NUTRIENT UTILIZATION AND REPRODUCTIVE PERFORMANCE IN BROILER BREEDER HENS

by

ALEXANDRA MARIA MENDOZA CASTRO

(Under the Direction of Jeanna Wilson)

ABSTRACT

Experiments were conducted to evaluate the influences of initial body-weight at photostimulation, diet density or feeding level on nutrient utilization and reproductive performance of broiler breeder hens. Additionally, the first experiment used two strains of broiler breeder females to determine if performance was similar when fed the different diets. These fast and slow feathering hens utilized dietary nutrients in a similar manner with no differences in body composition; however, the slow feathering hens laid more eggs to 34 wk of age than the fast feathering hens. Females with greater body weight produced a greater number of eggs through 40 wk of age. Low-body weight hens experienced body gains but were delayed, inconsistent layers through 40 wk of age. Feeding high-density diets or slightly more of a medium-density diet did not encourage greater egg production.

INDEX WORDS: Broiler breeder hens, body weight, density diets, fast and slow feathering, feeding level

NUTRIENT UTILIZATION AND REPRODUCTIVE PERFORMANCE IN BROILER BREEDER HENS

by

ALEXANDRA MARIA MENDOZA CASTRO

D.V.M., The University of La Salle, Colombia (South America), 1995

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment

of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

© 2006

Alexandra Maria Mendoza Castro

All Rights Reserved

NUTRIENT UTILIZATION AND REPRODUCTIVE PERFORMANCE IN BROILER BREEDER HENS

by

ALEXANDRA MARIA MENDOZA CASTRO

Major Professor:

Jeanna L. Wilson

Committee:

Adam J. Davis Guillermo Zavala

Electronic Version Approved:

Maureen Grasso Dean of the Graduate School The University of Georgia December 2006

ACKNOWLEDGEMENTS

To God, thank you for helping me to look at you when the circumstances seemed difficult to continue, for staying with me every time, even when I though You were not here; thank you for the beautiful opportunities You have given me to improve my education.

To Dr. Jeanna Wilson, thank you for being my mentor and for supporting me in all ways throughout this process. I sincerely appreciate your time, patience, dedication and understanding as an outstanding human being and professional.

To Dr. Adam Davis, thank you for helping me to organize my priorities in order to alleviate and prevent stressful situations. Your support and listening helped me to improve my study methodology. Again thank you for your guide and advice.

To Dr. Guillermo Zavala, thank you for your help and support during the termination of my experiments, it is an honor to work with such a knowledgeable professional and great person. Thank you for your patience and advice.

To Dr. Bill Dozier, thank you for the time you dedicated to correct and to improve my paper.

To Dr. Michael Lacy, thank you for giving me the opportunity of studying at UGA, for your kindness and understanding.

To Dr. Ken Powell, thank you for being my mentor, my godfather and my friend. You helped me to believe, and you introduced me to this poultry world in U.S. Thank you for helping me to improve my process of reasoning.

iv

To Dr. Pedro Villegas and the staff of the Poultry Disease Research Center at UGA (PDRC) thank you for all your help not only providing us different tools to perform our periodic sampling but also guiding me in my academic learning and treating me as part of your team; thank you for being my family in U.S.

To Dr. Nick Dale and his family for being always very supportive, helpful, and optimistic with me and my family; thank you for guiding me during this journey and thank you for your enthusiasm.

To Dr. Rafael Fernandez and his family for your support, encouragement and understanding. You have always being an important part of my personal and professional development

To Benton Hudson and Jason Richardson: thank you for all your help when I started working here and thank you for the support you gave me during the setting of my experiments.

To our team and staff at the research farm thank you for your dependability and kindness.

To my parents, thank you for the unyielding support and love that I have being given throughout life, despite the distance. You made me into the person that I am today. I love you and I appreciate all your effort done for my education.

To my husband, thank you for being there during this process, for helping me with my experiments and encouraging me to achieve my goals. Specially thank you for your patience and sense of sacrifice in order to achieve our professional goals.

V

TABLE OF CONTENTS

Page					
ACKNOWLEDGEMENTS iv					
LIST OF TABLES					
LIST OF FIGURESx					
INTRODUCTION					
CHAPTER					
1 LITERATURE REVIEW					
Reproductive Anatomy of the Hen					
The Control of Ovulation9					
Reaching Sexual Maturity11					
The Evolution of the Broiler Breeder Hen12					
Influence of Light on Reproduction14					
Obesity and Reproduction15					
Reproductive Abnormalities16					
Feeding Regimens in Broiler Breeders20					
Nutrient Densities and Requirements					
References					
2 STATEMENT OF PURPOSE					

3	INFLUENCE OF INITIAL BODY WEIGHT AND DIETARY NUTRIENT
	DENSITYON NUTRIENT UTILIZATION AND PERFORMANCE OF FAST
	AND SLOW FEATHERING BROILER BREEDER HENS45
	Abstract46
	Introduction47
	Materials and Methods49
	Results and Discussion51
	Conclusions
	References

5	CONCLUSIONS	9	4
---	-------------	---	---

LIST OF TABLES

Page

Table 3.1: Ingredient composition and calculated nutrient analysis of the developer and layer		
diets provided to the breeder pullets and hens61		
Table 3.2: Influence of dietary treatment and initial BW on BW gains and % rate of gain during		
three periods in SF broiler breeder hens62		
Table 3.3: Influence of dietary treatment and BW on egg production, reproductive tract weight		
and index throughout the experimental period (22 to 34 wk) in SF broiler breeder hens		
and between genetic strains63		
Table 3.4: Influence of initial BW on relative body composition at 21 wk of age in immature SF		
broiler breeder females64		
Table 3.5: Influence of initial BW, dietary treatment and genetic strain on relative body		
composition at 34 wk of age65		
Table 3.6: Influence of dietary treatment and BW on nutrient utilization throughout the		
experimental period (22 to 34 wk) in SF broiler breeder hens		
Table 3.7: Overall nutrient utilization by physiological state (22 to 34 wk of age) 67		
Table 4.1: Ingredient composition and calculated nutrient analysis of the developer and layer		
diets provided to the breeder pullets and hens		
Table 4.2: Feed Intake and management		
Table 4.3: Influence of feed level and initial BW group on subsequent BW, BW gains and gain		
rates by periods		

Table 4.4: Influence of feed level and BW group on overall BW (23 to 40 wk of age) and egg				
production and egg characterization (29 to 39 wk of age)	.89			
Table 4.5: Influence of feed level and BW on % total and hatching egg production by				
period	.90			

LIST OF FIGURES

	Page
Figure 3.1: Experimental design	68
Figure 4.1: Experimental design	91
Figure 4.2: Influence of initial BW and age on subsequent BW (23-34 wk)	92
Figure 4.3: Interaction of BW and age on percentage total egg production	93

INTRODUCTION

The profitability of the commercial broiler breeder industry is based upon efficient reproduction that requires hens to produce a good number of hatching eggs while their progeny have rapid and efficient growth. Broiler breeders have been genetically selected for meat yield, which is inversely related to reproductive performance. Feed restriction programs and lighting programs are used by broiler breeder managers to prevent these birds from expressing their growth potential and to improve the efficient production of fertile hatching eggs (Renema and Robinson, 2004).

Differences between slow and fast feathering broiler breeder hen body weight (**BW**), body weight gains, flock uniformity or egg production have been reported by a number of authors (Dunnington and Siegel, 1986; Katanbaf et al., 1989a,b; O'Sullivan et al., 1991; Agri Stats, 1994 and 2002). These studies include both results from growth and laying periods, but do not report findings on nutrient utilization of broiler breeder pullets or hens. Specific undesirable traits such as skeletal deformities, metabolic diseases and reduced livability have been observed. It is believed these negative traits are associated with the genetic selection for rapid growth in meat type chickens, especially in slow feathering (**SF**) strains (Robinson et al., 1993; Griffin and Goddard, 1994; Julian, 1998).

In the first study of the current research the objectives were (1) to evaluate SF hens that varied in BW at photostimulation when fed three diets differing in nutrient density, (2) to compare the body composition, reproductive organ development and nutrient utilization at

photostimulation and post peak in egg production, (3) to determine if there are differences in fast feathering (**FF**) and SF broiler breeder strains for body composition, reproductive organ development and nutrient utilization. In the second study the objectives were (1) to measure possible influences of BW and feeding level on reproductive performance and livability, and in addition (2) to describe and identify reproductive abnormalities that might be present in unproductive hens.

CHAPTER 1

LITERATURE REVIEW

Reproductive Anatomy of the Hen

Anatomy and Physiology.

The highly organized reproductive system of the hen results in the formation of an egg yolk. Ideally, it is only a single egg yolk per day, each and everyday after sexual maturity. This system involves the brain, the adenohypophysis (anterior pituitary) and the ovary. The liver is also considered an integral part of the system because of its involvement in the yolk protein and lipid formation. The oviduct adds albumen around the yolk then the shell membranes are added around the yolk. Ultimately the shell is added around these membranes. The oviduct must also facilitate the passage of spermatozoa from the site of the sperm storage tubules in the oviduct is also critical for the production of fertile hatching eggs due to the fact that the sperm can be stored there for about two weeks (Bakst, 1993; Proudman, 1995; Etches, 1996).

The Hypothalamus.

One function of the hypothalamus is to control reproduction in the hen. This organ receives input from other brain centers that detect and monitor such things as daylength, nutritional status and stress through neurotransmitters, as well as signals coming from the environment. It has been shown that the hypothalamus must be ready to respond to light stimulation before the onset of egg production (Johnson, 2000). The role of the hypothalamus in the control of reproduction is to release gonadotrophin releasing hormones or **GnRH**, which are

small proteins that stimulate the release of gonadotrophin hormones from the anterior pituitary (Johnson, 2000).

There are two types of LHRH hormones in chickens similar to mammalian luteinizing hormonereleasing hormone. One is the chicken LHRH-I, which differs from the mammalian hormone by the substitution of one amino acid. This hypothalamic hormone triggers the secretion of LH by the chicken and turkey pituitary. The second hormone is the chicken LHRH-II, and it differs from chicken LHRH-I by the three amino acid substitutions. Both hormones, LHRH-I and LHRH-II, are able to stimulate the secretion of LH; however, LHRH-II is found in the chicken hypothalamus in low quantities and probably does not control the release of LH from the pituitary (Sharp et al., 1990). In the turkey, LHRH-II concentration in the hypothalamus has been reported to vary with reproductive state (Rozenboim et al., 1993), and it is also more effective than LHRH-I in releasing LH when administered to male turkeys (Guemene and Williams, 1992). A second hypothalamic releasing hormone that is important in the control of reproduction in poultry is the vasoactive intestinal peptide (VIP), which is a 28-amino acid peptide, first discovered in the gut and named for its effect on blood flow. This hormone is also found in the brain, where it functions as a prolactin-releasing hormone in the chicken (Macnamee et al., 1986) and turkey (Opel and Proudman, 1988). Additional studies have found changes in hypothalamic VIP and pituitary prolactin secretion during reproduction, showing that these hormones have a major effect on the reproductive cycle (Mauro et al., 1992).

The hypothalamus has specialized cells that receive light energy at photostimulation in response to longer days. It is important to note that the recognition of day length does not involve the eyes, but these specialized cells within the brain. The message from the hypothalamus

(GnRH) is sent directly to the adenohypophysis through the blood vessels that link those two organs (Johnson, 2000).

The Adenohypophysis.

The adenohypophysis is the organ that produces the hormones that travel to the gonads, stimulating the reproductive function in the long and short term. This organ receives messages from the hypothalamus, leading to the release of two important gonadotrophin hormones: luteinizing hormone (**LH**) and follicle stimulating hormone (**FSH**).

The hormone LH, which is essential for sexual maturation and daily egg production, is also produced by the adenohypophysis of mammals. The output of LH into the blood stream is directly related to the output of GnRH reaching the adenohypophysis. The role of LH is to stimulate the production of sex steroids in the follicles of the ovary and to stimulate androgen hormone production from the testes in males. This hormone is an integral component of the daily events of ovulation translated in daily egg production (Johnson and van Tienhoven, 1980). The hormone FSH is involved in hierarchal follicular development and differentiating granulosa cells steroidogenesis in the prehierarchal follicle granulosa cells. It is important to note that FSH's direct involment in sex steroid production is not significant compared to LH (Scanes et al., 1977).

The Neuro-Hypophysis.

The neuro-hypophysis or posterior pituitary lies adjacent to the adenohypophysis. The function of this organ is to store arginine vasotocin and mesotocin. Vasotocin controls the smooth muscle contraction needed at oviposition, and it is also the major antidiuretic hormone in birds (Johnson, 2000). There is little information about the physiological role of mesotocin in birds (Koike et al., 1998). Robinzon et al., (1988a) found that infusion of mesotocin does not

influence arterial blood pressure or heart rate. In addition, mesotocin reduces circulating concentrations of aldosterone (Robinzon et al., 1988a). There is evidence suggesting a independent control of vasotocin and mesotocin (Nouven et al., 1984; Koike et al., 1988; Bottje et al., 1989; Klempt et al., 1992)

The Ovary.

All birds have a right and left ovary and oviduct during the early embryonic stages, but the distribution of the primordial germ cells to the chicken ovary changes by the fourth day of incubation. The regression of the right oviduct starts at the tenth day of incubation and it is influenced by the Mullerian inhibiting substance (Hutson et al., 1985). As a consequence, hens only have a left functional ovary and oviduct.

In a pullet, the ovary is a mass of small and undeveloped ova, and at least 2,000 are visible. This organ is supported by the stroma, and it normally stays in this condition until the bird reaches sexual maturity. Only a few of the ova (250-500) will be able to reach sexual maturity and eventually will be ovulated. The mature ovary of the hens is arranged with a hierarchy of follicles based on size, and the largest follicle is called the F1 follicle, the second largest follicle is F2 and so on. The F1 follicle is less than 24 hr from ovulation while the F2 follicle is 48 hr from ovulation and so on. The follicles can be classified by size and color as follows: the smallest follicles contain white yolk and measure less than 6mm in diameter; as they are recruited into the pool of larger follicles they become yellow, and they can be classified in large yellow follicles (**LYF**) which are 10 mm or greater in diameter, and small yellow follicles (**SYF**), with a size of 5-10 mm in diameter (Johnson, 1990).

The ovary receives blood supply from the ovarian artery, which is a branch of the dorsal aorta (Hodges, 1965). The blood supply is greater to the five largest follicles (Scanes et al.,

1982). All veins from the ovary join to the two main anterior and posterior veins, which eventually finish in the posterior vena cava. The wall of the follicle consists of a single layer of granulosa cells that lie very close to the yolk, and in the largest follicle they produce progesterone in response to circulating LH.

Surrounding the granulosa layer is a layer of theca tissue, which is a mixture of structural tissue, nerves, blood vessels and other specialized cells that secrete steroid hormones. Different authors have established that the ovary is well innervated by adrenergic and cholinergic fibers and this enervation within the theca layer increases as the follicle matures (Gilbert, 1969; Dahl, 1970; Unsicker et al., 1983).

The theca layer has an important role in estrogen and androgen production and in the sexual maturity process (Nalbandov and James, 1949). As the plasma levels of estrogens increase, the secondary sexual characteristics become evident, showing changes such as the bright red color and enlargement of the comb and wattles, a characteristic feather molt before the mating period and a widening of the pubic bones to allow egg passage (Johnson, 2000). Estrogen also stimulates liver production of egg yolk lipids. Finally, estrogen stimulates the oviduct and plays a major role in albumen deposition. The theca cells of the small follicles produce estrogens and androgens in response to photostimulation, and it is believed that these cells are involved in feather patterns and comb growth in females.

After ovulation the post-ovulatory follicle (**POF**) remains. The POF contains the granulosa cells and the theca cells but the cellular activities of these cells decrease gradually as the time from post-ovulation increases (Chalana and Guraya, 1978). The POF tissues slowly disappear by apoptosis and the tissue is completely reabsorbed by six to ten days postovulation. The POF may influence the nesting behavior and Gilbert et al. (1978), suggested that it can be

important in timing oviposition. Follicles that initially begin to grow but fail to reach full maturation become atretic and die by apoptosis and the lipid of the follicle is reabsorbed (Tilly et al., 1991).

The Oviduct.

As stated before, the oviduct of the hen is derived from the left Mullerian duct, and it starts to enlarge after 16 weeks of age. The oviduct is innervated by sympathetic and parasympathetic nerves (Johnson, 2000), and consists of five regions: infundibulum, magnum, isthmus, shell gland, and vagina. The oviduct is located within the peritoneal cavity and is suspended by a dorsal and a ventral ligament. After ovulation, the ovum is taken up by the infundibulum, which is not directly connected to the ovary. The ovum passes through the infundibulum in 15 to 30 minutes. The first layer of albumen is produced in the infundibulum (Johnson, 2000).

The ovum then passes to the magnum which has a length of 33 cm in the chicken, and is the site of most of the albumen deposition. Estrogen stimulates a differentiation of the epithelium into tubular gland cells, ciliated cells, and goblet cells. Tubular glands produce ovoalbumin, lysozyme, and conalbumin under estrogen stimulus, while goblet cells synthesize avidin under the effect of progesterone and estrogen (Tuohimaa et al., 1989). The ovum traverses the magnum for two to three hours, and then passes into the isthmus which adds the shell membranes. Shell and the mammillary core formation starts at the distal portion of the isthmus (Johnson, 2000).

The uterus or shell gland has a prominent longitudinal muscle layer lined medially with both tubular gland and goblet cells. Salts and fluid that contains carbonic anhydrase, acid phosphatase, esterase, bicarbonate and ions from the tubular glands (Salevsky and Leach, 1980) are added to the albumen. The forming egg remains in the shell gland for 18 to 26 hours

(Johnson, 2000). Calcification of the egg is a gradual process that slows down during the last two hours before oviposition. Shell pigments are deposited by ciliated cells present in the epithelium of the shell gland approximately 30 minutes before laying (Johnson, 2000).

The uterovaginal sphincter muscle separates the uterus from the vagina, with the vagina opening into the cloaca. The vagina does not play a role in the egg formation but is important in the expulsion of the egg. The uterovaginal junction has specialized sperm-storage tubules where the spermatozoa remain viable for about 7 or more days in the chicken and 14 or more days in the turkey hen. This area has good blood supply (Gilbert et al., 1968; Burke et al., 1972; Tingari and Lake, 1973).

The Control of Ovulation

Ovulation is the release of mature yolks from the ovary, and the mechanism is similar in most birds. However, the rate of ovulation is strikingly different between commercial layers and broiler breeder hens due to the different genetic selection goals. Table-egg layers or commercial layers are selected for reproductive efficiency and they have a very efficient and organized recruitment of follicles in the ovary that translates to higher egg production (Gilbert, 1971; Williams and Sharp, 1978; Johnson, 2000). In contrast, meat-type hens or broiler breeder hens are intensively selected for fast efficiency growth rate, feed efficiency, and high breast meat yield. As a consequence, broiler breeder hens are more susceptible to recruiting an excessive number of follicles and being more erratic in the follicular maturation and ovulation which results in a higher number of loss or unsettable eggs (van Middelkoop, 1972; Hocking et al., 1987, 1989; Yu et al., 1992c; Robinson et al., 1991, 1993a,b).

In general, laying hens produce an egg per day, and the eggs laid on successive days make up a sequence of eggs. Sequences are separated by one or more pause days where no egg is

laid. Hens that lay long sequences of eggs have a higher production rate and shorter duration between successive ovulations than hens that lay short sequences. The first egg of a sequence is laid within one to two hours after the house lights come on, and the timing of ovulation is synchronized by the onset of the darkness period. Subsequently, each egg in a sequence is laid later in the day, and the last egg of a sequence is laid around nine to ten hours after the lights are turned on. Six to eight hierarchical yellow follicles are considered a normal amount to be present in productive egg laying strains (Gilbert, 1971; Williams and Sharp, 1978) while the ovaries of broiler breeder hens fed ad libitum contain ten to fourteen hierarchical yellow follicles at a given time (Hocking et al., 1987).

About four to six hours before ovulation, there is surge of non pulsatile GnRH which leads to a peak of LH plasma concentration (Johnson and van Tienhoven, 1980). The open period for LH release, begins at the onset of the darkness period, and this period defines the hormone activity. Some researchers have reported an additional peak of LH at 11-14 hour before ovulation, although the significance of this peak has not been determined (Etches and Cheng, 1981). If there is a mature pre-ovulatory follicle it will respond to this burst of LH release by producing progesterone. Subsequently, this progesterone will stimulate further LH release and so on in a positive feed back loop. The ovulation of the largest yellow follicle is the end point, and as stated above, it occurs about six to eight hours after the LH surge (Johnson, 2000).

