IDENTIFYING BROILER BREEDER MANAGEMENT – NUTRITION INTERACTIONS TO OPTIMIZE CHICK PRODUCTION

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Summary

Broiler breeder hens grow more efficiently and are leaner than ever before due to positive results from broiler genetic selection strategies. Effective ovary management is an integral part of a successful breeder management program. Optimum ovarian morphology and reproductive efficiency is realized when the pre-maturational period is managed very conservatively in terms of increases in feed allocation. Feed allocation programs need to be based on a solid understanding of the reproductive physiology of these birds and defining factors influencing their growth and reproductive efficiency. By identifying ‘reproductive attitudes’ of individuals and their incidence in a population, more effective refinement of broiler breeder management strategies will be possible.

I. INTRODUCTION

Broiler breeders have a lot expected of them. This parent must have the genetics for rapid and efficient growth, and yet exhibit a high rate of egg production to supply the next generation of broiler chicks. While breeding programs have resulted in annual improvements in broiler growth, breast muscle yield, feed efficiency and disease resistance (McCarthy and Siegel, 1983) decades of selection for meat production traits have impaired the reproductive ability of broiler parents (Siegel and Dunnington, 1985). By the 1970’s there were indications that growth selection negatively affected egg production traits. In their comparison of high and low juvenile body weight lines, Udale et al. (1972) showed that the high weight lines had increased rates of internal ovulation and defective egg production (36% versus 2% in high and low weight birds, respectively).

Broiler breeders are feed restricted from early in life to optimize reproductive performance. These birds have been demonstrated to be prone to multiple hierarchies – a situation that could be alleviated by feed restriction (Van Middelkoop, 1971). The use of feed restriction in modern broiler breeders has limited the expression of such negative reproductive responses to cases where birds have been overfed at a time when the ovary is especially sensitive to excess nutrient intake. These birds are changing in terms of their reaction to lighting programs as well (Joseph et al., 2002). Whereas specialized genetic selection has meant that egg production is not remarkably different from what it was a few years ago, hatching egg producers have had to work hard at fine tuning strain specific procedures for nutrient allocation and photoperiod management. As the modern broiler breeder continues to change due to the impact of genetic selection for improved growth efficiency and meat yield, there is value in understanding how our management priorities have changed along with the bird.

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II. MANAGING OVARIAN FOLLICULAR DYNAMICS

The ovary is the core of a successful broiler breeder. This is the point where the internal balance between growth and reproduction will interface with external management methods. In general, a hen with a well-coordinated reproductive system will have an ideal state of physical maturity and number of large ovarian follicles (ovarian, yolky follicles greater than 10 mm diameter) at sexual maturity to support a strong, sustainable reproductive effort.

However, many external factors can affect egg production. Specific feed ingredients, bird age, and flock management decisions can directly affect semen quality, the oviduct environment, and the egg environment. Furthermore, even small degrees of over or under feeding have been shown to negatively impact egg and chick production (Katanbaf et al., 1989a; 1989b; Robinson et al., 1998a; 1998b). Something as simple as not adjusting feed allocation for temperature changes can affect nutrients available for reproduction and storage due to altered metabolic requirements. Understanding the ovarian function of the chicken and its interaction with nutritional status, age, and strain is essential to the effective production of fertile eggs with a high probability of hatching.

Both bird age and feeding level can influence how the ovary develops. Extra feed can highly stimulate large yellow follicle development, although this stimulation is greater at younger photostimulation ages (Renema et al., 2000). Broiler breeders are thought to be most responsive (or 'estrogenic') in the weeks immediately following photostimulation. During this period, the estrogen output by the ovarian follicles is increasing, and will not decrease to its mature baseline concentration until egg production is underway (Bacon et al., 1980). Allowing excess nutrients at this time may potentially be the most detrimental for normal ovary development. The most critical period for avoiding sudden increases or excessive feed allocation appears to be 2 to 4 wk after photostimulation. This period is a time of flux in the management of nutrients, as the bird switches from primarily growth to a reproductive state. The reproductive and metabolic hormone pathways do not appear to be mature enough to withstand the challenge of a sudden increase in nutrient intake.

The ad libitum feeding of broiler breeder females from photostimulation results in an 80 to 100% greater increase in Luteinizing Hormone (LH) and Follicle Stimulating Hormone (FSH) than in feed restricted birds by 3-d after photostimulation resulting in an accelerated sexual maturation process (Renema et al., 1999). This feed-driven accelerated sexual maturation process is typically also associated with elevated ovarian large yellow follicle numbers. The primary influence on how many large, yolky follicles form on the ovary is body weight. However, when you compare birds of the same size, the one consuming more feed will have more large follicles (Hocking, 1993).

