SELECTION FOR INCREASED BODY WEIGHT IN POULTRY. WHAT ROLE DOES SELECTION AGE HAVE ON RESPONSE?

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ABSTRACT

Selection for rapid growth at a specific age has resulted in a tremendous growth response. Thus, in response to this success, the age at which selection is applied has been adjusted to younger ages. The work described here is a composite of several selection studies which were designed to obtain an understanding of the relationship between selection age and growth. The first selection program discussed included the response to selection of 4 quail lines selected 8 generations for increased body weight at 10, 17, 28 and 40 days of age. Selection age had a profound effect on the magnitude of growth but had little effect on the sigmoid shape of the growth curve. In general, weight selected lines were competitive with the other lines until the age at which selection was applied. After this time, early selected lines were smaller then the late selected lines. Two additional lines selected for rate of growth around the point of inflection (POI) were described. In general, selection for rapid growth prior to and slow growth after POI (Line HL) effectively changed the pattern of growth in form without changing asymptotic values. Selection for slow early and rapid late growth (Line LH) resulted in change in asymptotic values with little change in form. Line HL possessed a compressed growth curve and was an early maturing. The various selection strategies should provide insight into existing selection programs.
INTRODUCTION

The poultry industry evolved rapidly from the sale of live birds in the market (1920s and 30s) to the further processed product of today. Although selection for rapid growth was being practiced, it was not until the early 1950's that the creation of line specific meat and egg type birds as well as events such as the Chicken of Tomorrow Contest allowed the broiler growth potential to be realized (Gyles, 1989). Thus, within a relatively short period of time selection age and market weights have shifted to earlier ages and heavier weights respectively. With this marked response has been the concomitant decrease in age at which BW selection is applied (Figure 1).

It has been speculated that this shifting of selection age has led to some of the physiological complications being (ascites, tibial dyschondroplasia) observed in today's rapidly growing poultry species. Katanbaf and coworkers (1988) reported on the concept of resource allocation as it relates to weight selected lines of chickens. Within this work, they described the timing of organ development as it relates to growth. Work in our laboratory has found similar results for the turkey (Figure 2). In general, organs responsible for supplying nutrients have a higher priority earlier in the growth period then those organs which have a relatively high nutrient demand. Thus, selection at younger ages may lead to emphasis of supply organs which would enhance the opportunity for lean mass deposition later. This concept was supported by Lilja and Marks (1991) who reported that late stage embryos from weight selected lines of Japanese quail had a higher proportion of gut tube then the randombred control from which the lines were initiated.

Growth curve analysis has been utilized as a means of understanding the effects of selection for increased body weight on the pattern of growth of turkeys (Johnson and Gowe, 1962: Abplanalp et al., 1963; Anthony et al., 1991a), chickens (Tzeng and Becker, 1981; Zelenka et al, 1986) and Japanese quail (Marks, 1978; Anthony et al., 1986). Within these works is often a discussion of how selection has altered the form (shape) and magnitude of the growth response (Asymptote). Ricklefs, (1967) provides an excellent description of growth curve analysis using 3 parameter equations (Logistic, Gompertz and Von Bertalantfy). These equations provide information regarding form, rate and magnitude of growth through prediction of points of interest on the curves, such as hatch, point of inflection (POI) and Asymptote. As a means of further understanding the effects of selection for growth in various species a summary manuscript was prepared (Anthony et al., 1991b) which attempted to condense growth information from turkeys, chickens and quail. One of the conclusions drawn from this work was "The time of selection in relation to the POI may influence the response in BW". Unfortunately this work was confounded by factors such as generation number, selection intensity and environmental factors. However, it did provide the basis for the selection trial to be described.
A selection experiment was initiated to study the effects of selection age on the growth response observed. Japanese quail were utilized as the animal model. The selection ages chosen were based on the relationship of selection age and respective age at POI for commercial/experimental poultry populations. For example, line H10 was selected for increased BW at 10 days of age and represented the relationship between selection age and POI for experimental lines of chickens (Anthony et al., 1991b). Line H17 represented selection for rapid growth at POI and the relationship between selection age and POI for commercial broilers (Barbato, 1991). Line H28 was selected for high BW at 28 days and represents a relationship observed in turkeys (Anthony et al., 1991b). Line H40 represents selection for increased body weight at mature weight. Initial heritabilities (parent offspring regression) for body weight at 10, 17, 28 and 40 days were .32, .29, .28 and .30 respectively. These heritabilities were consistent with that observed for Japanese quail (Sefton and Siegel 1974) and other poultry species (Kinney, 1969) and indicated that response should be consistent between lines.