Under normal conditions, ovulation follows oviposition by a period of about 15 to 45 minutes. However, this can be different when the hen lays an egg late in the afternoon. In this case, the hen does not ovulate soon after oviposition because her open period for LH release and for ovulation has been exceeded. This hen will not lay an egg the next day. She will have a pause day. Consequently, the hen will hold the mature F1 follicle, overnight, and ovulate it at the very

start of the next open period for LH release, which is early in the day and a new sequence will begin. The fact that the hens hold the follicle overnight (about sixteen hours) means that the first yolk in a sequence is heavier because of the continued egg yolk deposition over the pause day (Johnson, 2000).

It is well documented that egg sequences in broiler breeder hens are shorter than egg-type hens managed under ideal conditions. In addition, laying sequences decline in length after reaching peak of egg production as the laying hen and the broiler breeder hen ages, achieving as low as two egg sequences (Jaap and Muir, 1968).

Reaching sexual maturity

Frisch and Revelle (1972) stated that reaching a determined BW is critical for attaining menarche in humans. Later these researchers modified their hypothesis and proposed that a minimal amount of body fat is necessary for the onset of menstrual cycles in pubertal females (Frisch, 1972; Frisch and McArthur, 1974). In rats the onset of puberty was influenced by body size and food intake (Kennedy and Mitra, 1963); however, (Glass et al., 1976) suggested that growth rate is more important than attaining of a fixed body weight in these type rodents.

In chickens, it has been proven that hens having low carcass fat or flesh are delayed in reaching sexual maturity (Eitan et al., 1979; Brody et al., 1980). There is evidence that BW threshold could be a factor in the initiation of egg production (Reddy and Siegel, 1977). More recent studies (Bornstein et al., 1984) have suggested a minimal requirement of lean body mass and/or fat content to reach sexual maturity. In contrast, Soller (Bornstein et al., 1984) indicated that a minimal lean body mass is necessary to start egg production, while Bornstein et al. (1984) indicated that fat content by itself is not sufficient to stimulate lay.

Other factors influencing sexual maturity are age, feeding regimen, light and genetic strain. The age requirement appears to be related to the maturation of the hypothalamus and to the release of GnRH in a proper manner (Johnson, 2000). Differences of age at sexual maturity have also been observed between some genetic strains when ad libitum fed or under more severe levels of feed restriction. These findings suggest that in addition to specific BW range and carcass composition, age is still an important factor that can not be manipulated (Eitan et al., 1979; Brody et al., 1980).

In low BW hens, Eitan et al. (1979) and Brody et al., (1980) reported that severe feed restriction causes a delay in initiation of lay, confirming previous observations (Foster and Taha, 1978; Auckland and Wilson, 1977). However, birds fed ad libitum generally reach adult BW (2,300-2,700 g) without initiating lay by 14 to 15 weeks of age, suggesting the possibility of a minimum age requirement (Eitan et al., 1979 and Brody et al., 1980). In agreement with these authors, Bornstein et al. (1984) found a negative relationship between low BW and the onset of egg production. More studies performed by Bornstein et al. (1984), showed evidence of a fixed BW range rather than a specific threshold of BW being necessary to start egg production.

The evolution of the broiler breeder hen

Studies concerning the growth rate of poultry began to appear in the 1930's (Asmundson and Lerner, 1933, 1934), when the economic importance of genetic purity and ornamental breeds was shifting to the development of breeds with both, meat and egg production potential (Singh, 1993). By the 1950's, selection had intensified for growth rate and efficiency. Less than twenty years later, the negative impact of selection for growth on the reproductive performance of the broiler-parent stock was becoming apparent in broiler breeder hens (Malloney et al., 1967; Jaap

and Muir, 1968; Renema and Robinson, 2004), Japanese quail (Marks, 1980) and turkeys (Nestor et al., 1980).

Today the broiler breeder female is a genetic compromise between two very different selection criteria. This parent stock must have the genetic capability for rapid and efficient growth; however these traits are related to an inability to self-regulate feed intake to a level acceptable for reproduction (Whitehead, 2000; Renema and Robinson, 2004). In addition, these hens must have a high rate of egg production in order to produce chicks for the meat industry. Intense selection for juvenile BW under ad libitum feeding has resulted in meat chickens that eat a volume of feed that is close to their gastrointestinal tract capacity (Nir et al., 1978; McCarty and Siegel, 1983; Barbato et al., 1984). This condition is possibly due to alterations in hypothalamic satiety mechanisms (Burkhart et al., 1983).

The modern broiler breeder is able to grow at 4.6 times the rate of a 1957 random bred strain (Havenstein et al., 2003a) with a six fold improvement in carcass yield when each strain was fed traditional diets for their time. Havenstein et al. (2003b) concluded that 85-90% of this improvement in performance was due to genetics and 10-15% due to nutritional changes. Increased genetic growth potential allows the progeny to reach market weight in one half (Havenstein et al., 2003a) to one day less each year (Gyles, 1989). With the development of the most recent high breast-yield strains, growth potential has continued to increase. In addition, Bulfield (2004) suggested that due to the low heritability of reproduction only modern genomic technologies may resolve the conflict between ever increasing growth rates and the need to efficiently reproduce.

Influence of light on reproduction

Light is important in coordinating an annual and daily reproductive cycle in domesticated poultry. Birds have an endogenous circadian cycle that is 24 hours in length. In wild birds, changing day length plays a critical role in timing the reproductive process, and this allows the offspring to be hatched in warmed conditions when food supply is adequate. In many birds, sexual activity is initiated by longer day length and decreases with shorter length day. Domestic poultry raised under a continuous photoperiod of six hours of light will reach the sexual maturity at about 21 weeks of age; however a progressively increasing photoperiod until 18 weeks of age advances the initiation of lay by two to three weeks (Morris, 1978).

In the broiler breeder industry sexual maturity is affected by exposing birds to increasing day lengths; therefore, by controlling the light environment poultry operations manipulate the bird's natural breeding response to increasing day length (Morris, 1978). Birds use the periods of light and dark to set their internal clock and control daily ovulatory cycles. The perception and transmission of light in birds is achieved through photoreceptors, which convert photon energy into a biological signal. As stated before, the photosensitive elements regulating the sexual behavior response lie in the hypothalamus; generating neural impulses, which are amplified by the anterior pituitary.

In mature birds, the pituitary produces and stores LH and FSH hormones. Once the stimulatory gonadotrophin signal is received from the hypothalamus, these hormones are released into the bloodstream by the pituitary to control the ovarian and testicular function. The stimulation of the hypothalamic photoreceptor is converted into an endocrine signal very quickly, and during the night of the first long day, plasma LH and FSH concentrations are significantly increasing.

Even though a photostimulatory cue can be important for initiating sexual maturation, the birds will eventually come into lay on short days. Once the thresholds for growth and hypothalamic maturity are reached, birds may spontaneously begin to mature, even without photostimulation. A maximal photostimulatory response can be reached with a photoperiod of 12 to 14 hours or more of daylight. The day light period usually reaches a maximum of 16 hours, but it can go higher in areas close to the Equator where curtain-walled (not black out) poultry houses are used, and longer day length is needed to photostimulate these birds. The shortest photoperiod needed to stimulate the release of LH is thought near 10.5 hours in the dwarf breeder (Dunn and Sharp, 1990).

An abrupt change of day length from eight to fifteen hours of light in a single step is more stimulatory to ovarian development than a smaller initial increase (Robinson et al., 1998). The consequences of the extra stimulation on productivity of the broiler breeder hen are not very clear. Noddegaard et al. (2000) reported that when broiler breeders were reared on a decreasing photoperiod and held on a three hours day light period from nineteen weeks of age, increasing the day length to eight hours near 36 weeks of age stimulated the reproductive hormone production and the rate of lay. The authors also found a better reproductive response when the day length was increased to sixteen hours at 44 weeks of age. The reproductive response to photostimulation is not impaired when it is delayed even when some birds have spontaneously commenced egg production (Noddegaard et al., 2000).

Obesity and Reproduction

Obesity, which results from excessive feed consumption, impairs the reproductive function in both mammals and broiler breeder hens (Fruhbeck et al., 2001; Katanbaf et al., 1989b). In mammals, triacylglycerol (**TAG**) accumulates in non-adipose tissue. Lipotoxicity

develops with obesity and is the potential cause of insulin resistance, diabetes, and ovarian dysfunction (Fruhbeck et al., 2001). In the past decade adipose tissue has been recognized as an active endocrine organ that mediates potential effects through various hormones including leptin (Fruhbeck et al., 2001).

Chen et al., (2006) reported similar lipotoxicity symptoms in feed-satiated broiler breeder hens, suggesting an obesity-associated mechanism for impaired egg production commonly observed in these hens. Changes in body and organ weights, hepatic and plasma TAG, nonesterified fatty acids, ovarian morphology, and egg production were measured in two studies. Cobb slow feathering broiler breeder hens were provided either 145 or 290 g of feed per day per hen for 10 days. In both studies no ovarian abnormalities were observed in those hens fed 145 g of feed per day per hen. In addition, feed-satiated hens experienced a rapid gain of 500 g of adipose tissue in ten days, and they had greater plasma concentrations of glucose, nonesterified fatty acids, TAG, insulin, and leptin. These hens were considered insulin-resistant due to persistent hyperglycemia. Feed-satiated hens had significantly more liver and abdominal fat compared to the restricted hens and these differences were related to the incidence of ovarian abnormalities. Average egg production was lower in the feed-satiated bird compared to the restricted birds (55.8 versus 73.3).

Reproductive abnormalities

The dramatic difference in body size between broiler breeders and commercial layers has been accompanied by changes in behavior and physiology (Jaap and Muir, 1968). Broiler breeder hens are susceptible to metabolic disorders and/or hormonal responsiveness, leading to reproductive abnormalities (Hocking et al., 1987, 1989; Yu et al., 1992c; Bruggeman et al., 1998a,b; Onagbesan et al., 1999). Full-fed hens show severe adiposity that is usually associated

with ovarian abnormalities. Restricting feed intake to approximately 50 to 60% of ad libitum has become a practical technique to reduce obesity and metabolic diseases and to improve egg production in broiler breeders (Katanbaf et al., 1989a,c; Etches, 1996; Bruggeman, et al., 2005).

The ideal number of large follicles at sexual maturity is thought to be 7 to 8 follicles of 10 mm or greater in diameter (Robinson et al., 1998). Body weight has a significant effect on follicular development and number of follicles (Robinson et al., 1993). The production of excessive numbers of follicles is a problem in both meat-type chickens (Hocking et al., 1987, 1989) and turkeys (Nestor et al., 1980; Hocking, 1992). When too many large yellow follicles are forming on the ovary, ovipositions may occur outside the normal time range of ovulation, while an egg is still forming in the oviduct, resulting in early expulsion of an egg or the formation of an abnormal shelled egg reducing egg production when compared to egg-type hens (Jaap and Muir, 1968; Renema and Robinson, 2004). In addition, meat-type hens have been reported to show arrhythmic laying patterns (Jaap and Muir, 1968; van Middelkoop, 1972) leading to a condition called erratic oviposition and defective egg syndrome.

It is well documented that broiler breeder hens fed ad libitum are susceptible to excessive follicular development seen as multiple hierarchies when the follicles were sorted by weight (Conrad and Warren 1940; Hocking et al., 1987, 1989; Robinson et al., 1991, 1993; Yu et al., 1992b). Conrad and Warren (1940) demonstrated that the majority of double-yolked or multipleyolked eggs result from simultaneous ovulations or from ovulations that occurred within 30 minutes of each other. On the other hand, low follicle number is a problem associated with under-weight pullets, which eventually lay but have poor persistency of lay. Different authors have documented that the number of follicles decreases with age, so under normal conditions, hens that have fewer follicles at sexual maturity will also have even fewer maturing follicles as

they age (Robinson et al., 1993; Bahr and Palmer, 1989). More recently Liu et al. (2001a) found that age, interval of time between LH surges, and increased magnitude between LH surges are important factors associated with decreasing egg production in turkey hens.

Follicular atresia is associated with a reduction in the rate of follicular ovulation (Johnson et al., 2001) or to alterations in hypothalamic sensitivity to steroid hormone feedback (Williams and Sharp, 1978b) and is also related to aging (Bahr and Palmer, 1987). Because of follicular atresia not all follicles that initiate development result in ovulation. Some follicles lose turgidity and over a period of several days the lipid are reabsorbed into the blood stream. Atretic follicles were described as flaccid, leaky, having a reddish brown color, and varying widely in weight in arrested laying turkey hens (Liu et al., 2001b). Feed intake has been related to follicular atresia, with full-fed broiler breeder hens having increased numbers of small atretic follicles when compared to restricted hens (Renema et al., 1999a). It is still not known why some follicles become atretic and others do not. Water or feed deprivations are conditions leading to total follicular atresia. Atresia occurs by apoptosis, which is a process described as a programmed cell death and differs from cell death caused by injury, infection or circulatory impairment because it does not elicit an inflammatory response (Tilly et al., 1991).

It is clear that several follicles are ovulated before the oviduct is mature and this situation is called unreconciled follicles. By necropsy of broiler breeder hens, Robinson and coworkers (1998) found that hens had more POF than could be accounted for by their first egg or a possible second POF for the recently ovulated follicle. It has been reported that full-fed broiler breeder hens had higher number of unreconciled POF's compared to feed-restricted hens (Robinson et al., 1998; Renema et al., 1999a). Birds coming into lay early seem to be prone to have unreconciled follicles (Renema et al., 1999a) and they also tend to have more large yellow

follicles (Hocking et al., 1988). Melnychuk et al. (1997) suggested that the increased incidence of unexplained POF in turkeys may be due to the ovary reaching a mature state prior to the oviduct, resulting in loss of potential eggs because of a oviduct mobility problem, which could also lead to phantom follicles (unreconciled follicles). Another possible explanation is an abnormal or lack of muscle contraction by the infundibulum that may be influenced by neural or hormonal control mechanisms associated with ovulation (Liu et al., 2001a,b). Internal ovulations are likely to occur throughout the reproductive life of the hen (Robinson, et al., 2003). Renema et al. (1999a) suggested that follicles ovulated prior to the first oviposition in broiler breeders are lost possibly due to internal ovulation. On the other hand Liu et al., (2001b) suggested a relationship between 'blind LH-P4 surges' and internal ovulations, especially in turkey hens selected for increased growth rate (Renema et al., 1995). The researcher observed a higher incidence of blind surges was in a line of turkey hens (RBC3) with poor egg production and greater mature body weight than the egg line hens (23% versus 8.9%) (Liu et al., 2002).

Internal ovulation occurs when the ovulated follicle fails to get into the oviduct for normal egg formation or moves backward from the oviduct into the body cavity. In the abdomen of an internal layer there can be a wide range of semi-formed eggs (i.e., follicle, membrane or hard shelled egg). Hens that have many internal ovulations develop peritonitis because the hen is unable to reabsorb the yolk present in the abdominal cavity. This condition has been observed in turkey hens with arrested lay and death approximately three weeks after egg production stopped. In these turkey hens, the ovary could be completely regressed or with multiple atretic follicles. The body cavity might have also contained putrid and cheese-like masses derived from the collapsed ovarian follicles (Liu et al., 2001c). Female chicks normally have the left oviduct and

ovary functional. However, Robinson et al. (2003) observed hens with two oviducts that were sometimes of normal size and appearance that suggested egg formation could occur.

Feeding regimens in broiler breeders.

The increased growth rate and high BW of broiler stocks are directly related to increased feed and water intake, and somewhat to improve feed efficiency (Marks, 1980, 1985). The severity and duration of feed restriction for broiler breeder chicks must continuously adapt to the changing genotype and selection goals. Feed restriction remains a subject of debate among welfare groups (Hocking et al, 2001; Mench, 2002). Several authors have investigated modified rearing programs to obtain good reproductive performance with a less severe feeding regimen to improve bird welfare (Robbins et al., 1986 and 1988; Boa-Amposem et al., 1991; Hocking, 1993; Savory et al., 1996; Bruggeman et al., 1999; Renema et al., 1999a; Savory and Larivière, 1999; Hocking et al., 2001, 2004). Quantitative feed restriction on a daily basis may reduce the uniformity of the flock due to competition for feed.

Ad Libitum and Feed Restricted Broiler Breeder Hens.

Broiler breeder hens fed ad libitum during the rearing period reach sexual maturity and begin laying eggs earlier than their feed restricted counterparts. Hens fed ad libitum also exhibit a dramatic drop in egg production at an earlier age and produce fewer eggs overall. The early advantage of ad libitum compared to restricted feeding throughout rearing is believed to be nullified by production of small eggs early in the laying period which are unsuitable for incubation (Hocking,1996). Renema et al. (1999a) used ad libitum feeding only after photostimulation, and found that the initial egg size did not differ between feeding regimens; however, the reasonable egg size of low body weight birds was due to the delay in the onset of lay in these birds. In addition, breeder females fed ad libitum from hatch have been reported to

have more than double the BW of restricted fed females by photostimulation age (Katanbaf et al., 1989a; Yu et al., 1992a). At 34 weeks of age full-fed hens showed an average of 9.1 LYF compared to the feed restricted group with 7.2 LYF. The occurrence of simultaneous development of follicles was 1.7 LYF in full-fed hens and 0.6 LYF for the restricted females (Yu et al., 1992b).

When ad libitum feeding begins at photostimulation, hens can weigh 26% (Renema et al, 1999a) to 33% (Yu et al., 1992a) more than feed restricted birds at sexual maturity. Katanbaf et al. (1989b) observed that full-fed broiler breeder hens depend upon an age threshold and to start laying, while feed-restricted hens start egg production later and are dependent upon a BW threshold and attaining a carcass fat composition to initiate lay. Besides being heavier, broiler breeders fed ad libitum have increased body fat, with at least a 50% increase in abdominal fat relative to BW at sexual maturity compared with feed-restricted hens (Bornstein et al., 1984; Yu et al, 1992a,b).This severe adiposity, is usually associated with ovarian abnormalities.

Bruggeman et al. (1999) reported that hens with ad libitum feed access from 7 to 15 weeks of age resulted in much greater BW gains compared to restricted birds. From 16 weeks of age to the first egg these BW gains were smaller in both, ad libitum and restricted hens. In another experiment Robinson et al. (1993b) reported that 44 weeks old hens fed ad libitum for fourteen days, had a greater number of LYF (from 5.8 to 7.0) than those fed restricted. In previous work the authors observed a similar number of laying sequences in ad libitum and feed restricted hens; however, a reduced prime sequence length was observed in hens fed ad libitum (14.9 days) compared to the 24.2 day sequence length of the feed-restricted hens (Robinson et al., 1991). In other experiments comparing feed restriction and ad libitum feeding programs, birds changed to an ad libitum feeding program were reported to initially eat larger amounts of

feed than birds having long term ad libitum access to feed (Hocking, 1996). After four days, feed intake decreased to a consistent level (Robinson et al., 1993a) and later in lay, when the degree of feed restriction became more relaxed, feed intake relative to BW was similar for both, ad libitum and restricted birds (Renema, unpublished data). Hocking et al. (2002) found that the higher BW of ad libitum hens resulted in increased maintenance requirements due to the greater body mass and the egg production efficiency was negatively affected. The number of chicks produced per unit of feed consumed was four fold higher in feed restricted hens compared to ad libitum fed hens.

Wilson et al. (1995) evaluated three different feeding programs for broiler breeders in rearing (1) a standard program with a relatively linear growth curve, (2) an early slow program with slow growth rates during early rearing period followed by more generous allocation after 19 weeks, (3) and an early fast program with BW above normal in early rearing. No significant differences in BW were observed between the three groups except at 56 and 58 weeks when the early slow hens were significantly heavier than the standard group. Pullets reared on the early slow program had lower values for head width at 20 and 22 weeks than those birds on early fast program. The authors suggested that head width reflects BW changes. They also found that birds on the early slow program had significantly less carcass protein than the early fast birds; these findings are likely due to the early slow birds having compensatory growth during the generous feed allocation after 19 weeks and depositing the excess dietary energy as abdominal fat and liver tissue. Carcass fat increased by 2.42% from 25 to 58 weeks of age with no significant differences noted for carcass protein and ash. Overall fertility levels were lower in early slow hens throughout the trial. Hatchability was higher in the early fast group and the number of eggs hatched per hen from 28 to 58 weeks was greater in the early fast and standard birds. In general,

overweight broiler breeders show poor egg production, fertility and hatchability, and an increased tendency of reproductive abnormalities (Robinson et al., 1991; Yu et al., 1992b; Robinson et al., 1993).

