Effect of genetic selection on growth parameters and tonic immobility in Leghorn pullets

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ABSTRACT Four genetic stocks of Leghorn pullets were used to evaluate the effects of genetic selection on growth and fearfulness behavior. Three of the stocks were the Ottawa randombred control stocks from 1950 (CS5), 1959 (CS7), and 1972 (CS10). The fourth stock was a 1993 commercial laying stock (CCS) whose ancestors were involved in the formation of the randombred control stocks. Pullets were reared in a brood and grow poultry house with flat deck cages. Each stock was comprised of 840 birds with 21 replicates per strain. Body weight and feed consumption were monitored biweekly. At 16 wk of age, a 20-hen sample from each strain was analyzed for BW, body composition, and tonic immobility. There were significant \( P < 0.05 \) differences among the stocks for BW of 1,403; 1,333; 1,332; and 1,428 g for the CS5, CS7, CS10, and CCS stocks, respectively. Furthermore, significant differences occurred with regard to feed consumption, livability, and frame size. There were no differences among the stocks in tonic immobility. Measurement of circulating corticosterone levels were shown to be significantly \( P < 0.05 \) higher in the CCS stock (7.64 ng/mL) than for both the CS5 (4.50 ng/mL) and CS7 (4.61 ng/mL) stocks, whereas the CS10 stock was intermediate with 6.45 ng/mL. Genetic selection has affected growth parameters, although there appears to be no change in fearfulness behavior but an increase in corticosterone levels in stocks from later years.

Key words: pullet, fearfulness behavior, genetics, tonic immobility

INTRODUCTION

The birds used in the commercial egg industry today are considerably different from their predecessors with regard to production traits. Havenstein et al. (2003) indicates that for broiler breeders, genetic selection has contributed 85 to 90% of the improved productivity seen; however, with layers, the contribution may not be as great due to management and nutritional advances. With generational changes in birds being so great, it is important to have a point of historical reference with which to evaluate improvements. Gowe et al. (1959) discussed some of the benefits of using control stocks in poultry research. Control stocks are a maintained point of historical reference illustrating how genetic selection has changed the bird used by the commercial egg industry with respect to production and physiology.

During the course of the past 4 decades, the primary breeders have selected for traits in the Leghorn that would enhance the efficiency of egg production. Selection emphasis changed periodically for the size of eggs, number of eggs, or age at first egg. Studies conducted throughout the years have isolated some general traits that could be associated with the different control stocks. Fairfull and Gowe (1986) reported that among the control stocks that they used, BW steadily declined from the older stocks to the smaller, more efficient, current stocks.

Primary breeders have been selecting for early sexual maturity in commercial layers for many years. Fairfull et al. (1983), Fairfull and Gowe (1986), and Jackson et al. (1986) have shown that the age of first egg steadily decreased in the control stocks formed in 1950, 1959, and 1972 throughout the years of selection. In tandem, egg weight has increased in the same fashion in the control stocks throughout the years of selection (Fairfull and Gowe, 1986; Jackson et al., 1986; McMillan et al., 1990), which corresponded with the market demand for larger eggs. Due to this selection pressure, egg size distribution also changed (Akbar et al., 1983). Fairfull et al. (1983), Fairfull and Gowe (1986), and Jackson et al. (1986) also reported that hen-day rate of production levels were higher in the more current stocks.

This study was undertaken to examine if genetic selection of commercial laying hens has influenced certain physiological parameters during the pullet phase. The
physiological parameters measured in this study were heterophil:lymphocyte ratios (H:L) and plasma concentrations of corticosterone (CORT), 3,5,3′-triiodothyronine (T₃), and thyroxine (T₄). These parameters were chosen based on previous research that has correlated them with certain aspects of the bird’s physiology.

The H:L is considered a measurement of long-term stress that may differ based on the selection for growth and early maturity in pullets. Gross and Siegel (1983) indicated that the H:L was also measuring physiological change. Gross (1990) found that H:L levels began to increase in chickens 18 h after exposure to a 30-s loud noise. This increase persisted for 20 h and returned to pretreatment levels by 30 h. It has also been reported that H:L levels increased in response to social stress (Gross, 1989), which may be in response to the changing social dynamics during growth and maturation of a flock.

