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Effects of Maternal Strain, Feeding Program and Photostimulation Program on Egg Quality, Chick Quality and Broiler Growth and Carcass Characteristics

By

Kim Adele Thorsteinson

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

Animal Science

Department of Agricultural, Food and Nutritional Science

Edmonton, Alberta

Fall, 1999

University of Alberta

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Degree: Master of Science

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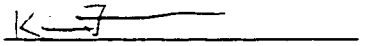

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Effects of Maternal Strain, Feeding Program, Photostimulation Program on Egg Quality, Chick Quality and Broiler Growth and Carcass Characteristics** submitted by Kim Adele Thorsteinson in partial fulfillment of the requirements for the degree of Master of Science in Animal Science

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ABSTRACT

Broiler breeder management has been implicated in influencing hatching egg quality, broiler performance and processing yield. However, few published data have been reported addressing this issue. At 20 weeks of age, 288 broiler breeder pullets of two strains, Shaver Starbro (SS) and an Experimental Line (EL) were randomly assigned to one of two feeding programs, Fast Feeding (FF) or Slow Feeding (SF) and to one of two photostimulation programs, Fast Photoperiod (FP) and Slow Photoperiod (SP). At 30, 40, 50 and 60 weeks of hen age, eggs were collected consecutively for one week. During that week the eggs underwent a preincubation storage treatment of 0, 1, 2, 3, 4, 5 or 6 d. At the end of each week, two eggs were randomly selected from each hen and egg traits were assessed. The remainder of the eggs were pedigree hatched and chick characteristics were assessed. When the hens were 61 weeks of age, eggs were collected, stored, pedigree hatched and the chicks raised to 6 weeks of age to determine how broiler production and carcass characteristics would be influenced.

Increased hen age resulted in increased egg weight (EW), increased relative yolk, yolk sac, total chick EW loss during storage, and decreased shell weight and specific gravity. Strain differences included greater relative yolk weight and decreased shell weight and specific gravity in eggs from EL hens compared to SS hens. Chicks from SS hens had greater carcass weights than chicks from EL hens. EL carcasses had greater eviscerated yield, *P. major*, *P. minor* and total breast weight than SS carcasses. Storage decreased EW, specific gravity and haugh unit score, while relative yolk sac and total hatchling weight increased. Gender differences included males having greater relative yolk sac, chick carcass and total chick weight, plus greater eviscerated carcass weight, front/back half weight, *P. major*, *P. minor* and total breast weight than females. Hen age and length of preincubation storage influenced egg and chick traits while strain and gender influenced broiler traits. Maternal management had a limited effect on traits measured.

ACKNOWLEDGMENTS

Many companies, agencies and individuals must be involved for research such as this to be accomplished. Agencies such as Alberta Agricultural Research Institute (AARI) must be acknowledged for programs, which provide funding and support for research in our industry. Companies and boards within the industry such as Shaver, Lilydale and the Alberta Chicken Producers see the importance of a thriving research program in Canada. They financially support projects that reflect on issues pertinent to consumers, producers, processors and further processors. The foresight and involvement of such agencies and companies have and will encourage many student researchers.

The individuals involved in making this research possible include Felicity Dennis, Giles Hinse, Lyle Bouvier, Shawn Rankin, Nigel Davidson, Nancy Robinson, Rob Renema, Gaylene Fasenko, Lea Swan, Nancy Joseph, Tommy Inglis, Jerry Emmanuel, Harry Klooster, Val Melnychuk, Ruth McGovern and Adam Spies. These people made the working environment at the farm and on campus more fun than work.

To Dr. Hardin, who has gone on to bigger and better things but is sorely missed in our department: thanks for your abundant statistical knowledge and patients with your students.

Many thanks to my supervisor Frank Robinson: his enthusiasm for learning is contagious. His 'big picture' thinking and hands-on approach to teaching will be an asset to many future students.

Thanks to my parents who have encouraged in me many qualities such as a diligent work ethic and an inquisitive mind (and yes mom, opa would love this). I would also like to thank Pat and Wilton, my mother and father in-law, for their constant encouragement. I also appreciate the home cooked meals in the freezer; many of which kept us well fed while I was busy writing.

To my husband Paul, the computer genius who has spent many nights editing and formatting this thesis. You have been very willing to sacrifice (big and small) for me to complete this, thanks sweetie.

Finally, I am most thankful to God who has given me these many opportunities.

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1.1 BACKGROUND

1.1.1 Introduction

Over the past 50 years, genetic selection in the broiler industry has resulted in drastic changes in body weight, growth rate and meat yield. Being highly heritable, selection for meat traits exhibit quick increases in weight gain and a decrease in days to market (Hunton, 1990). Early selection resulted in 50–100 g increases in gain per generation and 1-2 d decreases to market weight per generation (Hunton, 1990). These dramatic improvements provide the makings of today's broiler which can reach a market weight of 2.0 kg in less than 42 d utilizing 1.9 kg feed/kg gain or better, compared to a 1957 broiler which reached 1.4 kg in 84 d on 4.06 kg feed/kg gain (Havenstein *et al.*, 1994).

These improvements in broiler growth have come at the expense of egg production in the parent stock or broiler breeder (BB) (Hunton, 1990). Unlike meat traits, reproductive traits have low heritability. Meat traits and reproductive traits are negatively correlated at the genetic level (Hunton, 1990). Early studies by Hunton (1969) and Moav and Moav (1966) demonstrated to breeding companies the economic loss associated with selecting for reproductive traits as opposed to meat traits. Such studies influenced breeding companies to exploit nongenetic methods of improving reproductive performance i.e., nutrition and lighting, rather than tackling the problem at the genetic level (Hunton, 1990). Because the industry is not prepared to go 'back in time' in terms of broiler genetics, BB management has intensified to improve egg production and hatchability. Management of BB parents through careful feed restriction and lighting programs has become essential to the industry.

1.2 FACTORS AFFECTING BROILER BREEDER REPRODUCTION

1.2.1 Introduction and Performance Objectives

To further identify how the last 50 years of selecting against reproductive fitness has come to affect the reproductive performance of the BB, one could compare the broiler breeder hen to her relative the egg layer or Leghorn. Leghorns can produce in excess of 320 eggs per production period, while a well-managed BB may only produce 184 eggs per production period (Robinson *et al.*, 1990). This difference in egg production can be explained by comparing the physiology of these two divergently selected stocks.

The first obvious difference between Leghorns and BB hens is their body size. With identical environmental and dietary conditions, meat breeds have been reported to grow about three times heavier than egg-type chickens at 10 wk of age (Plavnik and Hurwitz, 1983). These differences increased beyond 10 wk of age (Brody *et al.*, 1980). A mature Leghorn will weigh approximately 1.5 kg (Oosterhoff, 1997) while a mature full-fed BB hen weighs approximately 4.6 kg (Yu *et al.*, 1992a). This difference has been attributed to genetic selection for appetite and growth rate in broiler lines. The BB ovary shares the same fate. While an *ad libitum*-fed Leghorn typically has seven or eight follicles on the ovary, a full-fed BB can have up to 12 follicles or more (Yu *et al.*, 1992b). These excess follicles on the ovary results in the formation of multiple hierarchies, i.e., more than one follicle at a specific level of maturity (follicles within 1 g of each other), which become a problem during ovulation. While a single hierarchy will allow for the recruitment of a single follicle at ovulation, a multiple hierarchy will allow two follicles similar in maturity to ovulate at the same time. Multiple ovulations result in poor egg quality since contact between two eggs in the shell gland results in mishaped eggs and since resources within the oviduct are limited, i.e., calcium available for only one egg. Therefore excess folliclular development in BB hens due to their genetic predisposition toward increased growth rate, has been associated with a reduction in settable egg production, the rate of fertility and hatchability (Yu *et al.*, 1992a). The incidence of multiple hierarchies has been known to decrease with proper feed restriction (Hocking *et al.*, 1987, Yu *et al.*, 1992b).

Another identifiable difference between the Leghorn and the BB hen can be seen while comparing their laying sequences throughout egg production. A laying sequence can be defined as the number of consecutive eggs laid or a clutch (Etches, 1990). A pause (non-laying day) separates one sequence from a second sequence. Pauses in a sequence reduce the total number of eggs laid. The prime sequence is referred to often since it is the longest sequence in the life of the hen. The average prime sequence length of a Leghorn hen is approximately 80, while a BB hen only sustains 40 d of uninterrupted egg production (Robinson *et al.*, 1990). This reduction in sequence length has also been linked to an overall decrease in chick production since the first eggs in a sequence have recorded increased embryonic death or decreased fertility (Robinson *et al.*, 1991; Fasenko *et al.*, 1992a). Early observations of arrhythmic sequences in BB lead to questions about changes in broiler genetics as the cause of altering the precision of ovulation timing in these strains (Jaap and Muir, 1968).

Jaap and Muir (1968) compared the high incidences of soft-shelled eggs, membrane eggs, double-yolked eggs and multiple ovulations (or two eggs laid in one day) in BB hens as compared to their Leghorn counterparts. At 28 wk of age, 3.7% of the eggs from BB were multiple ovulations while only 0.5% of the Leghorn eggs were multiple ovulations, in a 24 h period. A term to embody the many reproductive inefficiencies in BB hens was developed by J.H. Van Middelkoop in 1971. This term "erratic oviposition and defective egg syndrome" or EODES includes atresia, internal ovulation, internal laying, soft-shelled or shelless eggs, double yolked eggs, more than one egg per d and short sequences (Van Middlekoop, 1971). The common thread that ties these anomalies together is that the incidence of EODES results in lower total settable egg production.

In conclusion, research has demonstrated a strong negative relationship between body weight and egg and chick production (Robinson *et al.*, 1993a). The BB hen is predisposed to multiple ovulations, shorter sequences and decreased total egg production. The work of this and future research is to bring the BB hen closer to maintaining egg quality and sequence length similar to her Leghorn conterpart while allowing her progeny to grow as broilers.

1.2.2 Strain

As phenotypes change towards higher breast muscle yield, it is questionable to what extent this shift in genetics will influence broiler breeder feed conversion and sensitivity or response to light, etc. For example, 'high yielding' broiler strains, those which have been selected for higher breast yield, have opened the door to potential changes in current management practices since these bird seem to respond to feed differently than conventional strains (Robinson *et al.*, 1999a). Whether this is due to the allocation of resources differently than previous strains or the nutritional cost of maintaining a larger breast muscle is not clear. It has also been postulated that high yielding strains may also become photorefractory sooner than do other strains (Robinson *et al.*, 1999a). These types of changes to the physiology of the bird may in turn require altered management practices. Researchers continually struggle to identify the influence of each year's genetics on management strategies.

Changes in traits such as egg size, chick size and yolk sac size have also been associated with changes in genetic selection. Research has observed that the egg weight to chick weight ratio can be

affected by individual genetic characteristics (Jull and Heywang, 1930) and strain genetic characteristics (Henderson, 1956). More specifically, dwarf broiler breeders produce chicks that are 68.4% of the egg weight while chicks from a standard strain consisted of only 67.3% (Whiting and Pesti, 1983). These changes can have profound effects on overall broiler performance.

1.2.3 Photostimulation Programs

Just as increasing day length stimulates most birds in the wild to begin egg production, so too domestic strains must be photostimulated to maximize reproductive efficiency. Light triggers hormonal changes in the bird via the hypothalamus. It was initially believed that light was perceived through the eye of the bird. This was discredited when identical maturational responses were observed in sighted and genetically or surgically blind birds (Hunton, 1990). Stimulation of the hypothalamic photoreceptors triggers the release of gonadotrophin releasing hormone (GnRH) which in turn stimulates the release of two gonadotropes; luteinizing hormone (LH) and follicle stimulation hormone (FSH) into the circulatory system. The gonadotropes then bind to theca and grandulosa cells of the ovarian follicles. Here androgen and estrogen production is stimulated from the small follicles and progesterone production stimulated from the largest preovulatory follicle (Etches, 1996). A complete explanation as to how the bird distinguishes changes in day length has yet to be identified.

The process by which increased day length is introduced to the bird to stimulate egg production, has produced two schools of thought on photostimulation programs. One theory presents the increase of light as a sharp signal that must be very obvious to the bird. This photostimulation program involves changing from 8L:16D during rearing to 15L:9D in a single step. This program has been termed 'fast photoperiod' (Robinson *et al.*, 1999a). The second theory is termed 'slow photoperiod' and involves increasing light gradually. The idea being if natural light increases are mimicked, the bird will respond to these changes favorably (Robinson *et al.*, 1995). Research comparing these two photostimulation programs has suggested that the slow photoperiod (SP) program is more beneficial than the fast photoperiod (FP). Although total egg production was not different between SP and FP hens, SP hens had 1.9% higher fertility, a 2.9% higher hatchability and a 2.9% higher hatch of fertile than FP treatment (Robinson *et al.*,

1999b). Although SP hens do not exhibit greater total egg production, the number of chicks produced by SP hens was greater than FP due to their superior fertility and hatchability.

Besides managing the rate of photostimulation, managers must also decide at what age birds best respond to a light cue. Early stimulation has been linked to increased production of small eggs early in lay and oversized eggs at the end of lay (Fuller, 1969) and therefore a reduced number of 'normal grade eggs'. In Leghorns, the increase in small eggs can be attributed to the reduced body size as well as immature body composition. It can be understood that a minimum body weight is needed for a hen to mature. Attempts to increase BB pullet body weight to facilitate early maturation have been unsuccessful (Leeson and Summers, 1982). Pullets raised on 20%, 10% and 5% increased feed allocation, successfully came into production early and peaked well, but failed to maintain egg production dropping to 60% by 28 wk of age. While the early maturing pullets and the control group maintained similar weights and feed intake during peak, the early maturing pullets gained more body weight post peak than did the control birds. Although the early maturing birds attained a mature body weight at 14 to 15 wk of age and displayed signs of sexual maturity, sexual maturity does not occur until 21 to 25 wk of age. It can be concluded that an 'ideal' body weight and an age requirement is necessary for proper maturation of BB hens. Robinson *et al.* (1996) suggested that delayed photostimulation (23 wk) can reduce the variation in age and body weight at first egg. Delayed photostimulation allows more birds to meet their body weight and age requirements for sexual maturation.

It is also clear that there are strain effects in the rate of hypothalamic maturation in BB at sexual maturity (Robinson *et al.*, 1999c). When days (post-lighting) to sexual maturation was compared in four strains in response to three feeding allocations were compared, an almost 8 d difference between strains was observed. Although two of the four strains were unaffected by the feed treatments, full-feeding brought the other two strains into sexual maturity sooner than restricting feed. This suggests an age threshold which limited the two former strains from reaching sexual maturity, while a body weight threshold limited the latter two strains. Past dogma included the importance of both an age and body weight threshold for sexual maturity irrespective of strain; however, this study suggests that photostimulation management be strain specific.

1.2.4 Feed Restriction Program

Because broilers are selected for appetite, feed is made available at all times to ensure maximum growth. When feed is made available *ad libitum* to BB there are serious consequences. The main response to *ad libitum* or full-feed in BB is the same as their progeny, increased body weight. In a study by Robinson and Wilson, (1996) full-fed hens were approximately 700 g heavier than feed-restricted hens. Mortality was increased in these full-fed hens due to prolapse, fatty liver syndrome and heart failure. Average egg production was lower, number of pauses was increased and the prime sequence length was shorter in full-fed hens as compared to their feed-restricted conterparts. Production problems in full-fed hens may be explained by the increase in the number of large yellow follicles on the ovary (Yu *et al.* 1992a; Yu *et al.*, 1992b; Yu *et al.*, 1992c) and subsequent multiple hierarchies associated with overfeeding (Hocking *et al.*, 1987). It was observed by Yu *et al.*, (1992a) that the increase in multiple hierarchies found in full-fed hens resulted in increased unsettable egg production and reduced rates of fertility and hatchability. It is therefore believed that obesity in BB disrupts normal reproductive function in hens during the first few days of over consumption (Robinson *et al.*, 1993b). For these reasons, feed restriction programs are essential for any BB operation.

Feed is generally administered to maintain BW according to BB weight guides published by the breeding companies. To better understand exactly how to administer feed to keep body weights on target, research has been done to see how specific feed allocations affect body weight, egg production, fertility and hatchability. 'Slow feed' and 'fast feed' allocation programs have been compared in research trials at the University of Alberta. Slow feed allocation (SF) is described as a very conservative program relying on moderate increases in feed whereas fast feeding (FF) is a more aggressive approach of generous feed increases (Robinson *et al.*, 1999a).

Use of the SF treatment resulted in an increase of 10.9 eggs in total as compared to the FF. The increased ovary weight and an increased follicle number of the FF treatment as compared to the SF treatment may explain the difference in egg production since more follicles does not translate into more eggs. Eggs from FF hens had a 0.6% (1-7 d) and 0.5% (7-14 d) higher incidence of embryonic mortality than did eggs from the SF hens. SF hens average sequence length (3.19 d) was longer than that of FF hens (2.65 d). Associated with a reduction in sequence length was a 10.7% increase in total number of

sequences during the entire breeder period. The SF treatment seems to be a potential method of regulating follicular recruitment while avoiding a loss in egg production as opposed to more aggressive feed allocation programs (Robinson *et al.*, 1999a).

1.2.5 Aging

It is well documented that as a hen ages, egg weight increases (Mather and Laughlin, 1979). This increase has been associated with an increase in yolk deposition (Bahr and Palmer, 1989). Follicles of older laying hens (150-200 wk old) were found to be larger than those found in younger hens (30-40 wk) (Joyner *et al.*, 1987). This increase in yolk deposition results in a larger absolute and proportional yolk weight (Rossi and Pompei, 1995).

Logically this increase in proportional yolk weight must result in the decrease of another component of the egg. In layers, Fletcher *et al.*, (1981) observed that as a hen ages, egg weight, dry shell weight and percent yolk weight increases, while percent shell and percent albumen decreases. A study by Hamilton (1978) stated the specific gravity (shell quality) decreases with hen age. From such studies, it is suspected that the functional characteristics of the eggshell may not be increasing proportionally, untimately affecting gas exchange vital for proper development. A hens inability to maintain the functional characteristics of the shell may suggest some cause for the decrease in hatchability as the hen ages (Nestor *et al.*, 1972). In Leghorn breeders this decrease in hatchability as the hen ages has been noted as most apparent after 50 wk of age (Wilson and Harms, 1988).

Advanced hen age is correlated with development rate (shorter incubation rate) and embryo weight (bigger chicks), regardless of egg weight (Shanawany, 1984). The following includes three possible explanations by the author: 1) more efficient utilization of nutrients by embryos from older flocks; 2) more efficient deposition of nutrients into the egg from older birds; and 3) the increase in shell porosity which has been observed to occur in BB eggs from flocks between 24 and 50 wk of age (Shananwany, 1984).

