SELECTION FOR HIGH EGG PRODUCTION IN THE DOMESTIC FOWL

Dr. Robert S. Gowe
Canada Department of Agriculture
Ottawa, Ontario, Canada
A long-term selection study with egg type chickens was started in 1950 and still continues. This study has the following objectives:

1. To compare the effects of applying the same closed-flock selection procedures in two strains - one with a broad genetic base (a synthetic strain - strain 04) and one with a narrow base (a closed flock at the start of the study - strain 03).

2. To investigate the 'limit' that could be reached in selecting for high egg production in these two populations being selected principally for high egg production, but also for the other essential traits in commercial stocks (livability, egg size, fertility, hatchability, shell thickness and interior egg quality), and to establish plateaued populations for research on methods of improving stocks that have plateaued.

3. To investigate the effects of 'part-year' record selection on 'complete-year' performance, since, the use of 'part-year' record selection halves the generation interval.

4. To maintain genetically constant control strains (strains 05 and 07) (a) to permit the separation of genetic and environmental trends over time, and, (b) to serve as gene pools for further genetic studies.

5. To provide a body of data for statistical genetic studies on genetic parameters (heritabilities, genetic correlations and inbreeding coefficients) and to estimate their change over generations, and to
study the relationship that exists between the actual genetic changes and theoretical expectations.

6. To provide well characterized experimental strains for other breeding, genetic, disease resistance, and nutritional research.

Data are reported showing the results of 23 and 22 generations of selection in the two strains (03 and 04) for the principal trait under direct selection - 'part-year' performance - and the trait under indirect selection - 'complete-year' performance. These results are compared with the unselected control strains (05 and 07) to estimate the genetic changes in the selected strains.

Evidence for a change in performance of the principal control strain (interaction of genotype and environment) when the selected and control strain birds were housed in individual cages rather than floor pens, are shown and some of the implications to interpreting genetic changes in the selection program discussed.

The performance of crosses of the selected experimental strains are compared with commercial stocks as an indirect estimate of the success of the selection scheme.

STRAINS USED

(a) Control strain 05 and selected strain 03

These two strains originated by a within-family division of a common base population of White Leghorn females in 1950. The same males were used on both population of females in the originating year. In 1948 only a small number of males were used and the strains therefore could be considered to have a narrow genetic base.

Control strain 05 was maintained without selection from 1950. Until 1958 it was reproduced annually as a random-breeding, unpedigreed, flock-mated population. Since 1959 strain 05 was reproduced as a pedigreed population using
80 sires and 240 females each generation, each male being mated to 3 females, and as far as possible each sire contributing a sire and each dam a dam as breeders in succeeding generations to minimize genetic drift (Gowe, Robertson and Latter, 1959). The early performance has been reported in detail (Gowe et al, 1959).

Selection in strain 03 commenced in 1951. The number of pullets housed at Ottawa in each of the following 22 years has varied between 476 and 1993. In 1969 the breeding population was expanded to 80 males and 224 females, and mated one male to three females, all these breeders were selected but selection pressure was obviously reduced for the sires. In 1970 the test population of strain 03 was reproduced without selection (i.e. selection was relaxed completely for one generation and partially for two generations). The 1971 population was again selected but with very limited selection pressure on the female side due to the limited number of females that were available for selection, then the population was again expanded and returned to 28 sires and 224 females. From 1972 on this population was continued on the standard selection program.

(b) Selected strain 04

Strain 04 was started in 1950 by importing hatching eggs from seven Canadian R.O.P. unrelated stocks that were chosen for their apparent better than average performance (from R.O.P. test records made on different farms). A 7 x 7 diallel including the diagonal was set up in 1951 and the resulting progeny from these 49 different matings were tested for performance, and selected in the next (1952 test year) and subsequent generations without reference to base strain origin. Selection therefore, started immediately allowing only one generation for recombination and crossing-over to take place. This population was considered to have a broad geneti...
base. Unfortunately, space available at that time did not permit maintaining an unselected sample of this strain. The number of pullets housed at Ottawa in each of the 21 years has varied between 304 and 2080 birds. This strain has been under continuous selection.

(c) Control strain 07

This strain originated from four widely used commercial Leghorn-type stocks being sold in North America in 1958 (Kimber K 137, Shaver 288, Hy-line 934A, and H & N Nick Chick) by importing hatching eggs. Pedigree matings were begun in 1959 forming two-way crosses as follows: A ⊗ x B ♂, B ♂ x A ♂, C ♂ x D ♂, and D ♂ x C ♂, using 20 males and 60 females from each of the four commercial strains (coded A, B, C and respectively). In 1960 pedigreed reciprocal crosses between unrelated two-way crosses were made, using 20 males and 60 females for each two-way cross. In 1961 and subsequently, 80 males were mated with 240 females (in 1961 each four-way cross contributed 10 males and 30 females) in a pedigreed but random manner avoiding sib matings, continuing the one-to-one representation for breeders in adjacent generations that started with the first two-way crosses. This procedure produced a strain that on the average had equal proportions of the genes of each of the four original commercial strains in the base population, including genes on the sex chromosomes. All matings up to 1966 were made, and progeny reared and housed at the Kentville Research Station under the direction of Mr. F. G. Proudfoot. Strain 07 was taken to Ottawa for testing with the selected lines in 1966. The performance records for the earlier years at Kentville (although produced in a different environment) showed that there was a low incidence of loss through disease, and a relatively high performance for production which resulted in a low level of within-family natural selection as the population was brought into equilibrium.
SELECTION PROCEDURES

