ENVIRONMENT, WELL-BEING, AND BEHAVIOR

Effects of Genetic Selection on Behavioral Profiles of Single Comb White Leghorn Hens Through Two Production Cycles

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ABSTRACT Four layer genetic stocks consisting of 3 Ottawa control strains (5, 7, and 10) and a commercial laying stock (CCS) were utilized to evaluate potential changes in behavioral profiles due to the effects of genetic selection through 2 production cycles. The Ottawa strains were started as random bred strains from the crosses of several popular commercial layers in 1950, 1959, and 1972, and the commercial strain used herein was from calendar year 1993, and its ancestors were involved in the formation of all of the random bred strains. The behavior study utilized 2 replicates from each strain that contained 4 cages, 6 hens/cage, for a total of 192 hens. Behavioral observations were recorded on 2 consecutive days beginning at 22 wk of age and every 28 d thereafter during the first production cycle, the molt period, and the second production cycle through 90 wk of age and periodic feather and Hansen's test scores recorded. Behavior profiles were similar between the control strains and the CCS, indicating that long-term genetic selection by commercial egg-type breeding firms to enhance production parameters has had no impact on laying strain behavior patterns. Appetitive behaviors were not affected by strain. During the molt, hens had reduced ($P < 0.05$) feeding and drinking frequencies in comparison with those observed during the first and second cycles. The data indicated that hens pecked inedible objects at a greater ($P < 0.0001$) frequency during the first cycle and molt than during the second cycle. Fearfulness scores were only influenced by production phase with the molt having the highest ($P < 0.01$) score of 3.46. Strain or production phase did not influence the frequency of aggressive and submissive acts.

Key words: chicken, laying hen, molt, behavior, fearfulness

INTRODUCTION

Domestication and the genetic selection of animals to be more highly adaptable to intensive agriculture is a fairly recent event in the history of humans (Craig, 1981). Ever since chickens came under the influence and subsequent domestication by humans approximately 4,000 yr ago, humans have selected them for their productivity in confinement (Craig, 1981). Because of the earliest behavioral studies and the determination by Schjelderup-Ebbe (1922) and Murchison (1936) that social orders are established in chicks, it has been suggested that bird behavior could elucidate the state of bird welfare. Other researchers (Fischer, 1975; Duncan et al., 1978; Duncan, 1980; Anderson et al., 1989) have developed the ethogram or behavioral profile of the domesticated hen in different environments and during the adaptation period after housing. As the birds adapt, the number of negative interactions between hens are reduced, thereby minimizing social stress and enhancing welfare. The repertoire of behaviors includes feeding, drinking, comfort, social, reproductive, and anti-predator behaviors with individual behaviors nested within these general categories. The social behaviors, which include aggression, escape/avoidance, and submission, as well as their relationship to stress indicators within an animal, are of particular interest as potential indicators of welfare. Davis et al. (2000) showed that strain had no effect on the physiological indicators of stress such as corticosterone levels and heterophil/lymphocyte ratios. Webster (2000) indicated that no apparent harm or debilitation to molted hens was observed when they were deprived of feed and that the hens adapted to the environmental change of feed withdrawal by the third day.

Random sample tests and strain tests have been conducted for many years to evaluate improvements in the production performance of commercial layers in relation to changes in genetics (Martin, 1960; Carey, 1987; Anderson, 1996; Flock and Heil, 2001; Anderson, 2002). Another way to assess genetic change is through the use of random bred control strains (Dickerson and Mather, 1976; Clayton, 1978; Jackson et al., 1986; McMillan et al., 1990; Gowe et al., 1993; Jones et al., 2001). These researchers focused on genetic changes over time on hatchability, fertility, feed conversion, maturity, egg production, and persistency of production using 2 production cycles with no focus on the poten-