Development of embryos at the time of oviposition increases as the age of the hen increases (increased area of the blastoderm) (Mather and Laughlin, 1979). This could be explained by the amount of time the egg spends in the oviduct of the bird. An egg may spend more time in the oviduct of an older bird because the oviduct is longer or the rate of passage of the egg is reduced. Hafez and Kamar (1955)

observed the mean oviduct length at sexual maturity (20 –28 wk old) to be 491 mm, while 8 wk later the mean oviduct length was 562 mm, followed by a reduction to 510 mm at 9 months of age and 375 mm at 12 months of age. These differences in oviduct length and the increasing fat content of the bird may impede the rate of egg movement through the oviduct.

Increased development of the embryo may also be explained by the position of the egg in the sequence, since position in the sequence is known to influence both the stage of development of the embryo and the unincubated area of the blastoderm. It has been reported that first or last eggs in a sequence contain embryos that are more advanced than intermediate eggs in the sequence (Mather and Laughlin, 1979). A negative correlation between sequence length and age has been identified in turkeys (Lerner *et al.*, 1993) and in BB (Robinson *et al.*, 1990). A reduction in sequences has been linked to an overall increase in chick production since first-of-sequence eggs have recorded increased embryonic death or a decreased fertility (Robinson *et al.*, 1991; Fasenko et al,. 1992a).

1.3 FACTORS AFFECTING EGG QUALITY

1.3.1 Introduction and Performance Objectives

One unique property of avian reproduction is the ability of the offspring to develop outside the body of the female. For this to be possible, the embryo must be provided with adequate amounts of essential nutrients and water to develop properly. The egg is the all-inclusive package in which the avian embryo can grow and develop. The egg is made up of yolk (ovum), albumen (thin and thick), and membranes all contained within the shell. With the proper attention to temperature and humidity, the embryo has everything it needs to hatch within 21 d. The quality of the egg is essentially made up of the quality of each of its components. The following describes in clearer detail the function of each portion of the egg and what factors affect the quality of this component.

1.3.2 Total Egg Weight

Research has identified a broad relationship between egg size and subsequent embryo and chick size (Wiley, 1950; Al Murrani, 1978; Jones, 1981). The correlation between egg weight and hatching weight ranges from 0.50 and 0.95. (Upp, 1928; Penquite and Milby, 1941; Wiley, 1950; Godfrey *et al.*,

1953; Axelsson, 1954; Henderson, 1956; Bray and Iton, 1962; Somaiah and Shirley, 1963; Saeki and Akita, 1971; Yannakopoulos and Tserveni-Gousi, 1987). Further defining this relationship has proven to be difficult. Some research supports the idea that changes are evident early in development, and that embryos of larger eggs will be further developed at the time of oviposition than smaller eggs. This is explained by the fact that larger eggs remain in the oviduct longer and therefore offers a longer developmental time prior to oviposition (Shanawany, 1984). Wiley (1950) supports this research observing a positive correlation between egg size and the number of embryonic cells in a given microscopic field and a negative correlation with cell size in very young embryos. Other research suggests that the effect of egg weight on embryo and chick weight is a 'temporary environmental influence' which begins after d 11 of incubation and gradually increases to a maximum at hatching (Bray and Iton, 1962). Although the details are not quite clear, the existence of a positive correlation between egg weight and embryo and chick size is well supported.

The ratio of egg weight to chick weight has been thoroughly studied and many equations have been postulated to calculate the size of chick that will result from a certain weight of egg. Shanawany (1987) proposed that hatchling weight(g) = 0.96 x egg weight(g)$^{0.90}$, using only egg weight as a factor. Tullet and Burton (1982) incorporated loss during incubation and the weight of shell and other residues at hatch to account for 97% of the chick weight at hatch. Their equation is as follows:

Chick weight at hatch(g) = 0.411 + 0.850(initial egg weight(g)) – 0.855(weight lost during incubation(g))

These equations although useful, can be limited by such factors as water loss after hatch.

1.3.3 Shell Quality

Hamilton (1982) defined shell quality as a synonym of 'shell strength'. This definition limits the importance of the shell's integrity to the plight of the table egg and fails to describe the shell as a functional unit during incubation. More than simply providing structural and protective properties to the egg and its embryo, the shell is an active facilitator of gas exchange during incubation.

Testing the 'quality' or integrity of the shell, while preserving the shell, can be done using specific gravity. Specific gravity has a positive correlation with eggshell weight (Peebles and Brake, 1987) and a positive correlation of nearly 0.8 with shell thickness (Foster and Weatherup, 1979). These correlations

plus its nondestructive and simple measurement makes specific gravity a widely used and accepted measure of shell strength.

A successful hatch is dependent upon proper weight loss during incubation. An egg must exchange an adequate amount of vital gases (CO_2 and O_2) and lose approximately 12 to 15 % of its weight in water during the hatching process to ensure a successful hatch (Rahn *et al.*, 1979; Tazawa, 1980). This weight loss is directly related to the thickness or quality of the shell. Weight loss is greater in thin-shelled eggs as compared to thick-shelled eggs (Rogue and Soares, 1994). Likewise, eggs having a specific gravity of 1.080 or less, displayed a greater increase in weight loss (Joyner *et al.*, 1987), had lower fertility, hatch, duration of fertility (McDaniel *et al.*, 1981) and lower viability (Roque and Soares, 1994) than did eggs with a specific gravity greater than 1.080.

It was established earlier that egg weight increases as the parental hen age increases. Roland (1979) observed an increase in egg weight of 14.5% and only a 2.9% increase in shell weight during a 9 month period. This disproportionate increase in egg and shell weight explains the decrease in specific gravity of 0.012 (Roland, 1979). Subsequent research by Fletcher *et al.* (1981) supports this, stating that egg weight and dry shell weight increases with hen age, as shell weight decreased as a percent of egg weight. Hamilton (1978) and Roland *et al.* (1975) suggest that decreases in shell thickness and specific gravity found in aging hens, is a result of an increase in egg weight without a proportionate increase in shell weight. Interestingly, eggs which had the largest increase in weight throughout lay, experienced the largest decline in eggshell quality. Absolute egg size and egg numbers had no influence on egg quality (Roland, 1979).

In a constant quest for increased growth rate, genetic selection may be exaggerating this disproportionate increase in egg size. In turkey strains selected for increased growth rate, shell weight was increased, as compared to a control (unselected) strain. However, strains selected for increased egg production had no effect on shell weight as compared to a control unselected strain (Christensen and Nestor, 1994). Shell weight was higher in a turkey strain selected for increased growth rate as compared to a strain selected for increased egg production (7.89g and 6.83g, respectively) (Christensen and Nestor, 1994). The functional characteristics of the shell (egg shell conductance and conductance constraints) increased more rapidly for unselected turkey strains than for strains selected for growth rate and egg

production (Christensen and Nestor, 1994). Thus, as egg weight increases with selection for growth and with age, the functional characteristics of the eggshell may not be increasing proportionally. With this balance altered, the exchange of vital gases for the proper embryonic development may be limited. The hen's inability to increase the functional characteristics of the shell may partially account for the decrease in hatchability as the hen ages (Nestor *et al.*, 1972; Christensen and McCorkle, 1982).

1.3.4 Weight Loss during Incubation

During embryonic development within the egg, water may be lost via diffusion through pores in the shell (Paganelli, 1980) or created through the oxidation of yolk lipids (metabolic water) (Ar and Rahn, 1980). This delicate balance allows oxygen to be available for embryo development and the escape of metabolic waste out of the egg. If the temperature and humidity within the incubator are constant, the rate of metabolic water produced will remain constant (Romanoff and Hayward, 1943; Romanoff, 1959). Therefore the most important process that determines the water balance within the egg is the water lost by diffusion through the shell (Tullet and Burton, 1982). A fertile egg will lose 400-450 mg of water per d during incubation (Etches, 1996). Insufficient moisture loss during incubation results in 'wet chicks' and unhealed navels while excessive moisture loss results in dehydrated chicks. Vital gas exchange has been estimated using weight loss of the egg (Paganelli *et al.*, 1978). It has been observed that at the time of external pipping, 12% moisture loss must occur for maximum hatchability (Davis *et al.*, 1988). All of this being done through the shell of the egg makes the effect of shell quality, on moisture loss during incubation, an important factor.

As the barrier for moisture movement in and out of the egg, the shell and its thickness has been the focus of most research surrounding moisture loss during incubation. It has been established that weight loss is higher in thin-shelled eggs as compared to thick-shelled eggs throughout the production period (Roque and Soares, 1994). Looking at the structure of the shell helps to understand this. The shell is made up of many pores through which a diffusive pathway is created. The thickness of the shell determines the length of the shell. The thicker the shell, the longer the pores and thus, the greater the resistance to gases diffusion (Rahn *et al.*, 1979). It has been said that a proper relationship between pore concentration and

pore length (shell thickness) is needed for optimal hatchability because both of these factors allow for the necessary weight loss of the egg during incubation (Burton and Tullett, 1983).

The consequences of poor shell quality extend beyond disrupting proper gas movement through the shell. Decreased eggshell porosity can result in decreased oxygen availability and therefore can be a major limiting factor on embyonic growth (Burton and Tullett, 1983; Tullett and Burton, 1987). This has been supported by work from Peebles and Brake (1985) who concluded that increased shell thickness (pore length) is associated with early embryonic mortality. However research by Peebles and Marks (1991) found that increased eggshell permeability was associated with an increased incidence of early and late deads.

1.3.5 Yolk Quality

The yolk (or follicle) is a rather large ovum as compared to mammalian ovum. The core of the ovum is composed of white yolk. This white yolk is compiled gradually from hatch until the follicle, then classified as a large white follicle, is recruited into the small yellow follicle heirarchy. Here yellow yolk is deposited in successive layers around the core. Studying the nutritional make-up of white and yellow yolk suggests that white yolk contains less protein and lipid and more water than does a large yellow follicle (Etches, 1996). When studying the large yellow follicles, its white yolk core is considered part of the follicle since the two are hard to distinguish apart. These components of the yolk are what sustain the growing embryo. Lipids are used as an energy source and an essential nutrient for tissue growth. Lipid metabolism is most prominent during the last 7 d of incubation, during which rapid embryonic growth occurs (Noble and Moore, 1964).

As stated earlier, egg weight increases with breeder hen age (Roque and Soares, 1994). This increase in egg weight is usually associated with an increase in yolk deposition (Bahr and Palmer, 1989). Leghorns experience the same trend, i.e., yolk weight and percent of yolk increased as hen age increased (Izat *et al.*, 1986; Rossi and Pompei, 1995). In turkeys, yolk weight and yolk as a percent of egg weight was negatively correlated with hatchability (Christensen and Nestor, 1994).

An egg's position within a sequence may also have some affect on yolk quality. Scott and Warren (1936) determined that the mature follicle from a first-of-sequence egg remains on the ovary approximately

16 h longer than any other sequence position. Consequently, a first-of-sequence egg takes about 40 h from oviposition to ovulation as compared to about 24 h for subsequent eggs (Etches, 1990). It has been suggested that this additional time spent on the ovary of the first-of-sequence egg, may have detrimental effects on fertility, hatchability and embryonic development at oviposition (Robinson *et al.*, 1991; Fasenko *et al.*, 1992a).

1.3.6 Albumen Quality

The function of albumen is one of protection and nourishment. Not only does albumen, along with the chalazae, hold the yolk in the center of the egg but it also prevents microorganisms from penetrating the embryo. Albumen also supplies water, proteins, and a variety of nutrients to the developing embryo (Benton and Brake, 1996). Albumen is a rich source of amino acids used during whole-body protein synthesis in a developing embryo. Embryos from high albumen content eggs had higher protein synthesis rates than did embryos from low albumen content eggs (Muramatsu *et al.*, 1990). Therefore the albumen and its proportion to the contents of the egg can be very important.

"Excluding disease, the single most important factor affecting the albumen quality of the freshly laid egg is the age of the bird that laid it" (Williams, 1992). Although albumen weight increases as the hen ages, percent albumen decreases due to the increase in percent yolk (Izat *et al.*, 1986). Chlorine, phosphorus and protein content of the albumen can also be altered by hen age. As protein content decreases with increasing hen age, a strong positive correlation can be observed in Haugh units (Cunningham *et al.*, 1960). To date, the most widely used and accepted measure of internal egg quality is the Haugh unit score (Williams, 1992). The Haugh unit is used to measure albumen height that takes into account the weight of the egg. Haugh unit values have been significantly correlated to more quality measurements than any other measurement studied including thin albumen, yolk centering, shape of thin albumen and percentage of thick and thin albumen. (Wesley and Stadelman, 1959).

The relationship between Haugh unit and hen age is essentially linear (Cunningham *et al.*, 1960). A decrease in Haugh unit score can also be described as a decrease in albumen quality or a decrease in albumen viscosity. This decrease in viscosity is thought to be a result of albumen liquefaction, a process that occurs within a few days of storage (Walsh, 1993). This process is temperature dependent and begins

when carbon dioxide escapes from the albumen causing the albumen to become more alkaline allowing liquefaction to commence. It is thought that this process of liquefaction may facilitate the movement of nutrients (Burley and Vadehra, 1989) and oxygen (Meuer and Baumann, 1988) necessary for the developing embryo. Thick albumen may provide one explanation why an increased incidence of early dead embryos has been reported in eggs set fresh as compared to eggs stored for a minimum amount of time. This thick albumen may impede sufficient oxygen from reaching the developing embryo (Benton and Brake, 1996).

The storage of hatching eggs can also contribute to the decrease in albumen quality. Early research by Romanoff and Romanoff (1949) found that as the albumen quality decreases with preincubation storage, a weight loss is also observed due to evaporative water loss. Since water is one of the nutrients supplied to the embryo via the albumen, moisture loss prior to incubation can be crucial. This egg weight loss due to storage has been related to embryonic mortality (Fasenko *et al.*, 1992b). The incidence of embryonic mortality was significantly higher in eggs that had been stored for longer periods of time and subsequently lost a greater amount of weight during storage due to moisture loss (Fasenko *et al.*, 1992b). Work done by Hurnik *et al.*, (1978) found that the poorer the albumen quality at oviposition, the more rapid the decline as a result of egg storage. The effects of preincubation storage on embryo development and hatchability will be discussed further in the following section.

1.3.7 Preincubation Storage

From oviposition on, the contents of the egg undergo continuous adjustments (Robinson, 1987). As the egg cools, the air cell is formed and continues to increase in size as moisture is lost via the pores in the shell. Loss in egg weight coupled with albumen liquefaction (as discussed in albumen quality) are the result of egg storage (Williams, 1992). The deterimental effects of storage prior to incubation on hatching eggs are inevitable for most hatching egg operations. Therefore, minimizing egg weight loss and albumen liquefaction while inhibiting microbial growth is the key to proper preincubation storage.

As the number of days of preincubation storage increases, egg weight loss due to moisture loss increases (Mather and Laughin, 1976). Proudfoot and Hamilton (1990) have suggested temperature standards for specific lengths of storage to help maintain egg quality. These authors observed that eggs

stored for less than 7 d should be stored at 16 to 17 °C and those stored for longer than 7 d should be stored at 11 to 12 °C. Haugh unit scores have been observed to decrease more slowly as storage temperatures decrease toward 0 °C (Proudfoot, 1962). Due to the cost of refrigeration, storing eggs at this temperature is rarely done in industry. A relative humidity of 80-85 % is suggested to reduce evaporative loss while inhibiting microbial growth (Hinton, 1968).

Research has shown that storage results in reduced embryonic development (Mather and Laughin, 1976) and reduces embryonic viability and therefore hatchability (Byng and Nash, 1962; Whitehead *et al.*, 1985). Fasenko (unpublished data, 1999) studied the precise time of reduced embryonic development due to egg storage. Comparing 4 and 14 d stored eggs, embryonic development was significantly lower in 14 d stored eggs after 6, 9, 12, 15, 18, 21 and 24 h of incubation. The number of additional hours of incubation required for 14 d stored eggs to reach internal and external pipping and hatching was approximately 10 h more than 4 d stored eggs. This supports findings of Kirk *et al.*(1980) who concluded that 1 d of storage = 1 h increase in hatching time. Reduced development and viability may be explained by work done by Funk and Biellier (1944) who observed the shrinking of blastoderm during storage. Similar work by Landauer (1967) reported that although embryos from stored eggs were smaller at 7 and 14 d, their growth rate was greater during the last 2 wk of incubation. Understanding how storage affects egg quality, embryo development and subsequent hatch may help to reduce detrimental effects.

1.4 FACTORS AFFECTING CHICK QUALITY

1.4.1 Introduction and Performance Objectives

Chick quality has always been difficult to define. From the hatchery's perspective it is defined functionally, as to whether or not a chick hatches on time and looks bright and lively with no developmental defects. A broiler producer's definition would include parameters such as livability, growth rate, immunological status, and body weights at processing. A processors view of chick quality would be based on criteria such as livability during transport to the processing line plus proper fleshing, body weights at processing and an empty gastrointestinal tract. Not knowing exactly what type of chick (big, small, long legs, yellow or white down, etc.) will give these results in the field, is where defining chick quality

becomes difficult. Current views on chick quality tend to include more attributes of the parent stock and less about the chick itself.

Very few attempts to define chick quality can be found in literature. Sinclair and Robinson (1987) suggested that chick quality could be related to the rate of moisture loss via the shell during incubation. Chicks from older flocks experience a higher degree of dehydration, possibly due to the larger surface area, decreased shell thickness and increased pore size of the egg shell. Other attempts to define chick quality and standardize a grading system have been quite extensive. Work done by Cervantes (1993) described a system in which physical, microbiological and serological scores are taken from a sample of chicks to determine chick quality. In Cervantes's work, it was recommended that 10 chicks per flock be sampled and that each flock be sampled at least once per month. He included nine areas of examination in the physical score including chick weight, appearance, legs, hocks, toes, eyes, vent, navel and hydration, and five areas in the microbiological score including total count, coliforms, *Staphylococcus aureus*, *Salmonella* and *Aspergillus sp.* The results of these two examinations are then averaged and the scores are rated, 100 being excellent and below 70 being unacceptable. In addition to the intensive nature of this scoring system and the limited size of the hatchery, the validity of hatcheries sharing and comparing results has been questioned. A pilot study was done at the University of Alberta to test Cervantes' chick quality system. Ten poultry researchers were given ten labeled chicks and each researcher graded each chick for physical characteristics according to Cervantes proposed quality system. The results were then compared and a large measure of variability between researchers was noted (Paul Goerzen, personal communication). Whether this variability could be minimized by specifically equating a physical abnormality with an appropriate reduction in score is questionable. More reliable and repeatable work in this area is needed if chick quality is going to be quantified.

