EFFECTS OF SELECTION FOR EARLY EGG PRODUCTION ON SEXUAL MATURITY, BODY WEIGHT AND SOCIAL DOMINANCE DURING ADOLESCENCE IN CHICKENS

by

MING LUNG JAN

B.S. in Agr., National Taiwan University, Taiwan, Rep. of China.

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James V. Craig
Major Professor

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INTRODUCTION

The existence of social organization within flocks of chickens has been known since 1922 (Schjelderup-Ebbe 1922, 1935). Agonistic behavior and recognition are the bases of social organization. Chickens develop aggressiveness before sexual maturity and display this trait by fighting, pecking and threatening. Recognition is based essentially on features of the head and neck in chickens (Guhl and Ortman, 1953). Separation for two or three weeks results in failure to recognize former penmates (Schjelderup-Ebbe, 1935).

Sparring or play fighting is observed by the second week, but true fighting is not seen until the sixth week of age (Guhl, 1958). Average age at peck-right formation was reported as about 8 weeks for males and 10 weeks for females (Miller, 1951). Dawson and Siegel (1967) found agressive encounters to peak in frequency at about 8 weeks of age. Social inertia can obscure changes in social dominance potential at later ages (Tindell and Craig, 1959).

Techniques for the measurement of aggressiveness and social status have been developed by Collias (1943), Guhl (1953, 1960), McBride (1958a, 1968), Siegel (1960), and Biswas and Craig (1971).

Agonistic behavior is influenced by heredity as shown by clear differentiation between strains in selection studies (Guhl *et al.*, 1960; Siegel, 1960; and Craig *et al.*, 1965). The advantages of hens high in the dominance or peck-order and phenotypic associations between social status and egg production have been discussed by

Sanctuary (1932), Guhl (1953), McBride (1958a,b) Tindell and Craig (1959 and 1960) and Biswas and Craig (1971).

Recent studies indicate that bidirectional selection for high and low social dominance within each of two heterogeneous base populations produced correlated responses in certain productivity traits (Craig, 1968, 1970; Craig and Toth, 1969; and Biswas and Craig, 1970). Differences in earliness of sexual maturity and body weight were particularly evident in strains selected for high and low social dominance.

A correlated response was also found when selection was for egg production in large floor flocks; pullets produced were socially dominant to pullets similarly selected except for being housed in single cages (Lowry and Abplanalp, 1970).

Because of phenotypic and genetic associations previously found between agonistic behavior, earliness of sexual maturity and body weight, further evidence was sought to determine the generality of those findings. Two strains which had been subjected to long-term selection resulting in early sexual maturity and their unselected control provided appropriate genetic materials for this study.

It was postulated that the earlier maturing strains would be more aggressive than their unselected control and that competitive effects in intermingled strain flocks might depress growth rate and delay sexual maturity of strains with lower social status.

REVIEW OF LITERATURE

Age at sexual maturity

Sampson and Warren (1939) reported collection of semen capable of fertilization from White Leghorn cockerels as early as 9.5 and 11 weeks of age. Parker et al. (1942) found first spermatozoa in testicular tissues of White Leghorn and New Hampshire cockerels at 12 weeks of age. Grosse and Craig (1960), working with 12 strains of 6 breeds, found mean age at first sperm collected by artificial stimulation to be 16.19 ± 1.85 weeks of age. They also found that socially-dominated males were later in sexual maturity than dominant males and age at first sperm production was significantly correlated with age at first egg for strains within breeds.

Pullet age at sexual maturity is influenced by genetic and environmental variables. The mean heritability estimated for age at sexual maturity from several studies is 0.39 (Kinney, 1969). Byerly et al. (1946) obtained data from 3,332 Single Comb White Leghorn pullets hatched during the 9 years, 1936 through 1945. They found pullets hatched the week of April 18 to average more than three weeks older at first egg than pullets hatched during the week of March 21. Relatively low phenotypic correlations reported for sexual maturity and body weights at 8, 9, 10 and 12 weeks of age, at housing and for mature birds were 0.07, -0.26, -0.18, -0.03, -0.17 and 0.12, respectively (Kinney, 1969).

Body weight

Body weight and body weight gain are estimated to be moderately to highly heritable traits, generally in the range from 0.35 to 0.53 (Kinney, 1969). They are also obviously influenced by nutritional and environmental treatments. Kinney's (1969) survey indicated that body weight was also influenced by either maternal or genetic dominance deviation effects, or both, up to mature weight.

Developmental aspects of social behavior

Dawson and Siegel (1962) found agonistic factors first appeared at about 2.5 weeks of age in cockerels and replaced sparring by the seventh week. Miller (1951) found that aggressive pecking appeared at four weeks of age in males and at six weeks in females. (Guhl (1958) mentioned a general sequence in which behavior patterns appear in chicks. The sequence and age at first occurrence of each behavior pattern was:

1. Escape or fear reactions: The escape reaction was common after the third day posthatching.

2. Frolicking: Frolicking began during the first week of age.

3. Sparring: By the second week frolicking lead to sparring.

4. Aggressive pecking: The earliest aggressive peck was noted late in the second week.

5. Avoidance: Avoidance of another chick in response to aggressive action was indicated during the fifth week.

6. Fighting: Fighting was observed as early as the sixth week, but usually ended without any decision.

Guhl (1958) also found that males began to establish dominance somewhat earlier than females; the mean ages at which males established peck-rights were 7.58 and 8.03 weeks, and for females they were 9.75 and 9.33 weeks, respectively.

Choudary and Craig (1972) assembled pullets at 6 weeks and reassembled half of the flocks again at 19 weeks of age. They found flocks assembled at 19 weeks of age had an average of about 40% more agonistic interactions when compared at that age with those assembled at 6 weeks, but the effect was temporary and disappeared by 30 weeks of age.

Inheritance of agonistic behavior

Potter (1949) found differences in aggressiveness among the White Leghorn, Brown Leghorn, Light Brahma, Brown Red Game and Rhode Island Red breeds. The White Leghorn was the most dominant breed. Williams *et al.* (1956) also found differences in aggressiveness among breeds of females. The order was Barred Plymouth Rocks, Silverbars, New Hampshires, and White Leghorns.

Komai, Craig and Wearden (1959) predicted, from heritability estimates, that selection should be effective in changing the aggressiveness level within a strain of chickens. Differences in social aggressiveness among strains were largely due to hereditary differences. The same result was reported by Tindell and Craig (1959). Tindell and Craig (1960) found significant differences between aggressiveness ranks of eight sire families of one strain.

Craig and Baruth (1965) found that lowered social dominance of males in pair contests was associated with increased homozygosity and that peck-order status of inbred females in six flocks assembled at different ages was inversely associated with their coefficient of inbreeding.