All lines were reproduced using a 36 pair mating system consistent with the system described by Nestor et al. (1982). In addition to the weight selected lines was a Random Bred Control (RBC) which was maintained with the weight selected lines. Approximately 400 progeny per line were reproduced each generation.

During generations 6-8 the lines were surveyed for growth characteristics. In Generation 7, growth curve data were generated through alternate day weighing of a random sample of quail. Data were exposed to analysis using the Gompertz equation. Figure 3a,b provides the general growth curves observed for the lines. Selection for rapid growth at any age was effective in increasing body weight when compared to the random bred control. It is interesting to note, however, that the response was not the same under each of the selection strategies. In fact, the selected lines were competitive with each other only to that point where selection was applied. After the respective age of selection, growth was found to be inferior to the lines selected at later ages. Realized heritabilities were calculated after the eighth generation of selection. The $h^2$ were based on cumulative selection differential and selection response expressed as a deviation from the RBC (Figure 4). The pattern of $h^2$ estimates were different from the original estimates predicted in the base population but were consistent with the growth patterns observed. The relatively low $h^2$ observed for the H10 line was likely due to factors such as scaling and residual maternal effects.

Growth curve analysis revealed that the major adjustments in growth were not in traits associated with form but rather magnitude (Table 1). For example,
all weight selected lines were lower than RBC for age at inflection and 90% of asymptotic weight. Body weight at these points, however, were only greater for H40 then the other lines. Slope at POI was not different for any of the weight selected lines but all greater then the RBC.

When weights are presented for each of the lines at each selection age (Table 2) one can see that all of the weight selected lines were heavier than the RBC at each of the sample ages. At 10 days of age weight selected lines did not differ in body weight, however, by 17 days of age line H10 was lower in weight then the other weight selected lines. By 28 days of age line H10 was smaller than H17 which was smaller than H28 and H40. At 40 days of age H40 was clearly the largest followed by H28. Lines H17 and H10 did not differ in 40 day BW, however had lower weight than the other weight selected lines. Similar differences were observed for yield data collected for the line. However, when the same data were expressed relative to BW the differences were eliminated for both supply and demand organs (data not presented). This finding indicates that the selection at different ages has not led to the emphasis of specific organs but rather a consistent increase in organ size regardless of selection age.

From an industry standpoint this work has significant implications. Poultry breeders (turkey and broiler) must understand the future markets for their products. The temptation to select at younger ages consistent with processing age could lead to an inferior product if the market were to shift to heavier weights. The converse situation would be in favor of earlier selection ages because one could produce a bird which would be competition at the age it were to be processed and easier to manage as a breeder because of the lower mature weight. Unfortunately, this selection experiment did not provide a great deal of new information regarding the sensitivity of the growth curve to change in form. Historically, selection programs have been simply adjusting the magnitude of growth to certain points on the growth curve (Figure 1) without substantially altering the shape of the curve.

SELECTION FOR THE MODIFICATION OF GROWTH PATTERN

As previously mentioned, rapid rates of growth have been linked, justified or not, to the incidence of physiological breakdowns (ascites, tibial dischondroplasia, obesity) observed in todays poultry species. Methods to curb the incidence of such problems include the slowing of early growth through nutritional means (Plavnik and Hurwitz, 1985; Plavnik et al., 1986; Shlosberg et al., 1991; Acar et al., 1995). Feed restriction of breeder flocks is a necessary evil in order to obtain acceptable reproductive performance. Restriction programs are designed to alter the shape of the growth curve without a negative impact on performance. Can the same result be achieved genetically or is the shape of the growth curve rigid?
Attempts have been made to shift the shape of the growth curve through applying selection pressure for high body weight early and low body weight late in the growth period (Gyles and Thomas, 1963; Merritt, 1974; Ricard, 1975). Unfortunately, these studies reported minimal success thus suggesting that such strategies were of little utility. This may have, however, been due to the age at which selection was applied. In most cases body weight selection was practiced at only two ages and both being post POI.

More recent attempts to modify the shape of the growth curve were reported. Barbato et al., (1992) described a divergent section program in chickens which utilized exponential growth rates to 14 and to 42 days posthatch. Marks (1995) reported on selection for body weight gain in Japanese quail between 2 and 4 weeks of age on split and complete diets. In both of these programs, a shift in philosophy occurred in that rates of growth are being considered rather then a measure at a single point in time.