1.4.2 Egg and Chick Weight

The effect of egg weight on chick size is well documented throughout literature (Wiley, 1950; Skoglund *et al.*, 1952; Bray and Iton, 1962; Al-Murrani, 1978; Jones, 1981). This relationship has been identified in very young embryos, where Wiley (1950) reported that egg size is positively correlated with the number of embryonic cells in a given microscopic field and is negatively correlated with cell size. This

relationship can be predicted as chick weight is between 62 and 76% of initial egg weight (Halbersleben and Mussehl, 1922; Upp, 1928; Jull and Heywang, 1930; Godfrey and Jaap, 1952; Godfrey and Williams, 1955; Henderson, 1956; Bray and Iton, 1962; Saeki and Akita, 1971; Guill and Washburn, 1973; Strong and Jaap, 1977; Bray, 1983; Whiting and Pesti, 1983; Petersen, 1984; Shanawany, 1987; Yannakopoulos and Tserveni-Gousi, 1987; Wilson and Harms, 1988).

This rather large range of 14% may be further explained by the difference between chick weight of the sexes. Many researchers have found male chicks to be larger than female chicks regardless of egg weight. (Godfrey and Jaap, 1952; Godfrey and Williams, 1955; O'Neil, 1955; Khan *et al.*, 1975). Burke and Sharp (1989) found that wet weights of 11 and 13 d male embryos as a percentage of egg weight were greater than those of female embryos. Dry weights however, showed no significant difference between the sexes. This apparent difference in moisture content between the sexes is supported by work done by Zawalsky (1962) where hatchling weight was corrected for egg size and hatch time (which is significantly shorter for female chicks), the difference due to gender was not significant (Zawalsky, 1962). Extensive discussion of moisture differences is important since chick quality has been expressed by the rate of moisture loss via the shell during incubation (Sinclair and Robinson, 1987).

1.4.3 Yolk Sac Characteristics

A developing embryo looks to the yolk for nutrients such as vitamins, protein and lipids for growth. As the avian embryo prepares for hatch, the yolk is internalized and is termed the yolk sac (Romanoff, 1960). The absorption of the yolk sac can ensure the chick of an adequate nutrient supply for 3 to 5 d posthatch (Chamblee *et al.*, 1992). More than 50 % of the total absorption of the yolk sac occurs in the first 48 h post hatch (Chamblee *et al.*, 1992). It has been postulated that early posthatch intake (dietary or yolk sac absorption) of carbohydrates triggers the initiation of growth (Thaxton and Parkhurst, 1976; Donaldson and Liou, 1976; Moran, 1989 and 1990).

Many suggestions have been given to describe the relationship between yolk sac size and chick size. Whiting and Pesti (1983) suggested that embryos from large eggs utilize nutrients more efficiently than embryos from small eggs. Skewes *et al.* (1988) suggested that chicks hatching from larger eggs would presumably have a survival advantage due to greater nutrient reserves. This would support the positive

correlation found between egg weight and chick weight to egg weight ratio. In the Bobwhite quail, egg weight is positively correlated with chick weight (0.88), yolk sac weight (0.38) and carcass (chick weight minus yolk sac weight) weight (0.73). Chick weight was positively correlated with yolk sac weight (0.37) and with carcass weight (0.86) however, carcass weight was negatively correlated with yolk sac weight (-0.16) (Skewes *et al.*, 1988). These findings suggest that a large chick would have a proportionally smaller yolk sac than a small chick and thus would use more of the yolk during development and have more reserves post hatch. The question of whether this increase in reserves would benefit the young broiler may be answered by looking at a study by Chamblee *et al.*, (1992), in which after 15 d, deutectomized chicks exhibited slower growth rates than undeutectomized chicks. However, this slower growth rate in deutectomized chicks was undetected at 4 wk of age. This suggests that yolk sac size does affect early growth rate but not growth potential, as there was no difference after 4 wk. This study also supports the idea that the trigger for initiating growth can be from yolk sac or dietary origin.

1.5 FACTORS AFFECTING BROILER GROWTH AND FEED CONVERSION

1.5.1 Egg and Hatchling Weight

As stated earlier, research has identified a strong correlation between egg weight and hatchling weight (Wiley, 1950; Al Murrani, 1978; Jones, 1981), it is therefore economically important to consider the potential effect of initial egg weight on subsequent broiler weight. Early experimentation found little association between egg weight or hatchling weight on body weight after 2 wk of age however, the correlation was generally positive in chickens (Upp, 1928; Wiley, 1950) and turkeys (Scott and Phillips, 1936). Contrary research shows a small positive relationship between egg or chick weight to body weight after 6 wk (Kosin *et al.*, 1952). Some recent research defined the correlation of egg weight and body weight at 5 to 8 wk, as significant and ranged from 0.3 to 0.5 (Proudfoot *et al.*, 1982; Petersen, 1984; Hearn, 1986).

Research comparing the weight of 12 wk old broilers from specific egg weight ranges, found that the heaviest broilers, which generated the most cash income, came from eggs weighing between 59 to 70 g (Skoglund and Tomhave, 1949; Skoglund *et al.*, 1952). Broilers with the poorest results came from eggs weighing less than 52 g (Tindell and Morris, 1964). Economic returns estimated from broilers hatched

from 60 to 69g eggs compared to 45 to 49 and 50 to 59g are $0.08 and $0.05 (US) per bird respectively (Somaiah and Shirley, 1963). Rules of thumb have been suggested to estimate the influence of egg size on broiler growth. Goodwin (1961) suggests a 12.7g increase in 9-wk broiler growth with each 1g increase in egg weight while, Somaiah and Shirley, (1963) suggest a 8.2 g increase in broiler growth from young breeders and a 2.6 g increase from old breeders for every 1 g increase in egg weight.

Raju *et al.* (1997) studied the effect of egg weight on hatchability, chick weight and post-hatch performance. Four groups of egg weights including A) up to 60g, B) 60.1 to 65g, C) 65.1 to 70g and D) >70g, were hatched and groups were reared separately or in competition with other groups. Although fertility and hatch weight as a percent of egg weight remained unaffected by egg size, hatchability decreased and hatchling weight increased with increasing egg weight. Body weight was significantly decreased in group A and increased in group C and D, while feed conversion remained comparable for all groups. Interestingly, rearing chicks according to hatch weight resulted in greater body weight at 6 wk of age with reduced variation in chick performance among groups, and decreased mortality (Raju *et al.*, 1997).

1.5.2 Strain

Work done at the University of Alberta has compared the weekly growth of broilers from four different strains including Cobb 500, Avian 24K, Hubbard HiY and Shaver Starbro. Body weights between strains were significantly different at d 0, with mean body weight ranging from 42.9 to 45.0g. This difference was no longer apparent at 42 d (Robinson, unpublished data, 1999). It can therefore be concluded that the different strains have different growth rates. Moran *et al.*, (1984) did similar work comparing two turkey strains, British United (BUT) and Nicholas and observed a slower initial growth rate exhibited by the BUT strain as compared to Nicholas. The opposite trend in growth rate occurred as the birds approached market weight. Interestingly, through the past 50 years of selection by various breeding companies, the market weight of different broiler strains remain very similar while their growth rates remain so distinct.

1.6 FACTORS AFFECTING BREAST YIELD AND CONFORMATION

An extensive experiment comparing four different BB strains and their progeny was conducted at the University of Alberta in 1997 and 1998 (Robinson, personal communication). Egg production, hatchability, sequence and egg quality measurements were performed on the BB parents and 6 wk body weights, feed conversion, breast yield and breast confirmation analysis was performed on the broiler progeny.

No significant differences in *Pectoralis major* area, width and center length were found between strains. The mean thickness of the *P. major* was significantly larger in two of the strains. Strains with significantly thicker *P. major*, also had larger total breast muscle, and more specifically, greater *P. major* weights. These preliminary results suggest that, in the process of selecting for increased breast muscle, the breast in turn has become thicker. The thickness of the breast muscle can affect the cooking time and is therefore important for further processors. Variation between strains can therefore affect the uniformity of the breast and result in inconsistent cooking times. The relationship between weight and conformation of the breast muscle will be an important focus for future research.

1.7 INTRODUCTION TO CHAPTERS

During the past 50 years, changes in the genetics of the broiler have been aimed at increasing body weight and growth rate. While these changes have been extremely successful in improving broiler production, they have been at the expense of egg production of the BB hen. Current research surrounding the BB hen include manipulating environment and management strategies to improve egg production, fertility and hatchability. Questions surrounding the effect of such strategies on subsequent egg quality, chick quality and broiler performance have been raised. The effects of parental strain, age, feed and photostimulation program and length of preincubation storage on egg quality and chick quality are examined in Chapters 2 and 3, respectively. Chapter 4 examines the effects of egg storage, parental strain, maternal feed and photostimulation program on growth performance of chicks from 60 wk old BB hens.

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2. EFFECTS OF AGE, STRAIN, FEEDING PROGRAM AND PHOTOSTIMULATION PROGRAM ON EGG CHARACTERISTICS IN BROILER BREEDERS HENS

2.1 INTRODUCTION

Continuing changes in broiler genetics resulting in a 3% increase in growth per year (McCarthy and Siegel, 1983) have had significant detrimental effects on broiler breeder (BB) egg production. The BB industry has responded by altering management strategies to maximize production. Management changes such as feed restriction have resulted in improvements in egg production, fertility, hatchability and viability over traditionally full-fed hens (Yu *et al.*, 1992). Recent research has focused on fine tuning such management tools with success in improving egg production (Muller, 1997). While the success of such management strategies are measured using parameters such as egg production, BB research has neglected to test the quality of eggs produced in terms of the productivity of resulting chicks.

Research dealing with the quality of hatching eggs, although not as extensive as research on table egg quality, has emphasized the importance of each portion of the egg. The shell of a hatching egg functions not only as protection but also as a functional organ during incubation. The importance of proper water loss during incubation is a function of the shell and is therefore directly related to shell quality (Tullet and Burton, 1982). Water loss also affects albumen quality. Benton and Brake (1996) suggested that thick albumen can impede the movement of oxygen and nutrients to the blastoderm. Therefore, the influence of BB management on these egg components can and should compliment research on BB production.

The present study aims to deliver a comprehensive investigation of how differences in management, genetics, hen age and egg storage affect egg quality, with particular importance focused on egg weight, egg composition, specific gravity, and Haugh unit score.

2.2 MATERIALS AND METHODS

2.2.1 Stocks and Management before 20 wk of Age

A total of 800 broiler breeder pullets of two strains were obtained from Shaver Breeding Farms Ltd. (Cambridge, Ontario). One strain was Shaver Starbro (SS) and the other was a Shaver experimental line (EL), further selected for breast yield. The pullets were reared strain separate in floor pens on 24 h of

light and zero (24L:0D). At 2 d of age, the lighting program was changed to 8L:16D. Pullets received *ad libitum* feed and water for 3 wk after which a skip-a-day feeding program was implemented. The pullets were beak-trimmed at 1 wk of age and individually wing-banded at 3 wk of age. Both strains were managed according to the Shaver Starbro guidelines for body weight. Weekly pen weights and birds per pen were tabulated to determine average body weight and weekly feed allocation. Individual body weight were recorded every 4 wk (4, 8, 12, 16 and 20 wk of age).

2.2.2 Stocks and Management After 20 wk of Age

At 20 wk of age, all birds were individually weighed and the 288 birds (144 of each strain) closest to the target body weight were individually caged. At 21 wk of age the birds were randomly assigned to one of two feed allocation treatments, Fast Feed (FF) or Slow Feed (SF) and one of two photoperiod treatments, Fast Photoperiod (FP) or Slow Photoperiod (SP). The FF treatment was a more aggressive feed allocation program as compared to the SF treatment (Table II-1). Birds were individually fed from 20 to 60 wk of age. Individual feed was weighed using an automated feed allocation system (Feddes *et al.*, 1995). At 21 wk of age, birds in the FP were subjected to an abrupt increase in the amount of light per d from 8L:16D to 15L:9D, while the birds in the SP treatment received a gradual step-wise increase in light per d (Figure II-1). A dusk-to-dawn lighting computer-controlled system was used to stimulate the natural increase and decrease of daylight as the light came on and off in the barn. A light-tight impermeable black polyethylene wall was constructed down the middle of the barn at 20 wk of age, to facilitate two distinct photoperiods within one room. Room temperature was monitored on each side of the partition twice per d (am and pm) to ensure the ventilation was being distributed evenly between each side of the room. Room temperature was maintained between 16 and 23°C.

Individual body weight data were recorded each wk and used to determine feed allocation. When increases in feed allocation exceeded more than 6 g / wk / bird, the increase was divided into two or three increments to avoid rapid increases in body weight.

Insemination was performed once per wk from undiluted, pooled semen taken from 60 Shaver Starbro males. The males were individually caged in the same facility as the females and managed according to the primary breeder recommendations.

2.2.3 Egg Collection and Handling

Egg collection was conducted at approximately 3:00 pm every day for 7 consecutive d during each sample wk (30, 40, 50 and 60 wk). A fresh egg weight was recorded and the eggs were stored up to 6 d at approximately 16 to 18°C and 56 % relative humidity. At the end of each sample wk, two eggs were randomly chosen from each hen and a second egg weight was measured and termed "stored egg weight". These eggs were left at room temperature for approximately 16 h (overnight), at which time a "break egg weight", specific gravity, albumen height and yolk weights were determined.

2.2.4 Specific Gravity and Albumen Height

On d 6 of the preincubation storage treatment, eggs were taken out of the cooler, weighed individually (stored egg weight) and left at room temperature overnight. The following morning all eggs were individually weighed prior to the measurement of specific gravity (break egg weight). Salt solutions ranged in specific gravity from 1.056 to 1.094 with 0.002 increments were prepared using a hydrometer. These solutions were tested frequently to assure the accuracy of each salt concentration. Beginning with the lowest salt concentration, eggs were dipped into increasing salt concentration solutions. The first salt concentration in which the egg floated was recorded and the eggs were rinsed with temperate water and hand dried using paper towels.

Each egg was broken and albumen height was recorded using an albumen height gauge (Queensboro Instruments, 645 Brierwood Avenue, Ottawa, Canada K2A 2J3). The yolk was removed from the albumen and weighed. To ensure all albumen was removed, the yolk was rolled on paper towel prior to being weighed. The shell was rinsed under running water and placed broken ends down on egg flats to air dry. After 1 wk, dry shell weight was recorded.

Albumen weight was determined by subtracting yolk weight and dry shell weight from break egg weight. Weight loss during storage was determined by subtracting stored egg weight from fresh egg weight. Albumen height was converted into Haugh Units (Haugh, 1937). If an egg was broken or a data point lost (ie., yolk broke before a weight was taken or membranes surrounding albumen were broken before height was taken, etc.) the egg was removed from the data set.

2.2.5 Statistical Analyses

The main experiment was designed as a 2 x 2 x 2 factorial with the main effects being maternal strain (SS or EL), feeding program (FF or SF) and photostimulation program (FP or SP). Egg trait data were also analyzed within the context of hen age (30, 40, 50 or 60 wk) and preincubation egg storage time (0, 1, 2, 3, 4, 5, or 6 d). The resulting experimental design was a 2 x 2 x 2 x 4 x 7 factorial and data were analyzed using the General Linear Models Procedure of SAS (SAS Institute, 1996). The error term for the three main effects being strain, feeding program and photostimulation program, was hen within the final interaction. Error variation including hen age and storage consisted of the variation between birds within the last interaction. Differences between means were evaluated using Fischer's protected LSD procedure (Peterson, 1985). Where observations between means were unequal, the largest standard error of the mean (SEM) was reported. Significance was assessed at the $P<0.05$ level unless otherwise stated. Because of the number of possible interactions in a 2 x 2 x 2 x 4 x 7 factorial, only pertinent interactions will be discussed.

2.3 RESULTS

No significant differences were observed for any egg quality parameter due to the main effects of feeding program or photostimulation program. Therefore the results of these main effects will not be discussed further in this chapter. Maternal management treatments were not distinct enough to influence the eggs produced. This means that such management practices can be adapted without affecting egg traits. However the treatments imposed were not very extreme compared to full-feeding. It is concluded that the hen did not change the components of the egg or the quality of each component in response to the feed or photostimulation program used in this study.

2.3.1 Egg Weight

No significanct differences were observed between means for fresh, stored and break egg weight due to strain differences (Table II-2). As expected, mean fresh, stored and break egg weight significantly increased with increasing hen age ($P=0.0001$). Mean fresh, stored and break egg weight decreased as days of storage increased ($P=0.0001$). Increased egg weight loss due to an increase in the number of days storage is well-documented (Mather and Laughin, 1976). This however, does not apply to the apparent

decrease in fresh egg weight since a storage treatment had not yet been implemented. We suspect that the large number of eggs used for this trial (1954) may have allowed for this difference to be detectable. We also expect that the increase in egg weight associated with increased hen age may be apparent during the duration of one wk collection of eggs. Since egg weight is known to increase approximately 10 g over 30 wk of production, an average increase egg weight seen within each wk would represent approximately 0.33 g. It is also clear that the increase in egg weight is more dramatic early on in production which could explain an increase in egg weight as age increased.

2.3.2 Egg Weight Loss

Maternal strain had no significant effect on absolute or proportional egg weight loss during storage. A 79% increase in absolute weight loss (p=0.0001) and a 62% increase in relative weight loss due to storage (p=0.0001) was observed between 30 and 40 wk of hen age (Table II-3). No significant differences in absolute or proportional weight loss were exhibited between any other hen age period. Absolute and relative egg weight loss due to storage significantly increased with increasing days of storage (p=0.0001). A distinct difference between d 2 and 3 of egg storage is evident in relative egg weight loss, before and after which there are no further significant differences in relative egg weight loss.

2.3.3 Egg Components

While fresh egg weight was not different between the strains (Table II-2), eggs from EL birds had greater proportional yolk weight (p=0.0226) and lower absolute and proportional shell weights (p=0.0001) than eggs from SS birds (Table II-4). No difference in either absolute or relative albumen weight was observed between the two strains. Absolute yolk, albumen and shell weight increased with hen age (p=0.0001)(Table II-4). However, relative to break egg weight, yolk is the only component that increased in weight with hen age (p=0.0001). Relative albumen and shell weight decreased with hen age (p=0.0001).