tial behavior changes or modern husbandry. In all cases production performance was shown to improve over the years. However, it is difficult to evaluate whether the improved performance was due to genetic selection, management, disease control, nutritional modifications, improved welfare, or a combination of these because many of these changes occurred simultaneously. Over the past 5 decades, primary breeding companies have selected for a combination of factors including egg production rate, egg size, egg quality, and the survival of the commercial strains in competitive multiple-bird cage environments. This selection emphasis has resulted in enhanced productivity (McBride, 1980). Theoretically, this selection should have resulted in concurrent selection for the strain's ability to adapt to the cage environment or to alter its behavior pattern or to have the ability to learn what components of their environment are self-benefiting using a cognitive process (Ewing et al., 1999). Craig and Muir (1998) indicated that domestication and subsequent genetic selection allowed humans to choose chickens that were adaptable to contemporary husbandry practices and confinement systems. They inferred that rapid changes in husbandry practices for egg-type stocks including stocking density, light control, and induced synchronized molting may have overwhelmed genetic selection in egg-type chickens thus impacting their behavior and compromising their welfare.

Craig (1992) suggested that some of the differences observed in behaviors among different genetic strains, under identical environmental conditions, must be a result of genetics. He indicated that genetics might be responsible for behaviors that have an adverse effect on hen productivity in multiple-bird cages. Thus, he reasoned that if the strain of caged pullets were selected based on performance and agonistic activities in multiple-bird cages, then their adaptation to that type of environment could be improved from one generation to the next. Subsequently, Muir and Craig (1998) indicated that selection against the specific behaviors of feather pecking and cannibalism would be a means of improving the hen's well-being. Anderson et al. (2004) examined potential differences in behavior patterns between 2 commercial strains and found that, behaviorally, these strains available in the late 1990s were very similar in their basic behavioral profile and behavioral patterns.

Therefore, a comparison of random bred control strains created years previously with a current commercial egg laying strain should help assess, at least to some degree, whether genetic selection for increased agronomic traits has affected laying hen behavior. The observation of behaviors in relation to the first cycle, molt, and second cycle phases of the productive life of a laying hen is important because synchronized molting has been purported to have negative effects on the welfare of the hen due to the initial period of fasting used to initiate the molt thereby stopping egg production (Olentine, 2002; Anderson et al., 2004). The objectives of this study were to determine if, under contemporary husbandry practices including 2 production cycles and molt, long-term genetic selection for agronomic traits has altered behavior patterns or fearfulness in laying hens. The utilization of random bred control strains should allow for some inference about the role long-term genetic selection for improved production performance has had on adaptability to caged production.

MATERIALS AND METHODS

Four genetic stocks were utilized in this study. Three Ottawa control strains were acquired from Agriculture Canada [i.e., strains 5 (**CS5**), 7 (**CS7**), and 10 (**CS10**)], and their performance was compared with that of a current commercial laying stock (**CCS**) produced in 1999. Gowe et al. (1993) and Fairfull et al. (1983) provide a description of the genetic backgrounds for the 3 random bred control strains. The CS5 strain was formed from a common base population of laying hens in 1950. The CS7 strain was formed in 1959 from 4 Leghorn strains composed of the H&N "Nick Chick", the Hy-Line 934A, the Kimber K137, and the Shaver 288. The CS10 strain was formed in 1972 from 4 commercial Leghorn strains: the Babcock B300, the H&N "Nick Chick", the Hy-Line 934, and the Shaver 288. These random bred strains had been maintained at Agriculture Canada in a random mating manner without selection since their formation. The current commercial stock (H&N International, GmbH, Cuxhaven, Germany, subsidiary of Lohmann-Wesjohann Group) utilized had a common ancestry with each of the control strains.

Hatching eggs were obtained and hatched simultaneously in incubators at the North Carolina Department of Agriculture and Consumer Services' Piedmont Research Station, Poultry Unit, located in Salisbury, NC. The chicks were grown at a common density of 310 cm^2/bird in a flat-deck, brood-grow cage facility. The rearing and lighting programs used on all strains were identical and were previously described by Anderson (1996). At 18 wk of age, birds from each of the 4 strains were moved to an environmentally controlled laying house that contained 144 replicates (36 replicates/strain). A phase feeding program was used that regulated diet formulations based on flock performance and feed intake. The molt program was initiated at 62 wk of age, and samples of hens were weighed to determine the average premolt BW with a target of 30% weight loss. The feed was removed and daylight hours reduced from 16 to 10 h. On the target date, or 14 d postinitiation of the feed removal, the hens were weighed and returned to feed (17% CP diet containing 3.7% Ca). Once 5% production was achieved, they were returned to the conventional layer diet. The husbandry and research protocols were approved in accordance with the North Carolina State University Institutional Animal Care and Use Committee policies and procedures. From within this research flock 2 replicates from each of the 4 strains were randomly selected for this behavior study.