Levels of CORT are a measure of more immediate stress. This has been supported by findings that the length of time during blood sampling procedures can lead to increased CORT levels (Johnson, 1981; Webb and Mashaly, 1984; Davis et al., 2000). Other studies have shown that CORT levels increased in laying hens after exposure to increased density and roosters in the cages (Mashaly et al., 1984; Koelkebeck et al., 1987).

The use of the cage environment for the housing of commercial table egg hens has been widely investigated. Koelkebeck and Cain (1984), Mench et al. (1986), and Koelkebeck et al. (1987) found that CORT levels were elevated in hens housed in floor pens compared with hens housed using other confinement techniques. Craig and Craig (1985) observed no differences in the levels of plasma CORT between chickens raised in colony cages and those raised in floor pens. Struwe et al. (1992) reported no differences in CORT levels in birds housed in cages with wire bottoms and those in cages with litter bottoms.

Plasma T₃ and T₄ levels in birds have been considered indicators of metabolism, growth, and maturation. Renden et al. (1994) showed reciprocal changes in T₃ and T₄ concentrations in broilers exposed to varying lighting programs. Klandorf et al. (1981) and Decuyper and Kühn (1988) found that daily rhythms of thyroid hormones were controlled by the feeding patterns of chickens. Klandorf et al. (1981) suggested that heat production was associated with T₃, not T₄. Klandorf et al. (1978) and Klandorf et al. (1988) found that stress was associated with a decrease in T₄ in birds. This decrease is thought to occur due to an increase in the conversion of T₄ to T₃ during periods of increased metabolic needs.

In lieu of these reports, the objective of the present study was to quantitate the development of the pullet and physiological changes before the onset of egg production. Monitoring the levels of plasma CORT, T₃, and T₄ present in the laying hens, as well as the H:L, will assist in determining if physiological changes have occurred due to the process of genetic selection in cage-reared pullets. In addition, the effects of genetic selection on hen fearfulness and possible associated responses of the stress indicators, H:L and CORT, would be determined.

MATERIALS AND METHODS

Four genetic stocks were used in this study. Three of the Ottawa control stocks were acquired from Agriculture Canada, Ontario [stocks 5 (CS5), 7 (CS7), and 10 (CS10)] and compared against a current commercial laying stock. Fairfull et al. (1983) and Gowe et al. (1993) have described the composition of the 3 randombred control stocks: CS5 was formed from a common base population of laying hens in 1950; CS7 was formed in 1959 from the H&N Nick Chick, Hy-Line 934A, Kimber K137, and Shaver 288; and CS10 was formed in 1972 from the Babcock B300, H&N Nick Chick, Hy-Line 934, and Shaver 288. These stocks had been maintained in a randombred, unselected manner since their formation. The 1993 commercial stock (H&N International GmbH, Cuxhaven, Germany, subsidiary of Lohmann-Wesjohann Group) used had a common ancestry with each of the control stocks. The procedures and animal care management were reviewed and approved by the North Carolina State University IACUC (Raleigh).

Hatching eggs were obtained and randomly placed into 2 incubators for hatching. This practice was used to prevent any variations among the stocks due to incubation differences. The chicks were placed in a flat-deck brood-grow cage facility with 18 replicate cages allocated to each of the stocks. Each replicate cage contained 40 females with a common density of 310 cm²/pullet. The pullets were reared using the same dietary commercial step-down protein regimen outlined by Anderson (1994).

Body weight and feed intakes were collected on a biweekly basis through the rearing period to 18 wk of age. Every 2 wk, 10 pullets were randomly sampled from each of 10 replicates per genetic stock (n = 100) to monitor BW using average group weights. At 18 wk of age, the pullets were individually weighed to determine flock uniformity. All feed provided to the pullets throughout each 2-wk period was weighed, and then at the end of each period, the feed remaining was weighed back to determine the total feed consumed for each cage replicate. From this total feed consumption, feed consumption/pullet per day and feed conversion were calculated.