A second set of weight selected lines were developed as a means of investigating the flexibility of the growth curve. The strategy was to place as much pressure on the rates of growth around the POI as to develop two lines which would differ in form. To accomplish this two lines were developed. Line LH was selected for low body weight gain between the ages 10 and 17 days and high body weight gain between 17 and 28 days of age. Line HL was selected for high growth between 10 and 17 days and low growth between 17 and 28 days of age. Preliminary work had indicated a correlation of -.13 between 10 - 17 and 17 - 28 day body weight gains, therefore, selection of this type would at least be compatible.

Figure 5 includes a summary of male growth data for Lines HL, LH and the RBC collected after 7 generations of selection. Line HL is characterized by rapid early growth and low late growth. Converse to this Line LH grew similar to the RBC until 17 days and then began to accelerate. Growth curves of Lines LH and HL intersect at approximately 28 days of age. This point of intersection will provide an interesting point of comparison between the two selected lines because although the two lines are the same BW they achieved this weight differently. Growth curve analysis using the Gompertz equation revealed some interesting differences (Table 3). Line HL appeared to have deviated from the RBC for those traits associated with form while Line LH was consistent with the RBC for most of the traits measured except that associated with asymptotic weight. Line HL had significantly more abdominal fat on an absolute and relative basis (Table 4) and was at a more advanced stage of reproductive development (males, Table 5; females, Table 6) at 40 days of age then either Line LH or the RBC from which it was derived. In effect, the growth curve of Line HL has been compressed thus resulting in a bird which grows rapid early and is early maturing. Despite a 16% difference in body weight between Line HL and RBC at POI there was no difference between the two lines at maturity (Table 7).
It appears that there is some flexibility in the shape of the growth curve. However, shaping the growth curve is labor intensive in that multiple measures of weight must be accumulated prior to selection. Unfortunately, the benefits of genetic manipulation of the growth curve are unclear at this time. Hopefully the work presented at this meeting and in future publications investigating selection for growth rates will provide the foundation for future selection schemes.

REFERENCES


Table 1. Growth Curve Parameters for weight selected quail as described by the Gompertz equation (X ± SEM)

<table>
<thead>
<tr>
<th>Line</th>
<th>Relative hatch</th>
<th>Inflection</th>
<th>Asymptote</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>age</td>
<td>weight</td>
</tr>
<tr>
<td>H10</td>
<td>.051 ± .002</td>
<td>15.4 ± .7</td>
<td>47.5 ± 1.4</td>
</tr>
<tr>
<td>H17</td>
<td>.051 ± .001</td>
<td>14.0 ± .3</td>
<td>47.5 ± 0.7</td>
</tr>
<tr>
<td>H28</td>
<td>.048 ± .001</td>
<td>14.6 ± .4</td>
<td>49.7 ± 0.8</td>
</tr>
<tr>
<td>H40</td>
<td>.049 ± .001</td>
<td>15.8 ± .5</td>
<td>54.6 ± 1.0</td>
</tr>
<tr>
<td>RBC</td>
<td>.052 ± .002</td>
<td>18.5 ± .8</td>
<td>47.1 ± 1.3</td>
</tr>
</tbody>
</table>

a,b Means within columns with different superscripts differ (P < .05)

1 H10 = quail selected for increased 10 - day BW;
   H17 = quail selected for increased 17 - day BW;
   H28 = quail selected for increased 28 - day BW;
   H40 = quail selected for increased 40 - day BW;
   RBC = Randombred control

Table 2. Body Weights (X ± SE) of male Japanese quail after 7 generations of selection

<table>
<thead>
<tr>
<th>Line</th>
<th>Day 10 (g)</th>
<th>Day 17 (g)</th>
<th>Day 28 (g)</th>
<th>Day 40 (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H10</td>
<td>28.7 ± 0.9</td>
<td>53.5 ± 1.2</td>
<td>87.3 ± 1.1</td>
<td>107.8 ± 1.3</td>
</tr>
<tr>
<td>H17</td>
<td>32.1 ± 0.9</td>
<td>59.0 ± 1.2</td>
<td>95.1 ± 1.3</td>
<td>113.2 ± 1.5</td>
</tr>
<tr>
<td>H28</td>
<td>31.1 ± 1.0</td>
<td>59.2 ± 1.5</td>
<td>98.2 ± 1.5</td>
<td>116.6 ± 1.5</td>
</tr>
<tr>
<td>H40</td>
<td>30.8 ± 1.0</td>
<td>60.2 ± 1.5</td>
<td>99.8 ± 1.6</td>
<td>124.6 ± 1.6</td>
</tr>
<tr>
<td>RBC</td>
<td>22.4 ± 0.8</td>
<td>41.5 ± 1.5</td>
<td>72.5 ± 1.8</td>
<td>95.2 ± 1.3</td>
</tr>
</tbody>
</table>

a,b,c,d Means within columns with different superscripts differ (P < .05)

1 H10 = quail selected for increased 10 - day BW;
   H17 = quail selected for increased 17 - day BW;
   H28 = quail selected for increased 28 - day BW;
   H40 = quail selected for increased 40 - day BW;
   RBC = Randombred control
Table 3. Growth Curve patterns for weight selected quail as described by the Gompertz Equation (\( \bar{x} \pm \text{SEM} \)).

