed with automatic chain feeders. Chicks were allowed *ad libitum* water from nipple drinkers. Pullets and cockerels were grown in sex separate rooms on pine shavings in environmental controlled (evaporative cooling and heated) 7.32m x 9.14m (24 ft x 30 ft) floor pens. Pullets were wing banded for identification. All procedures were approved by the animal care and use committee at the University of Georgia.

At 20 wk of age, all pullets were weighed and selected to create 30 pens of 35 pullets with a uniform weight distribution (21 wk). Fifteen of the pens were assigned to one of the following treatments: SAD or everyday (ED) feeding. Birds on the ED feeding were provided restricted feed amounts everyday from 21-65 wk. The SAD feeding treatment provided twice the feed amount on an every other day basis from 21-26.5 wk (or 8% egg production), and then

birds were changed to the same daily feed amount as the ED treatment from 26.5-65 wk. In each 3.65m x 2.73m (12 ft x 9 ft) pen, there were 35 hens and 4 roosters. At 21 wk, the birds were photostimulated with 14 h of light per day. Both feeding treatments received the same total amount of developer feed with *ad libitum* access to water from nipple drinkers. At 25 wk of age, birds were changed from the developer diet to a laying diet (Table 1). Females consumed feed from three feed pans per pen which allowed for 9.14 cm (3.6 in) of feeder space per hen. The hen pans were fitted with male exclusion grills to prevent roosters from stealing feed. Males were given a separate pan feeder and provided a limited quantity of feed based on the average body weight to attain recommended weight gain throughout the experiment. Male to female ratio was held constant between 10-11% by replacing of male mortality from a pool of extra males. Beginning at 42 wk, males were rotated among pens to sustain fertility as no younger males were available to add to the pens to boost fertility. Each pen was arranged with 2/3 litter area and1/3 elevated slats and contained a six hole nest box. All mortality was recorded, and necropsies were performed as necessary.

Beginning at 26.5 wk, twenty-five samples of blood were collected every four weeks from the same pen of each treatment. One pen from each treatment was selected based on median egg production rate of the hens in comparison to the other 14 pens. Fifty blood samples were collected from the same hens for the entire study. The blood samples were collected between 1300 and 1500 h for each collection date. Blood was collected from the brachial vein and immediately placed into individual glass vacutainers (Becton, Dickinson, and Co., Franklin Lakes, NJ) containing EDTA as an anticoagulant and stored on ice. Samples were centrifuged at 1,000 x *g* at 4ºC for 10 min. Plasma was collected from each sample and frozen at -80ºC. Plasma progesterone and estradiol concentrations were determined by RIA using the Coat-A-

Count ® Progesterone Kit and the Coat-A-Count ® Estradiol Kit (Diagnostic Products Corporation, Los Angeles, CA). Plasma total thyroid hormone (total T_3) and free thyroid hormone (free T_3) was measured by RIA using a Coat-A-Count ® Total T_3 Kit and Free T_3 Kit (Diagnostic Products Corporation, Los Angeles, CA). The RIA procedures were conducted following the manufacture's protocol. Samples were counted with a Wallace Wizard (1470) gamma counter (Perkins Elmer, Shelton, CT). These RIA kits have previously been utilized for analyzing free T_3 (Shirley *et al*., 2003) and estradiol (Sun *et al*., 2006) in chickens.

Birds were weighed weekly from 20-40 wk and every two weeks from 42-65 wk. For each weigh period, birds in five of the 15 pens per treatment were weighed. The pens were in weigh groups that were consistent for the duration of the study which allowed for individual pens to be weighed every three weeks. All birds were weighed at 20, 26, 39, and 65 wk. Eggs were manually collected three to four times per day, and egg production was calculated weekly from daily egg counts. At the time of egg collection, all eggs were classified as either normal or abnormal (cracked, double yolked, abnormal, membrane or dirty). A maximum of 90 eggs from each pen were incubated every two weeks from 28 to 44 wk and monthly from 48 to 65 wk. Eggs were collected and stored 7 d prior to each incubation period at 18.3 – 19.9 ºC in an egg storage cooler at the UGA Poultry Research Center. All hatching eggs from a single day of production were weighed and recorded one day prior to each incubation period. Eggs were candled (12 d), transferred (19 d), and hatched (21 d) in Natureform incubators. Temperature settings from 0 to 18 and 19 to 21 d were 37.8 and 37.2 º C, respectively. Relative humidity settings from 0 to 19 and 20 to 21 d were 53% and 70 %, respectively. Infertile eggs and eggs containing early dead embryos (> 7 d) were removed following candling. Residue from each hatch was examined and eggs characterized as containing early dead (>7 d), mid dead (7 to 14 d)

or late dead embryos (15 to 21 d) along with eggs that were pipped. Eggs that were cracked during transfer to the hatcher were removed from the data set as loss eggs. Hatchability of fertile and hatchability of total eggs set were calculated after each incubation period.