Two pullets from 10 replicates (n = 24-stock) were randomly selected at 16 wk and transported to the laboratory for a comparison of frame size and body composition. The pullets were weighed, and then frame measurements of shank and keel lengths were taken on each pullet using the methods outlined by Anderson et al. (1995). Postmortem weights were collected after each phase of processing to determine blood, feather, and nonviscerated carcass weight. Additional information collected includes weights of abdominal fat, head
plasma samples were analyzed with the standard cali-
test parallelism, undiluted and diluted pooled chicken
tra-assay CV (4.3%) and the interassay CV (6.0%). To
radioimmunoassay kits were used to calculate the in-
CA). Pooled plasma CORT levels, as determined by the
noassay kits (Diagnostic Products Corp., Los Angeles,
to the methods of Davis et al. (2000) using radioimmu-
corded as the H:L.
1,000× total magnification. The ratio counted was re-
counted on each smear under an oil immersion lens of
PA). The first 100 heterophils and lymphocytes were
staining kit (Fisher Laboratory Products, Pittsburgh,
with blood sampling. The blood smears were allowed
to dry and smears were later stained using a leukostat
smears were collected at 5°C. Plasma samples were collected and frozen at
1000 × g for 15 min at 5°C. Plasma samples were collected and frozen at
−29°C in microcentrifuge tubes until analysis.
A blood smear was made for each pullet concurrently
with blood sampling. The blood smears were allowed to
dry and smears were later stained using a leukostat
staining kit (Fisher Laboratory Products, Pittsburgh,
PA). The first 100 heterophils and lymphocytes were
counted on each smear under an oil immersion lens of
1,000× total magnification. The ratio counted was
recorded as the H:L.
Plasma hormone analyses were conducted according to
the methods of Davis et al. (2000) using radioimmu-
noassay kits (Diagnostic Products Corp., Los Angeles,
CA). Pooled plasma CORT levels, as determined by the
radioimmunoassay kits were used to calculate the in-
tra-assay CV (4.3%) and the interassay CV (6.0%). To
test parallelism, undiluted and diluted pooled chicken
plasma samples were analyzed with the standard cali-
and neck, shank, liver, proventriculus, gizzard, small in-
testine, whole eviscerated carcass, hind quarters, whole
breast, and wings. The weights were then analyzed by
the percentage of total BW.
Brachial blood samples were obtained from 2 ran-
domly selected pullets from each rearing house replicate
by stock (n = 36/stock). The samples were collected at
the same time of the day (1100 to 1200 h) at 18 wk
of age just before the move to the laying facility. So-
dium heparin was used as an anticoagulant, and blood
samples were collected in 3-mL syringes. Samples were
collected from the brachial vein of each pullet within
45 s of being caught. Beuving and Vonder (1978) and
Davis et al. (2000) found that immobilization of greater
than 45 s increased the CORT levels of chickens. The
needle was removed from the syringe and the blood was
placed in test tubes that were held on ice. The samples
were refrigerated and centrifuged at 500 × g for 15 min
at 5°C. Plasma samples were collected and frozen at
−29°C in microcentrifuge tubes until analysis.

A blood smear was made for each pullet concurrently
with blood sampling. The blood smears were allowed to

dry and smears were later stained using a leukostat
staining kit (Fisher Laboratory Products, Pittsburgh,
PA). The first 100 heterophils and lymphocytes were
counted on each smear under an oil immersion lens of
1,000× total magnification. The ratio counted was
recorded as the H:L.
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noassay kits (Diagnostic Products Corp., Los Angeles,
CA). Pooled plasma CORT levels, as determined by the
radioimmunoassay kits were used to calculate the in-
tra-assay CV (4.3%) and the interassay CV (6.0%). To
test parallelism, undiluted and diluted pooled chicken
plasma samples were analyzed with the standard cali-
brators. The observed and expected values (in ng/mL)
were calculated as the percentage of observed/expected
values and ranged from 85 to 102%. The coat-a-count
antiserum (Diagnostic Products Corp., Los Angeles,
CA) was highly specific for corticosterone. The highest
level of cross-reactivity occurred with 11-deoxycortico-
sterone at 1.58% and the lowest level was 0.012% with
dehydroepiandrosterone. Pooled plasma thyroid levels
were also used to determine the intra-assay CV (2.92%)
and the interassay CV (7.14%). Parallelism was once
again tested using pooled laying pullet plasma. The
percentage of observed/expected values ranged from
95.95 to 102.5%.