Selection in both strains O3 and O4 was directed principally at increasing the egg production potential of these strains through selection for hen-housed egg production from housing to 273 d of age (a part-year test of 18 weeks in the laying house, up to 1968 and, 19 weeks since 1969 when housing was completed at 140 d of age). A combination of individual records, and full-sib and half-sib family records was used to evaluate females. Males were selected on the basis of the performance of their full- and half-sisters.

For the first three generations, no selection for egg size was practiced but after size dropped substantially in the first two selected generations, this trait was also put under positive selection and the selection pressure increased in 1960.

Using independent culling levels, selection at a lower level of intensity was directed at maintaining existing levels of fertility, hatchability, rearing viability and laying-house viability. The latter trait was also selected for directly in the principle criterion of selection - hen-housed egg production. In general, no direct selection was applied to body weight at any age, sexual maturity (except of course indirectly through selection for the highest number of eggs laid to the fixed age of 273 days, which was the procedure used to select for hen-housed egg production), or egg quality characteristics other than egg size. However, in the last three generations the selection program has been modified to direct some selection pressure to improving shell quality (specific gravity) and the internal egg quality characteristics albumin height and the frequency of blood spots.

For the first 6 years (up to the 1957 breeding season) some of the breeding males and females of both strains that had been selected on part-year records were
randomized to each cage assigned to that strain. The pullets of all strains were housed in floor pens (houses with windows) and trap-nested from 1950 to 1964. Starting in 1965, all pullets were housed in individual 20-cm (8 inch) modified stair-step laying cages in windowless houses. Egg records were maintained for 5 consecutive days per week throughout the experiment. Housing was at 160 d of age, up to 1955, then at 147 d of age up to 1968 and from 1969 on the birds were housed by 140 d of age. Through 1955, the populations were also trap-nested on range prior to housing. Egg records for the period 148 to 497 d (500 d for earlier years up to 1964) were used for this study up to 1968. From 1969, egg records covered the period 141 d to 497 d (20 weeks to 71 weeks). All records were adjusted to a 7 d week basis.

From 1950 to 1963, test populations were reared and housed at three locations (Harrow, Ont., Agassiz, B.C. and Brandon, Man.) besides Ottawa. From 1951 to 1955 test populations were also housed at Charlottetown, and from 1950 to 1955 populations were housed at Lethbridge. The females and males housed at Ottawa were the only ones available for selection, although the performance records at the different test locations were available to estimate the genetic and environmental trends up to 1963. From 1964 to the present the selected and control population were tested at Ottawa only. Data from Ottawa only are presented in this report.

All mash rations fed ad libitum were used in the laying house throughout the test. Major changes in ration formulation were made in 1952, 1956, 1965, 1968 and 1970.

Artificial light was provided for a period of 13 h per d during the laying house (with windows) test up to 1964. (The artificial light was maintained at 16 hours from June 21st to the end of the test in 1964). From 1965 to 1968 a 14 hour day was provided in windowless cage houses. With the start of confinement
retained for a second breeding season, and in a few cases for a third and fourth season. Those birds were re-selected on the performance of first their progeny records for the part-year, and secondly, if kept another year, on the basis of their progeny records for the complete year. Less than 20% of the breeders were retained beyond the first breeding season. From 1958 on, selection was directed entirely at the part-record, no older birds retained as breeders. Therefore, in the first six generations selection was directly partially to annual production.

TEST PROCEDURES

In general the plan was to intermingle the pullets of all strains from hatching to the end of the production tests in all years, so that, environmental conditions for the several strains, and families within strains, were kept as similar as possible. The overall design philosophy called for periodic up-dating of the management program including the diets to keep conditions as close to common industrial standards as was possible and practical. Control (unselected) populations were provided to separate genetic and environmental trends.

From 1950 to 1967 test populations were brooded in colony houses and reared on range until housed. From 1968 on all pullets were reared to maturity in multi-deck brooding-rearing cages in a windowless house. In 1968, half the population of each strain was reared in separate replicated cages, families being intermingled within cages, and half the population was reared by inter-mingling strains and families over replicated cages. There was no differences between strains reared in these two different ways, therefore, they were not intermingled after 1969 for the rearing period, but the cages for each strain were assigned randomly throughout the house, and progeny of each sire were
in all populations. Vaccination started with the 1971 population.