Statistical Analysis

Data were analyzed using SAS version 9.1 mixed model (SAS Institute, 2003). Each treatment was represented by 15 replicate groups of 35 hens. The source of variation was treatment. The least squares means procedure was used to detect significant ($P < 0.05$) differences using the PDIFF function. All percentage date were subjected to arc sine transformation. While conclusions were drawn from the transformed date, percentage data (nontransformed data) are presented for relevance.

Results

The mean body weights over the entire experimental period between the SAD and ED fed hens (3721.67 vs 3690.67) were significantly different ($P = 0.0002$) (Figure 2.1). There appeared to be a trend starting at 34 wk that continued through 65 wk that the SAD fed birds were slightly heavier than the ED fed birds (Figure 2.1). Weekly body weights were significantly larger in SAD fed hens during the early lay period (23-24 wk of age), close to peak egg production (32 wk of age), and the late lay period (48, 54, 58, and 60-65 wk of age). The BW uniformity was equal at 20 wk when birds were placed in treatment pens and at 26 wk when all birds were weighed. This 26 wk measure was five days prior to changing the SAD fed hens to ED feeding. The weekly coefficient of variation for BW uniformity was not significantly

different between the two treatments (Figure 2.2). Mortality was not significantly different between ED and SAD fed hens throughout the entire experiment.

Hens fed on an ED basis had significantly greater total percentage egg production (TEP) ($P \leq 0.0001$) than the SAD fed birds (48.85% vs. 55.17%). In addition, weekly egg production was significantly greater in birds fed ED, except at 35, 37-39, and 47 wk of age (Figure 2.3). The ED fed birds began to lay 11 d prior to the hens provided SAD feeding, and the ED fed hens were at 10% TEP 7 d prior to the SAD fed hens. At 31 wk of age, ED fed birds peaked in TEP at 72.3% while the SAD fed birds peaked during 30 wk of age at 67.1%. The ED fed hens continued to produce eggs at a higher percentage than the SAD fed hens through 65 wk. Hen-day (HD) egg production at 65 wk of age was 155 eggs for SAD fed hens and 172 eggs for ED fed hens resulting in a 17.1 egg per hen housed, or 5.2% increase, with ED feeding following photostimulation (Table 2.2). Hen-housed egg production (HH) at 65 wk of age for SAD fed hens was 123.8 eggs and 144.30 eggs for ED fed birds with a difference of 19 eggs or 7.1% increase (Table 2.2). Overall, hatching egg production (HEP) was significantly greater in ED fed hens (42.30% vs. 48.22%) through 65 wk of age ($P < 0.0001$). In addition, weekly HEP was significantly greater in ED fed hens, except for wk 35 and 37-39 when there is no significant differences (Figure 2.4). While there are no significant differences in percent double yolked eggs, cracked eggs, and membrane eggs, there was significantly higher percentage of dirty eggs ($P = 0.0001$) and abnormal eggs ($P = 0.0027$) in ED fed hens (Table 2.3).

Overall fertility was not significantly different between SAD and ED fed hens, but hatchability of eggs set (81.45% vs. 83.55%) and hatchability of fertile eggs (85.78% vs. 87.96%) were significantly greater in ED fed hens ($P = 0.0148$ and $P = 0.0043$) (Table 2.4). From the residue analysis, ED fed hens had fewer occurrences of early and late embryonic death

(Table 2.4). Also, the percentage of pipped and contaminated eggs was significantly lower in ED fed hens (Table 2.4). The eggs from ED fed hens tended to be larger (63.23 g) than the SAD fed hens (63.96 g), and therefore, the overall egg weight means are significantly different ($P \leq 0.0001$). Weekly eggs weights were not significantly different except at 32 and 34 wk of age (Figure 2.5).

