Manipulating Reproductive Potential: Growth Profile and Photostimulation Age Effects in Broiler Breeders

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Introduction

Managing broiler breeders over time is like hitting a moving target. While broiler 42-day body weight is increasing each year, the target body weight for male and female broiler breeders is decreasing (Rustad and Robinson, 2002). In 1979, Hubbard male and female breeders were approximately 50% of the 42-day broiler weight. In 2001, this percentage had decreased to 36.1 for males and 30.3 for females. The situation for knowing what nutrients these birds need is compounded by the development of "yield" varieties, carrying increased amounts of breast muscle yield, often on a smaller carcass frame. The introduction of these new genotypes to meet consumer demands has improved the growth potential of the bird, but has also created difficulty in the management of the broiler breeder hens. The modern breeder female has the genetics for rapid and efficient growth, yet requires a good rate of egg production to supply the next generation of boiler chicks. These birds are changing in terms of their reaction to lighting programs as well (Joseph et al., 2002). However, the timing of management practices such as light stimulation, and increasing feed allocation lighting need to be considered as a single program.

A breeder hen that will lay at high rates is one that has a finely tuned ovulatory cycle. Such birds are thought to have ideal carcass composition at sexual maturity and to have an optimal number of large ovarian follicles at sexual maturity. The ovaries of growth-selected strains are particularly sensitive to improper nutrient allocations during the sexual maturation process. Small degrees of over or under feeding need can negatively impact egg and chick production (Katanbaf et al., 1989a; 1989b: Robinson et al., 1998a, 1998b). Having too few large follicle scan result in gaps in laying sequences and hence shorter than normal sequences. This is a problem seen in hens undergoing follicular atresia (follicle dissolution). Having too many large ovarian follicles is a problem associated with obesity, or with pullets being exposed to a large positive energy balance after photostimulation (Yu et al., 1992). It can be a vicious cycle; with obesity continuing to worsen as the rate of egg production remains low and / or goes into early decline due to excess feed intake. The substantial overfeeding of hens for as little as 2 wk between 23 and 31 wk of age has been found to reduce fertility and hatchability throughout production (Ingram and Wilson, 1987). The primary influence on how many large, yolky follicles form on the ovary is body weight. But when you compare birds of the same size, the one consuming more feed will have more large follicles. Refinements in feeding programs are becoming increasingly important with the development of high breast-yield strains, and with continued increases in the growth potential at the expense of reproductive potential. The amount of feed allocated to broiler breeders during rearing and early lay can change frame size and breast muscle fleshing in the birds (Wilson *et al.*, 1995). Breeder females given lower than usual or higher than usual feed allocation divert more energy to carcass growth and less to reproductive processes. Selection for broiler breeder egg production is not as heritable or profitable as selection for growth traits. Modern feed allocation programs need to be based on a solid understanding of the reproductive physiology of these birds to optimize reproductive performance.

Flock Uniformity

Pullet quality, particularly in terms of flock uniformity, is also a critical factor in creating a hen with high post-peak production potential. Delaying photostimulation to allow the smaller pullets more time to become physically mature can pay for itself in the form of increased egg production. Monitoring the fleshing of the pullets at key ages is an important tool for assessing juvenile flocks, particularly in our new, high breast-yield strains. During sexual maturation, the change in fleshing in time may become even more important than raw changes in body weight for creating a bird capable of maximal production rates. Once birds have passed peak production, an aggressive feed withdrawal program, while successful in some instances, may not be recommended for flocks with poor uniformity due to the added stress of feed restriction. Competition for a dwindling food supply can negatively impact body weight uniformity, as the assertive birds get larger at the expense of the smaller, less aggressive birds.