By plotting the selected strains as a deviation from Control 05 it can be seen that selection for part-year performance has been effective (Figure 2). Strain 03 is 27 eggs above the control after 22 generations of selection – just over one egg per generation, while strain 04 is 34 eggs above the control after only 21 generation of selection – over 1.5 eggs per generation (Figure 2).

Note that the new random bred control (07) derived from 4 commercial strains in 1958, and that has been essentially in genetic equilibrium for the period it was tested in this experiment does not lay as many eggs as the two selected strains. It is about equivalent in part-year performance to the two selected lines in 1958, the year of origin of this control.

(b) Age at first egg, laying house mortality to 273 d body size at 365 d, and egg weight

The data for these 4 important economic traits are shown in Figures 3 to 6, all as a deviation from control strain 05. As expected, age at first egg decreased in the two selected strains as selection for high egg number to a fixed age puts heavy emphasis on early sexual maturity. Mortality in the laying period declined marginally with selection for the part-year production index. There was some differential response (interaction) to the heavy Marek's Disease outbreak in 1969 and 1970 (Figure 4). Body weight declined in strain 03 but remained relatively stable in strain 04 (Figure 5). Egg size increased, particularly after the selection pressure was increased in 1960 (Figure 6). Egg size is now comparable to stocks used by commercial breeders.

To this point the story is quite reasonable and probably could be quite logically subjected to the usual genetic analysis. The difficulty in analyzing
cage rearing in 1968, a constant 14 h day was provided the first year from hatching to the end of the test. In 1969, this was changed to a decreasing light regime of 15 min. per week for 20 weeks during the rearing period (from 16 h to 11 h 15 min.) followed by an abrupt increase to a 13 h day for the first week in the laying test and then a 14 h day to the end of the test. The 1970, 1971 and 1972 populations were reared under a constant 6 h day with dim (1.6 lux) red lights, and starting at 17 weeks (18 weeks in 1972) day-length was increased by 30 minutes per week until the birds received a 16-h day which was maintained to 497 day of age. The red lights were changed to white lights (40 lux) when the pullets were housed in individual cages between 137 and 140 days of age.

The production record was arbitrarily broken into 3 periods of 18 weeks, 16 weeks and 16 weeks (the first period was 19 weeks after the birds were housed at 140 d of age starting in 1969). These three production periods are coded 1, 2 and 3 respectively, code 4 indicates the first two production periods were combined and code 5 indicates all three were combined (the complete egg production test).

RESULTS

(a) Egg production to 273 d (part-year record - pd. 1)

The mean hen-housed (production index) performance for the two selected strains and the two controls is shown in Figure 1. The original control strain (05) can be seen to have performed in a relatively constant way over the 23 test years for this trait. There was perhaps a slight improvement in production over the first 5 test years, due either to improved management conditions (environment), or to some within strain natural selection as it came into genetic equilibrium.

A severe outbreak of Marek's Disease in 1969 and 1970 depressed performance
Just deviating the selected strains from the control would therefore underestimate the genetic change in the selected strains. It should be pointed out that the means plotted for all the hen-day rate graphs reported here are based on birds that survived the full test year (497 days), and the hen-day rate values start at the day of first egg. Also, all birds that failed to lay at a 20% rate in any of the 3 periods were eliminated to remove the effects of gross morbidity. Therefore, these egg production data (Figures 8, 9 and 10) attempt to estimate the "true" egg producing ability of the hens with as little influence as possible from other traits such as sexual maturity, livability and morbidity. The hen-housed egg production values, of course, contain all these other components.

For the second period (the second 16 weeks of production shown in Figure 9) there are two major drops in performance. In 1954, a Newcastle outbreak depressed production in all three strains, but this drop probably does not disturb any long-term interpretation of the results. When all strains were housed in cages in 1965, Control 05 dropped in performance drastically (Figure 9). Rate of production partially recovered for Control 05 with the rearing light program changes made in 1969. There was little drop in the selected strains associated with cage housing, or with these same light changes for period 2.

Rate of lay for the last third of the laying year is shown in Figure 10. Here the drastic effect of cage housing on Control strain 05 is clearly shown. This environment (cages) has also depressed performance in the selected strains and the Kentville control (07), but not to the same degree. Again the light changes from 1967 to 1972 (or an adaptation phenomenon) has resulted in better performance of the Control strain 05 since 1967. The higher rate of production for control 05 in 1969 and 1970 (Figure 10) can probably be attributed to the "culling effect"
the data and in interpreting the results, arises when the detailed information for the correlated traits is examined, in particular the egg production data, both expressed as hen-housed production for the complete test year, and as rate of production for the complete and partial test years. The Marek's Disease outbreak in 1969 and 1970 also confounded the results.