A flock with poor ovarian control will have a normal peak production, but undergo more rapid decline in egg production. Unfortunately this may be indicative of either too few or too many large yellow follicles. Having too few large follicles can result in gaps in laying sequences and hence shorter than normal sequences. This is a problem seen in hens undergoing follicular atresia (follicle dissolution), photostimulated too early, or being underfed. Having too many large ovarian follicles is a problem associated with obesity or overfeeding (Yu et al., 1992). The hen can grow even more overweight as the rate of egg production remains low or goes into early decline due to excess feed intake.
III. BIRD VARIABILITY AND REPRODUCTIVE EFFICIENCY

If consumers could dictate how the poultry industry functioned, variation in growth, conformation and efficiency would not exist. The food industry is striving to achieve an increased level of product consistency and bird-to-bird variation is not wanted. However, this same variability is essential for the continued movement in genetic selection programs towards more desirable bird-types. Without natural variation, genetic progress would be stalled at the current bird-types. The ‘ideal hen’ with the perfect balance between growth and egg production traits, is more of an exception to the rule rather than the common occurrence in the broiler breeder barn.

Commercially, body weight, egg production, fertility and hatchability values are collected on a barn or farm basis. However, variation among individual hens affects how they do or do not respond to environmental or treatment conditions. For example, a high proportion of the unsettable eggs produced by a flock are from a small number of birds (Renema et al., 2001). Individual response to environmental cues can also vary. Proudman and Sipes (2002) reported no change, moderate sensitivity, or extreme sensitivity in turkey hens given a short-term reduction in light period. A range of variability in egg weight exists within individual hens. Egg weight-based differences in hatchability have been reported to be more closely related to deviations in egg weight from the individual hen mean egg weight than from the population mean egg weight (Wilson, 1991). University of Alberta egg weight data shows a 15 g range in breeder flock egg weight at a given age, while variation within individual hens ranges from 5 to 15 g (Renema, unpublished observations).

There are good reasons to work towards achieving a uniform flock – particularly at the end of the pullet phase, when a high proportion of the birds will ideally respond similarly to the photostimulatory cue. Whereas delaying photostimulation to allow the smaller pullets more time to become physically mature may appear counterproductive for the productivity of the larger birds, most hens will compensate with a greater rate of lay that will typically result in similar overall production (Robinson et al., 1996).

IV. EARLY PULLET GROWTH AFFECTS BODY WEIGHT UNIFORMITY

Early feed management practices are believed to have a long-term impact on frame size, fleshing, and body weight uniformity. Falling short of 4 week weight or protein intake targets is believed to adversely affect frame size and hen weight management. To test the impact of early feeding on frame size and fleshing, a study was performed comparing the effects of full feeding broiler breeder pullets until 1 or 3 weeks of age on frame size, fatness and fleshing at 4, 8, 12, and 16 weeks of age (Renema et al., 2005). The transition to feed restriction was smoothed by starting it already at 1 week of age. Ross 308 pullets (720) were placed at day of hatch (8 pens) and provided ad libitum access to feed for 1 (1WK) or 3 weeks (3WK) of age. Body weight was recorded twice/week to allow the growth profiles to be gradually converged (target of 8-10 weeks of age). At 4, 8, 12, and 16 weeks, external carcass and fleshing scores were recorded for all birds, and 14 birds/pens were dissected for assessment of muscle mass, fatness, and reproductive development.
Table 1. Body weight (g), shank length (mm), chest width (mm) and relative breast muscle weight (%) of broiler breeder pullets fed ad libitum for 1 (1WK) or 3 (3WK) of age and dissected at 4, 8, 12, or 16 wk of age.

<table>
<thead>
<tr>
<th>Age</th>
<th>Body weight</th>
<th>Shank length</th>
<th>Chest width</th>
<th>Breast muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1WK</td>
<td>3WK</td>
<td>1WK</td>
<td>3WK</td>
</tr>
<tr>
<td>4 wk</td>
<td>451 b</td>
<td>586 a</td>
<td>61.5 b</td>
<td>66.9 a</td>
</tr>
<tr>
<td>8 wk</td>
<td>893 b</td>
<td>963 a</td>
<td>81.0 b</td>
<td>84.1 a</td>
</tr>
<tr>
<td>12 wk</td>
<td>1,318</td>
<td>1,248</td>
<td>98.0</td>
<td>98.4</td>
</tr>
<tr>
<td>16 wk</td>
<td>1,634</td>
<td>1,613</td>
<td>103.1</td>
<td>102.3</td>
</tr>
</tbody>
</table>