These 8 replicates consisted of 4 contiguous cages (61 × 35.5 cm) containing 6 hens/cage for a total of 24 hens/replicate. The density and feeder space were 361 cm^2 and 10.2 cm/hen, respectively, throughout the study. Observations were made from the same replicates throughout the experiment on cages that maintained a constant hen population. Behavior observations were conducted on 2 consec-

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Table 1. Effect of strain and production phase on behavioral acts and profiles independent of conspecific during 3 production phases

Source	Standing	Crouching	Preening	Movement	Comfort movement	Feather pecking
Strain[1]			(acts/bird per min)			
CS5	0.272	0.069	0.030	0.019	0.001	0.006
CS7	0.283	0.057	0.034	0.017	0.002	0.005
CS10	0.263	0.070	0.032	0.013	0.002	0.004
CCS	0.287	0.048	0.029	0.013	0.002	0.004
Pooled SE	± 0.030	± 0.008	± 0.008	± 0.002	± 0.001	± 0.001
Phase						
First cycle	0.273	0.044^Y	0.026^X	0.019^X	0.001	0.006
Molt	0.287	0.044^Y	0.038^Z	0.018^X	0.002	0.006
Second cycle	0.268	0.095^X	0.029^X	0.010^Y	0.001	0.002
Pooled SE	± 0.016	± 0.007	± 0.005	± 0.002	± 0.001	± 0.001
Strain × phase	NS	NS	NS	NS	NS	NS

[X–Z]Means different within columns are significantly different ($P < 0.0001$).

[1]CS5 = Ottawa control strain 5; CS7 = Ottawa control strain 7; CS10 = Ottawa control strain 10; CCS = current commercial stock.

utive days every 4 wk. The first cycle began at 22 wk of age and ended at 62 wk of age. The molt phase was from 62 to 66 wk of age when observations were conducted at 2-wk intervals to capture 2 time points of potential rapid behavior changes (i.e., d 2 and 3 of the fast, and d 2 and 3 postfast). This was followed by the second cycle, 4-wk observation interval from 66 through 90 wk of age.

On each observation day, 1 cage containing 6 hens in each of the 8 replicates was randomly selected as the starting point and was observed in ascending or descending replicate order. Observation times were selected based upon a report by Anderson et al. (1989), which indicated that a diurnal activity pattern associated with feeding and other activities occurred. The 2 observers were trained to utilize the modified scanning technique developed by Anderson and Adams (1991), which resulted in no discernible behavior disruptions among the hens in the cage. The observer dressed in caretaker attire and stood approximately 1.5 m from the front of the cage to be observed. The observations commenced after being immobile in front of the cage for approximately 45 s as the hens continued their normal activity. The observation times began at lights on (0500 h), midday (1200 h), and evening (1800 h) and consisted of two 5-min periods at approximately 50-min intervals. Within each 5-min period, the behavioral acts that a hen could perform independently of cage mates [standing, crouching (**CR**), preening (**PR**), moving (**MV**), comfort movements, and feather pecking (**FP**)] were recorded along with the appetitive behaviors of feeding (**FD**), drinking (**DR**), and pecking inedible objects (**PI**). Those behaviors performed by each hen were recorded at 1-min intervals. In addition, social behaviors [those requiring the interaction of 2 hens: aggression (**AG**), avoidance and escape behavior (**AE**), peck hen in neighboring cage (**PN**), submissive acts (**SUB**), and pecked by a hen in a neighboring cage (**PBN**)] were recorded as they occurred during each 5-min period. The descriptions and definitions for the 16 behaviors observed were based on the definitions of Na-Lampang (1989) and Hurnik et al. (1995). The definition for FD was modified to include feeding actions in the feed

trough where feed is normally present, to accommodate the fasting period when no feed is present in the trough.