Nutrient Densities and Requirements

Dietary nutrients are critical to support different processes such as bone and feather formation, egg production, embryonic development, carcass tissue, hormone production, immune response, blood and temperature regulation in addition to basic needs for living. Growth rate can be potentially limited by modifying the quality of the diet. Diets that are deficient in protein or an essential nutrient limit growth, and diet formulation can be adjusted to manipulate growth up to mature body size. Different attempts at qualitative feed restriction level have been made with manipulation of fatty acid and amino acid levels in the diet (Leeson and Summers, 1991). While mean flock BW can often be manipulated with qualitative feed restriction, BW uniformity of a flock is usually negatively affected (Leeson and Summers, 1991). Quantitative feed restriction is now universal with broiler breeders of all ages (Leeson and Summers, 1991).

Wilson (1997) reported that nutrient utilization and metabolism vary between genetic strains; therefore marginal nutrient deficiencies could potentially affect hens from different strains in different ways. While commercial laying stocks voluntarily consume appropriate feed quantities to meet their growth, metabolic and egg production requirements, broiler breeder stocks consume feed beyond their nutrient requirements (Etches, 1996). As appetite and BW for age increase in commercial broiler breeder flocks, so nutrient restriction of young breeders must start at earlier ages and be of increasing severity to older ages. Unlike other types of poultry, the absolute requirements of broiler breeders are influenced by both, restricted feeding level and nutrient specifications of the diets. These dual effects mean that nutrient intake can be controlled

much more closely, and represent a great potential for matching intake to requirement (Leeson and Summers, 1991).

Influence of nutrient density on reproduction

Dietary Protein

Wilson and Harms (1984) evaluated the nutrient requirements of layer hens during egg production, and determined that crude protein (**CP**) need was 20.6 g/hen/day, which suggests the possibility that protein levels are higher than necessary in standard industry practice. Broiler breeder pullets continue to be fed a starter diet between 16 to 18% CP (Anonymous, 1985-1986) for 2 to 3 weeks. After the starter period pullets are quantitatively feed restricted and switched to a grower or developer diet that is lower in protein (14 to 16% CP) and slightly lower in energy (Anonymous, 1985-1986; Renema et al., 1999a,b; Robinson et al., 2001). Breeder laying diets have 14 to 16% CP and are slightly higher in energy (Renema et al., 1999a,b; Robinson et al., 2001). Hens fed a diet formulated to contain 16% of CP had better hatching egg numbers in comparison to hens fed 18% of CP from 23 to 48 weeks of age (Joseph, 2002).

Protein intake during the first part of rearing period is important for future egg production and hatchability. Lilburn et al., (1987) evaluated the effects of two diets containing 13.5 or 15.5% of CP during the first 3 weeks of rearing period. The author reported that low protein diets reduced egg production (56.3 versus 59.3% respectively) and total hen housed production (133 versus 140 eggs/hen) when compared with a diet containing 15% CP. Walsh and Brake (1997) reported that a higher CP diet (17%) fed until 24 weeks of age improved hatchability by 1.5% from 28 to 64 weeks, compared with a diet containing 14% of CP. The same researchers also evaluated the effects of a linear or concave female feeding program using either a high or low level of protein to 20 or 24 weeks of age and evaluated subsequent broiler breeder fertility. Their results agreed with a previous report (Lilburn and Myers-Miller, 1990) that the pattern of feed allocation during the rearing period could affect egg production and fertility. Lilburn and Myers-Miller, (1990) also observed a significant improvement in fertility due to the level of dietary protein fed during the growing period.Pullets fed a higher protein diet (15% CP) had better overall fertility than those fed the marginal 14% CP diet. Contrary to Walsh and Brake (1997) findings, Hocking, Bernard and Robertson (2002) found no effect of low protein diets on fertility. More recently, Hudson et al., (2000) evaluated the effects of dietary protein during the first six weeks of the rearing period using 12, 16 or 20% of CP diets. The number of eggs per hen was higher in hens fed higher levels of CP during the first six weeks of rearing period.

Turkey hens, similar to chicken broiler breeder hens have been selected for excessive body weight which has resulted in significant reproductive problems. Therefore different studies have reported on the dietary requirements of these birds. For turkey breeder hens, greater protein intake increased feather weight and length along with BW (Wylie and Hocking, 1999). Sikur et al. (2004) evaluated the effects of nutrient density on growth and carcass traits in slow and fast feathering turkey hens fed a low protein diet (12-14% CP) or a high protein diet (18% CP). The authors reported that the SF hens responded differently to the protein intake than the FF hens in feather score and BW gain. The high protein diets improved the feather score in SF hens when they consumed the high protein diet from 32 through 56 weeks of age. At 11 days of age SF females were 11.5% heavier than FF hens, and SF hens stayed heavier throughout the trial. However, from 24 to 28 weeks FF hens were 0.9 kg heavier than their SF counterparts. *Dietary Energy*

In general, commercial broiler breeder management guides recommend a starter diet in the range of 2,800 to 2,970 kcal ME/kg and 16 to 19% CP. After 2 to 3 weeks of age, the pullets
are placed on a quantitative feed restriction program and switched to a grower or developer diet lower in protein (14 to 16% CP) and energy (2,750 to 2,850 kcal ME/kg) (Anonymous, 1985-1986; Renema et al., 1999a,b; Robinson et al., 2001). The grower diet is typical fed until the birds are close to starting lay (23 weeks of age). Once egg production starts, hens are fed a breeder I diet that is similar in protein (15-16% CP) and energy (2,860 kcal/kg) levels with higher calcium level (1.75% calcium in grower to3.25 % calcium in the breeder I). Breeder II diets are fed after 40-45 weeks of age to control egg size and this is accomplished by reducing the protein level by approximately 0.05% (Anonymous, 2005).

Energy intake is important for maintenance (i.e., temperature regulation, tissue repair, feed digestion, and normal activity), growth, and reproduction. Different factors such as housing temperature, body weight, rate of egg production and egg size, influence the caloric needs of the hen. Despite the importance of energy for reproduction, there is very little research examining the effect of energy intake and egg production. Brake (1990) demonstrated that hens fed diets containing 2,760 kcal ME/kg improved fertility, compared to hens fed lower (2,670 kcal ME) or higher (2,850 kcal ME) levels of energy.

Excess energy intake has been shown to result in more LYF development, and low reproductive performance (Hocking et al., 1987, 1989; Robinson et al., 1991, 1993b). This condition has been associated with increased erratic oviposition, double yolked-eggs, shell deformities, internal ovulation and oviposition (van Middlekoop, 1972; Yu et al., 1992b). Recently high yielding broiler breeder hens have been estimated to need 390 kcal ME/hen/day (Dozier, 2003).

Influence of nutrient density on carcass conformation

There is little published information on the relationships between nutrient intake and carcass development of breeder pullets and hens. The concept of skeletal growth or frame size and its relationship to the overall rearing program has become an important topic. In 1984, Leeson and Summers reported shank length measurements as an indicator of skeletal development in growing Leghorn and broiler breeder pullets. They found that differences in BW were associated with similar trends in shank length and keel length. Increasing protein from 16 to 22% significantly increased BW, shank length and keel length of Leghorn chicks. Increasing dietary energy only improved growth and did not affect skeletal measurements.

Bornstein et al. (1984) reported a negative correlation between abdominal fat and age at first egg. Lilburn (1989) evaluated effects of nutrient density during rearing period on BW, skeletal and muscle growth in broiler breeder pullets at 8, 12 and 16 weeks of age, feeding either a commercial broiler starter diet or a pullet grower diet. This author found that frame size or skeletal growth in broiler breeders is primarily a function of BW gain, and the differences in dietary protein and energy can influence the rate of gain and indirectly influence skeletal growth. Although simple control of BW gain by feed restriction, effectively limited skeletal growth while pectoralis major muscle increased and abdominal fat decreased when a broiler-type starter diet (23% CP and 3,313 kcal/ME/kg) was fed compared with a pullet starter diet (15% CP and 2,885 kcal/ME/kg). The author concluded that when energy intake is equalized during rearing, increased protein intake (23% CP) significantly increase the weight of muscle depots and decreased abdominal fat. More recently Lilburn and Myer-Miller (1990) suggested that there is a critical age after 25 weeks of age when carcass development will not be affected by the high or low protein and energy diets.

Wagner (1979), Leeson and Summers (1984), and Lilburn (1989) reported that the dietary effects on skeletal development disappear once BW is equalized via restricted feeding. On the other hand, it has been reported that very low dietary protein levels can significantly reduced shank length during the ad libitum starter period (Leeson and Summers, 1984; Lilburn et al., 1987). Wagner (1979) also observed that when chickens from different nutritional treatments were grouped according to keel length, there were significant differences in pectoral muscle weights. Lilburn (1989) suggested that dietary protein intake is more important than energy in controlling growth of 2 to 4 weeks old birds, while in older restricted fed pullets (Lilburn et al., 1987) and hens (Spratt and Leeson, 1987) the relationship between energy intake and BW gain maybe stronger.

With this strong relationship between poor reproductive performance and overweight hens, feed intake is routinely restricted to approximately 50 to 60% of ad libitum to reduce or avoid obesity and metabolic diseases and improve egg production in broiler breeders (Katanbaf et al., 1989b; Bruggeman, et al., 2005). One of the objectives for the first experiment (Chapter 3) was to evaluate different diet densities for crude protein (CP) and metabolizable energy (ME). The moderate (M-D) laying diet was formulated according to the current standard industry diets for broiler breeders, along with a high (H-D) and low (L-D) density diets (Agri Stats, 2004-2005). These diets were fed to three different BW groups of females to determine the influence on BW gains, nutrient utilization and reproductive performance in a slow feathering meat strain. The same data was collected to determine if average BW SF females differs from their reciprocal fast feathering cross when fed the moderate density diet. The purpose of the second study was to determine possible influences of BW at photostimulation along with feeding level might have on reproduction, livability or level of reproductive abnormality.

REFERENCES

Agri Stats, Inc. Jan.-Dec. 2004. Live production annual agri stats report. Fort Wayne, IN 46825.

Agri Stats, Inc. Jan.-Dec. 2005. Live production annual agri stats report. Fort Wayne, IN 46825.

Anonymous. 2005. Cobb Breeder Management Guide. Cobb Vantress. Siloam Springs, AR.

- Anonymous. 1985-1986. Hubbard Farms Broiler Breeder Management Guide. Hubbard Farms. Walpole, NH.
- Asmundson, V. S. and I. M. Lerner. 1933. Inheritance of rate growth in domestic fowl II. Genetic variation in growth of Leghorns. Poult. Sci. 12:250-255.
- Asmundson, V. S. and I. M. Lerner. 1934. Inheritance of rate growth in domestic fowl III. Comparative rates of growth in Leghorns and Rocks. Poult. Sci. 13:348-352.
- Auckland, J. N. and Wilson, S. B. 1977. Mineral and vitamin supplementation of a whole wheat diet for developing pullets. Br. Poult. Sci. 18:121-127.
- Bacon, W. L., and H. K. Liu. 2003. Influence of photoperiod and age of photostimulation on the incidence of polycystic ovarian follicle syndrome in turkey breeder hens. Poult. Sci. 82:1985-1989.
- Bahr, J. M., and S. S. Palmer. 1989. The influence of aging on ovarian function. Poult. Biol. 2:103-110.
- Barbato, G. F., P. B. Siegel, J. A. Cherry, and I. Nir. 1984. Selection for body weight at 8 weeks of age. 17. Overfeeding. Poult. Sci. 63:11-18.

Bakst, M. R. 1993. Oviductal sperm storage in poultry: a review. Reprod. Fertil. Dev. 5:595-599.

Boa-Amposem, K., N. P. O'Sullivan, W. B. Gross, E. A. Dunnington, and P. B. Siegel. 1991.Genotype, feeding regimen, and diet interactions in meat chickens. 3. General fitness.Poult. Sci. 70:697-701.

- Bornstein, S., I. Plavnik, and Y. Lev. 1984. Body weight and/or fatness as potential determinants of the onset of egg production in broiler breeder hens. Br. Poult. Sci. 25:323-341.
- Bottje, W. G., K. R. Holmes, H. L. Neldon, and T. K. Koike. 1989. Relationships between renal hemodynamic and plasma levels of arginine vasotocin and mesotocin during hemorrhage in the domestic fowl (Gallus domesticus). Comp. Biochem. Physiol. A92: 423-427.
- Brody, T., Y. Eitan, M. Soller, I. Nir, and Z. Nitzan. 1980. Compensatory growth and sexual maturity in broiler females reared under severe food restriction from day of hatching. Br. Poult. Sci. 21: 437-446.

Bulfield, G. 2004. Poultry breeding in the post-genomics era. Br. Poult. Sci. 45:5-8.

- Bruggeman, V., O. Onagbesan, E. D'Hondt, N. Buys, M. Safi, D. Vanmontfort, L. Berghman, F. Vandensande, and E. Decuypere. 1999. Effects on timing and allowance feed allowance-genotype interactions in broiler breeder hens. Poult. Sci. 84:298-306.
- Bruggeman, V., E. D'hondt, L. Berghman, O. Onagbesan, D. Vanmontfort, F. Vandesande, and E. Decuypere. 1998a. The effect of feed intake from 2 to 24 weeks of age on LHRH-1 content in the median eminence and gonadotropin levels in pituitary and plasma in female broiler breeder chickens. Gen. Comp. Endocrinol. 112:200-209.
- Bruggeman, V., O. Onagbesan, D. Vanmontfort, L. Berghman, G. Verhoeven, and E. Decuypere. 1998b. Effect of long term food restriction on pituitary sensitivity to cLHRH-1 in broiler breeder females. J. Reprod. Fert.114:267-276.
- Bruggeman, V., O. Onagbesan, O. Ragot, S. Metayer, S. Cassy, F. Favreau, Y. Jego, J. J. Trevidy,K. Tona, J. Williams, E. Decuypere, and M. Picard. 2005. Feed allowance-genotype interactions in broiler breeder hens. Poult. Sci. 84:298-306.

- Burke, W. H., F. X. Ogasawara, and C. L. Fuqua. 1972. Study of the ultrastructure of the uterovaginal sperm-storage glands of the hen, Gallus domesticus, in relation to the mechanism for the release of spermatozoa. J. Reprod. Fertil. 29:29-36.
- Burkhart, C. A., J. A. Cherry, H. P. Van Krey, and P. B. Siegel. 1983. Genetic selection for growth rate alters hypothalamic satiety mechanisms in chickens. Behav. Genet. 13:295-300.
- Chalana, R. K., and S. S. Guraya. 1978. Histophysiological studies on the postovulatory follicles of the fowl ovary. Poult. Sci. 57: 814-817.
- Chen, S. E., J. P. McMurtry, and R. L. Walzem. 2006. Overfeeding-induced ovarian dysfunction in broiler breeder hens is associated with lipotoxicity. Poult. Sci. 85:70-81.
- Conrad, R. M., and D. C. Warren. 1940. The production of double yolked eggs in the fowl. Poult. Sci. 19:9-17.
- Dahl, E. 1970. Studies of the fine structure of ovarian interstitial tissue. 3. The innervation of the thecal gland of the domestic fowl. Z. Zellfrosch. Mikrosk. Anat. 109: 195-211.
- Dozier, W. A. 2003. Nutritional considerations for broiler breeders. Poult. Digest Online. 4:1-6.
- Dunn, I. C. and P. J. Sharp. 1990. Photoperiodic requirements for LH release in juvenile broiler and egg-laying strains of domestic chickens fed ad libitum or restricted diets. J. Reprod. Fert. Title90:329-335.
- Dunnington, E. A. and P. B. Siegel. 1986. Sex-linked feathering alleles (K, k+) in chicks of diverse genetic backgrounds. 1. Body temperatures and body weights. Poult. Sci. 66:168-170.
- Eitan, Y., M. Soller, I. Nir and Z. Nitzan. 1979. Heavy broiler breeders of light body weight. Meshek Ha'Ofot, 25: 333-336.
- Etches, R. J. 1996. Reproduction in poultry. CAB International, Wallingford, UK.

- Etches, R. J. and K.W. Cheng. 1981. Changes in the plasma concentrations of luteinizing hormone, progesterone, oestradiol and testosterone and in the binding of follicle-stimulating hormone to the theca of follicles during the ovulation cycle of the hen (Gallus domesticus). J. of Endocrinol. 91:11-22.
- Foster, W. H., and Z. T. Taha. 1978. Whole grain diets for pullets. Br. Poult. Sci. 19: 233-242.
- Frisch, R. E. 1972. Critical weight at menarche: similarity for well-nourished and undernourished girls at different ages, and evidence for historical constancy. Pediatrics. 50: 445-450.
- Frisch, R. E., and J. W. McArthur. 1974. Menstrual cycles: fatness as a determinant of minimum weight for height necessary for their maintenance or onset. Science. 185: 949-951.
- Frisch, R. E., and R. Revelle. 1974. Height and weight at menarche and a hypothesis of critical body weights and adolescent effects. Science. 169: 397-399.
- Fruhbeck, G., J. Gomez-Ambrosi, F. J. Muruzabal, and M. A. Burrel. 2001. The adypocyte: a model of integration of endocrine and metabolic signaling in energy metabolism regulation. Am. J. Physiol. Endocrinol. Metab. 280:E827-E847.
- Gilbert, A. B., M. E. Reynolds, and F. W. Lorenz. 1968. Distribution of the spermatozoa in the oviduct and fertility in the domestic birds. Innervation and vascular supply of the uterovaginal sperm-host glands of the domestic hen. J. Reprod. Fert. 17:305-310.
- Gilbert, A. B. 1969. Innervation of the ovary of the domestic hen. Quart. J. Exp. Physiol. 54: 404-411.
- Gilbert, A. B. 1971. The ovary. Pages 1163-1208 in: Physiology and Biochemistry of the Domestic Fowl.Vol. 3. D. J. Bell and B. M. Freeman, ed. Academic Press, London, UK.
- Gilbert, A. B., M. F. Davidson, and J. W. Wells. 1978. Role of the granulose cells of the postovulatory follicle of the domestic fowl in oviposition. J. Reprod. Fertil. 52: 227-229.

Glass, A. R., R. Harrison, and R. S. Swerdloff. 1976. Effect of undernutrition and amino acid deficiency in the timing of puberty in rats. Pediatric Research. 10: 951-955.

Gyles, N. R. 1989. Poultry people and progress. Poult. Sci. 68:1-8.

- Griffin, H. D. and C. Goddard. 1994. Rapidly growing broiler (meat-type) chickens: Their origin and use for comparative studies of the regulation of growth. Int. J. Biochem. 26:19-28.
- Guemene, D., and J. B. Williams. 1992. In-vitro and in-vivo responses to chicken LHRH-I and chicken LHRH-II in male turkeys (Meleagris gallopavo). J. Endocrinol. 132:387-393.
- Havenstein, G. B., P. R. Ferket, and M. A. Qureshi. 2003a. Growth, livability, and feed conversion of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poult. Sci. 82:1500-1508.
- Havenstein, G. B., P. R. Ferket, and M. A. Qureshi. 2003b. Carcass composition and yield of 1957 versus 2001 broilers when fed representative 1957 and 2001 broiler diets. Poult. Sci. 82:1509-1518.
- Hocking, P. M. 1992. Genetic and environmental control of ovarian function in turkeys at sexual maturity. Br. Poult. Sci. 50:1672-1682.
- Hocking, P. M. 1993. Effects of body weight at sexual maturity and the degree and age of restriction during rearing on the ovarian follicular hierarchy of broiler breeder females. Br. Poult. Sci. 34:793-801.
- Hocking, P. M. 1996. Role of body weight and food intake after photostimulation on ovarian function at first egg in broiler breeder females. Br. Poult. Sci. 37:841-851.
- Hocking, P. M., R. Bernard, and G. W. Robertson. 2002. Effects of low dietary protein and different allocations of food during rearing and restricted feeding after peak rate of lay on egg

production, fertility and hatchability in female broiler breeder hens. Br. Poult. Sci. 43:94-103.