By 3 weeks of age, the daily gain of the 3WK pullets was double that of the 1WK pullets, which resulted in significantly more weight and fleshing at 4 weeks of age (Table 1). The 3WK birds weighed 30% more, had a larger shank and keel length, and carried a higher proportion of breast muscle (12.6% compared to 11.5%) than the 1WK birds. The groups still differed in some traits at 8 weeks of age, but were similar in comparisons after 10 weeks of age, when the body weight profiles met. The body weight uniformity of the 1WK birds was better than that of the 3WK birds from 14 weeks of age (CV of 13.0% compared to 16.7%). At 16 weeks of age, the frame size and fleshing of the birds were indistinguishable, and body weight uniformity was worse in the 3WK birds. In sister pullets from this study that continued on to sexual maturity, there were no differences in how these birds entered lay, or in carcass or reproductive traits at that time (Renema, unpublished observations). Maintaining very tight control body weight profiles through more frequent feed allocation decisions may contribute more to the effective management of broiler breeder productivity than simply following feeding guides.

V. INFLUENCE OF GROWTH HISTORY ON FEED UTILIZATION

In many ways, the post-peak feeding period is not as critical as the pullet phase, or the sexual maturation and early production period. The condition of the reproductive system at the onset of production has long-term effects on the potential reproduction of the hen (Robinson et al., 1998a, 1998b). While the post-peak period (from approximately 32 to 60 weeks of age) is the most financially important, production problems at this time are generally the result of damage done earlier in the life of the breeder. For example, overfeeding of hens for as little as 2 weeks between 23 and 31 weeks of age has been found to reduce fertility and hatchability throughout production (Ingram and Wilson, 1987).

In a recent study, we grew broiler breeders on rapid or slow BW profiles between 5 and 12 weeks of age, and merged the BW targets by 32 weeks of age. By the time birds were dissected at 58 weeks of age there was a clear, long-term effect of pre-peak nutrient allocation on muscle, fat and the ovary (Table 2). The hens fed the early aggressive, HIGH profile carried a slightly increased proportion of breast muscle than those of most of the less aggressive treatments by sexual maturity (data not presented). At 58 weeks of age, it was striking how the HIGH profile hens still had more breast muscle, but also had a smaller ovary and less abdominal fat. These hens entering lay with extra fleshing maintained this extra muscle mass at the expense of the ovary. Birds of all treatments were maintaining very little fat. With reduced nutrient stores to rely on to cover shortfalls in nutrient requirements and the easy diversion of nutrients into fleshing, this shows how effective management continues to demand a higher degree of attention to detail.
Table 2. Breast muscle weight (g), abdominal fatpad weight (g) ovary weight (g) and total egg production (\#) at 58 weeks of age in broiler breeders grown on growth profiles varying in target body weight between 5 and 32 weeks of age

<table>
<thead>
<tr>
<th>Growth profile</th>
<th>Breast muscle</th>
<th>Abdominal fatpad</th>
<th>Ovary</th>
<th>Total eggs</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>451(^b)</td>
<td>586(^a)</td>
<td>61.5(^b)</td>
<td>66.9(^a)</td>
</tr>
<tr>
<td>Moderate</td>
<td>893(^b)</td>
<td>963(^a)</td>
<td>81.0(^b)</td>
<td>84.1(^a)</td>
</tr>
<tr>
<td>Standard</td>
<td>1,318</td>
<td>1,248</td>
<td>98.0</td>
<td>98.4</td>
</tr>
<tr>
<td>Low</td>
<td>1,634</td>
<td>1,613</td>
<td>103.1</td>
<td>102.3</td>
</tr>
</tbody>
</table>

It can be difficult to formulate diets to optimize egg production, fertility, and hatchability as little is known about the nutritional requirements of the embryo. Growth-selected stocks have low immuno-responsiveness (Siegel et al., 1984) due to either inadvertent negative selection pressure combined with growth efficiency selection. The developing embryo is especially sensitive to vitamin deficiency, which will result in death, malformation or some other atypical response (Leeson and Summers, 2001).

The importance of the macro-minerals and electrolytes for the maintenance of hen productivity is well established. This has meant that study of the carry-over of minerals from hen to chick for the enhancement of early growth and immunity is being done with the trace minerals (Kidd, 2003). Manganese, selenium, zinc, and vitamin E in the maternal diet have been identified as important for the improved immunity of the progeny and ability of the embryo to survive incubation.