As days of storage increased, absolute yolk and albumen weight decreased (p=0.0035 and p=0.0001, respectively) (Table II-4), while shell weight remained unchanged (p=0.2970). Proportionally, yolk and shell weight increased with increased days of storage (p=0.0002 and p=0.0001, respectively)

while albumen weight decreased (p=0.0001). This suggests that moisture loss as a result of preincubation egg storage was limited to the albumen.

Table II-5 shows the interaction effect of age and strain on egg composition. At 30 wk of age SS hens laid significantly larger eggs than EL hens but by 50 wk of age this difference disappeared. Change in egg composition due to age was also strain specific. Eggs from EL hens began the production period with a significantly greater percentage of albumen weight than eggs from SS hens and comparable relative yolk weight. By 40 wk of age, eggs from EL hens contained significantly greater yolk weight than eggs from SS birds and while albumen weight remained comparable. This trend in egg composition continued through 60 wk of age. Therefore, although egg weight of both strains increased with age, relative yolk weight increased to a greater extent in eggs from EL hens as compared to eggs from SS hens. Although relative albumen weights between strains were significantly different early in the production period no difference in Haugh unit score was evident during this time. However, differences in Haugh unit score occured during the 50 and 60 wk sample periods. This may be a result of increases in egg weight, which increases the surface area of albumen undergoing moisture loss during egg cooling (air cell formation). This coupled with the consistently lower shell weights of eggs from EL birds may explain the lower Haugh unit score of eggs from EL birds during 50 and 60 wk of age.

2.3.4 Egg Characteristics

A significantly lower specific gravity was found for eggs from EL birds as compared to eggs from SS birds (p=0.0001) (Table II-6). This corroborates the lower shell weight (absolute and percent) observed earlier in eggs from EL hens (Table II-4). Mean specific gravity decreased significantly between each sample age (p=0.0001) and between each additional day of storage (p=0.0001) (Table II-6). Changes in specific gravity due to egg storage (1.078 to 1.070) were similar to changes due to hen age (1.080 to 1.070). It is interesting to note that the extent of egg quality deterioration observed over the life of the hen is essentially the same as egg quality deterioration over 7 d of storage.

Haugh unit score was not affected by strain differences. Although significant differences in Haugh unit score were observed as the hen aged, the pattern was not linear (p=0.0001) (Table II-6).

Table II-7 describes the interaction effect of hen age and days of storage on egg characterisitics. Eggs from 30 wk old hen decreased 0.004 units in specific gravity due to 7 d of storage while eggs from 50 wk old hen dropped 0.01 units during the same length of storage. Therefore eggs from older hens are more susceptible to drastic decreases in specific gravity as d of storage increases ($p=0.0001$) (Table II-7). Haugh unit score decreased significantly with the increase in days of storage ($p=0.0001$). Haugh units decreased approximately 7 units over 7 d of storage, with the greatest decrease evident between d 0 and d 1 (2.36) (Table II-7).

2.4 DISCUSSION

The greatest increase in absolute fresh, stored and break egg weight occurred between 30 and 40 wk of age (6.2, 6.0 and 5.9 g, respectively). Hamilton (1978) also observed the largest increase in egg weight in Leghorns to be early in production (between 23 and 32 wk). The mean increase in egg weight (fresh, stored and break) over the entire production cycle (30 wk) was 9.9, 9.6 and 9.6 g, respectively in that study. Comparatively, a 10.2 g increase in egg weight over 25 wk of production was observed in BB hens (Mather and Laughlin, 1979) and a 10.6 g increase over 32 wk of production in Leghorn hens (Fletcher *et al.*, 1981).

In the present study, eggs from young hens (30 wk) lost significantly less moisture (absolute and relative) during storage than did eggs from post peak hens (>40 wk). This is contrary to a study by Meijerhof *et al.*, (Submitted) in which moisture loss due to 7 d of storage was not different between eggs laid by hens at 33 or 55 wk of age. This reduction in moisture loss observed in the eggs of young hens may be a result of the combination of egg size and shell weight. Young breeders lay small eggs with proportionally more shell than eggs laid later in the production period (Table II-3). Smaller eggs not only have a thicker shell, which provides more resistance for the movement of gases, but also have reduced surface area from which moisture loss through evaporation can occur. The inability of the shell from eggs of young hens to release moisture may be associated with depressed hatchability found in young BB flocks (Roque and Soares, 1994) and problems associated with thick albumen (Benton and Brake, 1996). It is therefore concluded that the increase in egg weight loss from eggs from hens aged 30 and 40 wk is primarily due to the large increase in total egg weight also observed during this time. Such an increase in

egg weight results in an increase in the evaporative surface area of the egg and may be responsible for the increase in moisture loss during storage.

Mayes and Takeballi (1984) reported that most commercial hatcheries aim to set eggs within 3 to 4 d of oviposition in the hopes of avoiding the negative effects of prolonged storage. Depressed hatchability of 0.5 % / d (Hodgetts, 1981) is the main concern when eggs are stored for a prolonged amount of time. Many researchers have tried to define what prolonged storage is. Scott (1933) suggests 7 d while Bohren *et al.* (1961) and Kirk *et al.* (1980) suggest hatchability begins to decrease after only 2 to 3 d of storage. In the present experiment relative moisture loss during the first 3 d of storage was significantly lower than loss due to 4, 5 or 6 d of storage. Evidence of gradual moisture loss can be seen in significant decreases in specific gravity score with each day of storage. The importance of optimal moisture loss during incubation (10-12%) has been well established (Mather and Laughlin, 1976). Mayes and Takeballi (1984) suggest that moisture loss during storage and moisture loss during incubation is cumulative in nature and therefore every attempt to prevent moisture loss during storage should be taken. Further aspects of the cumulative nature of moisture loss prior to incubation and during incubation will be discussed in Chapter 3.

Roland *et al.* (1975) was the first to link the disproportionate changes in egg components to the decrease in shell quality as Leghorn hens age. Roland suggests that, depositing shell which does not proportionately increase with the increase in egg weight as the hen ages, results in a thinner shell and poorer shell quality later in lay. This is evident in the present study in which fresh egg weight increased while relative shell weight and specific gravity decreased significantly with hen age. The largest increase in egg weight was observed during 30 and 40 wk of age. This increase coincided with the largest decrease in specific gravity, supporting Roland's theory that changes in proportional egg components affect egg (shell) quality. Roland (1979) observed an increase of egg weight (14.5%) and a decrease in specific gravity (0.012 units) over a 9 month period in Leghorns. The current study found an increase in egg weight (14.4%) and a decrease in specific gravity (0.010 units) over only 30 wk in BB. Rapid decline in relative shell weight with age in BB hens only exaggerates the decline in specific gravity score and clearly defines the plight of the BB hen concerning egg quality.

An increase in proportional yolk weight with hen age has been well established in meat-type hens (O'Sullivan *et al.*, 1991; Applegate and Lilburn, 1996) and in egg-type hens (Fletcher *et al.*, 1981; Rossi

and Pompei, 1995). The increase in percent yolk weight with hen age is due to an increase in dry matter or yolk solids rather than moisture in BB (O'Sullivan *et al.*, 1991) and Leghorn hens (Fletcher *et al.*, 1983). It has been suggested that this increase in the availability of lipid resources to the embryo and improvements in embryo metabolism may be associated with the higher embryonic weight and hatchability apparent in older hens. The impact of increased proportional yolk weight on chick weight and subsequent performance will be addressed further in the following chapters.

Fletcher *et al.* (1983) suggests that the only way to increase yolk solids is to increase yolk content by selecting for larger eggs or by collecting eggs from older hens. Rather than select for larger eggs, the broiler industry has selected for increased body weight but with similar results. Since body weight has been highly correlated with egg size (Shanawany, 1987; Anthony *et al.*, 1989) we would expect that each years selection criteria (increase body weight, muscle mass, etc.) would result in larger hens and larger eggs with more proportional yolk. Such a theory is consistent with research in which hens selected for increased abdominal fat (Cahaner *et al.*, 1986) and body weight (Anthony *et al.*, 1989) laid eggs consisting of relatively larger yolks with greater lipid content than unselected strains. It is not surprising then that the EL hens laid eggs with proportionally more yolk than did SS hens. Unfortunately this increase in proportional yolk appears to be deposited at the expense of proportional shell weight. Anthony *et al.*, (1989) also reported a significantly lower percent shell weight in high body weight hens (8.56 %) as compared to low body weight hens (9.60 %). The repercussions of this can be seen in significantly lower specific gravity scores for eggs from EL hens (1.072) as compared to eggs from SS hens (1.076). The interaction of hen age with strain further describes the further selected hen's (EL) susceptibility to the added effects of age on the components within the egg. This information is helpful in describing a trend associated with breast muscle (and therefore body weight) selection and egg quality in meat-type birds.

Research in Leghorn hens has found a decrease of 10 Haugh units as hen age increased from 34 to 57 wk (Poggenpoel, 1986). We would expect Haugh unit score to decrease with hen age since research has shown that albumen from eggs of older hens is less viscous than is the albumen from the eggs of younger hens (Fletcher *et al.*, 1983). Monsey *et al.* (1977) for example, found that the proportion of thick to thin albumen was drastically altered in eggs from 50 wk old hens at which time thick albumen was approximately half the amount it was at the onset of lay. We may attribute the Haugh unit results as the

hen age increases in the current study, to inconsistent environmental conditions in the barn and/or laboratory in which albumen height was recorded.

The increase in albumen liquefaction due to an increase in egg age is widely acknowledged but not well understood (Burley and Vadehra, 1989). Benton and Brake (1996) suggest that the storage of eggs is essential to allow for the liquefaction of albumen and therefore prevent resistance to gas diffusion and nutrient availability. Significant reductions in Haugh unit score were observed during the first 4 d of storage after which the decreases were more gradual. Changes in Haugh unit score seem to occur shortly after relative moisture loss due to storage plateaued. The interaction of hen age and storage suggests that, as the hen ages, the degenerative effects of storage are slowed. Table II-7 showed that Haugh unit score do decrease as days of storage increases during each age period but the decrease is smaller for each increasing age period. For example, eggs laid by 30 wk old hens decreased 8.53 units over 7 d of storage compared to a decrease of 5.14 units of eggs from 60 wk old hens over the same length of storage. This suggests that storage time, as Benton and Brake (1996) recommend, is all the more important for eggs of older BB hens.

In conclusion, hen age and strain influenced egg weight and egg components. As hen age increased egg weight increased mainly due to the disproportionate increase of yolk weight at the expense of shell weight. The impact of this disproportionate change in egg components was evident in decreaseing specific gravity score with hen age. Egg weight was not different between strains but eggs from EL hens had significantly greater proportional yolk weights and lower shell weight than did eggs from SS hens. Eggs from EL hens also had lower specific gravity scores than did eggs from SS hens. Preincubation egg storage resulted in moisture loss from the albumen and significantly lower specific gravity score and Haugh unit score. Maternal feed and photostimulation treatments had no influence on egg traits.

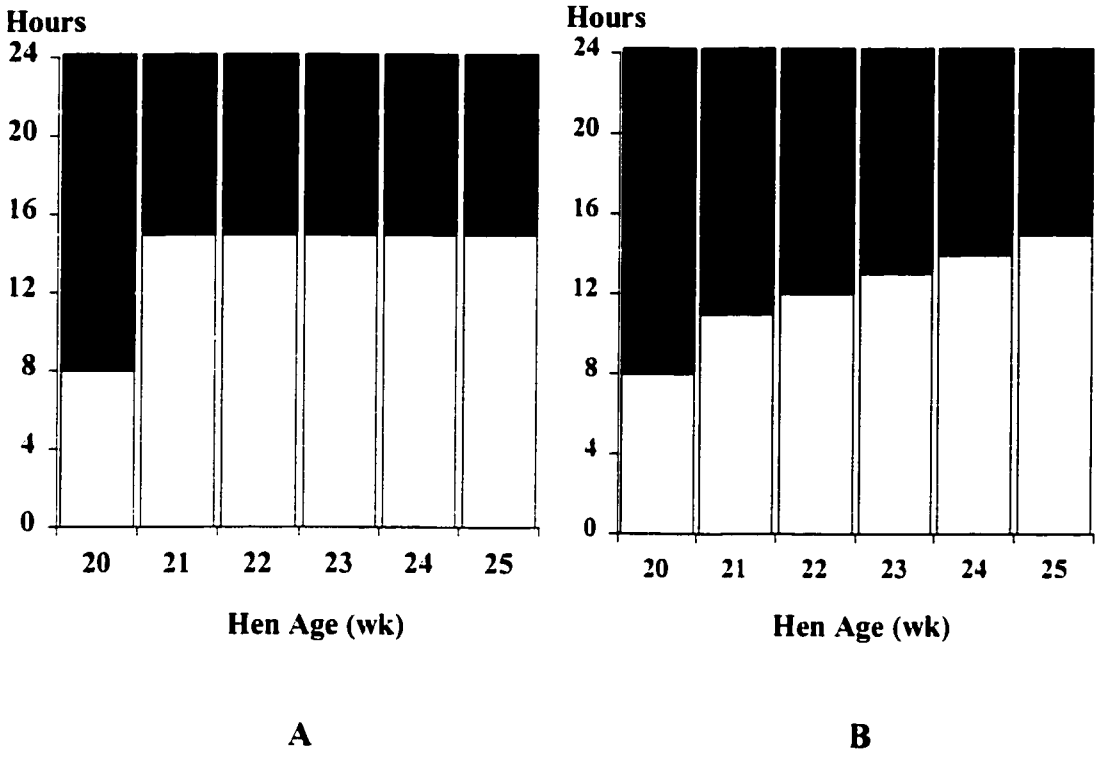

Figure II-1 **Photostimulation programs** - Number of hours of daylight (white bars) and dark (black bars) per 24 hour period A. Fast photostimulation program B. Slow photostimulation program.

Table II-1. **Daily feed allocation of feeding program (fast or slow) from 21 to 60 wk of age for all birds individually caged (g/bird/d). When feed increases exceeded 6 g/wk, the allocations were divided into two or three smaller equal increases that wk.**

	Feeding Allocation(g / bird / d)	
Age (wk)	Fast Feed (FF)	Slow Feed (SF)
21 to 22	125	100
22 to 23	130	105
23 to 24	130	113
24 to 25	130	119
25 to 26	130	128
26 to 27	130	137
27 to 28	140	140
28 to 29	142	148
29 to 30	143	153
30 to 31	147	158
31 to 32	150	158
32 to 33	152	158
33 to 34	152	158
34 to 35	150	156
35 to 36	148	154
36 to 37	145	151
37 to 38	144	150
38 to 39	141	147
39 to 40	139	145
40 to 41	139	144
41 to 42	138	143
42 to 43	138	143
43 to 44	138	143
44 to 45	136	141
45 to 46	136	141
46 to 47	134	138
47 to 48	134	138
48 to 49	133	137
49 to 50	131	136
50 to 51	131	135
51 to 52	130	134
52 to 53	130	133
53 to 54	129	133
54 to 55	129	133
55 to 56	125	129
56 to 57	125	129
57 to 58	125	129
58 to 59	125	129
59 to 60	125	129

Table II-2 **Effects of maternal strain, feeding treatment, photostimulation treatment, hen age and preincubation egg storage on fresh egg weight, stored egg weight and egg weight just prior to breakout (g).**

Main Effects	Fresh egg weight (g)	Stored egg weight (g)	Egg weight prior to breakout (g)
Strain			
EL[1]	64.8	64.4	64.2
SS[2]	65.2	64.8	64.6
SEM	0.4	0.4	0.3
Feeding Tmt.			
FF[3]	65.2	64.8	64.6
SF[4]	64.8	64.4	64.2
SEM	0.4	0.4	0.3
Photostimulation Tmt.			
FP[5]	64.7	64.3	64.1
SP[6]	65.3	64.9	64.7
SEM	0.3	0.4	0.3
Hen Age (wk)			
30	58.8^{d}	58.6^{d}	58.5^{d}
40	65.0^{c}	64.6^{c}	64.4^{c}
50	67.4^{b}	66.9^{b}	66.7^{b}
60	68.7^{a}	68.2^{a}	68.1^{a}
SEM	0.1	0.1	0.1
Preincubation Storage (d)			
0	65.3^{ab}	65.3^{a}	64.9^{ab}
1	65.6^{a}	65.3^{a}	65.2^{a}
2	64.9^{bc}	64.6^{bc}	64.5^{bc}
3	65.3^{ab}	64.8^{b}	64.7^{b}
4	64.8^{cd}	64.2^{c}	64.1^{cd}
5	64.6^{cd}	64.1^{cd}	63.9^{d}
6	64.4^{d}	63.7^{d}	63.7^{d}
SEM	0.2	0.2	0.2

Main Effects	Probability		
Strain	0.5112	0.4394	0.4672
Feeding Tmt.	0.4019	0.3660	0.4023
Photostimulation Tmt.	0.1737	0.2126	0.2141
Hen Age	0.0001	0.0001	0.0001
Preincubation Storage	0.0001	0.0001	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table II-3 **Effects of maternal strain, feeding treatment, photostimulation treatment, hen age and preincubation egg storage on egg weight loss during storage (g) and relative to fresh egg weight (%).**

	Egg Weight Loss During Storage	
Main Effects	(g)	(%)
Strain		
EL[1]	0.586	0.894
SS[2]	0.556	0.828
SEM	0.035	0.050
Feeding Tmt.		
FF[3]	0.574	0.866
SF[4]	0.568	0.856
SEM	0.034	0.050
Photostimulation Tmt.		
FP[5]	0.557	0.851
SP[6]	0.585	0.871
SEM	0.034	0.050
Hen Age (wk)		
30	0.323[b]	0.544[b]
40	0.578[a]	0.886[a]
50	0.703[a]	1.035[a]
60	0.681[a]	0.979[a]
SEM	0.051	0.075
Preincubation Storage (d)		
0	0.350[c]	0.515[b]
1	0.419[c]	0.624[b]
2	0.468[bc]	0.708[b]
3	0.645[ab]	0.971[a]
4	0.680[a]	1.029[a]
5	0.768[a]	1.159[a]
6	0.670[a]	1.022[a]
SEM	0.070	0.103
Main Effects	Probability	
Strain	0.5353	0.3358
Feeding Tmt.	0.9074	0.8895
Photostimulation Tmt.	0.5596	0.7827
Hen Age	0.0001	0.0001
Preincubation Storage	0.0001	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table II-4 **Effects of maternal strain, feeding treatment, photostimulation treatment, hen age and preincubation egg storage on egg composition on an absolute basis (g) and relative to break egg weight (%).**