- Hocking, P. M., A. B. Gilbert, M. Walker, and D. Waddington. 1987. Ovarian follicular structure of White Leghorns fed ad libitum and dwarf and normal broiler breeders fed ad libitum or restricted until point of lay. Br. Poult. Sci. 28:493-506.
- Hocking, P. M., A. B. Gilbert, C. C. Whitehead, and M. A. Walker. 1988. Effects of age and early lighting on ovarian function in breeding turkeys. Br. Poult. Sci. 29:223-229.
- Hocking, P. M., D. Waddington, M. Walker, and A. B. Gilbert. 1989. Control of the development of the ovarian follicular hierarchy in broiler breeder pullets by food restriction during rearing.Br. Poult. Sci. 30:161-173.
- Hocking, P. M., M. H. Maxwell, G. W. Robertson, and M. A. Mitchell. 2001. Welfare assessment of modified rearing programmes for broiler breeders. Br. Poult. Sci. 42:424-432.
- Hocking, P. M., V. Zaczek, E. K. M. Jones, and M. G. Macleod. 2004. Different concentrations and sources of dietary fiber may improve the welfare of female broiler breeders. Br. Poult. Sci. 45:9-19.
- Hodges, R. D. 1965. The blood supply to the avian oviduct with special reference to the shell gland. J. Anat. 99:485-506..
- Hudson, B. P., R. J. Lien, and J. B. Hess. 2000. Effects of early protein intake on development and subsequent egg production of broiler breeder hens. J. Appl. Poult. Res. 9:324
- Hutson, J. M., P. K. Donahue, D. T. McLaughlin. 1985. Steroid modulation of Mullerian duct regression in the chick embryo. Gen. Comp. Endocrinol. 57: 88-102.
- Jaap, R. G. and Muir, F. V. 1968. Erratic oviposition and egg defects in broiler-type pullets. Poult. Sci. 47: 417-423.

- Johnson, A. L. 2000. Reproduction in the female. P. 569-596. In Avian Physiology. G. Causey Whittow, ed. 5th Ed. Honolulu, Hawaii.
- Johnson, A. L. 1990. Steroidogenesis and actions of steroids in the hen ovary. CRC Crit. Rev. Poult. Biol. 2:867-873.
- Johnson, A. L., and A. van Tienhoven. 1980. Plasma concentrations of sex steroids and LH during the ovulatory cycle of the hen, Gallus domesticus. Biol. Reprod. 23:386-393.
- Joseph, N. S., A. J. Dulaney, F. E. Robinson, R. A. Renema, and M. J. Zuidhof. 2002. Effects of age and photostimulation and dietary protein intake on three strains of broiler breeders varying in breast meat yield. Poult. Sci. 81:597-607.
- Julian, R. J. 1998. Rapid growth problems: Ascites and skeletal deformities in broilers. Poult. Sci. 77:1773-1780.
- Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel. 1989a. Restricted feeding in early and late-feathering chickens. 1. Growth and physiological responses. Poult. Sci. 68:344-351.
- Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel. 1989b. Restricted feeding in early and latefeathering chickens. 2. Reproductive responses. Poult. Sci. 68:352-358.
- Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel. 1989c. Restricted feeding in early and latefeathering chickens. 3. Organ size and carcass composition. Poult. Sci. 68:359-368.
- Kennedy, G. C. and J. Mitra. 1963. Body weight and food intake as initiating factors for puberty in the rat. J. of Phy. 166: 408-418.
- Klempt, M., F. Ellendorff, and R. Grossmann. 1992. Functional maturation of arginine vasotocin secretory responses to osmotic stimulation in the chick embryo and the newborn chicken.J. Endocrinol. 133:269-274.

Koike, T. I, K. Shimada, and L. E. Cornett. 1988. Plasma levels of immunoreactive mesotocin

- and vasotocin during oviposition in chickens: Relationship to oxytocic action of the peptides
 in vitro and peptide interaction with myometrial membrane binding sites. Gen. Com.
 Endocrinol. 70:119-126.
- Leeson, S., and J. D. Summers. 1984. Influence of nutritional modification on skeletal size of Leghorn and broiler breeder pullets. Poult. Sci. 63:1222-1228.
- Leeson, S., and J. D. Summers. 1991. Commercial Poultry Nutrition. Guelph, Ontario, Canada.
- Lilburn, M. S., K. Ngiam-Rilling, and J. H. Smith. 1987. Relationships between dietary protein, dietary energy, rearing environment, and nutrient utilization by broiler breeder pullets. Poult. Sci. 66:1111-1118.
- Lilburn, M. S., and D. J. Myers-Miller. 1990. Effect of body weight, feed allowance, and dietary protein intake during the pre-breeder period on early reproductive performance of broiler breeder hens. Poult. Sci. 69:1118-1125.
- Lilburn, M. S. 1989. Growth and development of broiler breeders. 2. Independent effects of dietary formulation versus body weight on skeletal and muscle growth. Poult. Sci. 68:1274-1281.
- Liu, H. -K., K. E. Nestor, D. W. Long, and W. L. Bacon. 2001a. Frequency of luteinizing hormone surges and egg production rate in turkey hens. Biol. Reprod. 64:1769-1775.
- Liu, H. -K., K. E. Nestor, D. W. Long, and W. L. Bacon. 2001b. Preovulatory luteinizing hormone surge interval in old and young laying turkey hens early in the egg production period. Poult. Sci. 80:1364-1370.
- Liu, H. -K., D. W. Long, and W. L. Bacon. 2001c. Concentration change patterns of luteinizing hormone and progesterone and distribution of hierarchical follicles in normal and arrested laying turkey hens. Poult. Sci. 80:1509-1518.

- Liu, H. -K., D. W. Long, and W. L. Bacon. 2002. Preovulatory surges of luteinizing hormone increases late in the reproductive period in turkey hens. Biol. of Rep. 66:1068-1075.
- Macnamee, M. C., P. J. Sharp, R. W. Lea, R. J. Sterling, and S. Harvey. 1986. Evidence that vasoactive intestinal polypeptide is a physiological prolactin-releasing factor in the bantam hen. Gen. Comp. Endocrinol. 87:481-493.
- Malloney, M. A., Gilbreath, J. C., Tierce, J. F., and Morrison, R. D. 1967. Divergent selection for twelve-week body weight in the domestic fowl. Poult. Sci. 46:1116-1127.
- Mauro, L. J., O. M. Youngren, J. A. Proudman, R. E. Phillips, and M. E. El Halawani. 1992. Effects of reproductive status, ovariectomy and photoperiod on vasoactive intestinal peptide in the female turkey hypothalamus. Gen. Comp. Endocrinol. 87:481-493.
- Marks, H. L. 1980. Early feed intake and conversion of selected and nonselected broilers. Poult. Sci. 59:1167-1171.
- Marks, H. L. 1985. Direct and correlated responses to selection for growth. Page 47-57 in Poultry Genetics and Breeding. Hill, W. G., J. M. Manson, and D. Hewitt. Ed. British. Poultry. Science Ltd., Harlow.
- McCarty, J. C. and P. B. Siegel. 1983. A review of genetic and physiological effects of selection in meat type poultry. Anim. Breeding Abstr. 51: 87-94.
- Melnychuk, V. L., F. E. Robinson, R. A. Renema, R. T. Hardin, D. A. Emmerson, and L. G. Bagley. 1997. Carcass traits and reproductive development at the onset of lay in two lines of female turkeys. Poult. Sci. 76:1197-1204.
- Mench, J. A. 2002. Broiler breeders: Feed restriction and welfare. World's Poult. Sci. J. 58:23-29.
- Morris, T. R. 1978. The influence of light on ovulation in domestic birds. In Animal Reproduction (H. Hawk, ed.), BARC Symposium Number 3, chapter 19, p. 307. Allenheld, Montclair.

- Nalbandov, A. V., and M. F. James. 1949. The blood-vascular system of the chicken ovary. Am. J. Anat. 85:347-377.
- Nestor, K. E., W. L. Bacon, and P. A. Renner. 1980. The influence of genetic changes in total egg production, clutch length, broodiness, and body weight on ovarian follicular development in turkeys. Poult. Sci. 59:1694-1699.
- Neuman, S. L., R. H. Harms, and O. B. Russell. 1998. An innovative change in energy restrictions for broiler breeder hens. J. Appl. Poult. Res. 7:328-335.
- Nir, I., Z. Nitzan, Y. Dror, and N. Shapira. 1978. Influence of overfeeding on growth, obesity and intestinal tract in young chicks of light and heavy breeds. Br. Poult. Sci. 39:27-35.
- Noddegaard, F., R. T. Talbot, and P. J. Sharp. 2000. Effects of delayed set-up lighting on plasma luteinizing hormone and reproductive function in broiler breeders. Poult. Sci. 79:778-783.
- Nouven, E. J., E. Decuypere, E. R. Kuhn, H. Michels, T. R. Hall, and A. Chadwick. 1984. Effect of dehydration, hemorrhage and oviposition on serum concentrations of vasotocin, mesotocin, and prolactin in the chicken. J. Endocrinol. 102:345-351.
- Onagbesan, O. M., B. Vleugels, N. Buys, V. Bruggeman, M. Safi, and E. Decuypere. 1999. Insulinlike growth factors in the regulation of avian ovarian functions. Domest. Anik. Endocrinol. 17:299-313.
- Opel, H., and J. A. Proudman. 1988. Stimulation of prolactin release in turkeys by vasoactive intestinal peptide. Proc. Soc. Exp. Biol. Med. 187:455-460.
- O'Sullivan, N. P., E. A. Dunnington, and P. B. Siegel. 1991. Relationships among age of dam, egg components, embryo lipid transfer and hatchability of broiler breeder hens. Poult. Sci. 70:2180-2185.

- Proudman, J. A. 1995. The biology of egg production and fertility. Proc. First International Symposium on the Artificial Insemination of Poultry. Baskt, M. R., and G. J. Wishart, Eds. Poultry Science Association, Savoy III.
- Reddy, P. R. K. and P. B. Siegel. 1977. Selection for body weight at eight weeks of age. 14. Effects of the sex-linked dwarf gene. Poult. Sci. 56: 1004-1013.
- Renema, R. A., F. E. Robinson, V. L. Melnychuk, R. T. Hardin, L. G. Bagley, D. A. Emmerson, and J. R. Blackman. 1995. The use of feed restriction for improving reproductive traits in male-line large white turkey hens. 2. Ovary morphology and laying traits. Poult. Sci. 74:102-120.
- Renema, R. A. and F. E. Robinson. 2004. Defining normal: Comparison of feed restriction and full feeding of female broiler breeders. World's Poult. Sci. J. 60:508-522.
- Renema, R. A., F. E. Robinson, M. Newcombe, and R. I. McKay. 1999a. Effects of body weight and feed allocation during sexual maturity in broiler breeder hens. 2. Ovarian morphology and plasma hormone profiles. Poult. Sci. 78:619-628.
- Renema, R. A., F. E. Robinson, J. A. Proudman, M. Newcombe, and R. I. McKay. 1999b. Effects of body weight and feed allocation during sexual maturation in broiler breeder hens: 1. Growth and carcass characteristics. Poult. Sci. 78:629-639.
- Robbins, K. R., G. C. McGhee, P. Osei, and R. E. Beauchene. 1986. Effect of feed restriction on growth, body composition and egg production of broiler females through 68 weeks of age.Poult. Sci. 65:2226-2231.
- Robbins, K. R., S. F. Chin, G. C. McGhee, and K. D. Roberson. 1988. Effect of ad libitum versus restricted feeding on body composition and egg production of broiler breeders. Poult. Sci. 67:1001-1007.

- Robinson, F. E., R. A. Renema, H. H. Oosterhoff, M. J. Zuidhof, and J. L. Wilson. 2001. Carcass traits, ovarian morphology and egg laying characteristics in early versus late maturing strains of commercial type chickens. Poult. Sci. 80:37-46.
- Robinson, F. E., G. M. Fasenko, and R. A. Renema. 2003. Female Reproduction: Reproductive Abnormalities. P 33-38. In optimizing chick production in broiler breeders. Spotted Cow Press Ltd. Edmonton, Alberta, Canada.
- Robinson, F. E., J. L. Wilson, M. W. Yu, G. M. Fasenko, and R. T. Hardin. 1993. The relationship between body weight and reproductive efficiency in meat-type chickens. Poult. Sci. 72:912-922.
- Robinson, F. E., R. A. Renema, L. Bouvier, J. J. R. Feddes, M. J. Zuidhof, J. L. Wilson, M.
 Newcombe, and R. I. Mackay. Effects of photostimulatory lighting and feed allocation in female broiler breeders. 1. Reproductive development. 1998. Can. J. Anim. Sci. 78:603-613.
- Robinson, F. E., M. W. Yu, M. E. Lupicki, and R. T. Hardin. 1993. Short-term consequences of a sudden increase in feed allowance in broiler breeder hens. Can. J. Anim. Sci. 73:159-167.
- Robinson, F. E., N. A. Robinson, and T. A. Scott. 1991b. Reproductive performance, growth and body composition of full-fed versus feed restricted broiler breeder hens. Can. J. Anim. Sci. 71:549-556.
- Robinzon, B., T. I. Koike, H. L. Neldon, S. L. Kinzler, I. R. Hendry, and M. E. El Halawani.
 1988a. Physiological effects of arginine vasotocin and mesotocin in cockerels. Br. Poult.
 Sci. 29:639-652.
- Robinzon, B., T. I. Koike, H. L. Neldon, and S. L. Kinzler. 1988b. Distribution immunoreactive mesotocin and vasotocin in the brain and pituitary of chickens. Peptides 9:829-833.

- Rozenboim, I., L. J. Silsby, C. Tabibzadeh, G. R. Pitts, O. M. Youngren, and M. E. El Halawani.
 1993a. Hypothalamic and posterior pituitary content of vasoactive intestinal peptide (VIP) and gonadotropin-releasing hormones I and II in the turkey hen. Biol. Reprod. 49:622-626.
- Salevsky, E., and R. M. Leach. 1980. Studies on the organic components of shell gland fluid and the hen's egg shell. Poult. Sci. 59:438-443.
- Savory, C. J., P. M. Hocking, J. S. Mann, and M. H. Maxwell. 1996. Is broiler breeder welfare improved by using qualitative rather than quantitative feed restriction to limit growth rate? Anim. Welf. 5: 105-127.
- Savory, C. J. and J. M. Lariviere. 1999. Effects of qualitative and quantitative food restriction treatments on feeding motivational state of growing broiler breeders. Br. Poult. Sci. 40:515-517.
- Scanes, C. G., P. M. M. Godden, and P. J. Sharp. 1977a. An homologous radioimmunoassay for chicken follicle-stimulating hormone: Observations on the ovulatory cycle. J. Endocrinol. 73:473-481.
- Scanes, C. G., H. Mozelic, E. Kavanagh, G. Merrill, and J. Rabii. 1982. Distribution of blood flow in the ovary of domestic fowl (Gallus domesticus) and changes after prostaglandin F-2α treatment. J. Reprod. Fertil. 64:227-231.
- Sharp, P. J., R. T. Talbot, G. M. Main, I. C. Dunn, H. M. Fraser, and N. S. Huskisson. 1990. Physiological roles of chicken LHRH-I and –II in the control of gonatrophin release in the domestic chicken. J. Endocrinol. 124:291-299.
- Sikur, V. R., F. E. Robinson, D. R. Korver, R. A. Renema, and M. J. Zuidhof. 2004. Effects of nutrient density on growth and carcass traits in fast and slow feathering female turkeys. Poult. Sci. 83:1507-1517.

- Singh, N. 1993. "The poultry industry". Pages 117-140 in: Animal Production in Canada. Martin, J., Hudson R. J., and Young B. A., ed. Faculty of Extension, University of Alberta, Edmonton.
- Spratt, R. S., and S. Leeson. 1987. Broiler breeder performance in response to diet protein and energy. Poult. Sci. 66:683-693.
- Tilly, J. L., K. I. Kowalski, A. L. Johnson, and A. J. W. Hsueh. 1991. Involvement of apoptosis in ovarian follicular atresia and postovulatory regression. Endocrinology 129: 2799-2801.
- Tingari, M. D. and P. E. Lake. 1973. Ultrastructural studies on the uterovaginal sperm-host glands of the domestic hen, Gallus domesticus. J. Reprod. Fertil. 34:423.431.
- Tuohimaa, P., T. Joensuu, J. Isola, R. Keinanen, T. Kunnas, A. Niemala, A. Pekki, M.Wallen, T. Ylikomi, and M. Kulomaa. 1989. Development of progestin-specific response in the chicken oviduct. Int. J. Dev. Biol. 33: 125-134.
- Unsicker, K., F. Seidel, H. D. Hofmann, T. H. Muller, R. Schmidt and A. Wilson. 1983. Cathecholaminergic innervation of the chicken ovary. Cell Tissue Res. 230:431-450.
- van Middelkoop, J. H. 1972. The relationship between ovulation interval of White Plymouth Rock pullets and the laying of abnormal eggs. Arch. Geflugelkd. 36:223-230.
- Wagner, J. 1979. The influence of the nutrition level of the skeletal growth in chicken. Pr. Mater. Zootech. 20:41-53.
- Walsh, T. J., and J. Brake. 1997. Effect of nutrient intake during rearing of broiler breeder females on subsequent fertility. Poult. Sci. 76:297-305.
- Whitehead, C. C. 2000. Nutrition: the integrative science. Br. Poult. Sci. 41:5-15.
- Williams, J. B., and P. J. Sharp. 1978. Ovarian morphology and rates of ovarian follicular development in laying broiler breeders and commercial egg producing hens. Br. Poult. Sci. 19:187-395.

- Wilson, H. R, and R. H. Harms. 1984. Evaluation of nutrient specifications for broiler breeders. Poult. Sci. 63:1400-1406.
- Wilson, H. R. 1997. Effects of maternal nutrition on hatchability. Poult. Sci. 76:134-143.
- Wilson, J. L., F. E. Robinson, N. A. Robinson, and R. T. Hardin. 1995. Effects of feed allocation on female broiler breeders. J. Appl. Poult. Res. 4:193-202.
- Wylie, L. M., and P. M. Hocking. 1999. Effect of lowering dietary protein concentration on feathering in modern and traditional turkeys. Br. Poult Sci. 40 (Suppl):S60-S61.
- Yu, M. W., F. E. Robinson, and A. R. Robblee. 1992a. Effect of feed allowance during rearing and breeding on female broiler breeders. 1. Growth and carcass characteristics. Poult. Sci. 71:1739-1749.
- Yu, M. W., F. E. Robinson, R. G. Charles and R. Weingardt. 1992b. Effect of feed allowance during rearing and breeding on female broiler breeders. 2. Ovarian morphology and production. Poult. Sci. 71:1750-1761.
- Yu, M. W., F. E. Robinson, and R. J. Etches. 1992b. Quantification of ovarian esteroidogenesis in the domestic fowl by incubation of intact large follicles. Poultry Sci. 71:346-351.
- Yu, M. W., F. E. Robinson, and R. J. Etches. 1992c. Effect of feed allowance during rearing and breeding on female broiler breeders. 3. Ovarian steroidogenesis. Poult. Sci. 71:1762-1767.

CHAPTER 2

STATEMENT OF PURPOSE

Broiler breeders have been genetically selected for meat yield, which is inversely correlated to reproductive performance. Differences in body weight, BW gains, flock uniformity or egg production between slow and fast feathering broiler breeder hens have been reported.

Although a number of researches have been performed on body weight and reproductive performance in broiler breeders, very little is known about nutrient utilization and mortality and morbidity issues in some genetic strains. Undesirable traits such as skeletal deformities, metabolic diseases and reduced livability have been associated with genetic selection for rapid growth in meat type chickens, especially in the slow feathering strain.

One goal of this research is to evaluate slow feathering hens that varied in body weight at photostimulation when fed three different diet densities to determine if reproductive performance would be improved by the nutrient consumption. The second goal is to evaluate the reciprocal cross of fast and slow feathering hens for reproductive performance. These goals were evaluated by measuring body composition, reproductive organ development and nutrient utilization. With a close monitoring of hen morbidity and mortality, ovarian abnormalities and differences in lay pattern, body weight, and nutrient consumption could be observed.

CHAPTER 3

INFLUENCE OF INITIAL BODY WEIGHT AND DIETARY NUTRIENT DENSITY ON NUTRIENT UTILIZATION AND PERFORMANCE OF FAST AND SLOW FEATHERING BROILER BREEDER HENS¹

¹ Mendoza, A.M., W.A. Dozier, A.J. Davis, and J.L. Wilson. To be submitted to Journal of Poultry Science.

ABSTRACT

A study was conducted to evaluate slow feathering (SF) broiler breeder females that varied in 21 wk BW and were fed diets varying in nutrient density. In addition, a strain comparison was made between SF and a fast feathering (FF) reciprocal cross female when both strains were average in BW and fed a commercially available (medium density) diet. At 19 wk of age, 107 SF pullets were selected from a commercial flock in three body weight (BW) ranges: high (H-BW), average (A-BW), and low (L-BW). Thirteen FF birds were selected that were A-BW. At 21 wk of age just prior photostimulation, a sample of 30 pullets were terminated and carcasses were packed and frozen for body composition analyses.