Guhl *et al.* (1960) found significant differences after several generations of selection for high and low levels of aggressiveness in White Leghorn chickens. Craig *et al.* (1965) used heterogeneous Cornell Control White Leghorns and NC-47 Rhode Island Reds for a selection study. They found the selected strains became differentiated for ability to win pair contests and for frequency of contests with aggressive behavior. They hypothesized that genotypes responsible for differences in agonistic behavior under conditions of selection might not be equally effective in a different environment.

Social behavior and sexual maturity

Hens high in the social order tend to mature earlier (Guhl, 1953; Tindell and Craig, 1959). Negative and significant phenotypic correlations were found between social rank and age at sexual maturity; r = -0.24, -0.38 and -0.29 for flock sizes of 8, 24 and 96, respectively (Tindell and Craig, 1960). Dominant strain females of White Leghorns and Rhode Island Reds tended to be earlier in sexual maturity when mixed with females of submissive strains or when kept in separate cages (Craig, 1968 and Biswas and Craig, 1970, respectively) but sexual maturity was later for White Leghorn dominant strain females when penned with their own kind (Biswas and Craig, 1970 and Craig, 1970).

Social behavior and body weight

Body weight has been found to be phenotypically correlated with social status. Tindell and Craig (1959) found hens high in the social order tended to be heavier at five months of age.

Guhl et al. (1960) found significant correlated responses in comparing White Leghorn lines selected for aggressiveness and social dominance, with the high line birds being heavier in body weight. Siegel and Siegel (1963) reported that selection for high and low body weight in a broiler stock resulted in a difference between the selected lines for percentage of initial paired encounters won. Positive genetic and environmental correlations of moderate magnitude were found between body weight and relative aggressiveness. Craig (1968) and Biswas and Craig (1970) found that a strain selected for higher level of social dominance was heavier in body weight than the submissive strain in the White Leghorn. The reverse situation was found in Rhode Island Reds (Craig, 1968). The significant but inconsistent correlated responses found in the various studies between body weight and social dominance ability indicate a complex and unresolved set of associations.

MATERIALS AND METHODS

Genetic stocks: Three strains of White Leghorns were used. The Ottawa Control strain (Oc) was established in 1950 by the Canada Department of Agriculture and has been maintained as a random breeding, unselected population. Precautions are taken each generation to minimize random genetic drift of gene frequencies and inbreeding.

The Ottawa Selected strain (Os) was derived from the same base population as O_c and has been selected primarily for large number of eggs produced per pullet to 40 weeks of age. This change has been produced largely by decreasing age at sexual maturity (Gowe et al., 1973).

The S_{275} strain was originated at the Lacombe, Alberta research station of the Canada Department of Agriculture in 1955 from a sample of the O_c strain and has also been selected for number of eggs to about 40 weeks of age with reduction in age at first egg as an important consequence (Frankham and Weiss, 1969).

All strains were imported as hatching eggs during August and September of 1970. Eggs were identified by strain only, but represented a wide sampling of families within each strain. The first generation of relaxed-selection chicks was hatched at Kansas State University during July, 1971. Each strain was reproduced by pedigree-hatched chicks from 11 (S_{275}) or 12 (O_c and O_s) single-sire matings involving 33 to 44 dams per strain.

Experimental chicks for the present study were progeny of the

July, 1971 hatched birds and therefore represent the second generation of relaxed selection for the O_s and S_{275} strains. Each strain was reproduced using 15 to 18 sires, each sire being mated with 3 females (average). Care was taken to maintain a wide genetic base within each strain. Thus, not more than 2 sires were from any one mating of the previous generation.

Pre-experimental procedures

Eggs of all strains were incubated concurrently and chicks were pedigree hatched October 31, 1972. They were wingbanded, sexed, dubbed, and vaccinated for Newcastle disease, bronchitis and Marek's diseases at hatching. Strains were separated, but male and female chicks were kept together in brooder pens at the Avery Research Center. They received 14 hours of light per day until the end of the study. Cockerels were moved to Call Hall and placed in experimental groups at 7 weeks of age. Pullets were reared in brooder pens and put on experiment at 18 weeks of age. Those ages were chosen on the basis of preliminary studies indicating that sexual maturity for a few extreme individuals would probably occur shortly thereafter.

Social environments

Males:

Full brothers were distributed by a restricted randomization scheme into intermingled or separated strain flocks at 7 weeks. There were 9 small intermingled flocks (4 O_s, 4 S_{275} and 4 O_c cockerels per group), 3 large intermingled (12 O_s, 12 S_{275} and 12 O_c per group) and 9 separated strain flocks (3 flocks of 12 each per strain). At 9 weeks of age the number of males per strain was reduced from 4 to 3 for small intermingled pens and from 12 to 9 for large intermingled pens and separated strain pens.

Pens for males consisted of wire-floored finishing-type batteries with feed and water supplied in troughs along the sides. Each pen was 38 cm. (15 in.) high. Small flocks were placed in pens of size 67 x 69 cm. (26.4 x 27.2 in.) and large flocks in pens of size 201 x 69 cm. (78.7 x 27.2 in.). Thus floor space per male was about 385 and 514 sq. cm. from 7 to 9 weeks and after 9 weeks of age, respectively.

Females:

Pullets utilized in this study were moved from brooder pens to individual cages at 15 weeks of age. Full sisters were distributed by a restricted randomization scheme into 6 intermingled flocks and 6 separated strain floor flocks in the same house at 18 weeks of age. Each of the three strains had 8 females in each of the 6 intermingled flocks. Each strain was also represented by 24 individuals in each of two separated strain floor pens. Intermingled flocks were placed in 2 blocks of 3 adjacent pens each. Floor pens were 152 x 229 cm. (60 x 90 in.), allowing 1,450 sq. cm. area per pullet.

Sexual maturity estimation

Males:

Male sexual maturity was defined by the following two criteria:

Criterion A: A male was considered to reach sexual maturity on the date when sperm were first observed microscopically in fluid collected by artificial stimulation. A second collection with sperm present was required within the next 3 trials to confirm the original date. This was done to prevent possible error due to contamination of the sample or mixing of collection funnels.

Criterion B: A male was considered mature by this criterion when the number of sperm and motility were scored as equal to or more than 3,3. The same or a higher score was required within the following 3 trials to confirm the original date for the same reasons as indicated for criterion A. The scoring system was as follows:

Scores	Number of sperm	Motility
0	None	None
1	One or few	Slow
2	Moderate	Moderate
3	Large	Rapid
4	Very large	Very rapid

Artificial stimulation was used in attempting to collect semen from all males twice weekly, on Tuesdays and Fridays, by the same person (M. L. Jan) from 7 to 18 weeks of age. Semen was examined under the microscope by another person (C. R. Polley) during this period. The first flock to be caught was randomly selected and the remaining flocks were caught in sequence. Males were stimulated for semen collection and birds were returned to their pens as rapidly as possible.