The fear response was determined via tonic immobi-
ility test (TI) as developed by Craig et al. (1984) and
modified by Anderson and Adams (1994). Pullets were
selected from the replicates that had not previously
been caught for blood-sample collection. Each pullet
was caught and carried to a curtain-enclosed area at
the end of the pullet house. They were placed on their
back in a Y-shaped cradle and restrained for 10 s to
induce TI. Then, the observer started a stopwatch and
sat 2 m from the pullet and observed. The duration of
TI was from the time of induction of TI until the pullet
had righted itself or until 15 min had elapsed.
The experimental design was a completely random-
ized design with 4 genetic stocks of chickens. The
analysis was based upon the replicate mean during the
rearing period, with each period being composed of 2
wk. Data were analyzed by period and by cumulative
grow-phase totals using the ANOVA procedure of SAS
(SAS Institute, 1989). The component weights for each
pullet were transformed so that component weight was
modified by Anderson and Adams (1994). Pullets were
selected from the replicates that had not previously
been caught for blood-sample collection. Each pullet
was caught and carried to a curtain-enclosed area at
the end of the pullet house. They were placed on their
back in a Y-shaped cradle and restrained for 10 s to
induce TI. Then, the observer started a stopwatch and
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analysis was based upon the replicate mean during the
rearing period, with each period being composed of 2
wk. Data were analyzed by period and by cumulative
grow-phase totals using the ANOVA procedure of SAS
(SAS Institute, 1989). The component weights for each
pullet were transformed so that component weight was
represented as a percentage of the total BW. Where
significant effects occurred, the significance was tested
using Duncan’s multiple range test (Steel and Torrie,

### Table 1. Effect of genetic selection on pullet BW (g) during the rearing period (n = 400)

<table>
<thead>
<tr>
<th>Stock</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS5</td>
<td>117a</td>
<td>266a</td>
<td>472a</td>
<td>730a</td>
<td>857</td>
<td>1,078a</td>
<td>1,225a</td>
<td>1,305a</td>
<td>1,403a</td>
</tr>
<tr>
<td>CS7</td>
<td>120a</td>
<td>258ab</td>
<td>441b</td>
<td>706ab</td>
<td>852</td>
<td>1,049b</td>
<td>1,201b</td>
<td>1,253b</td>
<td>1,333b</td>
</tr>
<tr>
<td>CS10</td>
<td>117a</td>
<td>258ab</td>
<td>437b</td>
<td>700b</td>
<td>832</td>
<td>1,027b</td>
<td>1,176b</td>
<td>1,233b</td>
<td>1,332b</td>
</tr>
<tr>
<td>CCS</td>
<td>111b</td>
<td>252b</td>
<td>453ab</td>
<td>715ab</td>
<td>847</td>
<td>1,059ab</td>
<td>1,215a</td>
<td>1,329a</td>
<td>1,428a</td>
</tr>
<tr>
<td>SEM</td>
<td>2.4</td>
<td>5.8</td>
<td>12.7</td>
<td>14.0</td>
<td>14.2</td>
<td>14.4</td>
<td>16.2</td>
<td>22.5</td>
<td>28.9</td>
</tr>
</tbody>
</table>

a,bMeans within a column with differing superscripts are significantly different (P < 0.05).

1CS5 = control stock 5; CS7 = control stock 7; CS10 = control stock 10; and CCS = current commercial stock.