	Yolk Weight		Albumen Weight		Shell Weight	
Main Effects	(g)	(%)	(g)	(%)	(g)	(%)
Strain						
EL[1]	19.4	30.1[a]	39.4	61.3	5.52[b]	8.60[b]
SS[2]	19.1	29.6[b]	39.6	61.3	5.87[a]	9.10[a]
SEM	0.1	0.2	0.3	0.2	0.04	0.10
Feeding Tmt.						
FF[3]	19.3	29.8	39.7	61.4	5.68	8.80
SF[4]	19.2	29.8	39.3	61.3	5.71	8.90
SEM	0.1	0.2	0.3	0.2	0.04	0.1
Photostimulation Tmt.						
FP[5]	19.2	29.8	39.3	61.3	5.65	8.82
SP[6]	19.3	29.8	39.7	61.3	5.74	8.89
SEM	0.1	0.1	0.3	0.2	0.04	0.1
Hen Age (wk)						
30	16.0[d]	27.4[d]	37.2[d]	63.5[a]	5.28[d]	9.03[a]
40	19.1[c]	29.6[c]	39.6[c]	61.5[b]	5.73[c]	8.90[b]
50	20.6[b]	30.9[b]	40.3[b]	60.4[c]	5.82[b]	8.73[c]
60	21.3[a]	31.3[a]	40.8[a]	59.9[d]	5.96[a]	8.76[c]
SEM	0.1	0.1	0.1	0.1	0.02	0.03
Preincubation Storage (d)						
0	19.2[bc]	29.5[c]	40.1[a]	61.8[a]	5.65	8.72[d]
1	19.5[a]	29.8[ab]	40.0[a]	61.4[b]	5.74	8.82[cd]
2	19.2[bc]	29.7[b]	39.6[bc]	61.4[b]	5.69	8.84[c]
3	19.3[ab]	29.9[ab]	39.6[b]	61.3[b]	5.70	8.83[c]
4	19.2[bc]	29.9[ab]	39.3[cd]	61.3[bc]	5.67	8.86[bc]
5	19.2[bc]	30.0[a]	39.0[de]	61.1[c]	5.71	8.95[ab]
6	19.1[c]	30.0[a]	38.9[e]	61.1[c]	5.71	8.96[a]
SEM	0.1	0.1	0.1	0.1	0.03	0.04

Main Effects	Probability					
Strain	0.1602	0.0226	0.5506	0.9168	0.0001	0.0001
Feeding Tmt.	0.5125	0.9311	0.3848	0.6179	0.6088	0.1611
Photostimulation Tmt.	0.3312	0.8369	0.3070	0.9295	0.0839	0.3629
Hen Age	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Preincubation Storage	0.0035	0.0002	0.0001	0.0001	0.2970	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table II-5 **Interactaion of maternal age (wk) by maternal strain on fresh egg weight (g), yolk as a percent of break weight (%), albumen as a percent of break weight (%), shell as a percent of break weight (%) and Haugh units.**

Interaction		Fresh Egg Weight	Relative Yolk Weight	Relative Albumen Weight	Relative Shell Weight	Haugh Unit
		(g)	(%)	(%)	(%)	
Age (wk) x Strain						
30	EL[1]	58.4[b]	27.5	63.7[a]	8.79[b]	77.17
	SS[2]	59.2[a]	27.4	63.4[b]	9.26[a]	77.19
40	EL	64.6[b]	29.9[a]	61.5	8.66[b]	73.76
	SS	65.3[a]	29.4[b]	61.4	9.15[a]	73.82
50	EL	67.4	31.2[a]	60.3	8.52[b]	79.69[b]
	SS	67.6	30.5[b]	60.5	8.93[a]	81.44[a]
60	EL	68.8	31.7[a]	59.9	8.44[b]	75.90[b]
	SS	68.5	31.0[b]	60.0	9.07[a]	78.25[a]
	SEM	0.2	0.1	0.1	0.04	0.40
Interaction				Probability		
Age x Strain		0.0019	0.0006	0.0046	0.0189	0.0014

[a,b] For each main effect or the interaction, means within a column with no common superscript differ significantly. Interaction means are compared within an age ($P < 0.05$).

[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9

[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9

Table II-6 **Effects of maternal strain, feeding treatment, photostimulation treatment, hen age and preincubation egg storage on specific gravity and Haugh unit.**

Main Effects	Specific Gravity	Haugh Unit
Strain		
EL[1]	1.072[b]	76.63
SS[2]	1.076[a]	77.70
SEM	0.0004	0.55
Feeding Tmt.		
FF[3]	1.074	77.34
SF[4]	1.074	77.00
SEM	0.0004	0.55
Photostimulation Tmt.		
FP[5]	1.074	77.73
SP[6]	1.074	76.60
SEM	0.0004	0.54
Hen Age (wk)		
30	1.080[a]	77.18[b]
40	1.075[b]	73.80[c]
50	1.072[c]	80.56[a]
60	1.070[d]	77.12[b]
SEM	0.0002	0.28
Preincubation Storage (d)		
0	1.078[a]	81.57[a]
1	1.077[b]	79.21[b]
2	1.075[c]	77.49[c]
3	1.074[d]	76.34[d]
4	1.073[e]	75.55[de]
5	1.072[f]	75.44[de]
6	1.070[g]	74.57[e]
SEM	0.0003	0.39

Main Effects	Probability	
Strain	0.0001	0.1594
Feeding Tmt.	0.3745	0.6542
Photostimulation Tmt.	0.2461	0.1436
Hen Age	0.0001	0.0001
Preincubation Storage	0.0001	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table II-7 **Interaction of maternal age (wk) by preincubation egg storage (d) on specific gravity and Haugh units.**

Interaction		Specific Gravity	Haugh Unit
Age (wk) x Preincubation Storage (d)			
30	0	1.082^{a}	82.26^{a}
	1	1.082^{ab}	79.25^{b}
	2	1.080^{cd}	78.13^{bc}
	3	1.081^{bc}	76.31^{cd}
	4	1.079^{de}	75.85^{de}
	5	1.080^{cde}	74.74^{ef}
	6	1.078^{e}	73.73^{f}
40	0	1.079^{a}	79.53^{a}
	1	1.077^{b}	76.52^{b}
	2	1.076^{bc}	73.72^{c}
	3	1.075^{c}	71.85^{cd}
	4	1.072^{d}	71.48^{d}
	5	1.073^{d}	72.16^{cd}
	6	1.070^{e}	71.28^{d}
50	0	1.077^{a}	84.40^{a}
	1	1.076^{a}	81.98^{b}
	2	1.073^{b}	79.92^{cd}
	3	1.071^{c}	81.47^{bc}
	4	1.070^{c}	79.44^{cd}
	5	1.067^{d}	78.39^{d}
	6	1.066^{d}	78.36^{d}
60	0	1.074^{a}	80.07^{a}
	1	1.073^{ab}	79.09^{a}
	2	1.072^{b}	78.20^{ab}
	3	1.069^{c}	75.71^{c}
	4	1.069^{c}	75.42^{c}
	5	1.067^{d}	76.46^{bc}
	6	1.066^{d}	74.93^{c}
	SEM	0.0005	0.87
Interaction		Probability	
Age x Days		0.0001	0.0400

[a,b] For each main effect or the interaction, means within a column with no common superscript differ significantly. Interactions means are compared within an age ($P < 0.05$).

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3. EFFECT OF BREEDER HEN STRAIN, FEEDING PROGRAM, PHOTOSTIMULATION PROGRAM AND PREINCUBATION EGG STORAGE ON CHICK CHARACTERISTICS

3.1 INTRODUCTION

Chick quality is an important factor for both hatcheries and producers alike. Improvements in chick quality can only be accomplished if standards are in place against which research can be compared. Unfortunately research has found this task to be easier said, than done. Cervantes (1993) proposed a system of chick grading, integrating physical, microbiological and serological factors together. While the proper aspects were covered, applying such an integrated system to the international market would need much more research.

To date, grading for chick quality includes ensuring parental health and status combined with the exclusion by obvious physical deformity. Small chicks and those with swollen hocks, unhealed navel, developmental defects, etc. are excluded from the population at the hatchery level. Parental status usually pertains to the flocks immune status, age and strain. Many times parental stock status is the main determinant of chick quality.

Genetic changes to broiler stock have had detrimental effects on the production performance of parent stocks. In response to this decline in production, the broiler breeder (BB) industry has responded by intensifying the management of parent stocks. These management strategies include feed restriction, focusing on body weight control and precise lighting programs, resulting in improved production, fertility and hatchability (Yu *et al.*, 1992). While the successes of such strategies are routinely measured by egg production, the resulting chick quality is also of industry importance.

The purpose of the present study was to determine what effects maternal strain, age, feed program, photostimulation program and preincubation egg storage has on the resulting broiler chick. With particular focus on residual yolk sac weight, chick carcase weight, total chick weight and moisture loss during incubation.

3.2 MATERIALS AND METHODS

3.2.1 Stocks and Management

Chapter 2 described the stocks, rearing, rations, housing facilities and experimental treatments used in the previous experiment and the present one. The following is a brief description of the rearing and production portion of the experiment (for further detail please refer to Chapter 2). A total of 400 birds of two strains, Shaver Starbro (SS) and a Shaver Experimental Line (EL) were reared in floor pens until 20 wk of age. At 20 wk, 288 birds closest to the target body weight were placed into individual cages and randomly assigned to one of two feeding programs, Fast Feeding (FF) or Slow Feeding (SF) and to one of two photostimulation program, Fast Photoperiod (FP) and Slow Photoperiod (SP).

3.2.2 Egg Collection and Handling

Eggs were collected daily and fresh egg weights were recorded. Shelless and abnormally shaped eggs along with cracked eggs were excluded from the experiment. Four age periods (30, 40, 50 and 60 wk) were chosen as sample wk. Eggs were collected for 7 consecutive d during these four sample wk and stored for up to 6 d. Eggs were stored in a cool room at 14 to 16°C and 56 % relative humidity. At the end of each sample wk, two eggs were chosen randomly from each hen for use in the first experiment (Chapter 2).

3.2.3 Pedigree Hatching

The remaining eggs (as many as five eggs per hen) were individually identified with a number (so that they could be traced back to the hen) and pedigree hatched at a local hatchery. The pedigree baskets were made from 25 mm wire mesh cut into 100 mm by 300 mm strips. These strips were then rolled and the ends were attached with metal clasps, forming a cylinder. Approximately 42 baskets fit into each hatcher tray, open end up. The baskets were secured to the hatcher tray and to other baskets using plastic ties. The identification number on the egg was written on a plastic tag and attached to the basket in which the egg was placed. Eggs were placed in the appropriate basket, and trays were covered with the same 25 mm by one inch wire mesh and tied down with plastic ties. After 18 d of incubation the eggs were

removed from the incubator and weighed (transfer weight). The eggs were returned to the appropriate tray and wheeled into the hatcher for the duration of hatch.

3.2.4 Carcass Examination

At hatch the tray lid was slowly retracted and each of the chicks were cervically dislocated and returned to its pedigree basket. The plastic tag from each basket was removed and attached to the leg of that chick. The chicks were placed individually placed into small plastic tubs (100 ml). The chicks were then transported to the Poultry Unit at the Edmonton Research Station (University of Alberta), where the chicks were weighed individually. The yolk sac was then teased out and both yolk sac and carcass (chick minus yolk sac) were placed into preweighed aluminium sample dishes. Each yolk sac and carcass was weighed individually resulting in the 'wet' weights. The samples were dried in an oven at 110°C. The samples were weighed at 24 h intervals until weight loss was complete.

3.2.5 Statistical Analyses

The main experiment was designed as a 2 x 2 x 2 factorial with the main effects being maternal strain (SS or EL), feeding program (FF or SF) and photostimulation program (FP or SP). Chick quality data were also analyzed within the context of hen age (30, 40, 50 or 60 wk), preincubation egg storage time (0, 1, 2, 3, 4, 5 or 6d) and gender of the chick (F or M). The resulting experimental design was a 2 x 2 x 2 x 4 x 7 x 2 factorial and data were analyzed using the General Linear Models Procedure of SAS (SAS Institute, 1996). Gender was removed from the analysis of fresh, stored or transfer egg weight data. The error term for the three main effects (strain, feeding program and photostimulation program) was hen within the final interaction. Error variation including hen age and storage and sex consisted of the variation between birds within the last interaction. Differences between means were evaluated using Fischer's protected LSD procedure (Peterson, 1985). Where observations between means were unequal, the largest standard error of the mean (SEM) was reported. Significance was assessed at the 0.05 level unless otherwise stated. Because of the number of possible interactions in a 2 x 2 x 2 x 4 x 7 x 2 factorial, only the influence of main effects on traits measured will be discussed.

3.3 RESULTS

3.3.1 Egg Weight

Fresh, stored and transfer egg weight were not affected by strain, feed or photostimulation program (Table III-1). However, increasing hen age did increase fresh, stored and transfer egg weight (p=0.0001). Unlike results in Chapter 2, fresh egg weight was unaffected by length of egg storage (P=0.0546). Stored and transfer egg weight did decrease due to increased d of storage (p=0.0001).

3.3.2 Yolk Sac Weight

Both absolute and relative dry residual yolk sac weight were not significantly affected by strain, feed or photostimulation program (Table III-2). Wet residual yolk sac weight, although not significantly affected by strain or feeding program was affected by photostimulation program. The progeny of SP hens had significantly larger absolute wet yolk sac weight and wet yolk sac weight as a percent of stored egg (p=0.0282) as compared to progeny of EL hens.

Both absolute and relative wet yolk sac weight and dry yolk sac weight increased with increasing hen age (p=0.0001). Over the total life of the hen, the wet yolk sac weight of her offspring increased by over 3 g, a 73.6 % increase and dry yolk sac weight increased by 1.8 g, a 96.4 % increase.

Wet yolk sac weight and dry yolk sac weight significantly increased as days of storage increased with the exception of absolute dry yolk sac weight which was not affected by storage length (P=0.0772). The gender of the chick also affected the weight of the yolk sac (wet or dry). Male chicks had significantly larger wet yolk sac weight and dry yolk sac weight.

3.3.3 Carcass Weight

Relative wet carcass weight and absolute and relative dry carcass weight were significantly greater in SS progeny as opposed to EL progeny (Table III-3). Wet chick carcass weight of SS progeny was not different than EL progeny. Absolute dry chick carcass weight was significantly greater in the progeny of SP hens as compared to FP hens (P=0.0169). Carcass weight was not affected by feed or photostimulation treatment.

Increasing hen age significantly increased absolute wet chick carcass weight (p=0.0001) but decreased wet chick carcass weight as a percent of stored egg weight (p=0.0001). Dry chick carcass weight increased with hen age until 50 wk of age after which dry chick carcass weight decreased (P=0.0001). Dry chick carcass weight as a percent of stored egg weight significantly increased between 30 and 40 wk of age after which relative dry chick carcass weight did not significantly increase until 60 wk of age (P=0.0001). As storage length increases absolute wet chick carcass weight decreased (P=0.0001). Dry chick carcass weight and dry carcass weight relative to stored egg weight was not significantly affected by storage.

Carcass weight was not affected by sex with the exception of relative wet chick carcass weight, in which male carcasses were larger than female.

3.3.4 Total Chick Weight

Total chick weight (carcass and residual yolk sac weight)was not affected by strain or feed program (Table III-4). Wet total chick weight and dry total chick weight from SP hens were significantly heavier than chick weights from FP hens. Relative wet total chick weight was also greater in progeny of SP hens as compared to FP hens. Relative dry total chick weight was not significantly affected by maternal photostimulation program. Wet total chick weight and dry total chick weight significantly increased as the hen aged (P=0.0001). As a percent of stored egg weight, wet total chick weight and dry total chick weight also increased as the hen aged (P=0.0001). Total chick weight was unaffected by storage with the exception of relative wet total chick weight, which increased with increasing storage (P=0.0032). Males had greater wet total chick weight (absolute and relative) than did female chicks. Sex had no effect on dry total chick weight.

3.3.5 Dry Matter Content

Dry matter content (DM) of the yolk sac, carcass and total chick were not affected by maternal strain, feeding program or photostimulation program (Table III-5). Residual yolk sac DM increased almost 8 % as the hen aged. Carcass DM of chicks from 30 old hens was significantly lower compared to carcass DM of chicks from 40 wk old hens. After 40 wk of age, as hen age increased the carcass DM of their progeny decreased until DM content of the carcass at 60 wk old hens was equal to 30 wk old hens.

Progeny of 30 wk old hens had significantly lower total chick DM than progeny from hens aged 40, 50 or 60 wk of age. Mean yolk sac DM ranged from 46.4 to 54.2 %. Mean carcass DM ranged from 20.6 and 21.9 %, while the total chick DM ranged from 23.5 and 25.6 %. Yolk sac, carcass and total chick DM was unaffected by storage and gender.

3.3.6 Moisture Loss During Storage

Maternal strain, feeding program, photostimulaton program and gender of the chick had no effect on moisture lost (or egg weight loss) during storage (Table III-6). The older the hen the greater the loss of moisture from her eggs due to storage (P=0.0001). Moisture loss as a percent of fresh egg weight also increased with hen age until 50 wk, at which time no further changes in moisture loss were detected (P=0.0001). Each day of storage resulted in an increase in moisture loss and relative moisture loss due to storage (P=0.0001). The largest change in moisture loss due to storage occurred between the day of oviposition and d 1, with the second largest increase between d 3 and 4. The smallest change in moisture loss was between d 2 and 3. These trends were also true for relative moisture loss.

3.3.7 Moisture Loss During Incubation

Maternal strain, feeding program, photostimulation program and sex of the chick did not affect moisture loss during incubation. Moisture loss during incubation increased with hen age until 50 wk at which time it decreased (P=0.0001) (Table III-6). As a percent of stored egg weight, weight loss during incubation decreased from 30 to 40 wk of age after which no significant decreases occurred until 60 wk of age (P=0.0001). Preincubation storage of hatching eggs decreased weight loss during incubation (P=0.0003). As a percent of stored egg weight, moisture loss during incubation was not affected by storage (P=0.0758).

3.3.8 Total Moisture Loss (Storage and Incubation)

Again maternal strain, feeding program, photostimulation program and sex of the chick did not affect total weight loss (Table III-6). As hen age increased total weight loss increased (P=0.0001). Total weight loss as a percent of fresh egg weight was significantly affected by hen age but

not in a linear manner (up or down) (P=0.0001). Total moisture loss decreased gradually until 3 d, after this time no significant change occurred. The same trend was observed for total weight loss as a percent of fresh egg weight. Seventy-five percent of the relative total moisture loss occurred between 0 and 3 d, while only 25 % occurred between 3 and 6 d.