A few males did not reach criterion A and/or criterion B by 18 weeks of age. They were classified as being 18 and 19 weeks of age by criterion A and criterion B, respectively (for statistical purposes).

Females:

Sexual maturity was estimated for females using a trapnesting method. Females were trapnested three days a week, i.e. on Tuesday, Wednesday and Thursday. Sexual maturity was calculated in weeks from the date of hatch until the first egg was laid.

A few females which did not attain sexual maturity by the trap-nesting criterion were palpated early in the morning during 29 and 30 weeks of age to determine whether they were responsible for floor eggs. Floor egg layers were therefore identified, but no age at maturity was assumed for them. Females which did not reach sexual maturity by the end of the study were assigned an age of 30 weeks for their age at first egg (for statistical purposes).

Behavioral observations

Males:

Observations on social behavior were begun when males were 10 weeks of age and continued through 12 weeks of age. Each of the 9 small intermingled strain flocks were watched 15 minutes per day. The first flock to be observed was randomly selected and the remaining flocks were observed in sequence.

A preliminary study was carried out to find a method which would increase the frequency of social interactions to facilitate peck-order determinations. Previous observations in this laboratory indicated that a feeding stimulus would have such an effect. However, the results of Duncan and Wood-Gush (1971) suggested that frustration of the feeding response might be even more stimulating. Five treatments were therefore set up; not hungry and feed available, fed after food removal for 4 hours, fed after food removal overnight, frustrated from feeding after 4 hours food removal and frustrated from feeding after overnight food removal. Five flocks were randomly selected and assigned from the 9 small intermingled flocks for the treatments in each trial. Four trials were completed during four consecutive days. Each flock was observed for a single 15-minute period during each trial. The results were as follow:

Agonistic interactions per 15-minute observations

	Not hungry	Hungry, Fed after		Hungry, Frustrated[1/]	
Trial	Feed available	4 hrs.	Overnight[2/]	4 hrs.	Overnight[2/]
1	0	6	12	2	5
2	5	1	4	0	19
3	0	16	29	5	6
4	3	15	6	4	17
Total	8	38	51	11	47
Hungry, feed available *vs.* Hungry, frustrated		89		58	
Hungry: 4 hrs. *vs.* Overnight		49		98	

1/: Feeders were placed back on the pen, but were covered with clear plastic. Birds could see the feed, but could not eat.

2/: Feeders were taken out at 9 p.m. and the birds were observed the next day morning between 7 and 9 a.m.

Social interaction rates were increased by observing hungry birds during feeding or during frustration. Birds which were without feed overnight, then presented with feed, had slightly more social interactions for the 15-minute observation period as compared to birds kept without feed for an equal period, then frustrated. Overnight deprivation followed by a 20-minute observation during feeding was used for establishing peck orders in this study.

All hungry birds would approach the feeder and engage in feeding as soon as the feeder was put back. After four or five minutes, the more dominant birds would start pecking and threatening submissive birds. After ten minutes, most birds would stop feeding, though birds low in the peck order would try to eat more feed.

The pair-contest method (Collias, 1943) was used for a few pairs that did not have a dominance relationship observed in the pen. All pair relationships were worked out by the end of 12 weeks of age.

Females:

Observations on social behavior were begun when females were 19 weeks of age and ended at 24 weeks of age. Observations were made between 10 A.M. and 4 P.M., five days a week. Each of the six intermingled strain flocks were watched for one 20-minute period per day. The observer would first enter each pen, move the regular tube-type feeder aside and place wet mash in a 22 cm. diameter shallow bowl on top of an inverted 30 cm. high bucket in the center of the pen.

Observations were made through wire screen. Most birds would approach the bowl of wet mash and engage in feeding as soon as possible. After about five minutes, dominant birds would start pecking and threatening their subordinates. Birds low in the peck order would usually either go to a corner of the pen or to the roost, waiting to approach the feed bowl. Social interactions and feeding usually decreased after 15 minutes. The wet mash stimulus which obviously increased the frequency of social interactions was also used by Choudary and Craig (1972). Social interactions were worked out for about 72% of all possible pair relationships. Over 70% were established for each flock.

Body weight

Males were weighed at 7, 10, 13 and 16 weeks of age. Females were weighed at 18, 22, 26 and 30 weeks of age.

Analytical procedures

Traits measured once only on individual birds, such as 7-week body weight in males, 18-week body weight in females, number of birds dominated and age at sexual maturity were tested by simple analyses of variance. Female data for number dominated and sexual maturity were analyzed both with and without statistical adjustment for differences in initial body weight. Split-plot design for analyses of variance was used to test differences in body weight gain due to ages, strains and housing methods since the same individuals were represented at different ages.

Strain-flock-social environment means were used as units of measure in analyses of variance. Means for males were based on data from 9 cockerels each. Small intermingled strain flock data were excluded for males to simplify computations. Female data used in analyses of variance likewise consisted of strain-flock-social environment means. Separated strain flock means were based on records from 24 pullets each. Intermingled flock means for strains were obtained by pooling results from 8 females per strain from blocks of 3 adjacent intermingled flocks. Thus, each strain's performance for females was estimated by average results from 2 separated and 2 synthetic intermingled flocks of 24 each.

RESULTS

Associations between number dominated, age at sexual maturity and initial body weight

Phenotypic correlation coefficients based on pooled sums of squares and cross products from within strain and flock subclasses are shown in Table 1.

Initial body weight was significantly correlated with number dominated in both sexes, 0.30 for males and 0.28 for females. Initial body weight was also significantly correlated with age at sexual maturity in females (-0.19) but not in males (-0.04 for criterion A and -0.14 for criterion B). Significant correlations between number dominated and age at sexual maturity by criterion A and criterion B for males and age at first egg for females were -0.36, -0.30 and -0.33, respectively.

Initial body weight

Initial body weight did not differ for strains of males at 7 weeks of age, but highly significant differences were detected for females at 18 weeks of age, Table 2. In the case of females, Oc and Os did not differ, but both strains were heavier than S_{275}.

Age at sexual maturity

Effects of strain and intermingled vs. separated strain social environments on age at sexual maturity were tested by analyses of variance, Table 3. Genetic differences were clearly important as

Table 1. Correlation coefficients between number dominated, age at sexual maturity and initial body weight.

Variables	Correlation coefficients Males		Females
Initial body weight[1/] and number dominated		0.30^{*}	0.28^{**}
Initial body weight[1/] and age at sexual maturity	Criterion A:	-0.04	-0.19^{**}
	Criterion B:	-0.14	
Number dominated and age at sexual maturity	Criterion A:	-0.36^{*}	-0.33^{**}
	Criterion B:	-0.30^{*}	

* $P < 0.05$

** $P < 0.01$

1/ Initial body weight for males at 7 weeks of age and females at 18 weeks of age.

indicated by highly significant strain differences within both sexes. Intermingling of strains had no apparent influence on attainment of maturity as compared to maintenance of strains in flocks of their own kind. Likewise, there were no suggestions of strain by treatment interaction; the strains had essentially the same age at sexual maturity whether intermingled or not.