(c) Laying house mortality to 497 d.

Figure 7 show the absolute level of mortality for the four strains for the complete test year. The Marek's Disease outbreak revealed the relative high degree of susceptibility of the two strains derived from a common base (03 and 05), and the relative resistance of strain 04 (Gründel et al, 1972 and 1974). The overall results suggest that there was a slight overall increase in the livability of the two selected strains for the full test year associated with selection for hen-housed egg production.

(d) Hen-day rate of egg production from day of first egg of survivors only

The part-year period, rate of egg production (period 1) for the control strain 05 was fairly consistent (around 78 to 79%) until 1970 when it jumped to 83 to 84% for the last 3 years (Figure 8). This change coincided with the change in the lighting program described earlier, and as it has been reasonably consistent since that change, it can very likely be attributed to the lighting program during the rearing period. An alternate explanation is that the severe within-family natural selection caused by the Marek's Disease has resulted in a correlated increase in egg production (Gavora et al 1974). This explanation isn't likely as there wasn't a continued high rate of annual production after vaccination, and it is unlikely that such a high degree of selection could have been imposed. (Figure 12) Although the selected strains also responded positively to this lighting change, they did not respond relatively as much (a light environment-genotype interaction)
abrupt real genetic change in the control strain (or the selected strains) due
to pedigree errors or a violent genetic change (drift or chromosomal ab erration)
in one or all of the populations. Fortunately, there are other sources of infor-
mation that support the hypothesis of genotype–environment interaction.

From 1962 to 1966 both control strains 05 and 07 were compared in the
Central Canada Random Sample test. For these test years all birds were housed
in replicated floor pens. The same parent populations supplied hatching eggs
for the Random Sample Test as for the experimental populations being reported here.
As can be seen in Table 1, there was no difference in performance of either
control strain at the Central Test over the critical 1964–1965 period comparable
to the large drop in performance of the Control Strain 05 when it was housed in
cages as shown in the figures presented and as summarized in Table 1.

In the two test years 1964 and 1965 large populations (over 1000) pullets
of strain 05 were housed at Brandon to estimate genetic parameters – again in
floor pens. These results are also shown in Table 1, and show no change in
performance of strain 05. These pullets also originated from the same parents
that provided the stock for the selection experiment reported here. The Brandon
data are reported in detail in the report by Gowe, Lentz and Strain (1973). It
is difficult to conceive of a genetic change in 05 when the performance of these
other test populations from the same parent stock are also considered.

To estimate the magnitude of this interaction (and to obtain data for a
correction factor) a separate experiment was set up in 1972 to compare the
performance of floor-housed and cage-housed birds of the three strains. It later
proved to be unfortunate that it was not possible to hatch and rear the stock
at exactly the same time of year as the original populations had been hatched.
since 34% and 40% of strain 05 died each year, and a large number were morbid or produced poorly in the last period laying less than 20% so their records were not included in these data.

When all three periods are pooled (Period 5) the data are shown in Figure 11. After selection for over 20 generations in two strains for part-year hen-housed production, there would appear to be little absolute positive change in the rate of annual egg production after the first 5 or 6 generations of selection.

Although the Control 05 changes in performance could possibly be due to other reasons than those suggested here, there is little doubt the changes themselves are real, since more than 1000 birds of each of the selected strains, and 480 birds of each control strain have been housed since 1963. These birds were randomized to several pens in 3 laying houses up to 1964, and to individual cages in two laying houses (each with two wings since 1963) and each year these large sub-populations have reacted similarly.

Any estimate of genetic change for rate of egg production in the selected strains by utilizing Control strain 05 would grossly bias upwards the genetic gain for rate of egg production in the last two periods and bias it down for the first period. Pooling the three periods doesn't do more than combine two positive and one negative bias. The long-term control (05) has failed to react to these management changes (cages vs. floor pens, and changes in the lighting program) in the same relative manner as the selected strains have done.

(e) Control strain 05 and its interaction with the environment

To this point, I have argued without direct evidence that there was a real strain-environment interaction. It could logically be debated that there was an
The mortality data revealed little of interest to this comparison other than the minor reversal of level of mortality in pens and cages from the 1964-65 comparison. Note, however, that the mortality of the cage group in the 1972 pen-cage experiment was comparable to the large test populations of the same generation.

When the sexual maturity data are examined in Table 2, it can be seen that the Control 05 has not changed significantly since 1964, as would be expected if there had been no genetic change (i.e. pedigree error, etc.), and little effect can be seen of the housing environment on this trait. The selected strains (03 and 04) have continued to decline in sexual maturity under continuous selection for hen-housed egg production.