<table>
<thead>
<tr>
<th>Line</th>
<th>Relative hatch wt</th>
<th>Inflection</th>
<th>Asymptote</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>age</td>
<td>weight</td>
</tr>
<tr>
<td>LH</td>
<td>.046 ± .002 (^b)</td>
<td>19.1 ± .8 (^a)</td>
<td>50.5 ± 1.1 (^a)</td>
</tr>
<tr>
<td>HL</td>
<td>.051 ± .001 (^a)</td>
<td>15.7 ± .7 (^b)</td>
<td>43.9 ± 1.5 (^b)</td>
</tr>
<tr>
<td>RBC</td>
<td>.052 ± .002 (^a)</td>
<td>18.5 ± .8 (^a)</td>
<td>47.1 ± 1.3 (^ab)</td>
</tr>
</tbody>
</table>

\(^a,b\) Means within columns with different superscripts differ (P < .05)

1 LH = line selected for low BW gain between 10 and 17 days and high BW gain between 17 and 28 days; HL = line selected for high BW gain between 10 and 17 days and low BW gain between 17 and 28 days; RBC = Randombred control.

Table 4. Abdominal fat measures (\( \bar{x} \pm \text{SEM} \)) for quail after 7 generations of selection

<table>
<thead>
<tr>
<th>Line</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fat (g)</td>
<td>% fat</td>
</tr>
<tr>
<td>LH</td>
<td>0.68 ± .07 (^b)</td>
<td>0.63 ± .07 (^b)</td>
</tr>
<tr>
<td>HL</td>
<td>1.15 ± .10 (^a)</td>
<td>1.15 ± .09 (^a)</td>
</tr>
<tr>
<td>RBC</td>
<td>0.69 ± .10 (^b)</td>
<td>0.72 ± .10 (^b)</td>
</tr>
</tbody>
</table>

\(^a,b\) Means within columns with different superscripts differ (P < .05)

1 LH = line selected for low BW gain between 10 and 17 days and high BW gain between 17 and 28 days; HL = line selected for high BW gain between 10 and 17 days and low BW gain between 17 and 28 days; RBC = Randombred control.
Table 5. Male Reproductive Traits (means ± SEM) for quail after 7 generations of selection

<table>
<thead>
<tr>
<th>Line</th>
<th>Testes</th>
<th>Day 40 BW</th>
<th>ADJ BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH</td>
<td>1.58 ± .58</td>
<td>103.9 ± 1.8</td>
<td>102.3 ± 1.8</td>
</tr>
<tr>
<td>HL</td>
<td>2.12 ± .54</td>
<td>98.4 ± 1.7</td>
<td>96.3 ± 1.7</td>
</tr>
<tr>
<td>RBC</td>
<td>1.44 ± .61</td>
<td>95.2 ± 1.3</td>
<td>93.8 ± 1.2</td>
</tr>
</tbody>
</table>

a,b Means within columns with different superscripts differ (P < .05)

1 LH = line selected for low BW gain between 10 and 17 days and high BW gain between 17 and 28 days;
HL = line selected for high BW gain between 10 and 17 days and low BW gain between 17 and 28 days;
RBC = Randombred control.

Table 6. Female Reproductive Traits (means ± SEM) for quail after 7 generations of selection

<table>
<thead>
<tr>
<th>Line</th>
<th>Follicles (n)</th>
<th>Ovary</th>
<th>Oviduct</th>
<th>Day 40</th>
<th>ADJ BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH</td>
<td>1.5 ± .4 b</td>
<td>1.54 ± .44 b</td>
<td>2.10 ± .49 b</td>
<td>113.8 ± 2.5 ab</td>
<td>109.9 ± 1.9 a</td>
</tr>
<tr>
<td>HL</td>
<td>3.7 ± .4 a</td>
<td>4.05 ± .46 a</td>
<td>5.35 ± .37 a</td>
<td>117.1 ± 2.4 a</td>
<td>105.2 ± 1.9 ab</td>
</tr>
<tr>
<td>RBC</td>
<td>1.5 ± .3 b</td>
<td>1.33 ± .31 b</td>
<td>2.30 ± .40 b</td>
<td>108.4 ± 1.7 b</td>
<td>103.7 ± 1.2 b</td>
</tr>
</tbody>
</table>

a,b Means within columns with different superscripts differ (P < .05)