Mean ages at sexual maturity for Os, S_{275} and Oc strain males and females are presented in Table 4 and frequency distributions for the same traits are shown in Figures 1 and 2. Data were pooled over social environments because those environments were not found to be a significant source of variation.

Table 2. Mean differences in initial body weight of Oc, Os and S_{275} for both sexes.

Strain	Males[1/]	Females[2/]
Oc	617	1,536[a]
Os	589	1,516[a]
S_{275}	587	1,431[b]

1/ Initial body weight in grams at 7 weeks of age.

2/ Initial body weight in grams at 18 weeks of age.

Note: Means followed by different superscripts differ significantly ($P < 0.01$) as indicated by least significant difference tests.

Table 3. Analyses of variance for age at sexual maturity of Os, S_{275} and Oc strain males and females in intermingled and separated strain flocks.

Source of variation	Males			Females		
	D.F.	Criterion A	Criterion B	D.F.	Age at first egg	
		M.S.	M.S.		M.S.	M.S.[1/]
Strain (S)	2	10.53***	14.53***	2	18.63***	19.31***
Treatment (T)	1	0.04	0.29	1	0.05	0.21
S x T	2	0.08	0.16	2	0.02	0.02
Within S&T	12	0.44	0.88	6	0.26	0.28

*** $P < 0.005$

1/ Adjusted by covariance technique to equal initial body weight equivalent.

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EXPLANATION OF FIG. 1

Frequency distributions for the mean ages at sexual maturity for Os, S_{275} and Oc strain males as defined by the two criteria.

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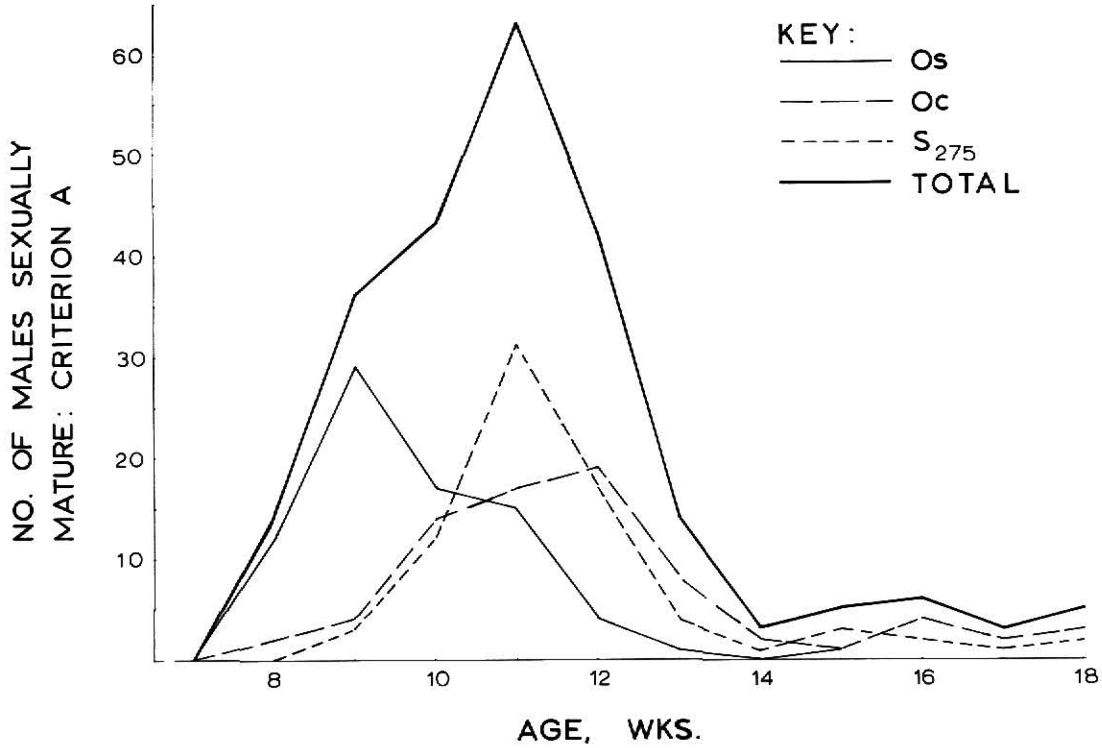
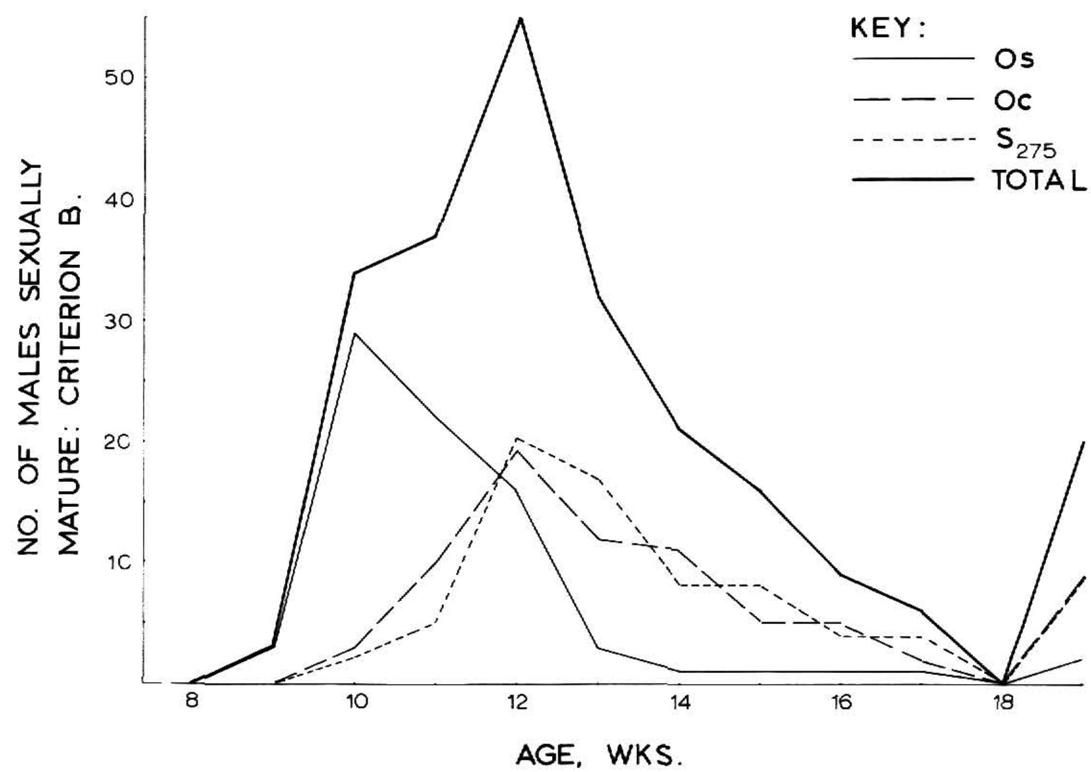

KEY:
Os
Oc
S_{275}
TOTAL
NO. OF MALES SEXUALLY MATURE: CRITERION A
60
50
40
30
20
10
8
10
12
14
16
18
AGE, WKS.