Plasma concentrations of estradiol were not significantly different between SAD and ED fed hens at 26 and 34 wk of age, but plasma estradiol concentrations were significantly elevated in SAD fed hens at 30 wk of age (Table 2.5). Although plasma progesterone concentrations were not significantly different at 26 wk of age, plasma concentrations of progesterone at 30 and 34 wk of age were significantly elevated and numerically elevated at 26 wk of age in ED fed hens (Table 2.5). Plasma concentrations of total T3 were significantly depressed in SAD fed birds at 26 wk of age, but were not significantly different at 30 and 34 wk of age (Table 2.5).

Discussion

Because the SAD hens were always numerically heavier than the ED hens from 34 wk of age until the conclusion of the study at 65 wk, the overall mean BW were significantly different ($P = 0.0002$). Weekly BW became significantly different during the late lay period (48, 54, 58, and 60-65 wk of age) because the SAD fed hens became increasingly overweight. Although the difference in weekly body weight is significant, the weights are not drastically different. At 65 wk of age SAD fed hens were 100 g heavier than the ED fed hens (4695 g vs. 4596 g). The difference in weight does not seem to be the cause of the egg production difference.

This study contradicts the theory that SAD feeding to first egg or 5 % egg production will improve body weight uniformity over hens fed on an ED basis. In agreement with Brooks

(1995) who compared SAD and ED feeding until 20 wk of age, a SAD feeding program did not initially influence body weight variation or body weight uniformity. In this research, when the SAD fed hens were changed to ED feeding at 26 wk, ED fed hens were equal in body weight uniformity to SAD fed hens. This trend continued throughout the study from 20 through 65 wk of age.

Egg production was significantly greater in ED fed hens. Since body weight means were significantly greater and egg production was lower in SAD fed birds, these results could support the hypothesis of Richards *et al*. (2003) that an excessive accumulation of adipose tissue takes away from the energy needed for egg production. However, the lower egg production in the SAD fed hens preceded their slow and steady increase in body weight gain. Both treatment groups received and consumed the same restricted feed allotment. Thus it could be argued that the weight increase in the SAD hens simply resulted from the energy savings from their reduced egg production being shifted towards fat production and demonstrates the utility of feeding broiler breeders based on egg production rates.

Although fertility was not significantly different between ED and SAD fed hens, the greater hatchability of eggs incubated and hatchability of fertile eggs could simply be related to greater rate of lay in the ED fed hens. Eggs from the ED fed hens had a lower occurrence of embryonic mortality in early and late dead. Robinson *et al.* (1991) explained that with a lower rate of lay there is lower embryo viability and higher embryonic mortality due to more first of sequence eggs. No explanation is apparent for the increase late embryonic mortality in the eggs of SAD fed hens.

In contrast with Renema *et al*. (1999b), the current research found elevated plasma concentrations of estrogen in SAD fed hens at 30 weeks which is also when the SAD birds

achieved peak egg production. Interestingly, the SAD fed hens had significantly higher plasma concentrations of estradiol at 30 wk of age and the numerically higher plasma concentrations at 34 wk of age suggests the that the SAD fed hens had more developing small follicles than the ED fed hens since the theca tissue of the small follicles are the primary source of estrogen in the hen (Senior and Furr, 1975; Robinson and Etches, 1986). Although the estradiol levels may suggest that the SAD fed hens had more developing small follicles than the ED fed hens, this did not lead to higher levels of egg production for the SAD fed hens.

Because of the positive feedback loop created by progesterone and LH to stimulate ovulation, it is understandable why progesterone is significantly elevated in ED fed hens at 30 and 34 wk of age. The higher plasma concentrations of the ED fed hens at 26 wk was indicative of the ED birds beginning to lay at an earlier age than the SAD birds. However, at 30 and 34 wk the ED fed hens had a much higher egg production and therefore, plasma progesterone concentrations were elevated due to the larger number of preovulatory follicles. These results can be related to Liu *et al*. (2004) who compared *ad libitum* and restricted fed hen plasma concentration levels of progesterone and reported the interval between LH and progesterone surges could be a factor that contributes to decreased egg production. An increased interval of plasma progesterone concentrations could be responsible for the lower mean plasma concentration of progesterone and the lower egg production.