Rate of egg production is shown in Table 3 for 4 periods. As noted in Figure 8, the regular test population of Control 05 jumped in rate of production early in the production cycle, it also did this in this separate experiment. Both the pen- and cage-housed groups followed this pattern, likely because of the common lighting program detailed earlier, which unfortunately did not duplicate the 1964-1965 lighting program for the rearing period. This early increase in rate of production has not increased the full production period performance (Period 5) of Control 05, in fact annual rate was slightly depressed, particularly for the cage-housed birds at the end of the laying test (Period 3). The rate of egg production in the two selected strains was also increased in period one, but changes for the complete test have been rather small, suggesting that the annual rate of egg production has not been greatly improved by intensive selection for hen-housed production for part-year performance.
Birds in this experiment also had to be housed, because of weather conditions in late November, at 103 days of age in their respective facilities instead of at 140 d of age. Lighting conditions were also not identical to those practiced in 1964 and 1965. Nevertheless the birds were range-reared (under natural declining light after hatching August 11th) and then housed with the light continuing to decline, (coinciding with the outside daylight). At 141 days the light period was abruptly increased to 13 hours for the pen-housed groups and to 14 hours for the cage group as was the practice in 1964 and 1965. However, it should be noted that because of the late hatch (August) the day-length was down to 8.7 hours when the birds were at 141 days of age, whereas in 1964 day-length was only down to 14.7 hours at housing in Aubust. Outside of the early housing, the light program differences and an up-dated drug and vaccination program the 1964-1965 environment was duplicated for both groups in terms of floor-spa management and feed.

The results are shown in Table 2 to 4. Data for the regular test populations of 1972 are also included in these tables to permit easy comparisons.

Data for the traits age at first egg and mortality are shown in Table 3. To simplify the presentation here, both the selected strain 03 and 04 and two sub-strains 01 and 02 (derived from 03 and 04 respectively) were included to increase the sample size since they were genetically almost identical. These sub-samples were derived by dividing the parent strains in 1970 for 02 and 1972 for 01 then selecting for hen-day rate of egg production instead of hen-housed egg production. All other selection criteria were kept similar. Although space does not permit presenting all the support data, the data obtained showed these sub-line performed almost identically to their parent strains justifying this procedure.
Hen-housed egg production data for this experiment are shown in Table 4. The overall drop in performance of Control 05 in cages in the 1972 test is almost the same as that shown in Figure 12 for the large test populations in the selection study. This is, however, partly coincidence rather than a full confirmation of the hypothesis that the performance of the Control 05 after 1964 decreased in performance because it apparently does not perform as well in cages as it does in floor pens. Cage livability was slightly poorer in the special test 1972 (Table 2). The lighting program had a positive effect on the control performance. These effects to some degree balanced to give the 19 egg drop in performance for the Control 05 in the special test.

Table 4 shows also that the selected strains have improved their overall performance in cages, perhaps since selection has been directed to performance in cages since 1965. This is particularly true for strain 3. As expected, there was little difference in the performance of the selected strains in cages or in floor pens in the 1972 test. This suggest that strains selected for cage performance do equally as well when put in a floor-pen environment, but the reverse may not necessarily be true.

It is quite evident that strain 05 has dropped in performance in cages, and that reasonable estimates of the genetic gain in the selected strains can only be made if this change in performance is taken into consideration, otherwise genetic gain for the selected strains will be overestimated.

(f) *Estimate of genetic change for hen-housed and hen-day egg production correcting for the interaction of Control 05 with the cage-floor environment.*

An attempt was made to correct for the Control strain genotype-environment
interaction with respect to hen-housed egg production records after 1964, by calculating the difference between the mean of the last six years of floor-pen housing, and the mean since this stock was housed in cages (1965) for period 5 deleting the two years of the Marek's Disease outbreak. This difference was 19 eggs. The curves were then adjusted (Figure 13) to show the estimated genetic change in the selected strains for this correlated trait.

It is evident (Figure 13) that selection for part-year performance (hen-housed egg production) has been successful in increasing 497 day performance up until about 1964 to 1966. Since that time there is little evidence of change in the 497 day performance of the 2 selected strains, despite the continuous improvement of the part-year record (Figure 2) for hen-housed egg production. The adjusted data show a considerable increase in annual egg production (hen-housed) of about 44 eggs from Strain 4 and 33 eggs for Strain 3. Most of this can be attributed to the increase in egg numbers in the part-year period, plus some increase in livability for the full production year. Very little of the annual record can be attributed to an increase in rate of production.