3.4 DISCUSSION

Early studies by Godfrey and Jaap (1952) described differences in hatchling weight according to breed, regardless of egg size. Chicks from larger meat birds utilised more of the original egg weight than did the chicks from smaller bantam lines. In Chapter 2 proportional yolk weights were different between strains. In the present study no difference between strains were evident between proportional residual yolk sac weights. This suggests the further selected strain (EL) utilised a greater proportion of yolk during the development stage. Since the carcass weight of chicks from the SS strain were significantly larger than that of the EL chicks, it can be concluded that the two strains metabolised the yolk to different extents. The SS chick utilised the yolk more directly for embryo growth while the EL strain utilised more of the yolk as an energy source to sustain and maintain growth. Differences in embryonic metabolism between breeds have been suggested in previous research by Byerly (1930) and Blunn and Gregory (1935).

Limited research is available to explain the effect of photostimulation program on chick components. Earlier work by Robinson *et al.* (1999) suggested that a SF program was superior to a FP program in terms of fertility, hachability and hatch of fertile. The present experiment suggests that eggs from hens subjected to the SP treatment utilised less yolk (wet and dry) during development and therefore hatched with proportionally larger yolk sacs. It is also important to note that this did not result in lower carcass weight as compared to chicks from FP hens. The consequences of an increased yolk sac availability at hatch has yet to be understood and will be discussed later in this chapter. Further research is needed to understand the impact of maternal photostimulation treatment on subsequent chick metabolism.

Sexual dimorphism has been well defined in broiler growth in which males grow faster than females with improved feed efficiency (Tufft and Jensen, 1991). In this case, a greater portion of the egg became yolk sac, carcass and therefore chick, when gender of the chick was male. Even as a dried sample, the residual yolk sac of the male chicks was heavier than was the yolk sac from female chicks. This

suggests that during embryonic development male embryos utilise less yolk sac to develop a larger carcass. Differences in embryonic growth between the sexes have been observed as early as 11 d (Burke and Sharp, 1989; Burke *et al.*, 1990). Henry and Burke (1998) suggested that more but smaller myofibers have been observed in male embryos as compared to female embryos. Such research suggests that early in development male chicks are given more of the building blocks for posthatch growth then female hatchlings. Greater potential for muscle growth coupled with additional yolk sac stores may give males a substantial advantage over their female counterparts.

An increase in hatchling weight (7.6 %), yolk sac weight (3.06 %) and carcass weight (4.5 %), was observed as the hen aged from 30 to 60 wk. This confirms not only that eggs from the youngest hens have the smallest yolks (O'Sullivan *et al.* 1991) and hatch with the smallest residual yolk sacs (Daly and Peterson, 1990) and total chick (Sinclair *et al.*, 1990), but that they hatch with the smallest chick carcass. However, hatchling weight and yolk sac weight, increased relative to stored egg weight while carcass weight decreased significantly. A similar trend was seen for the dry components of hatch as a percent of stored egg weight. Therefore, more of the egg produced by an older hen, which we know from the data in Chapter 2 to be yolk, appears as residual yolk sac at hatch, and less of that egg becomes carcass.

Tufft and Jensen (1991) found that chicks hatched from older hens (47 wk) contained a greater DM content than did chicks from younger hens (31 and 37 wk). The present study supports this observation and suggests that this relationship does not change for hens after 47 wk of age (Table III-5). Carcass DM changes with hen age, although significant, do not clearly define this relationship (Table III-3). The combined increase of yolk sac and carcass DM between 30 and 40 wk of age results in a significant increase in total chick DM. After 40 wk of age, the combination of a decreased in carcass DM and an increase in yolk sac DM, fails to result in any change in total chick DM. This suggests that more of the chick DM from older hens is composed of yolk sac DM as opposed to carcass DM.

The increased proportion of yolk in eggs from older hens was established in Chapter 2 and in past research by O'Sullivan *et al.* (1991). The present study suggests that this proportionately larger yolk results in a proportionately larger yolk sac at the expense of carcass weight. A decrease in yolk moisture content with hen age has been described in past research by O'Sullivan *et al.* (1991) while Moran and Reinhart (1980) found that yolk sac moisture content decreased as the hen ages; this has been further

confirmed in the present study. What remains to be seen is if this increase in yolk sac, and specifically yolk sac DM, facilitates increased growth potential for a growing broiler chick. Since yolk sac absorption precedes the initiation of post hatch growth in hatchling broilers by approximately 24 hr, and since more than 50 % of the absorption occurs before 48 hr post-hatch, the presence of yolk sac is crucial for the time prior to placement (on farm, *ad libitum* feed). Hence we would expect that chicks from older hens would be better equipped to survive transport and other stresses early post hatch. But is more residual yolk sac necessarily better if the hatchling carcass size is compromised? Further research will be needed to answer this question.

Research has shown that egg storage results in reduced embryonic development (Mather and Laughin, 1976; Fasenko, unpublished data, 1999) and reduces embryonic viability and therefore hatchability (Byng and Nash, 1962; Whitehead *et al.*, 1985). Becker *et al.* (1968) and Kirk *et al.* (1980) concluded that 1 d of storage = 1 additional h of hatching time. Reduced development and viability may be explained by work done by Funk and Biellier (1944) which observed the shrinking of blastoderm during to storage. Similar work by Landauer (1967) reported that although embryos from stored eggs were smaller at 7 and 14 d, their growth rate was greater during the last 2 wk of incubation.

Storage effects on egg components have been covered thoroughly in Chapter 2. As yolk weight has been seen to increase proportionately with storage, yolk sac (wet and dry) as a percent of stored egg weight increased with increasing storage. This proportional increase in wet yolk sac weight is evident in an increase in total chick weight as a percent of stored egg weight. This however does not explain why absolute wet yolk sac weight decreases as storage increases. This suggests chicks from eggs that are stored seem to utilise less of the yolk (wet or dry) prior to hatch than did eggs not stored. Noble *et al.* (1986) suggested that poor utilisation of yolk can be linked to higher embryonic mortality. In the previous chapter most moisture loss during storage was identified as lost exclusively from albumen, in the present chapter wet chick carcass weight decreased with increasing storage, suggesting that albumen weight may influence carcass weight. The fact that dry chick carcass is not influenced by storage supports the latter statement.

Weight loss increased with hen age and storage, which corroborates with results presented in Chapter 2. Absolute weight loss during incubation and total weight loss increased with hen age while relative weight loss during incubation and relative total weight loss however decreased with hen age.

Contrary to research by Meijerhof (Submitted) where eggs from 33 wk old hens lost less relative moisture during incubation and during total weight loss than did eggs from 55 wk old hens. Which supports the rationale that as size of the egg increased (hen ages), surface area increases and therefore increased opportunity for moisture loss.

Similar to data shown in chapter 2, each day of storage significantly increased the moisture loss and relative moisture loss of the egg. Weight loss during storage increased with increasing days of storage and weight loss during incubation while decreased with days of storage. This is evident since relative weight loss during incubation is unaffected by storage. During incubation the egg releases less moisture if it was stored prior to incubation. Is the moisture loss during incubation regulated depending on the length of storage the egg withstood prior to incubation? Results in Table III-6 suggest that storage increases the total moisture loss of the egg but that total moisture lost is limited either by storage length or moisture loss.

This experiment suggests that the increased proportional yolk present in older hens (evident in Chapter 1) can be found post hatch, as increased residual yolk sac. Just as proportional albumen decreased with hen age (Chapter 1) so too did chick carcass weight as a percent of stored egg weight. Therefore the trend of larger chicks at the end of the production cycle is mainly due to increased residual yolk sac weight and not increased chick carcass weight. Male chicks hatched with greater carcass and residual yolk sac weigth. Weight loss due to preincubation egg storage was significanlty increased with each day of storage. Egg weight loss due to preincubation storage significanlty influenced total weight loss (storage and incubation). The longer the egg was stored, the greater the residual yolk sac weight. Therefore less yolk sac was used during development suggesting different metabolism rates between fresh and stored embryos. Strain differences also suggest differences in embryonic metabolism. Similar to Chapter 1, maternal photostimulation and feeding treatment had little to no effect on chick traits measured.

Table III-1 **Effects of maternal strain, feeding program, photostimulation program, hen age and preincubation egg storage on fresh egg weight (g), stored egg weight (g) and transfer egg weight (g).**

Main Effects	Fresh Egg Weight (g)	Stored Egg Weight (g)	Transfer Egg Weight (g)
Strain			
EL[1]	64.9	64.5	57.2
SS[2]	65.0	64.6	57.4
SEM	0.4	0.4	0.4
Feeding Tmt.			
FF[3]	65.0	64.6	57.3
SF[4]	64.8	64.5	57.3
SEM	0.4	0.4	0.4
Photostimulation Tmt.			
FP[5]	64.5	64.1	56.9
SP[6]	65.3	65.0	57.7
SEM	0.4	0.4	0.4
Hen Age (wk)			
30	58.8[d]	58.6[d]	51.7[d]
40	64.9[c]	64.5[c]	57.3[c]
50	67.3[b]	66.8[b]	59.2[b]
60	68.8[a]	68.2[a]	60.9[a]
SEM	0.1	0.1	0.1
Preincubation Storage (d)			
0	65.0	65.0[a]	57.6[a]
1	65.2	65.0[a]	57.7[a]
2	65.1	64.8[ab]	57.5[ab]
3	64.8	64.4[bc]	57.1[bc]
4	64.9	64.3[c]	57.1[bc]
5	64.9	64.3[cd]	57.1[bc]
6	64.6	63.9[d]	56.8[c]
SEM	0.2	0.2	0.2

Main Effects	Probability		
Strain	0.8699	0.8977	0.7665
Feeding Tmt.	0.7319	0.7524	0.8806
Photostimulation Tmt.	0.1212	0.1193	0.1171
Hen Age	0.0001	0.0001	0.0001
Preincubation Storage	0.0546	0.0001	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).

[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9

[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9

[3]FF=Fast Feed Allocation Program (Table II-1)

[4]SF=Slow Feed Allocation Program (Table II-1)

[5]FP=Fast Photoperiod (Figure II-1)

[6]SP=Slow Photoperiod (Figure II-1)

Table III-2 **Effects of maternal strain, feeding program, photostimulation program, hen age, preincubation egg storage and sex on wet and dry yolk sac weight (g) and relative to stored egg weight (%).**

	Yolk Sac			
	Wet		Dry	
Main Effects	(g)	(%)	(g)	(%)
Strain				
EL[1]	5.65	8.62	2.86	4.34
SS[2]	5.41	8.29	2.79	4.27
SEM	0.13	0.17	0.07	0.10
Feeding Tmt.				
FF[3]	5.58	8.51	2.87	4.37
SF[4]	5.48	8.40	2.77	4.24
SEM	0.12	0.16	0.07	0.10
Photostimulation Tmt.				
FP[5]	5.33[b]	8.20[b]	2.77	4.24
SP[6]	5.73[a]	8.71[a]	2.88	4.37
SEM	0.13	0.17	0.08	0.10
Hen Age (wk)				
30	4.12[d]	6.99[d]	1.91[d]	3.24[d]
40	5.14[c]	7.95[c]	2.55[c]	3.93[c]
50	5.67[b]	8.42[b]	2.93[b]	4.35[b]
60	7.18[a]	10.47[a]	3.90[a]	5.70[a]
SEM	0.07	0.10	0.04	0.10
Preincubation Storage (d)				
0	5.26[c]	8.01[d]	2.74	4.17[b]
1	5.32[de]	8.08[cd]	2.73	4.14[b]
2	5.49[cd]	8.35[bcd]	2.79	4.24[ab]
3	5.54[c]	8.49[b]	2.81	4.31[ab]
4	5.56[cb]	8.52[b]	2.79	4.27[ab]
5	5.82[a]	8.89[a]	2.97	4.52[a]
6	5.73[ab]	8.83[a]	2.91	4.48[a]
SEM	0.08	0.11	0.07	0.11
Sex				
F	5.47[b]	8.34[b]	2.77[b]	4.23[b]
M	5.59[a]	8.55[a]	2.88[a]	4.39[a]
SEM	0.04	0.06	0.04	0.06

Main Effects	Probability			
Strain	0.1841	0.1603	0.5333	0.5866
Feeding Tmt.	0.5367	0.6076	0.3386	0.3815
Photostimulation Tmt.	0.0267	0.0259	0.2849	0.3753
Hen Age	0.0001	0.0001	0.0001	0.0001
Preincubation Storage	0.0001	0.0001	0.0772	0.0321
Sex	0.0175	0.0117	0.0371	0.0347

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table III-3 **Effects of maternal strain, feeding program, photostimulation program, hen age, preincubation egg storage and sex on wet and dry chick carcass weight (g) and relative to stored egg weight.**

	Carcass			
	Wet		Dry	
Main Effects	(g)	(%)	(g)	(%)
Strain				
EL[1]	39.5	61.3[b]	8.27[b]	12.9[b]
SS[2]	40.0	61.9[a]	8.52[a]	13.2[a]
SEM	0.2	0.2	0.08	0.1
Feeding Tmt.				
FF[3]	39.9	61.8	8.47	13.1
SF[4]	39.6	61.5	8.32	13.0
SEM	0.2	0.2	0.07	0.1
Photostimulation Tmt.				
FP[5]	39.4	61.6	8.27[b]	12.9
SP[6]	40.0	61.7	8.52[a]	13.1
SEM	0.2	0.2	0.08	0.1
Hen Age (wk)				
30	36.6[c]	62.5[a]	7.61[c]	13.0[b]
40	40.1[b]	62.1[b]	8.60[b]	13.4[a]
50	41.1[a]	61.5[c]	8.94[a]	13.4[a]
60	41.1[a]	60.3[d]	8.42[b]	12.4[c]
SEM	0.1	0.1	0.11	0.04
Preincubation Storage (d)				
0	40.1[a]	61.8	8.45	13.0
1	40.0[ab]	61.7	8.47	13.1
2	39.6[cd]	61.3	8.41	13.0
3	39.7[bc]	61.7	8.59	13.3
4	39.6[cd]	61.6	8.34	13.0
5	39.4[d]	61.5	8.28	12.9
6	39.3[d]	61.7	8.24	12.9
SEM	0.1	0.2	0.13	0.2
Sex				
F	39.6	61.5[b]	8.45	13.1
M	39.8	61.8[a]	8.33	13.0
SEM	0.1	0.1	0.07	0.1

Main Effects	Probability			
Strain	0.1411	0.0180	0.0163	0.0281
Feeding Tmt.	0.3857	0.3144	0.1634	0.2550
Photostimulation Tmt.	0.0662	0.6961	0.0169	0.2285
Hen Age	0.0001	0.0001	0.0001	0.0001
Preincubation Storage	0.0001	0.4695	0.2516	0.5357
Sex	0.1814	0.0232	0.1279	0.1631

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table III-4 **Effects of maternal strain, feeding program, photostimulation program, hen age preincubation egg storage and sex on wet and dry total chick weight (including yolk sac) weight (g) and relative to stored egg weight (%).**

	Chick			
	Wet		Dry	
Main Effects	(g)	(%)	(g)	(%)
Strain				
EL[1]	45.1	70.0	11.12	17.2
SS[2]	45.4	70.2	11.31	17.5
SEM	0.3	0.2	0.1	0.1
Feeding Tmt.				
FF[3]	45.4	70.3	11.34	17.5
SF[4]	45.1	69.9	11.10	17.2
SEM	0.3	0.2	0.1	0.1
Photostimulation Tmt.				
FP[5]	44.7^{b}	69.8^{b}	11.04^{b}	17.2
SP[6]	45.7^{a}	70.4^{a}	11.40^{a}	17.5
SEM	0.03	0.2	0.10	0.1
Hen Age (wk)				
30	40.7^{d}	69.5^{c}	9.52^{d}	16.3^{c}
40	45.2^{c}	70.1^{b}	11.15^{c}	17.3^{b}
50	46.7^{b}	69.9^{b}	11.87^{b}	17.8^{a}
60	48.3^{a}	70.8^{a}	12.33^{a}	18.1^{a}
SEM	0.1	0.1	0.1	0.04
Preincubation Storage (d)				
0	45.4	69.8^{bc}	11.19	17.2
1	45.4	69.8^{bc}	11.20	17.2
2	45.1	69.6^{c}	11.20	17.3
3	45.3	70.2^{ab}	11.41	17.7
4	45.2	70.2^{abc}	11.13	17.3
5	45.2	70.4^{a}	11.25	17.5
6	45.1	70.5^{a}	11.15	17.4
SEM	0.2	0.2	0.1	0.2
Sex				
F	45.1^{b}	69.8^{b}	11.23	17.4
M	45.4^{a}	70.3^{a}	11.20	17.3
SEM	0.1	0.1	0.1	0.1

Main Effects	Probability			
Strain	0.5700	0.2566	0.2046	0.1096
Feeding Tmt.	0.3728	0.1354	0.1020	0.0805
Photostimulation Tmt.	0.0247	0.0150	0.0159	0.0692
Hen Age	0.0001	0.0001	0.0001	0.0001
Preincubation Storage	0.6805	0.0032	0.7467	0.5249
Sex	0.0200	0.0002	0.7763	0.8926

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table III-5 **Effects of maternal strain, feeding program, photostimulation program, hen age, preincubation egg storage and sex on residual yolk sac, chick carcass, and total chick weight (including yolk sac) dry matter as a percent of wet weight (%).**

	Dry Matter Content		
	Yolk	Carcass	Total Chick
Main Effects	(%)	(%)	(%)
Strain			
EL[1]	49.7	21.0	24.6
SS[2]	51.0	21.7	25.1
SEM	0.6	0.3	0.2
Feeding Tmt.			
FF[3]	50.6	21.2	24.9
SF[4]	50.1	21.5	24.8
SEM	0.6	0.3	0.2
Photostimulation Tmt.			
FP[5]	51.1	21.3	24.7
SP[6]	49.6	21.4	25.0
SEM	0.6	0.4	0.2
Hen Age (wk)			
30	46.4[d]	20.9[b]	23.5[b]
40	49.3[c]	22.1[a]	24.9[a]
50	51.5[b]	21.9[ab]	25.5[a]
60	54.2[a]	20.6[b]	25.6[a]
SEM	0.9	0.1	0.1
Preincubation Storage (d)			
0	51.1	20.9	24.6
1	51.1	21.1	24.7
2	50.2	21.8	25.1
3	49.8	21.7	25.1
4	49.7	21.8	24.9
5	50.3	21.4	25.0
6	50.0	20.9	24.6
SEM	1.0	0.6	0.4
Sex			
F	50.0	21.7	25.0
M	50.7	21.0	24.7
SEM	0.5	0.3	0.2

Main Effects	Probability		
Strain	0.1348	0.1464	0.1765
Feeding Tmt.	0.5234	0.5870	0.7812
Photostimulation Tmt.	0.0688	0.8470	0.4751
Hen Age	0.0001	0.0275	0.0001
Preincubation Storage	0.8241	0.7699	0.7891
Sex	0.3298	0.1201	0.2681