Lower plasma T_3 concentration at 26 wk in the SAD fed hens compared to the ED fed hens is likely a reflection of fact that the last feeding for the SAD fed birds was 30 h prior to collection of the blood samples versus the ED fed hens consuming feed 6 h prior to blood collection. In subsequent blood collection periods the plasma T_3 concentrations are similar. Feeding status is known to effect thyroid hormone concentrations. Specifically, lower feed

intakes result in lower plasma T_3 concentrations (Buyse *et al*., 2000; Bruggeman *et al*., 1997). It is interesting that the differences in total T_3 concentrations appear to be reflected in free T_3 concentrations. At 26 wk of age, plasma free T_3 concentrations in the SAD fed hens were well below the lowest standard curve concentration (data not shown). In contrast, the ED fed hens had a mean plasma concentration of free T3 of 0.7265 pg/mL (SEM ± 0.0580). These results suggest that SAD feeding may lead to drastic fluctuations in plasma total T_3 and free T_3 concentrations due to the fasting period associated with SAD feeding. Such fluctuations that lead to the exposure of low levels of T_3 during early follicular development may be detrimental to ovarian development and may play a role in the subsequent lower egg production observed for the SAD fed hens. The role of thyroid hormones in the reproductive axis is just starting to emerge (Yoshimura *et al*., 2003), and our results indicate that further research is needed to explore the possibility that a low thyroid hormone status during times of fasting for broiler breeder pullets that have been light stimulated for reproduction is detrimental to normal ovarian and follicular development.

These results indicate that the fasting period associated with SAD feeding during early lay until 5% egg production caused permanent ovarian developmental changes that resulted in consistently lower egg production throughout the entire production cycle. It is unknown why SAD feeding affects ovarian development during this critical period. However, one factor that merits further investigation is the potential link between daily thyroid hormone status and early ovarian development. Furthermore, even though ED feeding during this critical early lay period clearly improved reproductive efficiency, the fact remains that there is still a substantial fasting period with ED feeding method that may be inhibiting even greater egg production potential.

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Table 2.1 Ingredient composition and calculated nutrient analysis of the diets provided to the breeder pullets and hens

Ingredients, % "as-is"	Starter (0 to 2 wk)	Developer (3 to 25 wk)	Layer (25 to 65 wk)
Corn (8.5% CP)	62.95	65.88	70.80
Soybean meal (48% CP)	22.24	15.00	18.11
Poultry oil	…	…	0.91
Wheat middlings	10.53	14.83	…
Limestone	1.16	1.28	7.33
Dicalcium phosphate	1.75	1.57	1.49
Sodium chloride	0.54	0.60	0.51
L-lysine HCl	0.10	0.13	0.12
DL-methionine	0.15	0.13	0.15
Trace mineral premix[1]	0.08	0.08	0.08
Vitamin premix[2]	0.50	0.50	0.50
Total	100.00	100.00	100.00
Calculated Analyses			
Crude protein (%)	18.0	15.0	15.0
Metabolizable energy (kcal/kg)	2,865	2,920	2,920
Calcium (%)	0.91	0.92	3.22
Non-phytate P (%)	0.45	0.42	0.38
Lysine (%)	1.00	0.83	0.83
Methionine (%)	0.43	0.38	0.39
TSAA (%)	0.73	0.64	0.64
Sodium (%)	0.21	0.20	0.20

[1] Trace mineral premix provided the following in milligrams per kilogram of diet: selenium (source = sodium selenite), 0.3; manganese (source = manganese sulfate), 120 for developer and 138-139 fro breeder diets; iron (source = ferrous sulfate), 89-95 for breeder diets; iodine (source = calcium iodate), 0.8.

[2] Vitamin premix provided the following per kilogram of diet: vitamin A, 11,000 IU; vitamin D3, 2,200 IU; vitamin E, 22 IU; vitamin K, 2.2. mg; vitamin B12, 0.02 mg; thiamine 4.4mg; riboflavin, 8.8 mg; vitamin B6, 4.4 mg; pantothenic acid, 22 mg; folic acid, 1.1 mg; biotin, 0.2 mg; choline, 383 mg.

Table 2.2 Overall egg production in hens fed on a skip-a-day (SAD) or everyday (ED) feeding basis during early lay.