KEY:
Os
Oc
S_{275}
TOTAL
NO. OF MALES SEXUALLY MATURE: CRITERION B.
50
40
30
20
10
8
10
12
14
16
18
AGE, WKS.

EXPLANATION OF FIG. 2

Frequency distributions for the mean ages at sexual maturity for Os, Oc and S_{275} strain females as calculated in weeks from the date of hatch until the first egg was laid.

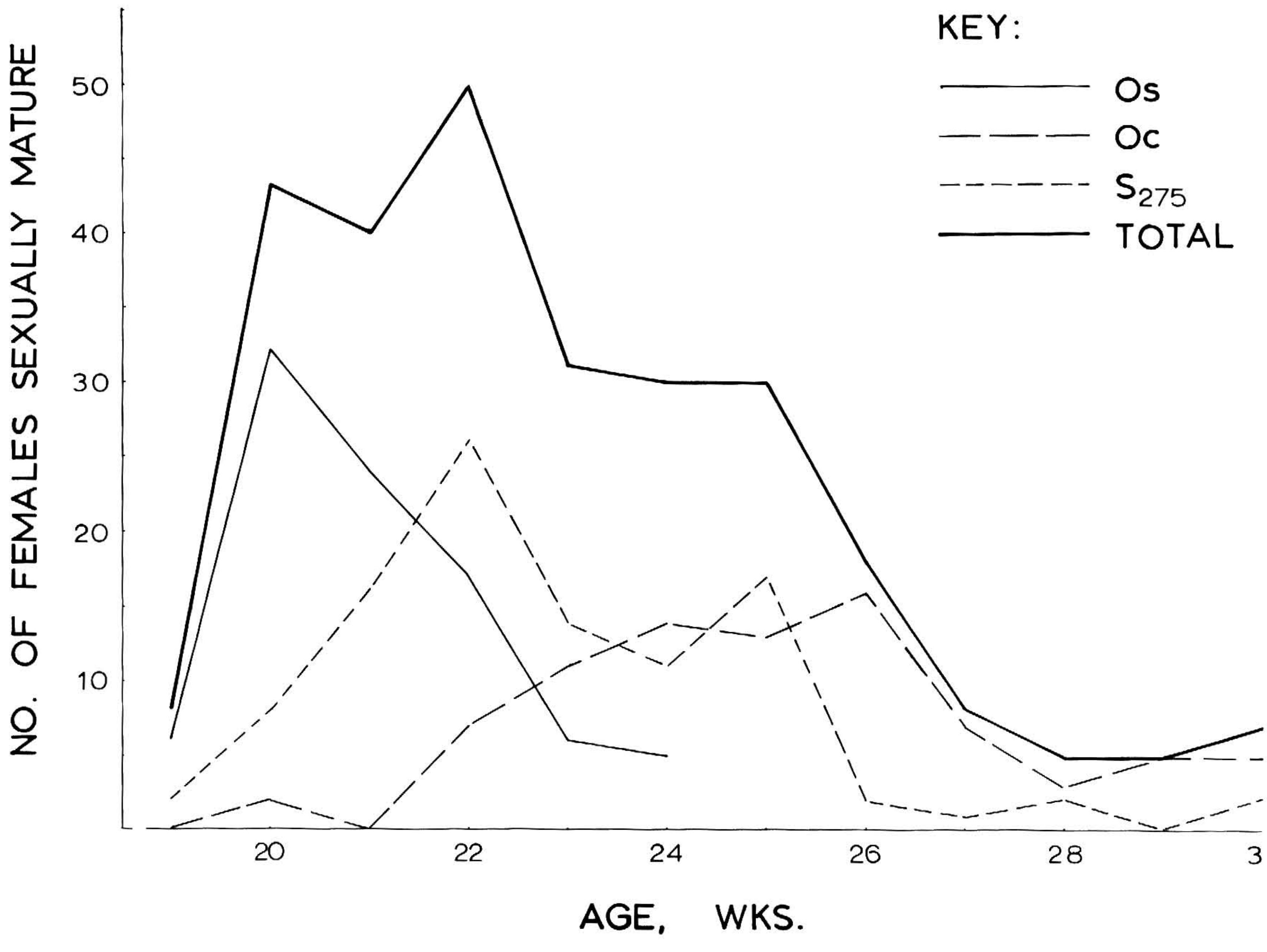

KEY:
Os
Oc
S275
TOTAL
NO. OF FEMALES SEXUALLY MATURE
50
40
30
20
10
20
22
24
26
28
3
AGE, WKS.

Table 4. Mean age in weeks at sexual maturity of Os, S_{275} and Oc strain males and females[1/]

Strain	Males		Females	
	Criterion A	Criterion B	Age at first egg	Adjusted[2/]
Os	9.9[a]	11.3[a]	21.1[a]	21.2[a]
S_{275}	12.0[b]	14.2[b]	22.7[b]	22.6[b]
Oc	12.3[b]	13.8[b]	25.4[c]	25.5[c]

1/ Data were pooled for separated and intermingled strain flocks. Means are based on 54 males and 96 females per strain.

2/ Adjusted by covariance technique to equal initial body weight equivalent.

Note: Means followed by different superscripts differ significantly ($P < 0.01$) as indicated by least significant difference tests.

Social status

Social status in intermingled flocks was estimated on the basis of number of individuals dominated. All pair relationship were determined in 9 small male flocks and approximately 72% of all relationships were known in 6 female flocks.

Mean numbers dominated by Os, S_{275} and Oc males and females are shown in Table 5. Strains of males were not significantly different. Because strains of males did not differ for initial body weight at 7 weeks of age, the number dominated was not adjusted for initial body weight in males. Although correlation coefficients between number dominated and age at sexual maturity were negative and significant

Table 5. Number of individuals dominated by Os, S_{275} and Oc males and females in single-sex flocks

Sex	Number of:		Strain		
	Flocks	Birds per flock	Os	S_{275}	Oc
Male	9	9	3.8	4.2	3.9
Female	6	24	11.8^a	5.9^b	5.9^b
Female Adjusted 1/	6	24	11.6^a	6.5^b	5.4^b

1/ Adjusted by covariance technique to equal initial body weight equivalent.