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table III-6 **Effects of maternal strain, feeding program, photostimulation program, hen age, preincubation egg storage and sex on egg weight loss during storage, incubation and total (storage and incubation) (g) and relative to stored egg weight (%).**

Main Effects		Weight Loss During Storage		Weight Loss During Incubation		Total Weight Loss	
		(g)	(%)	(g)	(%)	(g)	(%)
Strain							
	EL[1]	0.401	0.610	7.29	11.34	7.69	11.88
	SS[2]	0.407	0.622	7.21	11.19	7.61	11.74
	SEM	0.007	0.010	0.12	0.18	0.12	0.18
Feeding Tmt.							
	FF[3]	0.407	0.619	7.30	11.34	7.70	11.89
	SF[4]	0.401	0.612	7.20	11.19	7.60	11.74
	SEM	0.007	0.010	0.12	0.18	0.12	0.18
Photostimulation Tmt.							
	FP[5]	0.407	0.622	7.23	11.33	7.64	11.88
	SP[6]	0.401	0.609	7.26	11.20	7.66	11.74
	SEM	0.007	0.011	0.12	0.18	0.12	0.19
Hen Age (wk)							
	30	0.256^{d}	0.437^{c}	6.83^{c}	11.67^{a}	7.09^{d}	12.06^{a}
	40	0.369^{c}	0.569^{b}	7.19^{b}	11.18^{b}	7.56^{c}	11.67^{b}
	50	0.480^{b}	0.714^{a}	7.66^{a}	11.48^{b}	8.14^{a}	12.12^{a}
	60	0.511^{a}	0.743^{a}	7.31^{b}	10.74^{c}	7.82^{b}	11.40^{c}
	SEM	0.008	0.012	0.06	0.10	0.06	0.10
Preincubation Storage (d)							
	0	0.005^{g}	0.003^{g}	7.43^{a}	11.46	7.44^{c}	11.46^{c}
	1	0.235^{f}	0.359^{f}	7.28^{abc}	11.23	7.51^{bc}	11.55^{bc}
	2	0.345^{e}	0.526^{e}	7.30^{abc}	11.31	7.64^{ab}	11.78^{ab}
	3	0.390^{d}	0.598^{d}	7.31^{ab}	11.38	7.70^{a}	11.91^{a}
	4	0.522^{c}	0.797^{c}	7.23^{bcd}	11.28	7.75^{a}	11.99^{a}
	5	0.624^{b}	0.950^{b}	7.13^{cd}	11.11	7.75^{a}	11.96^{a}
	6	0.705^{a}	1.08^{a}	7.07^{d}	11.10	7.78^{a}	12.06^{a}
	SEM	0.009	0.014	0.07	0.11	0.07	0.12
Sex							
	F	0.406	0.618	7.27	11.29	7.67	11.84
	M	0.402	0.614	7.23	11.25	7.63	11.79
	SEM	0.005	0.008	0.037	0.060	0.038	0.060

Main Effects	Probability					
Strain	0.4812	0.4128	0.6027	0.6383	0.6396	0.5760
Feeding Tmt.	0.4855	0.6381	0.5685	0.5495	0.5534	0.5434
Photostimulation Tmt.	0.4680	0.3167	0.8558	0.6164	0.8908	0.5860
Hen Age	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Preincubation Storage	0.0001	0.0001	0.0003	0.0758	0.0001	0.0001
Sex	0.4995	0.6683	0.3553	0.5792	0.3226	0.5552

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).

[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9

[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9

[3]FF=Fast Feed Allocation Program (Table II-1)

[4]SF=Slow Feed Allocation Program (Table II-1)

[5]FP=Fast Photoperiod (Figure II-1)

[6]SP=Slow Photoperiod (Figure II-1)

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4. EFFECTS OF BREEDER HEN STRAIN, FEEDING PROGRAM AND PHOTOSTIMULATION PROGRAM AND PREINCUBATION EGG STORAGE ON BROILER GROWTH AND CARCASS CHARACTERISTICS

4.1 INTRODUCTION

Broiler breeders (BB) are genetically selected for specific broiler traits including growth rate, appetite, feed conversion and breast muscle yield. They are expected to maintain high egg production, egg quality, fertility and hatchability; traits which are selected for in Leghorns. Growth traits of broilers and reproductive traits of Leghorns have been identified as genetic opposites (Siegel and Dunnington, 1985). That is, it is impossible to select for both types of traits in one bird. Early papers suggested the economic value of selecting for broiler traits as opposed to egg traits in the BB, therefore industry was encouraged to find other means of improving BB egg production. The industry responded by researching changes in management strategies such as feed restriction, strict body weight control and precise lighting implementation and scheduling to improve production. Success in improving egg production, hatchability and egg quality have been evident through such careful management (Yu *et al.*, 1992).

The BB hen has been known to influence her progeny in many ways. The genetic selection for increased body weight has been the most obvious of these in recent history. Egg weight has been known to increase as the age of the hen increases (Mather and Laughlin, 1979; O'Sullivan, 1991). In turn it has been well documented that hatching egg weight can influence hatchling weight (Bray and Iton, 1926; Upp, 1928; Wiley, 1950; Axelsson, 1954; Henderson, 1956; Somaiah and Shirley, 1963; Saeki and Akita, 1971; Yannakopoulos and Tserveni-Gousi, 1987). Research surrounding the influence of hen age on development and growth of the broiler chick have suggested that the influence is a temporary one which begins after 11 d of incubation and gradually increases to a maximum at hatch (Bray and Iton, 1962), while others suggest that it can be detected up to 18 d posthatch (Pinchasov, 1991). The rate of embryonic growth has also been linked to the position of the egg within the sequence and age of the hen (Mather and Laughlin, 1979) among other influences. Maternal age and strain influence egg composition (Roland, 1975; O'Sullivan *et al.*, 1991), hatch composition (Applegate and Lilburn, 1996) and DM content of hatch composition (Chapter 3).

The present study aims to identify and explain any effects the management strategies implemented for improving BB production may have on broiler growth and carcass characteristics. Particular focus will be on weekly weight gain, body weight at 6 wk, eviscerated carcass weight and breast muscle yield.

4.2 MATERIALS AND METHODS

4.2.1 Stocks and Management

The following is a brief description of the rearing and production portion of the experiment, for further detail please refer to Chapter 2. A total of 400 birds of two strains, Shaver Starbro (SS) and a Shaver Experimental Line (EL) were reared in floor pens until 20 wk of age. Both strains were managed according to the Shaver Starbro guidelines for body weight and feed allocation. At 20 wk, 288 birds closest to the target body weight were placed into individual cages and randomly assigned to one of two feeding programs, Fast Feeding (FF) or Slow Feeding (SF) (Table II-1) and to one of two photostimulation program, Fast Photoperiod (FP) and Slow Photoperiod (SP) (Figure II-1).

4.2.2 Egg Collection and Handling

At 61 wk, eggs were collected daily for 7 consecutive d and fresh egg weights were recorded. Eggs were stored in a cool room for as long as 6 d at 14 to 16°C and 56 % relative humidity. At the end of the sample wk, the eggs from each hen (up to seven eggs per hen) were individually identified with a number and pedigree hatched at a local hatchery. For a detailed description of the pedigree hatch procedure, refer to Chapter 3.

4.2.3 Growth and Carcass Examination

At hatch, the chicks were legbanded with a number corresponding with their hatch identification. The chicks were then transported to the Poultry Research Unit at the Edmonton Research Station (University of Alberta), where they were individually weighed. The birds were placed, sex separate, in floor pens by parental treatment (32 pens). Birds were individually weighed each wk and feed consumption was recorded. At 2 wk of age, the legbands were replaced with wing bands.

At 42 d of age, the birds were processed at a local processing plant (Lilydale Foods, Edmonton, Alberta). Immediately after evisceration and trimming, the birds were removed from the processing line. In a cool room (air chilled to 4°C) whole eviserated, front half, back half, *Pectoralis major* and *Pectoralis minor* weight were recorded. Removal of *P. major* and *P. minor* was performed by Lilydale personnel according to industry standards.

4.2.4 Statistical Analyses

The main experiment was designed as a 2 x 2 x 2 factorial with the main effects being maternal strain (SS or EL), feeding program (FF or SF) and photostimulation program (FP or SP). Chick quality data were also analyzed within the context of preincubation egg storage time (0, 1, 2, 3, 4, 5 or 6 d) and gender of the chick (F or M). The resulting experimental design was a 2 x 2 x 2 x 7 x 2 factorial and data were analyzed using the General Linear Models Procedure of SAS (SAS Institute, 1996). Gender was removed from the analysis of fresh, stored or transfer egg weight. The error term for the three main effects being strain, feeding program and photostimulation program, was hen within the final interaction. Error variation including storage and sex consisted of the variation between birds within the last interaction. Differences between means were evaluated using Fischer's protected LSD procedure (Peterson, 1985). Where observations between means were unequal, the largest standard error of the mean (SEM) was reported. Significance was assessed at the 0.05 level unless otherwise stated. Because of the number of possible interactions in a 2 x 2 x 2 x 7 x 2 factorial, only the influence of main effects on traits measured will be discussed.

4.3 RESULTS

4.3.1 Egg Weight

Egg weight was not affected by strain or feeding program (Table IV-1). As in the previous chapters, stored egg weight decreased significantly with increasing days of storage (P=0.0129). The effect of storage was no longer detectable after 18 d of incubation (transfer egg weight). Eggs from SP hens were 1.4 g heavier at transfer (transfer from incubator to the hatcher at 18 d) than eggs from FP hens.

4.3.2 Moisture Loss during Storage and Incubation

Weight loss during storage was unaffected by all treatments except storage (Table IV-2). Absolute and relative egg weight loss increased significantly with each day of increased storage, with the exception of d 6. Inversely, absolute and relative weight loss during incubation decreased with increasing d of storage. Egg weight loss during incubation as a percent of stored egg weight was significantly greater in eggs from FP hens as compared to SP hens. Strain, feeding treatment, or gender did not affect egg weight loss during incubation.

4.3.3 Weekly Body Weight

As expected, both strain and gender significantly affected weekly body weights (Table IV-3 and 4). During the first 4 wk, group body weights were significantly greater for EL birds than SS birds. Body weight between strains differed by 5.1 % during wk 1, 5.6 % during wk 2, 4.3 % during wk 3 and 2.8 % during wk 4. By wk 5 and 6, however, a difference between strains was no longer detectable.

Female chicks were significantly heavier during wk 1 and 2, while male body weight was significantly heavier during wk 3, 4, 5 and 6. Body weights were significantly greater for chicks from hens exposed to FP compared to hens exposed to a SP, during wk 1. This effect was not apparent after wk 1. Weekly body weight was not affected by maternal feeding treatment or the length of egg storage.

4.3.4 Eviscerated Carcass Weight

Maternal feeding treatment, photostimulation treatment and length of egg storage had no effect on eviscerated carcass weight or yield (Table IV-5). As expected, eviscerated carcass weight was 13.4 % greater for male than female carcasses (P=0.0001) but carcass eviscerated yield (eviscerated carcass as a percent of live 6 wk body weight) was unaffected by gender. Although eviscerated carcass weight was unaffected by strain, EL birds had significantly greater eviscerated carcass yield (1.5 %) than did SS birds (P=0.0017).

4.3.5 Front and Back Half Weights

Front and back half weights were only affected by gender, in which males had greater front and back half weights (Table IV-6) (P=0.0009 and P=0.0098, respectively). The front and back half measurements were unaffected by any other treatment.

4.3.6 Pectoralis major and Pectoralis minor

Although front half weight was not significantly affected by strain (Table IV-6); total breast, *Pectoralis major* (*P. major*) and *Pectoralis minor* (*P. minor*) weight were significantly greater in EL birds as compared to SS birds (Table IV-7). EL birds had 5.6, 5.7 and 5.3 % greater total breast, *P. major* and *P. minor* weight respectively, as compared to SS birds. Total breast, *P. major* and *P. minor* weights were not significantly affected by feeding program, photostimulation program or egg storage. Males had 10.3 % greater total breast muscle weight and 10.9 % greater *P. major* weight than female carcasses but female carcasses had greater 8.9 % *P. minor* weight than male carcasses.

As a percent of eviscerated carcass weight (Table IV-8), EL birds had 5.6 % larger *P. major*, 5.7 % larger *P. minor* and therefore 5.3 % greater total breast muscle weight than did SS birds. This is a considerable increase in breast muscle as a result of genetic selection. Breast muscle as a percent of eviscerated weight was not affected by feeding program, photostimulation program or egg storage. As a percent of eviscerated carcass weight, female broilers had a larger *P. minor* than did male broilers (P=0.0001), while *P. major* as a percent of eviscerated weight was not affected by gender.

As a percent of total breast weight, male broilers had more *P. major* (P=0.0031) and females had more *P. minor* (P=0.0031) (Table IV-9). *P. major* and *P. minor* as a percent of total breast weight was not affected by strain, feeding program, photostimulation program or egg storage.

4.4 DISCUSSION

The effect of storage on hatching eggs was only detectable in egg weight loss during storage, incubation and stored egg weight. Storage has been linked to retarding early embryonic growth, which in turn increases the length of incubation time (Mather and Laughlin, 1976; Fasenko, unpublished data, 1999). Proudfoot (1969) suggested that preincubation storage also reduces hatchability. In the present trial,

detrimental effects of storage were not detected for traits studied after chicks hatch. This suggests that if stored eggs are clearly identified at the hatchery and special care is given to hold chicks in the hatchers for additional time to improve hatchability, the effects of storage would be minimal in terms of chick performance.

Egg weight loss during incubation as a percent of egg weight was significantly higher for eggs from hens exposed to FP as compared to eggs from hens exposed to SP. This resulted in lower mean egg weight at transfer for eggs from FP hens compared to eggs from SP hens. The reason for this is not clear since no difference in shell weight or specific gravity was observed between maternal photostimulation treatment (Table II-4) nor was a similar effect observed in either of the previous trials.

The presence of a photostimulation program effect on wk 1 body weight is also difficult to explain. Higher wk 1 body weight in FP progeny as compared to SP is opposite to the weight of hatchling, yolk sac and carcass observed in Chapter 3, in which SP progeny had consistently greater hatch components than FP progeny. It would be expected that additional carcass weight and yolk sac stores would suggest an advantage for growth in SP progeny during the first wk. Since this effect was not present for the remainder of the trial, the effect of maternal photostimulation does not limit production.

The absence of maternal feeding program effect and the limited effect of maternal photostimulation program and preincubation storage time suggests that what's good for the goose is good for its gosling (i.e. hen is good for the chick). The management strategies used in the present study to increase egg production in the maternal population do not seem to dramatically affect the growth potential of its progeny.

The effect of strain was detectable in weekly body weight up to 4 wk after which no difference could be determined. Similarly, Moran *et al.* (1984) noted distinct growth patterns between two turkey strains but no difference in final body weight. A study using four different broiler strains at the University of Alberta also described four distinct growth patterns. Hatchling weights were significantly different as were 21 d body weight but by 35 d no significant differences between strains could be detected (Robinson, unpublished).

Muller (1997) observed a significantly larger breast muscle as a percent of body weight in the EL maternal stock as compared to SS maternal stock at 20 wk, first egg and 60 wk of age. Therefore it is not

surprising to find increased eviscerated carcass yield, total breast muscle, *P. major* and *P. minor* weight and increased *P. major* and *P. minor* as a percent of eviscerated carcass weight in the EL progeny. The sum of these carcass characteristics is evidence of successful selection for breast muscle yield in the EL strain. The present data also suggest that selection for breast muscle includes the selection for both *P. major* and *P. minor* equally since no significant differences were detected for *P. major* and *P. minor* as a percent of total breast muscle weight between strains.

As discussed briefly in the previous chapter, sexual dimorphism has been identified as early as 11 d of incubation (Burke and Sharp, 1989; Burke *et al.*, 1990). Henry and Burke (1998) suggest smaller but more myofibers found in males as compared to female embryos provide the building blocks for greater posthatch growth. It was suggested that particular embryonic androgens might be responsible for such differentiation in muscle development (Henry and Burke, 1998). Early differentiation in muscle structure between the sexes can explain obvious differences at processing. Differences in fleshing between sexes at 6 wk of age in the present trial included heavier eviscerated carcass, front half, back half, total breast, *P. minor* and *P. major* and *P. major* weight as a percent of total breast weight in male carcasses as compared to female broilers. Similarly Robinson (unpublished data, 1999) observed heavier eviscerated carcass, front half, back half, *P. major* and total breast weight in the male population as compared to the female population. Contrary to observations of Robinson (unpublished data, 1999) where female carcasses had 6.9 % more *P. minor* than male carcasses, males in the present study had 8.6 % larger *P. minor* than the female carcasses. In the present trial, females had 0.2 % larger *P. minor* as a percent of eviscerated carcass weight and 0.5 % larger *P. minor* as a percent of total breast muscle weight. These findings are consistent with observations of Korver (unpublished data, 1999) in which female *P. minor* as a percent of eviscerated carcass weight was on average 0.4 % higher than the male population.

Differences in metabolism between the sexes have also been suggested. Burke (1992) found yolk-free hatchling carcasses of male chicks as a percent of egg weight to be greater than that of female chicks. In the data presented in Chapter 3, yolk sac, carcass and total chick weight as a percent of initial egg weight of male chicks were larger than female chicks. Therefore male chicks utilized nutrients within the egg more efficiently than did female chicks.

Other research has focused on post hatching growth in which selection criteria such as appetite may be amplifying sexual dimorphism. Marks (1985) found that both feed and water intake is involved in early body weight differences in broilers. Differences in feed and water intake between sexes were not significant until 10 d post-hatch, at which time male commercial broilers consumed more than female counterparts resulting in greater body weight. Differences in feed intake may explain how male chicks become significantly heavier by 3 wk of age and remain heavier until market weight. It also dismisses the idea that increased residual yolk sac found in male chicks will be advantageous for early post hatch growth, since the female chicks were significantly heavier in the first and second wk post hatch. Restricting commercial males to ingest equal amounts of feed to females resulted in slightly greater male body weight than the females, suggesting that differences in feed efficiency also exist (Marks 1987).

In conclusion, selection for further breast muscle growth was successful in the EL broilers. Evidence of this was greater eviscerated yield, total breast muscle weight, *Pectoralis major* and *Pectoralis minor* weight in the EL broilers as compared to the SS broilers. Although each strain had disinct growth rates both strains had similar 6 wk body weights. Female broilers had greater average body weights up to 2 wk after which the males had consistently greater body weights. Male carcasses also had greater eviscerated weight, front half and back half weights and greater total breast muscle weight, , *Pectoralis major* and *Pectoralis minor* weight than did female carcasses. Female carcasses however, had greater *Pectoralis minor* weight as a percent of eviscerated weight then male carcasses. Preincubation egg storage and maternal feed and photostimulation treatments had little to no influence on broiler traits measured.