1 LH = line selected for low BW gain between 10 and 17 days and high BW gain between 17 and 28 days;
HL = line selected for high BW gain between 10 and 17 days and low BW gain between 17 and 28 days;
RBC = Randombred control.
Table 7. Body Weights (means ± SE) of male quail after 7 generations of selection

<table>
<thead>
<tr>
<th>Line</th>
<th>Day 10 (g)</th>
<th>Day 17 (g)</th>
<th>Day 28 (g)</th>
<th>Day 40 (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LH</td>
<td>22.4 ± .9  b</td>
<td>44.4 ± 1.6  ab</td>
<td>79.6 ± 2.2 a</td>
<td>103.9 ± 1.8 a</td>
</tr>
<tr>
<td>HL</td>
<td>26.0 ± .9  a</td>
<td>48.0 ± 1.6  a</td>
<td>79.4 ± 1.3 a</td>
<td>98.4 ± 1.7 b</td>
</tr>
<tr>
<td>RBC</td>
<td>22.4 ± .8  b</td>
<td>41.5 ± 1.5  b</td>
<td>72.5 ± 1.8 b</td>
<td>95.2 ± 1.3 b</td>
</tr>
</tbody>
</table>

a,b Means within columns with different superscripts differ (P < .05)

1 LH = line selected for low BW gain between 10 and 17 days and high BW gain between 17 and 28 days;
HL = line selected for high BW gain between 10 and 17 days and low BW gain between 17 and 28 days;
RBC = Randombred control.
Figure 1. Predicted patterns of growth for the chicken of 1925 and the broiler of 1950, 1975 and 1990.

Figure 2. Relative growth rates for organs in Turkeys.
Figure 3. Growth Curves of male Japanese quail selected for high body weight at 10 (HIO), 17 (H17), 28 (H28), and 40 (H40) days of age.

Figure 3a. Curve from hatch to 40 days

Figure 3b. Curve from hatch to 18 days.
Figure 4. Generation means (deviation from RBC) plotted against cumulated selection differentials for selected lines of quail.

Figure 5. Growth Curves of Japanese quail selected for high early (10-17 day), low late (17-28 day) gains (HL), low early high late gains (LH) and RBC.
Question: J. Arthur

Do you have an idea of how much more final body weight you would have had in comparison to the LH and HL lines if you had an HH line?

Response: N. Anthony

It would have been nice to have both a HH and a LL line to complement LH and HL. Unfortunately, space did not allow for the additional lines. Despite this, I think a HH line would have had growth resembling line H28 (at least for asymptotic weight). Lines LH and HL currently mature at the same weight as H10 and RBC, respectively.

Question: M. Grossman

There is evidence in chickens, especially in females as they reach sexual maturity, that there are multiple points of inflection. Is this also true in quail?

Response: N. Anthony

This is something that we have observed in chickens but not in the quail model. We have attributed some of this to the timing of fat deposition which occurs relatively late in Japanese quail and is somewhat consistent with sexual maturity. Broilers have a much greater propensity to deposit fat throughout the growth period.

Comment: B. Muir

Selection for HL or LH in the way you described is equivalent to selection for maximum difference. In that case, maximum overall gain may be zero. To ensure a positive overall gain while retarding gain of a segment of the curve, a restricted selection index would be preferable.

Response: A. Anthony

Preliminary growth curve analysis revealed a fair amount of variation for pattern of growth. How do you exploit these differences? The most ideal situation would be to weigh all birds every day and select the desirable pattern. I chose to identify LH and HL birds by the rate of growth around the point of inflection. The restricted index selection may have guaranteed a response but I am not sure we would be answering the same question.
Question: M. Akbar

The conclusion was made that, in broilers the decrease in the age of selection did not change the proportion of various organs (e.g. breast, legs, etc.) in the carcass. What do you think about the applicability of this statement in the other meat species (e.g. ducks)?

Response: N. Anthony

The conclusion made was based on a short term selection trial on Japanese quail selected for increased body weight at different ages. After 8 generations of selection we observed absolute change in organ weight. No changes in relative organ weight were observed. I would expect similar responses for other poultry species maintained under a similar selection scheme.