At 22 wk of age pullets were started on one of the three experimental diets. Diets were formulated to provide three different nutrient densities based on CP and ME and were assigned across BW groups in the SF strain. Birds were fed a high nutrient density (H-D diet; 16% CP, 3000 kcal of ME/kg), medium nutrient density (M-D diet; 15 % CP, 2920 kcal of ME/kg) or a low nutrient density (L-D diet; 14 % CP, 2850 kcal of ME/kg) diet. All the FF birds were fed the M-D diet. Data for BW, egg production and egg weight were summarized on weekly basis during the course of the trial. Starting at 22 wk of age, manure samples were collected every two wk, and percent CP and moisture, along with energy (kcal/g) levels were determined. The experiment was terminated at 34 wk of age and BW, and reproductive measurements (ovary weight, oviduct weight and size of ovarian hierarchy) were taken. All organs were returned to the carcass, and frozen for body composition analysis.

The SF and FF retained similar levels of dietary energy and nitrogen and had no differences in BW and body composition except at 34 wk of age when FF hens had significantly more relative abdominal fat than SF hens. In addition, SF hens produced more hatching eggs

than FF hens. High BW and A-BW hens (SF group) produced more eggs through 34 wk of age. Feeding a H-D diet did not increase egg production over a M-D diet and prolonged feeding of a H-D diet might encourage excess BW gain or fat deposition. The L-D diet was unable to sustain acceptable egg production when compared to the M-D diet. These results suggest that breeder diets fed in early lay can have a 15 % CP level which is 1 % lower than the recommended 16 % CP by the primary breeder without a loss in egg production.

INTRODUCTION

The modern broiler breeder female is a genetic compromise between two very different selection criteria. This parent must have the genetics for rapid and efficient growth, and yet exhibit a high rate of egg production to supply the next generation of broiler chicks (Renema and Robinson, 2004). The negative relationship between growth and reproductive fitness has been recognized for over 30 years in the poultry industry (Malloney et al., 1967; Jaap and Muir, 1968; O'Sullivan, Dunnington and Siegel, 1991). Currently, broiler breeder BW is routinely controlled through restricted feeding programs from an early age to reduce reproductive problems associated with genetic selection for growth (Renema et al., 1999a) and to enhance the production of fertile hatching eggs (Lilburn and Myers-Miller, 1990). No one program is the best for all situations, and successful breeder managers adjust for differences in management and nutrition during the rearing and early production periods (Lilburn and Myers-Miller, 1990).

Differences in growth, reproduction and disease resistance between slow and fast feathering hens have been documented by a number of authors (Warren and Payne, 1945; Lowe and Garwood, 1981; Dunnington and Siegel, 1986). More recently, broiler integrator records indicate differences between feather sexable and non-feather sexable broiler breeder hens (SF versus FF) for BW, BW gains, flock uniformity and egg production. Industry statistics in 1994

revealed that SF broiler breeder hens were two to three eggs behind FF hens in total egg production and that their lifetime mortality was 1-2% greater than FF hens (Agri Stats, 1994). By 2002 total egg production per bird for the SF hens had declined to three to four eggs less than FF hens and mortality for the SF hens was to 2-4% higher than FF hens (Agri Stats, 2002). Research indicates that the persistency of lay is lower in SF hens due to depressed ovulation rates for SF birds at 46 and 49 wk of age (Katanbaf et al., 1989b). Additional differences between these genetic strains have been reported for BW at 3 and 64 wk of age when the SF hens were heavier than the FF hens (Katanbaf et al., 1989a). Cloacal temperatures at 7 wk of age were higher for FF than SF (41.6 versus 41.4 C, respectively) (Katanbaf et al., 1989a). O'Sullivan et al., (1991) reported that SF hens matured at a later age, had fewer ovulations, produced fewer hatching eggs, and laid a heavier first egg but had no differences in mortality when compared to FF hens.

Although a number of researchers have studied BW at sexual maturity, BW gains, and reproductive performance, very little is known about nutrient utilization in broiler breeder hens. Thus periodic sampling and proximate analysis of the manure beginning at sexual maturity through peak egg production may yield specific differences between FF and SF strains of hens. In addition, BW of the hen is known to influence initiation of lay and overall reproductive performance (Reddy and Siegel, 1977; Eitan et al., 1979; Brody et al., 1980; Bornstein et al., 1984). While it is not ideal to have birds with a wide range of BW consuming a common feed level or nutrient package, this situation is prevalent in large commercial flocks. Therefore, in the current research three diet densities were provided to three BW groups of SF hens to determine if one of these diets would provide a better nutrient package and improve reproductive performance or in someway help hens compensate for BW variation.

MATERIALS AND METHODS

Pre-trial management

Slow-feathering (SF) and fast-feathering (FF), Cobb 500 broiler breeder pullets were grown in commercial facilities, and at 19 wk of age 107 SF pullets were selected based on BW. At 21 wk of age, the selected BW groups were as follows: low (L-BW), 1670-1948g; average (A-BW), 2004-2398g, and high (H-BW), 2604-2949g. A comparable group of 13 A-BW, FF pullets was selected from another commercial facility. These birds were transported to the Poultry Research Center at The University of Georgia and placed in a 7.3 x 9.2 m (24 x 30 ft) floor pen. Day length was continued at 8 hr of light per day. The pullets were wing banded for identification. All pullets were given an industry standard developer diet (Table 3.1) on a feed restricted basis (skip-a-day program) until 21 wk of age when the pullets were switched to one of the breeder diets that was fed on a feed restricted basis (everyday). Just prior to light stimulation at 21 wk of age, 11 L-BW, 9 A-BW and 6 H-BW SF pullets and 4 A-BW, FF pullets (for a total of 30 pullets) were killed and BW measured. The Ovary and oviduct were removed from each bird, weighed and then they were returned to the carcass. Each carcass was vacuumed sealed in plastic and frozen for later whole body scans to determine carcass composition using a dualenergy X-ray absorptiometry (DEXA) method that provides an estimate of total body composition for lean, fat and bone mineral through the Hologic QDR 1000 x-ray densitometer, at Oklahoma State University (Mitchell et al., 1997; Dixon, 2003).

Trial management

At 21 wk of age the pullets were moved to individual cages equipped with a nipple drinker and separate feed trough. Day length was increased to 14 hr of light and 10 hr of darkness from 22 to 34 wk of age. Beginning at 22 wk of age hens were assigned to one of three

broiler breeder layer diets (Table 3.1) that provided different levels of CP and ME. These diets were formulated as follows: low (L-D diet; 2,850 kcal/kg of ME, 14% of CP); medium (M-D diet; 2,920 kcal/kg of ME, 15% of CP) or high (H-D diet; 3,000 kcal/kg of ME, 16% of CP), density diets, and these diets were fed from 22 to 34 wk of age. The A-BW, FF birds were fed the M-D diet. Daily feed allocation was the same across the dietary treatment groups and followed primary breeder guidelines, ranging from 105g per bird per d at 22 wk to 155g per bird per d at 30 wk of age. All birds were weighed weekly and egg production was recorded daily and summarized on a weekly basis. Eggs were characterized as described by Bruggeman et al. (2005) and the categories were as follows: double yolk (DY), membrane (M), cracked (C), abnormal (A) or normal (N) hatching eggs. All normal hatching eggs were weighed daily.

At 34 wk of age, all hens were killed and BW measured. Ovarian development was assessed by counting the number of large yellow follicles (over 10 mm), large yellow atretic follicles and eggs in the reproductive tract. Ovary and oviduct weight were measured. The relative size of the reproductive organs in comparison to BW was calculated by using ovary and oviduct weights in the following formula: *Reproductive index* = (ovary weight + oviduct weight) x 100/BW (Clulow and Jones, 1982). As with the pretreatment pullets, the ovary and oviduct were returned to the carcass, and then the birds were vacuumed sealed in plastic and frozen for later body composition analyses.

Manure sampling

Starting at 22 wk of age and continuing every other week through 34 wk of age, a 48 h manure sample was collected from each hen. Prior to feeding the hens on day one of the collection, a plastic tray was placed underneath each cage. Forty-eight h later, the trays were removed, and feathers, spilled feed and broken eggs were removed from the tray to prevent an

over-estimation of manure protein and energy content. Manure was blended, weighed and divided into two air tight plastic containers. Samples were frozen and submitted for proximate analysis of percent moisture, CP, and gross energy (kcal/g) by standard AOAC methods (AOAC, 1990). Any remaining feed in the individual bird's trough was weighed and the amount used to correct feed intake.

Statistical Analysis

Data were analyzed using the Mixed Model procedure of SAS version 9.1 (SAS Institute, 2005) in an unbalanced block design with two genetic strains (SF and FF), three BW groups (L-BW, A-BW, and H-BW, and three diet densities (L-D, M-D, H-D diets) (Figure 3.1). Means were separated by least square means using the PDIFF function. Significance level was $P \le 0.05$. All percentage data were subjected to arc sine transformation, while conclusions were drawn from the transformed data, only non-transformed data are presented for relevance.

RESULTS AND DISCUSSION

In general, initial BW had a greater short term impact on subsequent BW gains and reproductive characteristics, while consuming different density diets had a greater influence on nutrient utilization in broiler breeder females. There were no significant interactions for BW by diet so only main effects will be presented. In addition, there were no significant BW group or strain influences noted for nitrogen and energy utilization (data not shown).

Body Weight Gain

The immature pullets randomly assigned to the three diet density groups did not have significantly different initial BW at 21 wk (Table 3.2). Hens consuming the H-D diet for 12 wk, weighed more than those on the L-D diet (Table 3.2). The highest rate of BW gain took place prior to the first egg (22-25 wk of age) with the hens consuming the H-D diet having

significantly greater gain (75.2 g) and 2.9% higher rate of gain than those eating the L-D density diet (Table 3.2). Neither BW gain nor rate of gain differed at 26-29 wk or 30-34 wk periods among the diet density groups.

The three BW ranges selected at the beginning of the study were still significantly different at 21 wk of age with the H-BW group weighing 899 g more than the L-BW group (Table 3.2). At 34 wk of age, the statistical relationship among the BW groups was similar to that observed at 21 wk but the difference between the H-BW and L-BW groups had declined to 388g. Furthermore, when BW gain and rate of gain was calculated by periods, the L-BW hens gained more and had a higher rate of gain during sexual maturation (22-25 wk) and early lay (26-29 wk) than the M-BW and H-BW groups of hens (Table 3.2). No differences in BW gain or percentage rate of gain were observed during the 30-34 wk period.

No differences in initial BW (21 wk), final BW (34 wk), BW gain or percentage BW gain were noted between SF and FF females (data not shown), which indicates that A-BW females from this reciprocal cross fed M-D diet, gained in a similar manner during sexual maturity and early lay (22-34 wk). These observations agree with Katanbaf et al. (1989c), who found few differences in BW between SF and FF genotypes through 65 wk of age.

Reproductive characteristics

Egg production (total and hatching eggs) was significantly influenced by diet density and initial BW (Table 3.3). There were no differences in non-settable egg production across diet density, BW or strain comparisons (data not shown). Hens consuming the medium and high density diets produced more eggs than those on the L-D diet (Table 3.3). High BW hens had significantly greater percentage of egg production compared to L-BW, and A-BW hens. The A-BW hens were intermediate in egg production (Table 3.3). The egg production relationship

among the BW groups agrees with earlier reports that the greater the BW at the initiation of lay the higher the percentage egg production (Reddy and Siegel, 1977, Foster and Taha, 1978, Auckland and Wilson, 1977, Summers and Lesson, 1983, and Lesson et al., 1988).

Initial BW significantly influenced ovary weight and total reproductive tract weight at 34 wk of age (Table 3.3). The A-BW and H-BW hens had heavier ovaries and reproductive tracts when compared to the L-BW hens at 34 wk of age. The ovary index was greater in A-BW hens than H-BW hens, suggesting that the H-BW hens had less ovarian tissue on a relative basis than the lower BW hens (Table 3.3). When measured at 34 wk, neither BW nor diet density had a significant influence on number of large yellow follicles or atretic large yellow follicles (Table 3.3).

The SF hens produced more hatching eggs than the FF hens (P=0.034), although total eggs were not significant (P=0.06) (Table 3.3). This observation disagrees with Katanbaf et al., (1989b) who reported that egg production was greater in FF strain hens than SF strain hens. However, in their study a majority of the difference in egg production occurred after 45 wk of age and in the current research egg production was only examined to 34 wk of age. The current finding also conflicts with industry flock statistics that indicate FF hens lay more overall eggs than SF hens (Agri Stat, 1998 and 2002). However, these differences appear due in part to a higher mortality rate in the SF strain of hens (Agri Stat, 1998 and 2002). No differences in mortality were observed between the FF and SF strains in this study (data not shown). Egg weight did not differ between the two strains (data not shown). Similarly, Katanbaf and coworkers (1989b) reported no differences in egg weight between FF and SF strains. There were no differences in ovary, reproductive tract weight and the ovary index between the two feathering strains in the current research.

As would be expected, H-BW hens laid significantly heavier eggs (54.8g) at the start of lay (26 to 28 wk) than the A-BW and L-BW hens (52.1g and 51.2g; A-BW and L-BW, respectively), while no differences in egg weight were observed from 29 to 34 wk of age (data no shown). Diet density had no influence on egg weight through 34 wk of age (data not shown).

Overall, feeding the broiler breeder hens a M-D diet (similar to industry average formulation) was adequate to obtain reasonable egg production. Feeding the hens a higher or lower density diet from photostimulation through peak egg production did not improve reproductive performance. Females that had higher BW at photostimulation had better overall egg production than the light weight females. The L-BW hens had a high rate of BW gain and were successful in building body mass but were poor egg producers, which emphasizes the importance of achieving target BW before photostimulation.

Carcass Composition

The pullets sampled from each BW group just prior to photostimulation at 21 wk of age had maintained the significant difference in BW that was present when the birds were selected at 19 wk of age (Table 3.4). The immature L-BW and H-BW females significantly differed in percentage carcass fat and abdominal fat when compared on a relative basis (Table 3.4). The relative values obtained for carcass fat and protein differed somewhat from those reported by Robinson et al. (1996) who measured carcass fat as 12.2% and carcass protein as 22.8% in 21 wk old broiler breeder pullets. Perhaps these differences are due to strain differences since Robinson and coworkers used a standard breeder (Shaver Starbro) compared with the high yielding strain (Cobb 500) used in this study. This observation suggests that important composition differences do occur in unrelated meat lines.

At 34 wk of age, BW was still significantly different among the BW groups (Table 3.5).

Relative body composition values at 34 wk indicate that the greater the BW the lower the carcass nitrogen content was. After 12 wk of consuming the different density diets, hens fed H-D and M-D diets did not differ in the final BW (Table 3.5) or body composition, except in total fat which was significantly lower in the hens fed the L-D diet (Table 3.5).

The 21 wk comparison of BW and body composition components in SF and FF strains of hens was not significantly different (data not shown). The FF hens had significantly greater abdominal fat content when compared to the SF hens (Table 3.5). Further research is needed to determine if the differences seen in the FF and SF hens in abdominal fat are associated with the differences in egg production observed for these two strains in the current research.

Nutrient Utilization

As might be expected, birds consuming the H-D diet had significantly greater nitrogen intake followed by those on M-D and L-D diets at all sample times between 22 and 34 wk of age (Table 3.6). Energy consumption was similar between hens consuming the L-D and M-D diets, while those on the H-D diet had a significantly greater energy intake (Table 3.6). Generally, nitrogen excretion (manure and egg) as a percentage of nitrogen intake was lowest in hens consuming the M-D diet and highest in the hens consuming H-D and L-D diets. While energy excretion was not significantly different for hens consuming the different density diets, energy utilization (AME_n) increased as the nutrient density of the diet increased. It was noted that nutrient utilization from the start of the data collection period at 22 wk (non-laying) of age through the end at 34 wk (post-peak in egg production) of age was dramatically different with percentage nitrogen excretion increasing with age or perhaps reproductive status. Because of this trend, data were sorted by reproductive status (non-laying or laying), yielding a more clear pattern of nutrient utilization. In non-laying hens nitrogen and energy excretion was similar across diet densities (Table 3.7). Nitrogen retention and AME_n increased as diet density increased. In broiler breeder hens that were in egg production, nitrogen excretion was highest in the hens consuming the L-D diet and similar in hens consuming the M-D and H-D diets (Table 3.7). Hens receiving the L-D diet retained the least amount of nitrogen while those on the higher density diets (M-D and H-D retention was similar) retained a greater amount of nitrogen. One explanation for the M-D and H-D hens having similar nitrogen retention is their similarity in 34 wk BW and overall egg production rate. Energy intake was similar in L-D and M-D hens and lower than that of the hens consuming H-D diet. The AME_n for laying hens increased with diet density. Hens consuming the H-D and M-D diets had higher AME_n than hens consuming the L-D diets, and this additional caloric intake was deposited as carcass fat as noted earlier.

Initial BW did not influence nutrient utilization over the 22-34 wk sample period (Table 3.6). When the data was sorted by reproductive status the only difference in non-laying birds was the L-BW females had a higher energy intake than the heavier females (Table 3.7). In laying females, nitrogen excretion, nitrogen excretion (manure and eggs) as a percentage of intake and nitrogen excretion in excreta (manure) as a percentage of intake showed that the H-BW hens excreted less than the lighter hens (L-BW and A-BW) and resulting in greater nitrogen retention in the H-BW hens. When in lay, A-BW and L-BW hens excreted more energy compared with the H-BW hens that retained more energy than the lighter hens. These observations suggest that heavier hens have greater nutrient requirements than lighter hens when in lay.

Slow feathering and FF hens did not differ in nitrogen or energy utilization (data not shown), suggesting that within this narrow BW range these two strains had similar nutritional needs.

CONCLUSIONS

The L-BW females had the fastest rate of gain from 22-29 wk of age; however, these L-BW hens were reproductively inefficient with the overall lowest egg production. The carcass composition analysis indicated that the higher BW hens had more abdominal fat. These observations confirm the importance of BW uniformity in growing broiler breeder flocks. If immature females have not reached target BW prior to photostimulation low egg production rates will result in light weight females, and feeding them a H-D diet will not allow them to compensate. Trying to compensate for low BW with a higher nutrient density diet had no beneficial effect on reproductive performance. The M-D diet in this study was formulated similar to an average broiler breeder layer I diet used by the commercial poultry industry. Deviating from the M-D diet, either with more or less nutrients was not beneficial to reproduction in this high yielding hen.

Energy utilization was greater the more dense the diet. High BW hens excreted less nitrogen and energy and retained more over time reflecting the continued weight gain with the H-D diet. Because of this utilization rate, long term feeding of H-D diets might cause excessive BW gains that could negatively affect egg production.

Slow feathering and FF hens fed M-D diet, utilized dietary nitrogen and energy in a similar manner, however, the FF hens had more abdominal fat than the SF hens and they had lower hatching egg production. These results suggest that the two strains partition energy intake differently.

This study indicates that Cobb 500 hens do not require high nutrient density diets from 22-34 wk of age. When evaluating whole body composition and nitrogen balance, the amount of dietary CP needed for the Cobb 500 hen during the lay cycle may be lower than primary breeder

CP recommendation for the Breeder 1 diet (16% CP, Cobb-Vantress Management Guide) (Anonymous, 2005). Based on the current data, reducing dietary CP from the primary breeder recommended level to 15% would have no adverse effects; however, dietary CP should be evaluated in future research with hens in floor pens. The primary breeder guidelines for ME in the Breeder 1 diet (2,860 kcal/kg) is between the low and M-D diet in this study, and it appears that this energy level is adequate for diet formulation during the early lay period (22-34 wk) based on this research.

REFERENCES

Anonymous. 2005. Cobb Breeder Management Guide. Cobb Vantress. Siloam Springs, AR.
Agri Stats, Inc. Jan.-Dec. 1994. Live production annual agri stats report. Fort Wayne, IN 46825.
Agri Stats, Inc. Jan.-Dec. 2002. Live production annual agri stats report. Fort Wayne, IN 46825.
Association of Official Analytical Chemists. 1990. Official Method of Analysis. 15th ed.
AOAC, Arlington, VA.

- Auckland, J. N., and S. B. Wilson. 1977. Mineral and vitamin supplementation of a whole wheat diet for developing pullets. Br. Poult. Sci. 18:121-127.
- Brody, T., Y. Eitan, M. Soller, I. Nir, and Z. Nitzan. 1980. Compensatory growth and sexual maturity in broiler females reared under severe food restriction from day of hatching. Br. Poult. Sci. 21: 437-446.
- Bruggeman, V., O. Onagbesan, O. Ragot, S. Metayer, S. Cassy, F. Favreau, Y. Jego, J. J. Trevidy,K. Tona, J. Williams, E. Decuypere and M. Picard. 2005. Feed allowance-genotype interactions in broiler breeder hens. Poult. Sci. 84:298-306.
- Clulow, J. and R. C. Jones. 1982. Production, transportation, maturation, storage and survival of spermatozoa in the male Japanese quail. J. Reprod. Fert. 64:259-266.