Feather scores were determined at 62 wk (the end of the first cycle) and 86 wk (the end of the second cycle) using the procedure developed by Adams et al. (1978). Feather cover was recorded on a scale of 1 to 9 for all hens contained in the replicates being observed, with a value of 1 indicating almost a complete lack of feather cover and 9 indicating a complete feather coat. Fear levels were evaluated by the Hansen's test (**HT**; Hansen, 1976) as modified by Jin and Craig (1988). The fear measurements began at 30 wk of age and the level of fearfulness in the modified HT ranged from 0 (no response) to 4 (severe AE; Hansen, 1976).

Statistical Analysis

A completely randomized experimental design was used for the behavior study. The main effects consisted of 4 strains, the CS5, CS7, CS10, and the CCS, the 3 production phases first cycle, molt, and second cycle and the 3 observation times for the total number of observations (n = 72). All of the behavior means were reported in the tables as acts/bird/minute.

Tests were conducted on the behavioral acts that a hen could be performed independently of cage mates and the appetitive behaviors by 4-wk periods for normality using the UNIVARIATE procedure (SAS, 1996). The period data were pooled into the 3 production phases to maintain a normal distribution and to delineate a production phase behavior pattern. The MIXED procedure was used to evaluate behavioral acts that hens could perform independently of cage mates, i.e., standing, CR, PR, MV, and comfort movements, and the appetitive behaviors of FD, DR, and PI (SAS, 1996). Means that were significantly different were separated using the least square means.

The behavior data associated with social acts, i.e., those requiring the interaction of 2 hens (AG, AE, PN, STO, SUB, STU, PBN, and FP), were count data found to have nonnormal distributions. They were analyzed using the GENMOD procedure (SAS, 1996) for Poisson regression

analysis with a log link function. Before the data were pooled into the different production phases, the data were analyzed by period within each production phase. This determined that there were no differences between periods within a phase. The data transformation used was to sum the behavioral frequencies within the production phase and to then add 1 to each of the behavior data points to eliminate the 0's. The logs for each of the behaviors within strain and phase were then calculated. The GLM procedure (SAS, 1996) was run to achieve the means separation by the least square means when there was a significant production phase effect as indicated by the GENMOD analysis. Analysis of the transformed data was applied to the untransformed means for reporting.

The analysis of the Hansen's test and feather scores used the 4 strains (CS5, CS7, CS10, and CCS) and the 3 production phases as the main effects. The data were transformed using a log transformation followed by a test for normality using the UNIVARIATE procedure (SAS, 1996). The normally distributed data were analyzed using the MIXED procedure (SAS, 1996). Means that were significantly different were separated using the least square means.

RESULTS AND DISCUSSION

Large genetic gains in production have been shown to have occurred in the CCS stock used in the industry today over those available in previous years (Dickerson and Mather, 1976; Jones et al., 2001). The frequencies of behaviors that can be performed by a hen independently of cage mates have not changed between the 3 historic strains and the current commercial strain studied (Table 1). This indicates that the genetic selection for productivity, as shown by Anderson (1996) in the CCS hens, had no impact on the behavioral patterns of the CCS as compared with those observed in the random bred control strains CS5, CS7, or CS10 (Jones et al., 2001). In this study the interplay between behavioral frequencies, with increases in one behavior being offset by corresponding decreases in one or more of the other behaviors, is difficult to interpret within this experimental design. This effect can be seen in this study where CR in the second cycle reached its highest frequency while the frequency of MV reached its lowest incidence. With the use of multiple production phases the emphasis on the changes that occur in welfare as the hen's age has been diminished, and instead more emphasis has been placed on the differences between strains and production phases. Welfarists have emphasized potentially negative behaviors of cage management systems even though Kjaer et al. (2001) showed that specific behaviors such as aggressive feather pecking could be reduced through divergent selection. Desire et al. (2002) indicated, however, that a better interpretation of welfare changes in layers may be that they are simply a response to an emotional experience and its impact on the complete behavioral response. This study concentrated on a number of basic laying hen behaviors to develop a hen's behavior pattern. The lack of behavior pattern shifts between strains in this study indicates that selection for improved production appears