### Table 2. Effect of genetic selection on overall feed consumption parameters and livability (n = 72)

<table>
<thead>
<tr>
<th>Stock</th>
<th>Feed conversion (feed/gain)</th>
<th>Feed consumption (g/bird per day)</th>
<th>Total feed consumption (kg/bird)</th>
<th>Livability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS5</td>
<td>5.27a</td>
<td>58.4a</td>
<td>7.4</td>
<td>93.3b</td>
</tr>
<tr>
<td>CS7</td>
<td>5.48a</td>
<td>57.6b</td>
<td>7.3</td>
<td>94.9a</td>
</tr>
<tr>
<td>CS10</td>
<td>5.33a</td>
<td>56.5b</td>
<td>7.1</td>
<td>95.0a</td>
</tr>
<tr>
<td>CCS</td>
<td>5.04b</td>
<td>56.9b</td>
<td>7.2</td>
<td>91.3c</td>
</tr>
<tr>
<td>SEM</td>
<td>0.11</td>
<td>0.8</td>
<td>0.2</td>
<td>0.05</td>
</tr>
</tbody>
</table>

a Means within a column with differing superscripts are significantly different (P < 0.05).

1CS5 = control stock 5; CS7 = control stock 7; CS10 = control stock 10; and CCS = current commercial stock.
The percentage of livability was converted to arcsin before analysis. Tonic immobility time was recorded in seconds, and before analysis, converted to $\log_{10}$ seconds. An analysis was conducted on the transformed righting times using proc GLM, and the means were separated using Duncan’s multiple range test.

## RESULTS AND DISCUSSION

### Pullet Growth, Feed, and Livability

At 2 wk of age, the CS5, CS7, and CS10 pullets had similar BW, whereas the CCS pullets were lighter (117, 120, 117, and 111 g, respectively; $P < 0.05$; Table 1). By 10 wk of age, there was no difference in pullet BW, whereas by 14 wk, the CS5 and CCS pullets were the heaviest ($P < 0.05$) and remained so through 18 wk. The CS5 was consistently one of the heaviest stocks for all sampling periods. The CCS began as the lightest pullet stock but transitioned to the heaviest stock as the pullet phase progressed. The changes in BW were similar to those reported (Martin, 1959) for the CS5 and for the CS10 (Martin, 1973). However, the pullet weight for the CS5 stock and the CCS stock differed from that presented by Anderson (2011). He reported that pullet weights from 1958 through 2009 decreased, whereas in this study, the CS5 and CCS stocks pullet weights were not different. This may have been due to the fact that these pullets were all grown on identical diets. The current commercial diets provided the CS5 stock with better nutrition than the 1958 diet would have in the 1958 random sample tests. The BW differences were surprising given that all of the pullets consumed similar amounts of total feed (Table 2). However, the CCS pullets had the lowest ($P < 0.05$) feed conversion of all of the stocks, supporting the conclusion of Havenstein et al. (2003) that feed efficiency or utilization of feed has improved in modern stocks of poultry. The CS7 and CS10 pullets had the highest livability at 94.9 and 95.0%, whereas the CCS pullets had the poorest livability at 91.3%. The poor livability of the CCS pullets in the current study is surprising because it does not correspond to the livability reported by Anderson (1994) for the same CCS, which was 5% higher under similar conditions.

### Frame Size and Body Composition

The stock subsample of the pullet BW at 16 wk were significantly different from one another (Table 3) but mirrored those taken from the full flock (Table 1) at a later age. At 16 wk, the CS7 pullets were intermediate in weight between the CS5 and CCS, which were the heaviest, and the CS10, which were the lightest-weight pullets. This variability at younger ages has been noted by breeders and industry personnel (G. B. Havenstein, former geneticist for H & N; personal communications). The sternum length for CS5 and CCS was greater ($P < 0.05$) than those of the CS7 and CS10 pullets (110.4 and 108.7 mm vs. 104.6 and 104.8 mm, respectively). The shank lengths decreased ($P < 0.05$) from CS5 to CS7 and to the CS10 stock with the shank lengths of 101.8, 99.8, and 98.0 mm, respectively, whereas the CCS pullet shank length of 99.2 mm was only different from the CS5 pullets.