- Dixon, S. J. 2003. An examination of broiler breeder composition methodology and energy metabolism. Master of Science Thesis. Stillwater, Oklahoma State University.
- Dunnington, E. A. and P. B. Siegel. 1986. Sex-linked feathering alleles (K, k+) in chicks of diverse genetic backgrounds. 1. Body temperatures and body weights). Poult. Sci. 66:168-170.

Foster, W. H., and Z. T. Taha. 1978. Whole grain diets for pullets. Br. Poult. Sci. 19:233-242.

- Eitan, Y., M. Soller, I. Nir and Z. Nitzan. 1979. Heavy broiler breeders of light body weight. Meshek Ha'Ofot, 25: 333-336.
- Jaap, R. G., and F. V.Muir. 1968. Erratic oviposition and egg defects in broiler-type pullets. Poult. Sci. 47: 417-423
- Katanbaf, M. N., E. A. Dunnington and P. B. Siegel. 1989a. Restricted feeding in early and late-feathering chickens. 1. Growth and physiological responses. Poult. Sci. 68:344-351.
- Katanbaf, M. N., E. A. Dunnington and P. B. Siegel. 1989b. Restricted feeding in early and latefeathering chickens. 2. Reproductive responses. Poult. Sci. 68:352-358.
- Katanbaf, M. N., E. A. Dunnington and P. B. Siegel. 1989c. Restricted feeding in early and latefeathering chickens. 3. Organ size and carcass composition. Poult. Sci. 68:359-368.
- Lesson, S., R. J. Etches, and J. D. Summers. 1988. Development of Leghorn pullets subjected to early light photostimulation. Can. J. Anim. Sci. 68(3):1267-1275).
- Lilburn, M. S. and D. J. Myers-Miller. 1990. Dietary effects on body composition and subsequent production characteristics in broiler breeder hens. Poult. Sci. 69:1126-1132.
- Lowe, P. C. and V. A. Garwood. 1981. Independent effects of K and k+ alleles and maternal origin on mortality and performance of crossbred chickens. Poult. Sci. 60:1123-1126.
- Malloney, M. A., J. C. Gilbreath, J. F. Tierce and R. D. Morrison. 1967. Divergent selection for twelve-week body weight in the domestic fowl. Poult. Sci. 46:1116-1127.

- Mitchell, A. D., R. W. Rosebrough and J. M. Conway. 1997. Body composition Analysis of chickens by dual energy X-ray absorptiometry. Poult. Sci. 76:1746-1752.
- O'Sullivan, N. P., E. A. Dunnington and P. B. Siegel. 1991. Relationships among age of dam, egg components, embryo lipid transfer and hatchability of broiler breeder hens. Poult. Sci. 70:2180-2185.
- Reddy, P. R., and P. B. Siegel. 1977. Selection for body weight at eight weeks of age. 14. Effects of the sex-linked dwarf gene. Poult. Sci. 56:104-1013.
- Renema, R. A. and F. E. Robinson. 2004. Defining normal: comparison of feed restriction and full feeding of female broiler breeders. World's Poult. Sci. J. 60:508-522.
- Renema, R. A., F. E. Robinson, M. Newcombe and R. I. McKay. 1999a. Effects of body weight and feed allocation during sexual maturation in broiler breeder hens. 1. Growth and carcass characteristics. Poult. Sci. 78:619-628.
- Renema, R. A., F. E. Robinson, J. A. Proudman, M. Newcombe and R. I. McKay. 1999b. Effects of body weight and feed allocation during sexual maturation in broiler breeder hens. 2. Ovarian morphology and plasma hormone levels. Poult. Sci. 78:629-639.
- Robinson, F. E., T. A. Wautier, R. T. Hardin, J. L. Wilson, M. Newcombe, and R. I. McKay.
 1996. Effects of age at photostimulation on reproductive efficiency and carcass traits 1.
 Broiler breeder hens. Can. J. Anim. Sci. 76(3):275-282).

SAS Institute. 2005. SAS User's Guide: Statistics SAS Institute Inc., Cary, NC.

Summers, J. D., and S. Lesson. 1983. Factors influencing early egg size. Poult. Sci. 62:1155-1159.

Warren, D. C., and L. F. Payne. 1945. Influence of the early-feathering gene upon a chick's growth rate. Poult. Sci. 24:191-192.

Table 3.1. Ingredient composition and calculated nutrient analysis of the developer and layer diets provided to the breeder pullets and hens

	Developer ³		Layer	
Ingredients, % "as-is"	Diet Density		Diet Density	
-	Medium (M-D)	Low $(L-D)^4$	Medium $(M-D)^5$	High $(H-D)^{6}$
	(20 to 21 wk)	(22 to 34 wk)	(22 to 34 wk)	(22 to 34 wk)
Corn (8.5% CP)	65.88	70.16	70.79	65.70
Soybean meal (48.4% CP)	15.00	14.93	18.11	21.09
Wheat middlings	14.83	4.66		
Dicalcium phosphate	1.58	1.47	1.49	1.47
Limestone	1.28	7.34	7.33	7.33
Poultry Oil			0.91	3.05
Sodium chloride	0.60	0.60	0.51	0.51
Vitamin premix ²	0.50	0.50	0.50	0.50
DL-methionine (99%)	0.13	0.13	0.15	0.16
L-lysine	0.13	0.12	0.12	0.10
Trace mineral premix ¹	0.08	0.08	0.08	0.08
Zinc Sulfate		0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00
Calculated Analyses				
CP (%)	15.0	14.0	15.0	16.0
ME (kcal/kg)	2,920	2,845	2,920	3,000
Arginine (%)	0.92	0.82	0.88	0.98
Lysine (%)	0.83	0.76	0.83	0.90
Methionine (%)	0.38	0.36	0.39	0.42
TSAA (%)	0.64	0.60	0.64	0.68
Calcium (%)	0.92	3.22	3.22	3.22
Available Phosphorus (%)	0.42	0.38	0.38	0.38
Sodium (%)	0.02	0.23	0.20	0.20
Zinc (ppm)	95	120	120	120
Copper (ppm)	5.45	16.00	16.00	16.00
Iodine (ppm)	0.80	0.80	0.80	0.80

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 for breeder 1 diets; iron (source = ferrous sulfate); 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 4.4 mg; riboflavin, 8.8 mg; vitamin B6, 4.4 mg; niacin, 88 mg; pantothenic acid, 22 mg; folic acid, 1.1 mg; biotin, 0.2 mg; choline, 383 mg. ³⁻⁵ Analyzed values for medium developer and breeder diets were analyzed to contain 15.2 % CP.

⁴ Low density breeder diet was analyzed to contain 14.3 % CP.

⁶ High density breeder diet was analyzed to contain 16.4 % CP
Fixed Effects	Initial	Final	BW gain	BW rate	BW gain	BW rate	BW gain	BW rate
	BW (g)	BW (g)	(g)	(%)	(g)	(%)	(g)	(%)
	21 wk	34 wk	22-23	5 wk^3	26-29) wk ³	30-34 wk ³	
Diet ¹								
L-D	2,288	3,562 ^b	382.7 ^b	16.0 ^b	308.0	10.4	81.9	2.5
M-D	2,307	3,669 ^a	393.4 ^b	16.0 ^b	305.0	9.9	74.6	2.2
H-D	2,274	3,711 ^a	457.9 ^a	18.9 ^a	258.8	8.4	114.8	3.2
SEM	17	39	21	0.8	37	1.2	18	0.5
P values	0.38	0.018	0.013	0.010	0.56	0.44	0.26	0.36
BW^2								
L-BW	1,838 ^c	3,455 ^c	505.4 ^a	23.9 ^a	412.0 ^a	14.5 ^a	107.4	3.2
A-BW	2,293 ^b	3,644 ^b	411.4 ^b	16.3 ^b	275.5 ^{ab}	8.7^{b}	103.6	2.9
H-BW	2,738 ^a	3,843 ^a	317.3°	10.7 ^c	184.3 ^b	5.6 ^c	60.3	3.3
SEM	17	39	21	0.8	37	1.2	18	0.5
P values	< 0.001	< 0.001	< 0.001	< 0.001	0.001	< 0.001	0.12	0.07

Table 3.2. Influence of dietary treatment and initial BW on BW gains and % rate of gain during three periods in SF broiler breeder hens

^{a-c} Means with different superscripts within a column signify significant differences ($P \le 0.05$) from a PDIFF comparison ¹ SF broiler breeder hens were given one of three breeder diets, L-D (14.0% CP, 2,845 kcal AME/kg, 0.76% lysine and 0.60% TSAA), M-D (15.0% CP, 2,920 kcal AME/kg, 0.83% lysine and 0.64% TSAA) or H-D density (16.0% CP, 3,000 kcal AME/kg, 0.90% lysine and 0.68% TSAA) (Table1). Values are least-squares means (n = 9).

² SF birds were selected according to 3 different BW ranges at 21 wk: L-BW (1,670 to 1,948 g), A-BW (2,004 to 2,398 g), and H-BW (2,604 to 2,949 g) fed breeder diet. Values are least-squares means (n = 9).

³ The experimental period was divided in three periods related to egg production.

Fixed	Total	Hatching	Ovary	Repro	Ovary	LYF ³	ALYF ³
Effects	Eggs	Eggs	wt	tract wt	index		
		-%		g]	No
D : 1							
Diet	c = ch	e e e b	e e ab				
L-D	65.8	64.1°	64.0°	132.0	1.6	5.6	1.5
M-D	69.7 ^a	67.2 ^a	67.0 ^a	134.0	1.7	5.5	1.3
H-D	68.5^{a}	66.5 ^a	66.0^{a}	138.0	1.6	5.7	1.6
SEM	3.0	3.0	3.0	3.0	0.05	0.1	0.3
P values	0.012	0.024	0.024	0.22	0.89	0.47	0.70
BW ²							
L-BW	62.2°	60.7°	58.0 ^b	129.0 ^b	1.7^{ab}	5.5	1.3
A-BW	66.8 ^b	64.4^{b}	64.0^{a}	137.0^{a}	1.8^{a}	5.7	1.4
H-BW	74.9^{a}	72.7^{a}	61.0^{ab}	137.0^{a}	1.6^{b}	5.5	1.5
SEM	3.0	3.0	2.0	3.0	0.06	0.1	0.3
P values	< 0.001	< 0.001	0.019	0.027	0.049	0.49	0.90
SF versus FF ³							
Strain							
FF (A-BW)	60.4	57 3 ^b	61.0	132.0	17	56	2.4
SF (A-BW)	68.4	66.1 ^a	68.0	140.0	1.8	5.9	1.4
SEM	3.0	4.0	4.0	4.0	0.1	0.3	0.5
P values	0.06	0.034	0.11	0.15	0.22	0.60	0.07

Table 3.3. Influence of dietary treatment and BW on egg production, reproductive tract weight and index throughout the experimental period (22 to 34 wk) in SF broiler breeder hens and between genetic strains

^{a-c} Means with different superscripts within a column signify significant differences ($P \le 0.05$) from a PDIFF comparison.

¹ SF broiler breeder hens were given one of three diets, L-D (14.0% CP, 2,845 kcal AME/kg 0.76% lysine and 0.60% TSAA), M-D (15.0% CP, 2,920 kcal AME/kg, 0.83% lysine and 0.64% TSAA) or H-D density (16.0% CP, 3,000 kcal AME/kg, 0.90% lysine and 0.68% TSAA) (Table1). Values are least-squares means (n = 9).

² SF birds were selected according to 3 different BW ranges at 21 wk: L-BW (1,670 to 1,948 g), A-BW (2,004 to 2,398 g), and H-BW (2,604 to 2,949 g) fed breeder diet. Values are least-squares means (n = 9). ³ Values are least-squares means involving 2 treatments: SF and FF hens fed with M-D diet only (Table 1). Values are least-squares means (n = 9).

⁴LYF refers to number of large yellow follicles and ALYF refers to number of atretic large yellow follicles measured at the end of the experiment at 34 wk.

Fixed Effects	BW	Nitrogen	Fat	Water	Ash	Abdominal fat
	(g)			DM bas	sis ²	
			L			_
L-BW	$1,840^{\circ}$	17.1	13.7°	63.7	2.5	0.4°
A-BW	2,295 ^b	16.8	14.5 ^{ab}	61.2	2.5	0.7^{b}
H-BW	2,565 ^a	17.3	15.8 ^a	61.7	2.6	1.1 ^a
SEM	33	0.5	0.3	1.0	0.1	0.1
P values	< 0.001	0.56	0.001	0.25	0.59	< 0.001

Table 3.4. Influence of initial BW on relative body composition³ at 21 wk of age in immature SF broiler breeder females¹

^{a-c} Means with different superscripts within a column signify significant differences (P \leq 0.05) from a PDIFF comparison.

¹ SF birds were grouped according to 3 different BW ranges at 21 wk: L-BW (1,670 to 1,948 g), A-BW (2,004 to 2,398 g), and H-BW (2,604 to 2,949 g), and were fed M-D developer diet (Table 1). Birds were terminated prior photostimulation. Values are least-squares means from SF pullets (L-BW, n = 11; A-BW, n = 9; H-BW, n = 6).

² Values are expressed on a dry matter basis.

³Relative values are expressed as a percentage relative to the BW.

Fixed Effects	BW	Nitrogen	Fat	Water	Ash	Abdominal
					4	fat
	(g)		5			
BW group ¹						
L-BW	3,455 [°]	17.2 ^c	17.8 ^b	59.5 ^a	2.6	1.6
A-BW	3,638 ^b	17.0 ^b	18.1^{a}	59.1 ^{ab}	2.6	1.4
H-BW	3,842 ^a	16.9 ^a	18.5 ^a	58.9 ^b	2.6	1.5
SEM	37	0.04	0.09	0.1	0.01	0.1
P values	< 0.001	< 0.001	< 0.001	0.008	0.89	0.18
Diet density ²						
L-D	3,562 ^b	17.1	17.9 ^b	59.2	2.6	1.5
M-D	$3,667^{a}$	17.0	18.2^{a}	59.0	2.6	1.6
H-D	3,705 ^a	17.1	18.3 ^a	59.2	2.6	1.5
SEM	38	0.04	0.1	0.1	0.01	0.1
P values	0.024	0.73	0.010	0.57	0.17	0.81
Strain ³						
FF (A-BW)	3,613	17.0	18.0	58.9	2.6	1.7^{a}
SF (A-BW)	3,717	16.9	18.2	58.9	2.6	1.3 ^b
SEM	66.0	0.1	0.2	0.2	0.01	0.1
P values	0.27	0.72	0.30	0.94	0.61	0.021

Table 3.5. Influence of initial BW, dietary treatment and genetic strain on relative⁵ body composition at 34 wk

^{a-c} Means with different superscripts within a column signify significant differences

 $(P \le 0.05)$ from a PDIFF comparison.

¹ SF birds were grouped according to 3 different BW ranges at 21 wk: L-BW (1,670 to 1,948 g), A-BW (2,004 to 2,398 g), and H-BW (2,604 to 2,949 g), fed breeder diet. Values are least-squares means (n = 27). ² SF broiler breeder hens were given one of three breeder diets, L-D (14.0% CP, and 2,845 kcal AME/kg, 0.76% lysine and 0.60% TSAA), M-D (15.0% CP, 2,920 kcal AME/kg, 0.83% lysine and 0.64% TSAA) or H-D (16.0% CP, 3,000 kcal AME/kg 0.90% lysine and 0.68% TSAA) density (Table1). Values are least-squares means (n =27).

³Values are least-squares means from A-BW group (SF and FF hens, n=9) fed breeder M-D diet (15.0% CP, 2,920 kcal AME/kg 0.83% lysine and 0.64% TSAA) (Table 1).

⁴Values are expressed on a dry matter basis.

⁵Relative values are expressed as a percentage relative to the BW.

			Nitrogen ⁴				Energy ⁵			
Fixed Effect	Intake (mg)	Excretion (mg)	Excretion (%)	Excreta (%)	Retained (mg)	Intake (kcal)	Excretion (kcal)	AME _n (kcal/kg)		
SF Hens ¹ Diet Density ²										
L-D	5,408 ^c	3,195 ^b	56.3	38.1 ^a	2,212 ^b	977 ^b	167	3,073°		
M-D	5,772 ^b	3,267 ^b	54.1	35.7 ^b	2,591 ^{ab}	986 ^b	161	3,132 ^b		
H-D	6,459 ^a	3,868 ^a	56.9	39.4 ^a	2,603 ^a	$1,026^{a}$	168	3,258 ^a		
SEM	69	142	2.0	1.0	92	12	5	19		
P values	< 0.001	0.001	0.53	0.028	0.008	0.006	0.62	< 0.001		
BW ³										
L-BW	5,879	3,428	55.4	37.5	2,451	998	168	3,144		
A-BW	5,859	3,502	56.4	38.5	2,357	994	167	3,153		
H-BW	5,900	3,428	55.5	37.3	2,499	998	161	3,166		
SEM	69	142	2.0	1.0	92	12	5	19		
P values	0.91	0.87	0.91	0.67	0.53	0.96	0.58	0.67		

Table 3.6. Influence of dietary treatment and BW on nutrient utilization throughout the experimental period (22 to 34 wk) in SF broiler breeder hens

^{a-c} Means with different superscripts within a column signify significant differences ($P \le 0.05$) from a PDIFF comparison.

¹Values are least-squares means (n=9).

² SF broiler breeder hens were given one of three diets, L-D (14.0% CP, 2,845 kcal AME/kg, 0.76% lysine and 0.60% TSAA), M-D

(15.0% CP, 2,920 kcal AME/kg, 0.83% lysine and 0.64% TSAA), or H-D (16.0% CP, 3,000 kcal AME/kg 0.90% lysine and 0.68% TSAA) (Table1).

³ SF birds were grouped according to 3 different BW ranges at 21 wk: L-BW (1,670 to 1,948 g), A-BW (2,004 to 2,398 g), and H-BW (2,604 to 2,949 g).

⁴⁻⁵ Values are expressed on a dry matter basis. Excretion refers to a total output of nitrogen or energy in manure and eggs from 22-34 wk of age. Excreta refers to total nitrogen or energy output on manure only. AME_n is expressed on an as is basis.

			Nitrogen ³				Energy ⁴	
Fixed	Intake	Excretion	Excretion	Excreta	Retained	Intake	Excretion	AME.
Effects	(mg)	(mg)	(%)	(%)	(mg)	(kcal)	(kcal)	(kcal/kg)
	(0)			Non- lave	er ⁵		· · ·	
Diet ¹				i toni iuyt				
L-D	4 623°	1 573	33.5	33.5	3.050°	832	118.6	3 173°
M-D	4.874 ^b	1.533	30.9	30.9	3.341 ^b	832	108.7	3.252 ^b
H-D	5.315 ^a	1,666	30.5	29.8	3.649 ^a	849	103.4	3.411 ^a
SEM	60	99	2	2	74	10	7	28
P values	< 0.001	0.58	0.34	0.22	< 0.001	0.35	0.26	< 0.001
BW ²								
L-BW	5,032	1,646	31.9	31.2	3,386	855 ^a	117.5	3,258
A-BW	4,897	1,472	29.6	29.6	3,424	830 ^b	105.9	3,293
H-BW	4,884	1,654	33.5	33.5	3,230	828 ^b	107.2	3,286
SEM	58	95	2	2	71	9	7	27
P value	0.09	0.27	0.22	0.21	0.11	0.05	0.36	0.89
				Initiating	lay ⁵			
Diet ¹								
L-D	5,483 ^b	2,911	52.5	40.3	2,571	993	170.9	3,056
M-D	6,014 ^a	3,172	52.6	38.2	2,841	1,023	174.0	3,093
H-D	6,179 ^a	3,259	51.4	42.5	2,920	979	173.9	3,190
SEM	200	491	2	5	435	35	19	62
P values	0.006	0.79	0.99	0.72	0.73	0.48	0.98	0.22
BW^2								
L-BW	6,013	3,684	59.5	44.2	2,328	1,020	195.2	3,045
A-BW	5,731	2,886	50.3	37.3	2,845	975	150.7	3,180
H-BW	5,931	2,772	46.7	39.5	3,159	1,000	172.9	3,114
SEM	199	490	2	5	434	35	19	62
P value	0.30	0.16	0.29	0.30	0.24	0.39	0.06	0.07
			I	Layer ⁵				
Diet ¹		h			h	h		
L-D	6,033°	4,584	75.9 ^a	41.9 ^a	1,449°	1,093 ^b	205.9	2,993 ^e
M-D	6,420	4,499	70.2°	37.3°	1,921ª	1,097	196.2	3,059
H-D	7,224ª	5,304ª	73.7 ^{ab}	44.9 ^a	1,920ª	1,145 ^a	208.5	3,164 ^a
SEM	39	105	2	1	110	6	4	15
P values	< 0.001	< 0.001	0.028	< 0.001	0.002	< 0.001	0.08	< 0.001
BW-	6 574	4 0008	7478	41 cab	1 cach	1.116		a ocaab
L-BW	6,574	4,898"	/4./~	41.6 ^{°°}	1,0/6°	1,110	206.9"	3,063°°
A-BW	6,391	4,9/5 ⁻	/5.4 ⁻	43.0^{-1}	1,01/~	1,119	210.4 ⁻	$3,053^{\circ}$
H-BW	0,511	4,515	09.7	38.9	1,998	1,100	192.9	3,101
SEIVI D voluc	38 0.26	104	∠ 0.015	1	109	0	4	13
P value	0.26	0.002	0.015	0.023	0.021	0.05	0.006	0.046

Table 3.7. Overall nutrient utilization by physiological state (22 to 34 wk of age)

^{a-c} Means with different superscripts within a column signify significant differences ($P \le 0.05$) from a PDIFF comparison.