Table 2. Effect of strain and production phase on appetitive behavior acts and profiles during a complete production period

Source	Feeding	Drinking	Pecking inedible objects
Strain[1]		(acts/bird per min)	
CS5	0.082	0.014	0.015
CS7	0.076	0.016	0.015
CS10	0.083	0.018	0.019
CCS	0.086	0.016	0.017
Pooled SE	± 0.017	± 0.003	± 0.003
Phase			
First cycle	0.096[a]	0.016	0.024[X]
Molt	0.072[b]	0.019	0.020[Y]
Second cycle	0.078[ab]	0.012	0.006[Z]
Pooled SE	± 0.011	± 0.002	± 0.003
Strain × phase	NS	NS	NS

[a,b]Means different within columns are significantly different ($P < 0.05$).

[X–Z]Means different within columns are significantly different ($P < 0.0001$).

[1]CS5 = Ottawa control strain 5; CS7 = Ottawa control strain 7; CS10 = Ottawa control strain 10; CCS = current commercial stock.

to have had little influence on behavior in contrast to what was suggested by Muir and Craig (1998).

The production phase (i.e., first cycle, molt, and second cycle) had the greatest impact on the behavioral patterns observed in the CS5, CS7, CS10, and CCS strains. The frequency of CR was lowest ($P < 0.0001$) during the first cycle and molt phase, then increased to the highest frequency during the second cycle. This appears to indicate that CR in this study is not associated with fear, new environment, or social status as proposed by Duncan (1980), Anderson et al. (1989), or Fischer (1975), respectively. Nor do these results correspond with those of Anderson et al. (2004), who showed no change in CR postmolt. Part of this difference may be due to the pooling of the period data into production phases in this study. The PR frequencies increased 46% ($P < 0.0001$) during the molt phase, then returned to premolt levels in the second cycle. This increase in PR behavior during the molt appears to be related to the physiological and productivity changes when the hens were shedding their old feathers and regrowing new feathers. The irritation associated with the molting process would be a logical component of PR frequency rather than a displaced foraging behavior as proposed by Huber-Eicher and Wechsler (1997). The frequency of MV behavior was similar during the first cycle and molt phases. The frequencies of MV decreased during the second cycle ($P < 0.0001$) to their lowest rate.

Much has been discussed concerning FP and the behavioral motivation for its actions (Huber-Eicher and Wechsler, 1997; Kjaer and Vestergaard, 1999; Oden et al., 1999; Bilcik and Keeling, 2000; Kjaer, 2000; McAdie and Keeling, 2000; Kjaer et al., 2001). However, in this study, FP was not different between strains or production phase and did not appear to be aggressive in nature but rather more associated with social grooming (Table 1). The lack of concurrent changes between PR and FP seems to indicate no apparent social facilitation mechanism as described by Keeling and Hurnik (1996) and Anderson et al. (2004).
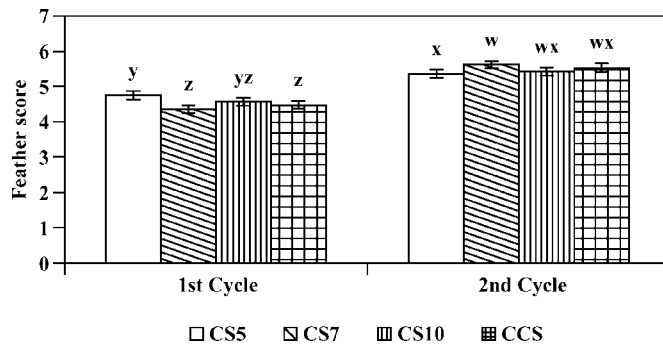
Figure 1. Interaction of strain and production phase on feather score. Feather scores ranged from 1 = no feather covering to 9 = complete feather covering. [w–z]Bars with different letters are significantly different ($P < 0.01$). CS5 = Ottawa control strain 5; CS7 = Ottawa control strain 7; CS10 = Ottawa control strain 10; CCS = current commercial stock.