From the 16 wk body component analysis, it was determined that the percentage of blood was greatest ($P < 0.05$) in the CS5 pullets (4%) and least in the CCS pullets (3.5%), however, feather and head and neck percentages were the lowest in the CS5 pullets at 6.4 and 8.1%, respectively (Table 4). All 3 of these measure-

<table>
<thead>
<tr>
<th>Stock</th>
<th>BW (g)</th>
<th>Sternum length (mm)</th>
<th>Shank length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS5</td>
<td>1,317a</td>
<td>110.4a</td>
<td>101.8a</td>
</tr>
<tr>
<td>CS7</td>
<td>1,260ab</td>
<td>104.6b</td>
<td>99.8ab</td>
</tr>
<tr>
<td>CS10</td>
<td>1,221b</td>
<td>104.8b</td>
<td>98.0b</td>
</tr>
<tr>
<td>CCS</td>
<td>1,323a</td>
<td>108.7a</td>
<td>99.2b</td>
</tr>
<tr>
<td>SEM</td>
<td>31</td>
<td>1.3</td>
<td>0.8</td>
</tr>
</tbody>
</table>

$a,b$Means within a column with differing superscripts are significantly different ($P < 0.05$).

Table 3. Effect of genetic selection on BW and frame size at 16 wk of age (n = 96)

<table>
<thead>
<tr>
<th>Stock</th>
<th>Blood</th>
<th>Feather</th>
<th>Head and neck</th>
<th>Shank with foot</th>
<th>Whole carcass</th>
<th>Fat</th>
<th>Proventriculus</th>
<th>Gizzard</th>
<th>Liver</th>
<th>Small intestine</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS5</td>
<td>4.0a</td>
<td>6.4b</td>
<td>8.1b</td>
<td>3.3</td>
<td>77.4</td>
<td>1.3</td>
<td>0.32ab</td>
<td>2.0</td>
<td>1.6</td>
<td>1.7</td>
</tr>
<tr>
<td>CS7</td>
<td>3.7ab</td>
<td>7.4ab</td>
<td>8.4ab</td>
<td>3.3</td>
<td>76.5</td>
<td>1.2</td>
<td>0.31b</td>
<td>2.1</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>CS10</td>
<td>3.6b</td>
<td>7.4ab</td>
<td>8.5</td>
<td>3.4</td>
<td>77.4</td>
<td>1.1</td>
<td>0.30b</td>
<td>2.1</td>
<td>1.6</td>
<td>1.8</td>
</tr>
<tr>
<td>CCS</td>
<td>3.5a</td>
<td>8.3a</td>
<td>8.4ab</td>
<td>3.1</td>
<td>76.0</td>
<td>1.4</td>
<td>0.37b</td>
<td>1.9</td>
<td>1.4</td>
<td>1.7</td>
</tr>
<tr>
<td>SEM</td>
<td>0.1</td>
<td>0.5</td>
<td>0.1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.2</td>
<td>0.02</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

$a,b$Means within a column with differing superscripts are significantly different ($P < 0.05$).

Table 4. Effect of genetic selection on body component as a percentage of BW at 16 wk of age (n = 96)
ments found similarities between CS7, CS10, and CCS pullets. The blood loss percentages correspond to the 3.8% discussed by Newell and Shaffner (1950). The current study examined blood volume of a bleed out that is much less than a determination of total blood volume. There were no differences in the shank with foot percentage or in the noneviscerated carcass. The only organ that differed as a percentage of BW was the proventriculus, which was heavier (P < 0.05) in CS5 and CCS pullets at 0.33 and 0.37%, respectively. The CS7 and CS10 had lower proventriculus percentages at 0.31 and 0.30%, respectively. The stocks did not differ for eviscerated carcass percentage or carcass component percentages (Table 5). Sandercock et al. (2009) showed that at 10 wk, organ and body component weights based on live weights were similar between laying stock and traditional chickens. The current findings are similar in that the organ and body component percentages are similar between the stocks, indicating that the BW changes have been proportional.