Selection for part-year hen-housed egg production to a fixed age does not seem to have had much effect on the annual rate of production (Figure 14) after 1966, unless the correction, that was estimated in the same way as that for the hen-housed production described above, for the control strain decrease in performance is over-correcting. Compare the uncorrected data for all strains shown in Figure 11 with the estimate of genetic trends in the selected strains shown in Figure 14.
(g) **Comparison of crosses of long-term selected strains with commercial egg production stocks**

The best estimate of the "success" of this selection program in improving stocks for commercial egg production is a direct comparison with the products of major breeding concerns. Since all commercial stocks make use of heterosis by some type of strain or inbred cross program, the only valid comparison would be a comparison of crosses of these selected strains with different commercial stocks. The first such test was conducted starting in 1972. Both the long-term selected population (03 and 04) and their sub population (01 and 02 respectively) were used to produce 4 crosses of the two genetically distinct populations. Hatching eggs of their principal strain being offered to the industry were obtained from 4 major North American breeders (in each case from a local franchise distributor). All stocks were hatched and reared, intermingled and tested through a 497 laying test period by housing in individual cages following the 1972 procedures used for the experimental populations. Data for the most important economic traits are shown in Table 5. Control strain 07 was also included in this test so that the results can be readily related to the tables and figures in this paper. It would appear that these experimental long-term selected populations are performing at a level comparable to base populations of commercial breeders since the crosses are performing similarly to those being sold to the industry by major breeders with respect to all the key traits. It is suggested that these experimental selection results may, therefore, have considerable practical significance to those breeding concerns producing commercial egg stocks.

(h) **Other factors**

Space does not permit detailing all the other results that are of necessity
considered and of interest to those selecting stocks for commercial use. However, it should be noted that the minor relation emphasis that has been continuously applied to hatchability and fertility has been sufficient to prevent any major deterioration of these traits in the selected strains.

Inbreeding in the two selected strains 03 and 04 has now increased to where the inbreeding coefficient for strain 03 is 15.4% at generation 22, and for 04 it is 18.1% at generation 21. At generation 22 the inbreeding for control strain 05 is 5.2%.

There is little doubt that the rise in inbreeding of the selected strains has decreased in fitness traits such as reproductive (or egg production) performance to some degree, but specific studies on the magnitude of this effect have not yet been undertaken. Rate of egg production from age at first egg is likely more influenced by inbreeding depression than age at first egg.

(1) Genetic parameters

The genetic parameters of the control strains 05 and 07 have been presented in the paper by Gowe, Lentz and Strain (1972) and will not be discussed further. Calculations have been completed of the genetic parameters for the selected populations generation by generation utilizing techniques designed to obtain the least biased estimate and making use of all test birds at all locations (for the earlier years). A preliminary report on these analyses was presented by Lentz and Gowe (1974), but the data are too extensive to include in this report.

SUMMARY AND CONCLUSIONS

1. Selection in two egg strains for multi-trait performance with emphasis on
   hen-housed egg production to 273 days of age has increased this latter
trait by 27 eggs in strain 03 in 22 generations (1.1 eggs per generation), and 34 eggs in strain 04 in 21 generations (1.5 eggs per generation). Figures 1 and 2)

2. This increase in hen-housed egg production was associated with a decrease in days to first egg of about 24 days for both selected strains. (Figure 3)

3. There was a slight decrease in mortality to 273 days and also to 497 days associated with part-year selection for hen-housed egg production, despite the increase in inbreeding. (Figures 4 and 7)

4. Early egg size was concurrently increased about 4 grams in both strains (Figure 6).

5. Body weight at maturity was not under direct selection, but declined significantly in one strain (03) and stayed constant in the other strain (04) (Figure 5).

6. The original low production control strain (05) decreased dramatically in egg production during the latter two-thirds of the laying year after the experimental populations were housed in cages starting in 1965 (Figures 9, 10, 11 and 12). Although the selected strains also decreased in rate of egg production during the last one-third of the production year it was not as large as the decrease in control 05 (Figure 10).

7. Evidence was presented to show that this control strain (05) change in performance after caging was not due to pedigree errors or genetic changes, but was due to a genotype-environment interaction.

8. Data were presented to show the control strain 05 also reacted differently to the changing light program than the two selected strains which further
complicated interpretation of genetic changes in selected strains.

9. When corrections were made to adjust for the genotype-environment interaction, for the most important correlated trait - annual hen-housed egg production, it was shown that annual egg production in the two selected strains was increased by about 48 eggs for strain 04 (over 2 eggs a year) and 33 eggs for strain 03 (about 1.5 eggs a year). Most of this increase in annual hen-housed egg production can be attributed to increases in the past-year record, and this in turn to a decrease in days for first egg, a slight increase in livability over the whole test period, and an increase in past-record rate of production (Figures 13, 3 and 8).

10. The rate of annual egg production increased only slightly up to 1966 in the two selected strains, and there is little evidence of an increase since then (Figure 13, Table 3).

11. There has been a shift in rate of production in all 3 strains due to a lighting program started in 1970 to where they all lay at a higher rate earlier in the test year (Figure 8, Table 3).

12. Crosses of the experimental selected strains (03 and 04) developed in this study compare favourable in performance with commercial stocks developed by leading breeding organization in North America (Table 5).