Note: Means followed by different superscripts, within rows, differ significantly ($P < 0.05$) as indicated by least significant difference tests.

in both sexes, it was not clear which was the independent trait. Therefore the data for social status were not adjusted for differences in age at maturity by covariance technique. In the case of females, mean numbers dominated for Os, S_{275} and Oc were 11.8, 5.9 and 5.9 respectively. Os was significantly more dominant than S_{275} and Oc. Similar results were obtained after adjusting by covariance technique to equal initial body weight equivalent.

Body weight gain

Differences between strains in body weight gain were very highly significant in both sexes, Table 6. The same result was found for periods. Social environment influenced body weight gain in females. Inconsistent gains by females of the 3 strains resulted in a significant interaction between strains and period. Those gains by strains and periods are shown in Fig. 3. In the case of males, an interaction was present between social environment and period. Inconsistency of gains in the two environments over the 3-week periods are shown in Fig. 4. Although hypothesized, no interaction was detected between strains and social environment for either males or females, Table 6.

Gains for Oc, Os and S_{275} males were 358, 321 and 310 gm., respectively, for the total period from 7 to 16 weeks of age, Table 7. Oc was significantly different from Os and S_{275}. In the case of females, total period gains for Oc, Os and S_{275} were 139, 88 and 103 gm., respectively. Weight gains for females of the 3 strains were all significantly different from each other, Table 7. Os females gained more than Oc and S_{275} in intermingled flocks as compared with gains in separated strain flocks (Table 8).

Table 6. Analyses of variance for gains in body weight during three periods of adolescence for Os, S_{275} and Oc males and females in intermingled and separated strain flocks

Source of variation	Males+		Females++	
	D.F.	M.S.	D.F.	M.S.
Strains (S)	2	11,414**	2	8,075***
Intermingled vs. Separate strain flocks (T)	1	352	1	2,515**
S x T	2	121	2	359
Error 1 1/	12	1,395	6	172
Periods (P)	2	193,979***	2	15,479***
S x P	4	798	4	2,221*
T x P	2	3,340*	2	673
S x T x P	4	574	4	1,025
Error 2 2/	24	728	12	468
Total	53		35	

1/ Between replications within S and T subclasses.

2/ Between replications within P within S and T subclasses.

\+ Periods for males were 7 to 10, 10 to 13 and 13 to 16 weeks of age.

++ Periods for females were 18 to 22, 22 to 26 and 26 to 30 weeks of age.

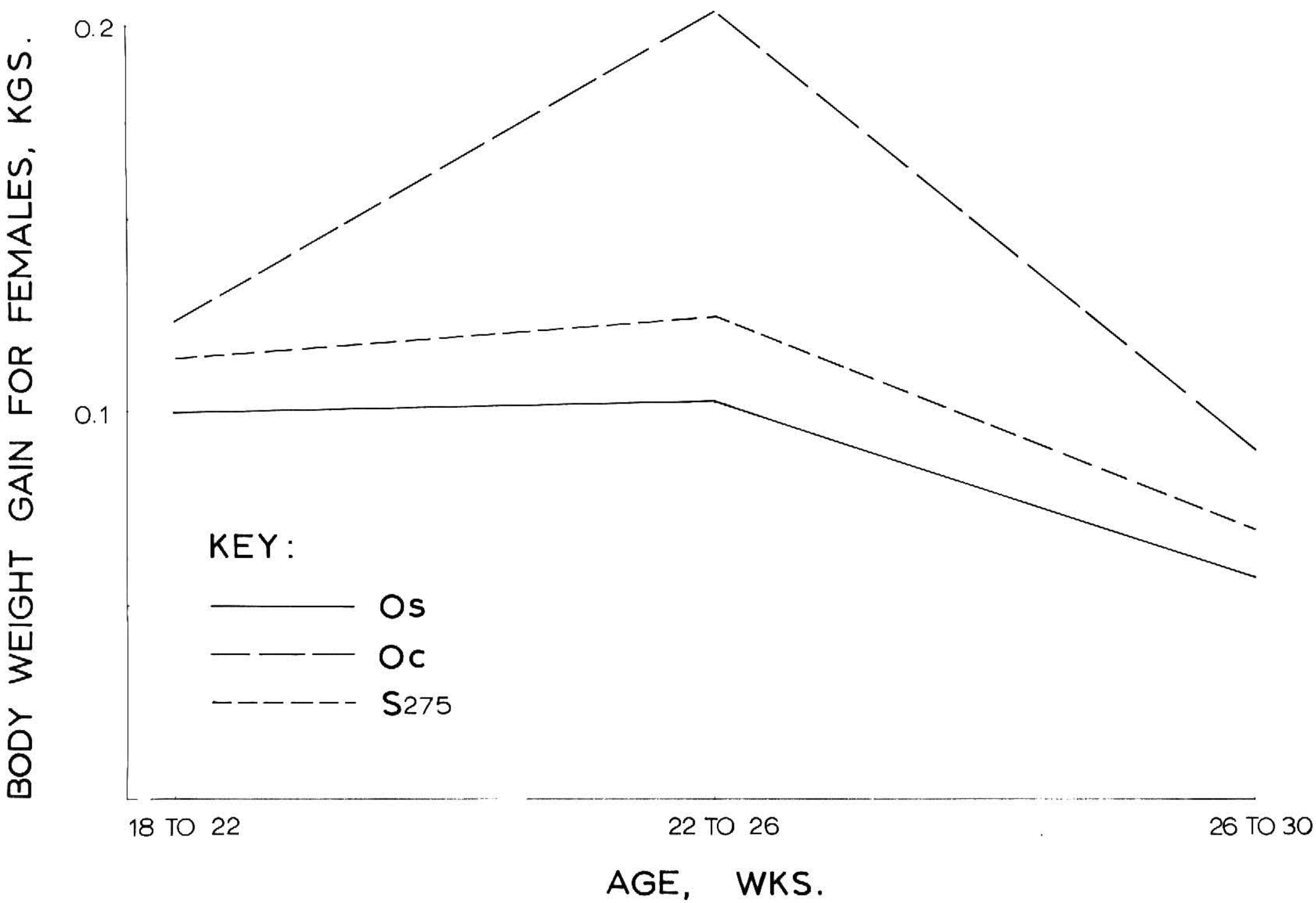
* $P < 0.05$

** $P < 0.01$

*** $P < 0.005$

EXPLANATION OF FIG. 3

Body weight gains of Oc, Os and S_{275} strain females by 4-week periods.


BODY WEIGHT GAIN FOR FEMALES, KGS.
0.2
0.1
KEY:
Os
Oc
S275
18 TO 22
22 TO 26
26 TO 30
AGE, WKS.

EXPLANATION OF FIG. 4

Body weight gains of males in separated and intermingled strain flocks by 3-week periods.