The hens in this study showed no corresponding changes between the levels of FP observed for a strain and its feather score, which is contrary to data reported by Hughes (1985).

The appetitive behaviors were not influenced by the strain, but FD and PI were affected by the production phase (Table 2), and there were no interactions between strain and production phase for these activities. During the molt phase the frequency of FD behavior declined following feed withdrawal at the end of the first cycle ($P < 0.05$), as would be expected, but during the second cycle the FD frequency did not recover to premolt levels but rather had an intermediate frequency. The DR frequency, in the continuous presence of water, did not differ between the production phases. This is contradictory to what was observed by Anderson et al. (2004) and Brake and Thaxton (1979) who showed a declined DR in a manner that corresponded to the drop in FD. There was a decrease ($P < 0.0001$) in the incidence of PI as the hens progressed through the 3 production phases. In the second cycle the frequency of PI acts dropped to levels that were far lower than those observed in the first cycle or molt phases. Elevated frequencies of PI may actually have 2 meanings. First, PI appears to be an exploratory behavior that is related to the environ-

ment in which the hens are located, allowing them to familiarize themselves with their surroundings in the first cycle (Anderson et al., 1989). The PI is a type of exploratory behavior using the beak as a tactile tool to facilitate familiarization with the surroundings. The hens peck at all objects as an instinctive response in the first cycle, which appears to replace other behaviors that may negatively impact its pen mates. In this study the PI frequency remained relatively high during the first cycle, dropped during the molt phase, reaching the lowest frequency in the second cycle, contrary to the findings in other species (Keys et al., 1950). This could mean that exploratory motivation may have been satiated with the return to full feed after a period of limited nutrient intake in the second cycle.

The behaviors associated with social interactions, i.e., AG, SUB, AE, PN, and PBN, had frequencies that were consistently low and were not influenced by the strain (Table 3). In addition, the production phase did not result in any significant changes in AG, SUB, AE, PN, or PBN levels observed. This appears to indicate that genetic selection for enhanced productivity and feed efficiency has not altered the aggressiveness of the hen. Anderson and Adams (1991) showed that approximately 67% of aggressive behaviors occur over the feeder indicating that potential increases in aggression during feed withdrawal would be easily observed. In this study, the lack of aggressive and submissive behavior changes across the production phases was most surprising. Duncan and Wood-Gush (1971) surmised that the hen's frustration resulting from the withdrawal of feed would result in increased incidences of aggression, and Anderson et al. (2004) showed a significant increase in aggression postfast. However, in this study, there was no significant change in AG frequencies during the transition from a nonfasted to a fasted state or between production phases indicating that aggression was not influenced by the absence of feed, which was contrary to the findings of Duncan and Wood-Gush (1971) and Anderson et al. (2004). The current findings support the data reported by Webster (2000), who indicated that there is no increase in AG due to the absence or presence of feed

Table 3. Effect of strain and production phase on aggression, submissive acts, avoidance and escape behaviors and pecks between hens in neighboring cages

Source	Aggression	Submissive acts	Avoidance and escape	Pecked neighbor	Pecked by neighbor
Strain[1]			(acts/bird per min)		
CS5	0.0010	0.0001	0.0009	0.0007	0.0004
CS7	0.0005	0.0001	0.0001	0.0004	0.0001
CS10	0.0005	0.0001	0.0001	0.0006	0.0004
CCS	0.0005	0.0002	0.0001	0.0007	0.0004
Pooled SE	± 0.0002	± 0.0001	± 0.0002	± 0.0003	± 0.0002
Phase					
First cycle	0.0008	0.0003	0.0004	0.0010	0.0004
Molt	0.0008	0.0000	0.0004	0.0004	0.0004
Second cycle	0.0002	0.0000	0.0002	0.0003	0.0002
Pooled SE	± 0.0002	± 0.0001	± 0.0002	± 0.0003	± 0.0001
Strain × phase	NS	NS	NS	NS	NS

[1]CS5 = Ottawa control strain 5; CS7 = Ottawa control strain 7; CS10 = Ottawa control strain 10; CCS = current commercial stock.