Strain Variation in Response to Feed and Photostimulation

Commercial broiler breeder female strains vary in the extent to which sexual maturation is influenced by nutrient intake (Robinson et al., 1998a). Four commercially available strains were obtained and reared on a common body weight target. The pullets were photostimulated at 22 weeks of age, when one of three feeding programs were imposed. The *Ad libitum* feeding program was used to act as a worst-case scenario for the effects of overfeeding on egg production traits. The Fast-Feed regimen was a feed restriction program that was adjusted weekly for egg production and body weight gains. The Slow-Feed regimen involved daily adjustments to the restricted diet to account for body weight gain, increasing by 1 g/d between 22 and 26 weeks of age, and 0.5 g/d until 31 weeks of age. The strategy was to have feed increases so gradual that the metabolism of the bird would not recognize a positive energy increase in nutrient availability and stimulate storage mechanisms.

There was approximately a 1 wk range in the mean age at first egg for the four strains. A*d-libitum* feeding did not accelerate sexual maturation in two of the strains. In the two strains where sexual maturation was not advanced by excess feed, the limiting parameter was probably hypothalamic maturation. The number of large yellow ovarian follicles was lower in the two strains that reached sexual maturity first. There appear to be specific “norms” for ovary development that are strain dependant. Feed allocation influenced number of large follicles, with *ad-libitum*-fed hens having more follicles than either of the other feeding treatments. These data strongly suggest that it is essential to follow management recommendations specific to a breeder genotype. Strains vary in terms of optimal age at photostimulation, and perhaps in the rate of increase of feed allocation.

Impact of Growth Selection on Sensitivity to Overfeeding

This study was designed to gain a better understanding of how breast muscle growth and maintenance link to the reproductive development of traditional and high breast-yield birds. For this experiment 234 female broiler breeders comprising three strains: Random-bred (unselected since 1977), Ross 308 (a high-yield bird suited for the whole-bird market), and Ross 508 (a very high-yield bird suited for the cut-up and further processing market). Each strain was raised to the same target BW at 20 wk of age using the 2001 Ross 508 feed guidelines. Beginning at photostimulation (22 wk of age) pullets were fed 100%, 120%, and 140% of the amount needed to maintain the standard Ross 508 growth curve.

The genetics of the birds affected how quickly they entered lay, with the Random-bred, Ross 508 and Ross 308 birds commencing lay 16.5, 20.2, and 27.4 after photostimulation, on average. Entry into lay was not accelerated by the excess feed of the 120 and 140% feeding treatments. The rapid onset of lay in all of our genetic lines indicates that the majority of the birds had acquired the appropriate level of growth and composition to support egg production. At sexual maturity (onset of lay), the Ross 508 birds had the highest proportion of breast muscle. Conversely, the Random-bred hens were the fattest – reflecting the less efficient growth of their older genetics.

Feeding regimen had a big impact on egg production, with 166, 159, and 137 settable eggs produced by the 100, 120, and 140% groups, respectively. Interestingly, the modern, high breast-yield Ross 508 birds were the most sensitive to overfeeding, producing 177 eggs with the 100% feed allocation compared to only 123 eggs on the 140% feed allocation. When coupled with decreased rates of fertility and hatchability in the 140% treatment, overfeeding had a devastating effect on chick numbers. A key factor influencing the egg production of these birds was the ability to maintain lay. At the end of the trial, 94% of the 100% feed allocation birds were still in active lay compared to 86% in the 120% allocation group and 63% in the 140% allocation group. The productivity of the Ross 308 hens was least impacted by feed allocation, demonstrating a better tolerance to a range of feeding profiles than either the Random-bred or the Ross 508 hens in this study.

Assessing Sensitivity to Growth Profile and Photostimulation Age

There is a clear move in the broiler breeder industry to later photostimulation ages – with recommendations of a minimum age at lighting of 23 wk being common. Along with the incredible growth potential of some modern breeder varieties, questions have surfaced about the viability of early photostimulation – assuming growth and uniformity issues have been addressed. Most current strains are capable of early maturing if a mature physical state has been achieved. This means that the biggest impact of altering the growth profile to achieve a body weight target at early or typical ages may be on frame size, which subsequently has a role in determining egg size. Feed allocation, particularly early in the pullet phase, can have a permanent effect on bone length and overall frame size.