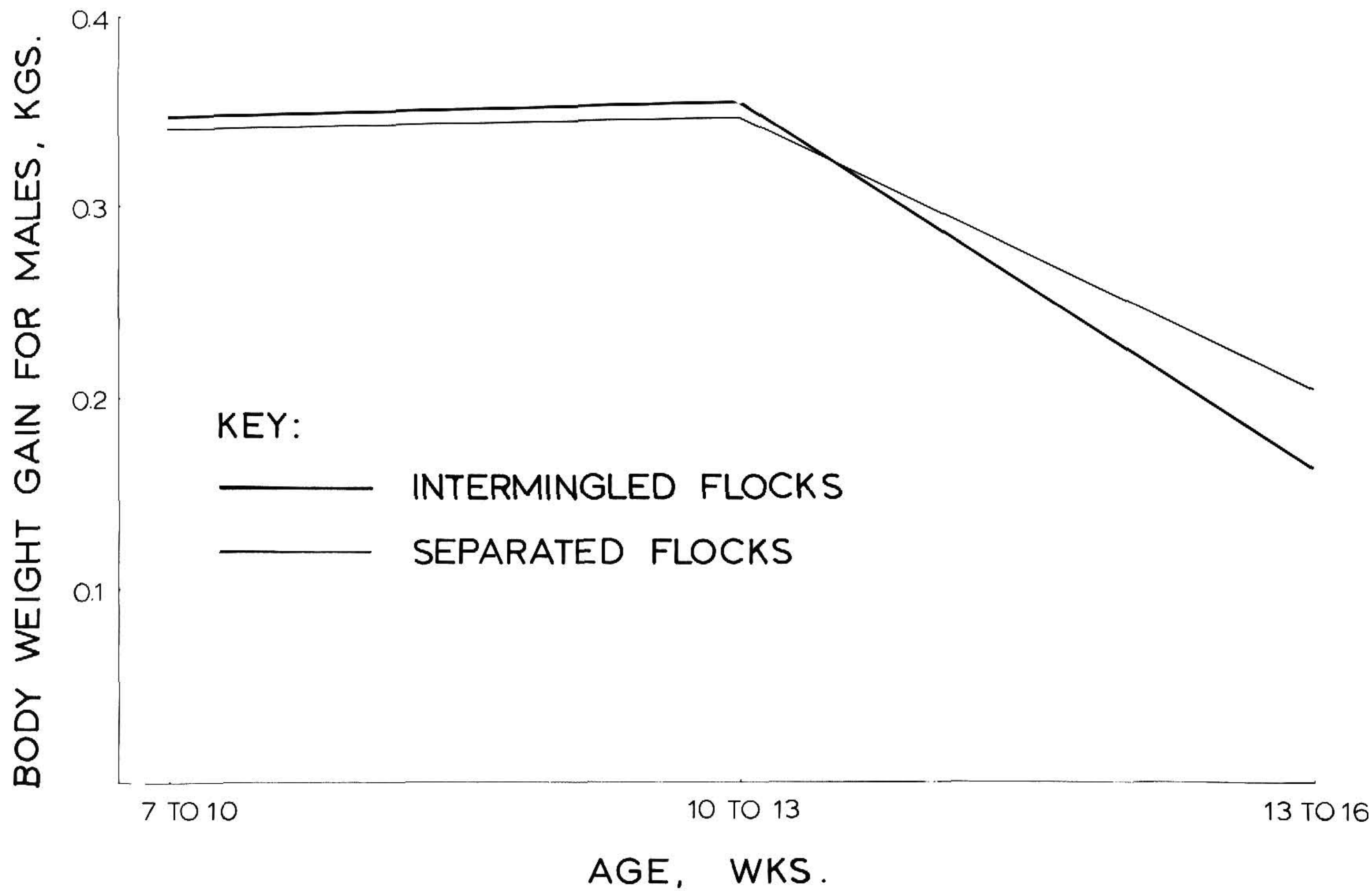

BODY WEIGHT GAIN FOR MALES, KGS.
0.4
0.3
0.2
0.1
KEY:
INTERMINGLED FLOCKS
SEPARATED FLOCKS
7 TO 10
10 TO 13
13 TO 16
AGE, WKS.

Table 7. Body weight gains of Oc, Os and S_{275} for both sexes.

Strain	Males[1/]	Females[2/]
	gm.	gm.
Oc	358^a	139^a
Os	321^b	88^b
S_{275}	310^b	103^c

1/ Body weight gains from 7 to 16 weeks of age

2/ Body weight gains from 18 to 30 weeks of age.

Note: Means followed by different superscripts, within sexes, differ significantly ($P < 0.05$) as indicated by least significant difference tests.

Table 8. Mean body weight gain in females from 18 to 30 weeks of age.

Strain	Intermingled flock	Separated strain flocks	Differences
	gm.	gm.	gm.
Os	102	74	28
Oc	147	131	16
S_{275}	106	93	13

DISCUSSION

Initial body weight was negatively and significantly correlated with age at sexual maturity in females and positively and significantly correlated with number dominated in both sexes. Number dominated was also negatively and significantly correlated with age at sexual maturity. Results for females agree with the reports of Tindell and Craig (1959), Guhl et al. (1960), Siegel and Siegel (1963) and Biswas and Craig (1970) who found that hens high in the social order tended to mature earlier and be heavier in body weight.

Craig (1968) reported that a strain selected for high social dominance was heavier than a strain selected for low social dominance in the White Leghorn breed but opposite correlated responses occurred in the Rhode Island Red breed. Biswas and Craig (1970) confirmed that the high social dominance strain of White Leghorn was heavier in body weight than the low social dominance strain.

In the present study, Os females were significantly more dominant than S_{275} and Oc; Os had heavier initial body weight than S_{275}, but did not differ from Oc at 18 weeks of age. The results of the several studies indicate a complex situation with inconsistent genetic correlations existing between social dominance and body weight in the several populations.

Os strain was sexually mature earlier than S_{275} and Oc in both sexes and was more dominant than the other two strains in female but not in male flocks. Unpublished data collected on other Os and S_{275}

males in this laboratory indicate Os to be significantly more aggressive than Oc and, S_{275} to be intermediate at 12 through 28 weeks of age. Craig and coworkers (Craig, 1968; Craig and Toth, 1969; Biswas and Craig, 1970) found that strains selected for high levels of social dominance had earlier sexual maturity. Results of the present study are therefore in accord with those of earlier studies, indicating that earliness of sexual maturity and aggressiveness are genetically correlated; earlier maturity goes with increased aggressiveness.

In the case of body weight, Oc males gained more than Os and S_{275} from 7 to 16 weeks of age. Oc females also grew more rapidly than Os and S_{275} from 18 to 30 weeks of age. There was an apparent lack of serious social competition between strains as relative gains were consistent in intermingled and separated strain flocks.