VI. LINKING GROWTH AND REPRODUCTIVE EFFICIENCY

Examination of individual growth and egg production profiles can reveal breeder hens that do not fit the classic balance between birds that lay well at the expense of growth, or grow very well while producing fewer eggs. Following a recent study, an individual 'snapshot' of production was compiled using feed intake, actual and target BW profiles, BW gains and losses, egg production, egg weight, and final carcass fat and protein concentrations. Each hen appears to have a different balance between the pull to lay eggs or to grow. However, some hens were present that were able to lay eggs very well and gain body weight relative to the flock average. Conversely, some birds on the same feed allocation grew very poorly and did not produce many eggs. To create an objective score of these various 'reproductive attitudes' scoring the balance between the pull to lay eggs or to grow, hens were also scored for overall efficiency (Figure 1).

Variation in feed utilization among hens exists that cannot be explained by metabolic body weight, body weight gain, and egg mass output (Van Eerden et al., 2004; Luirting and Urrff, 1991a). This variation can be reflected in hen Residual Feed Intake (RFI). The RFI is the difference between observed and predicted feed intake and is a measure of feed efficiency that estimates the remaining part of the variation in feed consumption that cannot be accounted for by changes in growth, maintenance or egg production (Schulman et al., 1994). Birds that consumed less feed than we calculated they needed had a negative residual feed intake. These are great birds because they are more efficient than we calculate they should be. Birds that consume more feed than we calculate they need for their activities end up with a positive residual feed intake – meaning that they are consuming more feed than we calculate they should. This remaining variation can be the result of differences in: 1) maintenance requirements, 2) partial efficiency in energy utilization, 3) energy demanding processes not accounted for, and 4) measuring errors (Luirting and Urrff, 1991b).
Figure 1. Template of ‘reproductive attitude’ classification. Hen growth and egg production efficiency was scored on residual feed intake and settable egg production.

If the reproductive attitude of the hen demonstrates good overall efficiency, will this carry forward to the broiler offspring? Defining the relationship between maternal efficiency and the quality of the broiler offspring is an essential step in providing support to future decisions on future breeder management methods and the provision of high quality broilers with desirable meat and growth traits.

VII. CAUSES OF VARIATION IN EFFICIENCY

One of the major sources of variation of RFI in laying hens is a difference in maintenance requirements among birds. Gabarrou et al. (1998) reported that a great part of variation in maintenance requirements in laying hens may be due to feeding activity, with less efficient hens demonstrating a higher regulatory thermogenesis resulting in dissipation of excess energy as heat. The liver, gut, and reproductive tract of broiler breeders represent 26 and 30% of the total energy expenditure in fed and fasted hens (Spratt et al., 1990). Differences in size and/or metabolic rate of these organs may have a considerably effect maintenance requirements. Interestingly, fasting increases liver and reproductive tract tissue metabolism in broiler breeders indicating the major role that liver plays in energy metabolism in fasten hens; and a compensatory response of magnum to an absence of dietary substrates for egg synthesis (Spratt et al., 1990).

Reports on causes of variation in RFI and heat production in laying hens were examined by Luiting (1990). Major sources of variation were attributed to physical activity, feathering density, basal metabolic rate, area of nude skin, body temperature, and body composition. However, further studies using divergent selection have shown a great importance of body composition and lipid metabolism to explain RFI variation Gabarrou et al., 1998). While basal metabolic rate was found to be similar in high and low RFI lines, differences in feeding activity and regulatory thermogenesis were found (Gabarrou et al., 1998). Variation in maintenance requirement may be attributed to differences in body composition. This can be affected by bird genetics, behavior and management, and may affect fat and protein deposition in body tissues, lipid metabolism, egg composition and the size and metabolic rate of liver, gut and reproductive tract.

Heritability of RFI has been estimated in laying hens from 0.30 to 0.60 (Hagger and Ahplanalp, 1978; Schulman et al., 1994; Luiting and Erff, 1991b). Schulman et al. (1994) looked for the genetic correlations of RFI and economically important traits in laying hens,
and only found a genetic correlation with feed consumption. Interestingly, when broiler stocks are provided a choice of protein and energy compared to a single, complete diet, they do not maximize their growth (Siegel et al., 1997). Instead, they will grow more slowly with a reduced feed efficiency, and ultimately be more fat while also having an enhanced immune response. In the continuing push to grow broilers more efficiency, sight of what is ‘normal’ for the bird must not be lost in commercial stocks.

VIII. CONCLUSIONS

The newer broiler breeder genetic strains are becoming more specialized and appear to have more specific management methods associated with them. Effective ovary management is an integral part of a successful breeder management program. Managing the broiler breeder female for optimal chick production requires an understanding of reproductive physiology, nutrition, and their interaction. With new analytical and descriptive tools to apply to daily broiler breeder management, the modern manager will be able to cope with the increasingly specific needs of the modern heavy breeder. By identifying ‘reproductive attitudes’ of individuals and their incidence in a population, more effective refinement of broiler breeder management strategies will be possible.

REFERENCES