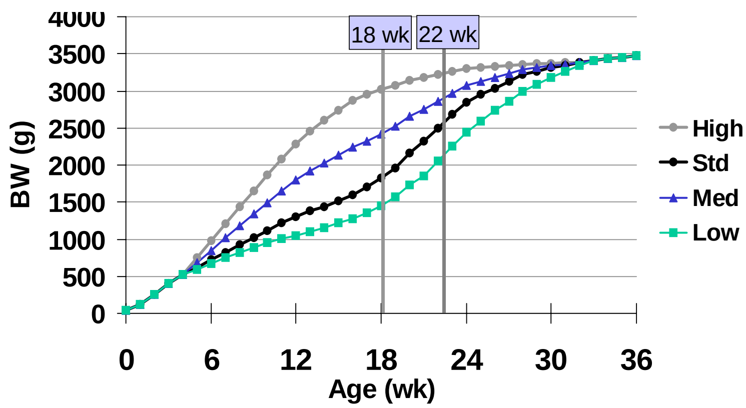
An experiment was performed to test how the interactions between genetic strain, age at photostimulation and body weight target impact growth rate and efficiency, nutrient partitioning, sexual maturation and reproductive efficiency. Basically, we wanted to see if current strains are equivalent in their response to extreme differences in their pullet growth curve and if this response differed with early (18 wk) or standard photostimulation ages (22 wk). We used 560 pullets from each strain (Hubbard Hi-Y, Ross 508, and Ross

708) to represent modern, high breast-yield strains. For comparison, the Ross 308 generates broilers that yield less breast muscle than the 508 or 708). The 4 body weight profiles separated at 3 wk and converged at 32 wk of age as follows STANDARD (approximates normal target BW profile of the breeder strains used); LOW (12 wk body weight target = 25% lower than STANDARD followed by rapid gain to 32 wk); MODERATE (12 wk body weight target = 150% of STANDARD followed by lower rate of gain to 32 wk); and HIGH (12 wk BW target = 200% of STANDARD followed by minimal growth to 32 wk) (Figure 1).

By dissecting birds throughout the growing period, at sexual maturity, and at the end of production, we would also have information on specifically how they decided to allocate nutrients between growth, storage, and egg production. Using carcass conformation measurements to determine the frame size and fleshing response, we could see the impact of specific feeding/lighting program choices on body dimensions. This was important because managing a short, stocky bird can be very different from managing a tall, lanky bird even when the body weights are the same. Ultimately we wanted to identify if modern strains are being challenged to their full production potential by their feed management programs and if there is a basis for moving towards strain-specific management of broiler breeders.

One of the primary effects of the growth profiles was on frame size. For example, by 18 wk of age, shank length (lower leg bone length) was reduced in the birds kept smaller early in life (LOW = 101.8 mm; STANDARD = 105.6 mm; MODERATE = 109.5 mm; and HIGH = 112.3 mm). While differences in the growth profiles limited the ability to interpret early measures of fatness, the long-term concern would be that feeding a small-framed to the same body weight target as a larger-framed bird will result in increased fatness and the triggering of reproductive disorders associated with overfed hens. Early photostimulation limited the proportion of breast muscle and abdominal fatpad in the pullets, as they would have been diverting some of their resources into developing the reproductive tract. While the Ross 508 birds had the heaviest fat pads the Ross 708 pullets had the greatest liver size by 24 wk of age with early photostimulation (18 wk = 1.72% of body weight; 22 wk = 1.40% of body weight). Higher breast-yield strains tend to have a lower body weight requirement for maturity, which may explain why the 708 birds were able to respond to early photostimulation so quickly. The 22-wk ovary weight was also influenced by age at photostimulation, but this was limited to the HIGH and MODERATE groups. A reproductive response to early photostimulation is not possible without a more aggressive growth profile, while severe restriction limits breast and fat tissue growth and reduces ovarian and oviduct development rate at photostimulation. Heavier pullets respond to early photostimulation by developing a reproductive system at the expense of breast muscle and fat pad growth.