Females of all strains gained more in intermingled flocks. Though a statistical interaction was not found, Os gained more than Oc and S_{275} in intermingled flocks as compared with gains in separated strain flocks (Table 8). This trend is consistent with the report of Tindell and Craig (1959) who found that more aggressive strains do better in interstrain competition than in pure strain flocks. Competition may stimulate more aggressive strains to higher performance levels in intermingled flocks.

There was an interaction between strains and period for weight gain in females. This result could be explained, at least in part, by the strains reaching sexual maturity at different ages. Under general conditions, chickens gain less rapidly after sexual maturity. Examination of Figure 3 suggests that such an explanation may be appropriate. Os and S_{275} matured at about 22 weeks whereas Oc females matured just before 26 weeks of age (Table 4). Thus different growth curves would be expected during the same chronological time periods.

An interaction was also present between social environment and period for weight gain in males. No explanation is readily apparent.

In the present study, intermingling of strains had no apparent influence on attainment of sexual maturity as compared to maintenance of strains in flocks of their own kind. The same result was obtained for both sexes and after adjusting by covariance technique to equal initial body weight equivalent for the females. This result is not surprising for males because the mean numbers dominated for the 3 strains did not differ significantly. However, strain differences for females were present for social status.

The present results are not as hypothesized for females as interactions of strain by social environment (strains separated vs. strains intermingled) were not present for either sexual maturity or gains in body weight although Os strain pullets were socially dominant in intermingled flocks. A possible explanation of these results may involve a change in relative social dominance among strains occurring soon after peck orders were worked out. This possibility is suggested by pair contest comparisons at later ages (Craig, unpublished).

SUMMARY AND CONCLUSIONS

Two strains of White Leghorn, Os and S_{275}, which had been subjected to long-term selection resulting in early sexual maturity and their unselected control, Oc, were used in this study to estimate genetic and environmental effects on social behavior, growth rate and sexual maturity during the adolescent stage. Males were assembled into 9 small intermingled flocks (4 Os, 4 S_{275} and 4 Oc per flock), 3 large intermingled flocks (12 Os, 12 S_{275} and 12 Oc per flock) and 9 separated strain flocks (3 flocks of 12 each per strain) at 7 weeks of age and the number of males was reduced from 4 to 3 for small intermingled flocks and from 12 to 9 for large intermingled flocks and separated strain flocks at 9 weeks of age. Female groups of 24 individuals each were placed in floor pens with 2 separated flocks per strain and 6 intermingled flocks (8 Os, 8 S_{275} and 8 Oc pullets per flock) at 18 weeks of age. Intermingled flocks were placed in 2 blocks of 3 adjacent pens each.

Data were collected on peck order status in 9 small intermingled flocks for males and in 6 intermingled flocks for females. Data on gains in body weight and age at sexual maturity were obtained in all flocks for both sexes. Traits measured once only on individual birds, such as 7-week body weight in males, 18-week body weight in females, number of birds dominated and age at sexual maturity were tested by simple analysis of variance. Female data for number dominated and sexual maturity were analyzed both with and without statistical adjustment for differences in initial body weight. Split-plot design for analysis of variance was used to test for differences in body weight gain due to ages, strains and housing methods.

The results indicated that initial body weight was significantly correlated with number dominated in both sexes and also significantly correlated with age at sexual maturity in females, but not in males. The correlations between number dominated and age at sexual maturity were significant in both sexes.

Strains of males did not differ in initial body weight and mean number dominated, but Os males were earlier in sexual maturity than Oc and S_{275}. In the case of females, Os was more aggressive than S_{275} and Oc. Os females were also earlier in maturity than Oc and S_{275}. Oc and Os females had heavier initial body weight than S_{275}.

Interactions of strain by social environment were not present for either sexual maturity or gain in body weight although Os strain pullets were socially dominant in intermingled flocks.

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EFFECTS OF SELECTION FOR EARLY EGG PRODUCTION ON SEXUAL MATURITY, BODY WEIGHT AND SOCIAL DOMINANCE DURING ADOLESCENCE IN CHICKENS

by

MING LUNG JAN

B.S. in Agr., National Taiwan University, Taiwan, Rep. of China.

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AN ABSTRACT OF A MASTER'S THESIS

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Department of Dairy and Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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ABSTRACT

Studies were conducted on three strains of White Leghorns (Os, S_{275} and Oc) to estimate age at sexual maturity, body weight, social status and interrelationships between those traits during the adolescent stage of development. It was postulated that the earlier maturing strains would be more aggressive than their unselected control and that competitive effects in intermingled strain flocks might depress growth rate and delay sexual maturity of strains with lower social status.

One hundred and eight males per strain were assembled into 9 small intermingled flocks, 3 large intermingled flocks and 9 separated strain flocks at 7 weeks of age. At 9 weeks of age, the number of males per strain was reduced from 4 to 3 for small intermingled flocks and from 12 to 9 for large intermingled flocks and separated flocks. Ninety-six females per strain were assembled into 2 separated flocks per strain and 6 intermingled flocks at 18 weeks of age.

Males sexual maturity was defined by two criteria. A male was considered to reach sexual maturity by criterion A on the date when sperm were first observed microscopically from fluid collected biweekly by artificial stimulation. Maturity by criterion B was attained when the number of sperm and motility were scored. In the case of females, sexual maturity was calculated in weeks from the date of hatch until the first egg was laid.

Observation on social behavior were begun when males were 10 weeks of age and continued through 12 weeks of age. Each of the 9 small

intermingled flocks was watched 20 minutes per day. For females, behavioral observations were begun when birds were 19 weeks of age and continued through 24 weeks of age. Each of the six intermingled flocks was watched for one 20-minute period per day, five days a week.

All males were weighed at 7 weeks of age and subsequently at 3-week intervals and females were weighed at 18 weeks of age and subsequently at 4-week intervals.

Traits measured once only on individual birds, such as 7-week body weight in males, 18-week body weight in females, number of birds dominated and age at sexual maturity were tested by simple analysis of variance. Females data for number dominated and sexual maturity were analyzed both with and without statistical adjustment for differences in initial body weight. Split-plot design for analysis of variance was used to test differences in body weight gain due to ages, strains and housing methods.

The results suggested that initial body weight was significantly correlated with number dominated in both sexes and was also correlated with age at sexual maturity in females. Number dominated and age at sexual maturity were significantly correlated in both sexes. Males did not differ in initial body weight and mean number dominated, but Os males were earlier maturing than Oc and S_{275}. In the case of females, Os was both more aggressive and earlier in maturity than S_{275} and Oc. Os females had heavier initial body weight than S_{275}, but did not differ from Oc.

Interactions of strain by social environment were not present for either sexual maturity or gain in body weight although Os strain pullets were socially dominant in intermingled flocks.