¹Broiler breeder hens were given one of three diets, L-D (0.76% lysine 0.60% TSAA, 14.0% AA/CP, and 2,845 kcal AME/kg), M-D (0.83% lysine 0.64% TSAA, 15.0% CP, and 2,920 kcal AME/kg) or H-D (0.90% lysine 0.68% TSAA, 16.0% CP, and 3,000 kcal

AME/kg) density (Table1). ² Birds were grouped at 21 wk according to 3 different BW ranges: L-BW (1,670 to 1,948 g), A-BW (2,004 to 2,398 g), and H-BW (2,604 to 2,949 g) ³⁻⁴ Values are expressed on a dry matter basis. Excretion refers to total output of nitrogen or energy in manure and eggs.

Excreta refers to total nitrogen or energy output on manure only. AME_n is expressed on an as is basis. ⁵ Physiological state referred as: non-layer (no egg production); initiating lay (egg production 1 to 4 eggs/wk), and layer (5 to 7 eggs/wk).



Figure 3.1. Experimental design.

CHAPTER 4

INFLUENCE OF FEEDING LEVEL AND BODY WEIGHT ON REPRODUCTIVE PERFORMANCE, MORBIDITY AND MORTALITY OF SLOW FEATHERING BROILER BREEDER HENS¹

¹ Mendoza, A.M., A.J. Davis, G. Zavala and J.L. Wilson. To be submitted to Journal of Applied Poultry Research.

SUMMARY

Differences in reproductive performance and livability in slow feathering broiler breeder hens have been reported by different authors and in field reports. A study was conducted to determine if BW at photostimulation or feeding level in the early lay period influences reproduction performance, morbidity or mortality. At 22 wk of age the pullets were selected in three BW groups: low (L-BW), average (A-BW) and, high (H-BW). Two different feed amounts, standard (STD) and standard plus (STD+) were assigned across the BW groups. The STD+ feeding level was 4 to 8% higher than STD feed amount. Egg production, BW, egg characterization and weight were summarized on weekly basis. Birds were observed for daily feeding and watering behavior along with signs of physical depression. The experiment was terminated at 40 wk of age and BW and reproductive measurements (ovary weight, oviduct weight, large yellow follicles (LYF) number and number of eggs in tract) were taken, and the reproductive index was calculated. Morbidity was closely monitored to characterize symptoms present in morbid hens, and mortality was recorded and necropsied. Pullets in the L-BW group were 10 days behind the heavier birds in initiating lay. While these L-BW hens experienced rapid BW gains during the study, this compensatory growth did not result in the same egg production measured in the heavier birds. Feeding slightly more feed (4-8% in the early lay period) did not improve egg production for the L-BW hens; however, the heavier females (A-BW and H-BW) produced more eggs when fed at the higher level. The first symptom noted in all morbid hens was a rapid change from consuming their daily feed allotment to feed refusal. All affected hens were heavier and more sexually developed than average. A total of 8.6% of the hens exhibited these symptoms which is less than observed in field observations. The less competitive cage environment likely prolonged symptoms and allowed survival in some hens.

Ovarian regression and evidence of fresh yolk material was present in the abdomen of hens that died. Necropsy results were inconclusive.

DESCRIPTION OF THE PROBLEM

The negative relationship between growth and reproductive fitness has been recognized for over 30 yr in the poultry industry [1, 2, 3]. More recently, broiler integrator records have shown differences between slow (**SF**) and fast feathering (**FF**) broiler breeder hens for BW, BW gains, flock uniformity and egg production. Industry statistics in 1994 indicated that SF broiler breeder hens produced 2-3 eggs less than FF hens and that their mortality was 1-2 % greater than FF hens [4]. In 2002 total egg production per SF hen had declined 3-4 eggs compared to the FF hens, and mortality for the SF hens had risen 2-4 % higher over that of the FF hens [5]. Katanbaf *et al.* [6, 7, 8] reported that the persistency of lay was lower in SF hens due to depressed ovulation rates for SF birds during the later part of the production cycle (46 and 49 wk of age). Additional differences were reported for BW at 3, 4 and 64 wk of age when the SF group was heavier than FF [6, 9]. Cloacal temperatures were higher for FF than SF (41.6 versus 41.4 C respectively) at 7 wk of age [6, 9]. O'Sullivan et al., [3] reported that SF hens matured at a later age, had fewer ovulations, produced fewer hatching eggs, and laid a heavier first egg with no differences in mortality when compared to FF hens.

We proposed that feeding in excess of breeder recommended levels could affect the reproductive performance and /or livability of broiler breeder females, and that heaviest and more reproductively developed hens are the females within the flock that are potentially more affected by metabolic or hormonal issues. For these reasons, the first objective of this study was to determine possible influences of BW and feeding level on reproduction, morbidity and

livability. In addition, this study described symptoms of morbid hens and necropsy results of these symptomatic hens that died during the study.

Broiler breeder pullets need to reach a physiological threshold and have adequate fleshing with optimum levels of protein and fat to reach sexual maturity [10]. In birds, thyroid hormones are involved not only with molting [11, 12] but also response to feeding. Decuypere and Khun [13] reported that T_3 was suppressed in fasted chickens, and others researchers reported that ad libitum fed broiler breeder females had higher T_4 plasma concentrations than feed restricted broiler breeders [14]. The final objective of the present study was to measure plasma total T_3 levels in order to determine if BW and feed level had any relationship to circulating T_3 levels. Key words: broiler breeders, body weight, feeding level, egg production, thyroid hormone and morbidity and mortality.

MATERIALS AND METHODS

Pre-trial management

Slow feathering Cobb 500 broiler breeder chicks were grown in a commercial facility, under standard industry management. At 12 wk of age, approximately 300 pullets were selected from a commercial flock and transported to the Poultry Research Center at the University of Georgia and housed in floor pens of 7.3 x 9.2 m (24 x 30 ft). Until 21 wk of age birds were fed a commercial broiler breeder developer on a skip-a-day basis (Table 4.1), and the birds were continued on 8 hr of light per day.

Trial

At 22 wk of age 288 birds were selected based on BW and placed in individual cages equipped with a nipple drinker and feeder. Birds were segregated in three different BW groups: low (**L-BW**), average (**A-BW**) or high (**H-BW**). Each BW group contained 96 hens, with 48

hens from each BW group assigned to standard (STD) or standard plus (STD+) feeding level. There were 288 slow feathering hens individually caged in replicate groups of 12 hens (Figure 4.1). Pullets classified as L-BW weighed between 1900 and 2200 g, while those that were A-BW weighed between 2450 and 2750 g, and the H-BW pullets weighed between 3000 and 3300 g. All pullets consumed a commercially formulated breeder layer diet fed on a restricted basis (Table 4.1) starting at 22 wk of age that provided 15% CP and 2920 kcal/kg ME. Birds were fed a STD or STD+ amount of feed, with the STD+ being 4 to 8 % more feed than the STD feed level (Table 4.2). All birds were weighed weekly at approximately the same time of day, and average BW of the females on the STD feeding level was used to increase feed amount to maintain primary breeder target BW. Birds were fed daily. Day length was increased to 14 hr of light and 10 hr of darkness from 22 to 40 wk of age. Egg production was recorded daily and eggs were classified as: double yolk (DY), membrane (M), cracked (C), abnormal (A) or normal (N) hatching eggs. Normal hatching eggs were weighed daily. Morbid birds were bled to obtain plasma for hormone analysis. At 40 wk of age all birds were terminated and final measurements were recorded including BW, oviduct weight, ovary weight and total reproductive tract weight, number of large yellow follicle number (LYF) (greater than 10 mm in diameter), and whether there was egg in tract at the time of death. Reproductive index (**RI**) was recorded as: RI = total reproductive tract weight (ovary weight + oviduct weight) x 100 / carcass weight [15].

RIA blood samples were collected from the all hens at the end of the study. Blood was taken from the brachial vein and immediately placed into individual vacutainers (Becton, Dickinson, and Co., Franklin Lakes, NJ) containing EDTA as anticoagulant and stored on ice. Samples were centrifuged at 1,000 x g at 4°C for 10 min. Plasma was collected from each sample and frozen at -80 °C. Plasma total thyroid hormone (total T₃) was measured by RIA using a Coat-

A-Count [®] Total T₃ Kit (Diagnostic Products Corporation, Los Angeles, CA). The RIA kits were used following the manufacture's protocol and as described for use with chicken plasma by Shirley and coworkers [16]. Samples were counted with a Beckman 5500 [®] gamma counter (Beckman Scientific Instruments Division, CA).

Statistical Analysis

Data were analyzed using the Mixed Model procedure of SAS (Version 9.1) [17], and means were separated by Least Squared Means using the PDIFF function when significant main effect ($P \le 0.05$) within or between ages occurred. All percentage data were subjected to arc sine transformation. While conclusions were drawn from the transformed data, only non-transformed data are presented for relevance. The experimental design consisted of two treatments: BW of immature pullets at 21 wk of age (L-BW, A-BW and H-BW) and feeding level from 21-40 wk of age (STD or STD+) (figure 4.1). The T₃ data were subjected to ANOVA according to the General Linear Model and Tukey's multiple comparison procedure [18] to detect significant differences between BW. A simple 2-way ANOVA was conducted to compare T₃ levels between the two feed treatments. All statistical procedures related to the T₃ study were done with the Minitab statistical software package (Release 13, State College, PA). Statistical differences were considered significant when P-values were < 0.05.

RESULTS AND DISCUSSION

Body weight, body gains and egg production

Initial BW significantly influenced subsequent BW throughout the experimental period, and the BW groups established at the beginning of the study maintained similar relationships through 40 wk (Figure 4.2). Differences among the three BW groups of females became less as the hens aged (Figure 4.2), suggesting possible compensatory growth in the L-BW hens from 23 to 31 wk of age. Low BW birds had significantly higher BW gains and rate of gain compared to A-BW and H-BW hens through 28 wk of age (Table 4.3). However, from 29 to 31 wk of age only L-BW and H-BW hens were significantly different (Table 4.3). During the period from 23 to 25 wk of age, females in the L-BW group had 10 and 16 % higher gain than the A-BW and H-BW hens, respectively. These rates of gain (10 and 16 %), are similar to previous reports in broiler chickens [19, 20, 21, 22] where authors suggested that broilers experienced compensatory growth when feed amounts or diet formulations allowed rapid gains that exceeded what is normally observed in the same breed of chicken at the same age [22]. In this study, the L-BW females remained the lightest group of birds but experienced rapid BW gains when placed in a less competitive environment for feed.

As would expected hens provided the STD+ feed regimen were significantly heavier than hens on the STD feeding program through 40 wk of age (Table 4.4). Feeding level significantly influenced BW gains only during the first period (23-25 wk) when birds on STD+ feed level gained at 3.7% greater rate than hens on the STD feeding level; subsequently, they maintained these gains through 40 wk of age (Table 4.3).

In this study, the average BW gains for the period of 23 to 25 wk, 26 to 28 wk and 29 to 31 wk were 24%, 7% and 3% higher respectively, when compared to the primary breeder recommended (Cobb 500 Slow Feathering Management Guide) BW gains [23]. The feed used in this study differed slightly from the primary breeder suggested nutrient levels. The developer diet had a similar CP level but the ME was higher than recommended (2,920 versus 2,770 kcal/kg). The breeder laying diet used in the study was lower in CP (15 % versus 16 %) and higher in ME (2,920 versus 2,860 kcal/kg) than the recommended levels (Table 4.1). Although a lower dietary protein level (15 % CP) was provided in the current study, this level was sufficient to support

growth (Table 4.3). The higher rates of gain observed in this study may be due to higher energy level in the study diet when compared to primary breeder recommendations. However, it is important to note that the pullet developer and layer diets were formulated similar to poultry industry average breeder diets.

Total and hatching egg production was significantly influenced by initial BW but not by feeding level through 39 wk of age (Table 4.4). High BW hens had significantly greater egg production than the L-BW hens, and A-BW hens were intermediate in egg production (Table 4.4). The L-BW birds were 10 days behind the H-BW group in initiating lay and their egg production remained lower than the other BW groups through 31 wk of age (Figure 4.3). In general, the higher the BW at photostimulation the higher the percentage egg production (Figure 4.3). These data agree with those of Reddy and Siegel [24], Foster and Taha [25], and Auckland and Wilson [26], who found that low 20 wk BW was associated with a delay in first egg. In addition, these authors reported that achieving a threshold in BW was necessary for the initiation of egg production. Summer and Lesson [27] noted that heavier birds come into production earlier with greater lipid content, and that age at sexual maturity is related to BW and composition [28].

Feeding maturing hens slightly more feed from 22 through 31 wk of age had no significant influence on egg production until 32 to 39 wk of age when total egg production was greater in the STD+ fed hens (Table 4.5). However, this increase in egg production was somewhat offset by an increase in cracked eggs produced by hens receiving the STD+ feeding level (Table 4.4). In addition, there was a significant interaction between BW group and feeding level (P=0.001) that indicates H-BW hens consuming the STD+ feed amount laid more DY eggs than hens in the other BW groups on STD+ or STD feeding level (1% versus 0.4%). This

observation supports previous findings that when broiler breeders consumed feed beyond that needed for egg production and body maintenance, more non-settable eggs were produced [10].

At 26 to 28 wk of age, there was a significant interaction between BW and feeding level for total egg production. When fed the STD or STD+ feed amount H-BW hens had greater egg production than their lighter counterparts (data no shown). The A-BW hens fed on a STD+ feed amount had a similar high rate of production. However, when the A-BW hens were fed the STD feed amount these birds laid at an intermediate level. The L-BW hens fed on STD+ feeding level had the lowest level of egg production for this time period, while feeding these L-BW hens at the STD feed level resulted in slightly higher egg production (data no shown). These findings highlight the importance of minimizing variation in BW within a flock to encourage maximum egg production. Feeding level could not compensate for pullets having low BW at photostimulation. Our findings agree with Robinson et al., [29] who confirmed the importance of BW at photostimulation and its impact on early egg production and potentially overall egg production.

Reproductive measurements

No significant differences were noted for oviduct, ovary, or total reproductive tract weight (data not shown), while oviduct index was significantly greater for hens consuming the STD over the STD+ feeding level (oviduct index, 1.79 or 1.7, respectively). This finding suggests that STD fed hens had more oviduct tissue on a relative basis than the STD+ fed hens. No significant differences were noted between feeding levels or BW groups for LYF, incidence of follicular atresia or eggs in tract at termination (data not shown). This observation agrees with Wilson et al. [30] who found little difference in reproductive tract measurements after hens have laid for a number of weeks (terminated at 58 wk of age).

Morbidity and symptoms

Excessive morbidity and mortality in SF hens has been reported by industry statistics and in clinical cases especially from 25 to 32 wk of age, which is a critical time for reproductive performance. Females in this study were monitored daily on an individual basis for changes in feed intake and egg production along with mobility problems that potentially could cause dehydration and physical depression. In general, the symptoms were present in higher weight, more sexually developed hens in the A-BW and H-BW groups and a small number of the heaviest L-BW females after this group experienced rapid compensatory growth.

The morbid symptoms started with an abrupt change in feed intake. Feeding behavior in the affected hens changed from consuming the full daily allotment to feed rejection (n=24) which was followed by physical depression that included loss of comb and wattle color, and a huddled posture. After four to five days of limited feed and water intake, affected hens were reluctant to move and showed secondary mobility or balance problems (i.e., limping and overextended legs and/or wings). By six to eight days surviving birds had dramatic BW loss and had stopped laying eggs. A third of affected hens (n=8) died between 10 and 15 days (2.8% of the flock). Those that survived (16 out of 24) had some level of recovery marked by an increase in feed intake. Slightly less than one third of the affected hens (n=7) resumed lay but on an inconsistent basis. The mobility impairment continued in all surviving hens. It is important to note that caging the hens prolonged morbidity and allowed longer term survival in some birds. However, in a commingled floor pen setting symptomatic birds would likely not survive more than 2-3 days due to male aggression and difficulty to access feed and water. Perhaps this accounts for the lower mortality noted in this study in comparison to field observed flocks.

Average BW hens on STD feed level had the least morbidity and mortality (1.16%) compared to the same BW group of hens on STD+ feed regimen (5.78%), suggesting that STD feed amount met hen needs without causing bird or egg production losses. In contrast STD feeding level in L-BW or H-BW hens increased % of morbidity and mortality (4.5 and 8.1% respectively), suggesting that these hens were negatively affected by this feed amount. Perhaps the H-BW and L-BW birds were 'underfed' for their body size and nutrient needs. High BW hens needed more nutrients to sustain their body size, while L-BW hens needed more nutrients for compensatory growth.

Mortality and necropsy findings

A majority of dead hens had yolk and/or caseous material in the abdominal cavity causing peritonitis, and congestion in the digestive tract with a liquid yellowish or greenish content. In addition, the presence of fresh egg yolk material in the abdominal cavity described as internal ovulation was found in those birds that had a relatively shorter morbid process. Other hens had regressing ovaries or atretic follicles especially when the morbid process was long and the individuals lost significant BW. Only one hen had cystic ovaries indicating that this reproductive tract abnormality was not involved in these poor performing hens. Average BW hens on STD feed amount had the least mortality with the opposite found when fed STD+ feeding level. On the other hand, H-BW and L-BW on STD feed were significantly more affected. Perhaps there nutrient needs or BW gains must be achieved without overfeeding to prevent triggering mortality as birds are starting to lay. While our findings agree with industry statistics [4, 5] and field reports, this type of variable and non-specific mortality has been more related to ad libitum feeding by other authors [6].

Total T₃ hormone analysis

Neither feeding level nor BW had significant effects on total T₃ plasma levels. In general, some of the morbid hens that had less severe symptoms had lower T₃ levels when sampled during their feed refusal period compared to samples taking during their recovery period after they had resumed eating. This observation that T₃ plasma levels were depressed during low feed intake agrees with previous reports [10, 13, 14, 31, and 32] that documented lower plasma T₃ levels during short term starvation or restricted verses ad libitum feeding. As with the affected birds in this study, once the birds were back on feed T₃ levels increased.

Total T₃ was positively related to egg production (P=0.009) with higher egg production coinciding with higher total T₃ levels (R-Sq=6.5%). Little is know about T₃ levels and reproductive function in poultry. In humans, thyroid hormones ease FSH-mediated LH/hCG receptor and progesterone secretion, and it has been reported that gonadal dysfunction may be a consequence of inadequate thyroid hormone availability at the ovary level [33]. Furthermore, gonadotropins and thyroxin appear to be necessary to achieve maximum fertilization rates and blastocyt development in humans [34]. Poppe and Velkeniers [34] also reported that abnormal thyroid hormones disturb the normal menstrual pattern affecting human fertilization failure in women undergoing in vitro fertilization. These reports support the importance of thyroid hormones role in reproduction and encourage further research to define the relationship among T₃ levels, feed intake and egg production in broiler breeder hens.