	HDEP[1]	HHEP[2]
SAD	155.06	125.23
ED	172.17	144.30
Difference	17.11	19.07
Difference (%)[3]	5.2	7.1

[1] Hen-day egg production (HDEP) (Total # of eggs/ # of hens alive) takes into account mortality. In our study, we found a 17 egg increase with everyday feeding after photostimulation.
[2] Hen-housed egg production (HHEP) (Total # of eggs/ # of hens upon placement in the laying rooms) does not take into account mortality. At 65 wk, a 19 egg per hen-housed production difference was found with between the two feeding methods.
3 The percent difference of the HD skip-a-day and everyday egg production was calculated by [17.11/ (155.06 + 172.17)]* 100 resulting in a 5.2 percent increase with ED feeding, and the percent difference of the HH skip-a-day and everyday egg production was calculated in a similar fashion resulting in a 7.1 percent increase with ED feeding.

Table 2.3 Evaluation of cull eggs of skip-a-day (SAD) and everyday (ED) fed hens from 26 to 65 weeks of age[1]

	% of Cull Eggs				
	Abnormal[2]	**Cracked[2]**	**Dirty[2]**	**Membrane[2]**	**Double yolked[2]**
SAD	0.48[a]	1.40	4.03[a]	0.08	0.55
ED	0.56[b]	1.45	4.36[b]	0.07	0.51

[1] Eggs were manually collected three to four times a day. Good and cull (eggs not suitable for incubation) eggs were recorded during each collection.
[2] Calculated as a percentage of total eggs recorded.

[a-b] Means with different subscripts within a column signify significant differences ($P \leq 0.05$) as a result of a PDIFF comparison.

Table 2.4 Overall fertility and embryonic viability of eggs produced by broiler breeder hens provided feed on skip-a-day (SAD) or everyday (ED) feeding program during early lay. [1]

	Fertility (%)	Hatchability of Eggs Set (%)	Hatchability of Fertile (%)	Early Dead[2] (%)	Middle Dead[2] (%)	Late Dead[2] (%)	Pips[2] (%)
SAD	94. 9	81.46[a]	85.78[a]	5.7[a]	0.14	4.3[a]	1.8[a]
ED	94.9	83.55[b]	87.96[b]	4.8[b]	0.21	3.5[b]	1.5[b]

[1] Values are least-squares means of 15 replicate pens of 35 hens at housing from 24 to 65 wk of age. Hens were naturally mated, and eggs were incubated and hatched every two weeks from 28 to 44 wk and monthly from 48 to 65 wk.

[2] Calculated as a percentage of fertile eggs.
[a-b] Means with different subscripts within a column signify significant differences ($P \leq 0.05$) as a result of a PDIFF comparison.

Table 2.5 Plasma concentrations of total triiodothyronine (T3), estradiol, and progesterone at 26, 30, and 34 weeks of age in skip-a-day and everyday fed hens[1].

	30	116.5 ± 0.127[a]	128.7 ± 0.193[b]
	Week	**Skip-a-day**	**Everyday**
Estradiol	26	168 ± 19.7	167 ± 16.7
pg/mL	30	132 ± 5.92[a]	105 ± 5.18[b]
Total T3	34	123 ± 7.08[a]	113 ± 5.01[b]
Progesterone	26	----[2]	---[3]
ng/dL			

[1]Beginning at 26.5 wk, twenty-five samples of blood were collected every four weeks from one pen of each treatment.
[2] All samples were below detection limit.
[3] Just under half of the hen sampled had plasma progesterone levels below the lowest detection limit of 0.10 ng/mL. The mean plasma progesterone concentration for the other hens was 0.26 ± 0.07
[a-b] Means with different subscripts within a row for each hormone signify significant differences ($P \leq 0.05$).