REFERENCES


Table 1

Comparison of control strain 05 and 07 on test at the Central Random Sample Test (CRST) and at Brandon over the period the selection study populations were changed from floor pens to cages

<table>
<thead>
<tr>
<th>Year</th>
<th>Ottawa Test Pop. (Floor &amp; Cage)</th>
<th>Control Strains in CRST (Floor)</th>
<th>Brandon Test Pop. (Floor)</th>
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<tr>
<td></td>
<td>Strain 05</td>
<td>Strain 05</td>
<td>Strain 07</td>
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<td></td>
<td>Hen-day % from AFE 148-497 D.</td>
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<td>65.8</td>
<td>68.3</td>
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<td>1962</td>
<td>11.2</td>
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</table>

Laying house Mort.% 148-497 D.

*Floor pens in 1962, 63, 64, and cages in 1965, 66.*
<table>
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**Mortality % 14d-497d.**

05: 21.5%
03: 13.1%
04: 8.7%

**Days to 1st Egg.**

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<tr>
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<td>Pd. 5</td>
<td>157, 156, 152, 151</td>
</tr>
<tr>
<td>04</td>
<td>Pd. 5</td>
<td>156, 153, 151, 152</td>
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</tbody>
</table>

1. 1972 test populations of 480 pullets for 05 and about 2000 pullets each for 03 and 04 - all cage housed.
2. Strains 01 and 03 combined for 1972 data
3. Strains 02 and 04 combined for 1972 data
4. Survivors only
Table 3

<table>
<thead>
<tr>
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<td>77</td>
<td>72</td>
<td>5</td>
<td>79</td>
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Hen day % production from A.F.E.

1. 1972 test populations of 480 pullets for 05 and about 2000 pullets each for 03 and 04 all cage housed.
2. Strains 01 and 03 combined for 1972 data
3. Strains 02 and 04 combined for 1972 data
Table 4  
Comparisons of selected and control strains  
housed in cages and floor pens

<table>
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<tr>
<td>5</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>73(^1)</td>
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1. 1972 test populations of 480 pullets for 05 and about 2000 pullets each for 03 and 04 - all cage housed

2. Strains 01 and 03 combined for 1972 data

3. Strains 02 and 04 combined for 1972 data
Table 5

Comparisons of 4 strain crosses of Ottawa selected lines, 4 commercials and a control for several traits - (1972-73)

<table>
<thead>
<tr>
<th>Male Strain</th>
<th>Female Strain</th>
<th>Laying Mort.</th>
<th>Age at First Egg</th>
<th>Hen-Housed Egg Prod. ***</th>
<th>Hen-day Egg Prod. ***</th>
<th>Egg Weight</th>
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<tr>
<td></td>
<td></td>
<td>%</td>
<td>d.</td>
<td>no.</td>
<td>%</td>
<td>g.</td>
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<tr>
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<td></td>
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<td>04 x 01</td>
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<td>263</td>
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<td>02 x 03</td>
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<td>63</td>
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<td>196</td>
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<td>61</td>
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<td>177</td>
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</table>

* - Commercial egg stocks

** - Control strain 07

*** - Production to 497 d. of age
CAPTIONS FOR FIGURES

Fig. 1. Hen-housed egg production (no.) from housing to 273 d for two selected and two control strains over years.

Fig. 2. Hen-housed egg production (no.) from housing to 273 d with two selected strains and control 07 plotted as a deviation from control 05 over years.

Fig. 3. Age at first egg (d) with two selected strains and control 07 plotted as a deviation from control 05 over years.

Fig. 4. Laying house mortality (%) with the two selected strains and control 07 plotted as a deviation from control 05 over years.

Fig. 5. Mature body weight (g) with two selected strains and control 07 plotted as a deviation from control 05 over years.

Fig. 6. Egg weight (g) as measured at 350 d, 1950 to 1964 and as measured at 225 d 1960 to 1972, with two selected strains and control 07 plotted as a deviation from control 05 over years.

Fig. 7. Laying house mortality for the complete test year for two selected strains and two control strains.

Fig. 8. Hen-day % egg production from age at first egg to 273 days of age, for survivors to 497 days only, for two selected strains and two control strains.

Fig. 9. Hen-day % egg production from 274 d to 385 d of age for survivors to 497 days only, for two selected strains and two control strains.

Fig. 10. Hen-day % egg production from 386 d to 497 d of age for survivors only, for two selected and two control strains.
Fig. 11. Hen-day % day production from age at first egg to 497 days of age for survivors only, for two selected and two control strains.

Fig. 12. Hen-housed egg production (no.) from housing to 497 days of age for two selected strains and two control strains.

Fig. 13. Hen-housed egg production from housing to 497 days of age with two selected strains and control 07 plotted as a deviation from control 05, data were adjusted after 1964 for control 05 interaction with the cage environment.