FIGURE 1. Body weight target profiles and photostimulation ages.



Body weight at sexual maturity (onset of lay) was 3.40, 3.21, 3.01, and 2.84 kg for HIGH, MODERATE, STANDARD, and LOW birds, respectively. The body weight differences impacted shank and keel length, indicating differences in frame size. Interestingly, ovary weight in the later maturing LOW birds (55 g) was 6 g heavier than in the other groups. The number of large yellow follicles on the ovary did not change with photostimulation age (average of 7.5 follicles), except in the HIGH birds, where it dropped from 8.1 in birds photostimulated at 18 wk to 6.5 in those photostimulated at 22 wk. Feed allocation to the HIGH birds was quite low during this period to keep the body weight on target, which likely impacted ovary development. The 18 wk photostimulation age increased excess large yellow follicle production of HIGH (55 % paired) compared to other growth profiles, while both small yellow follicle number and atresia in small yellow follicles were increased.

Production Traits

Egg production traits were monitored through to 58 wk of age. All of the rearing growth profiles converged at 32 wk of age and remained the same for the rest of the trial. The LOW growth profile delayed onset of lay, particularly in 18 wk PS-age birds. Birds on these treatments had not reached the adequate state of maturity to fully respond to a photostimulatory cue. The pullet is very efficient at continuing to allocate nutritional resources to growth and away from reproduction when growth is not complete. While delaying photostimulation normally allows the smaller birds more time to reach a mature state, their slowed entry into production was even more significant when their feed allocation is considered. During the period immediately after photostimulation at 18 wk, the LOW birds had a very high feed allocation relative to that of the other growth curve treatments in order to allow them to reach the BW targets during this period. Despite what would normally be considered excess feed, sexual maturation was still delayed. In contrast, the feed allocation to the HIGH profile birds was quite low at this time. Sexual maturation was only delayed in the Ross 708 hens, suggesting that these birds do not tolerate nutrient shortages well. These birds carried a greater proportion of breast muscle than the other strains, which may contribute to their inability to cope with declining nutrient availability at this critical stage. Photostimulating birds at 22 wk of age alleviated most of these problems. Despite a wide range in growth profiles, birds were much more uniform in their reproductive traits when the later photostimulation age was used.

There was no effect of growth history on initial egg weight, demonstrating that age may be more important than frame size in influencing early egg weight. However, an 18 wk PS-age resulted in production of 16.0 small eggs (<52 g) compared to 7.9 in 22 wk birds. A settable, 52 g egg weight was reached earliest by STANDARD birds (26.7 wk of age). Early in lay, hens lay eggs on consecutive days in a characteristically long laying sequence called a prime sequence. Prime sequence length generally correlates well with overall egg production. In this study, prime laying sequence length was reduced by 7.0 eggs, on average, in MODERATE and HIGH birds (mean = 15.0 d) compared to other profiles. This seems reversed, but along with some other early production traits, demonstrates that the lower feed allocation the MODERATE and HIGH birds received during sexual maturation to keep them on their BW target did affect some early production traits.

Ultimately, by 58 wk of age, the 18 wk PS-age birds yielded 8 more eggs (170) than 22 wk PS-age birds, with no affect on unsettable egg production. On average, total egg production was similar among growth profile treatments. However, there was variability in the productivity of specific strains grown on some profiles. The Ross 708-HIGH hens, for example, under-performed (138 eggs) compared to the other profiles (mean = 166.3). Alternatively, Ross 508-HIGH birds laid the same number of eggs as Ross 508-STANDARD birds (mean = 178.7).

In examining the growth profiles of individual hens from the different growth profiles, it was clear that there are strain-based strategies for managing reproduction. The Ross 708 tied up nutrients deposited during the pullet phase tightly, and was unable to mobilize nutrients from storage as they were needed under conditions of dietary deficiency. This may be partly due to their increased breast muscle mass. Under more normal feeding conditions these birds performed very well. The Hubbard Hy-Y hens appeared much more able to mobilize nutrient stores, and were not hindered by the very low feed allocations provided to the HIGH birds during sexual maturation. Ultimately feeding profiles affected egg production traits differently among strains, with little effect of photostimulation age.