Table 4. Effect of strain and production phase on feather score and modified Hansen's test scores

Source	Feather score[1]	Hansen's test[2]
Strain[3]		
CS5	5.05	2.75
CS7	4.99	2.85
CS10	5.01	3.15
CCS	5.01	2.97
Pooled SE	± 0.06	± 0.08
Phase		
First cycle	4.54[Y]	2.73[B]
Molt		3.46[A]
Second cycle	5.50[Z]	2.61[B]
Pooled SE	± 0.05	± 0.07
Strain × phase	0.01	NS

[A,B]Means different within columns are significantly different ($P < 0.01$).

[Y,Z]Means different within columns are significantly different ($P < 0.0001$).

[1]Feather scores ranged from 1 = no feather covering to 9 = complete feather covering.

[2]Modified Hansen's test scores ranged from 0 = calm to 4 = extreme fearfulness and avoidance behavior.

[3]CS5 = Ottawa control strain 5; CS7 = Ottawa control strain 7; CS10 = Ottawa control strain 10; CCS = current commercial stock.

during the different production phases. In addition, the redirection of aggressive behaviors to FP or PI proposed by Bilcik and Keeling (2000) was not apparent in this study.

Feather scores have not been impacted by the long-term genetic selection for increased productivity, as indicated by comparing the feather scores from the 3 historic strains with the scores of modern commercial strain (Table 4). Based upon the productivity differences observed between these same strains (Jones et al., 2001) it was thought that the CS5, CS7, and CS10 strains would have better feather scores than higher egg producing CCS hens. However, there were no differences between the CS5, CS7, CS10, and CCS strains in feather scores. Hens at the end of the first cycle had lower overall feather scores ($P < 0.0001$) than the same hens had at the end of the second cycle. This may be the result of the feather replacement that occurs due to molting and that the second cycle in this study was shorter. The significant interaction ($P < 0.01$) of strain and production phase (Figure 1) indicates that the CS7 and CCS strains had lower feather scores than the CS5 and CS10 strains during the first cycle, but in the second cycle this was reversed.

Modified HT scores were utilized as a direct measure of fearful behavior in this study, and no differences were observed between the historic and modern strains throughout the entire experiment (Table 4). The HT score was significantly higher ($P < 0.01$) during the molt phase where fearfulness indicators should be elevated due to feather loss as expected due to the feather loss found by Anderson et al. (2004). If feather loss was the trigger then this corresponds with the findings of Adams et al. (1978), Craig et al. (1986), and Okpokho et al. (1987), all of whom observed that during the production phase, birds with the highest HT score had the poorest feather score. Okpokho et al. (1987) also determined that strains differing in escape and avoidance behaviors differed in nervousness and feather loss. Unfortunately, in this study a concurrent feather score was not done during the molt phase. The absence of feed may also be a cause of the increase in HT because during the second cycle HT scores returned to premolt levels.

The hens in this study did not display the behavioral patterns that were noted previously associated with famines of which starvation is a component (i.e., increased aggressiveness and antisocial behaviors) as described in the review by Keys et al. (1950) of other species. However, during controlled fasts, Keys et al. (1950) indicated that fasting individuals appear somewhat lethargic, which was similar to the behaviors displayed by the hens in this study. The hens were passive in nature and exhibited low incidences of negative social behaviors throughout the study. It does appear that long-term selection for enhanced production has not changed the frequencies of behaviors birds perform to better fit their reproductive state or changing environment in cages. Because the behavior patterns did not appear to change due to selection, this suggests that behavior patterns are apparently influenced marginally as productivity increases. This supports the supposition that perhaps other indicators, including the physiology, morphology, and reemphasis on the importance of productivity, should be used as indicators of strain improvement (Curtis, 2006).

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