Fig. 14. Hen-day % egg production from age at first egg to 497 days of age of survivors only, with the two selected strains and control 07 plotted as a deviation from control 05, data were adjusted after 1964 for control 05 interaction with the cage environment.
HEN-HOUSED EGG PRODUCTION (PERIOD 1)
HEN-HOUSLED EGG PRODUCTION AS DEVIATION FROM 05 (PERIOD 1)

-10 -5 0 5 10 15 20 25 30 35 40 45

SELECTED
03
04
CONTROL
05
07

Fig. 2
AGE AT FIRST EGG (days) DEVIATION FROM 05
Laying House Mortality % as Deviation from 05 (Period 1)

Year of Hatch:
- 1950
- 1952
- 1954
- 1956
- 1958
- 1960
- 1962
- 1964
- 1966
- 1968
- 1970
- 1972

Selected

Control

- 05
- 07
- 03
- 04
365-d. BODY WT. (dg) AS DEVIATION FROM 05
EGG WEIGHT (g) AS DEVIATION FROM 05 (PERIODS 1 and 2)
LAYING HOUSE MORTALITY (%) PERIOD 5
HEI/DAY PERCENTAGE PRODUCTION (PERIOD 2)
HEN-DAY PERCENTAGE PRODUCTION (PERIOD 3)
HEN-DAY PERCENTAGE PRODUCTION (PERIOD 5)

SELECTED

04

03

CONTROL

05

07

Fig. 11
HEN-HOUS ED EGG PRODUCTION (PERIOD 5)
HEN HOUSED EGG PRODUCTION PERIOD 5 AS DEVIATION FROM 05
ADJUSTED AFTER 1964
HEN DAY PERCENT PERIOD 5 DEVIATION FROM 05
ADJUSTED AFTER 1964
DR. ROBERT S. GOWE - "SELECTION FOR INCREASED EGG PRODUCTION IN THE FOWL"

N. GOHER: How would you assess the effort of inbreeding on performance and what do you have in mind in the future with the increased inbreeding in the selected strains?

GOWE: No doubt inbreeding has depressed performance to some degree. No specific analyses have been undertaken to estimate the magnitude of this effort, but part of the increase in performance of the strain-crosses (Table 5) over the pure strains (Tables 3 and 4 and graphs) is no doubt due to eliminating the in-breeding depression. The second part of this question cannot be answered simply, but one approach being made by a colleague at this Institute - Dr. Gavora - is to derive inbred lines from the selected strains, test them for performance, select between lines, for the most part, and then re-combine the inbred lines to hopefully produce strains that perform better than the parent strain both as a pure strain and in crosses.

R. NASSAR: Could the increase in heritability in cages from that in pens be due to genotype-environment covariance or correlation rather than to a change of additive genetic variance?

GOWE: Statistical tests on the significance of the increase in heritability I've shown to-day are currently being undertaken. The approach is to try and establish whether the components of variance and covariance changed significantly over time and with this change in environment, and if so, what components changed the most. However, the within year (i.e. within environment) components do not contain the interaction in question, although, of course, they contain the random micro-environment-genotype interaction associated with the different response of sire families to minor environmental differences associated
with their test progeny.

JIM CRAIG: Would you predict that your selected strains would do relatively well, or poorly, if placed in multiple-bird cages (relative to the unselected controls) and why?

GOWE: Your research Jim would suggest (if I interpret it correctly) that in the cage environment I am not selecting for aggressiveness. If production is negatively correlated in a genetic way with aggressiveness, the strains selected in a single-bird cage environment should, I think, do better than the control strain, eventually, in a multiple-bird cage environment, since there should be less aggressiveness in the selected strains. This question should and could be answered by an appropriate experiment. Perhaps I can convince our nutritionists to test this point in future, while they are investigating some aspect of the nutrition of the laying hen. The trouble with this type of experiment is that very large numbers of birds are required for meaningful results.

G. HAVENSTEIN: Is the apparent change in heritability during the years following caging simply an effect of a decrease in the amount of environmental variance (competitive effects)? Did the sire components tend to remain constant?

GOWE: As I indicated in my reply to Dr. Nassar, the appropriate analyses have not been completed in testing the significance of the change in the separate components of variance, but this is the approach being taken. The answer must await these analyses, but it would appear from the data I've seen, if my memory serves me correctly that the sire variance component increased with caging of the strains.

GERRY FRAIRS: Was the change in light management confounded with the Marek's vaccination program change?
GOWE: The Marek's vaccine program started in 1971 following heavy losses to Marek's in 1969 and 1970. The light effect (i.e. 6 hour day during the rearing period) started in 1970. The light effect (Figure 8) coincides with this change and not the vaccine change, which occurred a year later.

JACK RUTLEDGE: After movement to cages, was there more genetic variation or a decline in the phenotypic variance?

GOWE: As I indicated earlier, I think the sire component of variance went up but I am going on memory, and until the data are statistically analyzed, it perhaps is better not to draw firm conclusions as to whether it was a change in the environmental or the genetical part of the phenotypic variance.