Table IV-1 **Effects of maternal strain, feeding program, photostimulation program and preincubation egg storage on fresh, stored and transfer egg weight (g).**

Main Effects	Fresh Egg Weight (g)	Stored Egg Weight (g)	Transfer Egg Weight (g)
Strain			
EL[1]	69.2	68.8	61.6
SS[2]	69.1	68.7	61.3
SEM	0.5	0.5	0.5
Feeding Tmt.			
FF[3]	69.1	68.7	61.4
SF[4]	69.2	68.8	61.5
SEM	0.5	0.5	0.5
Photostimulation Tmt.			
FP[5]	68.6	68.1	60.7^{b}
SP[6]	69.7	69.3	62.1^{a}
SEM	0.5	0.5	0.5
Preincubation Storage (d)			
0	69.4	69.4^{a}	61.8
1	69.3	69.0^{ab}	61.6
2	69.2	68.8^{abc}	61.6
3	69.1	68.6^{bc}	61.3
4	69.2	68.7^{bc}	61.2
5	69.1	68.5^{bc}	61.3
6	68.9	68.2^{c}	61.2
SEM	0.3	0.3	0.3

Main Effects	Probability		
Strain	0.9013	0.8333	0.5949
Feeding Tmt.	0.9233	0.9141	0.8967
Photostimulaton Tmt.	0.0845	0.0814	0.0256
Preincubation Storage	0.8601	0.0129	0.5224

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-2 **Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex on egg weight loss during storage and incubation (g) and relative to fresh egg weight (%).**

	Weight Loss During Storage		Weight Loss During Incubation	
Main Effects	(g)	(%)	(g)	(%)
Strain				
EL[1]	0.460	0.665	7.21	10.5
SS[2]	0.456	0.664	7.41	10.8
SEM	0.014	0.020	0.1	0.2
Feeding Tmt.				
FF[3]	0.457	0.665	7.31	10.7
SF[4]	0.459	0.665	7.30	10.6
SEM	0.014	0.021	0.1	0.2
Photostimulation Tmt.				
FP[5]	0.466	0.680	7.44	10.9^{a}
SP[6]	0.450	0.650	7.17	10.4^{b}
SEM	0.014	0.020	0.1	0.2
Preincubation Storage (d)				
0	0.015^{f}	0.015^{f}	7.62^{a}	11.0^{a}
1	0.239^{e}	0.348^{e}	7.38^{ab}	10.7^{a}
2	0.345^{d}	0.500^{d}	7.23^{bc}	10.5^{ab}
3	0.465^{c}	0.676^{c}	7.27^{bc}	10.6^{ab}
4	0.585^{b}	0.850^{b}	7.47^{ab}	10.9^{a}
5	0.789^{a}	1.143^{a}	7.21^{bc}	10.5^{ab}
6	0.770^{a}	1.121^{a}	6.97^{c}	10.2^{b}
SEM	0.021	0.030	0.13	0.2
Sex				
F	0.453	0.656	7.39	10.7
M	0.463	0.673	7.23	10.6
SEM	0.011	0.016	0.07	0.1

Main Effects	Probability			
Strain	0.8370	0.9650	0.3140	0.2987
Feeding Tmt.	0.9221	0.9815	0.9601	0.8423
Photostimulation Tmt.	0.3918	0.2914	0.1737	0.0440
Preincubation Storage	0.0001	0.0001	0.0051	0.0438
Sex	0.5058	0.4580	0.0997	0.2832

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-3 **Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex on broiler body weight (g) during week 1 – 3.**

	Body Weight		
	Week 1	Week 2	Week 3
Main Effects	(g)	(g)	(g)
Strain			
EL[1]	139.2[a]	356.6[a]	693.0[a]
SS[2]	132.5[b]	337.8[b]	664.2[b]
SEM	1.3	2.9	4.7
Feeding Tmt.			
FF[3]	134.7	345.7	677.6
SF[4]	136.9	348.7	679.6
SEM	1.3	2.9	4.8
Photostimulation Tmt.			
FP[5]	139.1[a]	349.3	682.4
SP[6]	132.6[b]	345.1	674.8
SEM	1.2	2.8	4.5
Preincubation Storage (d)			
0	138.4	353.7	688.6
1	138.1	352.8	683.7
2	134.9	346.3	675.9
3	136.2	349.4	682.2
4	133.6	341.7	670.9
5	135.5	341.7	677.1
6	134.2	345.2	672.4
SEM	1.6	4.0	7.2
Sex			
F	137.7[a]	350.7[a]	668.4[b]
M	133.9[b]	343.8[b]	688.8[a]
SEM	0.8	2.1	3.8

Main Effects	Probability		
Strain	0.0002	0.0001	0.0001
Feeding Tmt.	0.2363	0.4454	0.7554
Photostimulaton Tmt.	0.0002	0.2783	0.2353
Preincubation Storage	0.1007	0.0832	0.4024
Sex	0.0014	0.0220	0.0002

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-4 Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex on broiler body weight (g) during week 4 – 6.

	Body Weight		
	Week 4	Week 5	Week 6
Main Effects	(g)	(g)	(g)
Strain			
EL[1]	1138.3[a]	1675.6	2058.7
SS[2]	1106.6[b]	1648.3	2046.2
SEM	7.8	11.8	15.2
Feeding Tmt.			
FF[3]	1114.1	1654.1	2038.7
SF[4]	1130.8	1670.0	2066.2
SEM	8.0	12.0	15.5
Photostimulation Tmt.			
FP[5]	1118.3	1653.7	2041.3
SP[6]	1126.6	1670.3	2063.7
SEM	7.5	11.3	14.6
Preincubation Storage (d)			
0	1134.5	1680.2	2076.6
1	1133.9	1687.3	2088.9
2	1125.6	1669.6	2060.9
3	1129.6	1663.2	2050.4
4	1102.1	1629.4	2016.7
5	1111.2	1642.4	2007.8
6	1120.3	1661.7	2066.0
SEM	13.0	19.2	26.1
Sex			
F	1076.4[b]	1566.8[b]	1926.3[b]
M	1168.6[a]	1757.1[a]	2178.6[a]
SEM	6.9	10.3	13.7

Main Effects	Probability		
Strain	0.0032	0.0894	0.5451
Feeding Tmt.	0.1197	0.3276	0.1883
Photostimulaiton Tmt.	0.4306	0.2963	0.2778
Preincubation Storage	0.3713	0.2212	0.1323
Sex	0.0001	0.0001	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-5 **Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex on eviscerated carcass weight (kg) and eviscerated yield (%) (eviscerated carcass weight as a percent of live weight).**

Main Effects	Eviscerated Weight (kg)	Eviscerated Yield (%)
Strain		
EL[1]	1.37	66.5[a]
SS[2]	1.34	65.5[b]
SEM	0.01	0.2
Feeding Tmt.		
FF[3]	1.34	66.0
SF[4]	1.36	66.0
SEM	0.01	0.2
Photostimulation Tmt.		
FP[5]	1.34	65.8
SP[6]	1.36	66.2
SEM	0.01	0.2
Preincubation Storage (d)		
0	1.37	66.1
1	1.38	66.2
2	1.37	65.9
3	1.34	65.4
4	1.33	66.4
5	1.33	66.1
6	1.36	66.0
SEM	0.02	0.5
Sex		
F	1.27[b]	66.0
M	1.44[a]	66.0
SEM	0.01	0.2

Main Effects	Probability	
Strain	0.0675	0.0017
Feeding Tmt.	0.1888	0.8803
Photostimulation Tmt.	0.1593	0.2496
Preincubation Storage	0.1469	0.6744
Sex	0.0001	0.9510

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-6 **Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex on front half carcass and back half carcass weight (g).**

Main Effects	Front Half Weight (g)	Back Half Weight (g)
Strain		
EL[1]	763.4	603.2
SS[2]	758.0	582.5
SEM	19.0	18.5
Feeding Tmt.		
FF[3]	768.9	575.3
SF[4]	752.5	610.5
SEM	19.3	18.8
Photostimulation Tmt.		
FP[5]	745.4	598.2
SP[6]	776.0	587.6
SEM	18.3	17.8
Preincubation Storage (d)		
0	770.5	603.6
1	754.4	626.9
2	771.6	584.6
3	712.0	630.0
4	746.5	588.0
5	812.0	513.1
6	757.6	604.0
SEM	37.0	36.1
Sex		
F	713.7[b]	557.2[b]
M	807.7[a]	628.6[a]
SEM	19.0	19.0

Main Effects	Probability	
Strain	0.8329	0.4115
Feeding Tmt.	0.5285	0.1650
Photostimulation Tmt.	0.2344	0.6709
Preincubation Storage	0.5451	0.2323
Sex	0.0008	0.0091

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-7 **Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex on total breast weight, *Pectoralis Major and Minor* weight (g).**

Main Effects	Total Breast Weight (g)	*Pectoralis Major* Weight (g)	*Pectoralis Minor* Weight (g)
Strain			
EL[1]	334.6[a]	268.6[a]	66.0[a]
SS[2]	316.9[b]	254.2[b]	62.7[b]
SEM	3.3	2.8	0.6
Feeding Tmt.			
FF[3]	322.5	258.4	64.2
SF[4]	329.0	264.4	64.5
SEM	3.4	2.9	0.6
Photostimulation Tmt.			
FP[5]	322.9	259.2	63.7
SP[6]	328.6	263.5	65.1
SEM	3.2	2.7	0.6
Preincubation Storage (d)			
0	328.0	262.9	65.1
1	334.8	268.2	66.6
2	324.8	261.8	63.0
3	327.1	263.2	63.9
4	319.1	255.1	64.0
5	316.7	253.4	63.3
6	329.8	265.1	64.8
SEM	5.6	4.8	1.1
Sex			
F	308.1[b]	246.4[b]	61.7[b]
M	343.4[a]	276.4[a]	67.0[a]
SEM	3.0	2.5	0.6

Main Effects	Probability		
Strain	0.0001	0.0002	0.0001
Feeding Tmt.	0.1558	0.1186	0.6874
Photostimulaiton Tmt.	0.2027	0.2616	0.1052
Preincubation Storage	0.1763	0.1872	0.1630
Sex	0.0001	0.0001	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
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[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-8 **Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex *on Pectoralis major* and *minor* weight as a percent of eviscerated weight (%).**

Main Effects	*Pectoralis Major* as a Percent of Eviscerated Weight (%)	*Pectoralis Minor* as a Percent of Eviscerated Weight (%)
Strain		
EL[1]	19.6[a]	4.85[a]
SS[2]	18.9[b]	4.69[b]
SEM	0.1	0.03
Feeding Tmt.		
FF[3]	19.2	4.79
SF[4]	19.4	4.74
SEM	0.1	0.03
Photostimulation Tmt.		
FP[5]	19.3	4.75
SP[6]	19.3	4.78
SEM	0.1	0.03
Preincubation Storage (d)		
0	19.1	4.73
1	19.4	4.83
2	19.3	4.66
3	19.6	4.79
4	19.1	4.81
5	19.1	4.79
6	19.4	4.76
SEM	0.2	0.06
Sex		
F	19.3	4.86[a]
M	19.2	4.68[b]
SEM	0.1	0.03

Main Effects	Probability	
Strain	0.0001	0.0004
Feeding Tmt.	0.3176	0.2522
Photostimulation Tmt.	0.8690	0.4944
Preincubation Storage	0.3558	0.3706
Sex	0.4766	0.0001

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

Table IV-9 **Effects of maternal strain, feeding program, photostimulation program, preincubation egg storage and sex *on Pectoralis major* and *minor* weight as a percent of total breast weight (%).**

Main Effects	*Pectoralis Major* as a Percent of total Breast Weight (%)	*Pectoralis Minor* as a Percent of total Breast Weight (%)
Strain		
EL[1]	80.2	19.8
SS[2]	80.1	19.9
SEM	0.1	0.1
Feeding Tmt.		
FF[3]	80.0	20.0
SF[4]	80.3	19.7
SEM	0.1	0.1
Photostimulation Tmt.		
FP[5]	80.2	19.8
SP[6]	80.1	19.9
SEM	0.1	0.1
Preincubation Storage (d)		
0	80.1	19.9
1	80.0	20.0
2	80.5	19.5
3	80.4	19.6
4	79.9	20.1
5	80.0	20.1
6	80.2	19.8
SEM	0.2	0.2
Sex		
F	79.9[b]	20.1[a]
M	80.4[a]	19.6[b]
SEM	0.1	0.1

Main Effects	Probability	
Strain	0.6280	0.6280
Feeding Tmt.	0.0932	0.0932
Photostimulation Tmt.	0.6727	0.6727
Preincubation Storage	0.3302	0.3302
Sex	0.0031	0.0031

[a,b] For each main effect means within a column with no common superscript differ significantly ($P < 0.05$).
[1]EL=Experimental Line, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[2]SS=Shaver Starbro, Shaver Poultry Breeding Farms Ltd., Box 400, Cambridge, ON, Canada N1R 5V9
[3]FF=Fast Feed Allocation Program (Table II-1)
[4]SF=Slow Feed Allocation Program (Table II-1)
[5]FP=Fast Photoperiod (Figure II-1)
[6]SP=Slow Photoperiod (Figure II-1)

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5. GENERAL DISCUSSION AND IMPLICATION

With increased demand for breast muscle in today's market, breeding companies will continue to select for improvements in breast muscle production. Each years genetic improvements in growth will in turn select against the reproductive potential of the parent stock (Siegel and Dunnington, 1985). In order to improve reproductive performance of broiler breeders (BB), research will continue to experiment with management strategies, including feeding programs and photostimulation programs. For example, feed restriction is used routinely in the industry to control body weight and minimize EODES (Van Middlekoop, 1971). Yu *et al.* (1992a; 1992b; 1992c) reported the use of feed restriction during rearing and breeding improves total egg production and persistence of lay. Subsequent research studying fast and slow feeding programs have reported hens fed gradual increases in feed had superior persistence of lay and total egg production than those fed aggressive increases in feed (Muller, 1997; Robinson *et al.*, 1999a). Fine tuning photostimulation programs have reported improvements in fertility, hatchability and hatch of fertile for hens exposed to a gradual lighting program as compared to hens exposed to a sudden increase in day length (Robinson *et al.*, 1999b). Although these results are very encouraging in terms of broiler breeder performance, it begs the question, if these small changes in management have such an influence on egg production, how do such changes affect subsequent egg, chick and broiler performance?

The objective of the present research was to determine if changes in broiler breeder management strategies had any effect on the value chain, which follows the breeder house. Does providing nutrients to a hen more aggressively as she becomes sexually mature change the components or the quality of those components in the resulting egg? Will those eggs provide a different environment for that chick to develop in and hatch from? Will the resulting chick differ in size and residual yolk sac, which in turn affect subsequent broiler growth? Because of the possible influence of hen age, preincubation storage and sex, these effects were also studied.

Effects of hen age on egg components were not surprising based on past research. Increased egg weight with hen age has been observed in Leghorns (Fletcher *et al.*, 1981), turkeys (Applegate and Lilburn, 1996) and broiler breeders (Mather and Laughlin, 1979). Research has found that increased yolk deposition with age (Bahr and Palmer, 1989), results in larger follicles (Joyner *et al.*, 1987) and proportionally greater yolk weight in the egg (O'Sullivan, 1991). Subsequent chicks hatched with greater

yolk sac and total chick weight as a percent of egg weight. The deposition of proportional yolk at the expense of proportional shell weight resulted in increased weight loss due to storage and specific gravity with hen age.

Weight loss due to storage affected both egg and chick quality. Eggs stored prior to incubation had greater proportional yolk weights due to moisture loss from the albumen. Chicks hatched from stored eggs were larger as a percent of egg weight as days of storage increased. This increase in chick weight was due to an increase in proportional yolk sac weight, since no effect of storage was detected for carcass weight. The absence of storage effects on broiler performance suggests the problems associated with storage can be essentially eliminated at the hatchery level by limiting the detrimental effects of storage on hatching eggs. Organizing eggs by their age (days stored) and increasing incubation time in relation to storage time as proposed by Mather and Laughlin (1976) may be one possible solution to improving the hatchability of eggs subjected to storage. Further research will be needed to see if broiler performance could be affected by egg storage, which exceeds 1 wk.

The effect of strain exaggerated the effect of hen age on egg components as discussed earlier. Strain differences observed between hatchling carcass weight suggested that differences in metabolism exists between the strains. Embryonic differences in metabolism and growth have been suggested in early work by Byerly (1930) and Blunn and Gregory (1935). The effects of strain were most obvious in terms of broiler performance and carcass characteristics. Although growth patterns between strains were not the same, final body weight at 6 wk of age were not different. Further selection for further breast muscle yield by the breeding company was successful, increasing eviscerated yield, total breast muscle, *P.major* and *P. minor* weight compared to the commercial strain. Improvements of 5.6 % in total breast muscle weight could have substantial economic benefits for processing companies.

Gender effects could be identified by examination of newly hatched chicks which show male embryos had a higher proportion of yolk sac, carcass and total chick weight than female embryos. Differences in total breast muscle, *P. major* and *P. minor* weight between sexes supported earlier research suggesting male embryos have smaller but more myofibrils than female embryos (Henry and Burke, 1998). This early divergence in muscle development along with research that suggests appetite differences

influence body weight differences between sexes (Marks, 1985) may explain gender differences in the present experiment.

Feeding program and photostimulation program had limited effects on egg quality, chick quality and broiler performance. This is encouraging for research aimed at improving broiler breeder reproductive performance. If effects to the subsequent generation are limited, researchers can exploit the potential of management strategies to improve production without fear of sacrificing egg, chick or broiler quality.

To put the knowledge gained from this these experiements into perspective, the results have been tabled (Table V-1). While hen age and preincubation storage influenced most egg and chick traits, they fail to influence many broiler traits. Most broiler traits were influenced by strain and gender differences.

Table V-1 **Number of egg, chick and broiler traits influenced by hen age, preincubation egg storage, strain, maternal photostimulation and feedingtreatment and progeny gender.**

Main Effects	Egg Traits	Chick Traits	Broiler Traits
Total Traits Measured	13	24	23
Hen Age	13	24	NA
Preincubation Storage	12	13	5
Strain	4	3	10
Photostimulation Tmt.	0	5	3
Feeding Tmt.	0	0	0
Gender	NA	7	14

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