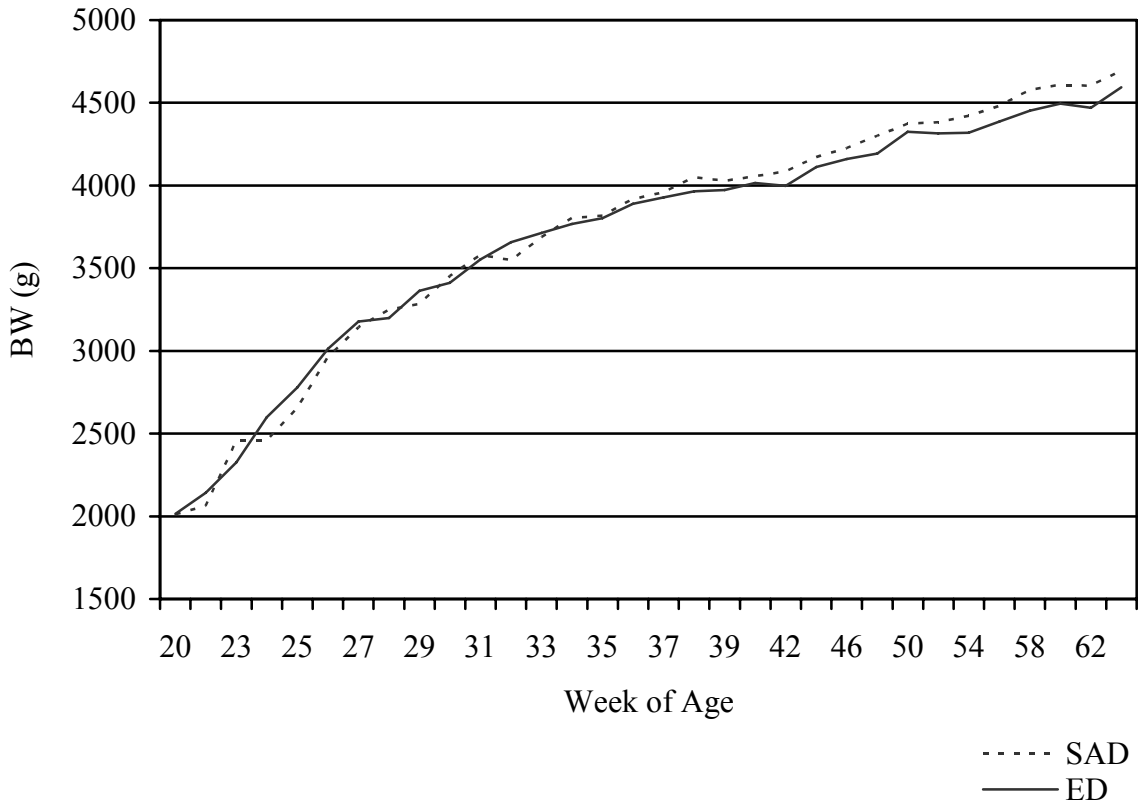

Figure 2.1 Body weight means of skip-a-day (SAD) and everyday (ED) fed hens from 20 through 65 wks of age. Values are the mean body weights of birds in 5 pens of 35 hens for each treatment except on weeks 25, 36, and 65 when all birds for each treatment were weighed. Overall, SAD fed birds had significantly greater body weights than the ED birds (P = 0.0002). Weekly body weight means were significantly different at 23-24, 32, 48, 54, 58, and 60-65 wk of age between the two treatments.