Preliminary Economic Analysis

All of the growth and production data in this study was input into a dynamic, multiphasic mathematical model of the broiler breeder supply chain. This model generated economic figures based on the average production traits of each treatment. The economic results represent mean egg production and feed intakes for each treatment, using settable eggs: normal shells and > 52 g in weight. In this preliminary analysis the lowest overall cost of production ($/chick; and therefore the highest profitability in this analysis) was in the Ross x Ross 508, on the STANDARD feeding curve, and photostimulated at 22 wk. In the Ross 508 and the Hubbard HI-Y, the 22 wk photostimulation was more profitable on the LOW, STANDARD and MODERATE curves. On the HIGH curve, however, early photostimulation was more profitable. R508 hens may to be able to produce eggs of adequate size early, drawing substantially from body reserves. The HI-Y trend was similar, with less success at producing early eggs of adequate size.

Profitability in the Ross 708 birds followed a pattern opposite of the other two strains. Saleable chick costs from Ross 708 hens were lower when photostimulated early. Nutrients provided nutrients in high quantities at the onset of egg production were readily diverted into eggs, increasing early egg size. These results may have changed if the study went through to 65 wk of age. In addition, this is based on individually-caged birds. From this work, we know that, under non-competative conditions (individually caged from 18 wk of age), broiler breeders are generally capable of doing well under a wide range of rearing BW profiles. The real story comes out when you look at the production patterns of individual birds.

Defining Hen 'Attitude Towards Reproduction'

We built an individual snapshot of production for each hen in the study. This was a compilation of feed intake, actual and target BW profiles, BW gains and losses, and every egg-laying day for that bird. Each hen appears to have a different balance between the pull to lay eggs or to grow. Most have a specific balance between these two pulls on their individual nutrient allocation. Hens that lay well will tend to do so by sacrificing some growth – causing them to progressively slip below the average BW of the flock, as well as their BW relative to the rest of the flock at housing. These 'martyr' hens give of themselves to support their progeny. For some, this does not end well. At some point, their body can no longer preferentially divert nutrients towards egg production, and they cease laying altogether ('burn-out' hen). Hens which are able to hang on to nutrients more tightly will increase in size relative to the flock average, but do so at the expense of egg production ('tight-fisted' hens). Scattered throughout this group in particular are the 'yo-yo' hens. These hens can go through repeated breaks in egg production when it starts to interfere with growth. Upon ceasing egg production, their nutrient balance shifts back towards the support of growth. The reproductive control center of these birds soon gets the message that the nutrient status will allow support of reproduction, and egg production begins again.

In every population, there are sub-groups that do not fit the model. A group we would like to see disappear are those that do not lay well and do not grow well. The hens we may value the most in the barn are the highly efficient 'superhens' that can lay eggs well while continuing to grow well relative to the population. They don't burn-out despite high rates of egg production and can maintain or even beat the average flock growth rate. The big question is if these hens are the perfect mix of growth and reproductive traits, what do their broiler offspring look like? A preliminary trial is underway to see if we can link these maternal reproductive traits to commercial broiler traits. The frequency of each reproductive attitude within the flock and within the experimental treatment groups is also being determined.

These same reproductive attitudes also exist in commercial flocks. By thinking about what is driving the reproductive effectiveness of different groups of hens within the flock, hopefully we can work towards making better flock management decisions. Breeding companies have put a lot of emphasis on achieving early body weight targets in pullets because of the long-term implications for frame size. While genetic selection programs tend to be similar, it is important to know if there is a wide range of responses to specific management methods, or if our new breeder varieties act similarly. Sensitivity to overfeeding, altered growth profiles, or photostimulation ages are key components of this type of analysis. Identification of differences would underscore the need to move towards strain-specific management.

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