CONCLUSIONS AND APPLICATIONS

Although the difference among the three BW groups declined with age, L-BW hens were not able to recover the 10 day delay in the initiation of lay and the general lower egg production

through 39 wk of age. These L-BW hens had rapid BW gains during the early lay period but this compensatory gain did not allow them to lay at a similar rate to those hens that were heavier at photostimulation. However, if the L-BW hens had not had the rapid weigh gain they probably would have never come into production. This observation emphasizes the influence of BW uniformity has on reducing the number of low BW, poor performing hens within a flock as a primary tool to maximize egg production. Where labor costs allow grading of pullets during the rearing phase, this practice continues to be a good way to improve BW uniformity in commercial broiler breeder flocks. However, other methods should be explored such as diet dilution or faster feed delivery within the rearing facility to improve BW uniformity of growing pullets. Feeding slightly more feed during the early lay period did not help L-BW hens compensate for low egg production. These observations emphasize the importance of having immature pullets at target BW prior to photostimulation or delaying photostimulation in order to achieve appropriate BW.

Necropsy findings were not conclusive in those hens that died during the study. A total of 8.6% of the hens showed signs of metabolic and reproductive disorders. Although the origin of this feed refusal, bird depression and mortality is not understood, the symptoms were outlined to assist with future inquiries into hen mortality.

Further investigation is needed to determine the role T_3 plays in reproduction of poultry. Generally, T_3 was depressed in the morbid hens that had low feed intake and increase as the hens recovered from the feed refusal. The relationship between metabolic and reproductive hormones is an important area for future research especially considering the feed restriction methods employed to prevent obesity in these meat-type birds.

REFERENCES AND ACKNOWLEDGEMENTS

1. Malloney, M. A., J. C. Gilbreath, J. F. Tierce, and R. D. Morrison. 1967. Divergent selection for twelve-week body weight in the domestic fowl. Poult. Sci. 46:1116-1127.

2. Jaap, R. G., and F. V.Muir. 1968. Erratic oviposition and egg defects in broiler-type pullets. Poult. Sci. 47: 417-423.

3. O'Sullivan, N. P., E. A. Dunnington, and P. B. Siegel. 1991. Relationships among age of dam, egg components, embryo lipid transfer and hatchability of broiler breeder hens. Poult. Sci. 70:2180-2185.

Agri Stats, Inc. Jan.-Dec. 1994. Live production annual agri stats report. Fort Wayne, IN
 46825.

Agri Stats, Inc. Jan.-Dec. 2002. Live production annual agri stats report. Fort Wayne, IN
 46825.

6. Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel. 1989. Restricted feeding in early and late-feathering chickens. 1. Growth and physiological responses. Poult. Sci. 68:344-351.

7. Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel. 1989. Restricted feeding in early and late-feathering chickens. 1. Reproductive responses. Poult. Sci. 68:352-358.

8. Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel. 1989. Restricted feeding in early and late-feathering chickens. 3. Organ size and carcass composition. Poult. Sci. 68:359-368.

9. Dunnington, E. A., and P. B. Siegel. 1986. Sex-linked feathering alleles (K, k+) in chicks of diverse genetic backgrounds. 1. Body temperatures and body weights. Poult. Sci. 66:168-170.

Sun, J. M., M. P. Richards, R. W. Rosebrough, C. M. Ashwell, J. P. McMurtry, and
 C. N. Coon. 2006. The relationship of body composition, feed intake, and metabolic hormones
 for broiler breeder females. Poult. Sci. 85:1173-1184.

11. Brake, J. P., P. Thaxton, and E. H. Benton. 1979. Physiologycal changes in caged layers during a forced molt. 3. Plasma thyroxine, plasma triiodothyronine, adrenal cholesterol, and total adrenal steroids. Poult. Sci. 58:1345-1350.

12. Lien, R. J., and T. D. Siopes. 1989. Turkey plasma thyroid hormone and prolactine concentrations throughout an egg laying cycle and in relation to photorefractoriness. Poult. Sci. 83:823-829.

13. Decuypere, E., and E. Kuhn. 1984. Effect of fasting and feeding time on circadian rhythms of serum thyroid hormone concentrations, glucose, liver monodeionidase activity and rectal temperature in growing chickens. Domest. Anim. Endocrinol. 1:251-262.

14. Bruggeman, V., D. Vanmontfort, R. Renaville, D. Portetelle, and E. Decuypere. 1997. The effect of food intake from two weeks of age to sexual maturity on plasma growth hormone, insulin-like growth factor-binding proteins, and thyroid hormones in female broiler breeder chickens. Gen. Comp. Endocrinol. 107:212-220.

15. Clulow, J. and R. C. Jones. 1982. Production, transportation, maturation, storage and survival of spermatozoa in the male Japanese quail. J. Reprod. Fert. 64:259-266.

16. Shirley, R. B., A. J. Davis, M. M. Compton, and W. D. Berry. 2003. The expression of Calbindin in chicks that are divergently selected for low or high incidence of tibial dyschondroplasia. Poult. Sci. 82:1965-1973.

17. SAS Institute. 2005. The SAS System for Windows, NT. Version 9.1 SAS Institute, Cary, NC.

 Neter, J., W. Wasserman, and M. H. Kurtner. 1990. Applied Linear Statistical Models., page 580. 3rd ed. Irwin, Boston, MA.

19. O'Sullivan, N. P., E. A. Dunnington, and P. B. Siegel. 1992. Correlated responses in lines of chickens divergently selected for fifty-six body weight. 1. Growth, feed intake, and feed utilization. Poult. Sci. 71:590-597.

20. Plavnik, I., and S. Hurwitz. 1985. The performance of broiler chicks during and following a severe feed restriction at an early age. Poult Sci. 64:348-355.

21. Plavnik, I., J. P. McMurtry, and R. W. Rosebrough. 1986. Effects of early feed restriction in broilers. I. Growth performance and carcass composition. Growth 50:68-76.

22. Yu, M. W., F. E. Robinson, M. T. Clandinin and L. Bodnar. 1990. Growth and broiler chickens in response to different regimens of feed restriction. Poult. Sci. 69: 2074-2081.

23. Anonymous. 2005. Cobb 500 slow feather breeder management supplement. Cobb Vantress. Siloam Springs, AR.

24. Reddy, P. R., and P. B. Siegel. 1977. Selection for body weight at eight weeks of age14.Effects of the sex-linked dwarf gene. Poult. Sci. 56:1004-1013.

25. Foster, W. H., and Z. T. Taha. 1978. Whole grain diets for pullets. Br. Poult. Sci. 19:233-242.

26. Auckland, J. N., and S. B. Wilson. 1977. Mineral and vitamin supplementation of a whole wheat diet for developing pullets. Br. Poult. Sci. 18:121-127.

27. Summers, J. D., and S. Lesson. 1983. Factors influencing early egg size. Poult. Sci.62:1155-1159.

28. Lesson, S., R. J. Etches, and J. D. Summers. 1988. Development of Leghorn pullets subjected to early light photostimulation. Can. J. Anim. Sci. 68(3):1267-1275).

29. Robinson, F. E., T. A. Wautier, R. T. Hardin, J. L. Wilson, M. Newcombe, and R. I. McKay. 1996. Effects of age at photostimulation on reproductive efficiency and carcass traits 1. broiler breeder hens. Can. J. Anim. Sci. 76(3):275-282).

30. Wilson, J. L., F. E. Robinson, N. A. Robinson, and R. T. Hardin. 1995. Effects of feed allocation on female broiler breeders. J. Appl. Poult. Res. 4:193-202.

McMurtry, J. P., I. Plavnik, R. W. Rosebrough, N. C. Steele, and J. A. Proudman.
 1988. Effect of early feed restriction in male broiler chicks on plasma metabolic hormones
 during feed restriction and accelerated growth. Comp. Biochem. Physiol. 91A:67-70.

32. Buyse, J., E. Decuypere, V. M. Darras, L. M. Vleurick, E. R. Kuhn, and J. D. Veldhuis. 2000. Food deprivation and feeding broiler chickens is associated with rapid and interdependent changes in the somatotrophic and thyroidtrophic axes. Br. Poult. Sci. 41:107-116.

33. Maruo, T., H. Matsuo, and M. Mochizuki. 1991. Thyroid hormone as a biological amplifier of differentiated trophoblast function in early pregnancy. Acta Endoc. (Copenhagen).125:58-66.

34. Poppe, K., and B. Velkeniers. 2004. Female infertility and the thyroid. Best Practice and Research Clinical Endocrinology and Metabolism. 18:153-165.

35. Cramer, D. W., P. M. Sluss, and R. D. Powers. 2003. Serum prolactin and TSH in an in vitro fertilization population: is there a link between fertilization and thyroid function? J. Ass. Rep. and Gen. 20:210-215.

Ingradiants 0/ "as is"	Developer	Layer		
ingredients, 70 as-is	Diet ³	Diet ⁴		
	(12 to 21 wk)	(22 to 34 wk)		
Corn (8.5% CP)	65.88	70.79		
Soybean meal (48.4% CP)	15.00	18.11		
Wheat middlings	14.83			
Dicalcium phosphate	1.58	1.49		
Limestone	1.28	7.33		
Poultry Oil		0.91		
Sodium chloride	0.60	0.51		
Vitamin premix ²	0.50	0.50		
DL-methionine (99%)	0.13	0.15		
L-lysine	0.13	0.12		
Trace mineral premix ¹	0.08	0.08		
Zinc Sulfate		0.01		
Total	100.00	100.00		
Calculated Analyses				
CP (%)	15.0	15.0		
ME (kcal/kg)	2,920	2,920		
Arginine (%)	0.92	0.88		
Lysine (%)	0.83	0.83		
Methionine (%)	0.38	0.39		
TSAA (%)	0.64	0.64		
Calcium (%)	0.92	3.22		
Available Phosphorus (%)	0.42	0.38		
Sodium (%)	0.02	0.20		
Zinc (ppm)	95.00	120.00		
Copper (ppm)	5.45	16.00		
Iodine (ppm)	0.80	0.80		

Table 4.1. Ingredient composition and calculated nutrient analysis of the developer and layer diets provided to the breeder pullets and hens

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 for layer diets; iron (source=ferrous sulfate), 89-95 for layer diets; iodine (source=calcium iodate), 0.8.

² Vitamin premix provided the following per kilogram of diet: vitamin A, 11,000 IU; vitamin D3, 2000 HJ \sim 5 20 HJ \sim 5 2

2,200 IU; vitamin E, 22 IU; vitamin K, 2.2 mg; vitamin B12, 0.0 2 mg; thiamine 4.4 mg;

riboflavin, 8.8 mg; vitamin B6, 4.4 mg; niacin, 88 mg; pantothenic acid, 22 mg; folic acid, 1.1 mg; biotin, 0.2 mg; choline, 383 mg.

³⁻⁴ Analyzed values for moderate developer and breeder diets were analyzed to contain 15.2 % CP.

$A = (wk)^{1}$	Feed	Level ² (g)	Comments ³
Age (wk)	STD	STD+	Comments
21	99	105	Photostimulation 14D:6D
22	99	105	
23	104	112	
24	107	116	
25	113	124	
26	125	130	
27	134	141	
28	140	149	
29	148	155	
30	150	157	
31	151	158	Peak feed intake
32	150	154	
33	149	155	
34	148	154	
35	150	154	
36	150	154	
37	150	154	
38	150	154	
39	150	154	
40	150	154	Termination of the study. Reproductive measurements. Bleeding
			for hormone work.

Table 4.2. Feed Intake and management.

¹ The experimental period was from 22 to 40 wk of age. ² The difference between STD and STD + feed levels was 4-8% increase in the amount of feed.

³ Photostimulation period started at 21 wk of age. Light stimulus was change from 8L:16D to 14L:10D. Daily monitoring for morbidity and mortality performed. At the end of the trial blood samples were taken for further hormone assay.

Fixed	BW	BW	Body	BW	BW	Body	BW	BW	Body	BW	BW	Body
Effects ¹		gain	gain		gain	gain		gain	gain		gain	gain
			rate			rate			rate			rate
	((g)	(%)		-(g)	(%)	(2	g)	(%)		-(g)	(%)
		Period I ⁴			Period II ⁵		I	Period III ⁶			Period IV ⁷	
Feed level ²												
STD	2,524 ^b	600^{b}	29 ^b	3,073 ^b	303	11	3,401 ^b	167	5	3,765 ^b	364	10
STD+	2,623 ^a	700^{a}	33 ^a	3,231 ^a	286	10	3,582 ^a	185	5	3,937 ^a	356	9
SEM	10	9	0.6	11	13	0.5	13	13	0.4	10	23	0.6
P value	< 0.001	< 0.001	< 0.001	< 0.001	0.40	0.09	< 0.001	0.35	0.63	< 0.001	0.80	0.47
BW group ³												
L-BW	2,220 ^c	715 ^c	40^{a}	2,920 ^c	397 ^a	15 ^a	3.376 ^c	214 ^a	7 ^a	3,775°	390	11
A-BW	2,603 ^b	649 ^b	29 ^b	3,177 ^b	276 ^b	9 ^b	3,493 ^b	179 ^{ab}	5 ^b	3,853 ^b	350	10
H-BW	$2,898^{a}$	586 ^a	23°	3,360 ^a	208 ^c	6 ^c	$3,604^{a}$	135 ^b	4 ^c	3,926 ^a	338	9
SEM	12	11	0.7	13	16	0.6	15	16	0.5	12	28	0.8
P value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.004	< 0.004	< 0.001	0.37	0.13

Table 4.3. Influence of feed level and initial BW on subsequent BW, BW gains and gain rates by periods.

^{a-c} Means with different superscripts within a column signify significant differences ($P \le 0.05$) as a result of a PDIFF comparison. ¹ Values are least-squares means involving two treatments (two feed levels and three BW groups) and four replications per treatment (12 birds per replication).

¹ SF broiler breeder hens were given one of two feed levels, standard (STD) or standard plus (STD+) of a medium density layer diet (Table1).
³ SF birds were grouped according to 3 different BW ranges, low (L-BW), average (A-BW) or high (H-BW).
⁴ Period I: 23 to 25 wk of age.
⁵ Period II: 26 to 28 wk of age.
⁶ Period III: 29 to 31 wk of age.

⁷ Period IV: 32 to 40 wk of age.

Fixed Effects ¹	BW	Total	Hatching	Double yolk	Membrane	Cracked	Abnormal shelled	
	23-40 wk	Egg Pr	Egg Production			Eggs	gs	
	(g)			(9	%)			
Feed level ²								
STD	3,382 ^b	59.7	57.0	0.4	0.4	2.1 ^b	0.2	
STD+	3,541 ^a	60.8	57.4	0.5	0.5	2.8^{a}	0.5	
SEM	6	0.6	0.5	0.06	0.06	0.2	0.03	
P value	< 0.001	0.442	0.616	0.209	0.083	0.004	0.220	
BW group ³								
L-BW	3,307 ^c	53.6 ^c	51.0 ^c	0.5^{b}	0.5	2.1	0.2	
A-BW	3,472 ^b	62.0 ^b	58.9 ^b	0.4 ^b	0.4	2.1	0.1	
H-BW	3,606 ^a	65.0 ^a	61.6 ^a	0.7^{a}	0.5	2.6	0.2	
SEM	7	0.7	0.6	0.08	0.07	0.2	0.04	
P value	< 0.001	< 0.001	< 0.001	0.011	0.363	0.092	0.058	
Feed level * BW								
group ⁴								
STD/L-BW	3,220	53.4	50.5	0.5^{bcd}	0.4	2.3 ^{cd}	0.3	
STD/A-BW	3,406	61.4	58.8	0.5^{bcd}	0.4	2.0^{bc}	0.1	
STD/H-BW	3,520	64.2	61.7	0.4^{bcd}	0.4	2.0°	0.2	
STD+/ L-BW	3,393	53.9	51.4	0.4^{cd}	0.6	1.9 ^{bd}	0.2	
STD+/ A-BW	3,537	62.6	59.0	0.3 ^d	0.4	3.2 ^a	0.09	
STD+/ H-BW	3,692	65.8	61.6	1.0^{a}	0.6	3.2 ^a	0.2	
SEM	10	1.0	0.8	0.1	0.1	0.3	0.06	
P value	0.060	0.826	0.844	0.001	0.394	0.005	0.715	

Table 4.4. Influence of feed level and BW group on overall BW (23 to 40 wk of age) and egg production and egg characterization (24 to 39 wk of age).

^{a-c} Means with different superscripts within a column signify significant differences ($P \le 0.05$) as a result of a PDIFF comparison

¹ Values are least-squares means involving two treatments (two feed levels and three BW groups) and four replications per treatment (12 birds per replication).

² SF broiler breeder hens were given one of two feed levels, standard (STD) or standard plus (STD+) of a medium density layer diet (Table1).

³ SF birds were grouped according to 3 different BW ranges, low (L-BW), average (A-BW) or high (H-BW).

⁴No significant interactions were noted, except for % of double yolk eggs and % of cracked eggs.

Fixed Effects ¹	Pe	Period I ⁴		od II ⁵	Peri	od III ⁶	Period IV ⁷	
	Total	Hatching	Total	Hatching	Total	Hatching	Total	Hatching
Feed level ²								
STD	3.2	2.9	41.2	38.2	75.4	71.5	75.0 ^b	72.2
STD+	3.5	2.9	42.4	37.6	74.5	70.2	77.0 ^a	73.6
SEM	0.8	0.7	1.0	1.5	1.0	1.3	0.6	0.6
P value	0.784	0.949	0.603	0.783	0.597	0.493	0.019	0.118
BW group ³								
L-BW	0.07^{c}	0.07^{c}	21.5 ^a	19.2 ^c	67.5 ^b	62.9 ^b	74.2 ^b	71.2 ^{bc}
A-BW	2.7^{b}	2.5 ^b	46.8^{b}	43.3 ^b	77.6 ^a	73.9 ^a	76.8^{a}	73.3 ^{ac}
H-BW	7.3 ^a	6.1 ^a	57.1 ^a	51.2 ^a	79.7 ^a	75.7 ^a	77.1 ^a	74.4 ^a
SEM	0.9	0.8	2.0	2.0	2.0	1.6	0.7	2.0
P value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.009	0.020

Table 4.5. Influence of feed level and BW on % total and hatching egg production by period.

^{a-c}Means with different superscripts within a column signify significant differences ($P \le 0.05$) as a result of a PDIF comparison. ¹ Values are least-squares means involving two treatments (two feed levels and three BW groups) and four replications per treatment (12 birds per replication).

²SF broiler breeder hens were given one of two feed levels, standard (STD) or standard plus (STD+) of a medium density layer diet (Table1).

³ SF birds were grouped according to 3 different BW ranges, low (L-BW), average (A-BW) or high (H-BW).
 ⁴ Period I: 23 to 25 wk of age.
 ⁵ Period II: 26 to 28 wk of age.

⁶ Period III: 29 to 31 wk of age.

⁷ Period IV: 32 to 39 wk of age.



Figure 4.1. Experimental design.



Figure 4.2. Influence of initial BW and age on subsequent BW (23-34 wk). The interaction of BW and age was significant (p=<0.001) during the experimental period (23-40 wk of age)



Figure 4.3. Influence of BW and age on percentage total egg production. The interaction of BW and age was significant (P>0.001) during the experimental period. Similar trend was noted for total hatching eggs production.

CHAPTER 5

CONCLUSIONS

These studies compared the nutrient utilization, reproductive performance and mortality of two strains of female broiler breeders of different initial body weights, fed different density diets and two feeding levels. In the first experiment, both strains of females utilized the nitrogen and energy in a similar manner; however, the slow feathering hens laid more eggs through 34 wk of age. Heavier females at photostimulation produced more eggs and deposited more carcass fat than lighter weight hens. Low body weight hens initially utilized nutrients for body weight gain, were slower to start lay and were poor egg producers to 34 wk of age. Feeding a higher density diet encouraged increased body weight gains and fat deposition in breeder hens while egg production was similar to those consuming a moderate density diet (15% crude protein, and 2,929 kcal/kg) to 34 wk of age..

Results from the second study, indicated that low body weight hens were 10 days behind average or high body weight hens in initiating egg production. The low body weight hens experienced rapid compensatory growth during the weeks after photostimulation, and by the end of the experiment were producing eggs at the same rate as average and heavy body weigh hens. However, overall egg production in the low body weight group was reduced in comparison to hens that were heavier at photostimulation. Feeding slightly more feed did not improve egg production in the light weight females; however, the heavier females fed the increased amount of feed did lay more eggs. Morbidity and mortality was more likely to be seen in the heavier, more sexually developed hens. Feed refusal was the first symptom observed in the 8.6% of the flock that became morbid. A third of these hens died, while the caged environment allowed prolonged

morbidity and even some limited recovery in a small number of hens. During the morbid stages, T3 levels were depressed and rebounded when feed intake was reinitiated. Necropsy results were inconclusive but included regressing ovary, atretric follicles, and free yolk material in abdomen.