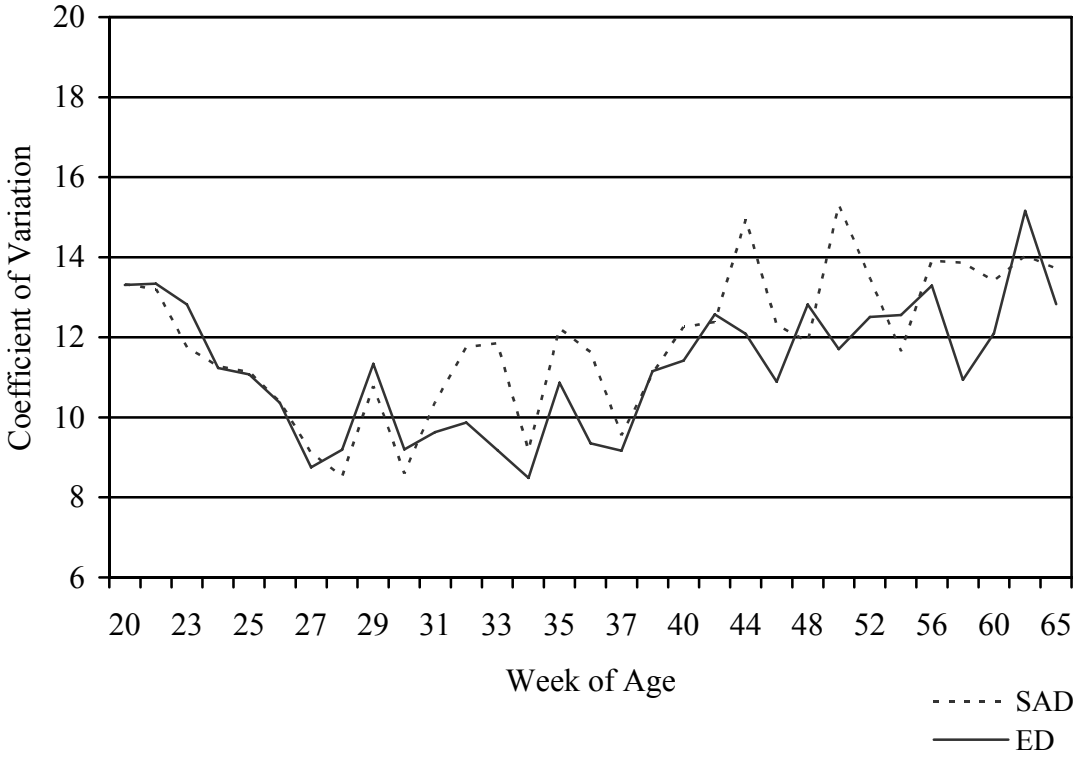

Figure 2.2 Coefficient of variation of body weight in skip-a-day (SAD) and everyday (ED) fed hens from 20 through 65 wk of age. Values are the mean body weights of birds in 5 pens of 35 hens for each treatment except on weeks 25, 36, and 65 when all birds for each treatment were weighed. Body weight coefficient of variation was not significantly different at any week between SAD and ED fed hens.

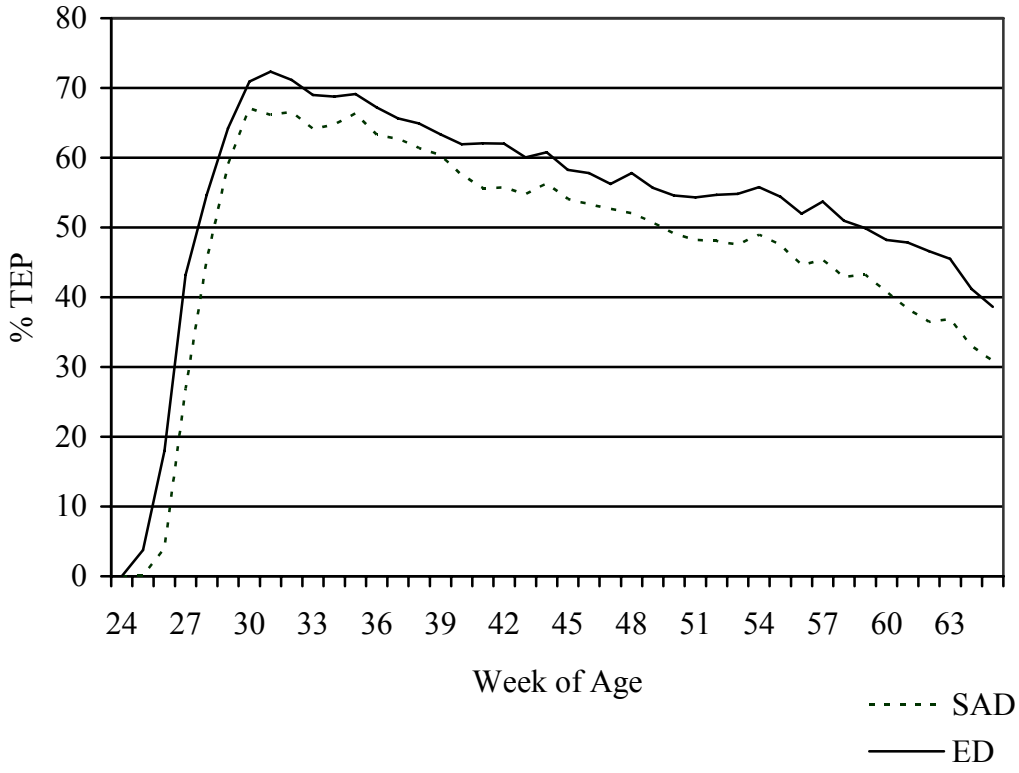

Figure 2.3. Percent total egg production (%TEP) of skip-a-day (SAD) and everyday (ED) fed hens from 24 through 65 wk of age. Values are the mean total egg production of the hens in the 15 pens from each treatment. Overall, ED fed hens produced significantly more eggs than SAD fed hens. Weekly egg production was not significantly different at 35, 37-39, and 47 wk of age.