**Fearfulness, Stress Response, and Hormone Levels**

The TI scores were not different between the genetic stocks, which was consistent with the results found by Craig and Muir (1989). Even though they showed that fear response could be selected for, selection pressure for production traits have not affected TI scores. The CCS stock had the highest (P < 0.05) H:L at 0.165 whereas the CS10 had the lowest at 0.088, with the CS5 and CS7 having intermediate ratios of 0.109 and 0.110, respectively (Table 6). The CORT level of the CCS was highest (P < 0.05) at 7.64 ng/mL compared with the CS5 and CS7 levels of 4.50 and 4.61 ng/mL, respectively. The CORT levels in the CS10 pullets were intermediate at 6.45 ng/mL. The differences in CORT levels appear to be related to the shift in age at 50% production reported by Jones et al. (2001). From 1950 through 1993 there was a 28-d reduction in the days to maturity. The drastic increase in metabolism of the CCS pullets at 18 wk versus the earlier stocks at this point would likely account for the increased CORT levels.

The levels of T₃ detected in poultry have been associated with metabolism (Gibson et al., 1986). The higher levels of T₃ for CS5 and CS7 could indicate a greater rate of metabolic change for the different stocks. Normal baseline or increased levels of T₄ in chickens have been found during periods of growth (Scanes et al., 1984; Decuypere and Kühn, 1988). The increased levels detected in the current study could be related to a period of growth. Furthermore, thyroid hormones participate in sexual maturation which would explain the high levels of T₄ at the beginning of lay (18 wk). It is at this point that the rapid development of the ovary and oviduct occur for the onset of production.

This study illustrates the effect of genetic selection on laying hen growth and development without the influence of different feeding programs as used in the past (Martin, 1959, 1973). The changes in CORT, T₃, and T₄ appear to be related to the shifts in development and in maturity (Jones et al., 2001).

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**Table 5.** Effect of genetic selection on dressed, eviscerated carcass components as a percentage of BW at 16 wk of age (n = 96)

<table>
<thead>
<tr>
<th>Stock</th>
<th>Eviscerated carcass</th>
<th>Whole breast</th>
<th>Saddle (rear quarters)</th>
<th>Wings</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS5</td>
<td>67.5</td>
<td>25.5</td>
<td>32.1</td>
<td>8.5</td>
</tr>
<tr>
<td>CS7</td>
<td>67.2</td>
<td>25.1</td>
<td>32.4</td>
<td>8.3</td>
</tr>
<tr>
<td>CS10</td>
<td>66.8</td>
<td>24.4</td>
<td>32.4</td>
<td>8.5</td>
</tr>
<tr>
<td>CCS</td>
<td>66.5</td>
<td>25.2</td>
<td>31.6</td>
<td>8.1</td>
</tr>
<tr>
<td>SEM</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
</tr>
</tbody>
</table>

¹CS5 = control stock 5; CS7 = control stock 7; CS10 = control stock 10; and CCS = current commercial stock.

**Table 6.** Effect of genetic selection on physiological parameters (n = 144)

<table>
<thead>
<tr>
<th>Stock</th>
<th>H:L</th>
<th>TI (s)</th>
<th>CORT (ng/mL)</th>
<th>T₃ (ng/mL)</th>
<th>T₄ (ng/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS5</td>
<td>0.109ab</td>
<td>267</td>
<td>4.50b</td>
<td>5.47a</td>
<td>9.49ab</td>
</tr>
<tr>
<td>CS7</td>
<td>0.110ab</td>
<td>227</td>
<td>4.61b</td>
<td>5.67a</td>
<td>10.15a</td>
</tr>
<tr>
<td>CS10</td>
<td>0.088b</td>
<td>357</td>
<td>6.45ab</td>
<td>4.39b</td>
<td>6.51b</td>
</tr>
<tr>
<td>CCS</td>
<td>0.165a</td>
<td>248</td>
<td>7.64a</td>
<td>4.34b</td>
<td>8.04b</td>
</tr>
<tr>
<td>SEM</td>
<td>0.032</td>
<td>57</td>
<td>1.31</td>
<td>0.38</td>
<td>0.73</td>
</tr>
</tbody>
</table>

¹H:L = heterophil:lymphocyte ratio; TI = tonic immobility score; CORT = corticosterone; T₃ = 3,5,3′-triiodothyronine; and T₄ = thyroxine.

²CS5 = control stock 5; CS7 = control stock 7; CS10 = control stock 10; and CCS = current commercial stock.
REFERENCES