Figure 2.4 Percent hatching egg production (%HEP) of skip-a-day (SAD) and everyday (ED) fed hens from 24 to 65 wk of age. Values are the mean hatching egg production of the hens in the 15 pens from each treatment. Overall, hens fed ED had significantly greater %HEP when compared to SAD fed hens. Weekly % HEP was not significantly different at 35 or 37 through 39 wk of age.

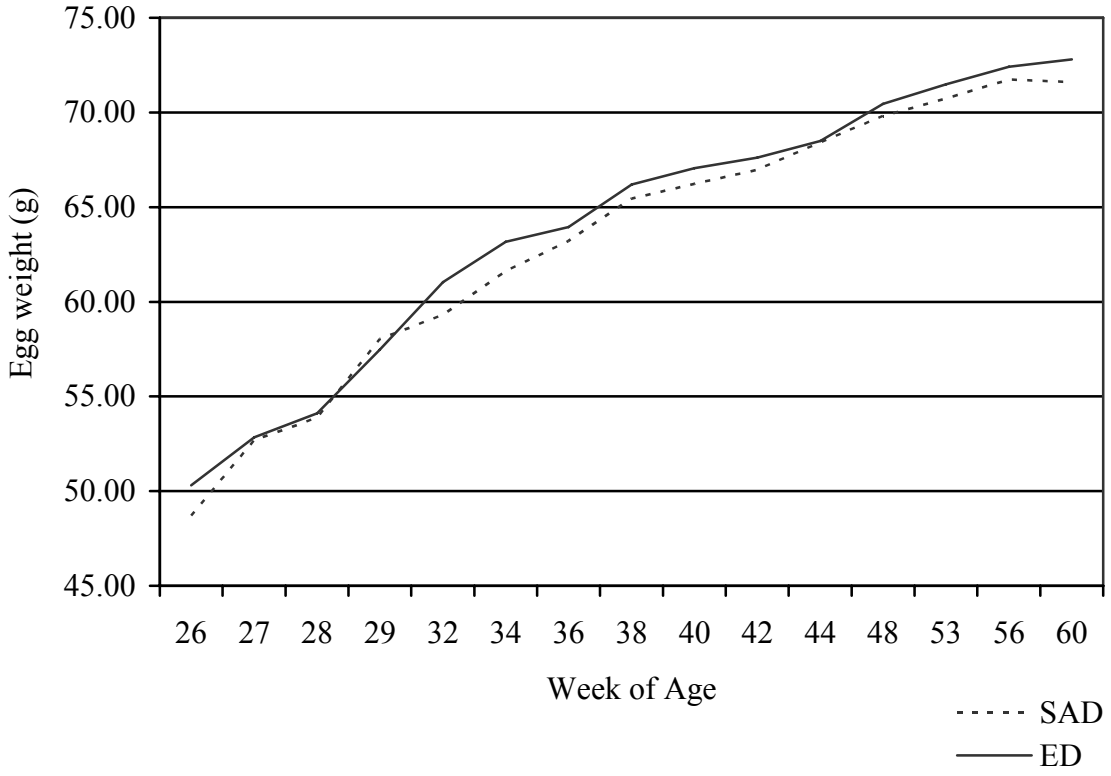

Figure 2.5 Weight of eggs produced by skip-a-day (SAD) and everyday (ED) fed hens from 26 through 60 wk of age. The overall mean egg weights were significantly different between SAD and ED, with ED being heavier. Weeks 32 and 34 were the only weekly eggs weights that were significantly different ($P < 0.05$).

CONCLUSIONS

This research compared reproductive performance in broiler breeder hens that were on a continual skip-a-day (SAD) feeding program through 8 % egg production with birds that were changed to everyday (ED) feeding at light stimulation. The results indicated that SAD feeding until early lay is detrimental to future reproductive success and suggest that daily nutrient intake during the time period from light stimulation until first egg is critical to the development of the hen's ovary and subsequently, egg production. Beginning ED feeding at light stimulation allowed the hen's daily access to feed and nutrients that facilitate physiological changes which allow for egg production. Changing birds to ED feeding at light stimulation, improved egg production in the Cobb slow-feathering broiler breeder hens. The importance of this improved egg production with ED feeding after photostimulation can be seen when our results are applied to a typical industry setting. For example, in a broiler breeder house with 10,000 hens, the 10-12 egg increase per hen housed would result in a minimum of 100,000 more egg. With an estimated 13 million broiler breeder hens in Georgia, implementing this management change would allow a 130 million egg increase in fertile egg production with no additional capital expenditures.